Pluto LNG Development, Burrup Peninsula

Woodside Energy Ltd

Report and recommendations
of the Environmental Protection Authority

Environmental Protection Authority
Perth, Western Australia
Bulletin 1259
July 2007

Environmental Impact Assessment Process Timelines

Date	Progress stages	Time (weeks)
17 Apr 2006	**Level of Assessment set (following any appeals upheld)**	
11 Dec 2006	**Proponent Document Released for Public Comment**	**34 weeks**
19 Feb 2007	**Public Comment Period Closed**	**10 weeks**
18 Jun 2007	**Final Proponent response to the issues raised**	**17 weeks**
9 Jul 2007	**EPA report to the Minister for the Environment**	**3 weeks**

RELEASE DATE:
9 July 2007.
APPEAL PERIOD CLOSE:
23 July 2007.

Assessment No. 1632

Summary and recommendations

This report provides the Environmental Protection Authority's (EPA's) advice and recommendations to the Minister for the Environment on the proposal by Woodside Energy Ltd to undertake the Pluto LNG project in the north-west of Western Australia.

Section 44 of the *Environmental Protection Act 1986* (EP Act) requires the EPA to report to the Minister for the Environment on the outcome of its assessment of a proposal. The report must set out:

- the key environmental factors identified in the course of the assessment; and
- the EPA's recommendations as to whether or not the proposal may be implemented, and, if the EPA recommends that implementation be allowed, the conditions and procedures to which implementation should be subject.

The EPA may include in the report any other advice and recommendations as it sees fit.

The EPA is also required to have regard for the principles set out in section 4A of the *Environmental Protection Act 1986.*

Key environmental factors and principles

The EPA decided that the following key environmental factors relevant to the proposal required detailed evaluation in the report:

(a) Marine impacts;

(b) Vegetation;

(c) Fauna – terrestrial species;

(d) Fauna – migratory/marine species;

(e) Indigenous Heritage;

(f) Air quality; and

(g) Greenhouse gas.

There were a number of other factors which were relevant to the proposal, but the EPA is of the view that the information set out in Appendix 3 provides sufficient evaluation.

The following principles were considered by the EPA in relation to the proposal:

(a) the precautionary principle;

(b) principle of intergenerational equity;

(c) the principle of the conservation of biological diversity and ecological integrity;

(d) principles relating to improved valuation, pricing and incentive mechanisms; and

(e) the principle of waste minimisation.

Conclusion

The EPA has considered the proposal by Woodside Energy Ltd to undertake the Pluto LNG Development in the north-west of Western Australia. The project would require extensive dredging both in Mermaid Sound and along the pipeline route, and the construction of a Liquefied Natural Gas (LNG) plant and export facilities on the Burrup Peninsula.

Marine components – The EPA notes that the predictions of coral loss adjacent to the export facility greatly exceed the threshold established in EPA Guidance Statement No. 29, related to benthic primary producers. The existing development around Mermaid Sound already exceeds the threshold of 10% loss for inshore corals. Although Woodside is of the view that its actual impacts would be less than those predicted, the modelled results are those that must be considered as possible. The EPA believes that the losses would only be acceptable if the proponent is able to devise and implement appropriate measures to fully offset the loss of coral. The EPA considers the current offset package being offered by Woodside is inadequate to address the potential loss of corals.

The proposal is also predicted to cause some loss of coral in the proposed Dampier Archipelago Marine Park. This Marine Park is expected to be gazetted shortly and the draft Management Plan for the park requires that development approvals be consistent with the management targets for the park. The proposal is currently predicted to exceed the management target of 'no change due to human activities' for the recreation zone around Conzinc Island. The EPA considers that significant impacts within the Marine Park are unacceptable.

The EPA notes that wastewater discharges to Mermaid Sound should be avoided and expects all options for reuse to be exhausted before a discharge is contemplated. The EPA considers that discharge to deepwater could be acceptable if managed to best practice standards.

As such, it is the EPA's opinion that the proposal, as presented, does not fully meet the EPA's objectives for the marine environment. However, provided stringent conditions that require, amongst other things, the:

- preparation and implementation of a Dredge Impact Management Plan to minimise impacts in Mermaid Sound and specifically <u>prevent</u> impacts to the proposed Marine Park, through best practice dredge methods and the timing of works with respect to sea and meteorological conditions;
- conservative 'stop work' trigger levels; and
- comprehensive monitoring,

are fully implemented and a substantive offset package is agreed, the Pluto LNG Development could be allowed to proceed.

The EPA has also provided 'other advice' recommending the Dampier Port Authority (DPA) take a leadership role in managing the cumulative impacts of dredging proposals within the DPA limits. This would allow for a consistent approach by all future proponents that would greatly assist the EPA in the assessment of future development proposals that may affect the marine environment in the DPA area.

Terrestrial components - The EPA undertook this assessment with regard to the established management framework for the Burrup Peninsula. In practical terms, preservation and promotion of cultural heritage values and the natural environmental values can be readily achieved in the proposed conservation area on the Burrup Peninsula. The EPA's objective is to ensure that conservation objectives are met in the context of the wider Burrup Peninsula and environmental impacts caused by the proposal are minimised and managed as far as practicable. The EPA considers that the disturbance footprint has been selected and optimised to avoid the most environmentally sensitive sections of the site and that impacts have been minimised to the extent practicable.

The EPA notes that the proposal would result in the permanent loss of native vegetation, fauna habitat and some Indigenous Heritage sites. However, having particular regard to the management framework for the Burrup Peninsula, it is the EPA's opinion that it is unlikely that the EPA's objectives for the terrestrial components would be compromised provided there is satisfactory implementation by the proponent of their commitments and the recommended conditions.

Recommendations

The EPA submits the following recommendations to the Minister for the Environment:

1. That the Minister notes that the proposal being assessed is the Pluto LNG Development;
2. That the Minister considers the report on the key environmental factors and principles as set out in Section 3;
3. That the Minister notes that the EPA has concluded that the proposal, as presented, does not fully meet the EPA's objectives for the marine environment, and that the current offset package being offered is not adequate to address the potential loss of coral. However, provided a substantive offset package is agreed and the stringent conditions are fully implemented, the Pluto LNG Development could be allowed to proceed; and
4. That should the proposal be approved, the Minister imposes the conditions and procedures recommended in Appendix 4 of this report.

Conditions

Having considered the proponent's commitments and information provided in this report, the EPA has developed a set of conditions that the EPA recommends be imposed if the Government should approve the proposal by Woodside Energy Ltd to undertake the Pluto LNG Development. These conditions are presented in Appendix 4.

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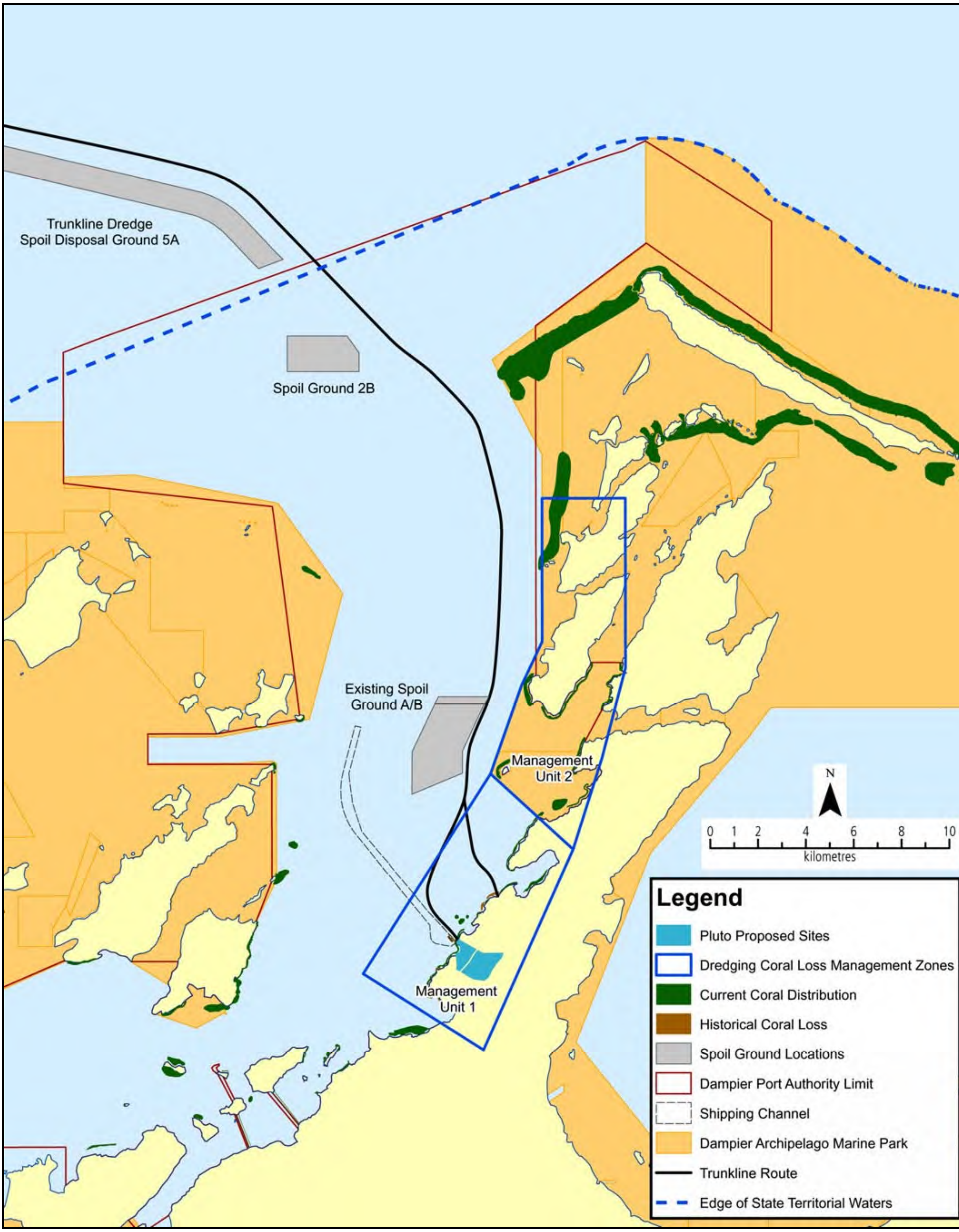
Trunkline Dredge
Spoil Disposal Ground 5A
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0 1 2 4 6 8 10
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1. Introduction and background

This report provides the advice and recommendations of the Environmental Protection Authority (EPA) to the Minister for the Environment on the key environmental factors and principles for the proposal by Woodside Energy Ltd (WEL) to undertake the Pluto Liquefied Natural Gas (LNG) Development in the north-west of Western Australia.

The terrestrial components of the Pluto LNG Development are proposed to be located on designated industrial land (Lease areas A and B) to the south of the existing North West Shelf Venture (NWSV) plant on the Burrup Peninsula (Figure 1).

LNG and condensate storage tanks are required for the Pluto LNG Development, and the construction of these tanks represents a critical time path for WEL. As such, WEL sought a separate approval for the Development of Industrial Land (Site A in figure 1) to allow limited site preparation activities to occur ahead of approvals for the overall Pluto LNG Development. The EPA reported on the proposed Development of Industrial Land on the Burrup Peninsula in September 2006 (EPA 2006) and the Minister for the Environment issued approval for limited site preparation in November 2006 (Statement 733).

Since the Pluto LNG Development involves environmental issues which fall under both State and Commonwealth jurisdictions, the environmental impact assessment was carried out jointly by the Western Australian EPA and the Commonwealth's Department of the Environment and Water Resources.

The Level of Assessment (LOA) was set at Public Environmental Review (PER) under the State *Environmental Protection Act 1986*, and at Public Environmental Report under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999.* A common ten-week public review period was set and a common PER document (WEL, 2006) was produced for both environmental impact assessment processes. The public review period commenced on 11 December 2006 and closed on 19 February 2007.

The potential impacts associated with dredging, spoil disposal and construction and operation in Commonwealth waters are not assessed within this report. Disposal of spoil within both State and Commonwealth waters is to be undertaken in accordance with permit conditions established pursuant to the Commonwealth *Environment Protection (Sea Dumping) Act 1981.*

Further details of the proposal are presented in Section 2 of this report. Section 3 discusses the key environmental factors and principles for the proposal. The Conditions and Commitments to which the proposal should be subject, if the Minister determines that it may be implemented, are set out in Section 4. Section 5 provides Other Advice by the EPA, Section 6 presents the EPA's conclusions and Section 7, the EPA's Recommendations.

Appendix 5 contains a summary of submissions and the proponent's response to submissions and is included as a matter of information only and does not form part of the EPA's report and recommendations. Issues arising from this process, and which have been taken into account by the EPA, appear in the report itself.

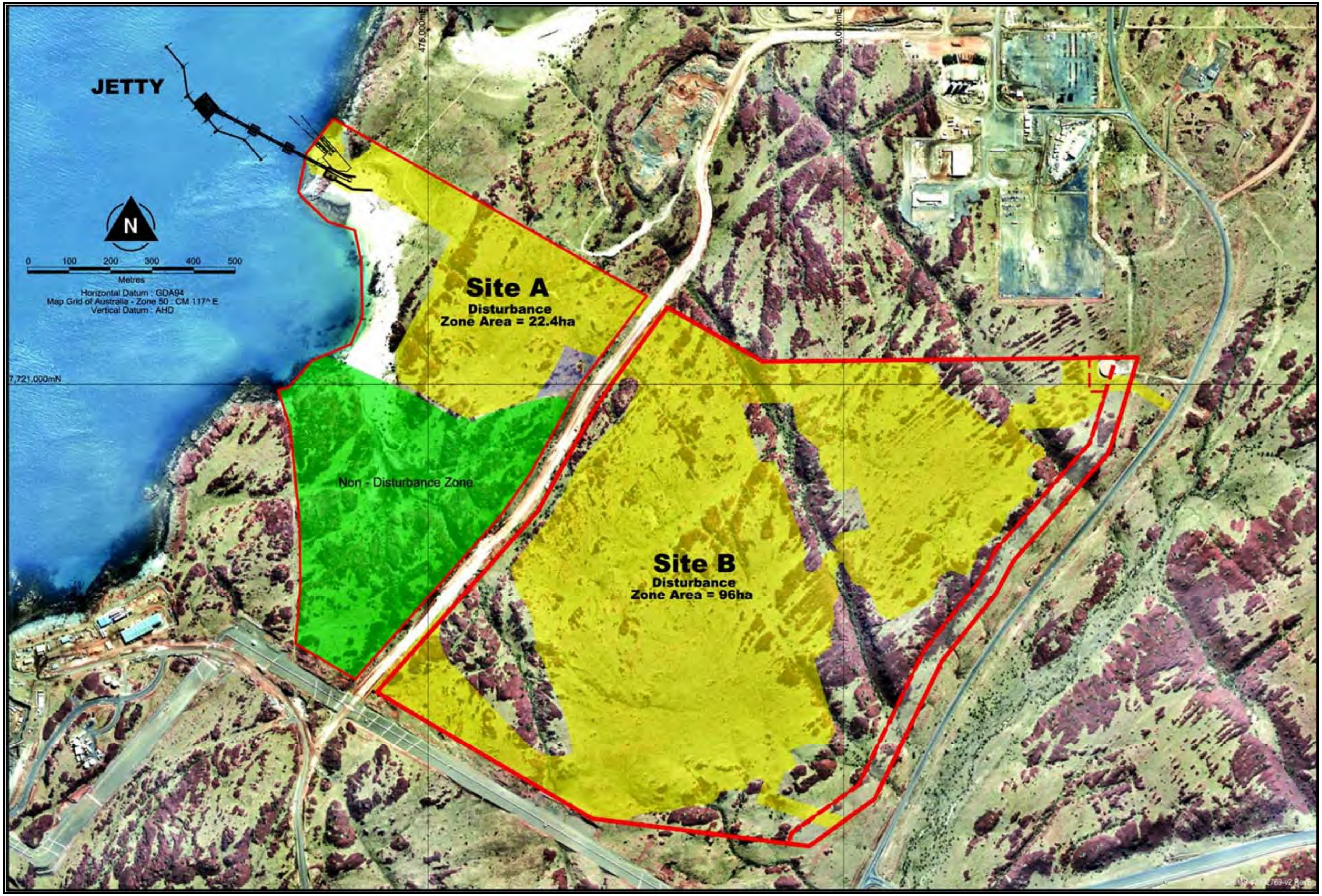

Figure 1: The proposed disturbance footprint on Sites A and B.

2. The proposal

Woodside Energy Ltd (WEL) has proposed to develop the Pluto gas field located offshore on the North West Shelf, approximately 190 kilometres north-west of Dampier. This proposal is for the construction and operation of facilities within Western Australian State territorial waters and on the Burrup Peninsula which would allow the gas field to be exploited.

The gas would be transported by a sub-sea trunkline to the west coast of the Burrup Peninsula where the gas processing plant would be located on two designated Industrial Lease areas. The storage and export facility would be constructed on Site A and the gas processing plant would be constructed on Site B (Figure 1).

LNG is produced by cooling the natural gas below -161 degrees Celsius so that it becomes a liquid. The liquid is one six hundredth of the gas volume and can thus be stored and transported to overseas markets. The production of LNG and condensate involves the following processes:

- gas receival and inlet separation;
- acid gas removal;
- gas dehydration;
- mercury removal;
- liquefaction;
- end flash and nitrogen removal;
- fractionation/heavies removal;
- refrigerant storage; and
- condensate stabilisation and export.

Gas turbines (GTs) are used for compressing the gas and for the plants power requirements.

Extensive dredging would also be needed for shipping tanker access to the export facility and gas trunkline installation. The gas trunkline, shipping channel and turning basin would require dredging over a two year period.

The main characteristics of the proposal are summarised in Table 1 below. A detailed description of the proposal is provided in Section 4 of the PER (Woodside, 2006).

Table 1: Summary of key proposal characteristics

Element	Description
Dredging	
• navigation channel:	approximately 10 kilometres long, 275 metres wide.
• turning basin:	approximately 800 metres diameter.
• berth pocket:	approximately 425 metres x 85 metres.
• nearshore trunkline trench.	approximately 32 kilometres long, 25 metres wide.
• total volume to be dredged:	up to 14 million cubic metres.
Marine disposal of spoil	
• spoil ground A/B:	up to 0.25 million cubic metres.
• offshore spoil ground:	up to 14 million cubic metres.
• reuse of spoil:	up to 0.8 million cubic metres.
Gas trunkline	
• gas field to LNG plant:	approximately 32 kilometres of route that is within State territorial waters.
Site works	
• clearing on Site A:	up to 22.4 hectares (within disturbance footprint).
• clearing on Site B:	up to 96 hectares (within disturbance footprint).
• salvage and relocation of heritage material.	
• drilling and blasting.	
• cut-and-fill activities.	
Product storage facility	
• two cryogenic LNG tanks:	each with a capacity of up to 160 000 cubic metres.
• three condensate tanks:	combined capacity of up to 130 000 cubic metres.
LNG Plant	
Two LNG processing trains.	
• total nominal capacity:	12 million tonnes per annum of LNG.
• power generation (each train):	5 x Frame-6 ‘dry low NO_X’ gas turbines.
• gas compression (each train):	3 x Frame-7 ‘dry low NO_X’ gas turbines.
• liquefaction plant (each train):	1 x Frame-5 gas turbine.
• administration buildings.	
• workshop buildings.	
• control buildings.	
• car parks.	
• internal roads.	
Domgas	
Domestic gas supply:	approximately 4 million tonnes per annum (to be refined at a later stage).
Flares	
• one on Site A:	storage and loading flare.
• three (combined) on Site B:	wet flare, LNG flare and common spare flare.
Export jetty	
• jetty:	approximately 500 metres long.
Wastewater treatment plant and marine outfall	
• discharge of treated wastewater:	up to 1000 cubic metres per day.

Temporary facilities

- A package wastewater treatment plant to provide tertiary treatment for up to 3000 persons. The plant would be located within the Site A disturbance footprint and the effluent would be discharged (irrigated) within the disturbance footprint.
- A lay-down area consisting of the quarry and nearby area just to the north of Site A. Both these areas have been previously cleared and the vegetation present is comprised of regrowth.
- A concrete batching plant.

Since release of the PER, a number of changes have been made to the proposal. These include:

- The layout of the gas processing plant has been revised resulting in an increase in the disturbance footprint on Site B from 66 to 96 hectares;
- The trunkline route Option A has been chosen and Option B is no longer being considered; and
- The dredge program has been revised with changes to spoil-grounds and scheduling.

The potential impacts of the proposal initially predicted by the proponent in the PER document (WEL, 2006) and their proposed management are summarised in Table ES-1 of the proponent's document.

2.1 Management Framework for the Burrup Peninsula

The Burrup and Maitland Industrial Estates Agreement (BIMIEA), between the Western Australian Government and the Traditional Custodians, was settled in 2003. The BIMIEA sought to balance large-scale industrial development with conservation and is designed to deliver long-term economic and social benefits to the local indigenous community. The agreement allocates 62% (5000 hectares) of the Burrup Peninsula for conservation and recreation. A total of 3000 hectares has been allocated for industrial use, of which about 1600 hectares is currently being used by industry.

As part of the broader BIMIEA, a Management Agreement was negotiated between the State Government, the Approved Body Corporate (Indigenous party), and the Executive Director of the Department of Environment and Conservation (DEC) for the non-industrial lands of the Burrup Peninsula. This agreement allows for joint management by the Traditional Custodians and the DEC, of the non-industrial lands and also requires a Management Plan.

The Draft Management Plan for the proposed Burrup Peninsula Conservation Reserve was recently released for public comment (DEC, 2006). The comment period closed on 11 September 2006. The draft plan advocates a balance between the protection of the internationally important heritage values of the Burrup Peninsula and the economic and social benefits the Burrup industries bring to the people of Western Australia.

Objectives of the draft plan include the preservation and promotion of the cultural heritage values of the land and the natural environmental values of the land, (including indigenous flora and fauna).

It is with regard to the above management framework that the EPA undertook this assessment. In practical terms, preservation and promotion of cultural heritage values and the natural environmental values can be readily achieved in the proposed conservation area on the Burrup Peninsula. The EPA's objective is to ensure that conservation objectives are met in the context of the wider Burrup Peninsula and environmental impacts caused by the proposal are minimised and managed as far as is reasonably practicable.

3. Key environmental factors and principles

Section 44 of the *Environmental Protection Act 1986* requires the EPA to report to the Minister for the Environment on the environmental factors relevant to the proposal and the conditions and procedures, if any, to which the proposal should be subject. In addition, the EPA may make recommendations as it sees fit.

The identification process for the key factors selected for detailed evaluation in this report is summarised in Appendix 3. The reader is referred to Appendix 3 for the evaluation of factors not discussed below. A number of these factors are relevant to the proposal, but the EPA is of the view that the information set out in Appendix 3 provides sufficient evaluation.

It is the EPA's opinion that the following key environmental factors for the proposal require detailed evaluation in this report:

(a) Marine impacts;

(b) Vegetation;

(c) Fauna – terrestrial species;

(d) Fauna – migratory/marine species;

(e) Indigenous Heritage;

(f) Air quality; and

(g) Greenhouse gas.

The above key factors were identified from the EPA's consideration and review of all environmental factors generated from the PER document and the submissions received, in conjunction with the proposal characteristics.

Details on the key environmental factors and their assessment are contained in Sections 3.1 - 3.7. The description of each factor shows why it is relevant to the proposal and how it will be affected by the proposal. The assessment of each factor is where the EPA decides whether or not a proposal meets the environmental objective set for that factor.

The following principles were considered by the EPA in relation to the proposal:

(a) the precautionary principle;

(b) the principle of intergenerational equity;

(c) the principle of the conservation of biological diversity and ecological integrity;

(d) principles relating to improved valuation, pricing and incentive mechanisms; and

(e) the principle of waste minimisation.

3.1 Marine impacts

Description

The Dampier Archipelago has been the subject of dredging since 1965 during which time, in excess of 31 million cubic metres (Mm^3) of marine sediments have been dredged. The majority of this spoil has been relocated to spoil-ground A/B (Figure 2).

The inshore coral communities in Management Unit 1 once covered 77 hectares, however 13 hectares have been lost through historical development and only 64 hectares now remain.

It is expected that dredging of the proposed navigation channel, turning basin, berth pocket, and nearshore trunkline trenches for the Pluto project would produce between 11 to 14 Mm^3 of spoil within the Dampier Port Authority (DPA) limits. The dredging program proposes to use:

- a cutter suction dredge;
- two trailer suction hopper dredges;
- a backhoe dredge; and
- a mini jack-up and blast barge.

The PER document describes plans to use the existing spoil-ground A/B, the offshore spoil-ground 2B, and spoil-ground 5 (along the trunkline route) over a 24 month dredging program.

The fate of sediments suspended by the proposed spoil dumping program was simulated using the three dimensional modelling system SSFATE. This model computes Total Suspended Solids (TSS) distribution and sedimentation patterns to predict the transport, dispersion and settling of suspended sediments released into the water (APASA 2006).

Effects on biota from dredging are caused by increased suspended solids in the water column, both from dredging and spoil disposal. Suspended solids can cause light attenuation, abrasion, clogging of pores, respiratory and feeding organs, and even the smothering of benthic biota.

In accordance with EPA Guidance Statement No. 29 "*Benthic Primary Producer Habitat (BPPH) Protection for Western Australia's Marine Environment*", the proponent has defined Management Units and predicted coral loss. These are presented in the PER document and shown in Table 2 below.

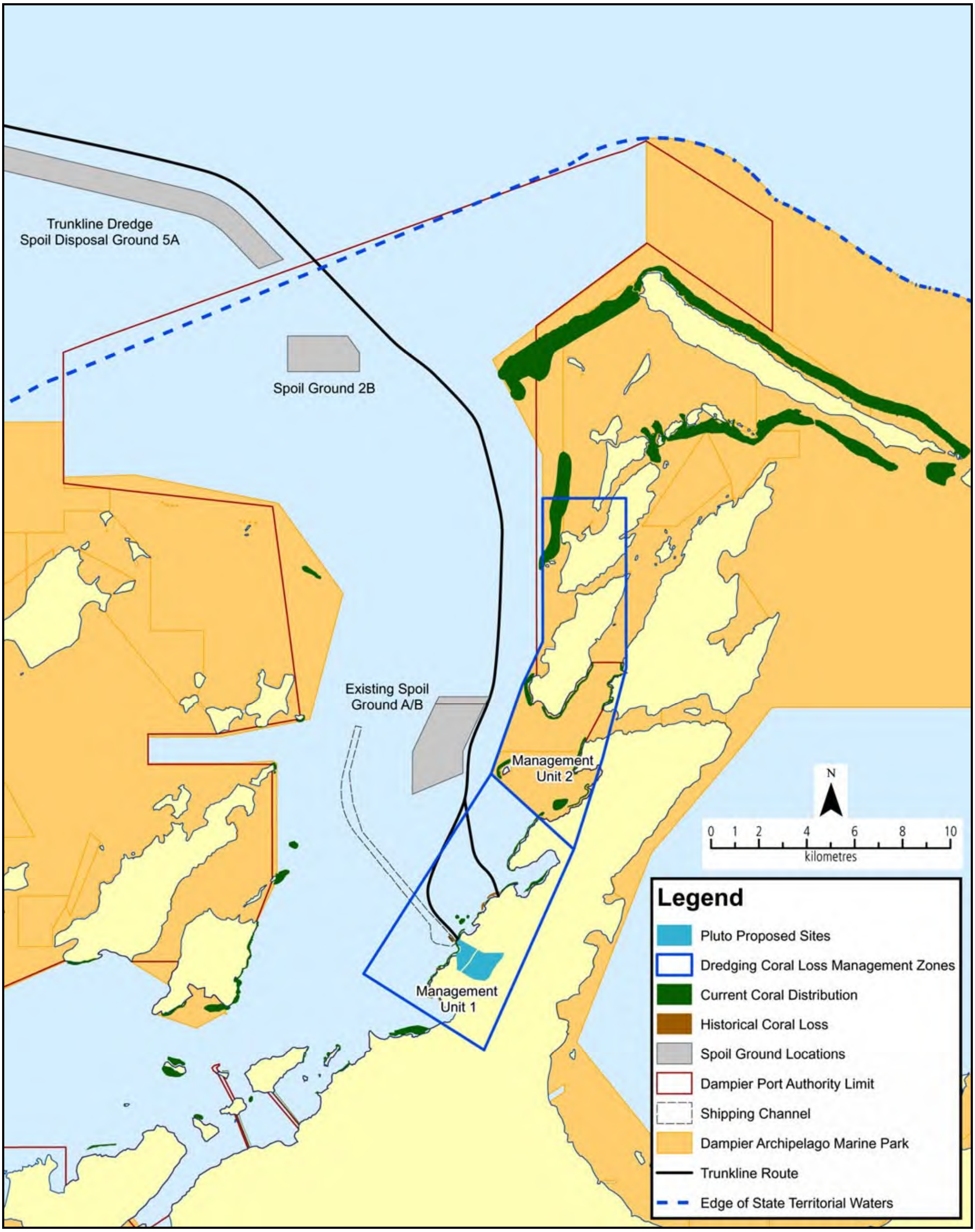

Figure 2: Coral distribution and Management Units (from WEL)

Table 2 Predicted coral loss due to the dredging program.

Management Unit	Historical loss	Predicted direct loss	Predicted indirect loss	Predicted cumulative loss
1	18.6%	2.7%	21.1%	**42.4%**
2	0%	0%	5.5%	**5.5%**

Submissions

The DEC requested additional information/clarification on the modelled predictions along with further modelling of dredge impacts. Aspects included the:

- high sedimentation threshold criteria used for coral mortality;
- omission of a sedimentation resuspension process in the dredge modelling;
- lack of light attenuation effects in the dredge modelling;
- need to model dredge and disposal activity for the entire program (including all simultaneous activity), and provide predictions of cumulative BPPH impact; and
- impact of dredging on other benthic primary producers (seagrass, algae).

The DEC advised that there was insufficient information regarding the proposed marine wastewater discharge, particularly with regard to contaminant concentrations and toxicity. The DEC also advised there was inadequate justification for not discharging to the multi-user pipeline. Neither the DEC, DPA or Department of Fisheries (DoF) supported a wastewater discharge to Mermaid Sound.

The Health Department of Western Australia (HDWA) noted that a marine discharge would need to meet the requirements of the Radiological Council. The DoF submission noted the importance of quarantine.

The Conservation Council of Western Australia (CCWA) noted that cumulative impacts on the marine environment should be fully assessed and that baseline surveys were required.

Assessment

The area considered for assessment of this factor is the State territorial marine waters of the Dampier Archipelago.

The EPA's environmental objective for this factor is to:

- Maintain marine ecological integrity and biodiversity;
- Ensure the criteria in Guidance Statement No. 29 are met; and
- Protect and maintain the interim environmental values (EVs) and environmental quality objectives (EQOs) set out in the Pilbara Coastal Water Quality Consultation Outcomes (DoE, 2006).

The EPA recently endorsed as interim the EVs and spatial allocation of EQOs described in the Pilbara Coastal Water Quality Consultation Outcomes report. The level of protection assigned to marine waters over much of the Pilbara region is ‘High’, however there are some small areas associated with ports and waste discharge points where the level of quality is reduced. The areas immediately surrounding the shipping facilities have been assigned a ‘Moderate’ level of ecological protection. There are also areas where the management goal is to maintain a ‘maximum’ level of quality, where there should essentially be no change from background conditions. The interim environmental quality plan allows for modification if a well justified case is put to the EPA.

The EPA’s Guidance Statement No. 29 is applied to proposals that are predicted to cause loss of BPPHs. The Guidance Statement describes, among other things, Category E Development Areas which should be applied to ‘Management Units’ to consider loss of BPPHs in areas designated for heavy industry and related purposes such as ports. In these areas it is the EPA’s expectation that a cumulative loss threshold of 10% would apply. However, when this 10% threshold has already been exceeded (through historical loss), the area becomes Category F where the EPA’s expectation is for no further net loss. Within Management Unit 1 there is historical coral loss of around 18% and it thus falls into Category F.

Category A is applied to Extremely Special Areas (e.g. Marine Park recreation zone) where the EPA expects no loss. Management Unit 2 is Category A. The south-west corner of the proposed “Dampier Archipelago Marine Park – East” includes Management Unit 2. This proposed Marine Park is expected to be gazetted shortly (Figure 2).

In response to queries on various aspects of the modelling, WEL provided data and undertook additional modelling of dredge plumes which incorporated the effect of resuspension. The model was also interrogated using coral mortality criteria based on background monitoring. This has resulted in revised coral loss predictions which are presented in Table 3 below. WEL has also advised that the duration of the dredging program has been reduced to 12 months.

Table 3 Predicted coral loss due to the dredging program (revised).

Management Unit	Historical loss	Predicted direct loss	Predicted indirect loss	Predicted cumulative loss	Category	EPA loss threshold
1	17.48%	1.64%	35.5%	**54.6%**	F*	0% net damage/loss
2	0%	0%	7.9%	**7.9%**	A	0%

* The historical loss in Management Unit 1 has already exceeded the threshold of 10% and therefore it falls into Category F.

WEL notes that data from previous dredging operations in Mermaid Sound shows that dredging has only resulted in coral mortality at sites closer than 250 metres to the dredging activity. This data implies that less than 9% of coral in Management Unit 1 is likely to be lost and no coral in Management Unit 2 would be lost. As such, WEL believes that the predictions in Table 3 are overly conservative.

The EPA is aware that predicting coral loss is subject to numerous uncertainties, and that the actual coral loss could fall somewhere between those based on previous dredge observations and the modelled predictions in Table 3, which WEL considers to represent the worst case.

Management Unit 1
The EPA notes that implementation of this proposal would modify the interim EQOs for Mermaid Sound as shown in DoE (2006). The area surrounding the turning basin would need to be assigned a Moderate level of ecological protection and if a wastewater discharge was approved, it may not be able to achieve a high level of ecological protection. The offshore spoil ground would also need to be assigned a Moderate level of ecological protection.

Within Management Unit 1, the EPA is particularly concerned with the significant amount of coral loss predicted. The EPA's expectation that a Category F area should be subject to no further loss of BPPH is clearly unachievable if this proposal were to proceed. In these cases Guidance Statement No. 29 notes that the proponent is expected to have developed an adequate environmental offset package to counterbalance the further loss of BPPH with the aim of achieving 'no net loss' or a 'net environmental benefit'. Substantial understanding of the ecological role, function and value of the BPPH within the local context is also expected along with a discussion of the consequences of removal of this BPPH. As such, the EPA expects proponents to present an offset package to mitigate the loss.

WEL has put forward a draft offset package (Appendix 6) which proposes a number of activities to mitigate the loss of BPPH. However, the EPA believes that the offset package (as presented) does not offset the coral loss. As such, further development of the package through consultation with the DEC would be needed to achieve 'no net loss' or an 'environmental benefit'.

Management Unit 2
The EPA notes that the proposed Dampier Archipelago Marine Park is expected to be gazetted shortly. Comment was sought from the Marine Parks and Reserves Authority (MPRA) who advised that the predicted loss of coral is inconsistent with the draft Management Plan for the proposed Marine Park, but acknowledged that consideration can be given to activities that may potentially produce impacts beyond those provided for within the draft Plan through formal EPA assessment.

The EPA notes the section from the draft Management Plan for the Marine Park on the 'objectives, strategies and targets' for development proposals, and that point 3 (Table on page 39) is relevant and reproduced below:

3. Ensure that approvals and the setting of conditions for new developments and operations are consistent with the management targets for the reserves and that appropriate monitoring conditions are applied to ensure these outcomes are achieved (DEC, MPRA, EPA, DoF, DoIR, DPI, TWA).

For the recreational zone (southern section of Management Unit 2), the target is "no change due to human activities in the reserve". The impacts currently predicted are thus inconsistent with the targets, although the issue of cause from activities outside of the reserve is a point for consideration.

The EPA agrees and believes that allowing development to impact on the management targets of the proposed Marine Park is unacceptable.

The main risk to the proposed Marine Park arises from disposal into spoil-ground A/B and trenching for the trunkline route adjacent to the proposed Marine Park.

WEL initially planned to dispose of 3.5 to 4.5 Mm^3 into spoil-ground A/B. However, following negotiations to reduce the potential for impact on the proposed Marine Park, WEL is now prepared to dispose of the majority (11-14 Mm^3) of the dredge spoil to the offshore spoil-ground 2B. WEL would like to retain the option to dispose of 0.25 Mm^3 of material from the NWSV channel trunkline crossing to spoil-ground A/B. The EPA notes that offshore spoil disposal could greatly reduce the risk to the proposed Marine Park, however it also notes that modelling undertaken by the proponent suggests that the proposed location of the offshore spoil-ground may result in turbidity and sedimentation impacts on other parts of the Marine Park. Further studies are therefore required to determine an optimum spoil-ground location to avoid impact on the Marine Park.

However, trunkline trenching and installation adjacent to the proposed Marine Park and the disposal of 0.25 Mm^3 of spoil into spoil–ground A/B still poses a potential risk to the proposed Marine Park.

The EPA believes that activities adjacent to the proposed Marine Park would need to be proactively managed and comprehensively monitored to ensure the proposed Marine Park is not compromised. The EPA notes that the proposed dredging, as presented, has not demonstrated this required level of management.

Wastewater discharge
The EPA notes that impacts from the disposal of hydrotest water, formation water, condensed water, grey water and sewage to Mermaid Sound have not been comprehensively addressed. WEL is unable to define the quality of the wastewater with any certainty at this stage. The impacts associated with the discharge have not been addressed in adequate detail.

The EPA notes that the disposal of wastewater to Mermaid Sound is not best practice and is not supported by the DEC, DPA or DoF. The EPA believes that wastewater discharge to Mermaid Sound should be avoided and expects all options for reuse to be exhausted before a discharge is contemplated. The EPA considers that discharge in deep water (>30m) outside the Dampier Archipelago could be acceptable if managed to best practice standards.

Quarantine
The EPA recognises the potential risks for the introduction of non-indigenous marine species to the Dampier Archipelago via dredges from previous dredging programs and shipping generally. The EPA therefore recommends that the dredges, dredging equipment and associated vessels be subject to appropriate inspection. The EPA has thus recommended condition 8 which addresses marine quarantine.

Offsets
WEL has proposed a series of offsets in relation to the potential marine impacts, primarily resulting for dredging and spoil disposal. These offsets are outlined in Appendix 5.

The EPA notes that the proposed offsets do not address the direct loss of corals resulting from the proposal but provides indirect support for a number of marine related issues. The EPA does not believe that this adequately recognises the importance of the corals within marine ecosystems in this area, and considers that WEL should provide direct offsets as well. The EPA acknowledges that this may be challenging but is considered necessary. Since there is uncertainty in the coral loss predicted, the EPA notes that direct offsets would need to address the coral loss that actually results in practice. Hence, the better the environmental performance of the dredge program, the smaller the direct offset that is required.

Conclusion
The EPA notes that due to the potential for significant exceedance of the coral loss threshold, the potential for impact on the proposed Dampier Archipelago Marine Park and the uncertainty regarding the environmental impact from the marine wastewater discharge, the proposal, as presented, does not fully meet the EPA's environmental objectives for this factor. However, the Pluto LNG Development could be approved provided a substantive offset package is agreed, and stringent conditions are fully implemented. The EPA has thus recommended "Condition 6 - Marine Impacts" and "Condition 7 - Deepwater Marine Outfall" which are detailed in Appendix 4, and parts of which are discussed below.

Condition 6-2 imposes limits to coral loss, condition 6-6 requires the proponent to prepare and implement a Dredge Impact Management Plan that demonstrates the dredge and disposal activities can achieve the management targets for the proposed Marine Park and minimise impacts on benthic habitats and communities outside the Marine Park. The Dredge Impact Management Plan would need to address:

- comprehensive monitoring;
- best practice dredge procedures;
- selection of a suitable location for the offshore spoil-ground that demonstrably does not cause impact on the Marine Park;
- optimum timing of works with respect to sea and meteorological conditions;
- conservative 'stop work' trigger levels; and
- contingency plans.

Condition 6-9 establishes a Dredge Environmental Management Group that among other things would provide advice on the adequacy of the Dredge Impact Management Plan. Condition 6-3, 6-4 and 6-5 specifies management actions (including stopping work) that are required when targets are exceeded.

Condition 7 specifies that chemical and toxicological testing be required should wastewater be discharged to deepwater and condition 8 specifies measures for marine quarantine.

Summary

Having particular regard to the:

(a) potential for cumulative loss of up to 55% of coral in Management Unit 1;
(b) lack of understanding of the ecological function of this coral;
(c) potential impact (up to 7% coral loss) on the proposed Dampier Archipelago Marine Park; and
(d) wastewater being discharged to Mermaid Sound,

it is the EPA's opinion that the proposal, as presented, does not fully meet the EPA's environmental objectives for this factor. However, provided a substantive offset package is agreed, and the recommended conditions are fully implemented, the Pluto LNG Development could be allowed to proceed.

3.2 Vegetation

Description

Industrial lease Sites A and B are located on the west coast of the Burrup Peninsula and are approximately 61 and 130 hectares in size respectively. The proponent has existing approval for site preparation activities on Site A including the clearing of up to 20 hectares. The Pluto LNG project requires additional clearing of 2.4 hectares on Site A and 96 hectares on Site B.

The Pluto LNG Development would thus result in the loss of up to 119 hectares of native vegetation. Thirty-three vegetation associations were identified on Sites A and B, of which fourteen occur within the disturbance area. A number of vegetation associations considered to be of high conservation value occur within the proposed disturbance area.

The proponent has chosen the northern end of Site A for the storage tanks in order to avoid vegetation and indigenous heritage sites concentrated in the south. Similarly, the gas processing plant has been designed to avoid the rocky valleys running across Site B.

Submissions

The DEC noted that weed management was a high priority. The CCWA noted that cumulative impacts should be fully assessed and that baseline surveys were required.

Assessment

The EPA's environmental objective for this factor is to ensure that impacts on the abundance, species diversity, geographic distribution and productivity of vegetation communities are avoided as far as practicable, and the unavoidable impacts are minimised.

The EPA notes that the northern part of Site A has been chosen for the disturbance footprint which avoids significant vegetation and flora species on the south of the site.

The percentage loss of vegetation associations of conservation significance is shown in Table 4.

Table 4: Vegetation Associations of conservation significance on Site A+B.

Vegetation Association (Trudgeon 2002)	Area to be cleared (hectares) on Site A+B	% removal from Site A+B	% removal from the Burrup
AbCcTe	0.55	100	81.0
AbCwTe	0	0	0
AcCaTe	0	0	12.8
AcImTe/TcCa	0.82	91.1	91.2
AcTe	0.12	12.3	3.0
AiFdTe	0.03	9.1	0.2
BaTcTe	0.19	48.5	10.6
CwTe	0.51	16.4	3.7
DsTsTe	0.0033	6.6	0.3
GpImTe	0.0072	0	0
IcImTe	0.04	90.7	17.0
R	20.95	38.2	1.0
SgTeTa	0.15	100	7.0
Sm	0	0	0
Sv	0	0	0
TcCvSe	0	0	0
TeAb	2.31	73.8	2.7
TeCa	11.12	100	30.8
TeEtSg	0.34	58.6	29.3
TeRm	0.14	43.8	0.3
TsAcTe	0	0	0

Note: this table includes clearing already approved for the site preparation activities on Site A.

The EPA notes that the loss of the majority of AbCcTe and AcImTe/TcCa is of particular concern but acknowledges that the 2005 surveys found that AbCcTe no longer occurs on the site. The EPA notes that AcImTe/TcCa is a mosaic of AcImTe and TcCa. AcImTe has 73.9% of its extent represented within the Burrup conservation zone and is not considered regionally significant. TcCa has 4.3% representation in the conservation zone and is the reason AcImTe/TcCa is considered significant. The EPA notes that both AcImTe/TcCa and TcCa occur elsewhere and accepts that the environmental objectives for the proposed Burrup Peninsula Conservation Reserve cannot realistically be fully achieved where industry is located within the designated Burrup Industrial Estate.

The EPA is satisfied that the disturbance footprint has been selected and optimised to avoid the most environmentally sensitive areas, particularly given the indigenous heritage values.

The EPA notes that the proponent has committed to preparing a Vegetation and Flora Management Plan (VFMP) and that the proponent has also proposed conservation zones to protect the areas not required for the proposal. The EPA considers these measures are adequate to minimise the avoidable impacts on vegetation.

Summary
Having particular regard to the:

(a) management framework for the Burrup Peninsula;

(b) Vegetation and Flora Management Plan; and

(c) proposed conservation zones,

it is the EPA's opinion that the proposal can be managed to meet the EPA's environmental objective for this factor.

3.3 Fauna -Terrestrial species

Description
The Pluto LNG project would result in the permanent loss of 22.4 hectares of natural habitat on Site A and 96 hectares on Site B and has the potential to impact on short range endemic species. Vehicles operating on and around the site during both construction and operation have the potential to kill or injure native fauna.

Short range endemics - survey work undertaken for the PER found specimens of a snail (camaenid genus *Rhagada*). These snails appear to be *Rhagada* sp '12' although there were some genetic differences.

Northern quoll (*Dasyurus hallucatus*) - listed as 'endangered' under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). It is a top order predator which has previously been recorded on the Burrup, however it was not captured in a recent (2003) Department of Environment and Conservation (DEC) survey. The northern quoll would favour rocky and drought refuge habitat. In the Pilbara its distribution is fragmented and mostly confined to the larger conservation reserves.

Pilbara olive python (*Liaisis olivaceus barroni)* - listed as 'vulnerable' under the EPBC Act and is also a top order predator that favours deep rock fissures and is often found near pools of water. It has a large home range which may reflect the movement required to find food and mates. A large portion of its habitat is conserved in Karijini National Park. Individual pythons have been sighted on the proposed site.

Submissions
The DEC noted that there is a level of uncertainty in regard to the taxonomy of the *Rhagada* snail species.

Assessment
The EPA's environmental objective for this factor is to ensure that impacts on the abundance, species diversity and geographic distribution of the native fauna is avoided as far as is practicable and the unavoidable impacts are minimised.

Short range endemics –although the snails collected on Site A and B look the same and resemble other specimens on the Burrup Peninsula, there are some genetic differences. They are likely to belong to the species (*Rhagada* sp"12") but further genetic analysis is required and WEL have committed to undertaking further genetic work to resolve the taxonomy. The EPA notes that specimens were also found outside the disturbance footprint and as such, the conservation status is unlikely to be affected by this proposal.

Northern quoll – the proponent has chosen and refined the disturbance footprint to minimise the impact on Indigenous Heritage sites. These heritage sites have the highest density around rocky hills, valleys and watercourses. The EPA notes that should the northern quoll be present on the site, it would likely favour the valleys and watercourses in the centre and south of Site A, which are outside the disturbance footprint. The EPA also notes that the northern quoll is sufficiently mobile to move away from site activities and is thus unlikely to be affected by this proposal.

Pilbara olive python - the proponent has chosen and refined the disturbance footprint to minimise the impact on Indigenous Heritage sites. Since these heritage sites have the highest density around rocky hills, valleys and watercourses, the EPA notes that much of the preferred habitat of the Pilbara olive python has also been avoided.

Additionally, the proponent intends to further minimise impacts through the implementation of a Fauna Management Plan (FMP) to minimise any loss of individual pythons. The FMP was prepared for the site preparation works on Site A and includes the following management actions:

- prior to site preparation activity, undertake a survey for the Pilbara olive python;
- capture and relocate specimens in consultation with the DEC;
- during site preparation activities, personnel would be instructed to report snake sightings and nominated personnel would be trained to capture any pythons found and relocate them in consultation with the DEC;
- designate access and onsite vehicle road/tracks;
- implement a speed limit on site; and
- limit vehicle traffic at night.

WEL has advised that there have been several sitings of the Pilbara Olive Python on the haul road between Site A and B, but none have been encountered to date during site preparation work on Site A.

The EPA considers that the above measures are adequate to minimise the loss of individuals. The EPA notes that there would be permanent loss of habitat, and the population size would likely adjust to the new carrying capacity of the remaining habitat. However, the EPA considers that the population is unlikely to be threatened. The EPA is also satisfied that loss of the pythons preferred habitat has been minimised as far as practical given the Indigenous Heritage values of the site.

The proponent has committed to preparing a Fauna Management Plan (FMP) and the EPA considers this would be adequate to minimise the unavoidable impact on fauna.

Summary

Having particular regard to the:

(a) management framework for the Burrup Peninsula; and

(b) Fauna Management Plan,

it is the EPA's opinion that the proposal can be managed to meet the EPA's environmental objective for this factor.

3.4 Fauna - Migratory/marine species

Description

The coast line of the proposed site includes approximately 400 metres of sandy beach. The proposed disturbance footprint extends from the rocky coast immediately north of the sandy beach across to the north-east corner of Site A and over most of Site B. The sandy beach area would only be subject to minimal direct disturbance.

Turtle species – the sandy beach may potentially be used by turtles for nesting activities. Artificial light can disorientate turtle hatchlings resulting in lower survival rates. Turtle species that occur within the Dampier Archipelago are the Loggerhead (*Caretta caretta*), Green (*Chelonia midas*), Leatherback (*Dermochelys coriaceaa*), Hawksbill (*Eretmochelys imbricate*) and Flatback (*Natator depressus*) turtle species. The loggerhead is listed as 'endangered' and the others are listed as 'vulnerable' under the EPBC Act.

Flatback turtle and possibly Green turtle nesting attempts were recorded on the beach during a survey in January 2006. Both of these species are listed as vulnerable and migratory under the EPBC Act. Based on these surveys, the southern half of the beach supported only low nesting effort. In a regional context, the Site A beach supports only a very minor turtle rookery.

Fish species and marine mammals – the Blue whale (*Balaenoptera musculus*) is listed as 'endangered' under the EPBC Act and the Humpback Whale (*Megaptera novaeangliae*) and Whaleshark (*Rhincodon typus*) are listed as 'vulnerable'. These species may occur within the project area.

Migratory birds – Appendix E in the PER list a number of migratory species that may occur in or adjacent to the project area. There is potential for some migratory birds to forage in the area or along the shoreline. Of these, the Southern Giant Petrel (*Macronectes giganteus*) is listed as 'endangered' under the EPBC Act.

Submissions

The DEC noted that information on light reduction strategies would be required.

Assessment

The EPA's environmental objective for this factor is to ensure that impacts on the abundance, species diversity and geographic distribution of migratory/marine fauna is minimised.

Turtle species – The EPA notes the low recorded nesting effort on the beach during surveys in 2005 and 2006 and that the nesting effort was by Flatback and possibly Green turtles and not the endangered Loggerhead turtle. WEL has advised that no turtles have been observed during the daily checks carried out from December 2006 to April 2007.

There are a number of turtle species present within the Dampier Archipelago and to ensure minimal disturbance to marine turtles, the EPA recommends the proponent be required to prepare a Turtle Management Plan (recommended condition 9). The main objective of the plan is to prevent impacts to marine turtles from shoreline construction activities, noise, vibration, light and vessel interaction and/or strike.

Fish species and marine mammals - The EPA notes that the species listed under the EPBC Act (Whales and Whalesharks) are likely to keep well clear of vessels involved in dredging and export activities and are unlikely to be significantly affected by the project.

Migratory birds - site preparation activities would not take place on the sandy beach and shoreline, but habitat removal within the 119 hectare disturbance footprint could reduce foraging resources. However, the area does not contain key foraging areas. As such, the EPA considers that the proposal is unlikely to have an impact on migratory birds.

Summary

Having particular regard to the:

(a) the low recorded turtle nesting effort; and

(b) recommended condition for a Turtle Management Plan,

it is the EPA's opinion that the proposal can be managed to meet the EPA's environmental objective for this factor.

3.5 Indigenous Heritage

Description

225 heritage sites were located during the ethnographic and archaeological heritage surveys over Sites A and B. These heritage sites reflect how Indigenous people utilised the landscape and are comprised of artefact scatters, isolated stone pit features and/or rocky outcrops with isolated (single) or multiple (up to 1000) petroglyphs. The majority of these sites are tightly clustered on the eastern and south-western margins of Site A and are associated with rocky hills, valleys and watercourses. On Site B, sites are mainly associated with the valleys running across the site.

The impact on heritage sites has been the subject of extensive consultation with the Traditional Custodians, anthropologists and archaeologists.

The disturbance footprint has been revised since publication of the PER and now contains 85 heritage sites. During the archaeological heritage surveys, 1490 rock art panels (rock faces with one or more rock art engravings) were identified, of which it is estimated that around 132 (approximately 9%) lie within the disturbance footprint. It should be noted that WEL has existing approval to relocate those engravings that are within the Site A preparation area. All or most of the rock art panels within the disturbance footprint are proposed to be retrieved and relocated.

Submissions
The majority of submitters were concerned about the loss of rock art and thought that further industrial development on the Burrup was unacceptable.

Assessment
The EPA's environmental objective for this factor is to ensure that conservation objectives are met in the context of the wider Burrup Peninsula and impacts of the proposal on heritage sites are avoided wherever practicable and unavoidable impacts are managed appropriately in consultation with the Traditional Custodians.

The EPA notes that the proponent has undertaken extensive consultation with the Traditional Custodians and has configured the proposal based on input from these consultations. The EPA notes the Department of Indigenous Affairs advice that the proponent's identification of impacts, risks, mitigation and control measures was appropriate.

The EPA notes that the proponent has revised the Site B layout and that there are now 85 heritage sites within the revised disturbance footprint.

The EPA recognises that the significance of heritage sites varies and accepts that the disturbance footprint has been selected and refined to minimise the loss of the most significant sites. In particular, the EPA notes that approximately 90% of the rock art panels fall outside the revised disturbance footprint and would be left in-situ.

Where heritage material cannot be avoided, the EPA supports the salvage, relocation and interpretation of heritage material that is displaced by industry, consistent with the requirements of the *Aboriginal Heritage Act 1972*. In particular, the EPA notes the plans for a visitor and interpretation centre in the Draft Management Plan for the Proposed Burrup Peninsula Conservation Reserve (DEC, 2006). Where material cannot be conserved in context on-site, the visitor centre may be a more appropriate reservoir for heritage material than the very basic storage that has historically occurred on the Burrup.

The EPA understands that 42 engravings have been relocated on Site A along with 2 archaeological scatters (stone tools and flakes). The host boulders were individually strapped to stop them from splitting and then wrapped in protective material to prevent scraping or scratching. The engravings were then lifted to a designated relocation zone, where they will remain undisturbed in a existing natural environment. WEL has advised that this relocation program on Site A has been 100% successful with no rock art being damaged in any way.

The EPA notes the proponents obligations under the *Aboriginal Heritage Act 1972* and understands that WEL has been granted Section 18 approvals to disturb sites and salvage artefacts from within the disturbance footprint.

The proponent has previously prepared a Cultural Heritage Management Plan (CHMP) as required by the environmental conditions for the site preparation activities on Site A. The EPA notes the importance of liaison with the Traditional Custodians, and has recommended that a CHMP again be required for the overall Pluto LNG project.

The EPA notes that over 90% of the rock art contained within Sites A and B would be unaffected and considers the requirement for a CHMP is adequate to ensure that the unavoidable impacts on heritage are managed appropriately.

Summary

Having particular regard to the:

(a) management framework for the Burrup Peninsula;

(b) recommended condition for a Cultural Heritage Management Plan; and

(c) provisions of Section 18 of the *Aboriginal Heritage Act 1972*; and

(d) successful relocation of artefacts within the Site A preparation area,

it is the EPA's opinion that the proposal can be managed to meet the EPA's environmental objective for this factor.

3.6 Air quality

Description

The principle source of air emissions from the gas processing plant are the gas turbines (GTs), used for power generation and gas compression. The main air emissions from these sources include; carbon dioxide (CO_2), oxides of nitrogen (NO_X), carbon monoxide (CO), ozone (O_3) and volatile organic hydrocarbons (VOCs) along with trace amounts of particulates and sulphur dioxide (SO_2). Carbon dioxide is addressed in the section on greenhouse gas and is not considered further in this section. At around 2200 tonnes per annum (tpa), NO_X is the dominant pollutant.

The proponent has proposed to minimise fugitive emissions by employing best practice technology (including flange and dry gas seals). The main emission sources listed in the PER (for the production of 12 Mtpa of LNG) are:

- power generation: ten Frame-6 gas turbines (dry low NO_X burners);
- gas compression: six Frame-7 gas turbines (dry low NO_X burners);
- liquefaction: two Frame-5 gas turbines;
- storing and loading flare; and
- wet flare, LNG flare and spare flare (combined).

TAPM, the CSIRO's Atmospheric Research air dispersion model, was used to predict local ground level concentrations (GLCs) and address regional impacts. The air dispersion modelling predicted compliance with the NEPM criteria for the key pollutants NO_X and O_3 for normal operations. For non-routine, upset conditions, some exceedances were predicted, however the exceedances did not occur near residential areas or other sensitive receptors. The GLCs of other pollutants during process upset conditions were predicted to be below 1% of the assessment criteria and not to cause significant impacts.

Submissions

The DEC advised that the air dispersion modelling undertaken was acceptable but that the modelling should be repeated with large regional sources included. The DEC also noted that best practice management for all emissions should be adopted. The HDWA noted that an Air Quality Management Plan should be required.

Public submitters were concerned about the impact that NO_X and SO_X emissions may have on the rock art.

Assessment

The area considered for assessment of this factor is the local and regional airshed surrounding the LNG plant.

The EPA's environmental objective for this factor is to ensure that emissions do not adversely affect environmental values or the health, welfare or amenity of the people and land uses by meeting statutory requirements and acceptable standards.

The EPA notes the air dispersion modelling predicts compliance with the NEPM criteria for NO_2 and O_3 during normal operations. For non-routine or process upset conditions, some exceedances of the NEPM criteria are predicted, although these do not occur near residential areas or sensitive receptors. The emissions of other pollutants during process upset conditions are unlikely to cause significant impacts. The EPA notes that the affect on regional air quality is predicted to be negligible.

The EPA agrees with the DEC's advice on best practice and has recommended that the proponent be required to prepare a Front End Engineering Design (FEED) report as set out in condition 11 of Appendix 4 which demonstrates that the proposed works adopt best practice pollution control measures to minimise emissions.

The deposition of NO_X on the Burrup Peninsula is predicted to be between 1 to 2 kilograms per hectare per annum. While this is much less than the World Health Organisation (WHO) vegetation guideline, the relevance of the WHO guideline to the vegetation on the Burrup Peninsula is uncertain. As such, the EPA believes that monitoring of nitrogen deposition and its effect on vegetation should be required.

The EPA notes that the investigations into the possible effects of industrial emissions on rock art are ongoing. The data collected so far by the Burrup Rock Art Management Committee suggests that there is no link between current emission levels and effect on rock art. The EPA considers the insignificant increase in cumulative deposition rates from the Pluto LNG Development is unlikely to change this conclusion.

The EPA notes the DEC's advice that the cumulative air quality predictions should be remodelled taking into account regional emissions from proposed industrial sources at Cape Preston and Barrow Island. While the addition of these remote sources would not change the conclusion of the air quality assessment, the increasing number of developments in the region makes it important to have the best information available.

The EPA thus recommends the proponent be required to prepare an Air Quality Management Plan (AQMP) that specifically addresses, amongst other things, the:

- modelling to revise predictions of cumulative air quality (including large regional sources such as those approved at Cape Preston and Barrow Island);
- monitoring of stack emissions;
- monitoring of ambient air quality; and

- monitoring of nitrogen deposition and its effect on vegetation,

as set out in recommended condition 10 of Appendix 4.

Summary

The EPA notes that the proposed use of best practice for fugitive emission control and the use of natural gas fired gas turbines results in ambient air quality that meets the NEPM criteria and the WHO criteria (for deposition). The relevance of the WHO criteria to the vegetation of the Burrup Peninsula environment is less certain.

Having particular regard to the:

(a) best practice control of fugitive emissions;

(b) recommended condition requiring a FEED report; and

(c) recommended condition requiring an AQMP,

it is the EPA's opinion that the proposal can be managed to meet the EPA's environmental objectives for this factor, provided the recommended conditions are made legally enforceable.

3.7 Greenhouse gas

Description

Initially, with one LNG processing train producing 6 Mtpa of LNG, WEL estimates greenhouse gas emissions to be 1.9 Mtpa of CO_2e (carbon dioxide equivalent). After 5 years, when the second LNG train comes online, and the total LNG production reaches 12 Mtpa, this would increase to approximately 4.1 Mtpa of CO_2e.

WEL predicts a greenhouse gas intensity of 0.35 tonnes of CO_2e per tonne of LNG. Based on benchmarking undertaken by the proponent, the greenhouse gas efficiency of the Pluto proposal is comparable with the North West Shelf Venture (NWSV) train 4 and 5 expansion and other LNG developments around the world.

Submissions

No issues were raised on this factor.

Assessment

The EPA's objective for this environmental factor, as set out in Guidance Statement No. 12 "*Guidance Statement for Minimising Greenhouse Gas Emissions*", are to:

- Minimise greenhouse gas emissions in absolute terms and reduce emissions per unit of product to as low as reasonably practicable; and
- Mitigate greenhouse gas emissions, mindful of Commonwealth and State greenhouse gas strategies and programmes.

To achieve this, the EPA expects that potential greenhouse gas emissions from proposed projects are adequately addressed in the planning, design and operation of projects, and that:

- Best practicable measures are applied to maximise energy efficiency and minimise emissions;

- Comprehensive analysis is undertaken of unavoidable emissions, to identify and implement appropriate mitigation measures; and
- An on-going programme is implemented to monitor and report emissions and periodical assessment is undertaken of opportunities to further reduce greenhouse gas emissions over time.

The EPA notes that WEL has selected proven energy efficient technology for the LNG plant, and has incorporated energy efficient practices such as load matching, waste heat recovery, flash gas recovery and no operational flaring. The Pluto gas reservoir contains about 2% naturally occurring CO_2 content, which is relatively low (e.g. Gorgon at 14% CO_2 and NWSV at 2.5% CO_2).

The EPA notes that LNG provides a benefit over the use of fuels such as coal and oil, in terms of the full life cycle greenhouse gas emissions. As such, the EPA acknowledges the important role LNG fulfils as a transition fuel. The EPA also notes a key initiative of the Western Australian Greenhouse Strategy is to "encourage the long term export of relatively cleaner fossil fuels such as LNG".

The EPA encourages all large emitters of greenhouse gas to consider greenhouse gas abatement measures such as geosequestration and greenhouse gas offsets throughout the life of their projects. For the Pluto LNG Development, the EPA expects that, as a minimum, WEL should offset the reservoir CO_2 gas released. This should be done for the life of the project and the EPA has thus recommended that a greenhouse gas abatement condition be applied to this project (condition 12). This condition includes a requirement to provide offsets (condition 12-2).

Summary

Having particular regard to the:

(a) greenhouse gas efficiency per unit of LNG produced being comparable with recent LNG developments; and

(b) recommended condition on Greenhouse Gas Abatement,

it is the EPA's opinion that the proposal can be managed to meet the EPA's environmental objectives for this factor, provided the recommended conditions are made legally enforceable.

3.8 Environmental principles

In preparing this report and recommendations, the EPA has had regard for the object and principles contained in s4A of the *Environmental Protection Act (1986).* Appendix 3 contains a summary of the EPA's consideration of the principles.

4. Conditions and Commitments

Section 44 of the *Environmental Protection Act 1986* requires the EPA to report to the Minister for the Environment on the environmental factors relevant to the proposal and on the conditions and procedures to which the proposal should be subject, if implemented. In addition, the EPA may make recommendations as it sees fit.

In developing recommended conditions for each project, the EPA's preferred course of action is to have the proponent provide an array of commitments to ameliorate the impacts of the proposal on the environment. The commitments are considered by the EPA as part of its assessment of the proposal and, following discussion with the proponent, the EPA may seek additional commitments.

The EPA recognises that not all of the commitments are written in a form which makes them readily enforceable, but they do provide a clear statement of the action to be taken as part of the proponent's responsibility for, and commitment to, continuous improvement in environmental performance.

4.1 Recommended conditions

Having considered the proponent's commitments and the information provided in this report, the EPA has developed a set of conditions that the EPA recommends be imposed if the proposal by Woodside Energy Ltd to proceed with the Pluto LNG Development, is approved for implementation.

Terrestrial Components
For this proposal, the terrestrial environmental impact (loss) is managed firstly by avoiding the most environmentally sensitive areas. The disturbance footprint has now been defined and the primary way to prevent further impact is to ensure that site preparation is restricted to the proposed disturbance area. As such, the disturbance footprint is accurately described in Schedule 1 of the recommended conditions.

Marine impacts
It is the EPA's opinion that the proposal, as presented, does not fully meet the EPA's objectives for the marine environment. However, provided a substantive offset package is agreed and stringent conditions are fully implemented, the Pluto LNG Development could be allowed to proceed.

The proponent has made commitments to prepare and implement various management plans and is currently developing these in consultation with relevant agencies. Many of these plans do not require auditing by the DEC. The EPA considers that the standard environmental conditions and the conditions relating to:

- coral loss limits and management trigger levels;
- a Dredge Impact Management Plan;
- a Dredge Environmental Management Group;
- the deepwater discharge of wastewater;
- a Marine Quarantine Management Plan;
- a Turtle Management Plan;
- a Cultural Heritage Management Plan;
- a Front End Engineering Design Report;
- an Air Quality Management Plan; and
- a Greenhouse Gas Abatement Plan,

should be imposed if the Government approves the proposal by WEL to undertake the Pluto LNG Development.

It should be noted that other regulatory mechanisms relevant to the proposal are:

- *Aboriginal Heritage Act 1972* – Section 18 approvals have been issued to allow the proponent to disturb heritage sites;
- *Environmental Protection Act 1986* – various Works Approvals and a Licence would be required for construction and operation of the Pluto proposal; and.
- *Environment Protection (Sea Dumping) Act 1981* - disposal of spoil within both State and Commonwealth waters is to be undertaken in accordance with permit conditions.

5. Other Advice

There has already been substantial development in Mermaid Sound and further development of port-related facilities is likely with future industrial development on the Burrup Peninsula. This presents difficulties for cumulative impacts within the Sound.

The EPA recommends that the Dampier Port Authority (DPA) take a leadership role in managing the cumulative impacts of dredging proposals within the DPA limits. This could provide a consistent approach by all future proponents that would greatly assist the EPA in the assessment of future development proposals that may affect the marine environment in the DPA area.

The EPA notes that impacts on the marine environment would be greatly reduced if port-related infrastructure was shared. Thus, the EPA expects future proponents of industrial development in Mermaid Sound to comprehensively justify additional single-user facilities.

6. Conclusions

The EPA has considered the proposal by Woodside Energy Ltd to undertake the Pluto LNG Development in the north-west of Western Australia. The project would require extensive dredging both in Mermaid Sound and along the pipeline route, and the construction of a Liquefied Natural Gas (LNG) plant and export facilities on the Burrup Peninsula.

Marine components – The EPA notes that the predictions of coral loss adjacent to the export facility greatly exceed the threshold established in EPA Guidance Statement No. 29, related to benthic primary producers. The existing development around Mermaid Sound already exceeds the threshold of 10% loss for inshore corals. Although Woodside is of the view that its actual impacts would be less than those predicted, the modelled results are those that must be considered as possible. The EPA believes that the losses would only be acceptable if the proponent is able to devise and implement appropriate measures to fully offset the loss of coral. . The EPA considers the current offset package being offered by Woodside is inadequate to address the potential loss of corals.

The proposal is also predicted to cause some loss of coral in the proposed Dampier Archipelago Marine Park. This Marine Park is expected to be gazetted shortly and the draft Management Plan for the park requires that development approvals be consistent with the management targets for the park. The proposal is currently predicted to exceed the management target of ‘no change due to human activities’ for the recreation zone around Conzinc Island. The EPA considers that significant impacts within the Marine Park are unacceptable.

The EPA notes that wastewater discharges to Mermaid Sound should be avoided and expects all options for reuse to be exhausted before a discharge is contemplated. The EPA considers that discharge to deepwater could be acceptable if managed to best practice standards.

As such, it is the EPA’s opinion that the proposal, as presented, does not fully meet the EPA’s objectives for the marine environment. However, provided stringent conditions that require, amongst other things, the:

- preparation and implementation of a Dredge Impact Management Plan to minimise impacts in Mermaid Sound and specifically <u>prevent</u> impacts to the proposed Marine Park, through best practice dredge methods and the timing of works with respect to sea and meteorological conditions;
- conservative ‘stop work’ trigger levels; and
- comprehensive monitoring,

are fully implemented and a substantive offset package is agreed, the Pluto LNG Development could be allowed to proceed.

The EPA has also provided ‘other advice’ recommending the Dampier Port Authority (DPA) take a leadership role in managing the cumulative impacts of dredging proposals within the DPA limits. This would allow for a consistent approach by all future proponents that would greatly assist the EPA in the assessment of future development proposals that may affect the marine environment in the DPA area.

Terrestrial components - The EPA undertook this assessment with regard to the management framework established for the Burrup Peninsula. In practical terms, preservation and promotion of cultural heritage values and the natural environmental values can be readily achieved in the proposed conservation area on the Burrup Peninsula. The EPA’s objective is to ensure that conservation objectives are met in the context of the wider Burrup Peninsula and environmental impacts caused by the proposal are minimised and managed as far as practicable. The EPA considers that the disturbance footprint has been selected and optimised to avoid the most environmentally sensitive sections of the site and that impacts have been minimised to the extent practicable.

The EPA notes that the proposal would result in the permanent loss of native vegetation, fauna habitat and some Indigenous Heritage sites. However, having particular regard to the management framework for the Burrup Peninsula, it is the EPA’s opinion that it is unlikely that the EPA’s objectives for the terrestrial components would be compromised provided there is satisfactory implementation by the proponent of their commitments and the recommended conditions.

7. Recommendations

The EPA submits the following recommendations to the Minister for the Environment:

1. That the Minister notes that the proposal being assessed is the Pluto LNG Development;
2. That the Minister considers the report on the key environmental factors and principles as set out in Section 3;
3. That the Minister notes that the EPA has concluded that the proposal, as presented, does not fully meet the EPA's objectives for the marine environment, and that the current offset package being offered is not adequate to address the potential loss of coral. However, provided a substantive offset package is agreed and the stringent conditions are fully implemented, the Pluto LNG Development could be allowed to proceed; and
4. That should the proposal be approved, the Minister imposes the conditions and procedures recommended in Appendix 4 of this report.

Appendix 1

List of submitters

Organisations:

Department of Environment and Conservation
Department of Health
Department of Fisheries
Dampier Port Authority
Western Australian Museum
Conservation Council Of Western Australia
International Federation of Rock Art Organisations
Ngarluma Aboriginal Corporation
GetUp!

Individuals:

R Clemens
J Gan and C Malcolm
A Vitenbergs

Note: The GetUp! organisation sent a submission with approximately 25 000 names obtained via their website.

Appendix 2

References

DEC (2006) *Proposed Burrup Peninsula Conservation Reserve - Draft Management Plan 2006-2016*, Department of Environment and Conservation, Government of Western Australia, July 2006.

D0E (2006) *Pilbara Coastal Water Quality Consultation Outcomes*, Department of Environment, Government of Western Australia, July 2006.

EPA (2004) *Benthic Primary Producer Habitat Protection for Western Australia's Marine Environment* , Guidance Statement No. 29, Environmental Protection Authority, Government of Western Australia, June 2004.

EPA (2006) *Development of Industrial Land on the Burrup Peninsula for Future Gas Development*, Bulletin 1228, Environment Protection Authority, Government of Western Australia, September 2006.

WEL (2006) *Pluto LNG Development – Draft Public Environment Report / Public Environmental Review*. Woodside Energy Ltd, December 2006.

WEL (2007) *Pluto LNG Development – Public Environment Report / Public Environmental Review*. *Supplement and Response to Submissions*. Woodside Energy Ltd, March 2007.

WEL (2007) *Pluto LNG Development – Addendum to Public Environment Report / Public Environmental Review. Supplement and Response to Submissions* Woodside Energy Ltd, June 2007.

Appendix 3

Summary of identification of key environmental factors and principles

Preliminary Environmental Factors	Proposal Characteristics	Government Agency and Public Comments	Identification of Key Environmental Factors
BIOPHYSICAL			
Vegetation	The proposal would result in the clearing of 119 hectares of native vegetation.	**Government agencies:** The DEC noted that weed management was an important issue. The DEC also recognised that the environmental objectives for the proposed Burrup Peninsula Conservation Reserve were not achievable within the designated Industrial Areas. **Public:** The CCWA noted that cumulative impacts needed to be addressed..	**Considered to be a relevant environmental factor.**
Fauna	The proposal would result in loss of habitat and has the potential to impact on short range endemics. Dredging could impact on marine fauna.	**Government agencies:** The DEC noted that further work was required to resolve the taxonomy of the snail species. **Public:** No issues raised.	**Considered to be a relevant environmental factor.**
Marine	The proposal would require extensive dredging and a marine wastewater discharge.	**Government agencies:** The DEC had a number of queries on the dredge and spoil disposal modelling. The DEC, DPA and DoF did not support a marine discharge. The HDWA noted that any discharge would need to meet requirements of the Radiological Council. **Public:** The CCWA noted that cumulative impacts needed to be addressed.	**Considered to be a relevant environmental factor.**
POLLUTION			
Air Emissions	The Pluto LNG development would emit various air pollutants.	**Government agencies:** The DEC advised that the air dispersion modelling was acceptable. The HDWA recommended an AQMP be required. **Public:** Submitters were concerned that acidic air emissions from the Pluto LNG could cause rock art to deteriorate.	**Considered to be a relevant environmental factor.**

Preliminary Environmental Factors	Proposal Characteristics	Government Agency and Public Comments	Identification of Key Environmental Factors
Groundwater Quality	The Pluto LNG development would use materials that have the potential to pollute groundwater.	**Government agencies:** No issues raised. **Public:** No issues raised.	Addressed through Part V Works Approval and Licence conditions and Storage of Dangerous Goods legislation. **Factor does not require further EPA evaluation.**
Greenhouse Gas	The proposal would emit 4.1 Mtpa of carbon dioxide equivalent.	**Government agencies:** No issues raised. **Public:** No issues raised.	**Considered to be a relevant environmental factor.**
SOCIAL SURROUNDINGS			
Indigenous Heritage	The proposal would necessitate the disturbance of Indigenous Heritage sites within the disturbance footprint. The Burrup Peninsula is internationally recognised for its array of ancient rock art (petroglyphs).	**Government agencies:** The Department of Indigenous Affairs advised that the proponent's identification of impacts, risks, mitigation and control measures was appropriate. The WA Museum queried underwater heritage matters. **Public:** Many submitters were of the view that further industrial development on the Burrup was unacceptable due to the impact on the rock art. There were also concerns that the National/World Heritage listing process should be completed. There was also concern about the consultation undertaken.	**Considered to be a relevant environmental factor.**
Industrial Risk	The Pluto LNG proposal would generate industrial risk.	**Government Agencies:** No comments received. **Public:** A submitter was concerned that the LNG inventory could explode with catastrophic consequences for the region.	The EPA does not assess industrial risk. The Pluto LNG project would be classified as a Major Hazard Facility and as such would be regulated under the *Explosives and Dangerous Goods Act 1961*. **Factor does not require further EPA evaluation,.**

PRINCIPLES		
Principle	**Relevant Yes/No**	**If yes, Consideration**
1. The precautionary principle *Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.* *In application of this precautionary principle, decisions should be guided by –* *(a) careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and* *(b) an assessment of the risk-weighted consequences of various options.*		
	Yes	Management measures need to be in place to ensure any unexpected heritage material that is uncovered during ground disturbing activities is dealt with appropriately. There is uncertainty over the level of impact to the marine environment. Marine Impacts are a relevant environmental factor discussed in this report.
2. The principle of intergenerational equity *The present generation should ensure that the health, diversity and productivity of the environment is maintained and enhanced for the benefit of future generations.*		
	Yes	Proposal has the potential to impact on future generations access to all the indigenous heritage and flora on the Burrup, however this is balanced by 62% of the Burrup being allocated for conservation and recreation. Heritage material to be disturbed would be catalogued and salvaged for future study. The appropriate development of tourism should enable greater numbers of people to experience the rock art and flora in a controlled manner which prevents destruction. Indigenous Heritage is a relevant environmental factor discussed in this report.
3. The principle of the conservation of biological diversity and ecological integrity *Conservation of biological diversity and ecological integrity should be a fundamental consideration.*		
	Yes	Proposal has the potential to impact the biological diversity of flora and fauna on the Burrup, however this is balanced by 62% of the Burrup Peninsula being allocated for conservation and recreation. Vegetation and Fauna are relevant environmental factors discussed in this report.

4. Principles relating to improved valuation, pricing and incentive mechanisms *(1) Environmental factors should be included in the valuation of assets and services.* *(2) The polluter pays principles – those who generate pollution and waste should bear the cost of containment, avoidance and abatement.* *(3) The users of goods and services should pay prices based on the full life-cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste.* *(4) Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structure, including market mechanisms, which enable those best placed to maximize benefits and/or minimize costs to develop their own solution and responses to environmental problems.*		
	Yes	The proponent should bear the cost of avoiding or abating pollution. Where environmental assets are lost, the proponent should bear the cost of offsetting those losses.
5. The principle of waste minimisation *All reasonable and practicable measures should be taken to minimize the generation of waste and its discharge into the environment.*		
	Yes	Emissions of greenhouse gas and pollutants to the air and marine environment should be avoided or minimised.

Appendix 4

Recommended Environmental Conditions

RECOMMENDED ENVIRONMENTAL CONDITIONS

Statement No.

STATEMENT THAT A PROPOSAL MAY BE IMPLEMENTED
(PURSUANT TO THE PROVISIONS OF THE
***ENVIRONMENTAL PROTECTION ACT 1986*)**

PLUTO LIQUIFIED NATURAL GAS DEVELOPMENT (SITE B OPTION)
BURRUP PENINSULA, SHIRE OF ROEBOURNE

Proposal: The proposal is for the construction of facilities for the development of the Pluto Gas Field on the North-West Shelf, and the processing and export of the gas at a liquefied natural gas plant to be constructed on the Burrup Peninsula. Extensive dredging will be undertaken adjacent to the export facility.

The proposal is further documented in schedule 1 of this statement.

Proponent: Woodside Energy Ltd.

Proponent Address: GPO Box D188, PERTH WA 6840

Assessment Number: 1632

Report of the Environmental Protection Authority: Bulletin 1259

The proposal referred to in the above report of the Environmental Protection Authority may be implemented. The implementation of that proposal is subject to the following conditions and procedures:

1 Proposal Implementation

1-1 The proponent shall implement the proposal as documented and described in schedule 1 of this statement subject to the conditions and procedures of this statement.

2 Proponent Nomination and Contact Details

2-1 The proponent for the time being nominated by the Minister for the Environment under sections 38(6) or 38(7) of the *Environmental Protection Act 1986* is responsible for the implementation of the proposal.

2-2 The proponent shall notify the Chief Executive Officer of the Department of Environment and Conservation (CEO) of any change of the name and address of the proponent for the serving of notices or other correspondence within 30 days of such change.

3 Time Limit of Authorisation

3-1 The authorisation to implement the proposal provided for in this statement shall lapse and be void within five years after the date of this statement if the proposal to which this statement relates is not substantially commenced.

3-2 The proponent shall provide the CEO with written evidence which demonstrates that the proposal has substantially commenced on or before the expiration of five years from the date of this statement.

4 Compliance Reporting

4-1 The proponent shall submit to the CEO environmental compliance reports annually reporting on the previous twelve-month period, unless required by the CEO to report more frequently.

4-2 The environmental compliance reports shall address each element of an audit program approved by the CEO and shall be prepared and submitted in a format acceptable to the CEO.

4-3 The environmental compliance reports shall:

1. be endorsed by signature of the proponent's Managing Director or a person, approved in writing by the CEO, delegated to sign on behalf of the proponent's Managing Director;

2. state whether the proponent has complied with each condition and procedure contained in this statement;

3. provide verifiable evidence of compliance with each condition and procedure contained in this statement;

4. state whether the proponent has complied with each key action contained in any environmental management plan or program required by this statement;

5. provide verifiable evidence of conformance with each key action contained in any environmental management plan or program required by this statement;

6. identify all non-compliances and non-conformances and describe the corrective and preventative actions taken in relation to each non-compliance or non-conformance;

7. review the effectiveness of all corrective and preventative actions taken; and

8. describe the state of implementation of the proposal.

4-4 The proponent shall make the environmental compliance reports required by condition 4-1 publicly available in a manner approved by the CEO.

5 Performance Review

5-1 The proponent shall submit a Performance Review report every five years after the start of operations to the Environmental Protection Authority, which addresses:

1. the major environmental issues associated with implementing the project; the environmental objectives for those issues; the methodologies used to achieve these; and the key indicators of environmental performance measured against those objectives;

2. the level of progress in the achievement of sound environmental performance, including industry benchmarking, and the use of best available technology where practicable;

3. significant improvements gained in environmental management, including the use of external peer reviews;

4. stakeholder and community consultation about environmental performance and the outcomes of that consultation, including a report of any on-going concerns being expressed; and

5. the proposed environmental objectives over the next five years, including improvements in technology and management processes.

5-2 The proponent shall make the Performance Review reports required by condition 5-1 publicly available in a manner approved by the CEO.

6 Marine Impacts

6-1 The proponent shall provide an appropriate offset package to the requirements of the Minister for the Environment, on advice of the Environmental Protection Authority.

6-2 The proponent shall undertake all works to ensure that the Limits of Coral Loss, specified in schedule 2, associated with each of the designated Impact Criteria Zones described and defined in Figure 3, are not exceeded.

6-3 If any Level 1 Coral Condition Management Trigger Criterion referred to in schedule 3 is exceeded, within 12 hours following detection of the exceedance, the proponent shall notify the Department of Environment and Conservation and provide details of the actions being taken to reduce turbidity-generating activities which are affecting that site; and within 24 hours of the criterion being exceeded, the proponent shall implement management actions to keep impacts within approved limits specified in schedule 2.

6-4 If any Level 2 Coral Condition Management Trigger Criterion referred to in schedule 3 is exceeded at any monitoring site, the proponent shall:

- immediately suspend all turbidity-generating activities;

- provide a report on the measures to be implemented to keep impacts below Limits in schedule 2, prior to recommencing any turbidity-generating activities which could affect that site; and

- provide a report, on advice of the Dredge Environmental Management Group, defining marine water quality conditions which will be met for the endorsement of the Minister for the Environment on advice of the CEO to allow for the recommencement of dredging to ensure that mortality and / or impacts will not exceed the limits specified in schedule 2.

6-5 If any Level 3 Coral Condition Management Trigger Criterion referred to in schedule 3 is exceeded at any monitoring site, the proponent shall:

- immediately suspend all turbidity-generating activities; and

- provide a report to the Minister for the Environment regarding the non-compliance with condition 6-2.

6-6 Prior to commencement of turbidity-generating activities, the proponent shall prepare a Dredge Impact Management Plan for dredge activities which demonstrates that the activities can achieve the management targets for the Marine Park and which demonstrates that management strategies will be employed which will minimise impacts on benthic habitats and communities (including corals) outside the Marine Park.

This plan shall address the following:

1. comprehensive monitoring of water quality, sediment deposition, and coral condition;

2. best practice dredge procedures;

3. selection of a suitable location for the off-shore spoil ground which demonstrably does not cause impacts on the Marine Park;

4. optimum timing of works with respect to sea and meteorological conditions;

5. establishment of conservative ‘stop work’ trigger levels;

6. identify and temporally define key ecological windows when dredging activity will not occur, such as during coral spawning periods; and

7. contingency plans.

Further details on the content required in this Plan is provided in schedule 4.

6-7 The proponent shall implement the Dredge Impact Management Plan required by condition 6-6.

6-8 The proponent shall make the Dredge Impact Management Plan required by condition 6-6 publicly available in a manner approved by the CEO.

6-9 The proponent shall resource a Dredge Environmental Management Group for the duration of the marine works and for such time before and after the marine works so as to carry out its function, to the requirements of the Minister for the Environment.

The role of the Dredge Environmental Management Group is to provide the Minister for the Environment, the Department of Environment and Conservation and the proponent with advice including, but not limited to:

1. the marine management plans;

2. the marine monitoring programs;

3. the management of turbidity-generating activities and marine works;

4. impacts on marine fauna and flora, including corals;

5. reporting; and

6. new management measures.

The membership of the Dredge Environmental Management Group may include:

- an independent chair appointed by the Minister for the Environment on advice from the CEO;

- experts appointed by the Minister for the Environment; and

- the following agencies may nominate one member each:

    - the Department of Fisheries;
    - the Dampier Port Authority;
    - the Department of Environment and Conservation; and
    - the proponent.

6-10 The proponent shall provide a report on a detailed survey of coral habitat and communities and the distribution of other benthic habitat types (including soft corals, sponges, algal reef communities) to the Department of Environment and Conservation at least one month prior to commencement of any marine works associated with the proposal.

6-11 Prior to commencement of any marine works, the proponent shall prepare, and submit to the Department of Environment and Conservation, a Scope of Baseline Marine Habitat Survey document to the requirements of the Minister for the Environment.

The objective of the document is to specify procedures to quantitatively determine the pre-development baseline distribution, community composition and health of benthic marine habitats (see note below) within the area which may be affected by any works associated with the proposal. This document shall address the following:

1. survey methods;

2. location and establishment of survey sites;

3. timing and frequency of surveys;

4. habitat classification schemes;

5. treatment of survey data; and

6. mapping methodologies.

Note: "Marine habitats" includes hard and soft coral communities, sponge communities, seagrass and macro-algal communities.

6-12 The proponent shall conduct a Comprehensive Field Survey, consistent with the approved Scope of Baseline Marine Habitat Survey document, and provide a report of the results to the Department of Environment and Conservation within six months following commencement of any works associated with the proposal.

This report shall:

1. contain spatially accurate (e.g. rectified and geographically referenced) maps showing the locations and spatial extent of the different marine habitat types and percentage cover of each component of their associated benthic communities including corals, macroalgae, non-coral macro-invertebrates and seagrass;
2. record the existing hard and soft corals, macroalgae, non-coral benthic macro-invertebrates, seagrass and demersal fish observed within the communities;
3. record the population structure, as size class frequency distributions, and other population statistics such as recruitment, survival and growth, of key hard coral species;
4. evaluate baseline pre-development health of the benthic communities at representative survey sites; and
5. include data provided in an appropriate Geographic Information System data set format.

6-13 Within three months following completion of the project works, the proponent shall repeat the Comprehensive Field Survey required by condition 6-12, and shall submit a report on the results of that survey to the Department of Environment and Conservation.

This will constitute the first Post-Dredging Marine Habitat Survey, reporting any changes which may have occurred between the Baseline Marine Habitat Survey and the first Post-Dredging Marine Habitat Survey.

6-14 The proponent shall repeat the Post-Dredging Marine Habitat Survey required by condition 6-13, at the same time of the year annually for three years, or until such time, as determined by the Minister for the Environment on advice of the Department of Environment and Conservation and the Department of Fisheries.

6-15 Within three months following completion of each of the surveys required by conditions 6-13 and 6-14, the proponent shall report the findings of each of the surveys to the Department of Environment and Conservation.

7 Deepwater Marine Outfall

7-1 If a marine wastewater discharge is required by the proponent, then the proponent shall construct the associated infrastructure so that wastewater is discharged into water of depth greater than 30 metres outside the Dampier Archipelago.

7-2 Prior to construction of the wastewater treatment plant or the marine outfall, whichever is the sooner, the proponent, in consultation with Department of Environment and Conservation, shall prepare a Marine Treated Wastewater Discharge Management Plan to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority.

The objective of this Plan is to ensure that the discharge of treated wastewater is managed to achieve simultaneously the following Environmental Quality Objectives as described in the document, *Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives* (Department of Environment, March 2006):

- Maintenance of ecosystem integrity with spatially-assigned levels of protection;
- Maintenance of aquatic life for human consumption assigned to all parts of the marine environment surrounding the ocean outlet;
- Maintenance of primary contact recreation assigned to all parts of the marine environment surrounding the ocean outlet;
- Maintenance of secondary contact recreation values assigned to all parts of the marine environment surrounding the ocean outlet;
- Maintenance of aesthetic values assigned to all parts of the marine environment surrounding the ocean outlet;
- Maintenance of cultural and spiritual values assigned to all parts of the marine environment surrounding the ocean outlet; and
- Maintenance of Industrial Water Supply.

This Plan shall address the following:

1. An assessment of the effect of wastewater flow rate on the number of dilutions the diffuser is predicted to achieve within the zone of initial dilution at maximum flow rate;
2. setting environmental values, environmental quality objectives and levels of ecological protection to be achieved around the outfall;

3. identification of environmental quality indicators and associated “trigger” levels for the implementation of remedial, management and/or preventative actions to protect the water quality and the marine environment based on the guidelines and recommended approaches in ANZECC & ARMCANZ (2000);

4. Whole Effluent Toxicity (WET) testing of wastewater, consistent with ANZECC requirements and addressing the items in schedule 5 (attached);

5. redesign and incorporation of a new diffuser, including timelines, in the event that the WET testing results show that the original wastewater diffuser is not achieving sufficient dilutions to meet a high level of ecological protection at the edge of the mixing zone;

6. verification of diffuser performance in terms of achieving the required number of initial dilutions under low energy/calm meteorological and sea-state conditions to achieve a high level of ecosystem protection (99% species protection) at the edge of the approved mixing zone;

7. a monitoring program to permit determination of whether the water quality objectives are being met; and

8. protocols and schedules for reporting performance against the Environmental Quality Objectives using the environmental quality trigger levels.

7-3 The proponent shall implement the Marine Treated Wastewater Discharge Management Plan required by condition 7-2.

7-4 The proponent shall make the Marine Treated Wastewater Discharge Management Plan required by condition 7-2 publicly available in a manner approved by the CEO.

7-5 Prior to submitting a Works Approval application for the wastewater treatment plant, the proponent shall:

1. characterise in detail the physical and chemical composition and flow rates of all wastewater streams within the site and, using the toxicity of mixtures principles, predict the theoretical toxicity of the combined wastewater after treatment;

2. determine, for all contaminants and nutrients the total annual loads of contaminants and nutrients in the wastewater discharge exiting the site; and

3. determine, for normal and worst-case conditions, the concentrations of contaminants and nutrients (for agreed averaging periods) in the wastewater discharge exiting the site.

7-6 Prior to submitting a Works Approval application for the wastewater treatment plant, the proponent shall demonstrate that the wastewater discharge will meet “best practicable technology” and waste minimisation principles for contaminants and nutrients.

7-7 Prior to submitting a Works Approval application for the wastewater treatment plant, the proponent shall design, and subsequently operate, plant and equipment on the site such that:

1. the contaminant concentrations in the wastewater effluent from the site, just prior to entry to the wastewater discharge system, meet (in order of preference):

   - the ANZECC/ARMCANZ (2000) 99% species protection level; or
   - the ANZECC/ARMCANZ (2000) 99% species protection level at the edge of an approved mixing zone;

2. the concentrations of contaminants in the wastewater effluent which can potentially bio-accumulate / bio-concentrate meet the ANZECC / ARMCANZ (2000) 80% species protection trigger levels just prior to entry into the wastewater discharge system; and

3. mass balances and inventories of toxicants can be maintained throughout the life of the plant so that their fate can be traced.

7-8 Within three months following commissioning and stabilising of plant operations, the proponent shall conduct an analysis of effluent properties and contaminant concentrations, to an analytical limit of reporting agreed by the Department of Environment and Conservation, demonstrating that they are substantially consistent with predictions.

7-9 Prior to operation, the proponent shall develop a Contingency Wastewater Management Plan which will consider alternate options for wastewater disposal in the event that the Water Quality Objectives are not met as determined through WET testing, diffuser performance monitoring or environmental quality monitoring, to the requirements of the Minister for the Environment.

7-10 In the event that the treatment plant malfunctions or goes off-line, the proponent shall include within the Contingency Wastewater Management Plan required by condition 7-9 alternative options for wastewater disposal to the timing and other requirements of the Minister for the Environment.

7-11 In the event that the water quality objectives are not being met, the proponent shall implement the Contingency Wastewater Management Plan required by condition 7-9.

7-12 The proponent shall review and revise the Contingency Wastewater Management Plan required by condition 7-9, as and when directed by the CEO.

7-13 The proponent shall make any revisions of the Contingency Wastewater Management Plan, as required by condition 7-12, publicly available in a manner approved by the CEO.

8 Marine Quarantine

8-1 Prior to commencement of dredging, the proponent shall prepare and implement a Marine Quarantine Management Plan to prevent the introduction of any non-indigenous species to the waters adjacent to the proposal both during dredging and operation, to the requirements of the Minister for the Environment.

8-2 Prior to commencement of dredging and within 48 hours following entry of the dredging equipment and other vessels associated with the proposal into the Port of Dampier, the proponent shall arrange for an inspection to be carried out by an appropriately qualified marine scientist to ensure that:

1. there is no sediment in the dredging equipment; and

2. any fouling organisms on the dredging equipment and other vessels associated with the proposal and any organisms in the ballast waters of the equipment and vessels do not present a risk to the ecosystem integrity of the marine waters of the Dampier Archipelago,

to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority.

8-3 Prior to the commencement of dredging, the proponent shall report to the Department of Environment and Conservation on the results of the inspection referred to in condition 8-2.

8-4 The proponent shall manage any sediment or fouling organisms found as a consequence of the inspection required by condition 8-2, to the timing and other requirements of the Minister for the Environment.

8-5 If, following the completion of dredging and disposal activities, the dredging equipment is to be transferred to another location within Western Australia's territorial waters, the proponent shall undertake an investigation employing an appropriately qualified marine scientist to identify the presence of / the potential for introduced marine pests, to the requirements of the Minister for the Environment.

8-6 In the event that any introduced marine pests are detected, the proponent shall put in place a Marine Pests Management Strategy to ensure that introduced marine pests are not transferred to other locations within Western Australia's territorial waters, to the requirements of the Minister for the Environment.

Note: In the preparation of the report required by condition 8-3, and in the development of any actions required by conditions 8-4 to 8-6, the Environmental Protection Authority expects that advice of the following agencies will be obtained:

- Department of Fisheries; and
- Australian Quarantine Inspection Service.

8-7 The proponent shall, for the life of the project, notify the Department of Environment and Conservation and the Department of Fisheries of any non-indigenous species detected in the waters adjacent to the project within 24 hours following detection.

8-8 In the event that non-indigenous species introduced by the proponent are detected during dredging or operation, the proponent shall take immediate action to prevent establishment or proliferation and action to control and eradicate them to the requirements of the Minister for the Environment.

9 Turtle Management and Monitoring

9-1 Prior to the commencement of works and in consultation with the Department of Environment and Conservation, the proponent shall prepare a Turtle Management Plan to the requirements of the Minister for the Environment.

The objectives of this Plan are:

- to provide a management framework to enable the proponent to manage the project so as to detect and mitigate as necessary [mitigate as defined in Environmental Protection Authority Guidance Statement 9] any impact upon marine turtles from the project; and

- to identify darkness strategies to reduce as far as possible lights or light glow interfering with nesting female turtles and hatchlings.

This Plan shall:

1. identify project-related stressors, causes of environmental impacts and potential consequences for marine turtles (including impact of noise, vibration, light overspill and glow, vessel strike, and changes to coastal processes); and

2. identify and demonstrate the effectiveness of proposed management measures to mitigate [as defined in Environmental Protection Authority Guidance Statement 9] project-related impacts and consequences for marine turtles.

9-2 The proponent shall implement the Turtle Management Plan required by condition 9-1.

9-3 The proponent shall make the Turtle Management Plan required by condition 9-1 publicly available in a manner approved by the CEO.

9-4 The proponent shall review the Turtle Management Plan required by condition 9-1 annually to the requirements of the Minister for the Environment.

9-5 The proponent shall report any marine turtle or other specially protected marine fauna mortality to the Department of Environment and Conservation within 24 hours following observation.

10 Indigenous Heritage

10-1 Prior to ground-disturbing activities, the proponent shall prepare, in liaison with the Department of Indigenous Affairs, and submit to the Department of Environment and Conservation, a Cultural Heritage Management Plan.

This Plan shall address:

1. the inclusion of cultural heritage awareness training in the workforce induction;

2. the signposting and fencing of nearby heritage sites to prevent unauthorised access;

3. the monitoring of ground-disturbing activities by an anthropologist/archaeologist and representatives of the Traditional Custodians; and

4. the retrieval and relocation of heritage material which lies within the disturbance footprint in consultation with the Traditional Custodians.

10-2 The proponent shall implement the Cultural Heritage Management Plan required by condition 10-1.

10-3 The proponent shall make the Cultural Heritage Management Plan required by condition 10-1 publicly available in a manner approved by the CEO.

11 Air Emissions

11-1 Prior to submitting a Works Approval application for the plant, the proponent shall submit a detailed Front End Engineering Design Report demonstrating that the proposed works adopt best practice pollution control measures to minimise emissions from the plant, to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority.

This Report shall:

1. set out the base emission rates for major sources for the plant and the design emission targets; and

2. address normal operations, shut-down, and start-up, and equipment failure conditions.

11-2 At least three months prior to operation, the proponent shall prepare an Air Quality Management Plan to the requirements of the Minister for the Environment.

The objective of this Plan is to ensure that best available practicable and efficient technologies are used to minimise and monitor air emissions from the plant.

This Plan shall include:

1. cumulative air quality modelling which uses data from the Front End Engineering Design Report and includes emissions from approved industrial sources at Cape Preston and Barrow Island;

2. proposed targets and standards;

3. an emissions monitoring programme, which includes nitrogen compounds, butene, toluene, ethylene, xylene, ozone, acrylene and hydrogen sulphide emissions from the plant;

4. an ambient air monitoring programme and a nitrogen deposition monitoring programme; and

5. annual reporting.

11-3 The proponent shall implement the Air Quality Management Plan required by condition 11-2.

11-4 The proponent shall make the Air Quality Management Plan required by condition 11-2 publicly available in a manner approved by the CEO.

12 Greenhouse Gas Abatement

12-1 Prior to commencement of construction, the proponent shall develop a Greenhouse Gas Abatement Program:

- to ensure that the plant is designed and operated in a manner which achieves reductions in "greenhouse gas" emissions as far as practicable;

- to provide for ongoing "greenhouse gas" emissions reductions over time;

- to ensure that through the use of best practice, the total net "greenhouse gas" emissions and/or "greenhouse gas" emissions per unit of product from the project are minimised; and

- to manage "greenhouse gas" emissions in accordance with the *Framework Convention on Climate Change 1992*, and consistent with the National Greenhouse Strategy;

to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority.

This Program shall include:

1. calculation of the "greenhouse gas" emissions associated with the proposal, as advised by the Environmental Protection Authority;

   Note: The current requirements of the Environmental Protection Authority are set out in: *Minimising Greenhouse Gas Emissions, Guidance for the Assessment of Environmental Factors, No. 12* published by the Environmental Protection Authority (October 2002). This document may be updated or replaced from time to time;

2. specific measures to minimise the total net "greenhouse gas" emissions and/or the "greenhouse gas" emissions per unit of product associated with the proposal using a combination of "no regrets" and "beyond no regrets" measures;

3. the implementation and ongoing review of "greenhouse gas" offset strategies with such offsets to remain in place for the life of the proposal;

4. estimation of the “greenhouse gas” efficiency of the project (per unit of product and/or other agreed performance indicators) and comparison with the efficiencies of other comparable projects producing a similar product, both within Australia and overseas;

5. implementation of thermal efficiency design and operating goals consistent with the Australian Greenhouse Office Technical Efficiency guidelines in design and operational management;

6. actions for the monitoring, regular auditing and annual reporting of “greenhouse gas” emissions and emission reduction strategies;

7. a target set by the proponent for the progressive reduction of total net “greenhouse gas” emissions and/or “greenhouse gas” emissions per unit of product and as a percentage of total emissions over time, and annual reporting of progress made in achieving this target. Consideration should be given to the use of renewable energy sources such as solar, wind or hydro power;

8. a program to achieve reduction in “greenhouse gas” emissions, consistent with the target referred to in (7) above;

9. entry, whether on a project-specific basis, company-wide arrangement or within an industrial grouping, as appropriate, into the Commonwealth Government’s “Greenhouse Challenge” voluntary cooperative agreement program.

   Components of the agreement program include:
   1. an inventory of emissions;
   2. opportunities for abating “greenhouse gas” emissions in the organisation;
   3. a “greenhouse gas” mitigation action plan;
   4. regular monitoring and reporting of performance; and
   5. independent performance verification.

10. review of practices and available technology; and

11. “Continuous improvement approach” so that advances in technology and potential operational improvements of plant performance are adopted.

   Note: In (2) above, the following definitions apply:

   1. “no regrets” measures are those which can be implemented by a proponent and which are effectively cost-neutral; and
   2. “beyond no regrets” measures are those which can be implemented by a proponent and which involve additional costs which are not expected to be recovered.

12-2 For the life of the project, the proponent shall provide greenhouse gas offsets that, as a minimum, offsets the reservoir carbon dioxide content released, to the requirements of the Minister for the Environment.

12-3 The proponent shall implement the Greenhouse Gas Abatement Program required by condition 12-1.

12-4 Prior to commencement of construction, the proponent shall make the Greenhouse Gas Abatement Program required by condition 12-1 publicly available in a manner approved by the CEO.

13 Decommissioning

13-1 Prior to submitting a Works Approval application for the plant, the proponent shall prepare a Preliminary Decommissioning Plan for approval by the CEO, which describes the framework and strategies to ensure that the site is suitable for future land uses, and provides:

1. the rationale for the siting and design of plant and infrastructure as relevant to environmental protection;

2. a conceptual description of the final landform at closure;

3. a plan for a care and maintenance phase; and

4. initial plans for the management of noxious materials.

13-2 At least six months prior to the anticipated date of closure, or at a time approved by the CEO, the proponent shall submit a Final Decommissioning Plan designed to ensure that the site is suitable for future land uses, for approval of the CEO.

The Final Decommissioning Plan shall set out procedures and measures for:

1. removal or, if appropriate, retention of plant and infrastructure agreed in consultation with relevant stakeholders;

2. rehabilitation of all disturbed areas to a standard suitable for the agreed new land use(s); and

3. identification of contaminated areas, including provision of evidence of notification and proposed management measures to relevant statutory authorities.

13-3 The proponent shall implement the Final Decommissioning Plan required by condition 13-2 until such time as the Minister for the Environment determines, on advice of the CEO, that the proponent’s decommissioning responsibilities have been fulfilled.

13-4 The proponent shall make the Final Decommissioning Plan required by condition 13-2 publicly available in a manner approved by the CEO.

Notes

1. Where a condition states "on advice of the Environmental Protection Authority", the Environmental Protection Authority will provide that advice to the Department of Environment and Conservation for the preparation of written notice to the proponent.

2. The Environmental Protection Authority may seek advice from other agencies or organisations, as required, in order to provide its advice to the Department of Environment and Conservation.

3. The Minister for the Environment will determine any dispute between the proponent and the Environmental Protection Authority or the Department of Environment and Conservation over the fulfilment of the requirements of the conditions.

4. The proponent is required to apply for a Works Approval and Licence for this project under the provisions of Part V of the *Environmental Protection Act 1986*.

Schedule 1

The Proposal (Assessment No. 1632)

The proposal is for the construction of facilities for the development of the Pluto Gas Field on the North-West Shelf. These facilities are for the transport and processing of the gas at a Liquefied Natural Gas (LNG) plant to be constructed on the Burrup Peninsula.

The gas is to be transported by a sub-sea trunkline to the west coast of the Burrup Peninsula where the LNG plant will be sited on two of the designated Industrial Lease Areas. The storage and export facility is to be constructed on Site A and the gas processing plant is to be constructed on Site B.

Extensive dredging will be undertaken to allow tanker access to the export facility and for gas-trunkline installation.

The proposal is described in the document *Pluto LNG Development – Draft Public Environment Report / Public Environmental Review*, prepared for Woodside Energy Ltd. (2006).

The main characteristics of the proposal are summarised in Table 1 below.

Table 1 - Summary of key proposal characteristics (Assessment No. 1632)

Element	Description
Dredging • navigation channel: • turning basin: • berth pocket: • nearshore trunkline trench. • total volume to be dredged:	 approximately 10 kilometres long, 275 metres wide. approximately 800 metres diameter. approximately 425 metres x 85 metres. approximately 23 kilometres long, 25 metres wide. not more than 14 million cubic metres.
Marine disposal of spoil • spoil ground A/B: • offshore spoil ground: • reuse of spoil:	 not more than 0.25 million cubic metres. not more than 14 million cubic metres. not more that 0.8 million cubic metres.
Gas trunkline • gas field to LNG plant:	 approximately 32 kilometres of route that is within State territorial waters.
Site works • clearing on Site A: • clearing on Site B: • salvage and relocation of heritage material. • drilling and blasting. • cut-and-fill activities.	 not more than 22.4 hectares (within disturbance footprint). not more than 96 hectares (within disturbance footprint).

Element	Description
Product storage facility • two cryogenic LNG tanks: • three condensate tanks:	 each with a capacity of not more than 160 000 cubic metres. combined capacity of not more than 130 000 cubic metres.
LNG Plant Two LNG processing trains: • total nominal capacity: • power generation (each train): • gas compression (each train): • liquefaction plant (each train): • administration buildings. • Workshop and control buildings. • car parks. • internal roads.	 12 million tonnes per annum of LNG. 5 x Frame-6 ‘dry low NOX’ gas turbines. 3 x Frame-7 ‘dry low NOX’ gas turbines. 1 x Frame-5 gas turbine.
Domgas Domestic gas supply	 approximately 4 million tonnes per annum (to be refined at a later stage)
Flares • one on Site A: • three (combined) on Site B:	 storage and loading flare. wet flare, LNG flare and common spare flare.
Export jetty • jetty:	 approximately 500 metres long.
Wastewater treatment plant and deepwater marine outfall • discharge of treated wastewater:	 not more than 1000 cubic metres per day.

Figures (attached)

Figure 1 - Site location and disturbance footprint (Site A).
Figure 2 - Site location and disturbance footprint (Site B).
Figure 3 – Impact criteria zones - coral.

Figure 1: *Site location and disturbance footprint (Site A).*

Site A Disturbance Zone (06/02/2007) Coordinates

P01, 475539.10, 7721203.70
P02, 475125.50, 7721439.10
P03, 475109.00, 7721448.40
P04, 475094.20, 7721460.80
P05, 475066.40, 7721479.50
P06, 474963.70, 7721534.80
P07, 474908.30, 7721564.70
P08, 474864.60, 7721587.00
P09, 474859.90, 7721566.75
P10, 474835.10, 7721547.30
P11, 474825.50, 7721545.10
P12, 474817.00, 7721539.90
P13, 474808.40, 7721537.85
P14, 474797.90, 7721543.40
P15, 474797.90, 7721554.01
P16, 474798.10, 7721566.40
P17, 474795.90, 7721577.70
P18, 474791.30, 7721587.70
P19, 474791.15, 7721602.35
P20, 474803.00, 7721621.80
P21, 474770.70, 7721639.80
P22, 474769.60, 7721636.80
P23, 474707.10, 7721556.30
P24, 474704.50, 7721538.50
P25, 474722.30, 7721504.00
P26, 474732.91, 7721504.00
P27, 474753.90, 7721498.90
P28, 474761.70, 7721492.40
P29, 474769.00, 7721485.00
P30, 474782.80, 7721475.15
P31, 474798.80, 7721465.25
P32, 474814.80, 7721461.40
P33, 474830.05, 7721461.25
P34, 474846.85, 7721461.55
P35, 474859.90, 7721464.20
P36, 475056.60, 7721352.30
P37, 475010.40, 7721271.00
P38, 475016.70, 7721247.70
P39, 474923.30, 7721083.40
P40, 474927.10, 7721009.90
P41, 475094.00, 7720917.00
P42, 475257.30, 7720965.00
P43, 475276.05, 7720994.35
P44, 475327.50, 7721086.90
P45, 475325.50, 7721091.00
P46, 475327.30, 7721094.40
P47, 475351.90, 7721084.00
P48, 475414.50, 7721064.30
P49, 475489.20, 7721163.40
P50, 475509.30, 7721163.10

Figure 2: Site location and disturbance footprint (Site B).

Site B Disturbance Zone (15/06/2007) Coordinates

P001, 476791.62, 7720954.78,	P002, 476756.65, 7720976.18,	P003, 476697.98, 7721012.08,	P004, 476695.96, 7721013.27,	P005, 476693.32, 7721014.69,	P006, 476690.49, 7721016.08,
P007, 476688.29, 7721017.04,	P008, 476684.99, 7721018.34,	P009, 476682.03, 7721019.35,	P010, 476677.68, 7721020.58,	P011, 476672.56, 7721021.66,	P012, 476665.53, 7721022.53,
P013, 476660.53, 7721022.73,	P014, 476655.95, 7721022.61,	P015, 476651.71, 7721022.24,	P016, 476647.86, 7721021.68,	P017, 476644.47, 7721021.02,	P018, 476640.39, 7721019.99,
P019, 476637.31, 7721019.04,	P020, 476633.82, 7721017.78,	P021, 476630.69, 7721016.48,	P022, 476628.11, 7721015.27,	P023, 476626.48, 7721014.44,	P024, 476614.27, 7721026.65,
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P031, 476528.14, 7721032.14,	P032, 476527.49, 7721023.41,	P033, 476526.52, 7721013.59,	P034, 476525.08, 7721003.37,	P035, 476525.09, 7720997.37,	P036, 476516.18, 7720995.97,
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P061, 476314.71, 7720937.09,	P062, 476299.38, 7720958.94,	P063, 476298.45, 7720961.41,	P064, 476292.18, 7720965.24,	P065, 476274.08, 7720959.37,	P066, 476229.47, 7720994.87,
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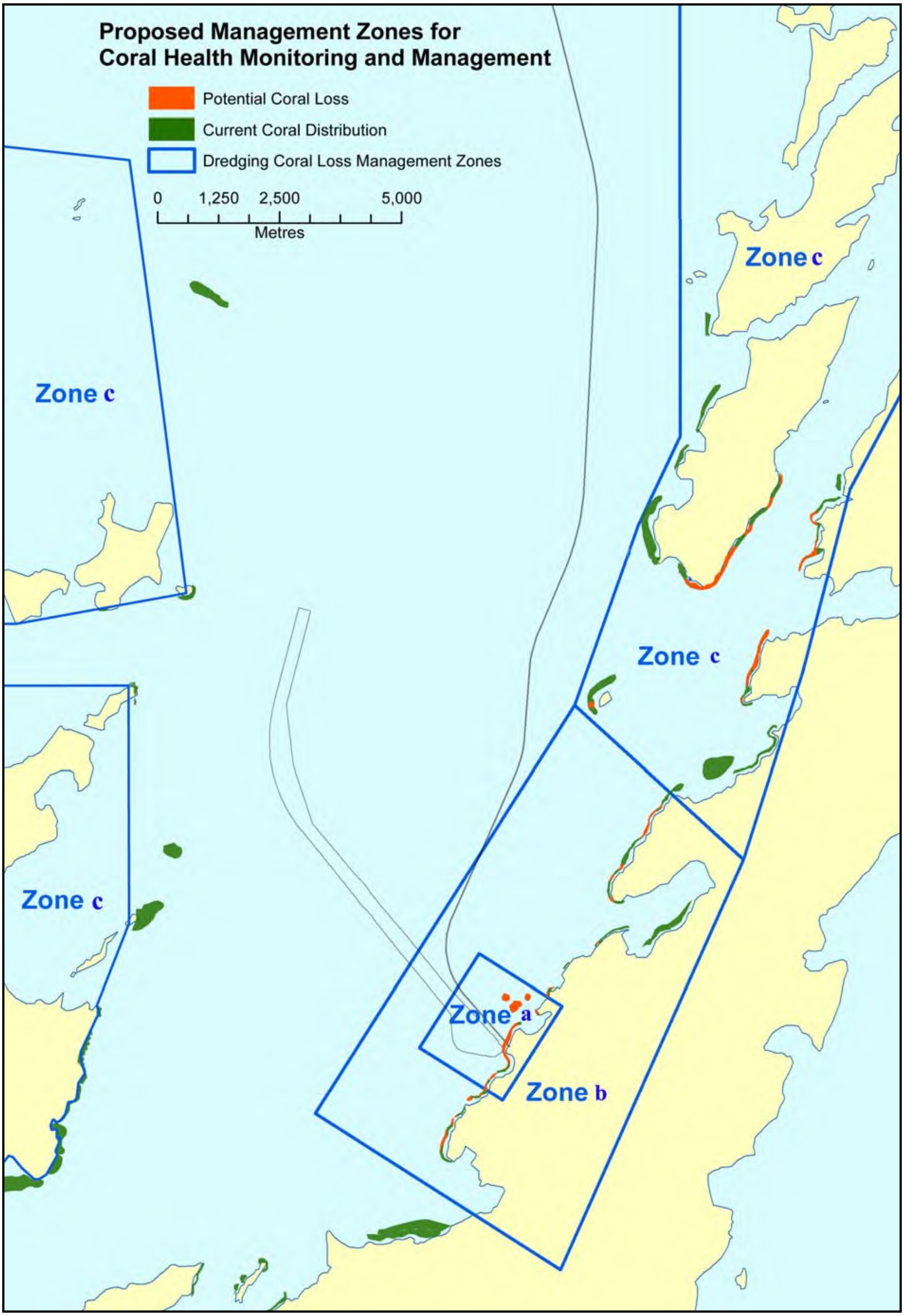

Figure 3: Impact criteria zones - coral.

Schedule 2

Limits of Coral Loss

Impact Criteria Zones	Direct Loss	Indirect Loss
A	12,100 m^2	100%
B	0	10% net detectable mortality
C	0	0% net detectable mortality

Notes:

Direct loss is defined as permanent removal of Benthic Primary Producer Habitat (BPPH) substrate and mortality of coral.

Indirect loss is defined as mortality of coral with no removal of BPPH substrate. BPPH may return at some future time, but this will be dependent upon the condition of substrate and successful recruitment.

The Change in coral mortality is determined by subtracting the baseline extent of Gross coral mortality from the extent of Gross coral mortality measured on a sampling occasion.

Net detectable coral mortality at a monitoring location is the result of subtracting the Change in coral mortality at the Reference Site from the Change in coral mortality at that Monitoring Site.

Net detectable coral mortality averaged is the result of averaging the net mortality of all monitoring locations within the Zone i.e. the mean of net mortality of any Zone.

Gross coral mortality at a site is expressed as a percentage of total coral cover at the time of sampling at that monitoring location.

In determining the coral loss, measurement uncertainty is to be taken into consideration.

See Figure 3.

Schedule 3

Coral Condition Management Trigger Criteria

The following Coral Condition Management Trigger Criteria apply to the management of all turbidity-generating activities:

Impact Criteria Zones	Level 1	Level 2	Level 3
A	N/A	N/A	N/A
B	5% averaged net mortality of coral taxa at monitoring sites measured on high and low tide daily.	8% averaged net mortality of coral taxa at monitoring sites within Zone B.	10% averaged net mortality of coral taxa at monitoring sites within Zone B.
C	7-day running median suspended sediments concentration at any coral monitoring site is greater than the 7-day running 80th percentile of the reference site/s data collected at the same time or some other water quality parameter determined by the proponent.	Sub-lethal effect on more than 10% of coral at any monitoring site within Zone C (sub-lethal indicators to be determined by the proponent.)	0% net detectable mortality of coral at <u>any</u> monitoring site within Zone C.

See Figure 3.

Schedule 4

Dredge Impact Management Plan

The objectives of this Plan are:

- to demonstrate that dredge activities can achieve the management targets for the Marine Park;
- manage turbidity-generating activities and works associated with the proposal;
- to ensure that the Limits of Coral Loss specified in schedule 2 are not exceeded; and
- to select an optimum location for the offshore spoil ground.

This Plan shall include the following elements:

(1) Scale maps showing:

1. the marine habitats, marine and coastal infrastructure, and Impact Criteria Zones A, B and C shown in Figure 3;

2. the locations and geographical coordinates of each Impact Monitoring Site and each Reference Site for water quality, sediment deposition and coral condition monitoring, and

3. site designs showing the placement of replicate sample stations, permanent benthic transects, re-locatable quadrats along the transects and marked individual coral colonies within each Impact Monitoring and Reference Site.

(2) A Water Quality and Sediment Deposition Monitoring Program which:

1. specifies monitoring frequency and the parameters to be measured;

2. details the use of *in-situ* deployable water quality and sediment deposition monitoring instruments, including those with the capability of real-time telemetry access to data;

3. sets out Operating Procedures and QA/QC protocols for environmental condition monitoring methods, site and field instrument maintenance, and data capture, analyses and interpretation;

4. demonstrates that the program has statistical power of 0.8 or greater to detect exceedances of the coral condition management trigger criteria specified in Schedule 3;

5. establishes a program to monitor environmental condition to establish predictive links between water quality, sediment deposition and the health of benthic biota and to enable timely management of turbidity-generating activities and marine works to ensure that limits specified in schedule 2 are not exceeded; and

6. establishes a survey program for determining the spatial and temporal extent of any changes in the physical properties of surface sediments (less than or equal to 10 cm depth), including sediment particle size composition, within the area of influence of the dredging.

(3) A remote sensing Water Quality Monitoring Program which:

1. evaluates options for collection of air-borne and/or satellite-borne hyperspectral data, to provide broad-scale, semi-quantitative information on extent and intensity of natural turbidity and the turbidity associated with the construction of marine infrastructure associated with the project;

2. specifies the techniques which will be employed, including the monitoring frequency, resolution and extent of coverage, and showing that coverage extends over at least the entire area predicted to be influenced by turbidity associated with the construction of marine infrastructure associated with the project;

3. sets out Operating Procedures and QA/QC protocols for remote-sensing monitoring methods, instrument maintenance where appropriate, and data capture, analyses and interpretation, including algorithm development; and

4. establishes a program to acquire remotely-sensed water quality data, for a period of at least one month prior to commencement of any turbidity-generating activities, and at regular intervals to enable timely management of turbidity-generating activities and marine works to ensure that limits specified in Schedule 2 are not exceeded, and for a period after turbidity-generating activities have ceased, to evaluate the timing and extent of attenuation of turbidity back to pre-development background levels.

(4) A Coral Condition Monitoring Program which:

1. specifies monitoring frequency for monitoring and reference sites;

2. sets out Operating Procedures and QA/QC protocols for coral condition monitoring methods, site maintenance, and data capture, analysis and interpretation;

3. demonstrates that the program has statistical power of 0.8 or greater to detect exceedances of the coral condition management trigger criteria specified in Schedule 3.

4. establishes a program to monitor coral condition against the Coral Condition Management Trigger Criteria in schedule 3.

(5) A Coral Management Framework which:

1. identifies the predicted autumn coral mass spawning periods;

2. specifies procedures to determine when coral spawning will occur outside the autumn mass spawning period;

3. specifies procedures to ensure that turbidity-generating activities which may impact on coral larvae survival cease at least five days prior to the coral spawning events predicted in accordance with items 1 and 2 above, on advice of the Department of Environment and Conservation and the Dredge Management Group;

4. specifies procedures to ensure that turbidity-generating activities do not recommence until at least three days after completion of each of the mass spawning events to allow for fertilisation, larval competency and settlement; and

5. specifies reporting procedures and protocols.

(6) An offshore Spoil-ground Site Selection Study which:

1. identifies options for the offshore spoil-ground;

2. uses modelling to evaluate these options through modelling to determine the extent of any impacts;

2. selects a site for the offshore spoil-ground that demonstrably does not cause impacts on the Marine Park; and

3. specifies monitoring to ensure that spoil disposed to the spoil-ground is not greater than that predicted.

(7) Develops a Best Practice Dredge Program which:

1. reviews current best practice dredge methods and equipment;

2. compare how the proposed dredge equipment compares to best practice;

3. identifies improvements that could be made to the proposed dredge equipment;

4. evaluates best practice management options for scheduling dredging with respect to meteorological conditions and sea state;

5. addresses the need for blasting and appropriate measures to minimise blast impacts ; and

6. prepares a dredge program based on the above information, to minimise impacts generally, and specifically to avoid impact on the Marine Park.

Schedule 5

Whole Effluent Toxicity Testing of Wastewater Discharge

1. The objectives of the Whole Effluent Toxicity (WET) testing program are:
    - to determine the toxicity of the wastewater;
    - to evaluate the potential risks to the marine environment associated with the marine discharge; and
    - to determine the number of dilutions of the wastewater that would be required to meet a high level of ecological protection (99% species protection level).

2. WET testing must be undertaken in accordance with the protocols and procedures recommended in ANZECC & ARMCANZ (2000);

3. WET testing shall be undertaken on the untreated produced water and the actual treated wastewater as soon as they become available.

4. After commissioning of the wastewater treatment plant the proponent shall identify worst case wastewater composition conditions and collect wastewater samples during these conditions for any further WET testing required;

5. WET testing shall be undertaken on the treated wastewater sampled during worst case conditions one month after commissioning of the wastewater treatment plant and annually thereafter, or immediately following any significant change in the composition of the treated wastewater.

6. The number of dilutions of the wastewater required to meet a 99% species protection level will be calculated using the BurrliOZ software provided free with ANZECC & ARMCANZ (2000).

Appendix 5

Proponents Suggested Environmental Offsets

CURRENT as at
17 JUNE 2007

PLUTO LNG DEVELOPMENT / BURRUP LNG PARK

STATE EP ACT ASSESSMENT

ENVIRONMENTAL OFFSETS PROPOSAL

Background

The Environmental Protection Authority (EPA) expects proponents to put forward commitments for environmental offsets where a development is predicted to have significant adverse residual impacts to the environment.

The EPA's Position Statement on environmental offsets identifies a number of important environmental assets which require offsets to be implemented if a development proposal is likely to have significant adverse residual impacts. Two assets which are of relevance to the Pluto LNG Development are:

- Native Vegetation:
  - Where adverse impacts to a native vegetation complex would result in a 30% or less representation of the pre-clearing extent of that vegetation complex in a region.
- Heritage:
  - Identified areas of State, National or World Heritage significance.
  - Places of Indigenous heritage of high importance.

In addition, the EPA's Guidance Statement No. 29 states that where predicted loss to benthic primary producer habitat (coral in this instance) exceeds prescribed loss thresholds an environmental offset package is required to counterbalance the further damage/loss of habitat. The EPA has set a 10% loss threshold for development areas such as ports. It is predicted that dredging for the Pluto port facilities will exceed this loss threshold in areas adjacent to Holden Point.

The Department of Environment and Conservation (DEC) has also requested that Woodside undertake further investigations into the taxonomy of short-range endemic species (land snails) in the proposed development area.

This document outlines proposed offset strategies to address potential impacts to cultural heritage, vegetation associations at Site A and Site B, land snail species, and corals in areas adjacent to Holden Point.

Proposed Environmental Offsets

Heritage

Of the estimated one million engravings on the Dampier Archipelago, the Site A and Site B lease areas contain about 3000 engravings. Of these, approximately 150 - 200 engravings fall within the proposed development area. Woodside has committed to avoid or relocate all of these engravings.

Woodside's relocation of heritage material at Site A was recently completed. This involved relocation of 42 engravings along with two archaeological scatters (stone tools and flakes). The engravings were lifted to a designated relocation zone, where they will remain undisturbed in an existing natural environment. The relocation program on Site A has been successful with no rock art damaged or destroyed.

This approach to cultural heritage management is unprecedented and involves expenditure of approximately $10 million on heritage surveys, additional salvageabilty surveys, site verification audits and relocation.

The Pluto LNG Development Cultural Heritage Framework outlines the heritage management process that will be followed during the execution of the Pluto LNG Development. Under this framework Woodside has committed to establishing conservation zones at Site A that will remain undisturbed throughout the development of the Burrup LNG Park (p.390 of the Draft PER). Woodside will not conduct any works in these conservation areas and will ensure that heritage sites are left undisturbed and in-situ. Heritage sites on Site B have also been identified for protection long term.

The management and protection of the conservation zones will be undertaken in close consultation with representatives of the Ngarluma, Yindjibarndi, Yaburarra, Mardudhunera and Wong-Goo-Tt-Oo groups. Subject to operational and safety requirements representatives of these groups will have ongoing access to the conservation zone in the southern section of Site A.

Woodside has made a commitment to the Indigenous groups to undertake an ethno-botanical study to examine likely links between past habitation, as evidenced in the rock art and heritage sites, and use of botanical resources on Woodside's leases and potentially at other sites on the Burrup Peninsula. The cost of undertaking this study is estimated to be $150 000 and is proposed as an offset.

Native Vegetation

The following activities are proposed to offset direct footprint impacts to restricted vegetation associations at Site A and Site B:

- previously disturbed areas that lie outside the proposed disturbance area will be rehabilitated. This would include the rehabilitation of weed infested areas, for example, coastal dunes (at Site A) and drainage lines.

- Trudgen (2002) identified 37 flora species on the Burrup Peninsula that are considered to be of conservation interest for numerous reasons, such as being newly discovered, newly recognised or apparently uncommon. Funding of research, such as botanical surveys or taxonomic studies on some of these species (e.g. species of conservation value occurring within Site A or Site B) would increase the knowledge of these species and provide further information on their distribution and taxa.

Woodside will commit $250,000 toward implementing the above strategies.

<u>Short-range Endemic Species (Land Snails)</u>

There remains some uncertainty with regard to the taxonomy of *Rhagada* snail species within the proposed development area. The DEC has recommended that Woodside commit to completing further genetic (nuclear analysis) investigations to resolve this uncertainty.

Woodside is supportive of this research and will undertake studies to further understand the taxonomy of *Rhagada* species collected at Site A and Site B. Woodside will commit $100,000 toward this research.

<u>Coral</u>

Implementation of direct offsets is difficult in the marine environment, particularly for losses of coral; therefore research is proposed as an alternative offset strategy.

The Indicative Management Plan for the Proposed Dampier Archipelago Marine Park (DEC 2005) outlines a range of management strategies for coral reef communities in the Archipelago including monitoring and research priorities. Research proposed as part of an offset package for Pluto should be consistent with these priorities.

Research associated with the implementation of Management Plans for Ningaloo Marine Park and Jurien Bay Marine Park is being coordinated through the Western Australian Marine Science Institution (WAMSI). Research in Mermaid Sound and the Dampier Archipelago Marine Park could be coordinated under a similar framework with funding for research provided to WAMSI by Woodside.

A commitment to a research fund that supports the objectives of the Dampier Archipelago Marine Park management plan, totaling $5 million over a period of five years commencing in 2008 is proposed. This commitment could be targeted to strengthen knowledge of the Mermaid Sound region (e.g. habitat mapping and taxonomic surveys) and the prediction of anthropogenic impacts (e.g. establishment of a standardised computer simulation model for Mermaid Sound) and investigate potential for coral rehabilitation/transplantation.

Table 1: Proposed Pluto LNG Development Environmental Offsets

Relevant Environmental Factor	Residual Risk	Proposed Offset	Proposed Expenditure	Stakeholders	Timeframe
Vegetation and Flora	Significant – assessed as High residual risk to two vegetation associations of conservation significance as identified by Trudgen (2002) which will be impacted in a regional context – risk assessment presented in PER Table 9-9, p.332 and Table 1, p. 5 Response to Submissions. Approximately 0.55 ha and 0.75 ha of AbCc'Te and AcImTe/TeCa respectively lie within the proposed disturbance footprint. Trudgen (2002) recorded one of these associations (AbCc'Te) within the Burrup Peninsula Conservation Reserve (19.3%) and the other (AcImTe/TeCa) elsewhere on the Burrup Peninsula (16.4%). Both of the above associations are comprised of common flora species which have wider distributions on the Burrup Peninsula. The Trudgen survey was conducted almost seven years ago and it is possible that the distribution of associations across the Burrup Peninsula has since varied;	Both direct and indirect offsets are proposed. Opportunities for direct offsets are limited as 62% of the Burrup Peninsula (the non-industrial areas) is included in the proposed Burrup Conservation Reserve. As a direct offset Woodside proposes to establish a conservation zone in the southern portion of Site A. Proposed offsets include: ▪ establish a conservation zone at Site A that will remain undisturbed throughout the development of the Burrup LNG Park (p.390 of the Draft PER). Woodside will not conduct any works in the conservation area. This will ensure that the population of *Terminalia supranitifolia* in the southern portion of Site A will remain undisturbed. ▪ rehabilitate previously disturbed areas within the lease that lie outside the proposed disturbance footprint. This would include the rehabilitation of weed infested areas, for example, coastal dunes (at Site A), drainage lines and the conservation area in Southern Site A. Conservation significant vegetation associations, as identified by Trudgen (2002) are contained in these areas. ▪ Trudgen (2002) identified 37 flora species on the Burrup Peninsula, that are neither rare or Priority flora, but are considered to be of conservation interest for numerous reasons, such as being newly discovered, newly recognised or apparently uncommon. Funding of research, such as botanical surveys or taxonomic studies on some of	$250,000	▪ DEC – input to survey scope and methodology ▪ Woodside would contract a third party to undertake survey work ▪ Woodside would make survey data available to DEC	2008 - 2009

Relevant Environmental Factor	Residual Risk	Proposed Offset	Proposed Expenditure	Stakeholders	Timeframe
	reflecting changing environmental factors like rainfall and the relative recruitment and loss of individuals of various species in the association. Individual flora species will not be endangered by this proposal. The proposed disturbance footprint does not contain any: ▪ Declared Rare Flora ▪ Priority 1 or 2 flora ▪ Threatened Ecological Communities One Priority 3 species (*Terminalia supranitifolia*) occurs within the proposed disturbance footprint. It is most abundant in the southern portion of Site A and also occurs elsewhere on the Burrup Peninsula. The southern portion of Site A will be set aside as a conservation zone and will remain undisturbed.	these species and associations of conservation significance (e.g. species or associations of conservation value occurring within Site A or Site B) would increase the knowledge and provide further information on distribution and taxa of flora and vegetation communities. The objective of the proposed survey is to verify the current distribution and status of species and associations of conservation significance on the Burrup Peninsula. This information would provide valuable input to the future management of vegetation and flora of conservation significance on the Peninsula.			
Benthic Primary Producer Habitat (Coral)	Significant – assessed as High residual risk – risk assessment is presented in PER, Table 7-36, p.252. Table 9 and 10 (p. 29) of the	Implementation of direct offsets is difficult in the marine environment, particularly for losses of coral. Potential direct offsets which could be available include restoration of degraded habitat, establishment of coral on existing or structures (e.g. seawalls) or creation of new structures (e.g. artificial reef), or offsetting future impact to corals	$5 million ($1 million/ annum for 5 years)	▪ Western Australian Marine Science Institution (WAMSI) - administer and direct research funds potentially through one of the six established	2008 - 2012

Relevant Environmental Factor	Residual Risk	Proposed Offset	Proposed Expenditure	Stakeholders	Timeframe
	Addendum to the Response to Submissions reports estimated potential loss of coral to be: ▪ up to 20 ha of direct and indirect loss of coral in Management Zone 1 – i.e. area closest to dredging associated with turning basin and navigation channel ▪ up to 23 ha of indirect loss of coral in Management Zone 2 Since preparing Response to Submissions on the PER, Woodside has committed to disposing of the majority of dredge spoil material into the proposed offshore spoil ground (2B) – this will significantly reduce potential indirect impacts to corals in Management Zone 2.	(e.g. phase out collection of coral for aquarium fishery). The potential of these offset strategies is considered limited as they either add little habitat (e.g. seawalls and other artificial structures) or require substantial further research to implement successfully. There is no proven technique for substantive direct offsets – therefore Woodside proposes to support research which can assist with the development and implementation of direct offsets and support research and management strategies in the proposed Dampier Archipelago Marine Park in line with the objectives of the Dampier Archipelago Marine Park management plan. Woodside considers that the objective of research related to development of direct offsets should be to provide a suite of techniques to enhance coral recovery by better understanding coral recruitment, developing techniques to enhance settlement and reduce mortality of coral recruits and understanding the role of herbivores in avoiding algae dominating reefs to the exclusion of corals.		research nodes (e.g. WAMSI Node 3 Managing and Conserving the Marine State: Best practice management and underpinning science) ▪ Woodside is a WAMSI Foundation Collaborator	
Short Range Endemic Species	Not significant – assessed as Medium residual risk during risk assessment undertaken for PER (ref. Table 9-11, p.335). However, proponent notes that DEC has requested offsets in relation to SREs (ref p.61 Response to Submissions) and uncertainty regarding the taxonomy of *Rhagada* species.	Direct offsets are not proposed as most specimens have been collected outside of the proposed disturbance footprint and residual risk is not considered significant. Woodside is committing to completing further genetic (nuclear analysis) investigations to resolve the remaining taxonomic uncertainty in relation to *Rhagada* specimens collected at Site A. The objective of the study is to conclusively determine whether *Rhagada* specimens collected at Site A and Site B are representatives of the one species *Rhagada* sp. '12'.	$100,000	▪ DEC – input to scope of study ▪ Woodside would contract a third party or the WA Museum to undertake any additional survey work ▪ Woodside will contract WA Museum to undertake proposed genetic analysis	2008

Relevant Environmental Factor	Residual Risk	Proposed Offset	Proposed Expenditure	Stakeholders	Timeframe
	In 2005 specimens of the camaenid genus *Rhagada* were collected at Site A and adjacent areas (PER Table 8-13, p. 318). Some of the specimens found within Site A showed some differences in shell size and shape and varied from other known *Rhagada* species. In 2006, snail specimens were collected at Site A, Site B, Site E (eastern Burrup) and adjacent areas to gather more information about the *Rhagada* species collected at Site A. Genetic analysis using mitochondrial DNA was undertaken to determine whether *Rhagada* specimens found across the sites were the same species. This analysis indicated that the specimens were more than likely *Rhagada* sp '12' which has been recorded previously on the Burrup Peninsula. Genetic analysis using mitochondrial DNA is not conclusive. The only way to confirm that specimens are all *Rhagada* sp '12' is to undertake nuclear DNA				

Relevant Environmental Factor	Residual Risk	Proposed Offset	Proposed Expenditure	Stakeholders	Timeframe
	analysis.				
Aboriginal Heritage	Not significant – assessed as Medium residual risk during risk assessment undertaken for PER (ref. Table 11-7, p.397). However, proponent has agreed to some offset measures with Traditional Custodians. Woodside estimated that it will leave in-situ and undisturbed an estimated 95% of engravings within Site A and Site B. About 150 engravings fall within the proposed disturbance footprint and it is Woodside's intention to avoid or relocate all of them. Woodside's relocation of heritage material at Site A was recently completed. This involved relocation of 42 engravings along with two archaeological scatters (stone tools and flakes). The engravings were lifted to a designated relocation zone, where they will remain undisturbed in an existing natural environment. The relocation program on Site A has been successful with no rock art damaged or destroyed.	It is Woodside's intention to avoid or relocate all engravings within the proposed disturbance footprint. Woodside has agreed to offset impacts to rock art by: ▪ establishing a conservation zone at Site A that will remain undisturbed throughout the development of the Burrup LNG Park (p.390 of the Draft PER). Woodside will not conduct any works in the conservation area and will ensure that heritage sites are left undisturbed and in-situ. ▪ conducting ethno-botanical study. Woodside was asked by the Traditional Custodians to avoid highly significant heritage sites in the eastern margin of Site A, at Holden Point and in the southern portion of Site A – these areas has consequently been included in a conservation zone (PER Figure 11-2, p. 390). The objective of the ethno-botanical study is to examine likely links between past habitation, as evidenced in the rock art and heritage sites, and traditional use of botanical resources on Woodside's leases and potentially at other sites on the Burrup Peninsula. It is intended that the study will be published in a peer reviewed journal.	$150,000 Rental rates for the lease area are determined on an area basis for the entire lease – the conservation area at Site A represents more than half of lease area for which Woodside will pay $44,000 p.a. in rental rates.	▪ Traditional Custodians (Ngarluma, Yindjibarndi, Yaburarra, Mardudhunera and Wong-Goo-Tt-Oo groups) would be directly involved in the study ▪ Woodside would be directly involved in the study and would also contract an anthropologist to assist with the study	2008

Appendix 6

Summary of Submissions and
Proponent's Response to Submissions

SINCLAIR KNIGHT MERZ

Pluto LNG Development

ADDENDUM TO PUBLIC ENVIRONMENT REPORT/ PUBLIC ENVIRONMENTAL REVIEW SUPPLEMENT AND RESPONSE TO SUBMISSIONS

- Rev 02
- 1 June 2007

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1. Introduction

1.1 Background

This document presents responses to comments made by the EPASU in relation to the Public Environment Report/ Public Environmental Review Supplement and Responses to Submissions (the Supplement) (March 2007) and the Revised Pluto LNG Development Dredging Simulation and Impact Assessment Report (May 2007). The comments are the outcomes of meetings held between the proponent and the EPASU and DEC on 1st and 8th May 2007. Subsequent to these meetings, a mutually agreed Scope of Work was drafted and commented on by the EPASU and DEC, prior to finalisation.

1.2 Document Structure

The remainder of this document is structured as follows:

- *Section 2* provides further assessment of dredging impacts with particular reference to predicted coral loss.
- *Section 3* responds to further queries on dredging.
- *Section 4* responds to queries on waste water discharges.
- *Section 5* addresses general comments.
- *Section 6* provides a reference list.

The document is supported by the following appendices:

- *Appendix A*: Baseline Water Quality Assessment Report April 2007 (MScience 2007a).
- *Appendix B*: Review of Recent Dredging Projects in Dampier Harbour (MScience 2007b).
- *Appendix C*: Benthic Habitats at West Lewis Island (MScience 2007c).
- *Appendix D*: Methods for Revised Dredge Modelling with the Inclusion of Sediment Resuspension (APASA 2007).

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2. Further Assessment of Dredging Impacts with Particular Reference to Predicted Coral Loss

2.1 Task 1: Further analysis of model outputs to determine effect of varying impact thresholds (intensity and duration) on the predicted area of impact.

Agreed Scope

- *A new level of sedimentation load will be established using baseline data from Tidepole Island where estimates of levels of sedimentation withstood by corals near dredging have been collected (data from the Angel Island site could potentially be used in the same way). Thresholds? If so, is tide pole analogous to the reefs around Angel Island and other impact sites? Please consider chronic and acute levels of sedimentation.*
- *A range of estimates of intensity-duration (frequency is also an important consideration) for sedimentation (mg/cm2/d) and suspended sediment concentrations (SSC; mg/L) will be established for inner and outer harbour areas using MacArthur et al 2002 type derivation.*
- *Investigate zone of influence using 80%ile intensity-duration (frequency) assessment for summer and winter and at different levels for inner and outer harbour areas.*
- *The output from Task 1 will be a series of impact zones: i.e. zone of potential loss, zone of potential impact, and zone of influence based on various combinations of intensity and duration of sedimentation and SSC.*

Notes:

- *Outputs will provide comparison of currently predicted impacts, based on previously established thresholds, with revised thresholds.*
- *Baseline field data for sediment measurements and coral measurements, which are yet to be fully analysed and interpreted, will be analysed and reviewed to provide inputs from model interrogation. Analysis of data to April 2007 will be available.*
- *The array of levels, durations and frequencies to be investigated will be determined by reference to the field data, McArthur et al 2002 methodology, literature and current and past data available for Mermaid Sound.*
- *Setting of the likely significance of each zone of influence, in terms of coral health, will be defined using a considered review of the methodology of McArthur 2002 and the wider literature and an analysis of previous dredging impact studies in Mermaid Sound (Task 3).*

Proponents Response

New Interrogations

The new interrogations were requested by the EPASU and primarily require the setting of new thresholds for SSC and sedimentation based upon data collected during the pre-dredging environmental baseline studies that commenced in August 2006. The new thresholds to be developed were also required to include relevant duration-frequency parameters that would allow the mapping of a zone of potential impact (based on SSC data) and a zone of potential loss (based on sedimentation data).

The expectation was that developing intensity-duration-frequency thresholds based on the baseline data could produce different estimates for the area of coral habitat that may be potentially impacted or lost.

The Baseline Data

The baseline data used to develop the new set of thresholds comprises information recently collected from a series of stations in Mermaid Sound. The Baseline Water Quality Assessment was undertaken by MScience (2007a) to provide some useful background information that could be used to help set relevant thresholds for the DSDMP. The full report prepared by MScience is provided in **Appendix A**. **Table 1** lists the stations sampled by MScience during the programme. Data recording commenced in August 2006 and was planned for completion in mid-May 2007.

- **Table 1 Period of Data Analysed and Station Zone (Reproduced from MScience 2007a)**

Station	Zone	SSC Data	ASSD Data	Depth (m) +
ANGI	Outer	15-Apr	Sep-Oct 06	5
HGPT	Mid	6-Mar	Oct 06	2.8
CHC4	Inner	19-Feb	Oct-Dec 06	1.9
MIDR	Outer	6-Mar	-	3.1
WINI	Inner	31-Mar	Dec -06-Feb 07	0.3
TDPL	Inner	5-Apr	Nov 06- Jan 07	-0.8
KGBY	Inner	4-Apr	-	0.3
HSHL	Outer	19 Sep -06	-	2.0

* recordings start in August 2006 for all stations except TDPL and KGBY which start in November 2006.

The locations of the stations are shown in **Figure 1** which also presents the position of three zones developed by MScience (2005) as a classification system for the coral communities in Mermaid Sound based upon observed differences in community types (inner/mid/outer).

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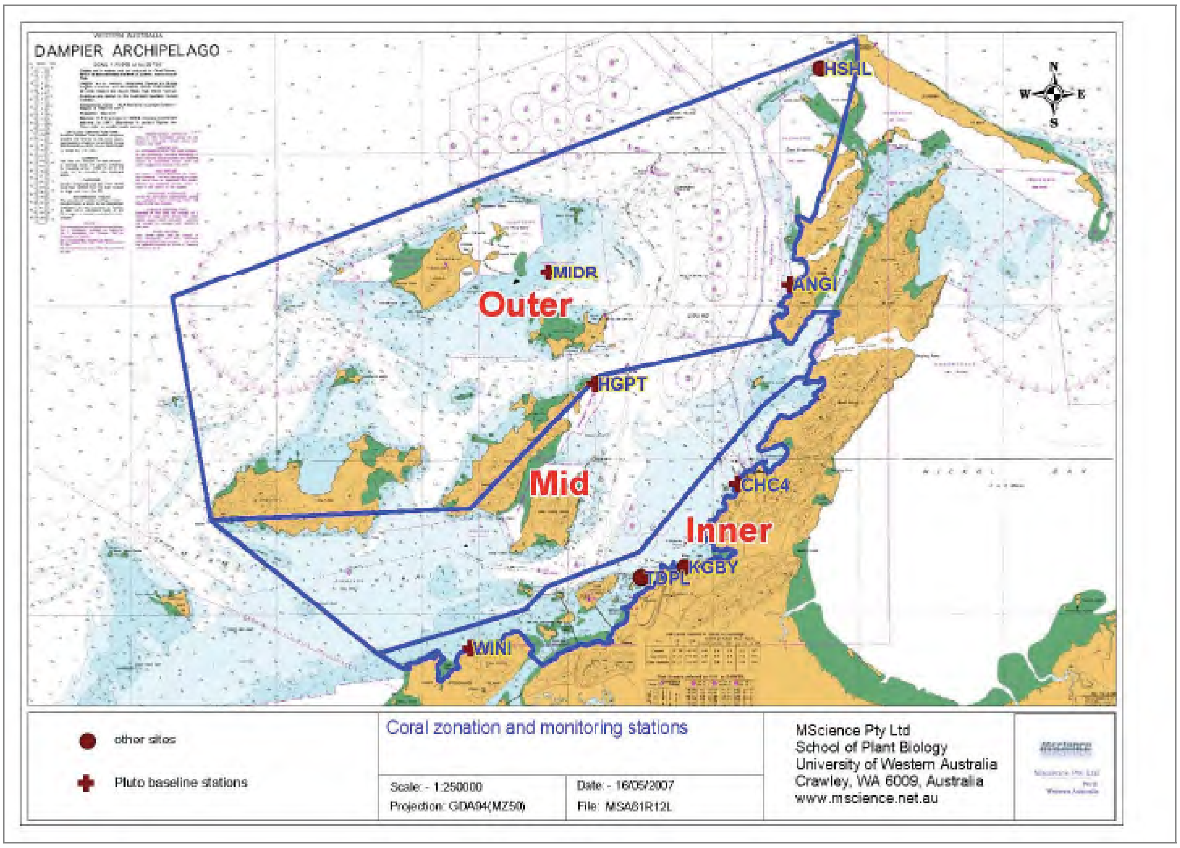
The zones have been included here as the baseline data shows some variability across Mermaid Sound with inner shore areas reporting higher levels of both SSC and sedimentation when compared to the mid and outer areas of the Sound. By implication these differences in SSC and sedimentation may have a considerable influence on the distribution of coral communities and appear to be strongly correlated with the current distribution of coral community types and therefore the zones have an ecological basis. The aim is to use the baseline data to construct a set of thresholds. Separating the stations into the 3 zones provides an opportunity to develop a set of thresholds relevant for each zone with each set possibly reflecting differences in sensitivity of the coral communities present.



- **Figure 1 Location of Sediment Stations and Coral Sensitivity Zones (MScience 2007a)**

SSC Baseline Data

The summary statistics for the SSC baseline data are presented in **Table 2**.

- **Table 2 Suspended Sediment Concentrations (mg/L) by Station and Zone (MScience 2007a)**

Site	Mean	Median	80%ile	95%ile	99%ile	Max
ANGI	4.21	2.22	4.3	12.4	51.0	143
HGPT	3.94	2.49	4.9	11.2	29.0	233
CHC4	10.75	7.39	15.6	28.1	58.0	276
MIDR	1.66	1.46	2.2	3.9	7.6	29
WINI	7.52	2.92	9.2	33.1	65.0	160
TDPL	8.43	4.03	10.3	33.8	73.7	273
KGBY	9.28	2.48	8.6	43.1	89.4	252
HSHL	4.81	3.64	5.5	14.5	39.7	145
Inner	9.0	4.2	10.9	34.5	71.5	240
Inner (-TDPL)	9.1	5.2	12.4	30.6	61.5	218
Mid	3.9	2.5	4.9	11.2	29.0	233
Outer	3.6	2.4	4.0	10.3	32.8	106

The TDPL station (Tidepole) was located near the recent Hamersley Iron Dampier Port Upgrade dredging programme, which took place between December 2006 –April 2007 and therefore may have experienced elevated values of SSC at this time, however the removal of TDPL data from the calculation of an average for the inner zone does not reduce the 95 and 99%iles very much.

The SSC averages for the mid- and outer zones are very similar over the life of the baseline monitoring period which, although relatively short (i.e. less than a year), has been long enough to capture some large SSC elevations, with the 95 and 99%iles for each zone markedly higher than the mean and median. This is an important observation because coral health has been monitored during the baseline data collection period and no discernible impacts on corals health were observed during these peaks in SSC. The implication is that events of this size and duration have not had a measurable impact on corals health.

The SSC data was also analysed for intensity-duration-frequency statistics and these are presented in **Table 3** for just one of the stations away from dredging (ANGI) to demonstrate that the majority of elevated SSC events were of short duration. The entire analysis for all stations is presented in **Appendix A**.

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- **Table 3 Intensity-Duration-Frequency Data for Hours of SSC at ANGI (Modified from MScience 2007a)**

mg/L	Hours					
	1	6	12	24	72	Max
10	30	5	2	1	1	128
20	15	2	2	2	0	50
30	9	4	1	1	0	30
50	8	2	0	0	0	7
100	0	0	0	0	0	1
Monthly Frequency-Durations for Multipliers of the 80%ile Concentration						
X1	136	12	4	3	1	180
X2	38	8	4	1	1	128
X5	16	2	2	2	0	46
X10	10	2	1	0	0	19
Monthly Frequency-Durations for Multipliers of the 95%ile Concentration						
X1	14	5	3	1	1	101

Sedimentation – Baseline Data

The pre-dredging environmental baseline studies provide information on background sedimentation. Some loggers experienced technical problems that affected the recovery of some data in the relatively high energy conditions at some sampling sites. Very low net sedimentation was recorded at a number of sites while other sites recorded elevated sedimentation in response to identified disturbances (dredging and the passage of a cyclone) (**Table 4**).

- **Table 4 Sedimentation Baseline Data ($mg/cm^2/d$) (MScience 2007a)**

Station	Sedimentation					
	Mean	Median	80%ile	95%ile	99%ile	Max
ANGI	1.4	0.0	2.6	5.8	6.3	6.3
HGPT	0.1	0	0	1.0	2.8	4.4
CHC4	5.0	3.7	8.3	13.5	18.2	23.1
MIDR	No data					
WINI	3.7	1.2	5.2	13.0	32.9	38.0
TDPL	4.7	1.8	7.5	20.8	25.1	25.1
KGBY	No data					
HSHL	No data					
Inner	4.5	2.3	7.0	15.8	25.4	28.7
Inner (-TDPL)	4.4	2.5	6.8	13.3	25.5	30.5
Mid	0.1	0	0	1.0	2.8	4.4
Outer	1.4	0.0	2.6	5.8	6.3	6.3

The levels of sedimentation for mid- and outer zones are quite similar for the period that baseline data was collected and are quite low when compared with the inner zone. The maximum levels of sedimentation recorded range from 4.4 mg/cm^2/d for the mid zone to 30.5 mg/cm^2/d in the inner zone (Tidepole Station data). Note however, that removing the Tidepole data does not greatly alter the summary statistics.

There does not appear to be a strong relationship between high SSC and high sedimentation in the baseline data. Observed SSC increased during the passage of strong weather conditions due to resuspension of fine sediments. Net sedimentation tended to decrease at these times.

Methodology for Developing Intensity-Duration-Frequency Thresholds

The analysis of the baseline data was a necessary first step in the development of a series of thresholds for both SSC and sedimentation based upon an intensity-duration-frequency analysis.

In the agreed scope of works, the proponent stated that the use of 80%ile baseline data would be investigated for the definition of thresholds, but an examination of the data in **Table 4** reveal that the 80%iles for both SSC and sedimentation for all three zones are very low. The use of these 80%iles as a component of the thresholds analysis would, in the proponents opinion, lead to the setting of thresholds that are too low to be a useful guide to the potential impact of the dredging on the marine environment as there is a reasonable probability they will be exceeded whenever natural conditions promote resuspension of fine sediments within the Sound. A number of these natural events can be anticipated during the time frame of the proposed dredging programme.

The calculations of the 80%iles for SSC in the inner, mid- and outer zones are presented in **Table** 2**.** The 80%ile for SSC for the mid-zone stations was calculated to be 4.9 mg/L and for the outer zone was 4.0 mg/L. These are low values and are exceeded by short term pulses of elevated SSC ranging up to 233 mg/L for the mid-zone and 106 mg/L for the outer zone as a consequence of natural events. These events have produced short term elevations which have been recorded during the period of baseline data collection and importantly have had no detectable impact upon the corals which were monitored over the same time period.

As the published information for background SSC on reefs suggests that 10 mg/L is quite common for SSC values in seawater over coral reefs not impacted by human activities (Rogers 1990) it would appear the selection of an 80%ile level for the mid- and outer zones as a threshold in Mermaid Sound which is less than half that value has no basis in terms of signalling a tangible risk of an impact (i.e. effects).

The 80%ile for the inner zone is higher at 10.9 mg/L (**Table 2**) reflecting the generally more turbid waters closer to the western shore of the peninsula and the SSC data collected from this zone has ranged up to 240 mg/L without any detectable impacts upon corals.

The water quality and corals monitoring programmes for previous dredging programmes in Mermaid Sound (MScience 2007b, **Appendix B**) provide no evidence that would support the use of the 80%iles of the baseline data collected since August 2006 as meaningful thresholds for any of the three zones. The coral monitoring data summarised in **Appendix B** also shows that despite substantial and prolonged elevations in SSC at several sites during dredging, there were no detectable impacts upon corals at these sites. Therefore, the proponent considers that use of the 80%iles calculated from the baseline data does not provide any useful information in terms of defining zones of potential impact or potential loss.

In the Draft PER, reference was made to the suitability of the methodology of McArthur et al 2002 as a template for the development of an intensity-duration-frequency thresholds analysis.

Setting Thresholds

The objective in setting thresholds is to set a level of SSC (and for sedimentation) which can act as a signal that potential impacts may occur and exceeding that threshold then triggers a series of pre-determined management responses. The underlying basis for the threshold is that a tangible risk of impact is evident once the threshold has been exceeded.

SSC Thresholds

The proponent notes that:

- Acute mortality (mortality events occurring within a period of less than a month) are most likely to be caused by smothering of corals by excessive sediment loading rather than low light or from irritation of coral membranes by suspended sediments; and
- Coral communities at which the baseline water quality data have been recorded have not shown significant levels of coral mortality over the monitoring period.

The proponent therefore concludes that the development of a series of thresholds for SSC based upon an intensity-duration-frequency analysis will produce potential zones of impact where corals may suffer sub-lethal effects, but not mortality. McArthur et al (2002) state:

"*The principal goal for deriving ecologically sound suspended sediment guidelines for ocean disposal should be to prevent significantly greater exposure beyond that to which the coral community is presently adapted. Any suspended sediments resulting from disposal activities should* *fall within the natural limits for that environment and thus cause no added stress to individual corals or the coral community."*

McArthur et al (2002) provide the following rationale for development of an intensity-duration-frequency approach to the setting of thresholds.

"Three factors were determined to be important aspects of coral and coral community effects of exposure to suspended sediments; 1) intensity, 2) duration, and 3) frequency.

Intensit*y: High suspended sediment concentrations place stress on corals, therefore suspended sediment values near the high end of the normal range of concentrations to which South Florida coral communities are exposed are most likely to have adverse effects on community structure. Suspended sediment concentrations due to natural conditions plus dredged sediment disposal should not exceed the highest values to which South Florida coral communities are normally exposed. The highest allowable values have been selected as the 99th percentile observed concentration. A lower value, the 95th percentile observed concentration, has been selected as a threshold concentration. This threshold concentration can be exceeded only for specified durations and frequencies as discussed below. Concentrations below this threshold value are not considered to significantly affect coral communities because of their naturally higher frequency of occurrence.*

Duration*: The average suspended sediment concentrations that persist in the environment throughout the year can be considered "background" levels of continuous or near continuous duration. These typical concentrations are not expected to adversely affect coral communities. High sediment concentrations may cause an adverse impact if the corals are exposed to these concentrations for sufficient time periods. Any significant increase in the time of exposure or duration of high sediment concentrations may result in excess stress in individual coral species and changes in community structure. Coral exposures to suspended sediment concentrations (dredged sediments plus native sediments) above the threshold value should not exceed the naturally occurring 95th percentile duration event.*

Frequency*: Suspended sediment concentrations that coral communities are most frequently exposed throughout the year are those to which corals are principally adapted and, therefore, are not expected to have an adverse impact. Higher values are those caused by storm events and other anomalies, which occur less frequently. Corals are able to tolerate occasional heavy sediment concentrations provided there is sufficient time for recovery between high sediment events. Any significant increase in the frequency of high sediment concentrations may cause a change in community structure due to the disappearance of those species with lower sediment tolerance. Suspended sediment concentrations above the threshold value due to dredged sediment disposal, for a specific duration, should not occur at a frequency such that the combined frequency of the dredging and natural events are significantly greater than would normally occur. The level of significance or frequency guideline has been selected as the upper 95th percent confidence interval."*

The MScience (2007) statistical analysis of the baseline SSC data reports a 95%ile for the inner zone of 34 mg/L, and 11.2 mg/L for the mid-zone and 10.3 mg/L for the outer zone respectively (**Table 2**). The values of the 95%iles for the mid and outer zones are close to the mean value of 10 mg/L reported by Rogers (1990) as the typical value for seawater over corals reefs with no human impacts.

MScience (2007a, **Appendix A**) demonstrate that the use of the 99%ile of the baseline SSC data to set the boundaries of a potential zone of impact would mean that all sites would be located within the impact zone even in the absence of dredging because the 99%ile data were observed during the baseline data gathering programmes.

The 99%ile absolute criterion should not be used to designate a zone of impact – although it could be used as a water quality target in managing dredging works. Instead, the second criterion of intensity-duration-frequency (McArthur et al 2002) could be used to establish zones of potential impact. Analysis of the baseline SSC data to produce the intensity-duration-frequency distributions is presented in **Table 5**. It is noteworthy that the majority of elevated SSC events are of short duration.

- **Table 5 Frequency of Exceedances of the 95%ile SSC for Various Durations**

Location	Hours					Mg/L
	1	**2**	**3**	**4**	**5**	**95%ile**
CHC4	35	8	0	0	0	28.1
KGBY	28	5	1	0	0	43.1
TDPL	35	15	10	5	3	33.8
WINI	67	35	21	10	4	33.1
Inner*	**16**	**8**	**5**	**2**	**1**	**35**
HGPT	43	8	3	1	0	11.2
MID*	**10**	**2**	**1**	**0**	**0**	**10**
HSHL	2	1	1	1	1	14.5
MIDR	17	3	1	0	0	3.9
ANGI	14	9	9	7	6	12.4
Outer*	**4**	**2**	**2**	**1**	**1**	**10**

From the data in **Table 5** it is possible to construct a series of intensity-duration-frequency (i-d-f) thresholds for each of the three zones (MScience 2007a, **Appendix A**) and these are displayed in **Table 6**. This set of intensity-duration-frequency thresholds was used to interrogate the model outputs.

- **Table 6 Suggested Allowable Frequency of Intensity-Duration Events Per Month**

	Inner	Mid	Outer
SSC threshold level (mg/L)	**35**	**10**	**10**
1 hour	16	10	4
2 hours	8	2	2
3 hours	5	1	2
4 hours	2	1	1
5 hours	1	1	1
6 hours	0	0	0

Setting Background SSC Values

Model predictions were originally produced in terms of SSC generated by dredging and disposal, or subsequent resuspension of this material and are additional to background. SSC concentrations in background data show a correlation with prevailing wave and current conditions, as well as tidal levels, reflecting a positive, non-linear, influence of bottom stress. Predictions for bottom stress were generated by APASA (2007) to simulate resuspension, hence data for bottom stress were available to apply variations in background SSC over time and space to correct initial model output to total SSC. MScience (2007a) describes the weighting that applied to relate bottom stress to background SSC within each zone based on the range of observed SSC and the range of predicted bottom stress.

Sedimentation Thresholds

The EPASU and DEC has indicated that the threshold levels of sedimentation as proposed in the Draft PER were possibly set too high and should be set by reference to the baseline sedimentation data.

The proponent has given an undertaking to produce a revised series of thresholds based upon the baseline sedimentation data but does not consider there is any evidence to suggest that this approach would produce a set of thresholds that are more meaningful indicators of potential corals mortality. On the contrary, the review of the literature provided in the Draft PER, and the review of other corals monitoring programmes during dredging in Mermaid Sound (MScience 2007b, **Appendix B**) support the proponents view that the original thresholds proposed for acute, medium and chronic thresholds should offer a reasonable prediction of coral loss based on a conservative approach that has been taken in the evaluation of potential coral losses.

As MScience (2007) notes, there is considerable uncertainty involved in extrapolating from data collected under conditions where corals did not die to make predictions about the levels at which coral death will occur. Figures for daily sediment loading were used in the Draft PER to indicate potential mortality and that is based upon information available for the causes of observed corals mortality in Mermaid Sound and the literature.

Acute Thresholds

The information presented in **Table 4** demonstrates that coral communities in the zones of sensitivity have survived the following maxima:

- Inner – 30 $mg/cm^2/d$
- Mid-Outer – 6 $mg/cm^2/d$.

A threshold for potential mortality should therefore be set above these respective values for the inner zone and the Mid-Outer zones. While it is possible to conclude the thresholds values should lie above the levels observed it is not possible to determine from the data how high above these maxima the sedimentation rates would have to be in order to cause mortality.

MScience (2007a, **Appendix A**) have suggested that in the absence of good data on the levels of sedimentation that will cause coral mortality in Mermaid Sound the best approach is to develop worst case – best case estimates. Worst case mortality for the interrogation exercise has been selected as maxima plus 10%. Alternative best case scenarios, provide a sensitivity analysis based upon multiples of the maxima observed within each zone was developed. The resultant worst to best case scenarios are presented in **Table 7** and were used to interrogate the model output data.

- **Table 7 Estimates of Worst Case to Best Sediment Loading that may Trigger Coral Mortality (MScience 2007a)**

Case*	Inner ($mg/cm^2/d$)	Outer-Mid ($mg/cm^2/d$)
Worst (1.1)	33	7
Best 1 (1.5)	45	9
Best 2 (2)	60	12
Best 3 (5)	150	30

* figures in parentheses represent multiples of the maximum deposition rate.

Medium-Term and Chronic Thresholds

The EPASU requested that some medium and chronic thresholds be presented for ‘vulnerable species’ which are taken to be the species found primarily in the mid- and outer zones, and are assumed to be largely excluded from the inner zone because they are vulnerable to increased sedimentation. Consequently, the following thresholds (**Table 8**) have been used to interrogate the model output for potential medium-term and chronic effects.

- **Table 8 Medium-Term and Chronic Thresholds for Model Re-interrogation**

Effect	Inner Zone	Mid-Outer Zone
Medium-term (5 days in 15 days)	60 $mg/cm^2/d$	12 $mg/cm^2/d$
Chronic (15 days in 30 days)	36 $mg/cm^2/d$	9 $mg/cm^2/d$

Threshold sedimentation rates chosen for the Mid-Outer zones, where coral species considered to be relatively 'vulnerable are living, are the acute best case 1 and acute best case 2 listed in **Table 7**.

Setting Background Sedimentation Rates

The baseline data indicated that sites in the inner zone had relatively net sedimentation rates less that 2.5 $mg/cm^2/d$ during periods excluding dredging operations and the period following a cyclone. The median value for the entire record (inclusive of those events) was 2.3 $mg/cm^2/d$. Moreover, there was no obvious correlation over time between sedimentation rates and measures of wave and current energy. Hence, model predictions for above background sedimentation were corrected by adding the median concentration (2.3 $mg/cm^2/d$) as a constant.

Baseline measurements of sedimentation in the outer zone had a median value of 0 and 95%ile value of 1.0. The latter was added to the model data to make estimates for total sedimentation rates.

Results

The results of the new modelling interrogations, using estimates for total SSC and sedimentation are provided in **Figure 2-5**. The figures should be interpreted with care because different threshold levels apply within each of the three zones for the SSC data and between inner and mid-outer zones for the sedimentation data. Bite also that the flagged locations are those where the thresholds were exceeded once during the simulation period. For SSC thresholds, locations are flagged where the intensity-duration threshold was exceeded for either the 6 hour, 5 hour, 4 hour, 3 hour, 2 hour or 1 hour frequency limit.

In keeping with the request from EPASU to produce zones of potential loss (mortality), impact and influence based upon the baseline data set the data outputs have been interpreted accordingly. However the revised zones of potential loss, impact and influence produced by this exercise are not considered to be a better estimate of the location and size of those zones than the estimates provided in the Draft PER and the Supplement and Responses to Submissions, where the proponent provided an interpretation based upon interrogations of the model outputs derived from the literature and first hand evidence of previous dredging programmes in Mermaid Sound (MScience 2007b, **Appendix B**).

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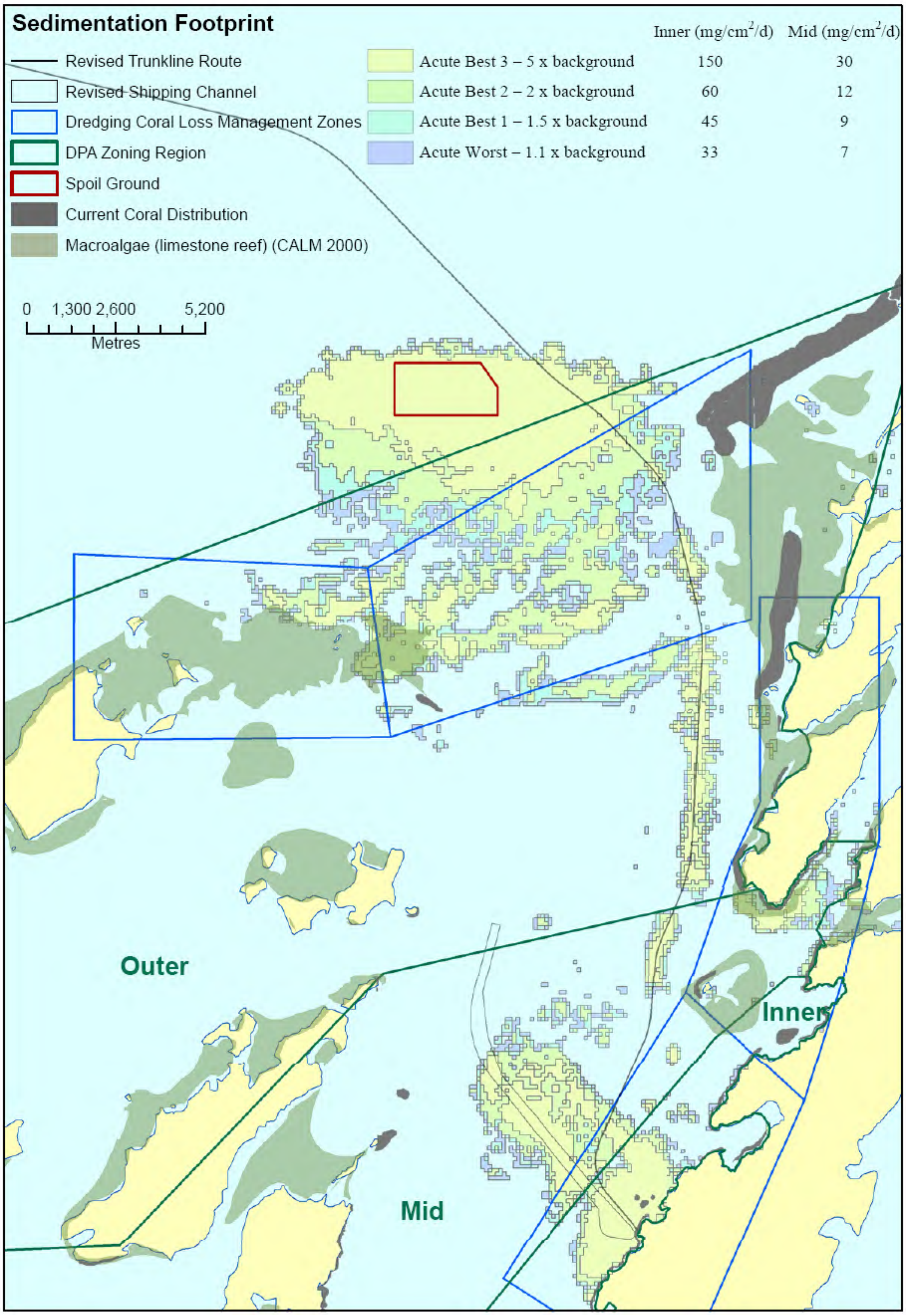
Zone of Potential Loss (Mortality)

Acute Sediment Thresholds

In **Figure 2** the worst case-best case scenarios are presented and it is important to note that while the footprints for the various cases are continuous in the figure, the thresholds upon which they are based vary considerably between the inner zone and the other two zones. It is noted that different thresholds apply within each of the marked zones in **Figure 2,** as defined in the key. Note also that the plot is constructed by compiling the outcomes predicted for three different general operations.

The acute best case 3 for example, is based upon a threshold set at five times the maxima observed during the baseline data collection period. For the inner zone, the footprint represents areas where daily sediment rates in excess of 150 mg/cm^2/day are predicted to occur while for the mid-outer zones the five times the maxima represents a daily sediment rate in excess of 30 mg/cm^2/d, which is considerably less than that which applies in the inner zone.



- **Figure 2 Predicted Footprint for Exceedance of Sedimentation Thresholds, based on derived worst and best case estimates for Acute Sedimentation.**

Inner Zone: Within the inner zone the footprint of the area receiving the different threshold sediment loads does not vary greatly, in relation to the area and position of the footprint generated from each sedimentation threshold. As pointed out in the Draft PER and the Supplement the modelling interrogations performed to date have consistently shown that most of the sediment mobilised into the water column as a consequence of the dredging would not move far before settling out. Inclusion of resuspension has not resulted in a marked change to this conclusion, because resuspension mostly affects the transport of fines. Fines that are transported away are predicted to disperse and undergo continuous resuspension – hence sub-threshold sedimentation rates are expected at most locations beyond 3 km of the operation.

Consequently, the footprints for lower levels of sedimentation rates within the inner zone are not substantially bigger than that predicted for the highest level of sedimentation rate which is almost 5 times larger than the worst case scenario threshold which is set at 33 mg/cm^2/d.

The footprint has expanded slightly within the inner zone compared with the footprints provided in the Draft PER and Supplement and therefore also within the management zone 1 that was identified in the Draft PER for the purpose of estimating potential coral loss. The potential impact of this expansion is discussed in some detail in the section on Predicted Coral Impacts (see below).

Mid-Zone: Within the mid zone the areas where acute worst –best case scenario thresholds will be exceeded are very similar to those predicted from the earlier modelling interrogations for this zone. The exception is the area at the mouth of Flying Foam Passage where the reefs lining either side of the passage are predicted to experience sediment loadings in excess of those selected as thresholds using the baseline data.

The corals on these fringing limestone reefs would experience exceedances of the nominated thresholds from both the turning circle dredging programme and also the trunkline dredging. The predictions of exceedances of thresholds at the mouth of the passage are due to the process of resuspension reworking material northwards from the turning circle area and eastwards from the trunkline path.

It is important to recognise that this location is classified as part of the Mid-zone, hence the lowest thresholds were applied here (7 mg/cm^2/d to 30mg/cm^2/d), much lower than those applied to adjacent locations that were in the designated Inner zone.

The figure shows that there is considerable variation in the predicted rate of sedimentation across and into the entrance of Flying Foam passage with the highest values (30 mg/cm^2/d) occurring on and around the southern tip of Angel Island and lower values (7 mg/cm^2/d) extending into the Passage.

There is coral habitat in this area and the area is located within Management Zone 2 as identified in the Draft PER. Using worst-best case extrapolation from field data, the potential area where mortality of corals is predicted is slightly increased in this area over that predicted in the Draft PER. The potential extra losses as a consequence of setting these new thresholds are examined below in the section on Predicted Coral Losses. The area also contains some areas of macro algae and the potential impacts of sedimentation on macro algae are addressed in **Sections 3.2** and **3.10.**

Outer Zone: There are predicted exceedances of the worst-best case thresholds for acute sedimentation within the outer zone associated with the trunkline dredging and the dumping of spoil into spoil ground 2B. The majority of the sediment exceedances predicted as a consequence of dumping into spoil ground 2B are related to the effects of resuspension of fines. There is considerable difference in the size of the effect zone depending upon the threshold applied to simulation of dumping into spoil ground 2B.

Examination of **Figure 2** shows that there are no areas of coral which currently lie within the predicted footprints of the various worst-best case scenarios. Therefore, there are no predicted losses of corals within the outer zone. The western side of the footprint will extend over an area which is reported to contain macro algae beds and the issue of potential impacts on macro algae is discussed in **Sections 3.2** and **3.10**.

Medium-term and Chronic Thresholds

Figure 3 presents the footprints generated by the new model interrogations using the medium term and chronic thresholds set for inner and mid-outer zones as per **Table 6**. It is noted that different thresholds apply within each of the marked zones in **Figure 3,** as defined in the key. Note also that the plot is constructed by compiling the outcomes predicted for three different general operations.

The most striking feature of the footprints is that they are virtually indistinguishable from the footprints generated for the acute sedimentation rates. This means that while these medium term and chronic events will be present over the same areas which are subject to a series of acute events, there are no increases in the areas of potential loss of corals when the results of the medium-term and chronic threshold predictions are included.

As previously noted, locations around the entrance of Flying Foam Passage were judged against the markedly lower thresholds set for the Mid-Outer zones (9 $mg/cm^2/d$ and 12 $mg/cm^2/d$) and coral loss may not necessarily follow from these thresholds (see discussion on Predicted coral losses below).

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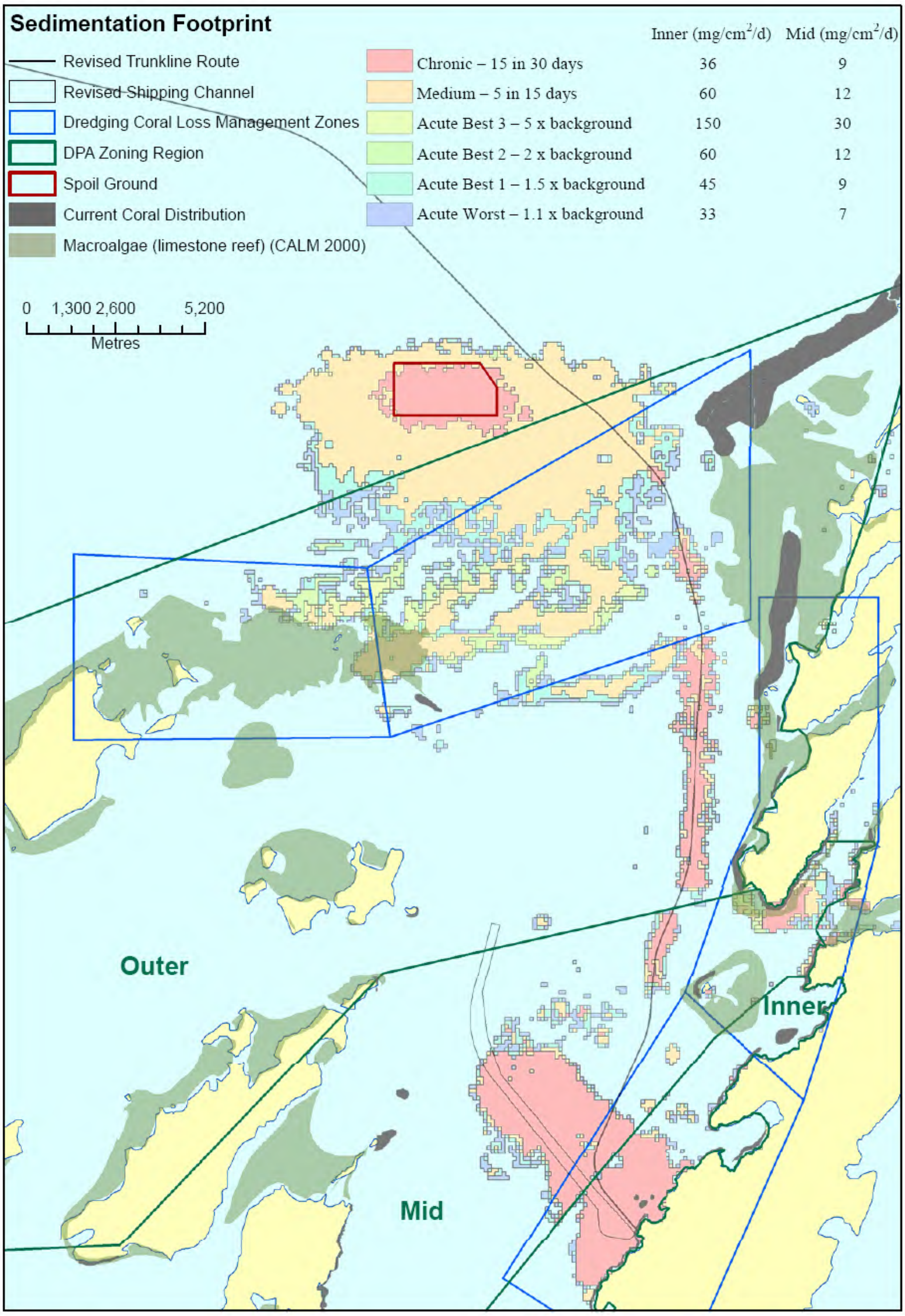

- **Figure 3 Predicted Footprint for Acute, Chronic and Medium Sedimentation Thresholds, based on derived worst and best case estimates for Acute, Chronic and Medium Term Sedimentation Thresholds.**

Zone of Potential Impact

Using the series of intensity-duration-frequency estimates developed from the baseline data for SSC produced the series of footprints displayed in **Figure 4**. It is noted that different thresholds apply within each of the marked zones in **Figure 4,** as defined in the key. Note also that the plot is constructed by compiling the outcomes predicted for three different general operations.

The threshold levels for each of the incremental events (stepwise by hours) are presented in **Table** 6 and reproduced in **Figure 4**. It is important to reiterate that the threshold values vary between the inner, mid- and outer zones and so even though the figure shows contiguous footprints for each set of events they are composites based on different threshold levels.

The footprint set generated for the six thresholds has been divided into two zones, based on the length of time of each group of events. Exceedence of thresholds for 4-6 hour events has been designated as the zone of potential impact primarily on the basis of the group representing one-third to half of the available daylight time and assuming the levels of SSC set for the thresholds would have some impact on light levels. This is an admittedly arbitrary approach but can be justified with reference to the durations and frequencies of events for the footprints now assigned to the zone of influence.

Thus, 1 hour events in which the SSC rises above 10 mg/L in the mid and outer zones are included in the footprint if they occur with a frequency greater than 10 events in month for the mid-zone and four events in a month for the outer zone. Intuitively it is likely that one or two events of 1-3 hours duration in exceedence of these frequencies will not significantly impact upon coral health, whilst an event with a duration of 4–6 hours elevated SSC could be construed as having a substantive (but sub-lethal) effect on corals (if it is accepted that the thresholds are meaningful in a biological context).

Within the zone of potential impact, based on the conservative thresholds, the footprint extends over a considerable area including some corals in all three zones.

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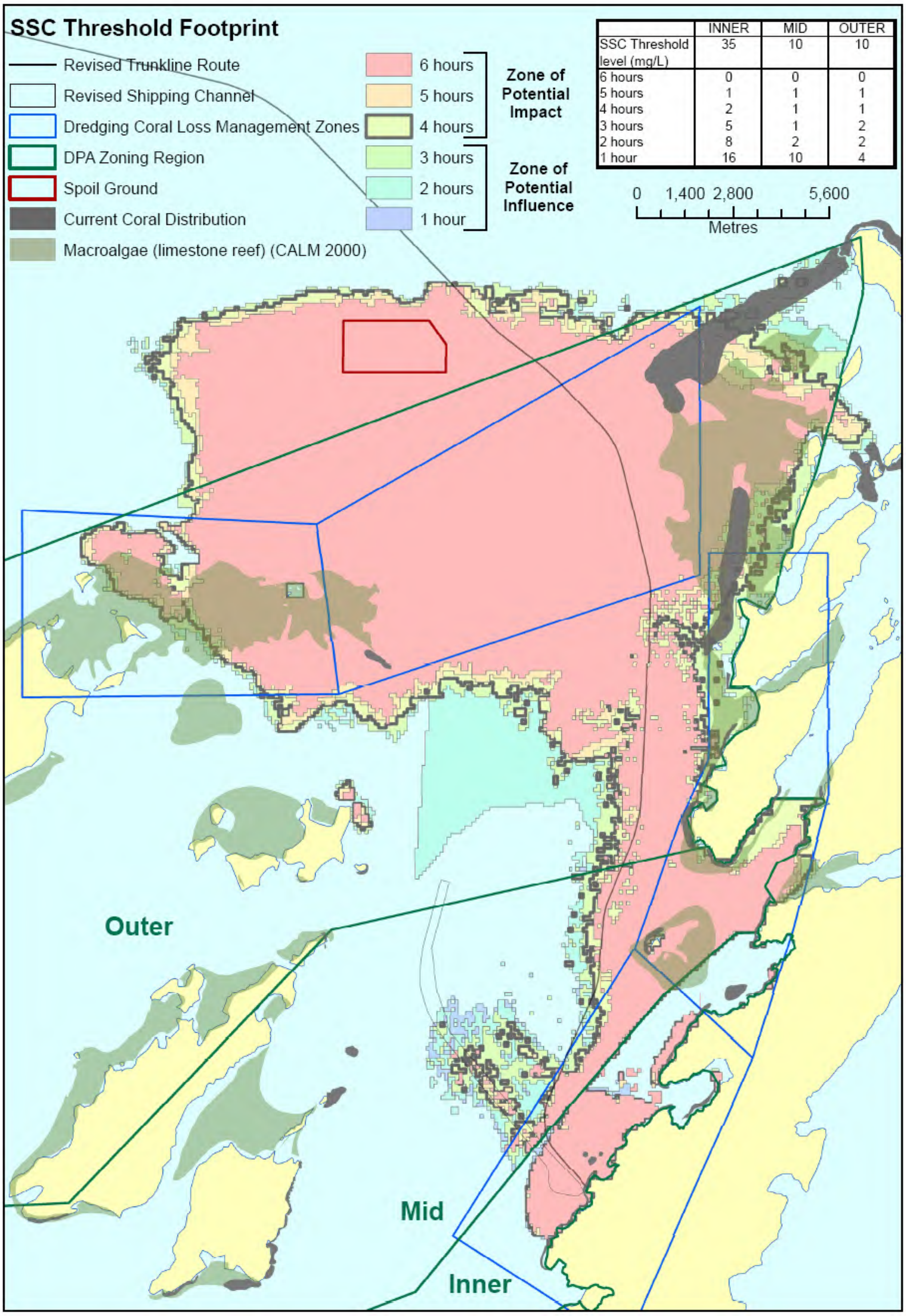

	INNER	MID	OUTER
SSC Threshold level (mg/L)	35	10	10
6 hours	0	0	0
5 hours	1	1	1
4 hours	2	1	1
3 hours	5	1	2
2 hours	8	2	2
1 hour	16	10	4

- **Figure 4 Predicted Footprints for SSC Thresholds based on the Intensity-Duration-Frequency Thresholds.**

Inner Zone: The threshold level for intensity within the inner zone was set at 35 mg/L and the footprint for zone of potential impact within the inner zone (**Figure 4** extends across corals that are also predicted to be impacted by sedimentation and it is possible that the stress from the elevated SSC events could add to the stresses on the corals in this area. It is not possible to determine whether these stresses are likely to be significant as there is no reliable data to show that the inshore corals will suffer sub-lethal effects at the threshold levels which have been set for the SSC intensity-duration-frequency analyses within the inner zone.

Mid Zone: In the mid-zone the zone of potential impact extends over a considerable area and the footprint includes the macro algae and corals around Conzinc Island and also extends up into Flying Foam Passage where it will cover the corals and macro algae on the fringing reefs at the mouth of that passage (**Figure 4**.

The threshold level for intensity in the mid-zone is 10 mg/L SSC and it is unlikely there would be any detectable impact at all upon corals in these areas. (macro algae are discussed in **Sections 3.2** and **3.10**) given that 10 mg/L is the mean value for background levels of SSC over coral reefs without human impact (Rogers 1990) and is well within the range of values that has been measured in the baseline data set without any evidence of impacts on corals. It is also important to note that MScience (2007) has estimated a general level of SSC for complete light extinction at 50 mg/L, which suggest that while 10 mg/L SSC will reduce light (and see section 1.2) it is not likely to be a significant impact on coral health over the time frames of hours rather than days.

As noted by Gilmour et al (2006), around inshore reefs of the Dampier Archipelago, background levels of suspended sediments varied among sites and months, but were consistently higher near the bottom where they were generally less than 10 mg L-1 and 4 NTU (MScience 2005). However, the levels of SSC did exceed 10mg/L and at those times there was no evidence of impact.

Gilmour et al (2006) also note the natural variability in levels of turbidity within the Pilbara complicates any attempt to determine threshold values for anthropogenic increases.

The use of background data to develop intensity-duration-frequency thresholds is supported by Gilmour et al (2006) but they point out that it must be based upon long-term variation in background levels of turbidity within the Pilbara and quantified at different sites over short and long time scales, and linked to impacts on the coral communities.

The recently completed baseline study (MScience 2007a, **Appendix A**) is considered as a useful starting point for the development of suitable baseline based thresholds, recognising, however, the limitations in making interpretation of sub lethal effects on corals in the absence of longterm data sets.

Outer Zone: The footprint of the area of potential impact within the outer zone is large and is based upon an intensity threshold of 10 mg/L. As already discussed, this value is the mean recorded over coral reefs free from human impact.

Within the zone lies a large area of corals around Legrende Island and there are also several large areas of macro algae habitat (discussed in **Sections 3.2** and **3.10**). The corals of this outer zone are among the best developed in the Sound (MScience 2005) and also experience the best water quality in terms of background SSC levels. Using the methodology of McArthur et al (2002) therefore implies there may be an impact in this area but the question remains as to whether a threshold of 10mg/L persisting over hours rather than days is likely to cause serious stress.

Gilmour et al (2006) note that increased turbidity and light attenuation primarily stresses corals by reducing the rates of photosynthesis of their zooxanthellae. For individual corals over periods of days to months, the physiological consequences of decreased light availability range from mild to severe stress. Note that the timescales quoted are days to months, whereas the timescales of the thresholds used here are for hours.

Zone of Influence

The EPASU requested the production of a zone of influence for the dredging and during the development of the necessary response the proponent examined the suitability of using the 80%ile of baseline SSC (varied across the three zones) to set the boundaries of the zone of influence. The rationale for not completing the mapping of an 80%ile for SSC has already been addressed in an earlier section.

However, the thresholds for durations of 1-3 hour events of elevated SSC have been mapped and it is proposed that these form the requested zone of influence. That zone is presented on **Figure 4** where it can be seen that it does not extend much further on the eastern side of the Sound than the zone of potential impact but does extend over a much larger area in the middle of the Sound. Throughout this zone, the frequency of short term elevations of SSC may be increased as a consequence of the dredging programme but these short term events are not anticipated to impact on corals (or macro algae).

Predicted Impacts on Corals

The potential impacts on corals are a major consideration of the outcomes of the reinterrogation of the modelling output. As expected, the production of thresholds based upon baseline data for SSC and sedimentation and using the methodology of McArthur et al (2002) for intensity-duration-frequency thresholds for SSC has produced larger footprints of the zone of potential impact and the zone of potential loss.

However, while the resulting footprints are larger they are not significantly larger, reflecting the models predictions that most sediments that are mobilised from the dredging programme will settle fairly rapidly. Observations that have been supported by the results of previous dredge monitoring programmes (MScience 2007b, **Appendix B**).

The footprints of the sedimentation threshold exceedances are shown in **Figure 5** with the total areas of coral habitat within each management zone that will covered by the sediment from the dredging programmes at the turning circle and the trunkline.

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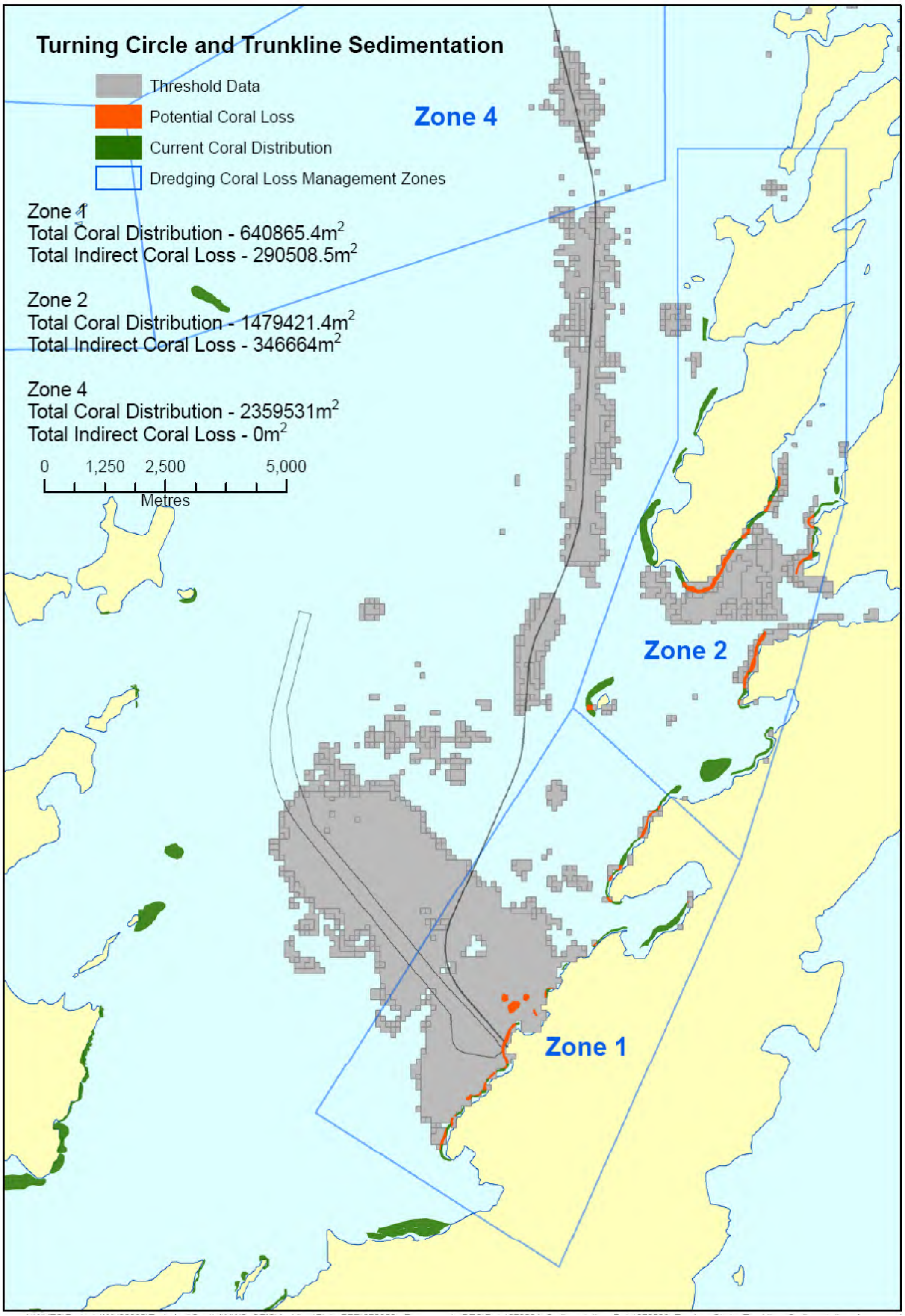

- **Figure 5 Predicted Footprints for Sedimentation from Turning Circle and Trunkline Dredging with Estimates for Potential Coral Loss**

In **Table 9,** the proponents previous estimation of potential corals losses is presented for comparative purposes**.** The Table contains the categories indirect loss and direct loss because that is the terminology used in the Draft PER and is included to avoid confusion, although no such distinction has been made in the figures showing areas of potential loss which have been presented here.

The estimate of direct loss has changed since the production of the Draft PER because of a slimmer footprint for the jetty construction at Holden Point and so the estimated total direct loss is now 1.64%. The rows in **Table 9** showing revised (threshold 100%) and revised (50%) refer to the supplementary interrogations that were completed and submitted in May 2007 showing a slight increase in the total area of potential cumulative loss as a consequence of a slightly increased footprint due to the incorporation of a resuspension component into the analysis. Note that the current area of corals present in both zones 1 and 2 has changed as a consequence of new distributional data supplied by MScience. The larger area of corals in zone 1 is due to the discovery of a patch of coral communities in Withnell Bay.

Attention is drawn to the column on the far right of Table 9 which presents the total for the potential cumulative losses in both zones 1 and 2 and in the Draft PER these were 42.4% and 5.5% respectively.

In the May 2007 results of revised modelling interrogations the 100% threshold prediction for loss was virtually the same as that made in the Draft PER, and is because of a revised (slightly lower) estimate of historical loss.

The May 2007 revision where a 50% of the original threshold was used produces an estimate in which the potential cumulative loss increases from 42.5% to 45.1% a change of 2.6%.

The proponent was requested to provide a set of new estimates of potential cumulative coral losses based upon thresholds set from the baseline data from sedimentation.

That data is provided in Table 10 and shows that there is an increase of potential cumulative losses in zone 1 if it is accepted that the thresholds based on baseline data are meaningful in that exceedances of these thresholds will lead to corals mortality. Thus the new percentage for potential cumulative loss of corals in zone 1 is 54.7%.

In both Tables 9 and 10 the proponent has combined the three components that comprised zone 2 in Table 7-35 of the Draft PER. The total area of corals BPPH in zone 2 has also increased slightly due to a reinterpretation of the data set.

Due to the predicted impacts of sedimentation on the corals at Flying Foam Passage the estimates of potential corals losses in zone 2 has risen, but again only if it is accepted that the sedimentation thresholds based on the baseline data are more likely to reflect the level of sedimentation at which mortality of corals would be observed.

All of the revised estimates are based upon the revised dumping plan where there is no dumping into spoil ground A/B.

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- **Table 9 Estimated Area of Direct Loss and Indirect Loss for Corals in the Draft PER and the Revised Data Submitted in May 2007 with the Original Thresholds (1005) and the Thresholds Halved (50%) (all values are m^2)**

Management Zone 1	Historical Area of BPPH	Current Area of BPPH	Current Historical Loss	Predicted Direct Loss	Predicted Indirect Loss	Predicted Cumulative Loss (Historical + Loss)	Potential Cumulative Loss
Draft PER	737 200	600 400	136 800 (18.6%)	20 000 (2.7%)	156 800 (21.1%)	157 000 (21.3%)	312 600 (42.4%)
Revised (100% threshold)	737 200	640 865.1	128 864.8 (17.48%)	12 100 (1.64%)	172 283.2 (23.4%)	140 964.8 (19.1%)	313 248 (42.5%)
Revised (50% threshold)	737 200	640 865.1	128 864.8 (17.48%)	12 100 (1.64%)	191 917 (26%)	140 964.8 (19.1%)	332 881.8 (45.1%)
Management Zone 2							
Draft PER Combined	4 244 500	4 244 500	0	0	232 900 (5.5%)	0	232 900 (5.5%)
Revised 100% threshold)	4 245 813.1	4 245 813.1	0	0	232 900 (5.48%)	0	232 900 (5.48%)
Revised 50%	4 245 813.1	4 245 813.1	0	0	232 900 (5.48%)	0	232 900 (5.48%)

- **Table 10 The Predicted Coral Losses with the Thresholds for Sedimentation set from Baseline Data (all values are m^2)**

Management Zone 1	Historical Area of BPPH	Current Area of BPPH	Current Historical Loss	Predicted Direct Loss	Predicted Indirect Loss	Predicted Cumulative Loss (Historical + Loss)	Potential Cumulative Loss
Baseline Data Thresholds	737 200	640 865.1	128 864.8 (17.48%)	12 100 (1.64%)	262 063 (35.5%)	140 964.8 (19.1%)	403 027.8 (54.7%)
Management Zone 2							
Baseline Data Thresholds	4 245 813.1	4 245 813.1	0	0	336 114.6	0	336 114.6 (7.9%)

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The proponent does not consider the new thresholds derived from the baseline data to be a reliable indicator of potential corals mortality. The review of the information from previous dredging programmes in Mermaid Sound (MScience 2007b, **Appendix B**) concludes that:

- Dredging has a bigger impact on water quality or coral health compared to spoil disposal;
- Substantial water quality impacts occur only at sites within 1 – 1.5 km of activity;
- Mortality of corals has only occurred at sites closer than 250m to dredging operations.

If those observations are applied to **Figure 5** which shows the zone of potential loss based on the new thresholds derived from baseline data it appears the new thresholds represent a gross exaggeration of the zone of potential loss. On the basis of water quality impacts within a distance of 1-1.5 km and mortality within 250 m of dredging the size of the zones of potential loss and of impact would be negligible.

While from a theoretical viewpoint the setting of thresholds based on baseline data is sound as it encompasses the range of environmental variability in sediment and SSC that corals normally experience it obviously requires a long term data set to more accurately define the limits to the coral communities tolerances. And it also requires some evidence of the reactions of coral communities under periods of duress when SSC and sedimentation are elevated well above the median. Such periods have occurred over short time intervals during the baseline study but in the absence of any evidence to the contrary it can only be concluded that over that entire range of sedimentation and SSC values recorded the corals have experienced little or no stress that could conceivably have been detected, and certainly no mortality.

Although it represents a good start the current baseline monitoring programme is short, relative to the lifespan of the organisms it is targeting. A data set spanning 20 years might provide a much more useful guide to the meaningful threshold levels for sedimentation and SSC that might be set for the corals in Mermaid Sound.

In the meantime the data from past dredging programmes is the only evidence available from Mermaid Sound upon which to base expectations of corals loss.

The results of monitoring corals during dredging programmes in the Sound suggest very strongly the coral communities are robust enough to survive the proposed dredging programme for the Pluto LNG Development and that the estimates of potential coral loss proposed in the Draft PER are in fact quite conservative.

The estimates provided in the Draft PER were compiled after a comprehensive review of the literature which included species specific data for as many of the species found in the Sound as information existed. The review of past dredging programmes supports the threshold levels originally proposed in the Draft PER as being more likely to be thresholds at which significant sub-lethal effects and partial mortality could be expected to occur.

2.2 Task 2: Evaluation of Potential Light Attenuation Impact

Agreed Scope

There was discussion at the 8 May 2007 meeting on the issue of whether it is possible (or meaningful) to develop a suitable parameter for light attenuation that can be investigated over varying durations and frequencies of exposure with the aim of determining potential impact. No consensus of opinion was reached at the meeting on what methodology could be used; all recognised the difficulties associated with any attempt to convert SSC into a measure of light attenuation in this particular environment.

As part of this task, investigation will be undertaken to evaluate whether it is possible to convert SSC to light (more specifically PAR) using relationships from the field data in a way that would give some confidence that the resulting parameter has some useful predictive capacity.

Preliminary examination of the baseline data set indicates there are some sites where there is evidence of some relationship between SSC and light, but at other baseline sites conditions of light and turbidity do not vary sufficiently over the life of the baseline programme to establish such relationships.

The following will be considered in the above assessment:

- *Relationship between SSC and light.*
- *Level of SSC at which midday light is extinguished.*

The baseline data should also be used to see what is the natural influences on the light and sediment climate and if the model is accurate in this regard. Given the baseline data indicates that light is largely tidally influence (depth) yet discussion on Tuesday indicated some wind wave influences (may be sight specific issues).

Additionally, light extinction caused by sediment resuspension (natural) during the day would probably be at the 95-99%. Impacts from light reduction will be chronic. Impact predictions must consider this.

Proponents Response

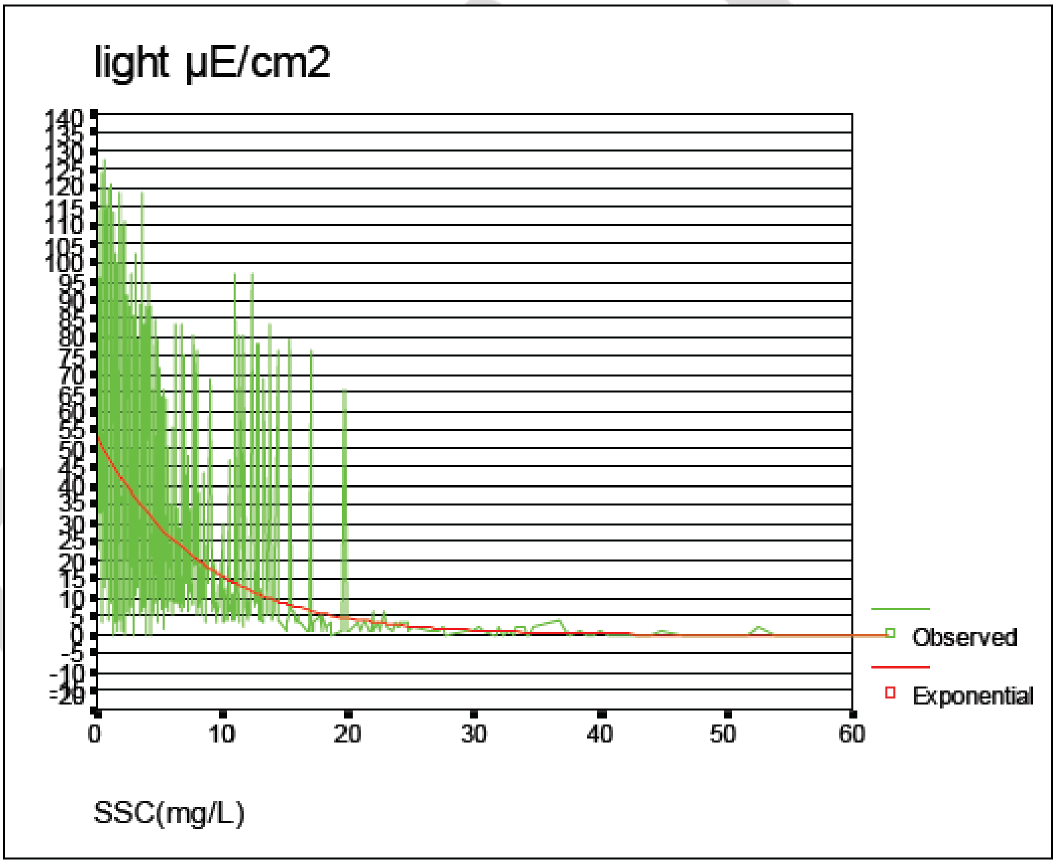
Relationship Between Light and SSC –Baseline Data (MScience 2007a)

MScience (2007a, **Appendix A**) investigated the relationship between light and SSC at the baseline data stations to determine whether a relationship could be developed that would allow the potential mapping of light attenuation as a threshold. All meters at the baseline stations logged light (PAR) in addition to estimating SSC over the same period. Depth of water over a meter has a significant direct effect on light reduction, but SSC can play a larger role when concentrations are high.

To examine the relationship between light extinction and SSC, light levels between 1000 hrs and 1400 hrs were correlated with SSC. The relationship was examined using the general model **Light = A*e**$^{\mathbf{(B*SSC)}}$ where A and B are derived from the empirical data. A typical data set is shown in **Figure 6** for the ANGI station where A=53 and B=-0.122.

Data were 'noisy' and most relationships had R^2 values of less than 0.2 (i.e. the relationship with SSC alone explains less than 20% of the variation). In addition to other influences such as tidal variation, it must be remembered that the SSC values from the meters only relate to water at the depth of the meter. Stratification of SSC is common in these waters with levels increasing towards the lower profile (Stoddart and Anstee 2005).

The proponent queries the rationale behind seeking to develop this relationship for the purpose of mapping thresholds of light attenuation as it is not commonly undertaken as an exercise precisely because the relationship is as typically noisy as demonstrated here. The most common approach to mapping potential zones of influence is to use SSC values and that is the approach which has been adopted in the preparation of the Draft PER.



- **Figure 6 Light Versus SSC at ANGI**

Light Extinction Estimates

MScience (2007a) has also examined the baseline data and compiled an estimate of the SSC at which light is expected to be extinguished at each station. These estimates are provided in **Table** 11 and the methodology of estimation is explained in **Appendix A**.

- **Table 11 Light Extinction Levels of SSC by Station (MScience 2007a)**

Site	**SSC Level (mg/L)**
ANGI	40
HGPT	n/a*
CHC4	100
MIDR	n/a*
WINI	70
TDPL	50

Site	SSC Level (mg/L)
KGBY	50
HSHL	n/a*
Inner	50
Mid	0
Outer	40

n/a* - at these sites, SSC values did not rise sufficiently high as to cause sufficient reduction in light levels as to allow estimation of extinction levels.

2.3 Task 3: Comparison of Pluto Impact Predictions with Past Dredging Programmes in Mermaid Sound

Agreed Scope

For this comparison, MScience will investigate relevant information from the following dredging programmes in Mermaid Sound:

- *2004 DPA dredging programme*
- *2004 Hamersley Iron dredging programme*
- *2005-6 Woodside dredging programme*
- *2006-7 Hamersley iron dredging programme.*

This will include information on dredging/disposal characteristics, measured water quality parameters and monitored impacts on nearby corals.

This task will include an assessment of threshold levels set by other dredging programmes in established zones of impact and influence and the basis of those thresholds. The analysis will compare the results of past monitoring programmes to determine whether or not thresholds were reached, or exceeded, and whether or not predicted impact (mortality of corals) occurred.

This assessment will provide contextual information for determining which of the threshold intensity-duration sets (and corresponding footprints) derived from Task 1 are the more realistic to use in defining zones of potential influence and impact.

This is a sound approach – however, most of these programmes did not collect real time WQ data so this will need to be taken into consideration.

Proponents Response

MScience (2007b) has undertaken a review of previous dredging operations within Mermaid Sound. This is provided in full in **Appendix B** and summarised below. It is also referred to in several responses within this document. The review concludes that:

- Dredging has a bigger impact on water quality or coral health compared to spoil disposal;
- Substantial water quality impacts occur only at sites within 1 – 1.5 km of activity;
- Mortality of corals has only occurred at sites closer than 250 m to dredging operations.

3. Further Queries on Dredging

3.1 Re-Use of Dredge Spoil Disposed in the Spoil Grounds

Discussion and response to 5.6 and 5.7 suggests that Woodside is considering re-use of dredge spoil disposed in the spoil grounds. This has not been discussed previously and would need to be incorporated into the proposal. The potential disturbance of previously dumped (and capped) contaminated sediment and modelling of the additional sediment plumes would also need to be assessed.

Proponents Response

At the time of the Draft PER submission, the proponent proposed to re-use some of the coarser material disposed of into spoil ground A/B (located within Mermaid Sound) for trunkline stabilisation. This would substantially minimise the amount of rock (approx. 165,000 m^3) that would need to be sourced from onshore quarries for this purpose and the associated environmental and safety issues related to quarrying, transporting, storing and handling large quantities of rock.

Following a preliminary review of cost and schedule implications, the proponent has committed to dispose all dredge spoil to the offshore spoil ground 2B to avoid potential impacts to the proposed marine reserve (approx 5 Mm3 of spoil was earmarked for disposal into spoil ground A/B adjacent to the proposed marine reserve area). However, the proponent would like to retain the ability to dispose of spoil from the NWSV channel crossing (<250,000 m^3) to spoil ground A/B. Dredging and trunkline installation across the NWSV channel will have significant time and access constraints for Woodside due to vessel traffic movements along the existing NWSV channel. Consequently, the proponent anticipates only having access to the channel 1 day/week over a short period of time for this aspect of the trunkline construction work. It will be very difficult to dispose of spoil from the channel to the offshore site due to the nature of some the equipment being used, which would be unsuitable for the more exposed conditions offshore, as well as the significant additional travelling time to and from the offshore site within the already short working window for undertaking this work. The offshore spoil ground 2B is 16 km further offshore than spoil ground A/B. The proponent is prepared to send the remaining approximately 5 Mm^3 that was previously allocated to spoil ground A/B to the offshore disposal site.

This change to the proposed dredging program obviously negates the need to further assess potential impacts from re-use of spoil recovered from spoil ground A/B. However, given the constraints associated with sourcing rock for trunkline stabilisation onshore the proponent would like to maintain the option of reusing some spoil from the offshore spoil ground.

Trunkline stabilisation works are not scheduled to commence until after pipelay activities during 2009. Therefore there will be opportunity to model and assess impacts from spoil reuse prior to this work occurring and suggest that this be included as a condition of approval prior to any stabilisation work commencing.

3.2 Benthic Habitat Map

A comprehensive benthic habitat map has not been provided. The habitat map provided only covers coral communities with >10% cover in any detail, but has not included existing coral communities along the NE coast of West Lewis Island. Mapping should include the soft bottom, platform reef and rocky reef substrates and their associated communities.

The additional data provided in Figure 7-31 of the Response to Submissions indicates that the extent of the algal community in the vicinity of the areas to be dredged, and the spoil dump sites, may be significant, particularly on platform reefs and other harder substrates. The date of the dredging expedition should be provided.

Proponents Response

Corals Along the NE Coast of West Lewis Island

The corals on the NE of West Lewis Island were not mapped because it was considered they were outside the potential zone of influence. It is correct that the original modelling interrogations produced several figures indicating these habitats would be within the zone of influence fo dredging (B-21, B-24, B-27, B-29, B-31, B-33) which are provided in the Technical Appendix to the Draft PER. However, the modelling interrogation that produced these results was based on the assumption that all sediment recovered by the dredging would be disposed into the existing spoil ground A/B and/or a trailer-suction hopper dredger would progress very slowly along the channel, and would therefore discharge from a location adjacent to West Lewis Island for many weeks. Simulations used winter conditions for these modelling exercises, hence the dredging location was upstream of prevailing winds. These dredging and disposal practices have since been amended to remove disposal significant disposal into A/B and to have the trailer suction hopper dredge working over a wider area, less intensely, on each case. Consequently, the potential zone of impact is not expected to reach this area at any time.

However, in response to the request for the coral communities on the NE coastline of West Lewis Island to be mapped, they have recently been surveyed by MScience and the resulting distribution map is presented in **Figure 7**. A description of the habitats at this location is provided in MScience 2007c (**Appendix C**).

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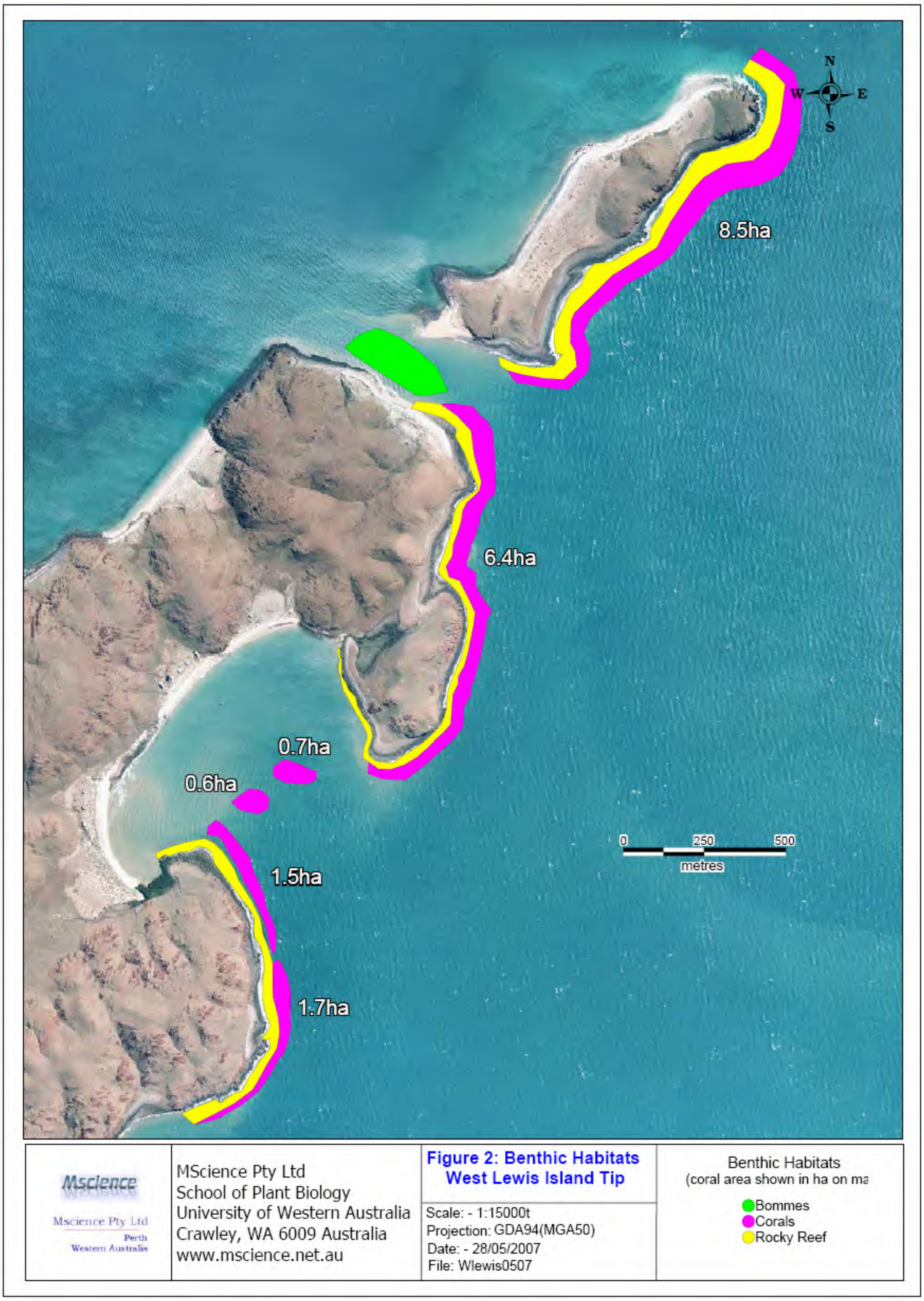

- **Figure 7 Benthic Habitats at West Lewis Island Tip (MScience 2007c)**

Macro Algae and Seagrass BPPH

The additional data provided in Figure 7-31 of the Supplement and Response to Submissions is misleading as an indicator of the presence or absence of Benthic Primary Producer Habitat because it presents the individual samples as ‘transects’. The additional data was collected from a scientific dredging programme undertaken by scientists from the WA Museum in July 1999 and was designed to obtain samples of fauna that could be identified to species (Hutchins et al 2004). A rake box dredge with a mouth area of 1200 mm x 330 mm and mesh size of 10 mm was towed at 2-3 knots for 10 minutes at each of 97 stations. Therefore each strip, or ‘transect’ of the bottom sampled by the dredge was 1.2 m wide and ranged in length from 600-900 m.

The dredge is not a quantitative sampling device but can be used to make semi-quantitative comparisons between the same dredge type over similar time periods, tow speeds, depths and on similar substrates with at least two replicates at each station. There was no replication in this survey so no semi-quantitative comparisons are possible.

The dredge has limitations as a sampling device, in that anything less than 1 cm in diameter will pass out through the mesh, including some soft, fleshy organisms that disintegrate. Once full, the dredge will not collect anymore of the macrobenthos, simply pushing material out of the way. It may also ride over the top of some benthos without catching any of it (the rake acts to avoid this problem on the type of dredge used in the survey). In areas of seabed overlain with very fine ooze, the dredge may disappear into it and run several metres below the surface, avoiding any live organisms that may be rafting on the surface.

What ends up in the dredge at the end of a single haul cannot be taken to be a quantitative sample of what was on the seabed that the dredge moved over. It is merely a quick and easy sampling device that is designed to provide specimens for taxonomic study.

Each of the dredge samples that form the basis of the ‘transect’ information presented in Figure 7-31 are described in the report on the dredging programme (Hutchins et al 2004). The report also contains a brief description of ‘habitat’ information which is presented in **Table 12.**

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Table 12 Description of 'Habitat' for Selected Dredge Stations in Mermaid Sound (After Hutchins et al 2004). All Samples Collected with the Rake Box Except 2a.

Station	Depth (m)	'Habitat' Description	Date
1	10	Rock, coarse sand; little material –frondose red algae and *Halophila*	14.07.99
2	18	Rock, grey muddy sand; very little material –sponges, soft corals and hydroids	14.07.99
2a	18	Grey muddy sand; very little material –drift sponges (scoop box dredge)	14.07.99
3	32-35	Muddy sand; coralline red algae and *Halophila*, free-living solitary corals	14.07.99
4	42-43	Muddy shelly sand, rubble and limestone rocks; sponges and gorgonians	14.07.99
22	37-38	Sand, few rocks, hydroids	17.07.99
23	37	Rock, sand; frondose red algae	17.09.99
26	34	Rock, muddy sand; frondose red algae, hydroids	17.09.99
27	33.5-34	Rock, muddy sand; very small catch –hydroids, soft corals	17.09.99
28	30.0-30.5	Rock, muddy fine sand; frondose red algae, hydroids	17.09.99
29	27-28	Rock, muddy sand, frondose red and brown algae, gorgonians	17.09.99
30	29-30	Rock, muddy sand; frondose red algae, hydroids	17.07.99
32	15-16	Rock, coarse sand, rubble; frondose red and brown algae, many sponges, hydroids, gorgonians	18.07.99
33	18-21	Coarse sand, rubble and shell; rhodoliths and frondose green and red algae, corals, soft corals and gorgonians	18.07.99
60	16-17	Mud, rock; frondose algae, sponges, hydroids, gorgonians	22.07.99
61	11	Mud, rock; red algae, few echinoids and holothurians	22.07.99
62	7-9	Fine shell, rocks, rhodoliths, frondose algae, sponges, gorgonians	22.07.99
63	11.5-12	Mud, gravel and shell (dredge spoil); very few sponges	22.07.99
64	12-14	Mud and rubble; sparse crustaceans and dead shells	23.07.99

The data presented in **Table 12** are the samples that were collected from stations at or near locations where the dredging programme will produce a plume (i.e. in or near the potential zone of influence). Figure 7-31 from the Supplement is reproduced here with the station numbers from **Table 12** added.

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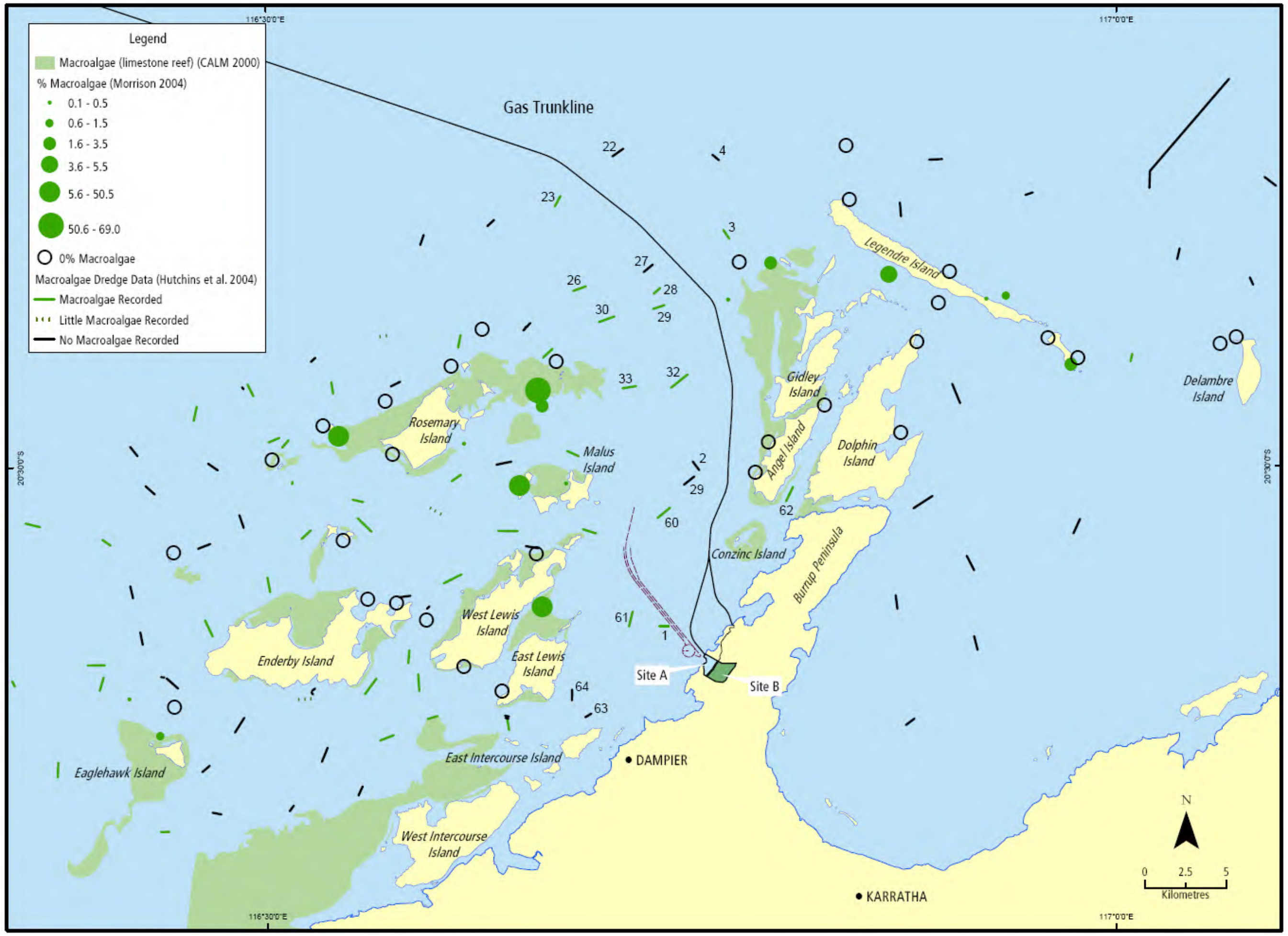

■ **Figure 8 Revised Macro Algae Distribution in Mermaid Sound (Figure 7-31 of Supplement and Responses to Submissions Document)**

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A number of the stations listed in **Table 12** record the presence of Benthic Primary Producers (BPP), including red algae (stations 1,3,23,26,28,29,30,32,33,60,61 and 62), brown algae (stations 29, 32, and 33) and green algae (station 33), the seagrass *Halophila* spp (stations 1 and 3) and also corals (station 33). However, none of the descriptions of 'Habitat' suggest that these BPP form a major component of benthos in terms of percent cover at any of these stations and it is not possible to draw that conclusion from the dredge data. The data records only presence or absence and there is no estimate of the relative proportions of any taxa inside each dredge haul so individual taxa of macrobenthos may be represented by a single record.

The presence/absence records of Hutchins et al (2004) were compared with the checklist of species and station records of the published taxonomic account of the species of macro algae collected by the dredge survey in the Sound (Huisman 2004). Only three of the stations listed in **Table 12** are mentioned (29, 30 and 32) in Huisman (2004) and only a single species of macro algae is recorded for each of these stations (station 29 –*Coelarthrum opuntia*, station 30 *Coelarthrum cliftoni* and station 32 *Echinophycus minutus*). This implies that very little macro algae material was collected by the dredge at those stations.

If the dredge was hauled up full, then the most that could be said about the potential coverage of habitat types is that the contents of the dredge in volume (about 0.36 m^3) are spread over an area of between 720-1080 m^2. This is a low density of coverage on this area of seabed and would fit with the findings of the CALM mapping exercise in Mermaid Sound (CALM 2000) and the surveys undertaken for the preparation of the Draft PER. It is possible that the dredge might have filled almost immediately after the start of the tow, and in these cases the material collected by the dredge is an underestimate as some material in the path of the dredge was not collected.

If the dredge is not full it is much more indicative of a sparse distribution of macrobenthos, although it is possible the dredge is still not catching everything in front of the mouth. For example, at station 1 (**Figure 8**) the description records very little material and implies the substrate over which the dredge passed was sparsely populated by macrobenthos. It is also interesting to note the presence of *Halophila* spp. at this station could be an artefact as there is no mention of how much seagrass was collected and whether it had been attached to the bottom when collected by the dredge (i.e. roots were attached). This species is quite common in drifts and might have been taken by the dredge from the water column.

The recent surveys (Draft PER Section6.3.1) undertaken for the areas to be dredged and to receive dredge spoil, produced results that were consistent with previous descriptions of the character of the seabed in these areas (CALM 2000; Jones 2004) and can be summarised as:

"*The nearshore marine survey of the proposed shipping channel into Site A recorded soft sediments only, with isolated and very sparse sponges, soft corals and macroalgae. The survey also identified* *seapens, macroalgae and seawhips in isolated areas of spoil ground 2B, albeit in very limited quantities"* (Draft PER p109).

There is nothing in the Hutchins (et al 2004) dredge survey data that is inconsistent with the findings of the recent marine surveys undertaken for the Draft PER.

The area around Conzinc Island was reported to have some macro algae beds in the CALM 2000 map of major marine habitats and there are also extensive areas of macro algae beds along the western sides of both Angel and Gidley Islands (**Figure 8**). The accuracy of the data for which the mapping exercise is based upon is uncertain. Spot dives (Morrison 2004) do not provide any clarification other than to record a coverage of 5.5% or less at the sites where the dives took place, but it is not obvious this can be extrapolated to the nearby areas.

Comparison of New Model Interrogation Outputs with Macro Algae Distribution

The new interrogations of the model outputs presented in this document has provided a series of revised footprints based upon a new set of thresholds for SSC and sedimentation derived from the baseline data collected by MScience, and including an intensity-duration-frequency sensitivity analysis (Refer to **Section 2.1**and **2.2**). For SSC thresholds the suggested frequencies and durations of elevated SSC events is provided in **Table 13**.

- **Table 13 Suggested Frequencies and Durations of Elevated SSC Events (MScience 2007a)**

SSC threshold Level (mg/L)	Inner	Mid	Outer
1 hr	35	10	10
2 hr	16	10	4
3 hr	8	2	2
4 hr	5	1	2
5 hr	1	1	1
6 hr	0	0	0

Inner Zone*:* **Figure 4** presents the revised thresholds for SSC for varying intensity-duration-frequency shows the areas where the frequencies of the different duration events are predicted to be exceeded. Within the inner zone there are no areas of seabed where macrolagae has been recorded in densities that would classify the area as supporting macro algae BPPH in significant quantities.

Mid-Zone: There is an area around Conzinc Island where the 1-6 hour threshold frequencies are predicted to be exceeded during the dredging of the turning circle and also the trunkline. The area around Conzinc Island was reported to have some macro algae beds in the CALM 2000 map of major marine habitats and this is shown in **Figure 8**.

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The large area of macro algae beds along the west side of Angel and Gidley Islands is also predicted to be subjected to events of elevated SSC that exceed the recommended frequencies for 1-6 hour duration events.

Outer Zone: **Figure 4** also presents the thresholds for SSC for the scenario where material deposited into spoil ground 2B is resuspended and transported and shows the areas where the frequencies of the different duration events are predicted to be exceeded. The area identified as macro algae beds in (CALM 2000) along the western sides of Angle and Gidley Islands is expected to experience times when the 1-6 hour threshold frequencies will be exceeded during the spoil ground 2B dumping phase of the programme, but while the shorter duration events will be experienced over a large area (the zone of influence), the 4-6 hour events (the zone of potential impact) are restricted to the northern area of the macro algae beds.

Interpretation of **Figure 4** for SSC thresholds requires care as the baseline conditions used to develop the thresholds vary and incorporation of these different baseline levels into the thresholds means the threshold level is dependent on the zone (**Table 2**). For instance, the inner zone has a much higher threshold (35 mg/L) than the mid and outer zones (10 mg/L).

It is the proponents view that the only areas where the ‘macro algae’ beds mapped by CALM may contain macro algae with a percent coverage greater than 5% is in the region around Conzinc Island, and also along the western side of Angel and Gidley Islands (**Figure 8**). In these areas the background threshold level is set at 10 mg/L which is relatively low. The combinations of duration and frequency events have been selected as triggers using the methodology of McArthur (2002) and refined by MScience (2007). The footprints generated by predictions of where these thresholds will be exceeded have been identified as zones of influence and potential impact , but that assumes a very low tolerance of elevations of SSC for the macro algae in Mermaid Sound.

An SSC of about 40 mg/L is reported to be the critical level for light extinction in the outer zone (MScience 2007) and that coupled with the relatively short duration of the elevated SSC events, strongly suggests that there will be minimal (or no) impact on macro algae from light attenuation associated with elevated SSC events from the dredging programme.

The new interrogations of the model outputs also developed a series of thresholds for sedimentation levels based upon the background (baseline data) collected by MScience (2007). Three different thresholds are presented (acute, medium-term, chronic) and the thresholds for each are derived from analysis of the background information available on sedimentation rates. A detailed explanation of how these thresholds have been derived is presented in **Sections 2.1** and **2.2** and those sections also contain a detailed discussion of the potential impact on corals of sedimentation exceeding these thresholds.

Potential Impacts on Macro algae

Figure 5 presents the footprint for sedimentation thresholds and shows that the majority of the area which will be subjected to increased levels of sedimentation has no significant macro algae habitat. Note that the Figure shows the area of influence for two different sets of thresholds, with higher levels of sedimentation thresholds set for the inner zone compared to the mid- and outer zones. As explained in **Section 2.1** and **2.2**, the sediment threshold levels set for the mid- and outer zones are the same because the background data showed no discernable difference in the intensity-duration-frequency of sedimentation events for these two zones.

The inner zone has higher sedimentation threshold levels reflecting the presence of higher levels of sedimentation events in the background data (MScience 2007a).

Figure 5 shows that the majority of the northern area which will be subjected to increased levels of sedimentation is located well offshore from the area alongside Angel and Gidley Island where the CALM (2000) map of major marine habitat suggested the presence of macro algae beds. There is an area off the south-eastern end of Angel Island where there is predicted to be elevated levels of sedimentation for part of the trunkline dredging programme and in this area, the CALM (2000) map suggested macro algae beds on limestone reefs, but there is no corroborative evidence. The survey undertaken by Hutchins et al (2004) reported frondose algae from one dredge haul in this area, but Huisman (2004) records a single species (*Asparagopsis taxiformis*) from this station.

There are no macro algae beds within the area which the interrogations predict will be subjected to elevated levels of sedimentation as a consequence of dumping at spoil ground 2B.

Sedimentation and Macro algae

In a review of the literature documenting the impacts of sedimentation on the flora and fauna of rocky coasts, Airoldi (2003) concludes that the impacts of sedimentation on macro algae, coralline algae and turf algae are not well understood and there is considerable debate in the literature about whether some types of algae benefit from an increase in sedimentation, or are negatively impacted, or are not affected at all. Airoldi (2003) concludes that site specific characteristics of habitats, sedimentation, co-acting factors, and the adaptive capacity of individual species may explain the lack of coherence in results and observations published in the literature.

Airoldi (2003) also points out that many of the studies that report an impact on macro algae from sedimentation do not provide a quantitative estimate of the amount of sediment, the type of sediment involved and the potential impact of other factors such as turbidity and often fail to identify the mechanisms whereby sedimentation has had a negative or positive effect on individual species. In short much of the published information is qualitative (see Figure 4 in Airoldi 2003).

The available information shows that macro algae and seagrasses are not significant components of the BPP Habitats present, and in the absence of well defined thresholds for the species of algae that might be present in the area but in very low densities, the development of any thresholds for macro algae in Mermaid Sound is problematic. The evidence for potential impacts of sedimentation on macro algae is discussed in greater detail in **Section 3.10**. The thresholds used in these interrogations are relatively low (**Table 8**) and are not expected to represent any potential impact to macro algae.

Therefore, corals were identified as the sensitive benthic primary producers which are known to be present in significant amounts and are known to be sensitive to increases in sediment and turbidity, although the pertinent thresholds for Mermaid Sound coral communities are subject to debate. The distribution of corals was accurately mapped, and suitable monitoring and impact sites were selected for monitoring before, during and after the dredge programme.

3.3 Environmental Quality Objectives

Modelling outputs should be mapped to show the areas where each of the Environmental Quality Objectives identified in the Pilbara Coastal Water Quality Consultation Outcomes report will not be met.

Proponents Response

In response to the Pilbara EQMF (from the Pilbara Coastal Water Quality Consultation Outcomes report) the proponent identified which values were likely to be impacted by dredging and which indicators (Water Quality parameters) were relevant (Table 5 of the Supplement and Responses to Submissions document).

The Pilbara EQMF does not set any numbers or thresholds. It recommends three zones: Maximum, High and Moderate and the objectives for each in terms of water quality are provided in **Table 14**.

- **Table 14 Environmental Quality Conditions for Pilbara Coastal Waters (Reproduced from Department of Environment 2006)**

Level of Ecological Protection	Environmental Quality Condition (Limit of Acceptable Change)	
	Contaminant Concentration Indicators	Biological Indicators
Maximum	No contaminants – pristine	No detectable change from natural variation
High	Very low levels of contaminants	No detectable change from natural variation
Moderate	Elevated levels of contaminants	Moderate changes from natural variation
Low	High levels of contaminants	Large changes from natural variation

The locations of the areas within Mermaid Sound where the different levels of ecological protection apply are provided in Map 9 of the Pilbara Coastal Water Quality Consultation Outcomes (Department of Environment 2006) and that figure is reproduced here (**Figure 9**).

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- **Figure 9 Pilbara Coastal Water Quality Consultation Outcomes**

The potential zone of influence from the proposed dredging programme will be mainly confined to the areas designated as either high or moderate ecological protection and there is some intrusion into areas rated as maximum ecological protection.

The Pilbara Coastal Water Quality Consultation Outcomes (Department of Environment 2006) list the limits of acceptable change for each of the three categories of maximum, high and moderate levels of ecological protection (**Table 14**).

With respect to the potential impact on water quality from the proposed dredging programme the proponent considers that the water quality parameters pH and dissolved oxygen are not expected to vary outside of the 80%ile and 20%ile of background levels and therefore have not been investigated as part of the modelling exercise.

Important water quality parameters that will be altered by the proposed dredging programme are turbidity and sedimentation and discussions with representatives of the EPASU indicated that the potential impact of fluctuations of these water quality parameters on ecosystem health and aesthetic values needed to be investigated. It was suggested that to assess the impact on Ecosystem Health Values the area where turbidity levels would exceed the 80%ile of background levels should be indicated on a map, and the area where sedimentation exceeds the 80%ile of background sedimentation should also be shown.

The proponent has undertaken a modelling reinterrogation exercise where both turbidity (as SSC) and sedimentation are examined in terms of intensity-duration-frequency for a range of background values of SSC and sedimentation derived from the recently collected MScience (2007a) baseline data (Refer to **Sections 2.1**and **2.2**).

The thresholds for the zones of potential impact and potential loss are based upon the 95%ile of the data recorded in the baseline study (MScience 2007a). The rationale for using the 95%ile is based on the application of the methodology of McArthur (2002) and is explained in detail in **Section 2.1**. As the outcomes are based on the water quality parameters of turbidity (SSC) and sedimentation and have been mapped, the response in **Section 2.1** is considered to be an adequate response to this comment on Environmental Quality Objectives.

It should be noted that the Pilbara Water Quality Consultation Guidelines list the levels of acceptable change, but there is no indication as to whether acceptable change is restricted to long term deviations from the background conditions or whether short term deviations form the background in water quality are also included.

Short term fluctuations in water quality already occur as a consequence of natural events like cyclones and the setting of water quality objectives presumably relates to the long term.

The second request was to assess the impact on the aesthetic value of water quality wherever increased turbidity produced water conditions with lower than natural (i.e. background) water clarity. The proponent consequently undertook (Table 5 of the Supplement and Responses to Submissions document) to show where the natural visual clarity will be reduced by more than 20 %.

The proponent understands the 'natural visual clarity' to be a function of the effect of suspended material on the ability of water to transmit light and the impact on aesthetic value to be increasingly cloudy water producing a negative response in terms of visual amenity as suspended sediment loadings increases.

The investigation of the baseline data recently completed by MScience (2007a) includes a plot of light versus SSC data collected from one of the baseline data stations (ANGI) which is indicative of the data collected from all stations. **Figure 6** shows that at station ANGI the data are noisy with the correlation exhibiting R^2 of less than 0.2 which means the relationship with SSC alone explains less than 20% of the variation. MScience (2007a) also point out that the SSC values only relate to the 'quality' of the water at the depth of the meter and the SSC values will vary above and below this depth.

Consequently, given the high level of noise in the data set the proponent considers any attempt to plot a zone showing the area where a reduction of "natural visual clarity" by an amount of more than 20% cannot be undertaken with any degree of confidence.

3.4 Re-suspension and Light Attenuation

Re-suspension is likely to increase TSS and sedimentation over coral areas and reduce light attenuation. It is also likely to cause sediment to accumulate in low energy areas, perhaps even at distance from the dredge/dumping activity. Because this is a 2 yr programme the effects are likely to be very significant.

Proponents Response

The proponent has significantly reduced the proposed programme in terms of sediment mass to be relocated and the time to complete, from the earlier advised estimates, with the benefit of reduced input of fines and a shorter duration of influence (refer also to **Section 3.11**).

Modelling with resuspension (refer to **Appendix D**) has indicated that resuspension of fine sediments would occur in Mermaid Sound, due to the seabed stress set up by waves and currents and the nature of the existing sediments. Resuspension was predicted to increase SSC on a fairly localised basis. i.e. the wave modelling indicated that seabed stress will vary spatially and temporally due to variations in exposure to prevailing conditions, and variations in intensity of wave forces. This would lead to the patchy and variable background SSC observed in the field data, in the absence of dredging. Because the seabed of Mermaid Sound consists of fine sediments, wave resuspension of existing sediments is expected to be the major contributor to the existing patchy and variable levels of SSC (and associated light attenuation) that are observed.

Dredging would vary the existing situation if the proportion of fines on the surface was increased either locally or generally. Modelling indicates that dredge-sourced fines should initially sediment within the areas influenced by the initial settlement plume (rather than universally) but disperse further over time. Modelling also indicate a tendency for fines to disperse (to make up a lower proportion of local fines) and to migrate from the system over time via the multiple channelways. The relevance of the contribution of dredge-sourced fines relative to background sourced fines would therefore depend on local magnitudes of increase and the tolerance of BPP components to the total (dredge + background) SSC experienced. Multiple dredging and disposal operations have been carried out in Mermaid Sound and the existing field data gives some indication of the existing baseline SSC patterns, with those influences included, as well as the tolerance of local BPP components to these patterns. The threshold analysis has taken the baseline values and responses into account.

The field (MScience 2007a) and model data both indicate that sedimentation does not increase concurrently with SSC, because the energy that creates resuspension tends to cause erosion instead of accretion. However, elevated sedimentation can occur after the passage of higher energy events. As for SSC, sedimentation appears to vary spatially, with wave-sheltered locations tending to trap sediments to some degree. This is consistent with the field observations where some sheltered sites are particularly “dirty”. Thus, the outcomes of sediment discharge would vary with the location in Mermaid Sound. Most locations in the mid-outer sound showed high resuspension rates (hence low net sedimentation) in the model outcomes, hence fines introduced to these areas would be less likely to accumulate. Areas of relatively higher trapping in the mid-outer sound appear to be limited to locations sheltered from the western sector, and this sheltering varies with the passage of storms. In contrast, the wave modelling indicated that the inner margin of the Sound should have higher rates of trapping, for sediments that are discharged in this zone, or migrate into this zone. Elevated sedimentation was not predicted in these areas from dredging off Holden Point because a net northward migration was indicated for the time of year that dredging is proposed. The low wave-energy predicted for the southern end of Mermaid Sound, together with a local input of fines (such as the overflow of a previous dewatering operation to the immediate south) may explain the DEC observation of a water-clay layer build up at a site in the south end of Mermaid Sound.

The analysis of model outcomes takes account of the local bottom-stress variation and position of sensitive receptors along the predicted sediment migration routes to quantify the SSC and sedimentation rates that are expected from the specific case of dredge discharge off Holden Point under summer conditions.

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Disposal of sediments to the offshore discharge site is one management step that has been taken to reduce the introduction of fines directly into Mermaid Sound. Simulation of a high fine content sediment mixture into this area under winter conditions indicates that fine sediments (clay –silt) are likely to be resuspended by levels of seabed stress predicted for the site. Under winter waves and currents, the modelling indicated a net southward migration with fines tending to migrate and disperse from the dump site into Mermaid Sound. The threshold analysis for SSC and sedimentation provides a guide to the significance of the SSC and sedimentation expected. Note that currents tend to parallel the shelf during summer conditions, hence the result shown here will be the seasonal worst-case

3.5 Vulnerable Coral Species

Medium and chronic thresholds for vulnerable coral species therefore also need to be included into the modelling outputs along with light reduction thresholds (this is a 2 year programme). Potential effects of turbidity induced light reduction have not been taken into account.

Proponents Response

Part of the re-interrogation of the model output in the present scope of work has included the setting of acute, medium and chronic thresholds for the corals species located in the mid and outer zones of the harbour. The classification into inner, mid- and outer zones was developed by MScience (2005) as a response to evidence which demonstrated the species composition and dominants of the corals communities of Mermaid Sound could be differentiated on the basis of their position in the Sound. The classification was supported by recorded differences in turbidity regimes which suggest the inner zone of corals is dominated by species that are more tolerant of higher turbidity.

The baseline data gathering exercise (MScience 2007a) has included 8 stations at which SSC have been measured since August 2006. These data are presented in **Table 13** (see **Section 2.1**) and included in the Table are calculations of SSC values by zone where the stations have been lumped to conform to the zonation pattern developed by MScience (2005). When the inner zone SSC mean, median and 95%ile values are compared to the mid and outer zones it is clear they are higher, suggesting that the coral communities occupying the inner zone have been subjected to higher levels of SSC than the coral communities of the mid- and outer zones. The mid-and outer zone results however show very little difference between these two zones in terms of recorded SSC.

Consequently, the use of background data to develop thresholds for the more ‘sensitive’ or ‘vulnerable coral communities that are believed to comprise those found in the mid and outer zones has assumed that the same level of 95%ile SSC will suffice for both mid- and outer zones.

3.6 BPPH Losses

BPPH losses need to be evaluated within a context of a map and statistics showing the area of permanent (or long-term) loss, the footprint area of short-term reversible loss and the area within which there is likely to be physiological or morphological impacts but not loss. The area beyond this last boundary should be the area of no impact. Given the lack of data on BPPH tolerances changes to background environmental conditions can be used to estimate the boundary, In the case of sedimentation or light attenuation the 80th percentile of natural background variability would be used as the criterion for modelling the boundary for no effects on BPPH. Where there is significant uncertainty around these thresholds then a best/worst and most likely scenario may be considered.

Proponents Response

The information provided in **Section 2.1** provides the response to this comment. The proponent has used the pre-dredging baseline studies data compiled by MScience (2007a) to develop a series of thresholds based upon the methodology of McArthur et al 2002.

The methodology adopted includes a worst case-best case scenario with respect to sedimentation.

3.7 Output from the Sedimentation Modelling

T*he output from the sedimentation modelling can only be taken as a guide. An estimate of worst case BPPH loss can be determined by drawing a generalised line around groupings of the polygons that represent sedimentation threshold exceedances.*

Response

The proponent interprets the request to include all groupings of the polygons that represent threshold exceedances within a single generalised line to mean that a line should be drawn to capture some outlying polygons that are disjunct from the larger areas of polygons generated from the modelling interrogations.

The rationale for this approach is that it represents a worst case scenario for BPPH loss. However, the current modelling outputs which have produced some outlier groupings of polygons is a product of a high resolution with a high degree of sensitivity. Consequently the production of any generalised line around the various groupings of polygons reduces the value of the model outputs, because it will include within the zones of potential impact and potential loss, areas of BPPH loss and impact which the model output has not predicted.

The output from the modelling is only a guide, but it represents a high degree of sophistication with respect to the input data, and how that data has been treated. The decision to resort to a model to provide predictions is based on the recognition that the movement of the plume is influenced by a complex suite of factors that require a high degree of integration and it is a backward step to begin drawing generalised lines on maps. The validation studies which have been undertaken demonstrate a strong correlation between predicted and observed outcomes and therefore provide a strong rationale for adopting the model outputs 'as is' for the basis for meaningful management strategies.

The predictive power of the model is one of the elements that will be tested during the proposed dredging programme. The information input could certainly be improved, for example there is currently no data on the SSC profiles through the water column during dredging programmes in Mermaid Sound, and that would be a useful piece of information, but until such time as that data is available, the modelling outputs produced here are best estimates.

It is worth noting that the modelling output is already considered by the proponent to present a worst case scenario, given that it was based on earlier dredging programme designs which included larger volumes, longer periods and the use of dredge spoil ground A/B. The more recent modifications include significant reductions in the volume of material, the duration of dredging, and locations of dump sites.

The model also used a very conservative over-estimate of the amount of material that would re-enter the entire water column through resuspension and therefore the predicted lateral transport of that material is considered to also be a gross overestimate (i.e. a worst case scenario).

3.8 Exceedence of the Threshold Criterion

Where losses of BPPH exceed the threshold criterion (Area 1 and 2) then the EPA expects the proponent to provide a substantial justification for the proposal supported by technically sound information demonstrating an understanding of the ecological role/function and value of the BPPH within the local context to help determine the significance of the potential impacts. There is also a need for an offsets package ***WEL.*** *See BPPH Guidance Statement.*

Proponents Response

The proponent provides the following assessment of the ecological role/function and value of the BPPH with the local context.

The threshold criterion for areas 1 and 2 (i.e. management zones 1 and 2) have been set by reference to the BPPH guidelines and are currently set at 0% for area 1, and 1% for area 2. As a starting point it is worth examining what these figures of 0% and 1% are meant to represent in terms of ecological role/function.

The BPPH guidelines aim to protect and maintain ecosystem integrity by setting limits to the amount of primary producer habitats that might be lost as a consequence of development projects in the marine environment. The 0% setting for area 1 is based on the information that historical losses within the management unit already exceed 10% and therefore no further losses are permitted.

The proponent argues that while there is evidence of a historical loss of some 17% of the area of BPPH (specifically corals habitat) that does not necessarily equate to a loss of 17% of the ecological role/function of that habitat. The current interpretation of the ecological role/function value as presented in the 10% rule is that 1 square metre of coral habitat anywhere within the designated management unit is the equal of any other square metre of coral habitat in terms of contribution to ecological role/function within the management unit.

Therefore the implication is that within areas 1 and 2 the predicted potential loss of 55% and 23 % of corals habitat respectively represents a loss of 55% and 23 % of ecological role/function and that amount of loss within these areas would then significantly impair ecosystem function. It is important to note that these losses are based upon the new threshold values used for model interrogation and the proponent considers these revised estimates to be gross over estimates of the likely corals losses, a view which is supported by the available data on previous dredging programmes (refer to MScience 2007b, **Appendix B**).

The question is whether it is fair to assume that all square metres of coral habitat are equal. It is highly likely that coral communities vary considerably in their individual contribution to ecosystem integrity, even over relatively small areas here in Mermaid Sound as elsewhere in the world (Hatcher 1990).

That is certainly the case with other BPPH such as mangroves where primary productivity can vary widely within a location and incidentally is very often obviously expressed in low percentage of coverage and reduced stature of the trees.

Coral communities in Mermaid Sound vary widely in the percent coverage of the substrate exhibited with the general trend for coral coverage to be low in the inner zone 10-20% and rising to coverage of 40% or more on some of the offshore reefs.

Given that the distribution and percent coverage of corals in the Sound appears to be largely determined by physical factors it could be assumed that not only are the corals of the outer areas of the Sound likely to be more diverse, and cover a larger surface area, with a potentially more complex three-dimensional structure, but are also likely to be far more productive (i.e. to produce more carbon per unit of area of coral) than the corals occupying the more turbid waters inshore.

Within the nominated management unit the amount of coral cover varies considerably ranging from under 10% to more than 20% and therefore if it is assumed the effect of physical factors is influencing the percentage of cover exhibited by the individual communities then it also is likely that individual communities may vary considerably in respect of primary productivity as a response to those same physical factors. And it is primary productivity which is the ecological role/function driving the ecosystem integrity the BPPH Guidelines presumably seek to protect and maintain.

Consequently, the proponent makes the point that what is important is not the percentage of coral BPPH area that may be lost, but the percentage of ecological role/function that is provided by the coral communities inside the management unit and how much of that may be lost or impaired by the development proposal.

Presumably the selection of an area of $50km^2$ size as the nominal area for management units was in part based on a belief that area of this size encapsulated many of the ecological roles/functions contained within the unit. That may be true for some areas of the Australian coastline, but is certainly not true for many others.

The management units are currently set at about $50km^2$ for areas 1 and 2 because this is the guidance received from the EPA in respect of the preferred size of management units but it has little to do with any perceived natural boundaries of ecological role/function. The proponent is not arguing here for a change in the current management unit boundaries, at this late stage of the approvals process, but rather arguing that in interpretation of the potential losses from within a management unit, the relevant scale should only be confined to the management unit if it can be shown that the unit is a logical encapsulation of localised ecological roles/functions, and that impairment of those ecological roles/functions can be shown to impair ecosystem integrity, which by definition must operate at the scale of ecosystem, whatever that relevant scale may be.

Elsewhere in this report the rationale is provided for the classification of the Sound into three broad zones on the basis of observed differences in the corals communities found within each zone, and the implication is drawn that physical factors are responsible for this differentiation (MScience 2005). Therefore, in an examination of ecological role/function it could have been more useful to develop management units which are defined by these zones. They will be much bigger than 50 km^2 but make more sense in terms of defining the perceived differences in ecological role/function which then define the contribution to ecosystem integrity.

Given that the zonation which has been observed by MScience (2005) could also be interpreted as a gradient of changing dominance, coverage and complexity from the inshore zone to the outer reefs of the Archipelago then there is also some value in viewing the entire Archipelago and certainly Mermaid Sound as a single ecosystem unit with a series of habitat types based upon geomorphology such as that proposed by Semeniuk et al 1982.

The other factor which suggests that Mermaid Sound may be best treated as a single ecosystem is that it is macro tidal and in other parts of the macro tidal tropical Australian coast, ecosystem units are by nature, typically large, e.g. King Sound and Darwin Harbour.

(AMSA 1997) noted that Australia's coastal and offshore marine habitats would best be managed as a system of Large Marine Ecosystems (LMEs) but also noted the boundaries of management units should be defined on a scientific basis although they are usually determined on the basis of historical or political grounds.

If the corals of the areas within area 1 and 2 are then considered from an ecological role/function in terms of contribution to the ecosystem integrity of Mermaid Sound then the potential loss of corals habitat does not appear quite as dramatic.

In **Figure 10** all the areas of potential coral loss are mapped and also shown are the areas of coral that is not expected to be impacted. The percentage of total coral losses from the proposed dredging is 1,220,554 m^2 compared to a total area of coral habitat of 12,286,400 m^2 or 9.9% of the total area of coral in the Mermaid Sound ‘ecosystem’.

In addition most of the corals identified as lying within the potential loss zone exhibit sparse coverage, an average of about 15% and this means that of the total area of habitat, only 15% is actually coral and so applying that to the calculated area of potential loss suggests the loss of actual coral is 183,083m^2 –the area of the seabed actually covered by coral. The total coral estimate on the other hand includes substantial areas of corals in the outer zone which have coverages approaching 35-40% of the substrate and so the actual coral total is probably somewhere between 25-40% of the total substrate area, or 3,071,600-4,914,560m^2.

If the comparisons where then made as a per unit area of actual coral (BPP) then the potential loss for the Sound would between 3.7-5.9% of the total of ecological role/function - if it can be assumed that corals have uniform productivity throughout the Sound. The proponent suggests it is not valid to assume the productivity of the inner zone corals is equivalent to those in the outer zone. The literature suggests a general range in corals primary productivity of 5-40g/m^2/d (Hatcher 1990; Hoegh-Guldberg 1999).

Although there is no data available on the primary productivity data for the corals communities in Mermaid Sound it is likely that the inner zone corals tend toward the lower end of this range, while the outer corals tend toward the upper end.

Therefore if the assessment of the impact on ecological role/function were to be based on the primary productivity per unit area, then the outcome would likely be to reduce further the potential loss of ecological role/function from the potential loss of the area sparsely populated by corals.

Another factor which should be taken into account when determining the impact of a potential loss of these corals areas on ecosystem integrity is the relative contribution of other BPP in the Sound.

There are other BPP present and although they are mostly sparsely distributed throughout the Sound there are areas where macro algae, and sea grasses are present in greater densities. None of these sea grass areas lies within the footprints of sedimentation or SSC and only a small part of the macro algae patches with higher densities and none of that is expected to be impacted.

While a higher value of ecological role/function may be ascribed to a corals habitat when compared to a macro algae habitat it can realistically only be done if the ecological role/function includes components such as ‘biodiversity’ and ‘habitat structure’ but even then it would be debateable whether the ecological role/function of a square metre of corals was worth more in terms of maintaining ecosystem integrity than a square metre of macro algae. It probably is the case that corals habitat in the Sound supports a higher diversity of fish as Hutchins (2004) reports a coral reef fish fauna of 465 species, relative to 106 species over soft sediments, 116 mangrove associates and 67 pelagic species. However, these figures could reflect bias in sampling effort.

It may seem odd to be considering the various habitat areas of seabed in this way, but in effect that is what the current BPPH Guidelines require in order to determine the relative value of potential losses.

Direct comparisons of benthic micro algae and macro algae primary production suggest that corals are not as productive, per unit of area, (Hatcher 1990) and given that corals comprise a relatively small area of the total habitats area within the Sound (and within the nominal management zones) it is likely that the overall contribution to primary productivity (as fixed carbon/m^2/d) within the Sound is also correspondingly small.

There are several observations to be made in respect of this assessment:

- Management units are best defined by ecological role/function and can be expected to differ widely in size and shape. The Guidelines acknowledge this but in the absence of better information the 50km^2 has become the default.
- Mermaid Sound is a logical base unit for determinations of ecosystem function.
- The total area of seabed covered by corals is relatively small and therefore the relative contribution to primary productivity in the sound may also be relatively small.

It is also important to consider that the great majority of areas that are estimated to be lost will likely be recolonised by corals at some point in the near future as the deposition of sediment upon the inshore reefs is expected to be a temporary phenomenon. That the losses are likely to be temporary should also be a mitigating factor in determination of the relative impact of the loss on ecological role /function and the contribution to ecosystem integrity.

Offsets

Woodside is currently in discussions with the Department of Environment and Conservation regarding commitments for environmental offsets to address predicted significant residual impacts from the Development. A formal environmental offsets proposal will be submitted to the Department next week. Woodside is proposing to offset potential impacts to benthic primary producer habitat (corals) through support of marine research in the Dampier Archipelago. The Indicative Management Plan for the Proposed Dampier Archipelago Marine Park (DEC 2005) outlines a range of management strategies for coral reef communities in the Archipelago including monitoring and research priorities. It is proposed that research supported via the Pluto offset package should be consistent with these priorities. Research associated with the implementation of Management Plans for Ningaloo Marine Park and Jurien Bay Marine Park is being coordinated through the Western Australian Marine Science Institution (WAMSI). Research in Mermaid Sound and the Dampier Archipelago Marine Park could be coordinated under a similar framework with funding for research provided to WAMSI by Woodside.

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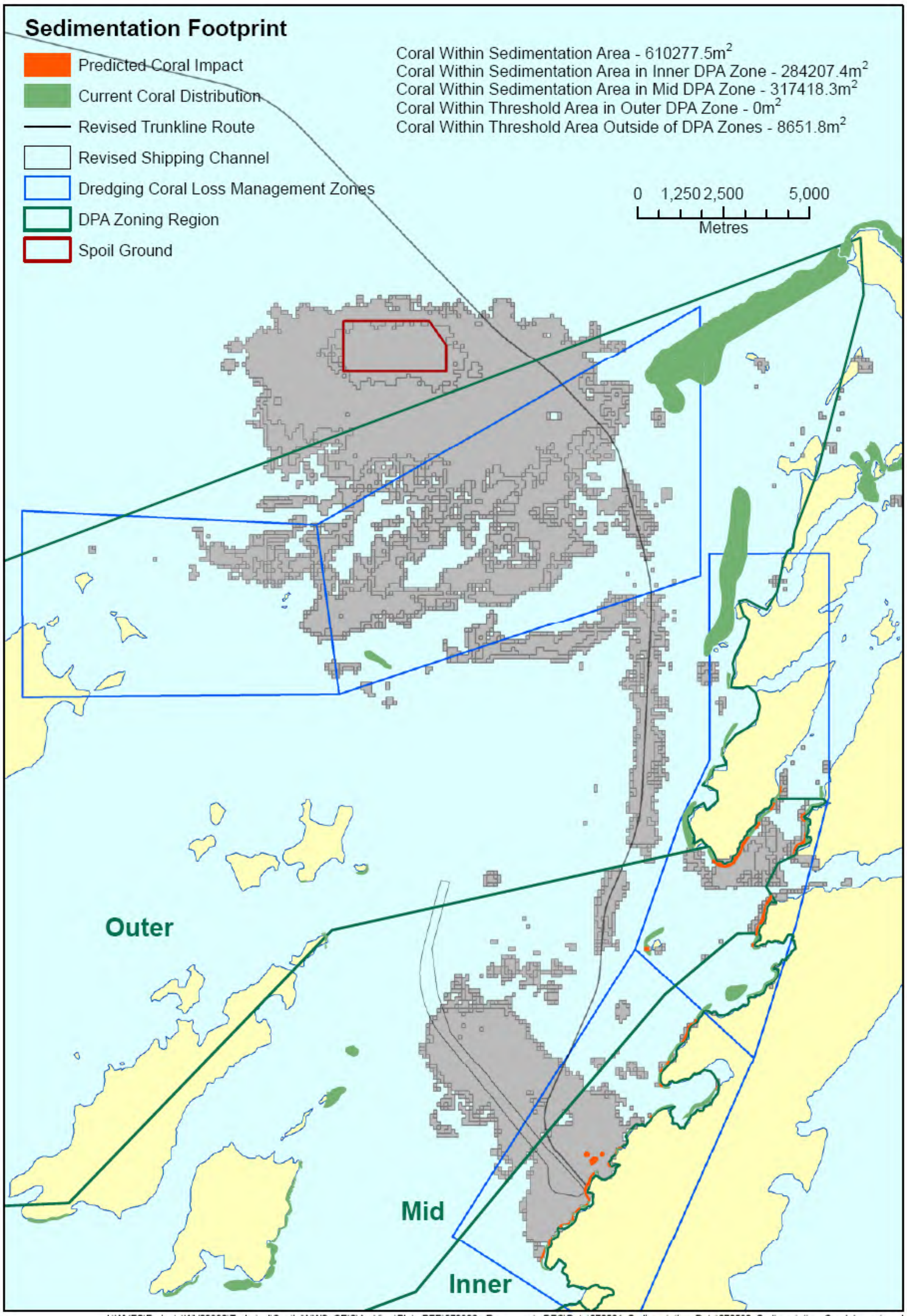

- **Figure 10 Sedimentation Footprint Showing Areas Where Corals Would be Potentially Impacted, Compared to Total Area of Corals in Mermaid Sound Ecosystem.**

3.9 Impacts to Corals on the West Side of Mermaid Sound

The proponent's response to 'comment 9.25' suggests that there will be no impacts to corals on the west side of Mermaid Sound and refers to TSS modelling results in Figure 8. However the sedimentation modelling results in ***Figure A21*** *(spoil disposal alone)* ***[should this be a ref to A11 and A12, there is no A21]*** *indicate that the acute sedimentation thresholds for sensitive species may be exceeded along the shoreline of NE West Lewis Island where corals are known to occur, but are not mapped. Incorporation of resuspension into the model is likely to exacerbate this effect.*

Proponents Response

Figure B21 (not A21) shows cumulative sedimentation without resuspension from intensive dredging for a full month in one location. The revised practice is to cast more widely and randomly on each pass, to reduce intensity of input. It is noted that the revised dredging programme assumes that a limited volume of dredged material will be disposed of into Spoil Ground A/B within Mermaid Sound with the bulk of material being disposed at offshore spoil ground 2b (refer to **Section 3.11**). Subsequently, the potential for impacts along the shoreline of NE West Lewis Island is considered unlikely.

A habitat map for the shoreline of NE West Lewis Island is provided in **Figure 7** (MScience 2007b)**.**

3.10 Macro-algal Communities and Seagrass

The BPPH assessment does not address potential impacts on macroalgal communities (what impact will sedimentation and turbidity have on this BPP and will the platform reefs be smothered by sedimentation?). Similarly, impacts on seagrass BPPH have not been properly addressed (will altered sediment particle size distribution in the vicinity of dredged areas and dump sites affect potential seagrass colonisation?).

Refer to response to Task 2 in Section 1 of this document also.

Proponents Response

The response provided to the comment in section 2.2 provides the details of why potential impacts from sedimentation and turbidity on macro algae and seagrasses have not formed a major part of the investigations undertaken by Woodside for this project. Briefly, the survey work undertaken to date has not revealed any significant BPPH of any type, other than corals, within the area identified as a potential impact zone. In the absence of any significant habitat of these two BPP types the

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proponent has focussed on addressing the issues surrounding the potential impacts of sedimentation and turbidity on the BPP (coral) which is present in significant quantities.

As outlined in **Section 3.2**, the available information on the impacts of sediment on macro algae has been recently reviewed by Aroldi (2003) who provides the following summary of the published information:

"Not all species and assemblages are equally affected by sedimentation and responses vary over space and time, depending on the characteristics of the depositional environment, life histories of species and the stage of development of individuals and assemblages, and in relation to variable physical factors, including hydrodynamics, light intensity and bottom topography."

For these reasons, the proponent concludes it is not currently possible to define a suitable set of thresholds for either sedimentation or turbidity that could be adopted for macro algae in Mermaid Sound. For example, the brown macro algae *Sargassum* spp. have been documented as a common component of the benthic macro algae in the Dampier Archipelago region and 3 species have been recorded, *S.decurrens*, *S. oligocystum* and *S.linerifolium* (Huisman and Borowitzka 2004). *Sargassum oligocystum* is the most widely distributed of the three species and is found throughout the tropical Indo-West Pacific (Huisman and Borowitzka 2004).

Literature searches for this species and the other two species produced few records that mentioned sedimentation, turbidity and dredging and in these references no indicators were found in respect of what range of turbidity and sedimentation the species typically encounter and what levels of sedimentation and turbidity might therefore serve as useful thresholds for the species in Mermaid Sound. For example, Mayakun and Prathep (2005) record *S.oligocystum* as one of a suite of species of macrolagae examined over wet and dry seasons at Samui, Thailand and conclude that the macro algae were highly seasonal in distribution and abundance with more species present during the dry season when waters were less turbid. However, no background turbidity data are provided, and the potential compounding impact of reduced salinity during the wet season months is not discussed.

Sargassum spp are reported to be seasonal in Mermaid Sound with peak biomass occurring in the summer and then the algae die out in winter. It is not known whether this observation applies to all three of the species so far reported from the Sound.

Typically where there is no data available for the suite of species present at a potential impact site, other species in the same genus or higher taxonomic classification are used to infer the likely impact. For example, in any examination of potential impacts of turbidity and sedimentation on *Sargassum* spp. information on the known responses of several species of *Sargassum* to increased sedimentation and turbidity can be useful.

Umar et al. (1998) reported that very high levels of sediment accumulation (up to 20 mm thick) on reefs affected recruitment, growth, survival and seasonal regeneration of *Sargassum microphyllum* but populations of the species were never completely extinguished and in some areas there was a positive correlation between *Sargassum* settlement and sedimentation. Umar et al (1998) also suggested an increase of twice the background level of long-term sediment deposition would reduce abundance but not lead to local extinction.

Catterall et al (1992) report that within two years of the cessation of dredging activities at Heron Island Reef (QLD), tall erect algae including some species of *Sargassum* (species not recorded) increased in overall abundance. In an assessment of the colonisation potential of a number of marine organisms Shanks et al (2003) report dispersal rates of *Sargassum mictum* of up to 193 km/yr. Ang (1985) examined the colonisation potential of two species of *Sargassum* (*S. siliquosum* and *S.paniculatum)* in the Philippines and reported recolonisation of bare substrate in 3-4 months. A similar study reported that new recruits of Sargassum spp. appeared in quadrats three months after the quadrats had been cleared during the reproductive season (Vuki and Price 1994).

Experimental studies of the colonization of *Sargassum* *plagiophyllum* on artificial substratum recorded a time lag of 9-10 months was needed for the recolonisation of a fresh substratum (Raju and Venugopal, 1971), suggesting that the rates of colonisation between various species of *Sargassum* may differ, and is likely to be influenced by a considerable number of environmental factors.

In the absence of any relevant data specific to the species actually present in Mermaid Sound the reference to what is known about cogeners is entirely justifiable, but may not always be relevant to all the species in a genus (Airoldi 2003).

In the present case the published literature on other species of *Sargassum* as quoted above, suggests that these species are more tolerant of increases in sediment and turbidity than coral species and are faster recolonisers of areas where short term changes in conditions have reduced or extinguished populations.

The lack of information on the ecological requirements and tolerances of the three species of *Sargassum* recorded from Mermaid Sound also applies to the large array of other macro algae species that have been recorded from Mermaid Sound (Huisman and Borowitzka 2004). Many of the other species of macro algae which inhabit similar areas to those colonised by *Sargassum* spp. may have similar, or widely different, tolerances to sedimentation and turbidity.

The decision to concentrate on corals as the BPPH communities to be assessed and monitored was therefore motivated by:

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- survey data indicating there are no significant macro algae habitats within the potential zone of impact
- the lack of information about what would constitute meaningful thresholds of SSC and sedimentation for macro algae species recorded in the Sound
- Evidence that macro algae populations in Mermaid Sound are highly seasonal in abundance and distribution
- Evidence that some macro algae species are tolerant of sedimentation and turbidity impacts.

The available information on habitat preferences and seasonal fluctuations in distribution and abundance for some macro algae suggests it is likely that if there are impacts on macro algae from sedimentation and turbidity, these will be small scale and that the algae will quickly recover from the disturbance (Airoldi 2003).

The impacts of the proposed programme of dredging upon seagrasses has not been examined in detail because the survey data collected for the Draft PER are consistent with previous survey results which do not record any significant seagrass habitat within the area that can be defined as the potential zone of impact (see Figure 7-32 in Supplement and Responses to Submissions).

The presence of the seagrass in the dredge at station 1 of the 1999 dredge survey (Hutchins et al 2004) has been discussed in **Section 3.2**.

Section 3.10 refers to altered sediment particle size distribution in the vicinity of dredged areas and dump sites affecting potential sea grass colonisation. Areas which currently have no sea grass habitat, and have not had any sea grass habitat according to the few surveys which have taken place in Mermaid Sound since 1999, appear to possess a low potential for sea grass colonisation.

If some of these areas bare of sea grasses have the right sediment grain size proportions for colonisation by sea grasses then it appears there are other factors which are limiting sea grass colonisation at those sites. The limiting factor/s may be depth, scour, exposure, turbidity, nutrients, DO, salinity or any combination of these and probably varies between sites. In these areas the addition of a film of different sediment grain sizes from dredging activities and spoil disposal may render the substrate temporarily unfit for sea grass colonisation, but unless the other factors that appear to prevent those areas being colonised by sea grasses now are removed or modified then the addition of different sediments is not likely to constitute a limiting factor.

The assumption is made that it is the addition of fines which is considered likely to render the substrate sediment grain sizes unsuitable for colonisation, and it should be noted that the model outputs demonstrate that considerable volumes of the fine material currently present in the Sound (and which would be added by the dredging programme) are resuspended and ultimately transported to depositional areas where conditions allow the accumulation of fines.

The areas with high potential for sea grass colonisation presumably already have sea grass now, or there are some records of sea grass present in these areas at some time in the recent past (Figure 7-32 of the Supplement and Responses to Submissions).

All of the areas where sea grasses are known to be present in significant densities are located outside the zone of potential impact and so are not expected to suffer any deleterious impacts as a consequence of the dredging programme.

3.11 Modelling for Two Year Programme

The proponent should incorporate sediment resuspension, medium and chronic sedimentation thresholds for vulnerable corals, thresholds for other BPP and any other DEC requirements into the model, ***then re-run the model for the entire two year dredging period.*** *The model should include effects from the three dredges, all spoil dumping activities, trunkline construction and propeller wash simultaneously so that cumulative impacts can be adequately assessed. If the proponent is considering reuse of the spoil dumped in the spoil grounds as an option, then this activity would also need to be incorporated into the model.*

Proponents Response

Modelling undertaken to date has focused on what are considered to be the most intensive aspects of dredging operations, and has included consideration of the footprint associated with spoil disposal plans. A high level outline of the sequence of dredging works as currently defined is provided below.

Sensitivity thresholds have been constructed and applied for medium and chronic sedimentation thresholds for vulnerable corals. The modelling has been applied to quantify the influence of resuspension for key operations, using worst-case seasonal conditions (refer to **Appendix D**).

The power of the model in this context has been in testing the influence of different variables to design a programme that will reduce the impact of the dredging programme. Conservative allowances have been included at various steps. Hence, extrapolations from this data are expected to be conservative.

Dredging works for the Pluto LNG Development were indicated in the Draft PER to span up to two years. It is important to note that the work programme does not involve two years of continuous dredging but will proceed with dredging activities occurring over shorter intervals at different times. The overall two year programme encompasses both dredging and post-dredging activities.

Every effort is being made to seek to reduce the duration of dredging and footprint associated with dredging and dredge spoil disposal activities.

The outcome of recent considerations include a commitment to revise spoil disposal plans so that the bulk of dredged material to be generated from the overall dredging programmes will be removed to offshore spoil ground 2B. This will significantly reduce volumes that would otherwise be disposed to the existing inner spoil ground A/B and should provide substantial environmental benefits in terms of the footprint.

Coarse spoil material to be deposited in the offshore spoil ground has been identified as likely to be suitable for backfill and stabilisation of the Trunkline. This option will be further evaluated in relation to its potential impacts during development of the Dredging and Spoil Disposal Management Plan.

For operational, logistical and safety reasons, there is a need to retain limited access to spoil ground A/B for aspects of dredging for the NWSV channel and shore crossing. There is a limited work window for safely undertaking the NWSV channel crossing work, which will require access to spoil grounds in reasonable proximity to the site to allow the work to be completed within the available work window. Moreover, the nature of the work will involve relatively small vessels that are not suited to offshore conditions.

Key aspects to highlight in relation to the likely sequence of dredging and post-dredging works, based on information currently available, is as follows (**Figure 11**):

- Dredging activities are not continuous over two years but rather are a series of discrete activities.
- The overall duration of dredging for completing the Berth Pocket, Turning Basin and Navigation Channel is expected to be about 12-13 months.
- Concurrent dredging activities on the Navigation Channel and Trunkline are likely to be of limited duration; this will include a short period (about 2-4 weeks) near the beginning of the dredging programme, when the early investment work on the Trunkline channel crossing will be undertaken, coinciding with the dredging works for the Turning Basin at Holden Point.
- The most intensive period of dredging activity will occur over the first 4-5 months, during the inshore works to create the Berth Pocket and Turning Basin at Holden Point. The work on the Berth Pocket is required to be started early to accommodate access for construction work for the nearby jetty.
- The bulk of dredging of the Navigation Channel is expected to span some 7-8 months; timing at this stage is indicated to be from about February 2008 through October 2008, although this may be subject to change should this work be progressed in stages.
- Pre-lay dredging associated with Trunkline works is likely to commence after the bulk of the Navigation Channel work is completed; pre-lay work along the Trunkline route is indicated to span about 4 months, starting from about November 2008.

- The bulk of dredging activities is likely to be complete by the completion of Trunkline pre-lay dredging work, when the programme then moves into Trunkline pipelay activities, extending for about 7 months.

Backfill and stabilisation work on the Trunkline will extend over about 4 months, from September 2009 to December 2009. This includes placement of quarry rock on sections of the route, backfill operations with sand / coarse calcareous material and installation of Gravity Anchors in the deeper offshore sections, beyond port limits.

This indicative timing may be subject to change as a result of ongoing work planning in relation to the proposed field operations.

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Activity	Approx. Duration	Likely Equipment	Months
			N D J F M A M J J A S O N D J F M A M J J A S O N D J
JEZ and Turning Basin dredging	4 mths	TSHD (2) and CSD (1)	
Navigation channel dredging**	8-9 mths	TSHD (1 or 2), CSD (1)	
Trunkline channel crossing dredging	2 weeks in 1 month	TSHD (1) CSD (1)	
Trunkline dredging KP1-6	2-4 weeks	TSHD	
Trunkline dredging KP11-85	10-12 weeks	TSHD	
Trunkline pipelay	~7 months	2 pipelay vessels	
Trunkline quarry rock placement	~4 months	Side dumper	
Trunkline backfill to KP50	~10-12 weeks	TSHD	
Trunkline Gravity Anchors > KP50	~4 months		
Berth Pocket, Turning Basin, Navigation Channel			
JEZ completions over 1 month in Feb 08 and by 1 March 08			
TSHD removes overburden -2 months; CSD working from JEZ at berth entry to cut and crush for final removal by TSHD			
Depending on presence of hard material (igneous rock) - possibility of drill and blast required inshore			
Priority and most intensive work to clear JEZ inshore area to accommodate jetty			
Continue rest of turning basin with CSD and follow up removal with TSHD working behind CSD.			
Options still being explored around most suitable method for dredging in JEZ / berth pocket			
Trunkline			
Trunkline channel crossing KP3.5-KP4.5 pre-investment work by 1 April 08			
Trunkline shore crossing blasting (30-40m) and BHD work ~ 3 mths in 2008 - timing to be advised and depending on equipment availability			
Trunkline pipelay over ~ 7 months from Feb 09 through Aug 09 - two vessels to work the inside and outside MS sectors; one vessel a DP			
Trunkline backfill/stabilisation to KP50 over 10-12 weeks from Sep 09 through Nov 09			
Gravity anchors stabilisation for >KP50 work over 4 months Sept 09 through Dec 09			
Quarry rock placement over ~4 months from Sept 09 through Dec 09			

- **Figure 11 Latest Proposed Dredging Programme**

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4. Waste Water Discharge

4.1 Hydrotest Water Additives

The hydrotest water additives for onshore tanks need to be determined and assessed through the EIA process. Because the discharge is into shallow inshore waters, the environmental risks are significantly greater than for offshore discharges. If this is not possible then worst case chemical additives can be considered to demonstrate that nearshore discharge of this hydrostat water can be managed within the constraints of the environmental quality management framework (Pilbara Coastal Water Quality Consultation Outcomes report).

Proponents Response

As stated in the Supplement, the proponent intends to test the onshore LNG and other storage tanks using seawater. In doing so, the residence time of the seawater in each tank will be minimised as far as reasonably practicable to reduce the risk of internal corrosion. Furthermore, consideration is also being given to using an active or passive cathodic protection system on selected elements of the tanks to aid in reducing corrosion. Using seawater has both environmental and economic benefits, as it reduces demand on the local potable water system and when discharged into the marine environment it represents negligible risk of impact to the receiving waters and ecology. It will also enable faster completion of the hydrotest activities.

Following the completion of hydrotesting activities the seawater will be routed to Mermaid Sound, via a discharge line and discharged from the export jetty. As the seawater used is intended to be untreated (that is, no chemicals added), ecological effects from this operation are likely to be negligible. A diffuser or energy dissipation device will be added to the end of the discharge line to minimise any potential physical impacts associated with the discharge activity (such as resuspending seabed sediments).

In the event that the planned hydrotest methodology for the onshore storage tanks is modified and treatment to hydrotest water (potable or seawater) is required, a risk assessment will be undertaken at the time to determine the significance of environmental and social effects associated with discharging into the nearshore marine environment. Based on the outcomes of the risk assessment, additional mitigation measures may be developed and implemented to reduce the residual risk to as low as reasonably practicable. These measures include selection of low toxicity chemicals as a pre-requisite for any treatment additives. Criteria to be used in the risk assessment will include the environmental quality management framework (Pilbara Coastal Water Quality Consultation Outcomes report, 2006).

At this stage, the proponent considers it unlikely that a hydrotest methodology requiring treatment of hydrotest water will be required. In the event that chemicals are added, discharge will require careful control to ensure adequate dilution (matched to the concentration, biodegradability and toxicity of chemicals selected) is achieved within a small area of influence around the jetty structure.

4.2 Performance Specifications of the Treatment Plant

The performance specifications of the treatment plant for removing the contaminants anticipated in the discharge is required since the table of predicted concentrations is not justified. If this is not possible then the performance characteristics of similar technology being used elsewhere could be provided to estimate likely waste water discharge quality. (It is also noted that the predicted metal concentrations will exactly meet the guidelines for high protection at the edge of a notional mixing zone. The proponent should endeavour to ensure that levels of contaminants in the discharge are such that concentrations are significantly below guidelines for high protection at the edge of the mixing zone to provide a safety margin.).

Proponents Response

Table 4 of the Supplement provides expected treated effluent quality parameters for the Pluto waste water treatment plant, following biological treatment via a membrane bioreactor. It should be noted these are 'typical' levels and values stated represent an assessment of what should be achievable based upon the use of best available technology and reported values from other comparable industrial facilities. Detailed design is yet to be finalised and levels are also subject to confirmation from waste water treatment vendors.

While predicted maximum metal concentrations will exactly meet the guidelines for high protection at the edge of the notional mixing zone 100% of the time (for 0.5% waste water), concentration of the metals will be less than half this for 95% of the time (for 0.21% waste water; refer to **Figure 13**). This is equivalent to the statistical requirement that the 95th percentile toxicant concentrations at an impact site must not exceed the guideline for that toxicant. It should also be noted that these predictions are based on worse case conditions for dilution (transitional season and neap tide) and that greater dilution are expected outside of these wind and tide combinations. Other conservatisms that need to be considered include:

- no weathering or reaction processes included in model (although this is not expected to be relevant for initial dilution outcomes)
- the modelling has been based on a maximum flow rate which is unlikely to be maintained for extended periods of time and furthermore, is not likely to be attained until several years after the as-built characteristics of the treatment package are tested and understood and WET results on the treated waste water discharge are available.

4.3 MEG and aMDEA

Toxicity information is required for MEG and aMDEA (the toxicity classification from Hinwood et al (1994) is not sufficient. What data was this based on? and does it relate to humans, mammals, insects, fish, aquatic plants, etc?

Proponents Response

The process chemical aMDEA is commonly used in gas processing and is the activated form of methyldiethanolamine (MDEA) (CAS# 105-59-9). It is 100% miscible in water (at 20 ^{o}C) and is classed as readily biodegradable. Toxicity studies indicate that MDEA and aMDEA biodegrade relatively rapidly in water (refer to **Table 15** and **Table 16**). This chemical is discharged at the existing Karratha Gas Plant at an average concentration of <15 mg/L and an annual load of <1064 kg/year in 2005/06.

Monoethlylene glycol (MEG) is used to prevent hydrate formation in pipelines. Studies have previously been conducted to assess the biodegradation of MEG in the existing environment. Price *et al*. (1974) assessed the biodegradation of ethylene glycol in salt water over a 20-day incubation period. Concentrations of up to 10 mg/l of ethylene glycol were used resulting in 20% degradation after 5 days and 77% after 20 days (Price *et al* 1974). Similar to aMDEA, MEG is also 100% miscible in water (at 20 ^{o}C) and is classed as readily biodegradable.

Toxicty information for aMDEA and MEG are provided in **Table 17** to **Table 19**. No ecological or social impacts are expected based on the available toxicity information for the concentrations of aMDEA (<1 mg/L) and MEG ((<1 mg/L) expected in the discharge.

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- **Table 15 Biodegradability of MDEA/aMDEA (all data from European Chemicals Bureau (2000)**

Method*	Test Substance	Type of Test	Inoculum	Degradation
OECD Guideline 301 A	MDEA	Aerobic – Ready biodegradability	Activated sludge	96% after 18 days
OECD Guideline 301 C	MDEA	Aerobic – Ready biodegradability	Activated sludge	79% after 28 days
OECD Guideline 302 A	aMDEA	Aerobic – Inherent biodegradability	Activated sludge, adapted	94% after 7 days
OECD Guideline 302 B	aMDEA	Aerobic – Inherent biodegradability	Activated sludge, adapted	96% after 14 days
OECD Guideline 302 B	MDEA	Aerobic – Inherent biodegradability	Washed activated sludge from sewage works	92% after 11 days

*OECD guidelines refer to the Organisation for Economic Co-operation and Development Guidelines for the Testing of Chemicals and are a collection of the most relevant internationally agreed testing methods used by government, industry and independent laboratories to assess the safety of chemical products (refer to http://www.oecd.org/dataoecd/38/2/5598432.pdf for further information).

- **Table 16 Harmonised Offshore Chemical Notification Format (HOCNF) Biodegradation Classifications**

HOCNF Classification	Biodegradation in 28 days
Readily biodegradable	>60%
Inherently biodegradable	>=20% & <=60%
Not biodegradable	<20%

- **Table 17 Summary of Ecotoxicity Results for aMDEA**

Common Name	Scientific Name	Exposure Period	EC, LC or NOEC (mg/L)	Test Substance	Method/Remarks
Fish					
Rainbow Trout	*Oncorhynchus mykiss*	96 hr	LC0 320; LC50 762	MDEA	semistatic
Ide (freshwater)	Leuciscus idus	96 hr	NOEC 460; LC50 >1000	MDEA	static
Fathead minnow (freshwater)	*Pimephales promelas*	96 hr	LC50 >1000 NOEC 500-600*	aMDEA	
Crustaceans					
Daphnia	*Daphnia magna*	24 hrs 48 hrs	EC0 250; EC50 400; EC100 >500 EC0 125; EC50 230; EC100 500	aMDEA	
Algae					
N/A	*Scenedesmus subspicatus*	72 hrs 96 hrs	EC50 37; EC20 11; EC90 >100 EC50 20; EC20 7.4; EC90 90	aMDEA	Alga test in accordance with UBA
Bacteria					
Activated sludge, industrial	N/A	30 mins	EC10 >1000 – No inhibition of respiration of the adapted activated sludge up to 1000 mg/L.	aMDEA	ISO 8192 “Test for inhibition of oxygen consumption by activated sludge”
N/A	*Pseudomonas putida*	17 hrs 16 hrs	EC10 270; EC50 410; EC90 820 TGK (Toxicity Threshold Concentration) = 11800	aMDEA aMDEA	Bacterial growth inhibition test – DIN 38412/8 design Cell multiplication inhibition test

All data from European Chemicals Bureau (2000) except * taken from Alpha (2003)

- **Table 18 Summary of Ecotoxicity results for Mono-ethylene Glycol**

Common Name	Scientific Name	Exposure period	LC0, LC50, LC100 or NOEC (mg/L)
Crustaceans			
Common shrimp, sand shrimp	*Crangon crangon*	48 hrs 96 hrs	LC50 100,000 LC50 50,000
Crayfish	*Procambarus*	96 hrs	LC50 91,430
Fairy shrimp	*Streptocephalus proboscideus*	24 hrs	LC50 54,497
Fish			
Goldfish	*Carassius auratus*	24 hrs	LC50 >5,000
Bluegill	*Lepomis macrochirus*	96 hrs	LC50 >10,000
Carp	*Leuciscus idus melanotus*	24 hrs 48 hrs	LC0, LC50 & LC100 >10,000 LC0, LC50 & LC100 >10,000
Rainbow trout	*Oncorhynchus mykiss*	96 hrs	LC50 41,000
Medaka, high-eyes	*Oryzias latipes*	24 hrs 48 hrs	LC50 >1,000 LC50 >1,000
Fathead minnow	*Pimephales promelas*	24 hrs 96 hrs 7 days (growth) 7 days (mortality)	LC50 >10,000 LC50 72,860 NOEC 15,380 NOEC 32,000
	Poecilia reticulata	96 hrs 7 days	LC50 16,000 LC50 49,300
Zooplankton			
Brine shrimp	*Artemia salina*	24 hrs	LC50 >20,000
Brine shrimp	*Artemia sp.*	24 hrs	LC50 20,000
Rotifer	*Brachionus calyciflorus*	24 hrs	LC50 117,933
Rotifer	*Brachionus plicatilis*	24 hrs	LC50 149,589

Common Name	Scientific Name	Exposure period	LC0, LC50, LC100 or NOEC (mg/L)
Water flea	*Ceriodaphnia dubia*	48 hrs 48 hrs 3 broods control (growth) 3 broods control (mortality)	LC50 (20C) 22,600 – 29,700 LC50 (24C) 6,900 – 13,900 NOEC 8,590 NOEC 24,000
Water flea	*Daphnia magna*	24 hrs 48 hrs	LC50 >10,000 LC50 48,342

All data from Pan Pesticides Database (2006) and The World Health Organisation (2000)

- **Table 19 Algal Ecotoxicity results for Monoethylene Glycol**

Common Name	Scientific name	End point	Concentration (mg/L)
green algae	*Scenedesmus quadricauda*	7 day toxic threshold	>10,000
green alga	*Selenastrum capricornutum*	96-h EC_{50} (growth, cell counts)	6,500-7,500
		96-h EC_{50} (growth, cell volume)	9,500-13,000
		168-h EC_{50} (growth, cell volume)	24,000
Cyanobacteria	*Microcystis aeruginosa*	biomass	2,000

All data from Pan Pesticides Database (2006) and The World Health Organisation (2000)

4.4 Wastewater Outfall and Dilutions

The number of dilutions required for the outfall is not known because there are no toxicity data for the effluent, therefore it is important that conservatism is built into the design and a high level of initial dilution is achieved. If the number of dilutions required to meet a high level of ecological protection can be determined with some confidence, then the proponent should model the spatial footprint around the outfall where the required dilutions would be exceeded 95% of the time. (This is equivalent to the statistical requirement that the 95th percentile toxicant concentrations at an impact site must not exceed the guideline for that toxicant.).

Proponents Response

The simulation of wastewater discharges in the Draft PER uses both a near field and far field model. The far field model takes into consideration the potential for recirculation of the discharged plume over the discharge location and the results are therefore more conservative than the near field results. The 95th percentile values (that is, the non-exceedence concentrations for 95% of the time) for the maximum concentrations at 25 and 50 m from the discharge location are 0.27% (364 dilutions) and 0.21% (458 dilutions), respectively (see **Figure 12** and **Figure 13**). It should be noted that these figures represent worse case conditions for dilution (transitional season and neap tides). These values are well below the indicative PNEC of 0.5%.

The far field model operates on a 25 m grid and therefore to understand resolution below this size, the near field modelling results must be examined. Near-field modelling results presented in the supplement document indicated that the required dilutions to achieve a PNEC of 0.5% will be met (100% of the time) at approximately 10 m from the discharge point. It is considered that further interrogation of the near-field model to determine the number of dilutions required to meet 95% of the time would not provide any additional or meaningful information at this point in time given that the PNEC value is indicative only. However, the proponent commits to undertaking this spatial interrogation once a PNEC for the actual effluent has been established.

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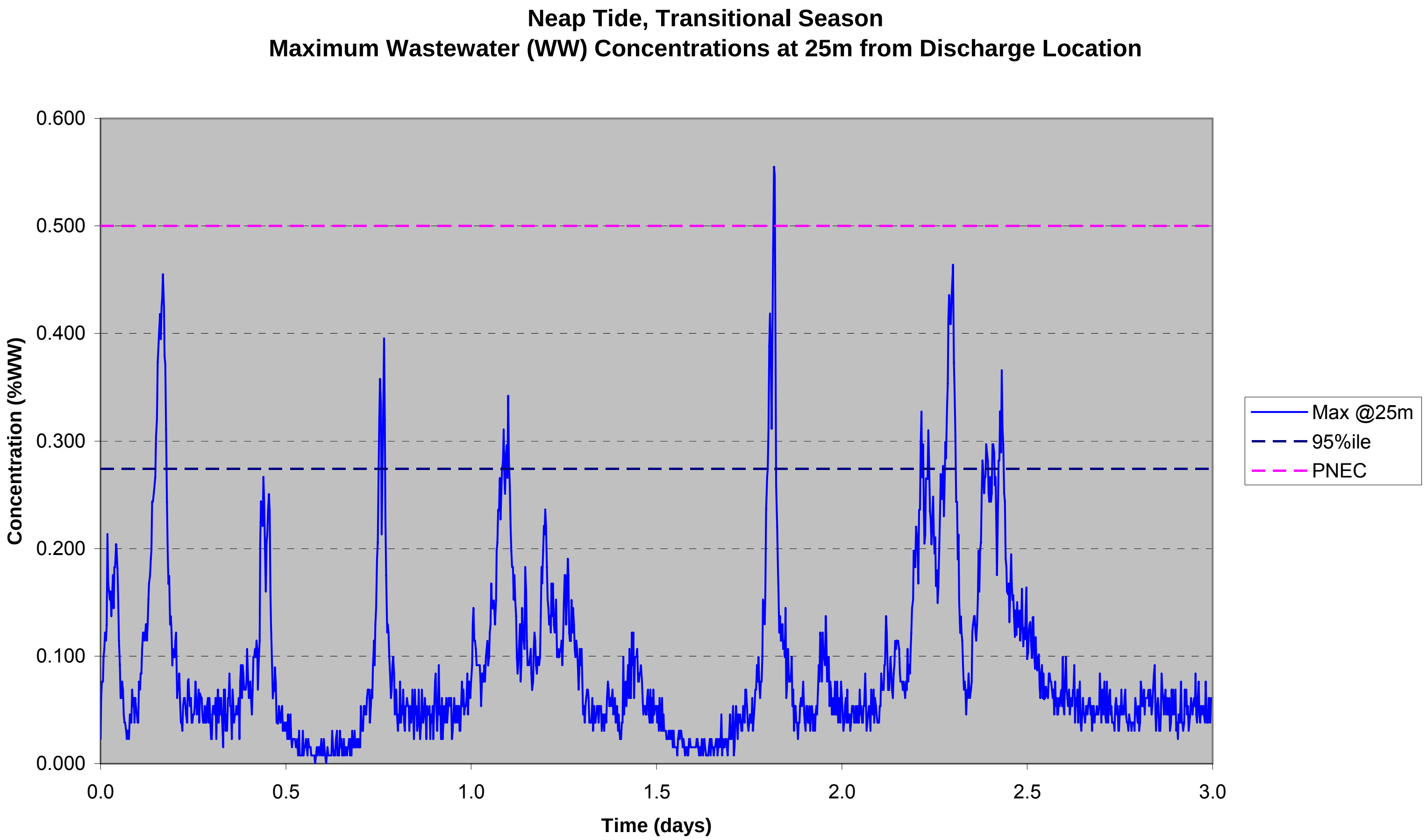
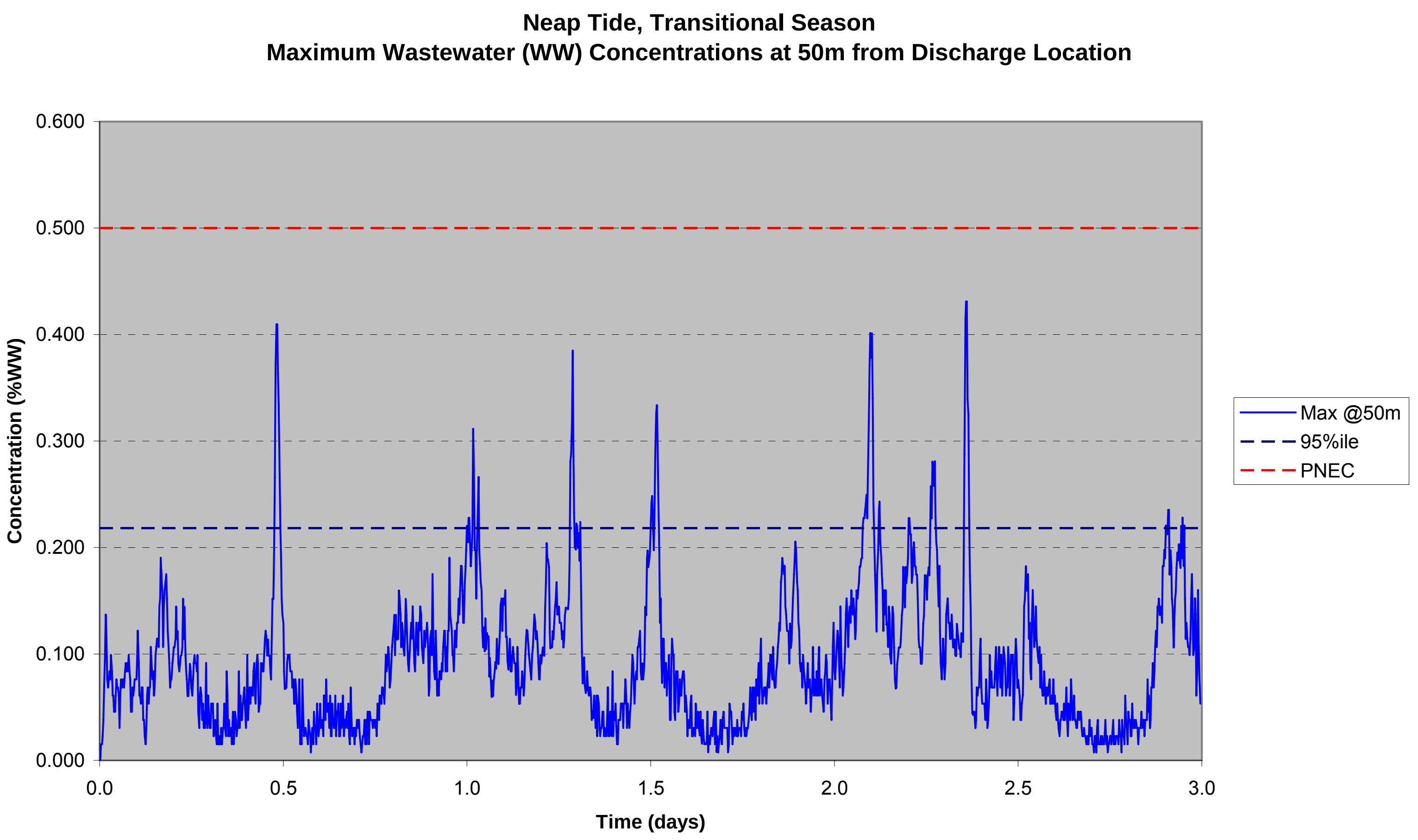


- **Figure 12 Maximum Waste Water Concentrations at 25 m from the Discharge Concentration**



- **Figure 13 Maximum Waste Water Concentrations at 50 m from the Discharge Concentration**

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4.5 Environmental Values/Environmental Quality Objectives

The outfall also needs to be considered within the context of the other environmental values/environmental quality objectives that relate to social uses and that apply to the area (maintenance of seafood safe for eating, recreation and aesthetics and industrial water supply. The EPA has an expectation that these environmental values will be protected everywhere and will only consider removal of a value from small areas where the need is well justified and there is community acceptance. (Note: for recreation the main issue is likely to be bacterial concentrations from sewage and grey water).

Proponents Response

The environmental values/environmental quality objectives that relate to social values were previously addressed in Table 5 of the supplement and are further addressed in **Table 20** below.

Based on current waste waster treatment system performance specifications, the treated waste water discharge at the end of the jetty will not result in exceedances of environmental quality criteria for fishing, aquaculture, recreation, aesthetic, industrial or spiritual values. It should be noted also that none of these activities will be permitted to be undertaken in the vicinity of the outfall given its proximity to the proposed jetty and LNG berthing facilities. Should the performance specification of the waste water treatment system change during future detailed design, social values will be maintained. Potential impacts to social values are not expected from the discharge of wastewater into Mermaid Sound

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- **Table 20 Assessment of Discharge Against Social Values**

Environmental Value (EV)	**Environmental Quality Objective (EQO)**	**Proposed EQC**	**Environmental Quality Guideline/Standard (EQG or EQC)**	**Assessment of Treated Waste Water Discharge**
Fishing and Aquaculture	Seafood for Human Consumption	▪ Thermotolerant faecal coliforms in water ▪ Thermotolerant faecal coliforms in fish flesh ▪ Metals and organics in fish flesh	▪ EQG: The median thermotolerant faecal coliform bacterial concentration should not exceed 14 CFU/100 mL, with no more than 10% of the samples exceeding 21 CFU/100 mL measured using the membrane filtration method. ▪ EQS: Fish destined for human consumption should not exceed a limit of 2.3 MPN *E. Coli* /g of flesh (wet wt.) in four out of five representative samples, and the fifth sample should not exceed 7 MPN *E. Coli* /g, with a maximum total plate count of 250 000 organisms/g. ▪ EQG: A range of metals and organics have environmental quality	Thermotolerant faecal choliform concentrations at end of pipe are not expected to exceed 10 CFU/100 mL. Concentrations will be monitored as part of the waste water management plan. Wastewater will be treated to a very high specification so that biological contaminants, metals, organics and other potential contaminants are highly unlikely to bioaccumulate or otherwise impact on the quality of seafood for human consumption.

Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed EQC	Environmental Quality Guideline/Standard (EQG or EQC)	Assessment of Treated Waste Water Discharge
			guidelines for levels in fish flesh.	
	Aquaculture	▪ Metals, inorganics and pesticides in water ▪ Dissolved oxygen ▪ pH	▪ EQG for toxicants: The 95th percentile of the sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the environmental quality guideline value. ▪ EQG for physio-chemical stressors: The median of the sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the following environmental quality guideline values. ▪ Dissolved Oxygen ≥5 mg/L ▪ pH 6-9	EQGs for potential toxicants of concern (ammonia and heavy metals) for a high protection of the marine ecosystem are more stringent than those for aquaculture values (with the exception of zinc) and will therefore be protected through adherence to the ecosystem EQGs. Aquaculture EQGs for metals (including zinc) will be met within a few meters of the discharge point. It should be noted that there are presently no active aquaculture leases in Mermaid Sound and that an exclusion zone of 50 m will apply around the jetty/outfall. It is therefore highly unlikely that any future aquaculture ventures established in close proximity to the discharge point will be impacted. Dissolved oxygen and pH levels at end of pipe are highly unlikely to vary significantly from background levels for these parameters.

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Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed EQC	Environmental Quality Guideline/Standard (EQG or EQC)	Assessment of Treated Waste Water Discharge
Recreation and aesthetics	Primary contact recreation values	▪ Faecal Pathogens ▪ pH ▪ Water clarity ▪ Toxic Chemicals – a range of chemicals including metals, inorganics and organics.	▪ EQG: Faecal Pathogens: The 95%ile bacterial content of marine waters should not exceed 200 enterococci/100mL ▪ EQS: The median of the sample concentrations from the area of concern (either from one sampling run or from a single site over an agreed period of time) should not exceed the range of 5 – 9 pH units. ▪ EQG: To protect the visual clarity of waters used for swimming, the horizontal sighting of a 200 mm diameter black disc should exceed 1.6 m. ▪ EQG: Toxic Chemicals – The 95%ile of the sample concentrations from the area of concern (either from one sampling run or	Thermotolerant faecal choliform concentrations at end of pipe are not expected to exceed 10 CFU/100mL. It is considered unlikely that discharged wastewater will cause faecal pathogens to exceed 200 enterococci/100mL in the vicinity of the discharge. pH levels at end of pipe are highly unlikely to vary significantly outside of the EQS. Water clarity is highly unlikely to be impacted by the treated waste water discharge. EQGs for potential toxicants of concern (metals) for a high protection of the marine ecosystem are more stringent than those for primary contact recreation values (except for Benzene – see below) and will therefore be protected through adherence to the ecosystem EQGs. Primary contact recreation EQGs for metals will be met immediately after discharge. Expected concentrations for benzene will be well below the primary recreation EQG (0.02 mg/L), immediately after discharge. It should be noted that a 50 m exclusion zone will apply to the jetty and turning basin. Primary contact recreation activities will therefore not be permitted in the vicinity of the discharge point.

Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed EQC	Environmental Quality Guideline/Standard (EQG or EQC)	Assessment of Treated Waste Water Discharge
			from a single site over an agreed period of time) should not exceed the environmental quality guideline values.	
	Secondary contact recreation values	▪ Faecal pathogens ▪ pH ▪ Toxic chemicals	▪ EQG: The 95%ile bacterial content of marine waters should not exceed 2000 enterococci/100mL. ▪ The median of the sample concentrations from the area of concern (either from one sampling run or from a single site over an agreed period of time) should not exceed the range of 5 – 9 pH units. ▪ Water should contain no chemicals at concentrations that can irritate the skin of the human body.	Thermotolerant faecal choliform concentrations at end of pipe are not expected to exceed 10 CFU/100mL. It is considered unlikely that discharged wastewater will cause faecal pathogens to exceed 2000 enterococci/100mL in the vicinity of the discharge. pH levels at end of pipe are highly unlikely to vary significantly outside of the EQS. Secondary contact recreation activities will not occur within the vicinity of the waste water discharge, nevertheless the treated waste water is highly unlikely to contain chemicals at concentrations that can irritate the skin of the human body.

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Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed EQC	Environmental Quality Guideline/Standard (EQG or EQC)	Assessment of Treated Waste Water Discharge
	Aesthetic Values	Water Clarity Fish Tainting Substances – large range of chemicals implicated in fish tainting – related to concentration in water column.	▪ The natural visual clarity of the water should not be reduced by more than 20% ▪ The 95%ile of the sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the environmental quality guideline values.	It is highly unlikely that treated waste water will result in impact on water clarity or fish flesh quality relevant to aesthetic values given the high level of treatment of the waste water proposed.
Cultural and Spiritual	Maintenance of cultural and spiritual values	No guidelines are relevant to the area within the vicinity of the discharge for cultural and spiritual values	No guidelines are relevant to the area within the vicinity of the discharge for cultural and spiritual values	No impacts are expected from the discharge of treated waste water on cultural and spiritual values.
Industrial Water Supply	Maintenance of industrial water supply values	No guidelines are relevant to the area within the vicinity of the discharge for industrial water supply values	No guidelines are relevant to the area within the vicinity of the discharge for industrial water supply values	No impacts are expected from the discharge of treated waste water discharge on industrial water supply values.

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4.6 Mixing Zone

The proposed mixing zone is larger than necessary. The modelling shows that it could be reduced to 20m diameter. Modelling shows the zone of initial dilution generally within 10m of the outfall (Figure 3 of the Response to Submissions).

Proponents Response

It is noted that Figure 3 of the Supplement is an output from near-field modelling and as stated earlier, does not account for recirculation of the plume. The size of the proposed mixing zone, needs to be considered in conjunction with the outputs from far field modelling (for example Figure 4 of the Response to Submissions) which indicates concentrations of waste water up to, but not exceeding, approximately 0.43% at 50 m from the discharge location. It is acknowledged that the mixing zone could potentially be reduced in size; however, a 50 m diameter zone is considered to provide a sufficient degree of conservatism given that the toxicity of the effluent has yet to be determined. The proponent remains committed to reducing the size of the mixing zone where results from WET testing and improvements in diffuser design allow (refer to **Section 4.2** for further discussion).

4.7 Framework Waste Water Management Plan

Table 6 of the Response to Submissions contains a framework for waste water management. It includes a commitment to undertaking WET testing of the waste water as soon as it becomes available and periodically after that. The proponent should make a commitment to undertake WET testing of the waste water as soon as waste water becomes available), one month after commissioning and annually thereafter or after a change in the composition of the waste water.

Response

Proponent acknowledges this comment. The Framework Waste Water Management Plan (originally provided in Table G-3 in **Appendix G** of the Draft PER and subsequently revised in the Response to Submission document) has been revised below. Revisions are shown highlighted (in red text) below.

■ **Table 21 Framework Waste Water Management Plan**

Waste Water Management Plan Format	
Management Issues	The discharge of waste water may result in marine physical and ecological effects including reduced water quality and toxicity effects to marine biota.
Objectives	To comply with applicable legislation and guidelines. To minimise the potential for adverse impacts on water quality.
Performance Indicators	Performance indicators will be developed consistent with relevant regulatory, local and Development requirements
Management Strategies	■ The residual total hydrocarbon in water concentration of waste water discharge will be less than 5 mg/l as an annual average for water discharged to Mermaid Sound. ■ Other measures employed to reduce the potential for environmental impact associated with waste water disposal are process design, procedures for chemical selection, dosing rates and operational maintenance and control of production equipment. ■ Woodside will put in place reduction targets and mitigation measures should the results of monitoring and/or investigations indicate a potential or actual unacceptable impact. ■ WET testing on actual treated waste water will be undertaken as soon as first water becomes available, one month after commissioning and annually thereafter or after a significant change in the composition of the treated waste water. Routine monitoring to ensure discharged waste water meets specified criteria. ■ Construction amenities will be regularly inspected and maintained, and effluent will be disposed of offsite at an appropriate facility. ■ During operation, approved sewage systems will be provided at Site B. ■ An appropriate monitoring and maintenance schedule for the sewage treatment system at Site B will be developed and implemented. ■ The oil-in-water meter will be regularly tested and calibrated as per acceptable standards to ensure its accuracy. ■ The concentration of total hydrocarbon in waste water discharged to Mermaid Sound will be measured daily. ■ A contingency plan will be developed to manage waste water in cases where unexpected volumes and/or quality of waste water are produced.
Monitoring	Monitoring of waste water will occur at source prior to commingling and at the discharge point. Waste water will be monitored in accordance with regulatory requirements and will include monitoring of discharge rates. A comprehensive monitoring programme will be put in place to confirm the prediction of no significant impact to nearshore communities and to ensure contaminants are not bio-accumulated by marine organisms. This will include agreed 'threshold values' for initiation of further studies and remedial actions as necessary. Monitoring will confirm that an appropriate level of ecological protection is being achieved at the edge of the agreed mixing zone. The concentration of total hydrocarbon in waste water discharged to Mermaid Sound will be measured daily. Routine monitoring to ensure treated waste water meets the EQMF social use values at end of pipe or within a distance, from point of discharge, agreed with the relevant authorities.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

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5. General Comments

5.1 Dredging Management Strategies

Given the level of uncertainty over the level of potential impacts from both the dredging and the waste water discharge it is important that as part of the EPA assessment process the proponent research and commit to effective management strategies for managing any unanticipated impacts from these two activities (e.g. Dredge rest periods, no overflow from barges, additional dilution built into the discharge diffuser).

Proponents Response

Dredging

A Framework Dredging and Spoil Disposal Management Plan (Framework DSDMP) for managing dredging and spoil disposal activities was presented in the Draft PER (Appendix I of the Draft PER). The purpose of the framework DSDMP was to provide Woodside, stakeholders and regulatory authorities with the level of assurance that predicted environmental impacts will be reduced to as low as reasonably practicable and that dredging activities are conducted in a manner consistent with Woodside's Environmental Policy.

Under the above Framework Plan, three stages of management strategies will be applied to minimise the environmental impact of dredging works. These are:

- Project design stage strategies – Designing the work to minimise the scope of dredging and avoid direct habitat losses.
- Active management strategies – Measures implemented throughout the dredging works.
- Reactive management strategies – Measures implemented on the basis of threshold limits.

The Framework DSDMP includes examples of protection and mitigation measures that will need to be considered as well as strategies that have been identified to minimise generation of turbidity from dredging and dredge spoil disposal. The environmental management approach and associated measures will be further developed in consultation with the DEC and the dredging contractor; and will be presented in the final DSDMP.

Waste water

Waste water diffusion modelling was based on a preliminary discharge diffuser design. Woodside commits to further work during the detailed design in improving the diffuser effectiveness. Possible improvements relating to port diameter, spacing and discharge rate will be investigated and it is considered likely that increased dilution can be achieved.

5.2 Comment on Revised Pluto LNG Development Dredging Simulation and Impact Assessment

The comment at the bottom of page 9 is noted: 'It also follows that, if the dredging contributes increased quantities of fine sediments to the seabed of Mermaid Sound, the long-term influence of this dredging programme (and previous dredging undertaken by Woodside and others) could be increased turbidity response to wave action.' This comment would also hold for more localised areas around a dredging or dumping site (ie. the longer the activity continues the greater the quantity of fine sediment available for resuspension).

Proponents Response

Results of the modelling indicate, as expected, that management of fines discharge will critical to minimising impacts of the dredging and disposal. Hence procedures that reduce fines discharge or direct the discharge from the Sound would reduce the potential impact.

Reworking of fines from many sources, including suspension by wind-waves and storms, seasonal run-off and shipping traffic is an existing condition. The field data (MScience 2007) indicate that BPPs at reef sites experience and tolerate variations in SSC and sedimentation. It is reasonable to expect that some of the fines that contribute to existing patterns were disturbed by dredging at some time as previously argued. The key to the significance of this source would be the magnitude and pattern of the contribution. The intensity-duration-frequency patterns of SSC and sedimentation that have been observed in the field data have been used to judge levels that are tolerable.

5.3 Spoil Disposal Into Offshore Spoil Ground 2B

It is important to note the prediction that spoil disposal into the offshore spoil ground 2B will result in elevated turbidity around coral habitats near the entrance to Mermaid Sound and that there will be a general southward movement of the fine sediments into Mermaid Sound and the Dampier Archipelago.

Proponents Response

The simulations under winter waves do indicate that uncovered fines will be disturbed from the offshore spoil ground 2B. Under winter currents (chosen as the worst-case), a net southward migration was predicted. This tended to raise SSC and to a lesser extent, sedimentation rates for reef locations around the entrance to Mermaid Sound. A low increase in net sedimentation was indicated due to the relatively high wave-energy affecting this zone. The threshold analysis considers the significance of the predicted levels of SSC and sedimentation.

5.4 Predicted Cumulative Coral Loss

Under the coral impact assessment for Holden Point (Section 4.1.1) there appears to be an error in the calculations for predicted cumulative coral loss resulting from the revised model. It is predicted that cumulative coral loss increases from 42% to 43% (an increase of 1%), however, by scanning figures 2 and 3 it appears that the likely increase in area of coral loss is in the ballpark of 7 - 10%.

Proponents Response

In response to the point raised above, the calculations for predicted coral loss were checked for potential errors. The values for predicted cumulative coral loss resulting from the revised modelling work are correct and loss increases 42% to 43%, using the original estimate of historical loss (18.6%) and the original threshold levels for sedimentation used in the draft PER. These calculations produce an increase in the estimate of potential corals loss of 1%.

The sensitivity analysis of the sedimentation threshold predicts the loss footprint (i.e. the area of the plume under which corals may be potentially lost) would increase from 43 to 46%, a relatively small increase in area when the threshold was halved. The estimates have been checked and are also confirmed as correct.

It is noted that Section 4.1.1 of the Revised Pluto LNG Development Dredging Simulation and Impact Assessment Report (May 2007), incorrectly states that the revised loss estimate associated with the additional, revised modelling uses the same baseline coral distribution data as were presented in the Draft PER (Figure 4 of the Revised Dredging Simulation and Impact Assessment – May 2007 corresponding to **Figure 14** below). The loss footprint calculations for the revised modelling (Figure 5 of the Revised Dredging Simulation and Impact Assessment – May 2007 corresponding to **Figure 15** and **Figure 16** below) are actually based upon more recent baseline coral distribution data compared to the data presented in the Draft PER. The more recent coral distribution data includes an area of coral habitat identified in Withnell Bay. This additional coral habitat was taken into consideration in above revised coral loss estimates and is the reason why the revised figure for overall coral loss increases by about 1% and not 7-10%.

The areas and percentages used in the calculations that produced the maps of predicted loss depicted in Figure 15 are the original historical loss estimate and the original threshold level and in Figure 16 the sensitivity analysis uses half the original threshold level.

Comparison of the estimates discussed here with the estimates shown in Table 9 in section 2.1 could be confusing, but the apparent disparity in amounts and percentages is easily explained.

In Table 9 of this document the original historical loss estimate used in the draft PER has been now been revised downward slightly from 18.6% to 17.48% because the new distributional data for corals provided by MScience showed that some of the area where corals had been assumed to be lost, actually has some coral cover.

When the revised historical loss estimate of 17.48% is used, then the calculation of potential cumulative loss for the case in the revised modelling where the original threshold is used produces an estimate of 42.5% (revised 100% threshold), which is virtually the same as that predicted in the draft PER.

The revised modelling work undertaken for the Revised Dredging Simulation and Impact Assessment – May 2007 also produced a sensitivity analysis where the original threshold was reduced to 50% of its level and that generated a potential cumulative loss of 45.1%, an increase over the draft PER estimate of 2.6% (see Table 9 in section 2.1).

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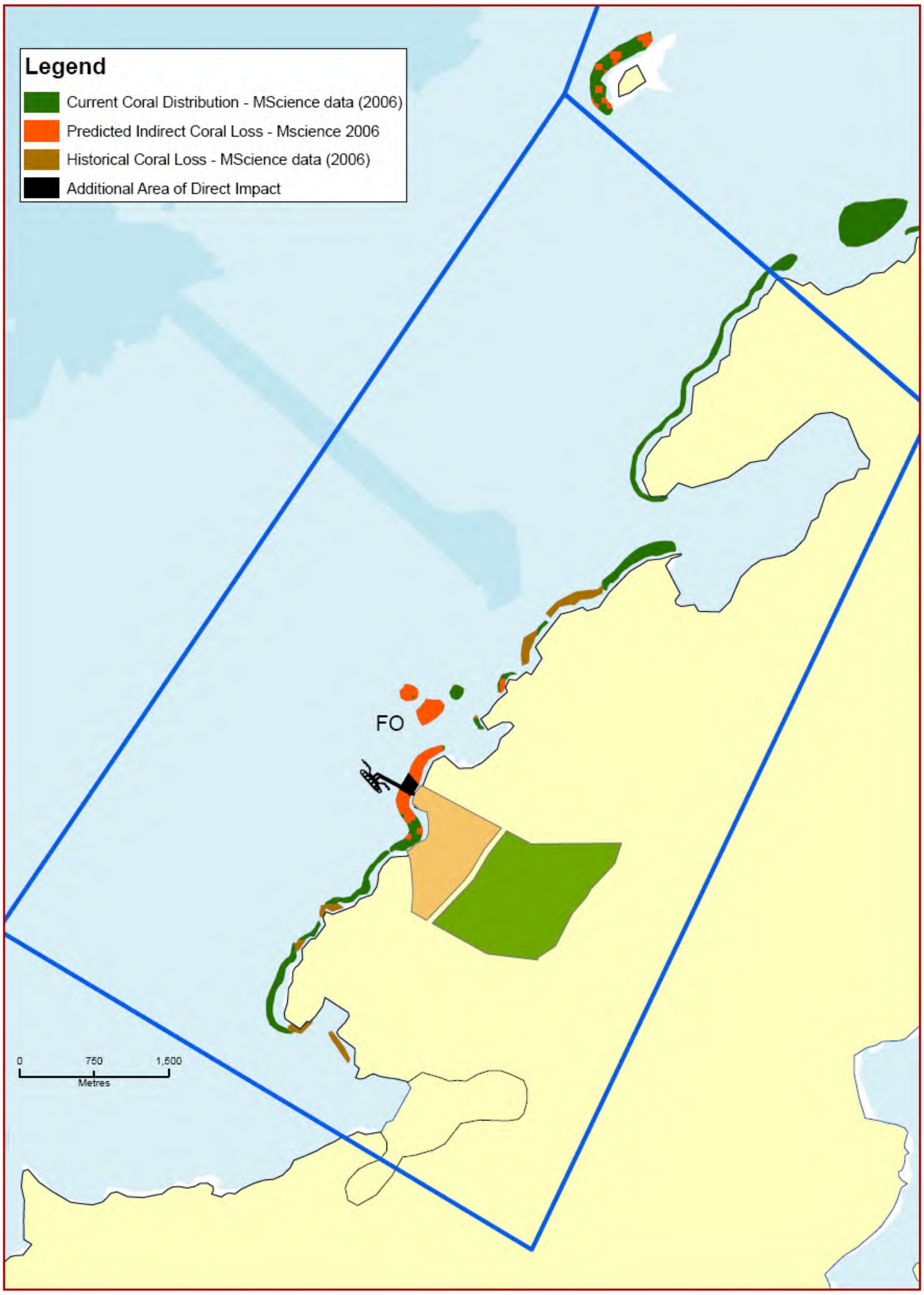
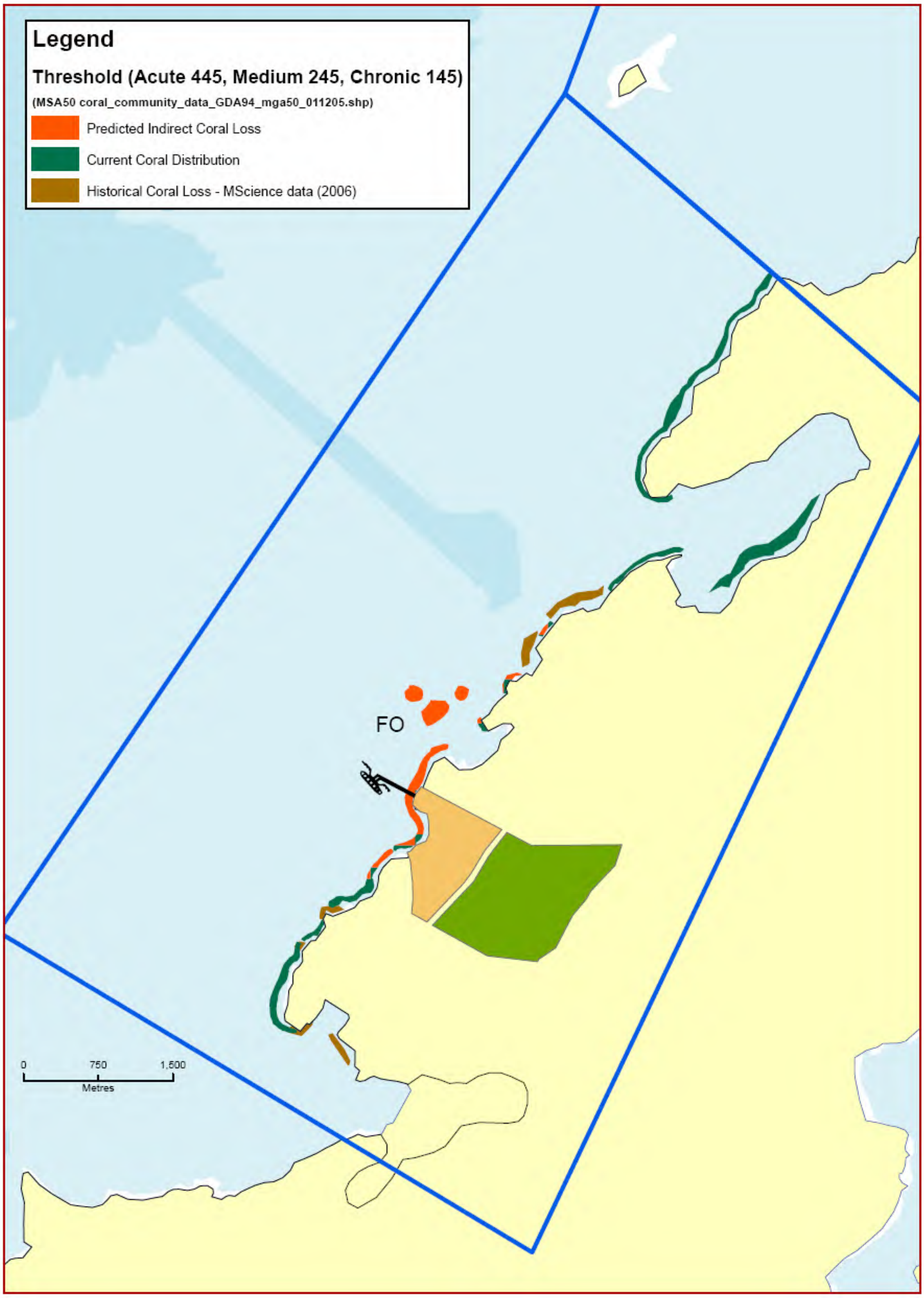


- **Figure 14 Draft PER Loss Predictions (Figure 4 from Revised Dredging Simulation and Impact Assessment – May 2007)**



- **Figure 15 Revised Loss Predictions (Figure 5 from Revised Dredging Simulation and Impact Assessment – May 2007)**

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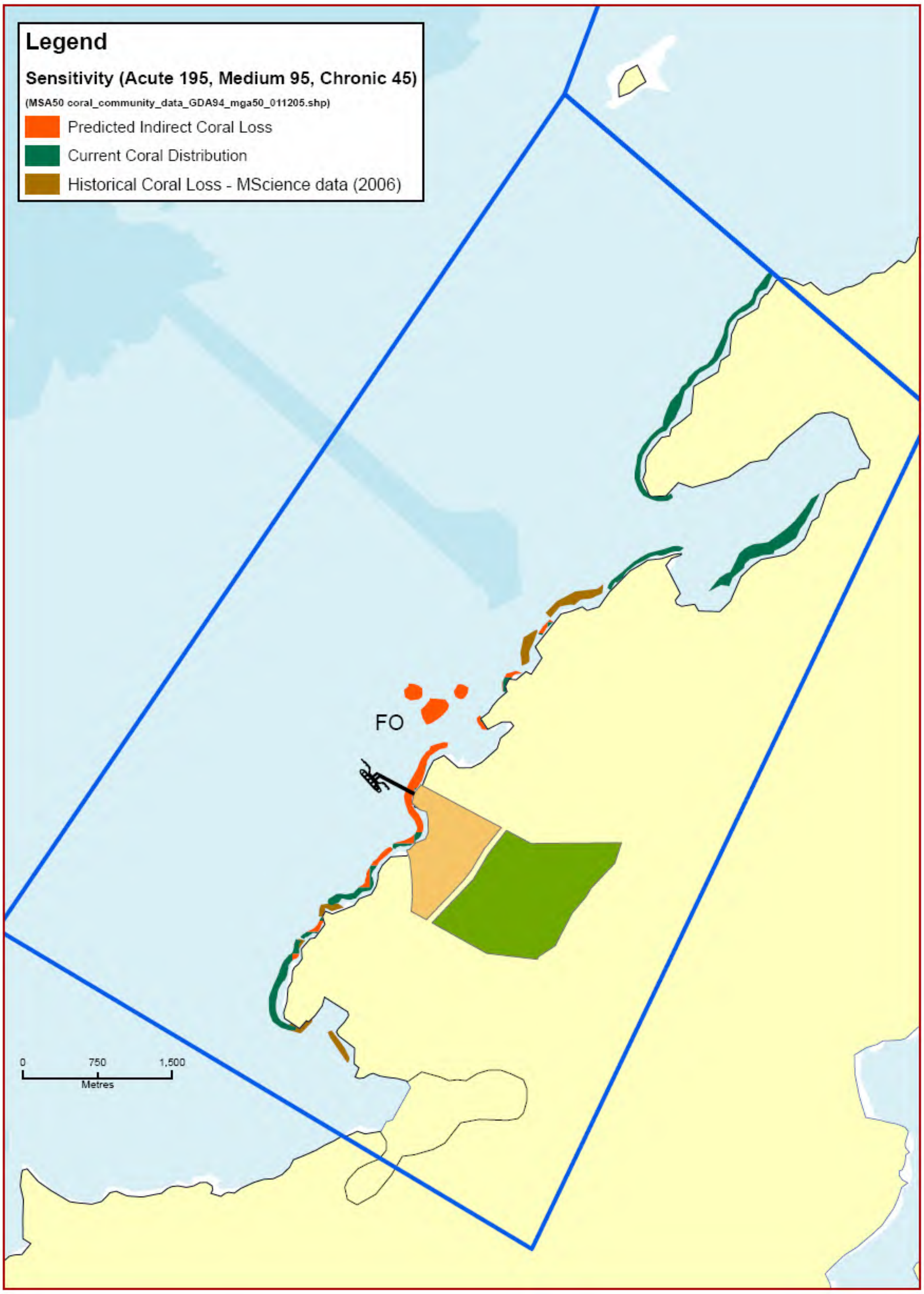

- **Figure 16 Loss Predictions from Sensitivity Analysis (Figure 5 from Revised Dredging Simulation and Impact Assessment – May 2007)**

5.5 Level of Sedimentation

The statement in Section 4.1.1: '…. The model indicates that dredging for longer (than the simulated 6 weeks) will probably not increase the level of sedimentation further than what is predicted during the 6 week simulation' is only an opinion and not supported by data. As stated in (1) above, the longer the activity continues, the greater the quantity of fine sediments likely to be available for resuspension.

Proponents Response

Proponent advises that this statement should be removed.

5.6 Vulnerable Coral Species Thresholds

The findings in the 3rd paragraph of section 4.2 and 2nd paragraph of section 4.3 support the need to develop medium-term and chronic sedimentation thresholds for vulnerable coral species as well as light attenuation thresholds and include them in the modelling.

Proponents Response

The latest outputs for further interrogation of the model findings have included within the scope of this work, the development of medium term and chronic sedimentation thresholds based upon the baseline data and drawing upon the methodology proposed by McArthur (2002).

The rationale for the selection of threshold values is explained in detail in **Section 2.1** and **2.2** and a detailed analysis of the results of the new interrogations is also presented in those sections of the document.

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Appendix A Baseline Water Quality Assessment Report April 2007 (MScience)

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PLUTO LNG DEVELOPMENT

BASELINE WATER QUALITY ASSESSMENT REPORT APRIL 2007

Report: MSA61R12

Report to:
Woodside Burrup Pty Ltd
240 St. Georges Terrace
Perth WA 6000
Australia

MScience Pty Ltd, School of Plant Biology (M090),
University of WA, Crawley, WA 6009, AUSTRALIA

Document Information

REPORT NO.	MSA61R12
TITLE	PLUTO LNG DEVELOPMENT : BASELINE WATER QUALITY ASSESSMENT REPORT APRIL 2007
DATE	17 May 2007
JOB	MSA61
CLIENT	WOODSIDE PLUTO PTY LTD Contract No. 0C00002273
USAGE	This report presents a preliminary evaluation of the Woodside Pluto water quality baseline data collected to mid April 2007 to support modelling of dredging impacts.
PRECIS	Baseline data are analysed to provide estimates of sediment load for use in worts case-best case estimates of coral mortality and estimates intensity-duration-frequency events for suspended sediments in calculating zones of impact for both robust and sensitive coral communities.
KEYWORDS	coral sediments baseline Dampier Woodside

Version-Date	Released by	Purpose
V.1- 17 May 07	JAS	Client Review
V1.1 28 May 07	JAS	Table 4 amended
V.2 30 May 07	JAS	Include client comments

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TABLES

FIGURES

1.0 INTRODUCTION

Woodside Burrup Pty Ltd (Woodside) commissioned MScience Pty Ltd (MScience) to undertake baseline studies on sediment flux and coral community dynamics within Mermaid Sound to provide baseline information to support environmental permitting and management of the Pluto LNG Development.

Recording of data was planned to occur over the period August 2006 to mid May 2007 to provide the following data:

- Turbidity and sedimentation estimates from in situ sediment meters at 5 locations to characterise the load, duration and frequency of sedimentation events;
- Estimates of change over time in coral cover for communities acting as potential impact and reference sites during the proposed dredging;
- Sediment characteristics for various sediment types and the relationships between sediment measures (NTU, SSC and sedimentation) to evaluate potential differences in the origin of sediments settling on coral communities.

Sediment and coral monitoring sites were established in late August 2006: coral and sediment data are collected monthly. In addition, Woodside has entered into a data sharing arrangement with Pilbara Iron Pty Ltd (PI) to access data from 2 water quality loggers placed close to dredging operations occurring December 2006 – April 2007.

Surveys on the Pluto program conducted to date include:

Survey	Dates	Comment
Baseline	20-24 August 2006	Established corals transects & sediment loggers
1	18-20 Sept 2006	Monthly coral survey & logger download
2	16-20 Oct 2006	Monthly coral survey & logger download, plus recruit counts
3	14-16 Nov 2006	Monthly coral survey & logger download
4	12-14 Dec 2006	Monthly coral survey & logger download
5	9-11 Jan 2007	Monthly coral survey & logger download
6	6-8 Feb 2007	Monthly coral survey & logger download
7	5-8 Mar 2007	Monthly coral survey in part
8	2-4 Apr 2007	Monthly coral survey & logger download

2.0 DATA PROCESSING

2.1 SEDIMENT METERS

Sediment meters used were the SAS meters developed by Dr Peter Ridd of James Cook University. The meters collect optical backscatter data (OBS) from a horizontal sensor and convert this to NTUe via an internal calibration (Thomas and Ridd 2005). That data was calibrated empirically using sediments collected from adjacent to the meter to provide a way to interpolate suspended sediment concentration (SSC) in mg/L (Table 1). Meters use the differential of the OBS from the horizontal sensor and that from a vertical sensor passing through a glass plate wiped every hour to provide an estimate of accumulated sediment surface density (ASSD) in mg/cm^2/d – also called deposition here. Meters were also equipped with light sensors logging PAR. All recordings were logged on a ten minute period.

As meters are placed at the same depth as the coral communities under observation, data on OBS and SSC will only be relevant to water at that depth. Light will be integrated throughout the profile having to pass from the surface through the entire water column.

Care must be taken in comparing estimates of sediment settling (ASSD or deposition) collected from these meters with estimates from sediment traps or models. A flat glass surface which only returns estimates when free of fouling will maximise the influence of resuspension.

Table 1. Calibration of NTU & SSC by station.

Station	Calibration
ANGI	2.4535*NTU + 0
CHC4	5.3199*NTU + 0
HGPT	3.6462*NTU+ 0
MIDR	2.2056*NTU + 0
WINI	2.9757*NTU - 0.8856
TDPL	2.4169*NTU + 0
KGBY	2.2542*NTU + 0
HSHL	3.416*NTU -8.5

2.2 DATA CLEANING & VALIDATION

OBS data can suffer from periodic short spikes due to a variety of factors (such as fish) occluding the omitted signal. SSC data were cleaned by removing any point that was over 5 mg/L and greater than 1.5 times its neighbours. These points were replaced with the average of the 2 neighbours.

ASSD data were examined visually (by an experienced observer of this data from James Cook University School of Mathematical & Physical Sciences) for patterns consistent with sedimentation terminated every hour by a wiper. These readings were aggregated to provide a deposition/d rate.

2.3 SEDIMENT METERS

Sediment meters in the Pluto baseline project were placed in the field in August 2006 (Figure 1; Table 2). The ANGI meter was inadvertently placed at the HSHL site and remained there collecting data until moved in September 2006. Meters at stations TDPL and KGBY were established in November 2006 as part of the monitoring program undertaken by PI.

Several sites did not record any data for the March period as an error in resetting meters in the lead-up to Cyclone George caused some meters to stop recording.

Zones of coral community sensitivity to sediments were established on the basis of coral surveys reported in MScience (2005). Those zones were established primarily on the basis of coral taxonomy and existing literature on which coral species are likely to be more or less robust to the effects of suspended sediment, light attenuation and sedimentation.

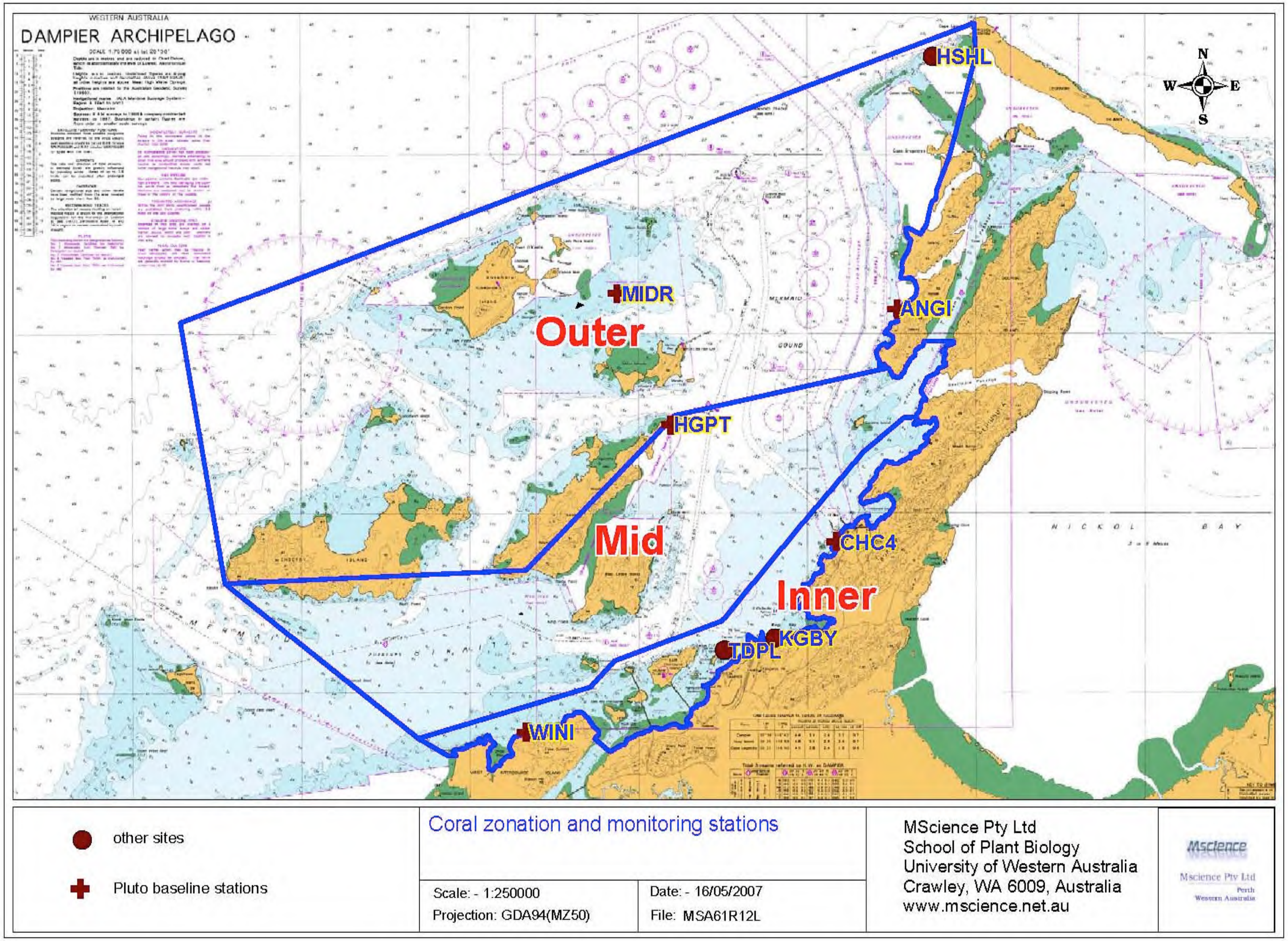
Table 2. Period of data analysed and station zone.

Station	Zone	SSC Data *	ASSD Data	Depth +
ANGI	Outer	15-Apr	Sep-Oct 06	5
HGPT	Mid	6-Mar	Oct 06	2.8
CHC4	Inner	19-Feb	Oct-Dec 06	1.9
MIDR	Outer	6-Mar	-	3.1
WINI	Inner	31-Mar	Dec 06 – Feb 07	0.3
TDPL	Inner	5-Apr	Nov 06 – Jan 07	-0.8
KGBY	Inner	4-Apr	-	0.3
HSHL	Outer	19-Sep-06	-	2.0

* recordings start in August 2006 for all stations except TDPL and KGBY which start in November 2006.

\+ depth of the SAS meters is expressed a m below LAT

Figure 1. Location of sediment stations and coral sensitivity zones.



3.0 BACKGROUND DATA

3.1 SSC BASELINE DATA

Various summary statistics for the SSC data are shown in Table 2. Statistics shown in the various zones are the averages of those statistics for the relevant stations in that zone.

Table 3. Suspended sediment concentrations (mg/L) by station and zone.

Site	Mean	Median	80%ile	95%ile	99%ile	Max
ANGI	4.21	2.22	4.3	12.4	51.0	143
HGPT	3.94	2.49	4.9	11.2	29.0	233
CHC4	10.75	7.39	15.6	28.1	58.0	276
MIDR	1.66	1.46	2.2	3.9	7.6	29
WINI	7.52	2.92	9.2	33.1	65.0	160
TDPL	8.43	4.03	10.3	33.8	73.7	273
KGBY	9.28	2.48	8.6	43.1	89.4	252
HSHL	4.81	3.64	5.5	14.5	39.7	145
Inner	9.0	4.2	10.9	34.5	71.5	240
Inner (-TDPL)	9.1	5.2	12.4	30.6	61.5	218
Mid	3.9	2.5	4.9	11.2	29.0	233
Outer	3.6	2.4	4.0	10.3	32.8	106

Statistics, aside for the maximum value, are similar for both the Mid and Outer zones. The high maximum value for the HGPT appears to be real and is one of a series of high values seen over 2 days during a period of strong north-westerly winds.

Removing the site TDPL from the Inner zone reduces the potential for the values of the Inner Zone to be elevated by the effects of dredging (December – April). However, this has only a small impact on lowering the 99%ile and maximum values while raising the mean and median.

In addition to calculating summary statistics above, it is possible to calculate intensity-duration-frequency statistics for SSC levels over the period of the study. Some possible combinations are shown in Table 4. It is clear from those values that the duration of elevated SSC levels is generally quite short – with values above the 80%ile rarely sustained above periods of 1 day.

Table 4. Intensity-duration-frequency data for hours of SSC at each station.

STATION		HOURS					
ANGI	mg/L	1	6	12	24	72	MAX
	10	30	5	2	1	1	128
	20	15	2	2	2	0	50
	30	9	4	1	1	0	30
	50	8	2	0	0	0	7
	100	0	0	0	0	0	1
	80%ile						
	x1	136	12	4	3	1	180
	x2	38	8	4	1	1	128
	x5	16	2	2	2	0	46
	x10	10	2	1	0	0	19
	95%ile	14	5	3	1	1	101
HGPT	mg/L	1	6	12	24	72	MAX
	10	56	0	0	0	0	5
	20	16	0	0	0	0	4
	25	9	0	0	0	0	2
	50	2	0	0	0	0	1
	100	0	0	0	0	0	1
	80%ile						
	x1	197	9	0	0	0	11
	x2	58	0	0	0	0	5
	x5	9	0	0	0	0	2
	x10	0	0	0	0	0	1
	95%ile	43	0	0	0	0	4
MIDR	mg/L	1	6	12	24	72	MAX
	10	1	0	0	0	0	2
	20	0	0	0	0	0	1
	25	0	0	0	0	0	0
	50	0	0	0	0	0	0
	100	0	0	0	0	0	0
	80%ile						
	x1	75	18	10	3	2	6
	x2	11	2	1	0	0	4
	x5	1	0	0	0	0	2
	x10	0	0	0	0	0	0
	95%ile	17	0	0	0	0	4
CHC4	mg/L	1	6	12	24	72	MAX
	10	263	20	8	2	0	35
	20	88	1	0	0	0	7
	25	53	0	0	0	0	3
	50	3	0	0	0	0	2
	100	0	0	0	0	0	1
	80%ile						
	x1	159	2	1	0	0	12
	x2	30	0	0	0	0	3
	x5	0	0	0	0	0	1
	x10	0	0	0	0	0	1
	95%ile	37	0	0	0	0	3

STATION		HOURS					
WINI	mg/L	1	6	12	24	72	MAX
	10	135	30	13	2	0	49
	20	96	13	5	0	0	19
	30	73	4	1	0	0	16
	50	28	0	0	0	0	4
	100	4	0	0	0	0	2
	80%ile						
	x1	143	37	15	2	0	50
	x2	104	13	5	0	0	20
	x5	37	0	0	0	0	4
	x10	4	0	0	0	0	3
	95%ile	67	2	1	0	0	16
TDPL	mg/L	1	6	12	24	72	MAX
	10	96	17	8	2	1	73
	20	54	10	1	0	0	23
	25	40	4	1	0	0	22
	50	17	0	0	0	0	5
	100	4	0	0	0	0	2
	80%ile						
	x1	90	17	7	2	1	73
	x2	52	9	1	0	0	23
	x5	16	0	0	0	0	5
	x10	3	0	0	0	0	2
	95%ile	35	1	0	0	0	7
KGBY	mg/L	1	6	12	24	72	MAX
	10	95	3	0	0	0	9
	20	59	0	0	0	0	6
	25	55	0	0	0	0	5
	50	18	0	0	0	0	4
	100	5	0	0	0	0	2
	80%ile						
	x1	100	3	0	0	0	9
	x2	64	2	0	0	0	7
	x5	28	0	0	0	0	4
	x10	6	0	0	0	0	2
	95%ile	28	0	0	0	0	4
HSHL	mg/L	1	6	12	24	72	MAX
	10	6	1	1	0	0	13
	20	0	0	0	0	0	1
	25	0	0	0	0	0	1
	50	0	0	0	0	0	0
	100	0	0	0	0	0	0
	80%ile						
	x1	8	5	2	0	0	17
	x2	4	1	1	0	0	13
	x5	0	0	0	0	0	0
	x10	0	0	0	0	0	0
	95%ile	2	0	0	0	0	6

3.2 DEPOSITION BASELINE DATA

Deposition data only exist for part of the monitoring period (Table 2) as the recording of deposition was often disrupted by fouling of the wiper mechanism and the recording plate. Some sites did not return any deposition data – which is often indistinguishable from a return of zero deposition.

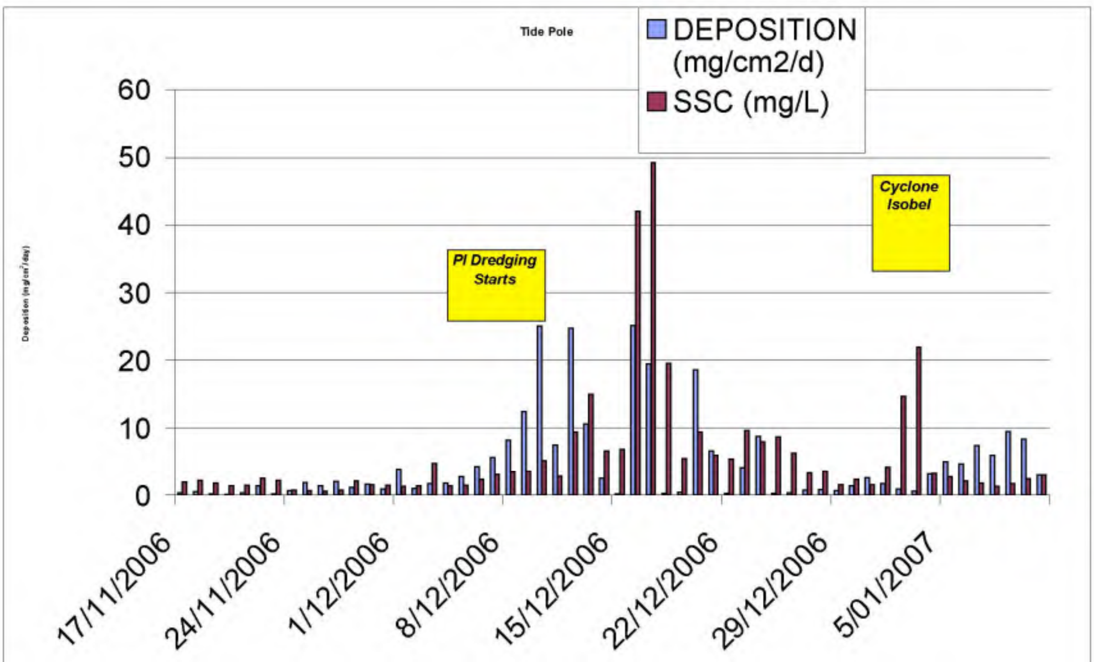
Table 5. Sediment deposition baseline data (mg/cm^2/d).

DEPOSITION						
	Mean	Median	80%ile	95%ile	99%ile	Max
ANGI	1.4	0.0	2.6	5.8	6.3	6.3
HGPT	0.1	0	0	1.0	2.8	4.4
CHC4	5.0	3.7	8.3	13.5	18.2	23.1
MIDR	no data					
WINI	3.7	1.2	5.2	13.0	32.9	38.0
TDPL	4.7	1.8	7.5	20.8	25.1	25.1
KGBY	no data					
HSHL	no data					
Inner	4.5	2.3	7.0	15.8	25.4	28.7
Inner (- TDPL)	4.4	2.5	6.8	13.3	25.5	30.5
Mid	0.1	0	0	1.0	2.8	4.4
Outer	1.4	0.0	2.6	5.8	6.3	6.3

As for SSC, Mid and Outer zones are very similar and removing the TDPL data from the Inner sites has little effect.

Deposition data is not necessarily well correlated with SSC levels. Resuspension of sediments by bottom stress in strong weather may cause high SSC levels, without any significant increase in sedimentation (Figure 2).

Figure 2. Deposition data vs SSC at the TDPL site.



4.0 LIGHT AND SSC

All meters logged light (PAR) in addition to estimating SSC over the same period. While it is clear that the depth of water over a meter has a significant direct effect on light reduction, SSC can play a larger role when concentrations are high. To examine the relationship between light extinction and SSC, light levels between 1000 hrs and 1400 hrs were correlated with SSC.

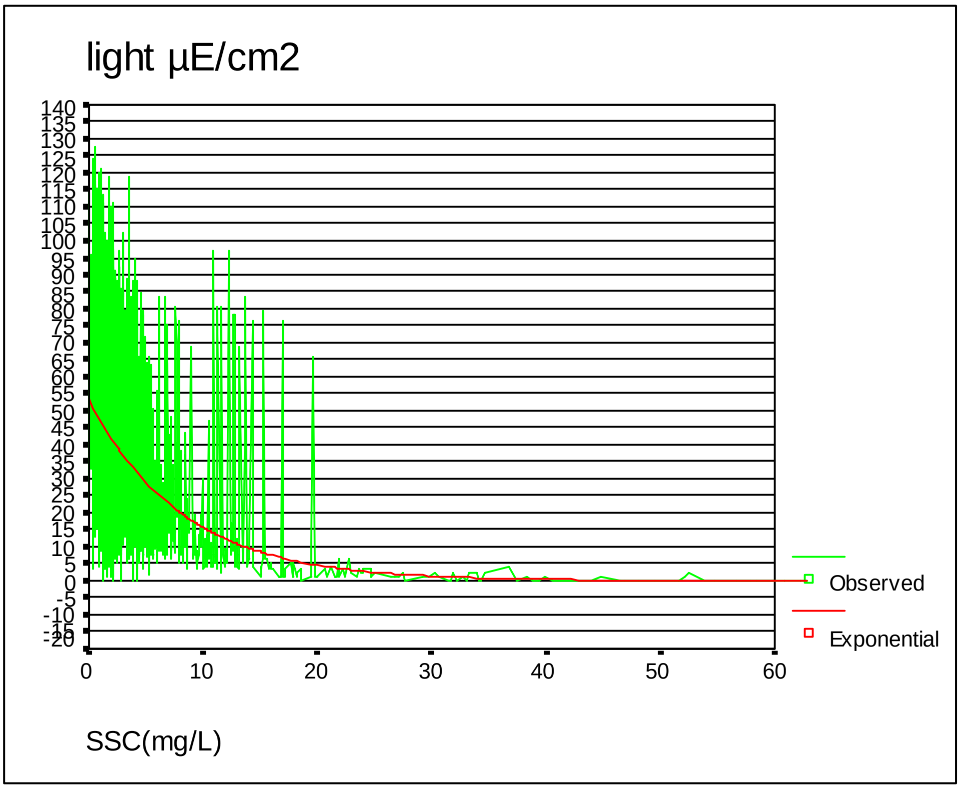
The relationship was examined using the general model

$$\textbf{Light} = \mathbf{A*e^{(B*SSC)}}$$

where A and B are derived from the empirical data.

A typical data set is shown in Figure 3 for the ANGI station where A=53 and B=-0.122.

Figure 3. Light versus SSC at ANGI.



Data were 'noisy' and most relationships had R^2 values of less than 0.2 (ie the relationship with SSC alone explains less than 20% of the variation). In addition to other influences such as tidal variation, it must be remembered that the SSC values from the meters only relate to water at the depth of the meter. Stratification of SSC is common in these waters with levels increasing towards the lower profile (Stoddart and Anstee 2005).

Using a combination of the derived relationships and visual assessment of scatter diagrams of SSC vs Light, it is possible to derive a set of values for each station at which light is effectively extinguished by SSC. In practice that value was where light was < 1 μE/cm^2. Estimated values are shown in Table 6.

Table 6. Light extinction levels of SSC by station.

Site	SSC level mg/L
ANGI	40
HGPT	n/a*
CHC4	100
MIDR	n/a*
WINI	70
TDPL	50
KGBY	50
HSHL	n/a*
Inner	50
Mid	
Outer	40

n/a* - at these sites, SSC values did not rise sufficiently high as to cause sufficient reduction in light levels as to allow estimation of extinction level

The variation in values of SSC derived as extinction points for individual stations will depend, amongst other things, on the depth of that station and the optical backscatter properties of local sediments (i.e. the relationship of NTU to SSC). Given those issues (see Tables 1 & 2) and the generally high level of 'noise' around the Light-SSC relationship, we have assumed a single point for all sites of 50 mg/L.

5.0 TRIGGER LEVELS

5.1 MORTALITY INDICATOR

This section is prefaced with a warning against relying heavily on the capacity of data collected during periods in which coral have not died, to be extrapolated to predict levels at which coral will die. The uncertainty of predictions made outside the domain of the data collection conditions has been well documented in ecology (Bradbury et al. 1984).

Derivation of a working indicator of water quality levels which may cause mortality of coral within the Pluto dredging project is based on the following assumptions:

- Acute mortality (mortality events occurring within a period of less than a month) are most likely to be caused by smother of corals from excessive sediment loading rather than low light or irritation form suspended sediments;
- Coral communities at which these water quality data have been recorded have not shown significant levels of coral mortality over the monitoring period.

Thus the indicator used here for a potential mortality is daily sediment load. Based on Table 5 we know that communities in the zones of sensitivity have survived the following maxima: Inner – 30 mg/cm2/d Mid-Outer 6 mg/cm2/d. Thus a mortality indicator will be above that value. It is not possible to determine from this data how far above these maxima sedimentation rates would need to occur to be lethal. In the absence of that knowledge, it may be prudent to use a worst case – best case estimate.

Worst case mortality might be represented as maxima plus 10%. Rather than try to specify the best case, it might be better to undertake a sensitivity test using multiples of the estimates of the 95%ile of sedimentation in Table 3 to produce Table 7.

Table 7. Estimates of worst case to best case mortality using sediment loading.

Case*	Inner $mg/cm^2/d$	Outer-Mid $mg/cm^2/d$
Worst (1.1)	33	7
Best 1 (1.5)	45	9
Best 2 (2)	60	12
Best 3 (5)	150	30

*figures in parentheses represent multiples of the maximum deposition rate

The values of Table 7 represent total deposition values (ie background and dredging).

For calculation of background SSC and sedimentation – see section 5.3.

5.2 ZONE OF IMPACT

There are a variety of estimates which may be used to calculate the level of suspended sediment or other water quality parameter which should be set as indicating one which may potentially cause stress or impact to coral communities. In the current context, the 'stress' or 'impact' is being evaluated for the community of established corals – rather than examining what may impact on the success of recruits.

One mechanism of determining a level indicating stress on adult organisms is to examine the background water quality over a period that these adults have survived and take some measure of the extremes they have survived as a 'stress' but not 'mortality' level. The Pluto PER has committed this project to follow the methods suggested in McArthur et al. (2002). That paper discusses how to establish guidelines for water quality parameters for the management of dredging such that generated sediment and light attenuation levels represent:

> *the natural limits for that environment and thus cause no added stress to individual corals or the coral community.*

McArthur et el. recommend the use of two measures of water quality to reflect the above level:

- the 99th percentile as a never to be exceeded value, and
- the 95th percentile of the frequency of occurrence of the 95th percentile of the distribution of the parameter where that occurs for various durations.

Use of the 99th percentile of SSC for the Inner and Mid-Outer zones values (Table 8) to designate a 'zone of stress' or 'zone of impact' is not appropriate. As these values are exceeded under background conditions at these sites without any dredging input, all sites would be classified as within the Impact Zone. The 99%ile absolute criterion should not be used to designate a zone of impact – although it could be used as a water quality target in managing dredging. Instead, McArthur et al.'s second criterion of intensity-duration-frequency should be used to establish zones of potential impact.

Table 8. Not to be exceeded SSC values by zone.

Zone	99%ile (mg/L)
Inner	60
Mid-Outer	30

Using the 95th percentile for SSC intensity at each station (Table 4) suggests that exceedences of more than 6 hours are rare. Table 9 presents the baseline data for durations below 6 hours where SSC exceeds the 95%ile at each site and a suggested limit trigger for each zone. The limit trigger is based on the 95%ile of each data set assuming that all sites with the exception of HSHL cover about 4 months of data (HSHL covers 1 month).

Table 9. Frequency of exceedences of the 95%ile SSC for various durations.

Location	Hours					mg/L
	1	2	3	4	5	95%ile
CHC4	35	8	0	0	0	28.1
KGBY	28	5	1	0	0	43.1
TDPL	35	15	10	5	3	33.8
WINI	67	35	21	10	4	33.1
INNER*	***16***	***8***	***5***	***2***	***1***	***35***
HGPT	43	8	3	1	0	11.2
MID*	***10***	***2***	***1***	***0***	***0***	***10***
HSHL	2	1	1	1	1	14.5
MIDR	17	3	1	0	0	3.9
ANGI	14	9	9	7	6	12.4
OUTER*	***4***	***2***	***2***	***1***	***1***	***10***

*frequency of exceedences of the 95%ile allowed per month.

As for other statistics the SSC 95%ile is similar for Mid and Outer although the frequency of exceedence is generally less for Outer. Exceedences of the 95%ille at station ANGI relate largely to the elevated SSC experienced around Cyclone George and could be discounted if it were not for the single month of data from HSHL which shows that an exceedence of the 95%ile occurs on one occasion. Thus the amalgamation of the data in Table 9 into an estimate of the frequency of intensity-duration events likely to occur without causing significant stress to coral communities (Table 10) provides for a single one-hour exceedence of the 95%ile SSC for both Mid and Outer sites.

Table 10. Suggested allowable frequency of intensity-duration events per month.

	Inner	Mid	Outer
SSC trigger level (mg/L)	35	10	10
1 hour	16	10	4
2 hours	8	2	2
3 hours	5	1	2
4 hours	2	1	1
5 hours	1	1	1
6 hours	0	0	0

Coral communities in areas where events with a monthly frequency of SSC exceeding those of Table 10 are predicted to occur should be classified as within the zone of predicted impact.

The above events will relate to the potential impacts of sedimentation covering corals, suspended sediments interfering with polyp extension and feeding, and light attenuation. Setting a further value for stress based on light attenuation is probably not able to be justified on the basis of existing understanding of how much light attenuation is likely to cause significant stress to these communities. In any event, were a value to be set based on the SSC levels of Table 6, its duration and frequency level would be likely to much less constraining than those of Table 10. With the capacity of corals living in turbid environments to switch to greater levels of autotrophy when light is limited (Anthony and Connolly 2004) it is likely that periods of light deprivation caused by the 95%ile of SSC at Inner or Mid-Outer zones would be significantly in excess of 6 hours.

5.3 Calculating backgrounds

The current form of the plume dispersion and deposition model from APASA considers only additional sediment caused by dredging. To allow that model to provide a factor to include the background SSC and sedimentation levels, it is necessary to stipulate a background level based on the baseline data.

It is clear that bottom stress is an important factor in driving SSC. The current model uses an estimate of bottom stress which goes from 0 (nil) to 1 (maximum). To convert that into an estimate of background Table 11 assigns a relationship between that factor and SSC exists such that the 2 are linearly related between 0-0 and 0.5B and Mean SSC and then between that mid point an 1B-99%ile SSC.

Table 11. Relationship for estimating background SSC from bottom stress (B).

B	SSC (mg/L)	
	Inner	Mid-Outer
0	0	0
.1	2	1
.2	4	2
.3	5	2
.4	7	3
.5	9	4
.6	12	6
.7	25	12
.8	37	19
.9	49	25
1.0	62	31

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Appendix B Review of Recent Dredging Projects in Dampier Harbour (MScience 2007b)

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PLUTO LNG DEVELOPMENT

REVIEW OF RECENT DREDGING PROJECTS IN DAMPIER HARBOUR

Report: MSA75R1

Report to:
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Document Information

REPORT NO.	MSA75R1
TITLE	PLUTO LNG DEVELOPMENT : REVIEW OF RECENT DREDGING PROJECTS IN DAMPIER HARBOUR
DATE	24 May 2007
JOB	MSA75
CLIENT	SKM - WOODSIDE BURRUP PTY LTD
USAGE	This report presents data for comparison with modelled projections of sediment dispersion and coral impacts from the Pluto LNG Development dredging.
PRECIS	This report presents a brief review of environmental aspects of major dredging projects undertaken in Dampier Harbour since 2003.
KEYWORDS	coral sediments Dampier dredging

Version-Date	Released by	Purpose
V.1- 24 May 07	JAS	Client Review
V.2-30 May 07	JAS	Include client comments

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EXECUTIVE SUMMARY

Records available for recent dredging programs within Dampier Harbour were reviewed to determine what information may be derived on the impacts that occurred on water quality and corals near to dredging and disposal sites and the distances at which such impacts occur.

Programs below include dredging over extended periods, often by two dredges at the one time and in close proximity to coral communities.

In general it appears that

- Dredging has been bigger impact on water quality or coral health than was spoil disposal;
- Substantial water quality impacts occur only at sites within 1 – 1.5 km of dredging or disposal activity;
- Mortality of corals has only occurred at sites closer than 250m to dredging operations.

2004 (Dampier Port Authority & Hamersley Iron)

Over almost a year of dredging (Jan-Oct) by programs at two sites in the Inner Harbour, substantive water quality impacts were seen only at sites closer than 1.5 km to dredging operations. Water quality impacts from spoil disposal were generally not substantive, even at sites closer than 1km to disposal grounds.

Coral monitoring showed it was likely that disturbance from dredging had no significant impact (adult mortality) at sites further than 200m from the dredge and that disposal operations had no impacts on coral mortality.

Suspended sediment concentrations of 60mg/L were observed at the single site where corals were impacted around the period of impact.

2005-6 (Woodside LNGV)

No mortality was seen at coral communities within 350m of the dredging operation or at sites around the disposal grounds over a 5 month dredging program. No corresponding water quality monitoring program was undertaken.

2006-7 (Pilbara Iron)

An intensive monitoring program of mortality rates of individual corals did not show any increase in gross mortality at sites within 300m of a dredging program lasting 5 months when compared with sites outside the radius of dredging impacts. In situ monitoring of suspended sediment concentrations and sedimentation showed that dredging exerted a bigger effect than a cyclone (for a site 300m from the dredged area) but that disposal was a lesser impact than a cyclone at 4km from the disposal site.

1.0 INTRODUCTION

Woodside Burrup Pty Ltd (Woodside) is undertaking an environmental assessment of the likely effects of the dredging component of the Pluto LNG Development project. That assessment attempts to use baseline data on water quality and figures from the scientific literature to develop predictions (through numerical models) of the lethal and sublethal zones of impact likely to eventuate from the dredging phase of the project.

To provide an additional source of information on what impacts might occur during the project it may be useful to examine the experiences of recent dredging projects with similar characteristics to the proposed Pluto dredging. The set of projects examined here are all similar to the Pluto dredging in that they cover:

- Programs which extend over several months within a relatively small area;
- Programs which move over 2Mm^3 of spoil
- Programs which use both trailer suction hopper dredges and cutter suction dredges – often simultaneously.

While the total length of dredging for the Pluto LNG Development is considerably more extensive than these programs, much of that work is staged to occur sequentially at several differing locations. Thus examination of the impacts of these programs on water quality and coral mortality may be helpful.

Examination of the long-term impacts of these projects has occurred, but has been largely confounded by new dredging projects and increased ship movements occurring after the project ceases.

2.0 DREDGING IN 2003-4

2.1 PROGRAMS

DPA Bulk Liquids Berth	
Where	Dampier Inner Harbour – Bulk Liquids Berth: Disposal- Northern Spoil Ground
What	Capital: Bulk Liquids berth and approach channel
Dates	8 Jan – 20 May 2004
Volumes	4.1 Mm^3
Dredges	THSD – *Cornelisse Zaanen*; Backhoe dredge - *Storken*

Pilbara Iron – Parker Point	
Where	Dampier Inner Harbour - Parker Point: Disposal- East Lewis Is & Northern Spoil Grounds
What	Capital: Swing basin, berth
Dates	8 May – 23 Oct 2004
Volumes	3.1 Mm^3
Dredges	THSD – *Cornelisse Zaanen*; Cutter Suction – *HAM218*; Backhoe dredge – *Obscured by Clouds* (first 2 dredges concurrent for most of June)

2.2 DATA COLLECTED

Coral monitoring occurred on a fortnightly basis using belt transects at 14 sites for DPA and 16 sites for Pilbara Iron. The primary parameter measured was the percentage cover of living coral which was set a maximum of 10% decline for additional dredge management and 30% decline for a 'cease dredging' limit.

Water quality data (including turbidity (NTU), suspended solids (SSC), pH, dissolved oxygen (DO)) was collected for both programs on a 3-day cycle at all coral monitoring sites. NTU was measured directly while SSC was derived from samples sent to the laboratory for gravimetric analysis.

2.3 OUTCOMES

Water quality impacts

Both projects

Full details of water quality during the dredging program can be found in Stoddart & Anstee (2005).

A general summary of key features includes:

Only weak associations between SSC and NTU were seen – generally around the 1 NTU = 2mg/L SSC range.

No apparent association of dissolved oxygen or pH was seen with elevated NTU or SSC.

Assessment of the NTU-SSC data show that levels were generally low at most sites with relatively short-lived peaks around some dredging events and a Cyclone. Some sites were project-specific and were not monitored for the entire period (See Stoddart & Anstee 2005). Data in Table 1, Figure 1 & Figure 2 show that the upper component of the distribution of NTU or SSC is only elevated substantively at sites close to the source of sediment – less than 1.5km. Sites close to dredging operations suffer much higher impacts on water quality than sites near to disposal grounds.

Critical distance in the two figures refers to the shortest distance from that site to either dredging or disposal grounds.

Table 1. SSC data by site for 2004 dredging.

Site	PERCENTILE (mg/kg)				Km to	
	Median	75	90	95	Disposal	Dredging
ANGI	3	5	8	9	4	15
COBN	4	6	11	12	5	10
CONI	3	5	8	9	2	9
DPAN	6	11	17	23	7	1
ELI1	3	4	10	11	0.2	6
ELI2	3	5	9	11	0.2	5
ELI3	3	6	10	12	0.2	5
GIDI	3	6	9	13	6	17
HGPT	3	4	11	13	6	11
HOLD	6	10	15	18	7	1.5
KGBY	3	6	12	15	6	1
MALI	3	5	9	15	5	12
NWIT	3	6	9	11	5	6
SUPB	7	13	25	42	7	0.2
SWIT	3	6	9	11	6	4
TDPL	3	7	11	12	4	0.4
WINI	3	6	9	12	9	12
WLI1	4	6	11	17	6	11
WLI2	3	5	10	12	7	11

Figure 1. Peak levels of NTU with distance to impact.

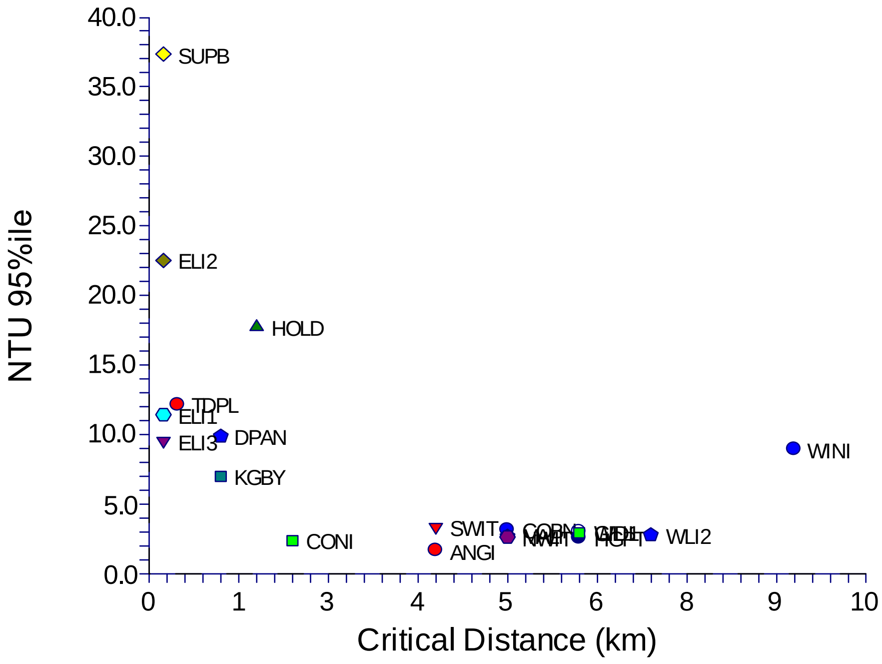
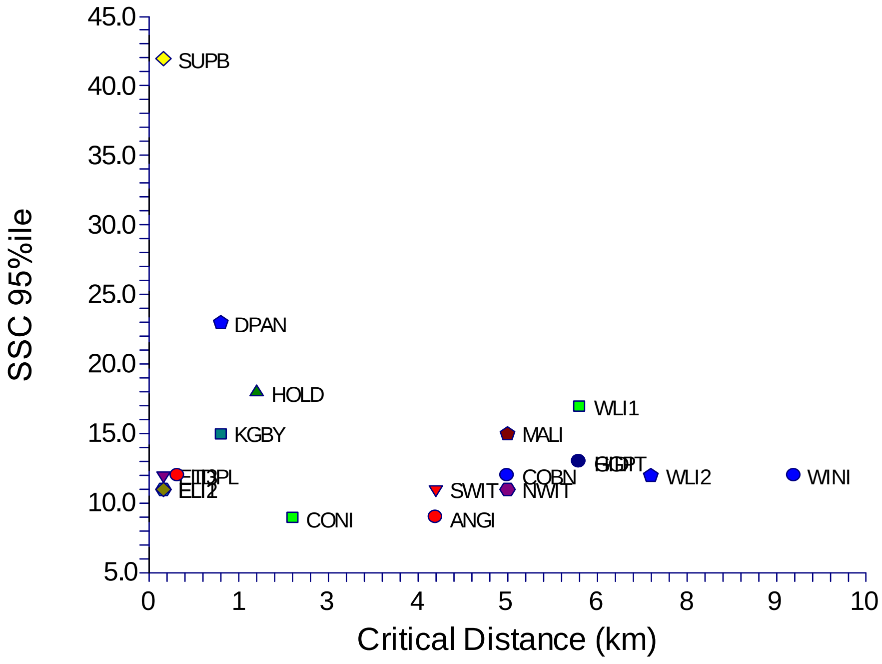


Figure 2. Peak levels of SSC with distance to impact.



Coral impacts

DPA

Several coral monitoring sites showed a clear decline in coral cover:

- substantive mortality occurred at the WLI1 and WLI2 sites due to freshwater inundation as the result of a cyclone;
- an 80% decline occurred at SUPB due to smothering by sediment
- some sites declined temporarily in cover estimates due to seasonal cover by macroalgae, but that did not appear to cause corresponding increases in mortality.

Peak sediment levels of over 60 mg/L were recorded in the 3-d monitoring on two occasions when it is postulated that the mortality occurred at SUPB (Stoddart & Anstee 2005). SUPB was within 200m of the dredging area and it is postulated that manoeuvring by the TSHD resulted in closer proximity of propeller wash.

No increased mortality was seen at sites close to the dredging where there was substantial and sustained increases in NTU/SSC – eg HOLD and DPAN (Figure 1, Figure 2).

No increased mortality was seen in coral communities monitored around the disposal grounds.

Pilbara Iron

The coral monitoring sites nearest to the dredging were the Tidepole Island and King Bay sites which were approximately 400m and 1km (respectively) from operations of the TSHD. Coral communities occurred even closer to the disposal site at East Lewis Island (200m). Divers noted plumes at all of the above sites on many occasions and reported fine sediments on corals and rocks.

Despite the above, the water quality impacts were small (Table 1, Figure 1 & Figure 2) and no significant mortality signal was detected (Stoddart et al. 2005).

3.0 2005-6

3.1 Programs

Woodside LNG V	
Where	Eastern Burrup – Karratha Gas Plant Disposal – Northern Spoil Ground
What	Capital: New berth & swing basin
Dates	11 Oct 2005 – 20 March 2006
Volumes	4.1 Mm^3
Dredges	TSHD *Cornelisse Zanen*; Cutter suction dredge - *Ursa*

3.2 Data Collected

Coral monitoring was conducted at 11 sites on 4 occasions (before, during and 2 after) using belt transects. The primary parameter measured was the percentage cover of living coral with the design established to test for a statistically significant decline of 10% against an action level of 50% decline.

MScience is not aware of any water quality monitoring conducted during this project.

3.3 Outcomes

Coral Impacts

The monitored coral communities nearest to the dredging occurred 350 and 800 m from the edge of the dredged area. Sites monitored around the disposal site were essentially the same as those in Table 1.

No decline in coral cover was seen at any of the Impact monitoring sites – although significant declines in coral cover did occur at Reference sites over the same period as a result of wave exposure and anchor damage.

4.0 2006-7

4.1 PROGRAMS

Pilbara Iron Pty Ltd	
Where	Parker Point Disposal – East Lewis Island & Northern Spoil Ground
What	Capital & Maintenance: New berth & swing basin, approaches
Dates	6 December 2006 – 24 April 2007
Volumes	3.5 Mm^3
Dredges	TSHD *Volvox Asia*; Cutter suction dredge – *Cyrus II*

4.2 DATA COLLECTED

Coral monitoring was conducted fortnightly at 16 sites using 100 individually located corals at each site. Estimates of partial mortality of the set of corals were compiled for each monitoring period.

Water quality parameters were collected manually on a 3d cycle for NTU (and by interpolation SSC), pH, DO and light attenuation at all coral monitoring sites. In situ meters gathered OBS and light (PAR) data on a 10 minute cycle to provide estimates of turbidity (NTUe), SSC (from laboratory calibrations), accumulated sediment deposition and light.

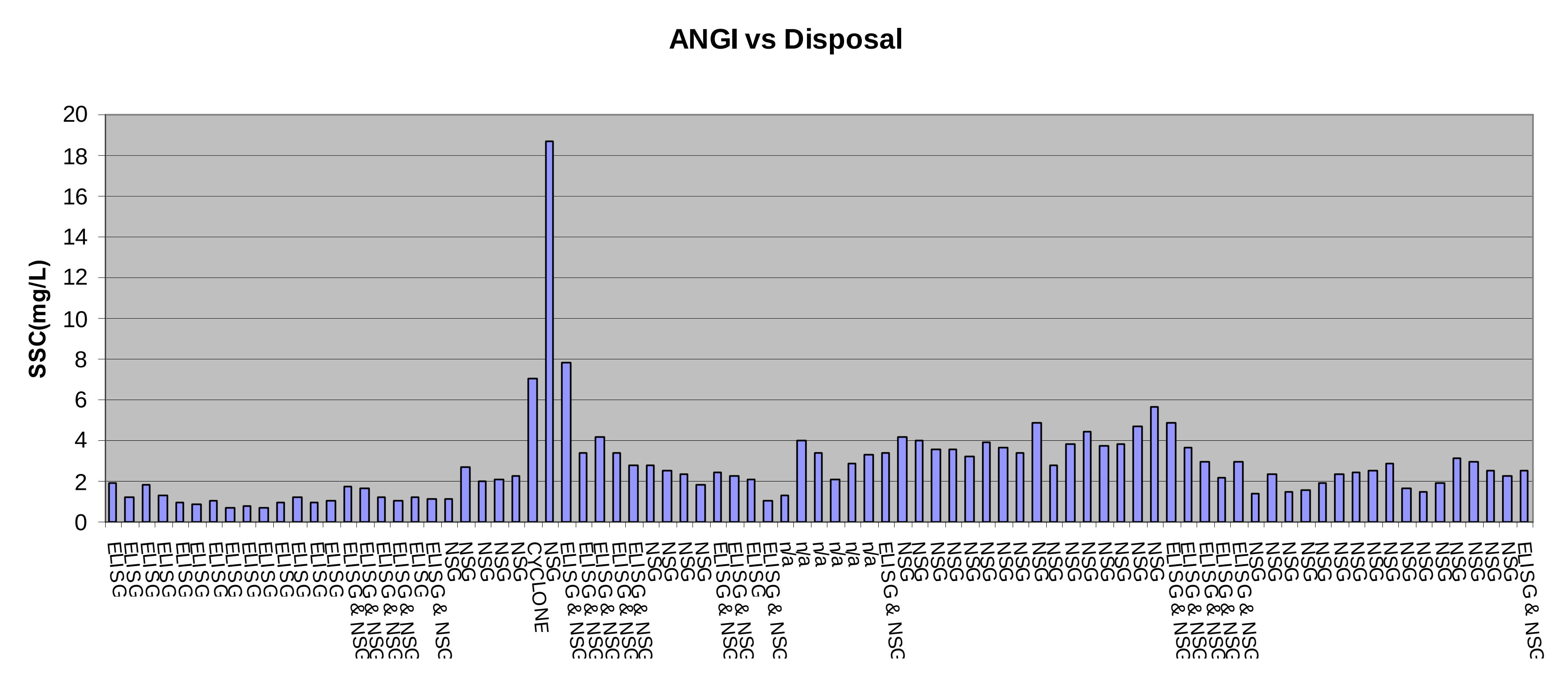
4.3 OUTCOMES

Water quality

This study did not have access to the water quality data collected on the 3-d cycle. Reports of that data have been provided monthly to the WA Department of Environment & Conservation.

Data from daily mean SSC show that cyclones had a larger impact on water quality than spoil disposal at a site approximately 4km from the disposal site. However, dredging impacts exerted a larger impact than cyclones at sites 0.3 and >1km from dredging operations (Figures 3 & 4).

Figure 3. Disposal location vs SSC (mg/L) at nearby site.



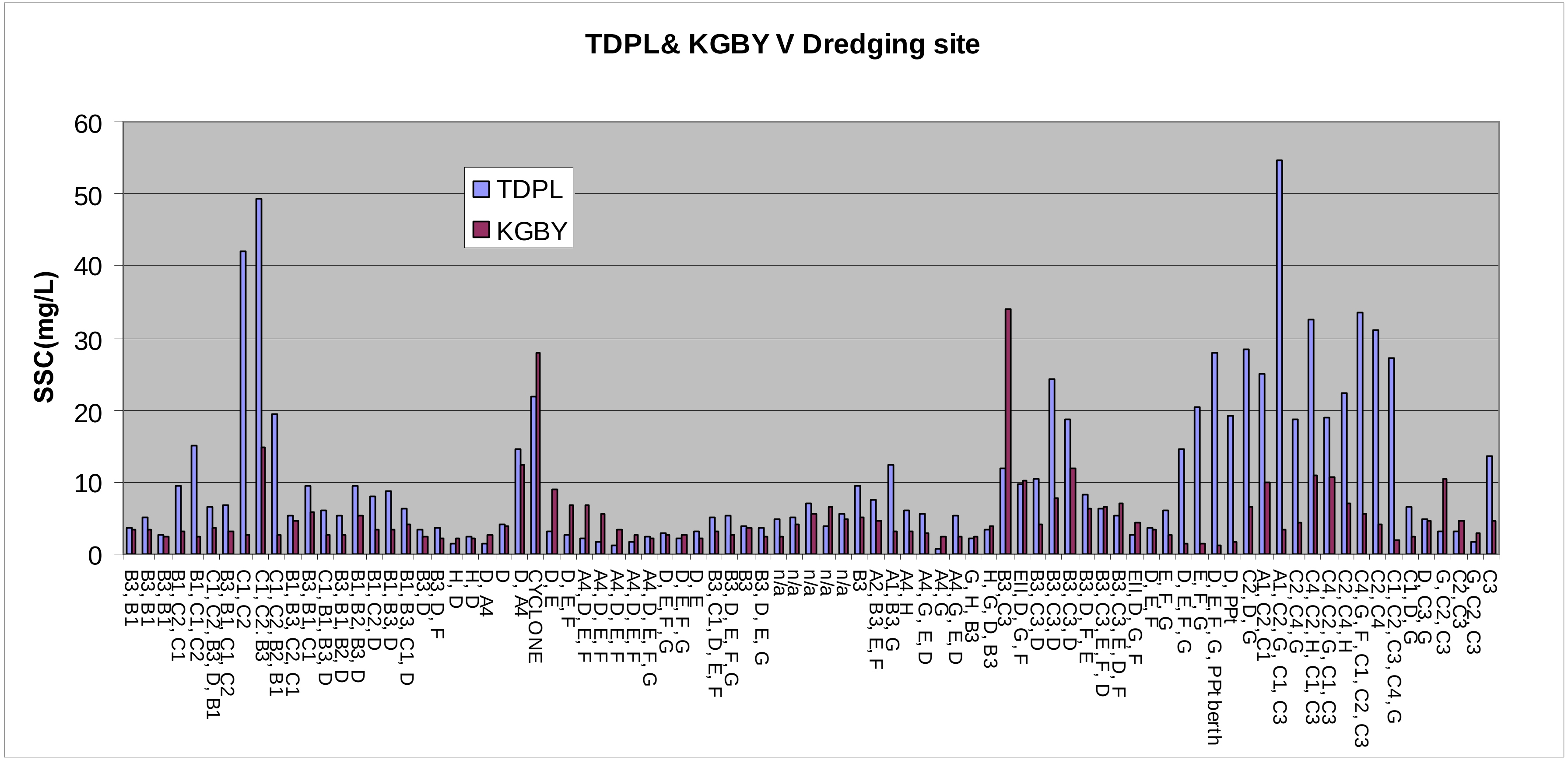
The graph starts in early December 2006 and goes to April 2007

SSC values are daily means

NSG – disposal occurring at the Northern Spoil Grounds

ELI – disposal occurring at the East Lewis Island Spoil Grounds

Figure 4. Dredging location vs SSC (mg/L) at nearby sites.



The graph starts in early December 2006 and goes to April 2007

SSC values are daily means

Site locations refer to dredging blocks as per permit documentation – A,B,C are close to site TDPL and G & E are closer to KGBY

Coral Impacts

Despite the substantial elevation of SSC and sediment deposition at the TDPL site (closer than 300m to dredging in this project), there was no clear elevation of mortality at that site compared to that at a similar exposed shallow-water site (WINI). Divers noted that corals were often covered with a fine layer of silt and in some cases partial mortality of corals was scored in mortality assessments where corals were partially obscured by sediments. Some corals were seen to die entirely. However, similar amounts of sediment-induced partial mortality were seen at sites distant from dredging. Following the cessation of dredging some of the apparent mortality attributed to sediment cover was seen to reverse as sediments cleared leaving live coral.

The above is work in progress and a full analysis of mortality patterns for that project has not been completed.

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Appendix C Benthic Habitats at NE Corner of West Lewis Island (MScience 2007c)

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Memo

MScience Pty Ltd
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University of Western Australia
Crawley, WA 6009
Email: admin@mscience.net.au

To: David Gordon

Cc: Russell Hanley, Stephen Ley

From: James Stoddart

Date: May 28, 2007

Subject:

At the request of the Pluto Project, benthic habitats between High Point and the northeastern tip of West Lewis Island were mapped on Wednesday the 16th of May 2007. The preliminary mapping was done primarily with the boat's depth sounder, then ground-truthed by divers.

Different habitats were distinguished on the sounder by their appearance—low relief and low reflectance indicated sand, moderate topography indicated rock, and irregular spiky topography indicated coral reef. Sand, rock and coral reef were the only benthic habitats encountered in the study area.

Spot dives on snorkel were undertaken to verify the interpretations made from the sounder. A total of 17 dives were undertaken in locations marked on Figure 1. At each location the diver was dropped close to shore and swam offshore, noting the position and width of the rock, sediment and/or coral reef habitats.

Most of the coastline in the survey area is rocky, with low cliffs rimmed by scree slopes of angular boulders. The boulders extend subtidally approximately 50m offshore on average. Boulders in the intertidal zone are lightly colonised by barnacles, and boulders in the subtidal zone are colonised by zoanthids and sparse corals (Rocky reef habitat in map).

Corals are most abundant between approximately 1 and 5m below LAT, where they form thin veneer reefs over the rock substrate. *Pavona* and *Porites* comprise the dominant coral genera based on area covered (Corals in map). At the outer edge of this zone the corals become patchy and give way to a flat medium to fine grained sediment.

Sandy beaches are present in the channel between High Point and West Lewis Island, and in the wide southeast-facing bay on West Lewis Island. The intertidal and subtidal habitats adjacent to the beaches are also sandy, with occasional coral patch reefs (Bommes in map) as indicated in Figure 2. *Pavona* and branching *Acropora* were the most common coral genera on these patch reefs. The surrounding sand is generally relatively thin, and is underlain by a hard flat limestone pavement.

Very little macroalgae or seagrass was observed at any of the dive sites.

Total area of coral mapped is approximately 19 ha in units as marked on Figure 2.

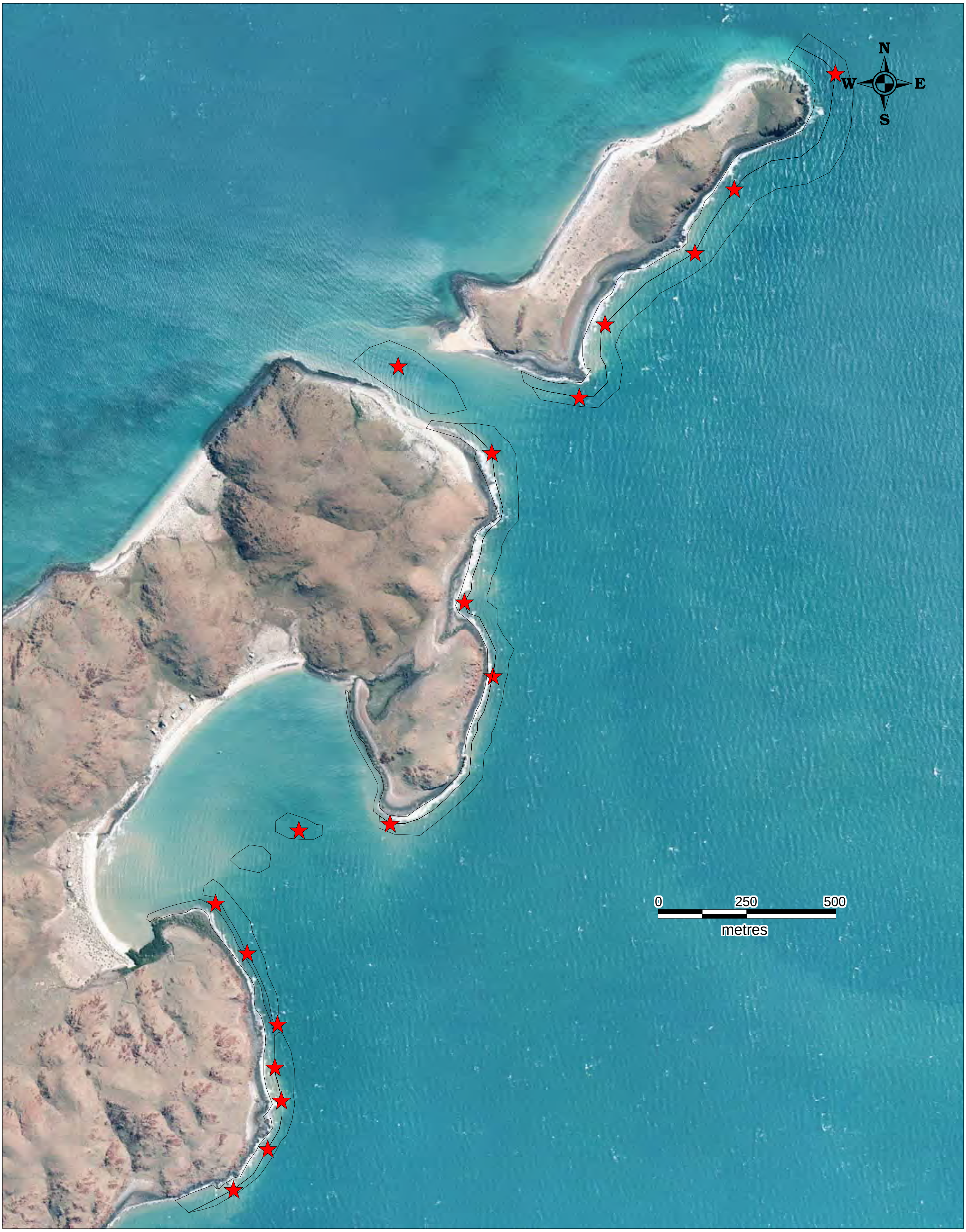

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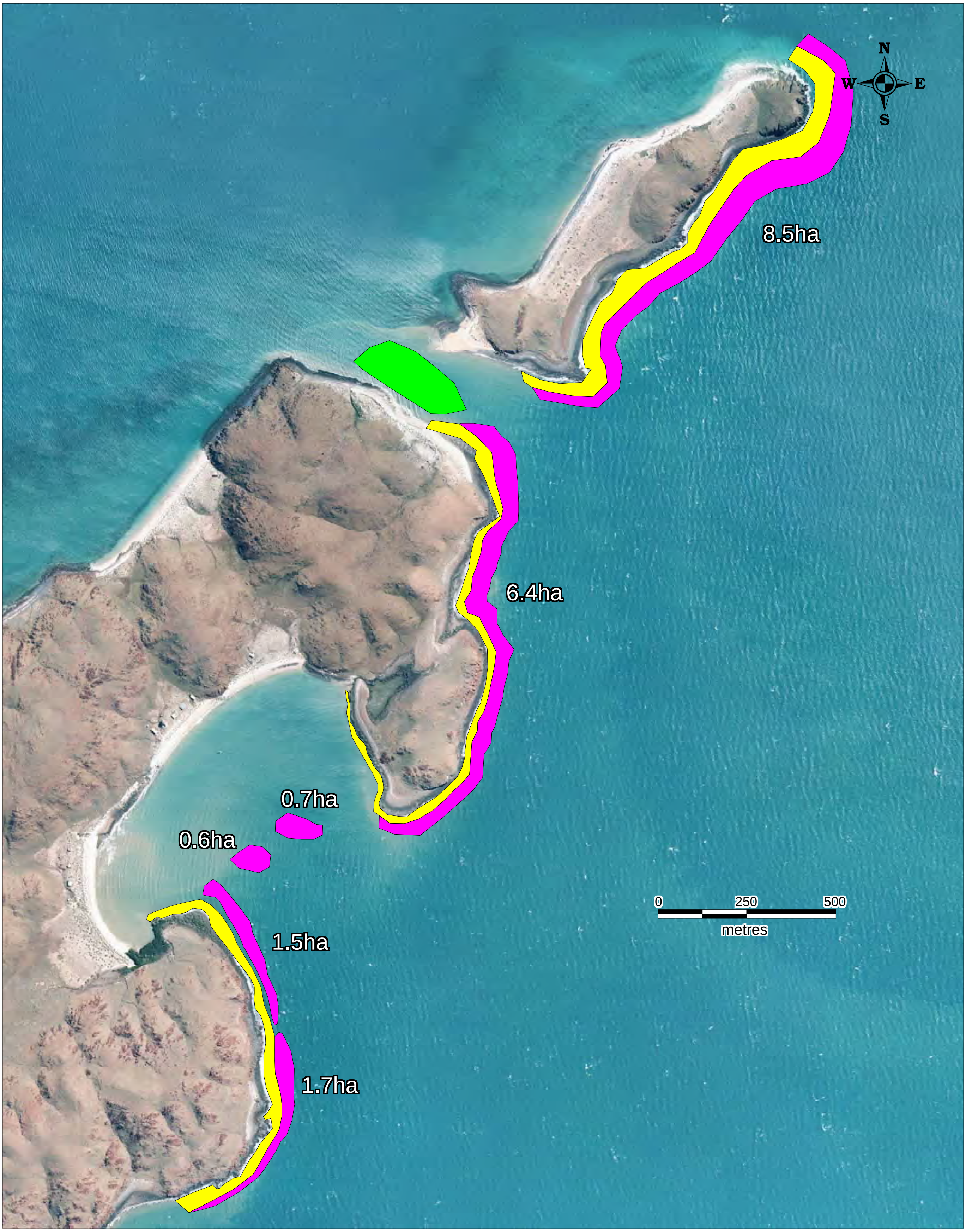
Figure 1: Location of sites for ground truthing

Scale: - 1:15000
Projection: GDA94(MGA50)
Date: - 28/05/2007
File: WLEW1

Benthic Habitat Mapping

★Dive sites



Mscience Mscience Pty Ltd Perth Western Australia	MScience Pty Ltd School of Plant Biology University of Western Australia Crawley, WA 6009 Australia www.mscience.net.au	**Figure 2: Benthic Habitats West Lewis Island Tip** Scale: - 1:15000t Projection: GDA94(MGA50) Date: - 28/05/2007 File: Wlewis0507	Benthic Habitats (coral area shown in ha on ma Bommes Corals Rocky Reef

Appendix D Methods for Revised Dredge Modelling with Inclusion of Sediment Resuspension (APASA 2007)

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Pluto LNG Development - Sediment Dispersion Study:

Methods for Revised Dredge Modelling with the Inclusion of Sediment Resuspension

Prepared by

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1 Methods

Numerical modelling was used to understand the effects of dredging on the Dampier Archipelago marine environment in terms of the redistribution of sediments, inclusive of resuspension processes. There are several aspects of the oceanography in the region which are important for inclusion in a model to properly represent the transport of dredged material over the shorter and longer terms. Processes include wind and tidally driven currents as well as locally generated, short-period waves and oceanic long-period swells. Turbulent mixing which is a product of these processes is also important for determining the fate and transport of dredged material. Sediment properties such as grain size and cohesiveness were also considered. The main steps involved in establishing a suitable model to determine the transport of dredged material were:

- Apply a previously validated three-dimensional hydrodynamic model covering the region (Encompassing Mermaid Sound, Dampier Archipelago and approaches) to produce a long-run circulation sample;
- Set up a robust wave model for the whole region, which included input of the hydrodynamic data (elevations and currents) from the hydrodynamic model;
- Validate predictions of the wave model against field measurement of wave characteristics in Mermaid Sound;
- Establish the relevant parameters to appropriately represent each type of dredging operation (derived during earlier calibrations, sensitivity tests and reviews of previous studies)
- Establish suitably conservative vertical mixing parameterisation to suit the processes in the region through sensitivity testing and calibration to field observations
- Conducting sediment transport modelling for defined dredging activity, following the most up to date dredging schedule for key operations:
    - Dredging of the turning circle/shipping berth
    - Dredging for trunkline trenching
    - Disposal at the offshore disposal ground
- Determine the locations likely to experience sedimentation rates known to be harmful to coral by applying thresholds for SSC and sedimentation rates (Acute, medium term and longer term) defined from analysis of field data collected and analysed by MScience [with observations during of a dredging operation]
- Calculate the median, maximum and 80th percentile of total suspended sediments during each operation

- Examine time series of exposure to sedimentation and suspended sediments in the water column at locations of interest within Dampier Archipelago

- Reporting of findings of results in relation to the modeling in APASA (2006) as well as any new effects resulting from the inclusion of waves and resuspension in the modelling process.

1.1 Hydrodynamic Modelling

Hydrodynamic modeling of Dampier Archipelago was performed using HYDROMAP. HYDROMAP is a 3D barotropic coastal model and has been used in previous studies of Dampier Archipelgo (i.e. APASA, 2006). The model was set up and validated in previous dredge modelling in Mermaid Sound and therefore only minor changes to the model input data were required for the present application. APASA (2006) has provided a detailed description of the model setup and input parameters as well as the validation study undertaken against current metering.

For the most recent investigation, HYDROMAP was run in three dimensions over a staggered Cartesian grid with cell sizes ranging from 1km (in the offshore waters) down to 125m. The key difference with APASA (2006) was that the model was run over two years for 2005 and 2006 and therefore different wind data was used. Winds were sourced from the NCEP reanalysis (Kalnay et al. 1996). This is a global surface hindcast model that uses atmospheric observations from the world's array of observation stations, inclusive of stations surrounding the study area. The data is updated six hourly with a spatial resolution of ~1.9° by ~2.0°. The model open boundary cells were forced with tidal phase angles and amplitudes from the Topex/Poseidon v6.2 global tidal model for the eight major constituents, as previously applied and validated.

Hydrodynamic model results were used as input wave model. Current velocities and water levels were converted to an ASCII grid format used by the wave model. Current data from HYDROMAP was also fed directly into the dredge model.

1.2 Wave model

Modelling of the waves through Dampier Archipelago was performed with the SWAN (Simulating WAves Nearshore) model. SWAN is a third-generation wave model and therefore accounts for wave generation process within the model domain as well as propagation of waves from the open boundaries. SWAN accounts for most aspects of wave physics including wave breaking, refraction, diffraction, wave setup as well as non-linear wave-wave interactions.

The model is phase-averaging and thus resolves the average wave field parameters over time (as opposed to phase-resolving where the peaks and troughs of individual wave trains are represented). The phase averaging property ensures that the model does not have grid sizing or time stepping issues and can therefore be applied over a large domain for a long period of time with managable computational requirements.

SWAN was run for a two year period for 2005 and 2006. The output of the model was three hourly which coincides with the period of the wave-input boundary data. Model output variables which are important for the calculation of the bottom stress include significant wave height, wave period, wave direction and maximum bottom orbital velocity.

Model data (including each of the above variables) was prepared as a NetCDF format using the COARDS convention for input into the dredge model.

1.2.1 Wave model Grid

A rectangular Cartesian grid (Figure 1) was used in the SWAN model mainly due to various numerical aspects of the model being more refined for this style of grid. In order to account for the effect the islands of Dampier Archipelago have on the wave field, the model domain had to span beyond the most offshore islands in the region. An optimal resolution of 500m was chosen so that most islands and peninsulas could be represented by the model whilst still being able to process the required temporal sample in a reasonable time. One month of data took approximately three days to run per processor. Hence a combined run time of 72 processor-days was required for this data set.

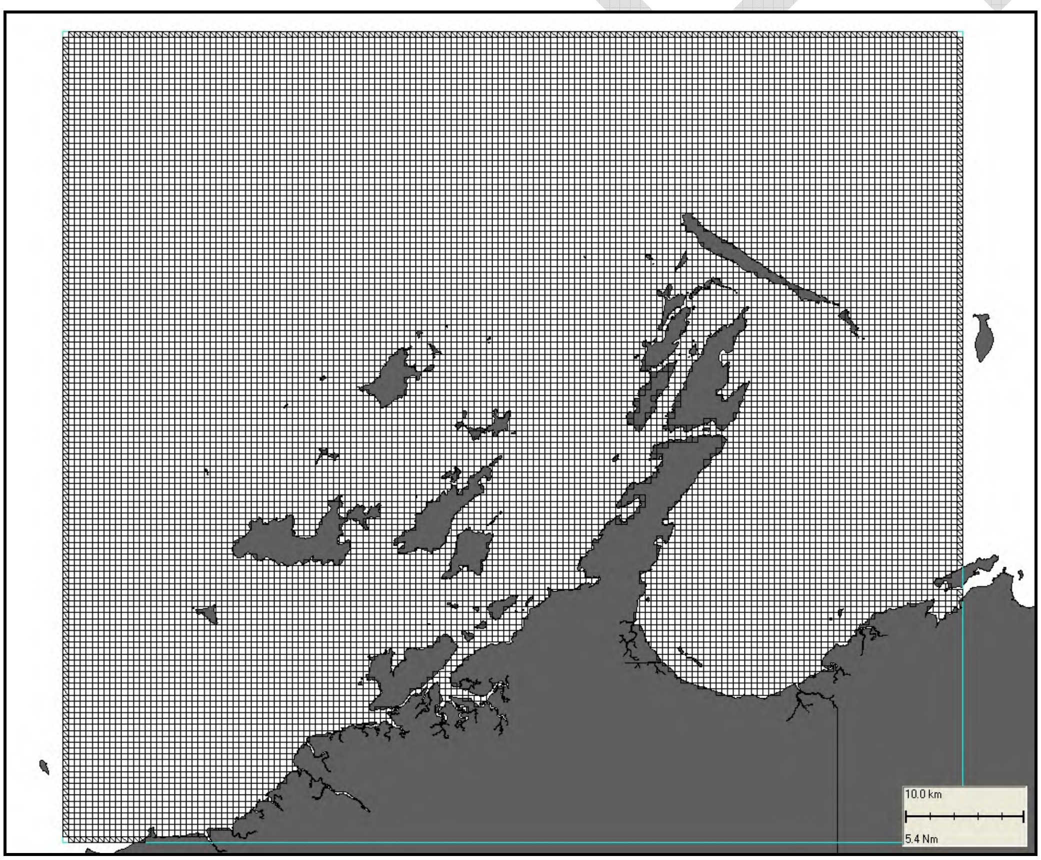

Figure 1: Model domain and grid used for SWAN model.

1.2.2 Wave Model Boundary Conditions

The boundary wave conditions were obtained from the NOAA WaveWatch III global wave model. Data from the adjacent grid point was used to represent conditions for significant wave height, wave period and wave direction at the open boundaries. The location of this point is -20.00° S 116.25° E, approximately 60 km NW of Mermaid Sound. Wind data was also sourced from the global wave model which was originally sourced from the Global Forecast System (GFS). Model boundary data was updated at three hourly intervals.

Analysis of the offshore wave boundary data showed that significant wave heights were generally in the range of 1-2 m but peaked greater than 3m during some events (Figure 2). Waves are predominantly from the southwest which represents swells generated in the southern Indian Ocean. During storm events, where significant wave heights exceed 3m, waves are typically directed from the north. During winter (June –August) offshore waves are directed from the east when the SE trade winds are the strongest at Dampier. Wave periods are commonly lower period seas (4-8 s) from the NE and NW. Swell waves (T > 12s) are only directed from the SW (Figure 3). The scatter plot in Figure 3 shows that only long period waves originate from this direction.

Wind data used to force the SWAN model exhibits good agreement with seasonal trends for the North West Shelf (Figure 4). Both the summer NW monsoon winds and the winter SE trades are represented by the data. Transitional periods such as March, April and October exhibit variable directional winds, as indicated by local measurements.

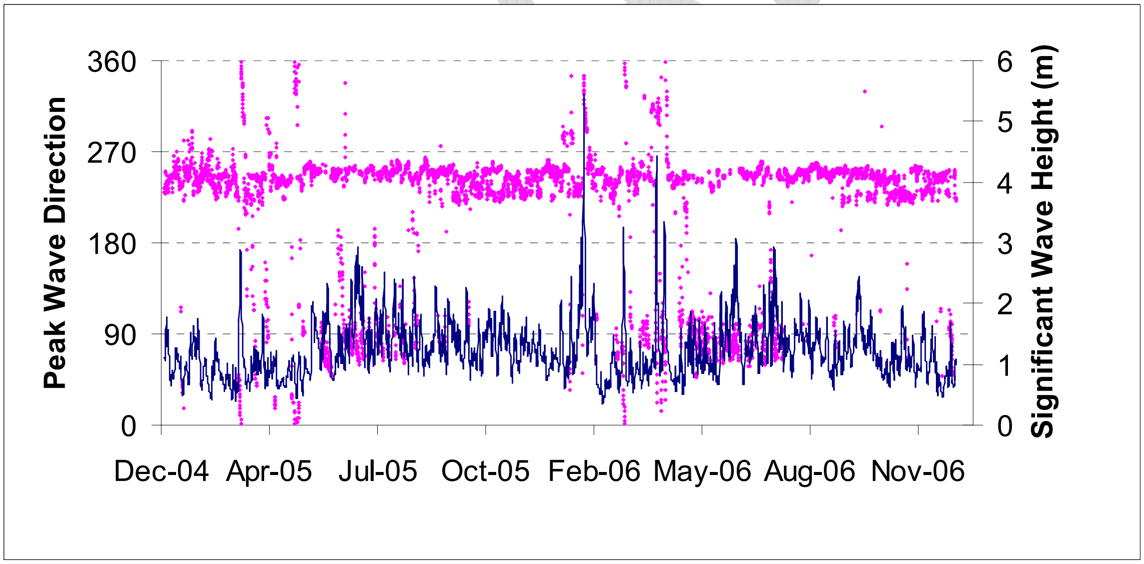

Figure 2: Time series of significant wave height and peak wave direction from the NOAA WaveWatch III model at a point near Dampier Archipelago.

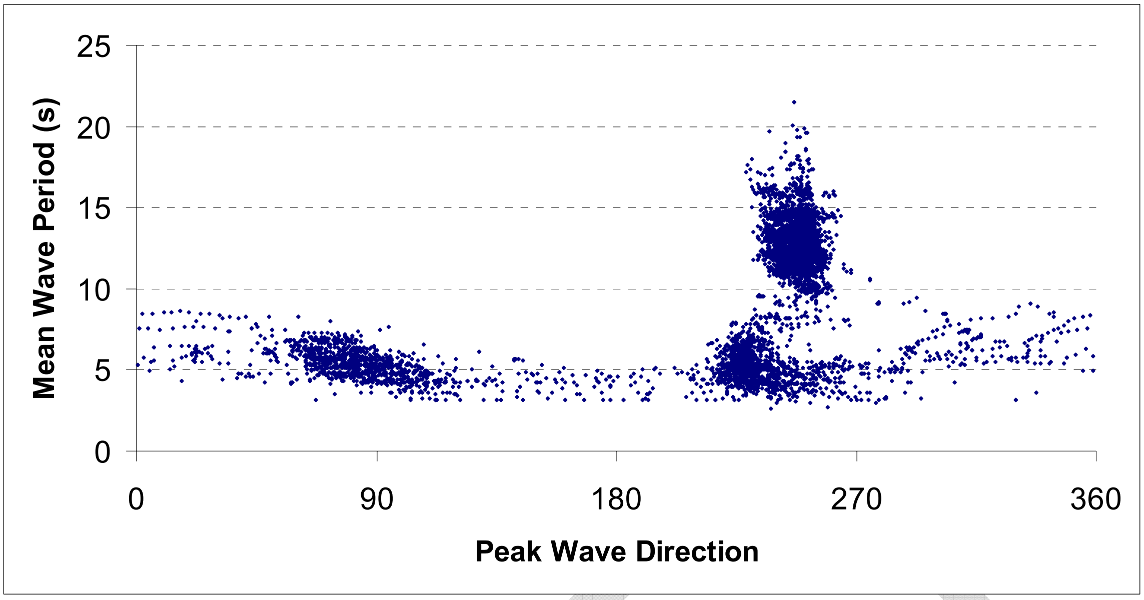

Figure 3: Scatter plot of mean wave period versus peak wave direction from the NOAA WaveWatch III model at a point near Dampier.

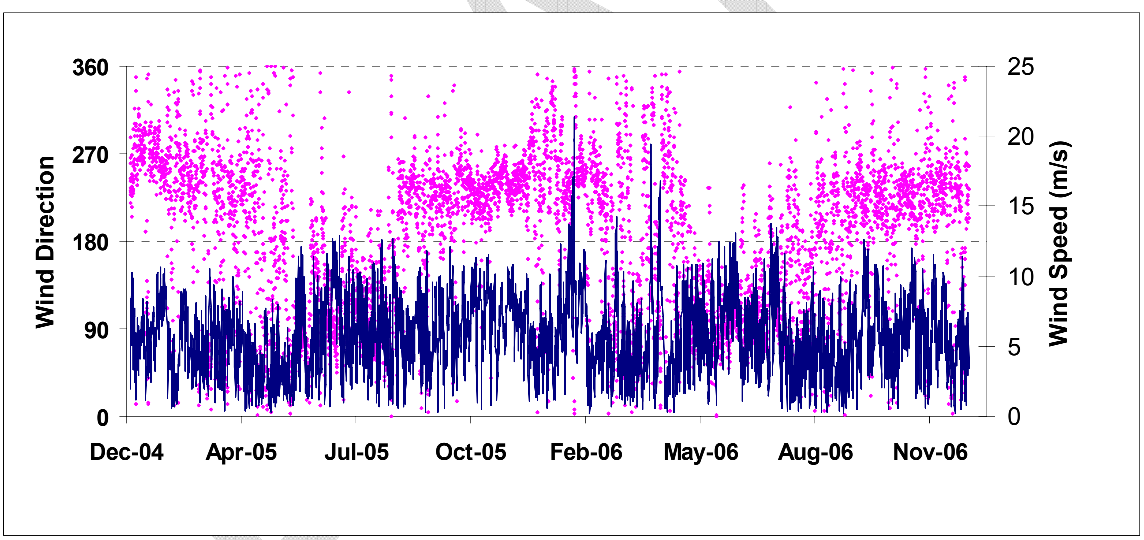

Figure 4: Time series of wind speed and direction from the GFS winds at a point near Dampier.

1.2.3 Input Tides and Currents

The effects of changing water levels and currents are important variables to be included in the wave model. Water levels effect both wave breaking and wave refraction due to alteration of the depth. Currents mainly effect the wave refraction but also contribute to wave setup. Current velocity and water level data were obtained from the HYDROMAP model for use as input into the SWAN model. As the HYDROMAP data did not span the entire wave model domain, certain regions in the model did not account for the effect of tides and currents. These regions were near the SWAN boundary and therefore were not of concern to the final model outcome.

1.2.4 Wave Model Outcomes

Sea breezes are reported to be the dominant mode of wave generation within Dampier Archipelago, with waves and swells tending to occur episodically and independently in any month (Hamilton, 1997). Analysis of a contour plot of the SWAN modeled wave field reveals that longer period swells do not generally propagate into Mermaid Sound (Figure 5). Only very short period (1-2 s) locally generated seas are present in Mermaid Sound. Contour plots of significant wave height reveal that wave energy is dissipated by the islands of Dampier Archipelago (Figure 6). As waves are diffracted by the islands, they diminish in height until they reach the lower reaches of Mermaid Sound. Spoil ground 2B and the northern sections of the trunk line are exposed to a larger proportion of the wave energy propagating from offshore. During intense storms from the north, the wider part of Mermaid Sound is more exposed to higher wave energy.

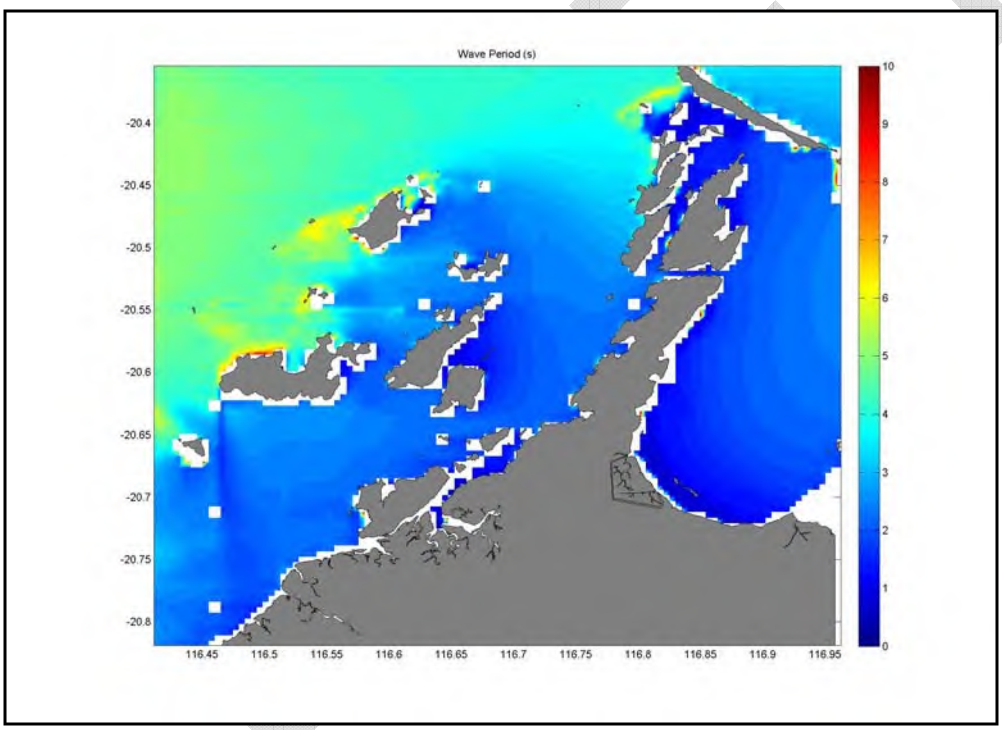

Figure 5: Contour plot of wave period (seconds) from the SWAN model.

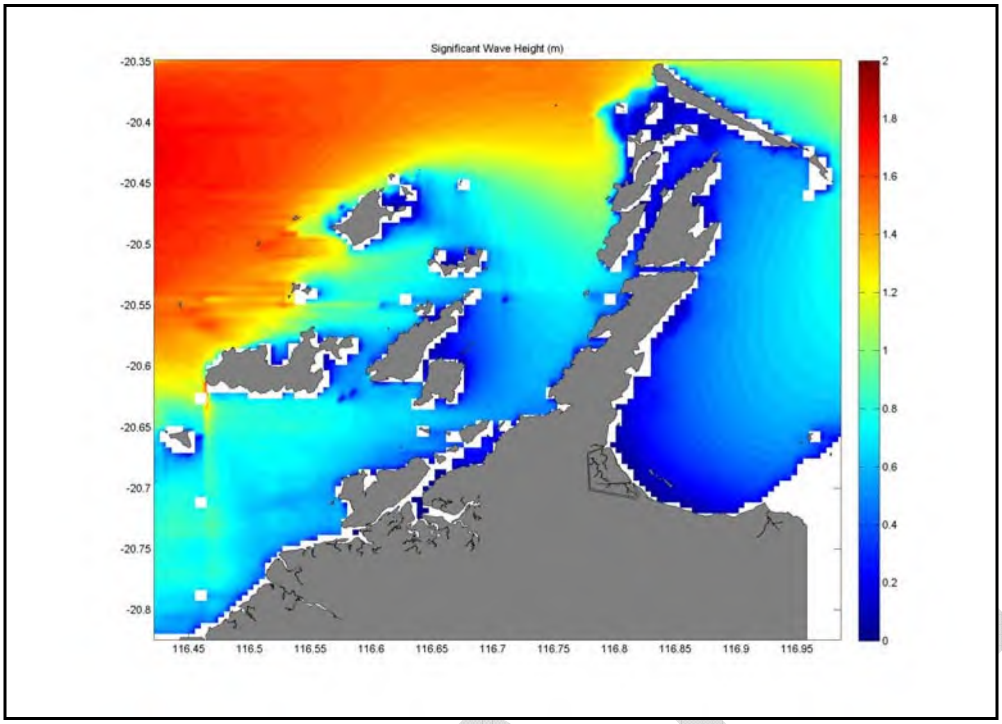

Figure 6: Contour plot of significant wave height (metres) from the SWAN model.

Although the waves within the lower reaches of Mermaid Sound are generally low in amplitude and have a shorter period than offshore conditions bottom-stress calculated from the modeled wave data indicate that they would contribute significantly to sediment resuspension in the Sound. The relative effect of waves on bottom stress is clearly evident from Figure 7, which shows estimates for a location immediately off Holden Point (mean depth 5 m). The bottom stress generated by both currents and waves is considerably larger (τ = 0.1-0.2 Pa) than that generated by currents alone (τ ~0.01 Pa). Current speeds are sufficient to theoretically suspend clays and fine silts (τ > 0.016 Pa) during peak tidal flows. However, currents combined with waves are predicted to generate enough bottom stress to resuspend fine grained sediments for a larger proportion of the time and to resuspend coarser grained sediments from the seabed episodically.

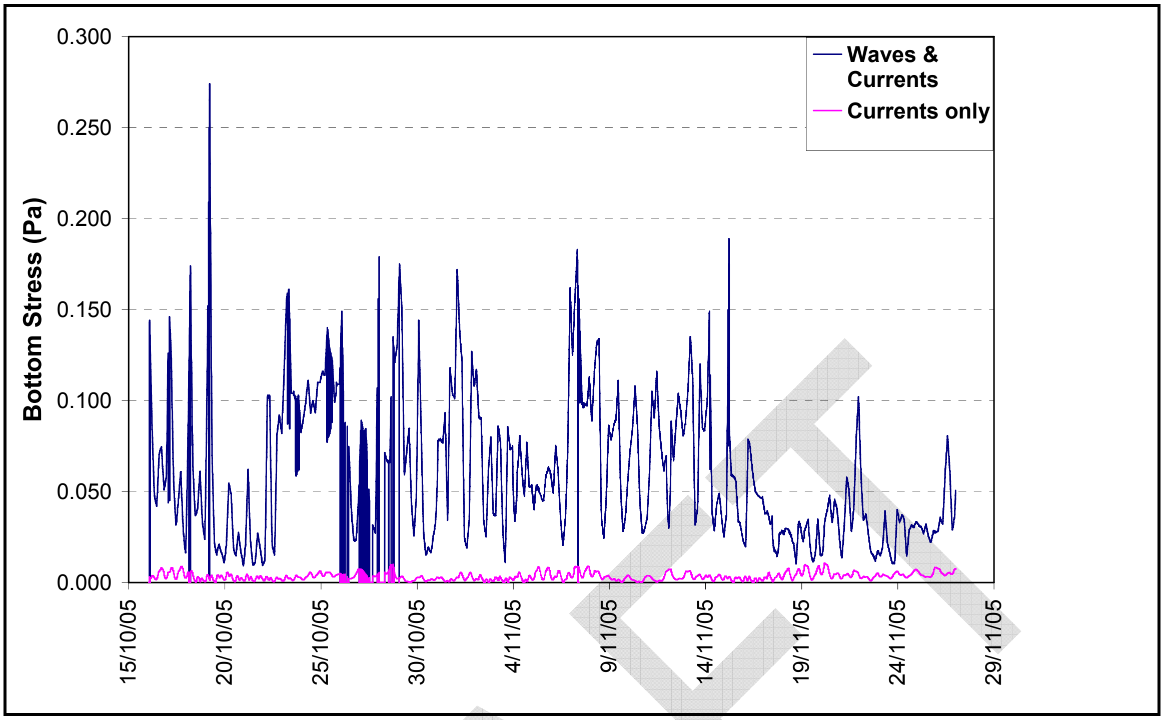

Figure 7: Time series of bottom stress calculated by the SSFATE benthic boundary layer model for a location close to Holden Point.

1.2.5 Wave Model Validation

To validate the SWAN performance, measurements from Mermaid Sound collected by MetOcean Engineers using the Navaid 9 DWR buoy were compared with model results. The buoy was located at 20.5464° S, 116.7164° E in 16 metres of water (Figure 8). The significant wave height H_s, the spectral mean wave period T_{01}, and the mean wave direction recorded by the buoy and hindcast by the model from the same point were compared over a 19 month period extending from January 2004 till July 2005. The wave data for the first half of month of October 2004 were missing, and the wave gauge was removed for a major service in the second half of July 2005. Therefore, these two months were excluded from any further consideration.

A comparison was also carried out of the NCEP GDAS 3-hourly wind analyses from the aforementioned NWW3 grid point and locally available wind speed and direction measurements from Karratha Airport (coordinates 20.7097° S, 116.7742° E).

Time series plots of the wave parameters for example months are presented in Figure 9 and Figure 10, and some monthly validation statistics are exhibited in Table 1, for all months. The statistics in Table 1 (the mean error *ME*, the root mean square error *RMSE*, the scatter index *SI*, and the correlation coefficient *R*) were computed using the following expressions:

$$ME=\frac{\sum_{i=1}^{N}(y_i-x_i)}{N}, \quad (1)$$

$$RMSE=\sqrt{\frac{\sum_{i=1}^{N}(y_i-x_i)^2}{N}}, \quad (2)$$

$$SI=\frac{RMSE}{\bar{x}}, \quad (3)$$

$$R=\frac{\sum_{i=1}^{N}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i-\bar{x})^2\sum_{i=1}^{N}(y_i-\bar{y})^2}}. \quad (4)$$

where x_i is the value observed at the i-th time step, y_i is the value simulated at the same moment in time, N is the total number of data points in the validation, $\bar{x}$ is the mean value of the observations, and $\bar{y}$ is the mean value of the simulations.

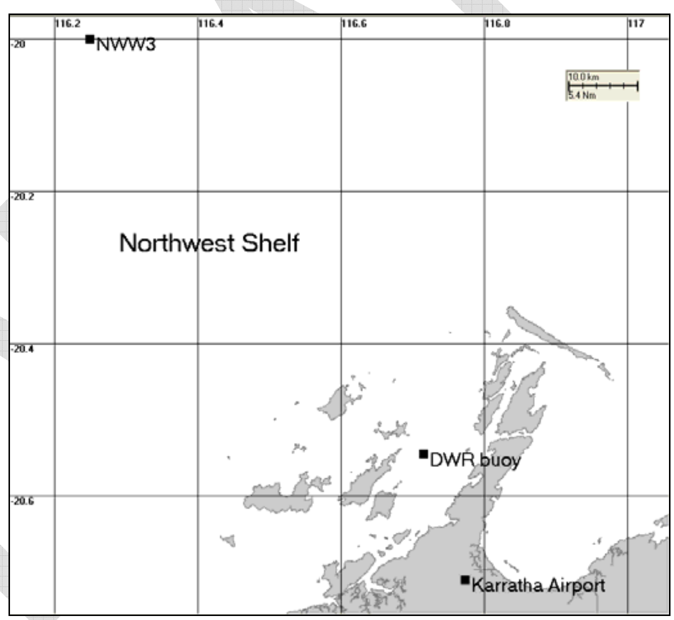

Figure 8: Locations of the observational measurement stations and NWW3 computational grid points.

1.2.6 Validation Results

In general, an analysis of the SWAN wave model outcomes reveals an overall good agreement between the measurements and model results. Figure 9 shows that the modelled wave parameters follow the observed trends and variability of the H_s, T_{01} and wave direction with the peaks well timed (see e.g. the H_s plots for January 2004, March

2005). This conclusion is also confirmed by the validation statistics from Table 1. This highlights that the wave conditions reproduced by the NWWIII global wave model were determining the sea states within Mermaid Sound. There were some local influences, probably local winds, generating local waves at the measurement site that resulted in marginally poorer predictive performance at times (eg. See April and August 2004, and February and April 2005.)

An analysis of the wind model statistics provides a deeper insight into the possible causes of episodic wave model discrepancies. From a wind and wave statistics comparison from Table 1 it follows that the model predicted waves showed highest correlations when synoptic-scale winds were dominating the wave climate. However, relatively only low correlation (> 0.3-0.4) between the NWW3 and local measurements for wind speed and direction were required to give relatively high correlation (0.6-0.9) between modelled and measured waves. Also, there were generally higher correlations between measured and modelled wave directions than between measured and modelled wind directions. One reason for this is that wave directions nearshore are steered by local bathymetry (e.g., under the influence of the refraction and diffraction processes).

For the significant wave height, the values of the *ME* were within the limits of -0.2-0.0m with the *RMSE* staggering between 0.1 and 0.3m. This shows that the bias in the H_s estimates was low. The *SI*, which is an important measure of skill for a wave model, was of order of 0.5-1.0 (with 0 being the theoretical best score). The values of these statistics were in good accord with the results published by other researchers for different areas in the Atlantic and Pacific Oceans (e.g., Guillaume, 1990; Khandekar and Lalbeharry, 1996; Makarynskyy et al., 2001; Pires Silva et al., 2002; Ris, 1997). The value of *R*, which indicates the strength and direction of a linear relationship between two random variables, generally is higher than 0.5, although there are some outliers. The highest correlations were observed in January and March 2004, and March 2005 (Table 1).

The bias in the T_{01} estimates was also low with the *ME* of 1-3s and the *RMSE* of 2-5s. The values of *SI* were of a similar order with the ones calculated for the H_s. The lower values of the correlation coefficients for this wave parameter reflect both its noisier nature - noticed in several wave studies (e.g. Makarynskyy et al., 2005; Makarynskyy and Makarynska, 2007) and some local wind influences in Mermaid Sound.

Notably, the SWAN wave model with forcing functions provided by the NWW3 performed well over the periods of typical seasonal wave conditions, which for the case were January-February and May-June, as well as for a transitional month of March (Hamilton, 1997). This implies that the SWAN model settings are appropriate for the case allowing for capturing the general trends of the sea states behaviour and, therefore, the model can be effectively used in the current dredging studies.

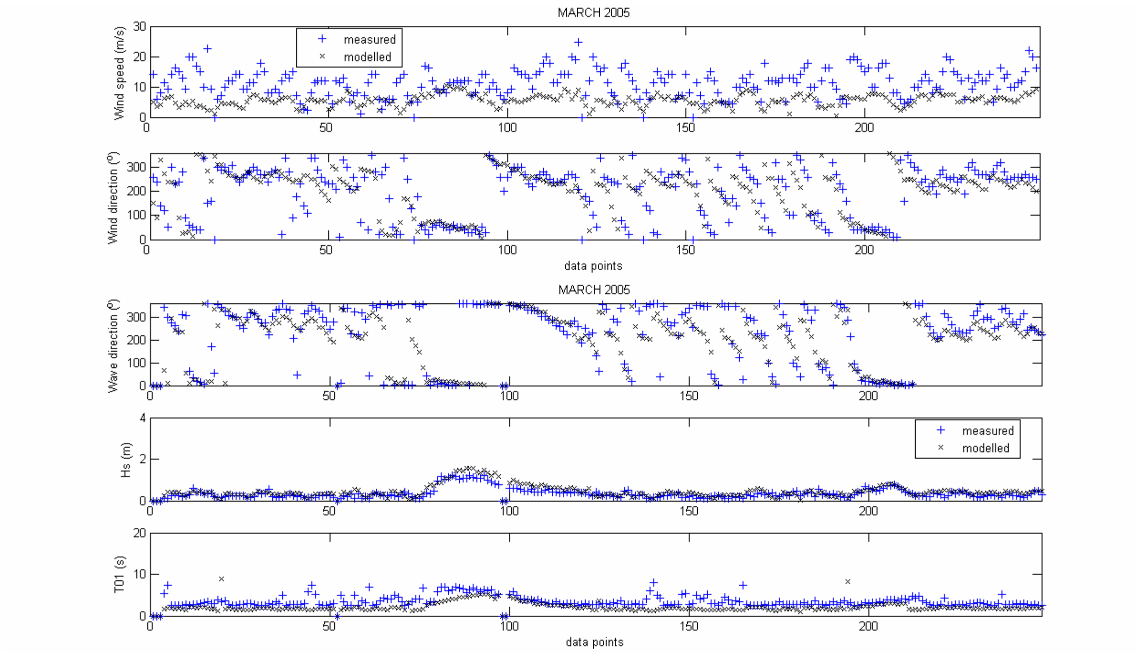

Figure 9: Time series plots of the measured and modelled wind speed and direction, significant wave height, mean wave period and mean wave direction for March 2005.

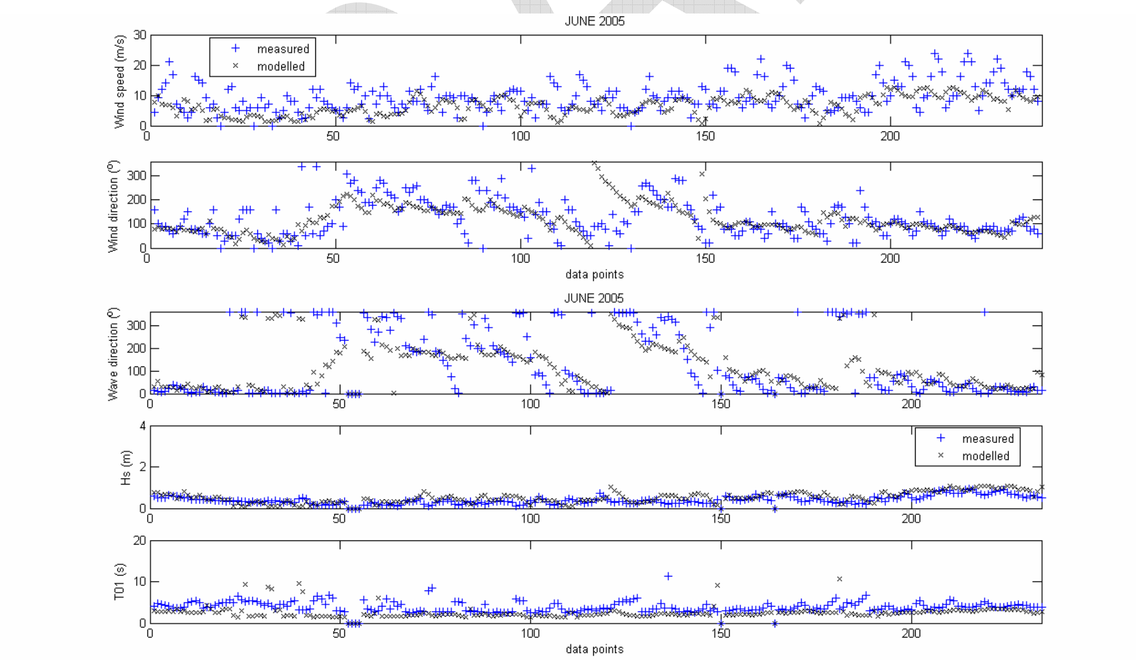

Figure 10: Time series plots of the measured and modelled wind speed and direction, significant wave height, mean wave period and mean wave direction for June 2005.

Table 1: Statistics of NCEP GDAS wind and SWAN wave model hindcast validated against Karratha Airport and DWR buoy measurements, respectively.

January 04	***ME***	***RMSE***	***SI***	***R***
Wind speed	5.95 m/s	7.08 m/s	0.58	0.48
Wind direction	1.02°	N/A	0.40	N/A
Wave direction	13.35°	N/A	0.40	N/A
H_s	-0.10 m	0.18 m	0.47	0.82
T_{01}	1.12 s	1.50 s	0.46	0.37
February 04				
Wind speed	6.18 m/s	7.65 m/s	0.61	0.53
Wind direction	10.96°	N/A	0.42	N/A
Wave direction	15.01°	N/A	0.42	N/A
H_s	-0.12 m	0.23 m	0.58	0.70
T_{01}	1.12 s	1.96 s	0.52	0.28
March 04				
Wind speed	4.75 m/s	7.09 m/s	0.65	0.55
Wind direction	-14.01°	N/A	0.61	N/A
Wave direction	-8.03°	N/A	0.84	N/A
H_s	-0.11 m	0.28 m	0.68	0.80
T_{01}	2.80 s	3.88 s	0.74	0.15
April 04				
Wind speed	4.31 m/s	6.33 m/s	0.72	-0.05
Wind direction	-9.48°	N/A	0.68	N/A
Wave direction	32.05°	N/A	0.72	N/A
H_s	-0.07 m	0.16 m	0.68	0.47
T_{01}	2.60 s	4.40 s	0.87	0.17
May 04				
Wind speed	3.01 m/s	5.59 m/s	0.60	0.34
Wind direction	-7.65°	N/A	0.60	N/A
Wave direction	19.79°	N/A	0.65	N/A
H_s	-0.15 m	0.21 m	0.63	0.61
T_{01}	2.47 s	3.78 s	0.76	0.17
June 04				
Wind speed	1.92 m/s	5.37 m/s	0.66	-0.02
Wind direction	10.18°	N/A	0.60	N/A
Wave direction	57.26°	N/A	0.76	N/A
H_s	-0.18 m	0.24 m	0.70	0.60
T_{01}	3.66 s	4.61 s	0.70	0.37

Table 2 (continued): Statistics of NCEP GDAS wind and SWAN wave model hindcast validated against Karratha Airport and DWR buoy measurements, respectively.

July 04				
Wind speed	3.01 m/s	5.93 m/s	0.64	0.23
Wind direction	1.19°	N/A	0.57	N/A
Wave direction	47.15°	N/A	0.78	N/A
H_s	-0.12 m	0.22 m	0.54	0.56
T_{01}	2.22 s	3.08 s	0.63	0.23
August 04				
Wind speed	3.50 m/s	6.56 m/s	0.64	-0.01
Wind direction	7.21°	N/A	0.51	N/A
Wave direction	62.92°	N/A	0.59	N/A
H_s	-0.20 m	0.28 m	0.83	0.14
T_{01}	2.00 s	3.14 s	0.70	0.01
September 04				
Wind speed	4.82 m/s	6.79 m/s	0.62	0.21
Wind direction	1.56°	N/A	0.41	N/A
Wave direction	43.88°	N/A	0.55	N/A
H_s	-0.17 m	0.24 m	0.75	0.52
T_{01}	2.18 s	3.35 s	0.71	0.20
November 04				
Wind speed	5.51 m/s	7.10 m/s	0.58	0.40
Wind direction	9.94°	N/A	0.40	N/A
Wave direction	29.20°	N/A	0.47	N/A
H_s	-0.13 m	0.19 m	0.67	0.75
T_{01}	1.37 s	2.31 s	0.71	0.41
December 04				
Wind speed	6.59 m/s	7.78 m/s	0.61	0.42
Wind direction	6.80°	N/A	0.42	N/A
Wave direction	28.58°	N/A	0.46	N/A
H_s	-0.13 m	0.21 m	0.64	0.49
T_{01}	1.23 s	2.08 s	0.62	0.17
January 05	*ME*	*RMSE*	*SI*	*R*
Wind speed	5.77 m/s	7.02 m/s	0.58	0.49
Wind direction	-11.39°	N/A	0.41	N/A
Wave direction	23.12°	N/A	0.34	N/A
H_s	-0.10 m	0.16 m	0.47	0.51
T_{01}	1.46 s	2.02 s	0.57	0.13

Table 3 (continued): Statistics of NCEP GDAS wind and SWAN wave model hindcast validated against Karratha Airport and DWR buoy measurements, respectively.

February 05	*ME*	*RMSE*	*SI*	*R*
Wind speed	5.78 m/s	6.99 m/s	0.66	0.46
Wind direction	-9.50°	N/A	0.49	N/A
Wave direction	-5.78°	N/A	0.62	N/A
H_s	-0.01 m	0.18 m	0.59	0.17
T_{01}	1.81 s	2.42 s	0.64	0.29
March 05				
Wind speed	5.78 m/s	7.19 m/s	0.64	0.27
Wind direction	-9.58°	N/A	0.59	N/A
Wave direction	27.94°	N/A	0.58	N/A
H_s	-0.10 m	0.17 m	0.49	0.89
T_{01}	1.37 s	1.87 s	0.54	0.46
April 05				
Wind speed	4.91 m/s	6.44 m/s	0.70	0.20
Wind direction	2.08°	N/A	0.64	N/A
Wave direction	61.43°	N/A	0.70	N/A
H_s	-0.10 m	0.23 m	0.98	-0.05
T_{01}	2.19 s	3.41 s	0.75	-0.01
May 05				
Wind speed	3.88 m/s	6.19 m/s	0.77	0.09
Wind direction	5.38°	N/A	0.70	N/A
Wave direction	27.55°	N/A	0.82	N/A
H_s	-0.01 m	0.17 m	0.49	0.61
T_{01}	2.07 s	3.59 s	0.71	0.29
June 05				
Wind speed	2.96 m/s	5.87 m/s	0.62	0.25
Wind direction	2.83°	N/A	0.59	N/A
Wave direction	20.12°	N/A	0.98	N/A
H_s	-0.12 m	0.23 m	0.59	0.66
T_{01}	1.43 s	2.28 s	0.59	0.13

1.3 Dredge Modelling

1.3.1 SSFATE Background

Sediment dispersion modeling of dredged material was carried out using the SSFATE dredge model (see Swanson et al. 2007). SSFATE is a Lagrangian particle tracking model useful for determining the fate of sediment. Each particle is assigned a mass for the amount of material it represents but is transported based on the properties of a single particle. After the transport calculation stage of the model, the results are applied to an Eulerian concentration grid using a Gaussian distribution of the mass over area. This gives the effect that the particles move as a plume and not as a clump of mass. Horizontal transport of material is due to advection by currents and diffusion. Current velocity fields are imported into the model from a separate hydrodynamic model. Vertical transport is based on particle settling rates and turbulent mixing which the model parameterises with vertical diffusion coefficients. Particle settling velocities are calculated using Stokes' law and through the complex processes of flocculation due to cohesiveness.

Deposition is based on a probability which is a function of bottom stress and concentration. Matter that is deposited can be resuspended if the critical bottom stress is exceeded. The model employs two different resuspension algorithms. The first applies to material deposited in the last tidal cycle (12 hours) and is from Lin et al. (2003). It accounts for the fact that newly deposited material will not be consolidated and will therefore resuspend with less effort than consolidated bottom material. The second algorithm is the Van Rijn method (Van Rijn, 1989) and applies to all other material that has been deposited prior to the start of the last tidal cycle. Swanson et al. (2007) summarise justifications and tests for these schemes.

The characterization of different dredge types is represented by the initial vertical distribution of released material as well as the sediment grain size distribution. For example the majority of sediment release from a trailer suction dredge is due to overflow of fine material. Therefore the initial vertical distribution of material is set to release near the surface and the grain size distribution is biased towards the finer material.

1.3.2 Benthic Boundary Layer Model

SSFATE applies a benthic boundary layer model for the calculation of bottom stress, which drives sediment resuspension. For the case where there are only currents, the quadratic friction law is used to calculate seabed stress which has the form:

$$\tau_c = \rho C_d u_c^2$$

where τ_c is the seabed stress due to currents, ρ is the density of seawater, u_c is the current at the seabed and C_d is a friction coefficient (0.003 was used by SSFATE). If a wave field is applied to the model, bottom stress is calculated using the method in Soulsby (1997) which accounts for the non-linear wave-current interactions.

The maximum stress at the seabed $\tau_{cw,max}$ is given by:

$$\tau_{cw,\max} = \sqrt{(\tau_{cw} + \tau_w \cos\varphi_{cw})^2 + (\tau_w \sin\varphi_{cw})^2}$$

where,

$$\tau_{cw} = \tau_c (1 + 1.2\left(\frac{\tau_w}{\tau_c + \tau_w}\right)^{3.2})$$

$$\tau_w = 0.5 f_w \rho u_{bm}^2$$

$$f_w = \min[1.39\left(\frac{A_w}{z_0}\right)^{-0.52}, 0.3]$$

$$A_w = \frac{u_{bm}}{\omega}$$

τ_w- bottom stress due to waves only
φ_{cw} - angle between the waves and the currents
f_w – wave friction factor
u_{bm} – maximum bottom wave orbital velocity
T – wave period
z_0 – depth at which velocity is zero (~ less than 0.1m)
ω – wave number (2π/T)

This scheme is a parametric approximation of other boundary layer models. Parameters were calibrated to give an approximate solution to the results of these models. The advantage of this method is that it does not involve any iterative solutions for friction coefficients, thus greatly reducing computational requirements. The Soulsby (1997) scheme for calculating seabed stress from waves-current interactions is also used in the Regional Ocean Modelling Systems (ROMS), a widely accepted model in the international scientific community.

1.3.3 SSFATE Model Scenarios

The sediment transport model SSFATE was used to simulate the effects of dredging on the marine habitat of Dampier Archipelago. Simulations represent key dredging activities. They were chosen based on the amount of activity occurring in an area as well as the proximity to sensitive habitats. For example, simulations for dredging of the turning circle represented the bulk of activities immediately off Holden Point, and the most intensive operation of the wider campaign. The simulations allow testing of various aspects of the dredging impacts for the proposed program. For example, testing of resuspension influences on the potential for subsequent exposure to sensitive receptors, or for accumulation in relatively quiet areas, for inputs at key locations.

The effect of sediment dispersion from dredging activities, and subsequent resuspension by waves and currents, was simulated for three main scenarios:

1) dredging of the turning circle near Holden Point, (summer conditions specifically chosen as worst case);
2) trailer suction dredging of the gas trunk line along the Eastern edge of Mermaid Sound; and
3) dumping of fine material into offshore spoil ground 2B (winter conditions specifically chosen as worst case)

Figure 11 highlights the areas of each dredging and disposal operation.

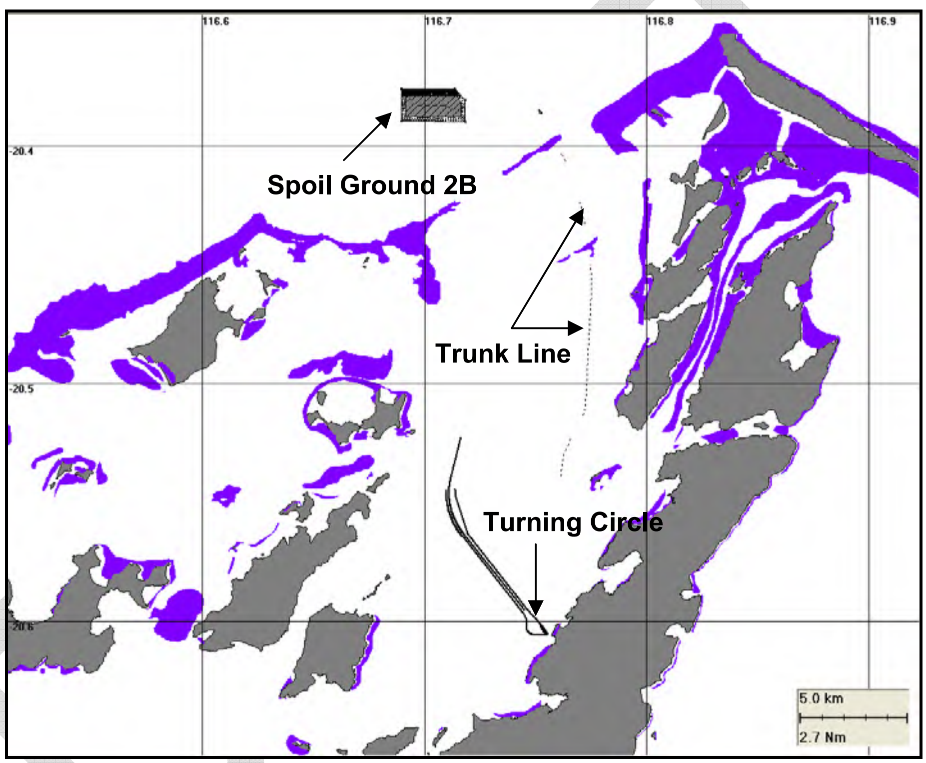

Figure 11: Locations of regions of concern for dredge modeling. Regions coloured purple are known locations of reefs supporting various BPP assemblages.

Simulations of the trunk line dredging and dumping into the spoil ground involved one type of operation, whereas activities within the turning circle involved multiple activities occurring simultaneously. The turning circle activities involved:

- Trailer suction dredging of any unconsolidated material
- Cutter suction dredging of the inner rock margin and discharging the material via a diffuser pipe into a pit
- Trailer suction dredge extracting material from the pit

- Cutter suction dredging of harder material within the turning circle and discharging directly to the seabed

- Trailer suction dredge collecting discharged CSD material from the turning circle

- Propeller wash generated by repeated, pulsed, movements of trailer suction barges moving over the shallow grounds leading to the shipping channel (for transport of spoil to the offshore ground).

The simulation covered 6 weeks of discharge from multiple sources of suspension. (Figure 12 shows the proportion of the entire operation over the turning circle and shipping berth). Wave and current data from October and November were applied as this is the period when this operation is currently proposed (Figure 12). The trunk line operation was also modelled for six weeks, but using wave and current data from February and March (Figure 13). The disposal into spoil ground 2B was simulated over a four week period, with the model ran on for a further 4 weeks to specifically address resuspension of sediments and subsequent retransport. Wave and current data from April and May (Figure 14) were used because winter winds were considered worst case for sensitive receptors closest to the site.

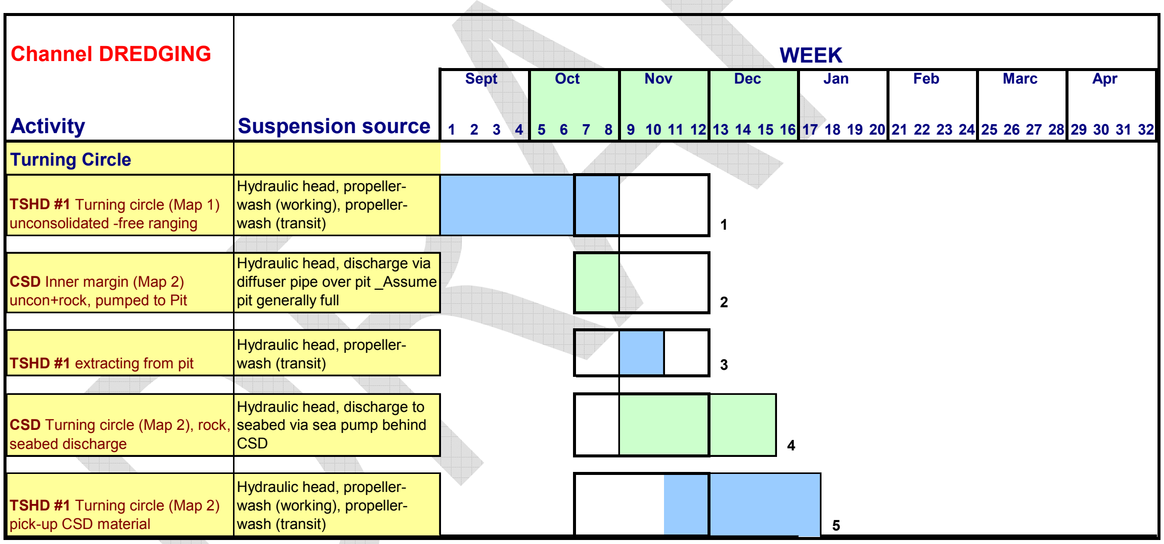

Figure 12: Timeline of the dredging operation within the turning circle. Six week period with border from weeks 7 - 12 is the time selected for modelling, because this was a period when all operations are running concurrently.

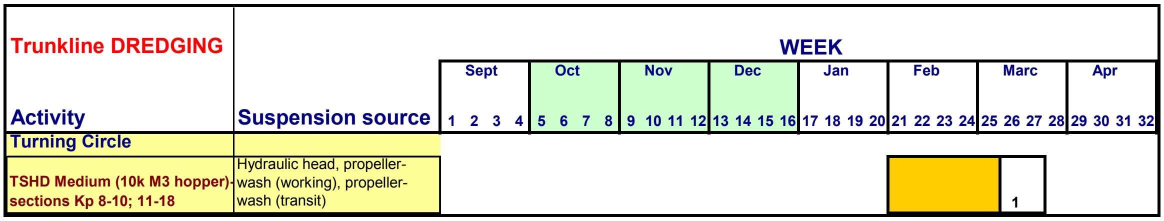

Figure 13: Timeline of the dredging operation for the trunk line. Period from weeks 21-26 is when the model was run. This period extended 2 weeks beyond the operation to test for resuspension of material.

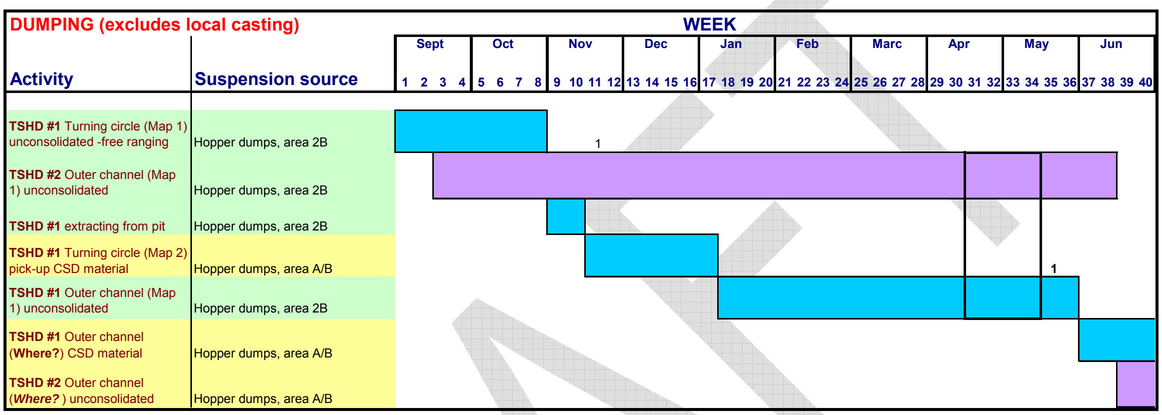

Figure 14: Timeline of the dumping operation. Period from weeks 31-34 is when the dredge model was set to discharge. The simulation was continued for 1 additional month to test resuspension of material under sample winter wind/wave conditions.

1.3.4 Characterisation of Different Dredging Operations

Each dredge type is a source of suspended sediment generation through overflow, direct loss at the dredge source, direct discharge to the water column or through propeller induced suspension. A loss rate was defined as a percentage of the total production rate for each dredge type and was based on of the above processes by which sediment was discharged into the water column. The sediment grain size distribution will vary based on the way the material is discharged into the water column and also by the sediment mixture of the region being dredged.

<u>Trailer suction dredging of unconsolidated material</u>
This operation occurs at the start of the dredging in the turning circle and involves a trailer suction dredge circling at a speed of 2 knots collecting material and transporting it to the spoil ground. The barge takes approximately one hour to fill and two and a half hours to transport the material to the dumping ground before returning. Sources of sediment suspension are through overflow and propeller wash. The loss rate was assumed to be a relatively conservative rate of 3% of the total production rate of 900 m^3/hr (APASA, 2006). Suspended material was skewed towards the finer material (Table 4) and the vertical distribution of material was concentrated higher in the water column (Table 5) to ensure current drift during initial settling was not underestimated.

Table 4: Sediment grain size distribution for TSHD of unconsolidated material

Classification	Passing Size (µm)	% of Total
Clay to medium silt	30	60
Coarse Silt	70	35
Very fine to fine sand	100	5
Fine to medium sand	200	0
Medium sand	500	0
Coarse sand	1000	0

Table 5: Initial vertical distribution of sediments in the water column setup by overflow of the TSHD vessel

Height above seabed (m)	% of suspended sediments
12	29
8	23
6	13
2	17
1	18

Cutter suction dredging with discharge via diffuser pipe

This operation involves cutting rock within the shallow inner margin of the turning circle and discharging the material via a pipe into a pit. The sediment is discharged via a diffuser plate approximately 5m above the seabed. There are two separate sources of sediment release, one at the cutter head and the other at the pit. The loss rate at the cutter head is assumed to be 0.3% of the total production rate of 1200 m^3/hr (APASA, 2006). The grain size distribution of lost material from the cutter suction dredge is heavily biased towards fines (APASA, 2006) (see Table 6). The vertical distribution of released sediments was closer to the seabed due to the discharge practice proposed to reduce the spread of fines.

Table 6: Grain size distribution of material lost at the cutter head of a cutter suction dredge

Classification	Passing Size (µm)	% of Total
Clay to medium silt	30	96
Coarse Silt	70	4
Very fine to fine sand	100	0
Fine to medium sand	200	0
Medium sand	500	0
Coarse sand	1000	0

Table 7: Initial vertical distribution of sediments in the water column setup by loss from the cutter suction dredge

Height above seabed (m)	% of suspended sediments
10	5
7	15
3	20
2	40
1	20

Material released into the pit via the diffuser pipe was a mixture of coarse and fine material (Table 8). The majority of the initial vertical distribution was centered around 5m above the seabed. However, to allow for the effects of billowing and to be conservative some material was released higher in the water column (Table 9).

Table 8: Grain size distribution of cutter suction material released via diffuser pipe into pit

Classification	Passing Size (µm)	% of Total
Clay to medium silt	30	43
Coarse Silt	70	21
Very fine to fine sand	100	11
Fine to medium sand	200	5
Medium sand	500	8
Coarse sand	1000	12

Table 9: Initial vertical distribution of sediments in the water column released via a diffuser pipe into a pit

Height above seabed (m)	% of suspended sediments
15	15
10	20
5	40
2	20
1	5

Trailer suction dredging of CSD material

Both the trailer suction dredging of CSD material from the pit and from the turning circle, have similar characteristics. Both have the same production rate of 690 m^3/hr and the same time to fill the barge. The key difference is that the dredge working the pit is nearly stationary whilst it picks up material. The vertical distribution of overflow material is the same as the previous trailer suction operation (Table 5). Although the trailer suction dredge collects the same material as that discharged by the cutter suction dredge, the grain size distribution is biased towards the fines (Table 10) to represent material lost due to overflow.

Table 10: Grain size distribution of cutter suction material lost via overflow from a trailer suction barge

Classification	Passing Size (µm)	% of Total
Clay to medium silt	30	56
Coarse Silt	70	32
Very fine to fine sand	100	8
Fine to medium sand	200	4
Medium sand	500	0
Coarse sand	1000	0

Cutter suction dredging of the turning circle

This operation involves cutter suction dredging of harder, consolidated material and discharging it via an underwater pipe to the seabed. The dredge has a production rate of 1200 m^3/hr. The discharged material has the same grain size distribution as that which was discharged into the pit (Table 8). The vertical distribution was biased towards the seabed, reflecting the discharge height, but with a proportion released towards the surface to account for billowing of the plume.

Table 11: Initial vertical distribution of sediments discharged via an underwater pipe from a cutter suction dredge

Height above seabed (m)	% of suspended sediments
10	5
7	15
3	30
2	50
1	11

Disposal of material into spoil ground 2B

This operation involved two trailer suction barges alternately dumping into spoil ground 2B. The amount of solid material being dumped each time was 2500 m^3 and dumps occurred randomly every one to three hours. The material was based on the finest mixture found in the SKM sampling (see APASA, 2006). The material had a strong bias towards the finer sediments, with coarser material being evenly distributed (Table 12). The initial vertical distribution from hopper dumping operations tend to be have a distribution spread higher in the water column, but concentrated in the lower half of the water column due to entrainment by the rapid sinking of heavier components (Table 13; Swanson et al. 2004).

Table 12: Grain size distribution of material being disposed into spoil ground 2B

Classification	Passing Size (µm)	% of Total
Clay to medium silt	30	55
Coarse Silt	70	26
Very fine to fine sand	100	12
Fine to medium sand	200	2
Medium sand	500	2
Coarse sand	1000	3

Table 13: Initial vertical distribution of sediments being disposed into spoil ground 2B

Height above seabed (m)	% of suspended sediments
12	15
8	20
6	25
2	29
1	11

Trailer suction dredging of the gas trunk line

The final operation involves trailer suction dredging of unconsolidated sandy material along the trunk line route. The procedure of this operation involves the dredge moving slowly along picking up material and transporting it to the spoil ground. The speed of progress was expected to be 3.5km/week. The production rate was expected to be 2000 m^3/hr in the first two sections of the trunk line and 3000 m^3/hr in the latter two sections where material is less consolidated. The loss rate due to overflow was assumed to be 0.3% and this was due to the mixture comprising of higher amounts of sand (Table 14). The vertical distribution of material from overflow was the same as for other trailer suction activities (Table 5).

Table 14: Grain size distribution collected by trailer suction dredge working along the trunk line route

Classification	Passing Size (µm)	% of Total
Clay to medium silt	30	60
Coarse Silt	70	35
Very fine to fine sand	100	5
Fine to medium sand	200	0
Medium sand	500	0
Coarse sand	1000	0

1.3.5 Propellor Wash Parameterisation

The simulation of dredging of the turning circle also took into consideration the effect of propeller wash generated by barges traversing between the dredge site and the spoil ground. In order to properly quantify the amount of material suspended, two separate methods were tested. Both methods are based on the findings in Damara (2004) however they do used different approaches.

The first method which was used in APASA (2006; PER document), involved replicating the suspended sediment profile in the water column estimated by Damara (2004) after a vessel travels past. The barge was estimated to travel at 12 knots and have an under keel clearance of between 2-5m depending on the state of the tide and the depth. The vertical concentration profile of suspended sediment for a vessel traveling at this speed was approximately 150 mg/L at the seabed and decreasing linearly to approximately 90 mg/L at the surface. In order for the model to replicate these concentrations, the production rate and initial vertical distribution of sediments were adjusted. The problem identified with this method is that water column concentration in SSFATE are calculated as an average over an Eulerian grid cell with a resolution of 100x100x3m. Subsequently, it was identified that this method grossly overestimated the sediment mass being released – hence previous predictions were an overestimation of propeller-wash input.

The revised approach involved estimating the total amount of mass suspended by propeller induced currents during each traverse. The approach involved estimating the flux of sediment from the seabed and converting it to total mass based on the area covered by propeller-wash during the transit (based on effect width reported by Damara 2004 and the length of the transit) and the amount of time required to complete the transit (based on the speed and distance). Sediment flux from the seabed was estimated from propeller-wash velocities reported by Damara 2004, using methods from Van Rijn (1989) which is also the method used to calculate resuspension rates by SSFATE (Swanson et al., 2007). The estimated total mass released during each transit was used as the dredge production rate for each transit in the mode, assuming 100% release to the water column. Van Rijn calculations indicated that the total mass released is highly sensitive to bottom velocity due to propellers. Damara (2004) indicates that propeller induced velocities for a vessel traveling at 12 knots with an under keel clearance of 3 m will be 0.5-0.6 m/s. In order to be conservative and to allow for errors in assumptions, a value of 0.8 m/s was chosen as the propeller induced velocity at the seabed.

Calculations of suspended sediment using the Van Rijn method revealed that the first method was releasing more than 20 times more sediment than would actually occur. If a propeller induced bottom velocity of 0.5 m/s was used the amount of sediment released was over 100 times less than the initial estimation. The production rate in the model was reduced by a factor of 20 in order to be conservative.

1.3.6 Vertical Mixing

The addition of energy to a shallow coastal environment through tides and waves, results in dissipation through bottom friction and turbulent mixing of the water column. The diffusion ([m^2/s]) is the model parameter which describes the degree of turbulent mixing. The vertical diffusion profile is particularly important as it is the only parameter within the model which determines upward transport of dredged material. The amount of turbulence affects the vertical concentration profile of suspended sediment in the water column. Obviously the more sediment that stays higher in the water column, the higher probability there is that it will be advected further by currents.

There is no literature on vertical turbulence estimates within Dampier. Katsumata (2006) estimates that the energy dissipation due to tides on the North West Shelf results in a vertical diffusivity of the order 10^{-4}-10^{-3} m^2s^{-1}. Results of that study were quantified using a large scale numerical model and are not based on any field data, other than to compare tidal magnitudes. However, this work did provide a range of vertical diffusion values to base the sediment transport model upon. The only field study which model results could be based upon was from measurements of suspended sediment after a dredging operation in Dampier by Stoddart and Anstee (2004). Measurements concluded that suspended sediment concentrations were well mixed in the near and far field of the dredging operation.

Four estimations of the vertical diffusion profile were tested. These were: a constant profile; a profile from Pritchard (1960); a profile from van Rijn (1986); and a user defined distribution to replicate a well mixed concentration profile of suspended sediment in the water column. Figure 15 illustrates the vertical diffusion coefficients throughout the water column using different methods. The value for the constant profile was set to 10^{-3} m^2s^{-1}. The Pritchard vertical diffusion profile accounts for the effects of currents only and requires a value for the Richardson number which is a dimensionless term describing the density stratification in the water column. This was given a value 0.1, typical for a well mixed water column. Values of vertical diffusion ranged between 10^{-7} m^2s^{-1}–10^{-4} m^2s^{-1}. The profile from van Rijn (1986) accounts for both waves and currents. It was developed based on suspended sediment concentrations under waves and currents in laboratory conditions. Vertical diffusion values ranged from 10^{-5} m^2s^{-1} at the seabed to 10^{-1} m^2s^{-1} using wave and current conditions representative of Mermaid Sound. The final more conservative profile was based upon the Pritchard values but an order of magnitude greater to be in better agreement to the range specified by Katsumata (2006).

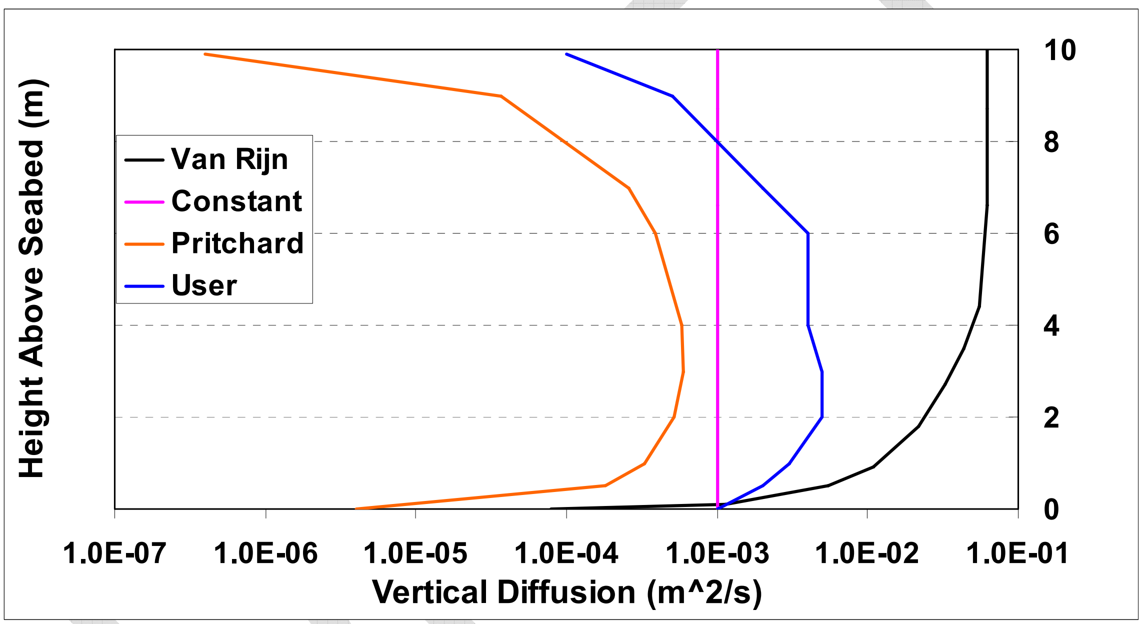

Figure 15: Different vertical diffusion profiles tested in SSFATE. Note that the Pritchard profile will vary with current speed.

Test simulations were run to determine the effect of changing the vertical diffusion profile on the concentration of particles in the water column (Figure 16). Results indicated that the constant coefficient and the Pritchard profile concentrated particles near the seabed, with the effect that transport rates are reduced. The van Rijn profile resulted in particles mixing into the surface layer, however it did tend to restrict the horizontal transport of material other than clay. The more conservative diffusion profile forced the greatest amount of mixing of sediment throughout the water column. It also forced sediment to spread further horizontally, thus the total area affected by sedimentation and suspended sediments was greater in SSFATE predictions. This latter vertical diffusion profile was ultimately chosen for use in SSFATE for operations within the shallower waters of Mermaid Sound, because it provided a conservative estimate for the area impacted by dredging, and providing a good replication of the vertical suspended sediment profile measured by Stoddart and Anstee (2004). The more conservative profile was considered a gross overestimate for the deeper waters of the dump site as this method predicted a high concentration of clay would be forced into the surface water layer, overstating the influence of wave energy penetrating to the depths of this site. This profile was adjusted to have a lower diffusion at the bottom (1.0×10^{-5}).

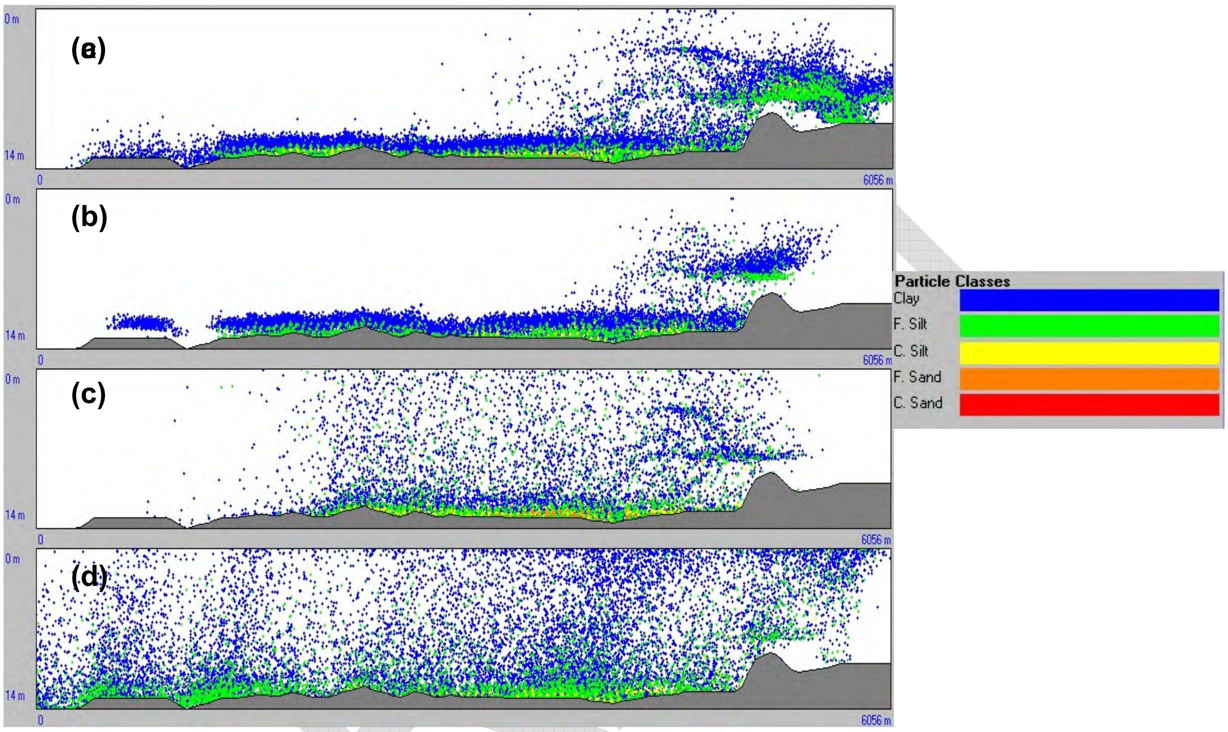

Figure 16: Vertical cross-section of suspended particles using different vertical diffusion profiles. (a) Constant (b) Pritchard (c) Van Rijn (d) User specified profile. Results are from test simulations and show the influence on the vertical distribution and horizontal transport predicted for particles of different size.

1.3.7 Post-processing model results

The SSFATE records a 3 dimensional field of SSC and sedimentation on an hourly time-step. This data was post-processed to apply an array of thresholds of influence defined by SKM and MScience, to derive zones of effect.

Multiple thresholds have been applied, allowing for sensitivity analysis, and comparison to field measures of impact.

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Pluto LNG DEVELOPMENT

Public Environment Report / Public Environmental Review

Supplement and Response to Submissions

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WOODSIDE

PLUTO LNG DEVELOPMENT
PUBLIC ENVIRONMENT REPORT/ PUBLIC ENVIRONMENTAL REVIEW – SUPPLEMENT AND RESPONSE TO SUBMISSIONS

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1. Introduction

The purpose of this document is to respond to public and government submissions on the Pluto LNG Development Draft Public Environment Report/ Public Environmental Review (Draft PER). The Draft PER was published by Woodside Energy Ltd. (Woodside), as proponent (owner and operator) of the proposed Pluto LNG Development, for public review for a period of ten weeks from 11 December 06 through to 19 February 07.

The Draft PER and PER Supplement and Response to Submissions (this document) make up the Final PER and will be provided to the Western Australian Environmental Protection Authority and Commonwealth Department of the Environment and Water Resources (formerly the Department of the Environment and Heritage) for assessment.

The PER Supplement and Response to Submissions consists of two sections which outline:

- modifications to the development concept since the Draft PER was published
- list of public and government submissions, comments and Woodside's responses.

2. Development Update

Section 4 of the Draft PER describes each of the key infrastructure elements of the proposal. Since the publication of the Draft PER in December 2006 front end engineering and design (FEED) has advanced, resulting in some modifications to the development concept. The following sections describe the key changes to the development scope.

2.1 Disturbance Footprint

As described in Section 4.7.2 of the Draft PER the gas processing facility will be located at Site B (approx. 130 ha in size) in an area gazetted by the State of Western Australia for industrial use. Since the publication of the Draft PER further engineering studies have indicated a need to change the Site B disturbance footprint due to:

- incorporation of 3D site digital terrain model (DTM) data in cut-to-fill estimates
- allowance for domestic gas (Domgas) pipeline corridor linkup to the gas processing facility
- revision of access required for transportation of plant modules from the Dampier Port Authority Material Offloading Facility to Site B.

Further changes to that footprint may be necessary as engineering studies progress.

These changes to the Site B disturbance footprint result in an increase in vegetation clearing from approximately 66 ha, as presented in the Draft PER, to approximately 90 ha. The difference between the disturbance footprints is shown in **Figure 1**.

The change in the Site B disturbance footprint results in changes to both the regional vegetation analysis and the local vegetation analysis presented in Section 9.3.1 of the Draft PER.

The resultant increase in impacts on significant regional vegetation associations is presented in **Table 1**, which is a revised version of Table 9-6 of the Draft PER. As shown in **Table 1**, the increase in clearing of vegetation associations recorded by Trudgen (2002) are generally less then 30%, with the exception of the following:

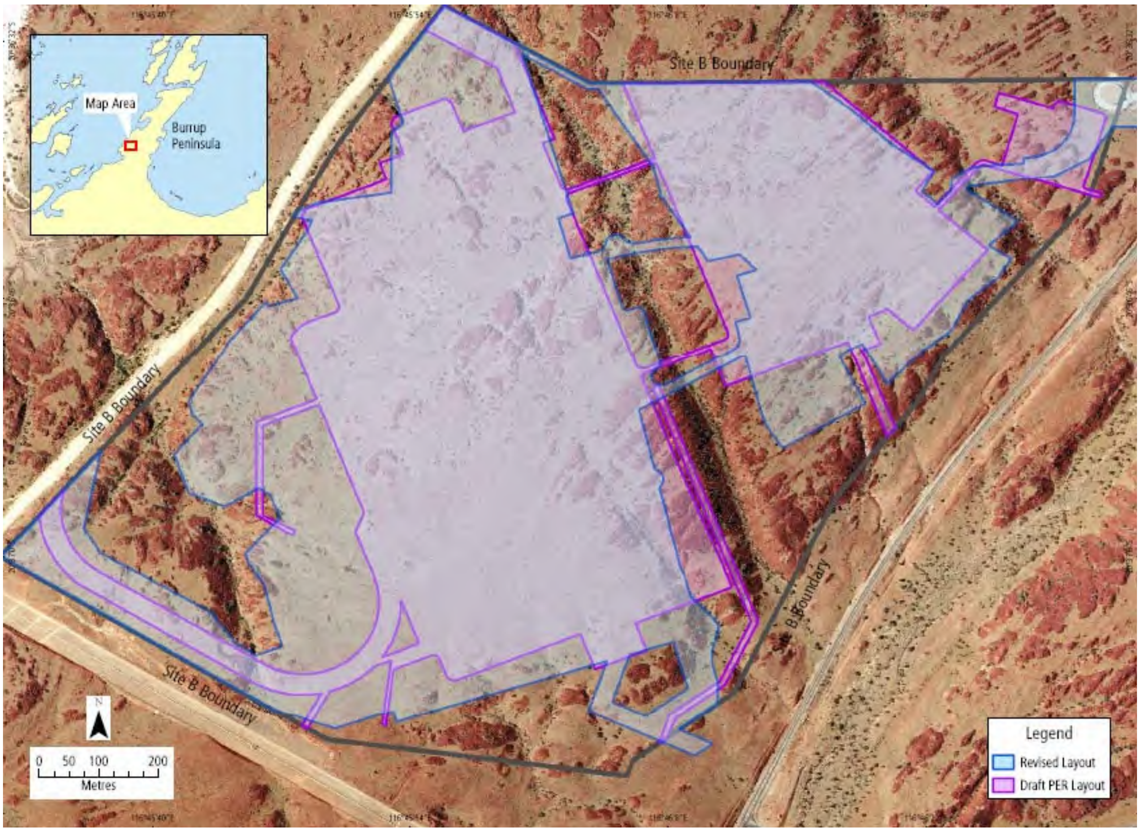
- vegetation association TeRm increases by 38.6% to 0.14 ha to be cleared
- vegetation association TeCa increases by 42.3% to 2.40 ha to be cleared
- vegetation association AcCaTe increases by 72.7% to 0.45 ha to be cleared

Note these percentages represent the extent of clearing of these vegetation associations within Site B. Despite the change in disturbance footprint, most vegetation associations of regional conservation significance will have more than approximately 75% of their regional extent remaining on the Burrup Peninsula. Three vegetation associations will have less then 75% of their regional extent remaining after clearing for the Pluto LNG Development:

- vegetation association AbCc'Te - 19.3% remaining compared to 35.2% remaining in Table 9-6 of the Draft PER
- vegetation association AcImTe/TeCa - 16.4% remaining compared to 14.4% remaining in Table 9-6 of the Draft PER
- vegetation association TeEtSg - 74.4% remaining compared to 89.6% remaining in Table 9-6 of the Draft PER.

The changes in the Site B disturbance footprint also affect potentially locally restricted vegetation associations. **Table 2** is a revised version of Table 9-7 in Section 9.3.1 of the Draft PER and demonstrates the changes in clearing requirements of potentially locally restricted vegetation associations (as described in Section 8.3.2.3 and 9.3.1 of the Draft PER). Local vegetation associations are considered potentially locally restricted when they cannot be easily compared to regional vegetation associations mapped by Trudgen (2002).

As demonstrated in **Table 2**, the change in disturbance footprint in the northern half of Site B is minor, resulting in slight increases to the clearing of vegetation associations recorded in Site B North by ENV (2006) (2 to 4% increase in clearing).



- **Figure 1: Draft PER and Revised Disturbance Footprint at Site B**

Table 1 Changes in Disturbance to Site B Vegetation Associations Recorded by Trudgen (2002)

Conservation Significant Vegetation Associations	Total Area in Burrup Peninsula (ha)	Area in Conservation Zone (ha)	Area in Conservation Zone (%)	Total Area in Pluto LNG Development (Prior to Clearing)			Area to be cleared for Pluto LNG Development				
				Site B (ha)	Site A (ha)	Site A laydown (ha)	Site B Draft PER (ha)	Site B 2007 Disturbance Footprint (ha)	Site A (ha)	Site A laydown (ha)	% Change in Site B Clearing from Draft PER to 2007 Disturbance Footprint
AbCc'Te	0.68	0.13	19.0	0.55	0	0	0.44	0.55	0	0	20.4
AbCwTe	64.52	3.31	5.1	0.0043	0	0.11	0	0.00	0	0.11	0.00
AcCaTe	3.48	0	0	0.52	0	0	0.066	0.45	0	0	72.7
AclmTe/TeCa	0.90	0	0	0.9	0	0	0.77	0.75	0	0	-1.5
AiFdTe	16.8	2.00	11.9	0.33	0	0	0.02	0.06	0	0	13.0
R^2	2068.25	1716.59	83.0	36.01	18.77	0.97	11.35	15.21	0.18	10.7	11.6
TcCvSe	0.95	0.23	23.7	0.014	0	0	0	0.00	0	0	0.0
TeCa	36.09	1.54	4.3	4.33	6.17	0.96	0.57	2.40	0.16	42.3	42.5
TeEtSg	1.16	0	0	0.58	0	0	0.12	0.30	0	0	30.4
TeRm	51.74	10.36	20.0	0.14	0.18	0	0.08	0.14	0	0	38.6

Conservation Significant Vegetation Associations	Draft PER Total Area to be cleared for Pluto LNG Development (ha)	2007 Disturbance Footprint Total Area to be cleared for Pluto LNG Development (ha)	Previous Clearing in Site A[1] (ha)	Cumulative Area to be cleared in Burrup Peninsula based on 2007 Disturbance Footprint (ha)	Cumulative Area to be cleared in Burrup Peninsula based on 2007 Disturbance Footprint (%)	Area remaining in Burrup Peninsula after clearing based on 2007 Disturbance Footprint (%)
AbCc'Te	0.44	0.55	0	0.55	80.7	19.3
AbCwTe	0.11	0.11	0	0.11	0.2	99.8
AcCaTe	0.07	0.45	0	0.45	12.8	87.2
AclmTe/TeCa	0.77	0.75	0	0.75	83.6	16.4
AiFdTe	0.02	0.06	0	0.06	0.4	99.6
R^2	12.50	16.36	2.57	18.92	0.9	99.1
TcCvSe	0.00	0.00	0	0.00	0	100
TeCa	1.69	3.53	4.08	7.61	21.1	78.9
TeEtSg	0.12	0.30	0	0.30	25.6	74.4
TeRm	0.08	0.14	0	0.14	0.3	99.7

Most of the requirements for additional land are in the southern half of Site B, resulting in increases (greater then 50% increase) for two potentially locally restricted vegetation associations (TcBaTeCa and TsBaCpTe), as recorded in Site B South by Astron Environmental (2005).

Site	Vegetation Association	Area Within Site (ha)	Draft PER Area to be Cleared (ha)	Draft PER % to be Cleared	2007 Disturbance Footprint Area to be Cleared (ha)	2007 Disturbance Footprint % Area to be Cleared	% Change from Draft PER to 2007
Site B South	BaTsFv	6.13	0.77	12.5	2.55	41.5	29
	ChCwTe	0.15	0.06	42.7	0.10	69	26.3
	CpTaCv	0.10	0.10	100	0.10	100	0
	SgTaCv	0.17	0.05	28.7	0.08	44.4	15.6
	TcFvAc	3.42	2.16	63.3	2.32	68	4.7
	TcBaTeCa	4.13	1.24	30.0	3.12	75.6	46
	TsBaCpTe	1.53	0.16	10.2	1.53	99.7	89.5
Site B North	BaTcAcPtTe	27.96	9.72	34.8	10.84	38.8	4
	TcBaRmPtTa	0.76	0.01	1.2	0.02	3.2	2
	TcRmTe	1.43	0.46	32.4	0.51	35.8	3.4
Site A	AcAeTe	0.162	0.13	82.0	N/A	N/A	N/A
	AcIcRm	0.599	0.08	12.8	N/A	N/A	N/A
	BaTsAc	16.77	2.5	14.9	N/A	N/A	N/A
	TapTe	0.078	0	0	N/A	N/A	N/A
	TsAcAe	1.696	0.33	19.2	N/A	N/A	N/A
	Ab*AjSfTe	3.56	3.56	100	N/A	N/A	N/A
	EvAcTa	0.07	0.07	100	N/A	N/A	N/A
	IcTa'Te	0.24	0.23	95.5	N/A	N/A	N/A

Note: N/A = Not Applicable, the Site A Disturbance Footprint has not altered from that presented in the Draft PER

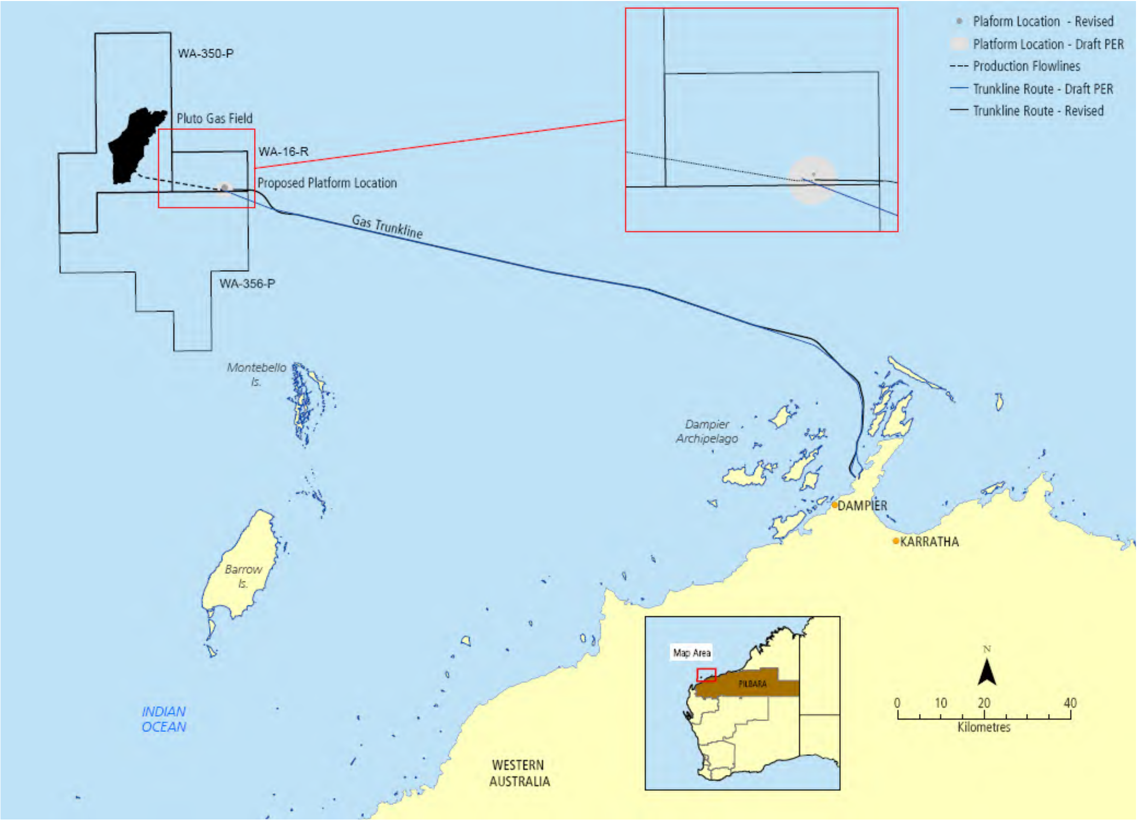
2.2 Offshore Trunkline Route

As described in Section 3.4 of the Draft PER the preferred gas trunkline route between the offshore platform and Site B comprises landfall at Holden Point (Site A) via Mermaid Sound (Option A). Engineering work is no longer progressing on Option B which would have reached landfall along the north-eastern coastline of West Intercourse Island via Mermaid Strait.

Option B has been discounted as the preferred trunkline route as a result of the significant additional onshore footprint required for this option (20 km additional onshore pipeline corridor) and the associated environmental and cultural heritage impacts. The seabed along the route through Mermaid Strait is also comprised of harder substrate which would have resulted in potentially more rock dumping requirements for pipeline stabilisation.

Woodside is not progressing environmental or cultural heritage assessments and approvals for trunkline Option B.

The preferred trunkline route (Option A) from the offshore platform to the gas processing facility at Site B on the Burrup Peninsula is illustrated in **Figure 2**.



■ **Figure 2: Revised Platform Location and Trunkline Route**

2.3 Wastewater Treatment and Disposal

The reference case for treatment and discharge of wastewater described in the Draft PER involved discharge of approximately 6 000 bpd of wastewater to Mermaid Sound via a short ocean outfall located at the end of the export jetty. The Draft PER also stated that all potable and plant service water would be sourced from Water Corporation's Harding Dam or Millstream supplies.

Although this option formed the reference case, alternatives to discharging treated wastewater to Mermaid Sound were being investigated and considered in the context of the Environmental Quality Management Framework for Mermaid Sound (DOE 2006a). Produced water has traditionally been considered a waste product of hydrocarbon production; however, given the scarcity of fresh water in the Pilbara region, options to re-use water are preferred by Woodside over disposal to sea.

Since publication of the Draft PER Woodside has revised the reference case for wastewater treatment and disposal to allow for extensive treatment of all wastewater streams to meet plant service water specifications. This will result in a high level of wastewater treatment and substantially reduced discharge volumes to Mermaid Sound. Woodside is continuing to investigate options to provide the remainder of treated wastewater to a third party, thereby negating the need to routinely discharge wastewater to Mermaid Sound. A discharge line to Mermaid Sound and ability to source service water needs from Water Corporation will need to be retained in the event of treatment system upsets and/or low produced water/runoff rates.

The wastewater discharge location has also been moved approximately 135 m to the east. This has resulted in decreased water depth at the discharge location from 8.7 to 6.7 m (relative to Lowest Astronomic Tide). Further wastewater dispersion modelling has been undertaken by Rob Phillips Consulting to reflect the revised discharge volume and change in discharge location.

As per the original results presented in the Draft PER, the revised modelling indicates that periods of low water depths and weak ambient current speeds are worse case conditions for mixing (**Figure 3**). Revised near-field modelling during slack water with current speeds of 0.02 m/s predicts initial dilutions of 1:256 (0.39% wastewater) at 10 m from the discharge location and 1:345 (0.29% wastewater) at 50 m from the discharge location (that is, the edge of the proposed mixing zone). This is an improvement on the 6000 bpd case discussed in the Draft PER which showed dilutions of 1:200 (0.50% wastewater) and 1:300 (0.33% wastewater) at 10 m and 50 m from the discharge location respectively.

Far-field modelling has also been revised to take into consideration the potential for recirculation of the plume over the discharge location. **Figure 4** presents the predicted wastewater concentration at the edge of the proposed 50 m mixing zone for the duration of the worse case model scenario (neap tide and low wind speeds). Concentrations peak at just over 0.4% wastewater; however, for 99% of the time concentrations remain below 0.4% wastewater. The spatial distribution of maximum instantaneous concentrations recorded over the duration of the three day simulation is shown in **Figure 5**. The 0.4% wastewater contour limit extends just beyond the 50 m mixing zone (denoted by red ring); however, as shown in **Figure 4**, these peak concentrations occur for a short duration.

Worse case mixing conditions (low wind and current speeds) occur for only a small percentage of time, and for prevailing conditions it is likely that concentrations at the edge of the mixing zone will be less than 0.1% wastewater (1:1000 dilutions) for the majority of the time.

Revised modelling concludes that the reduction in wastewater discharge volume will result in improved dilution in the near-field.

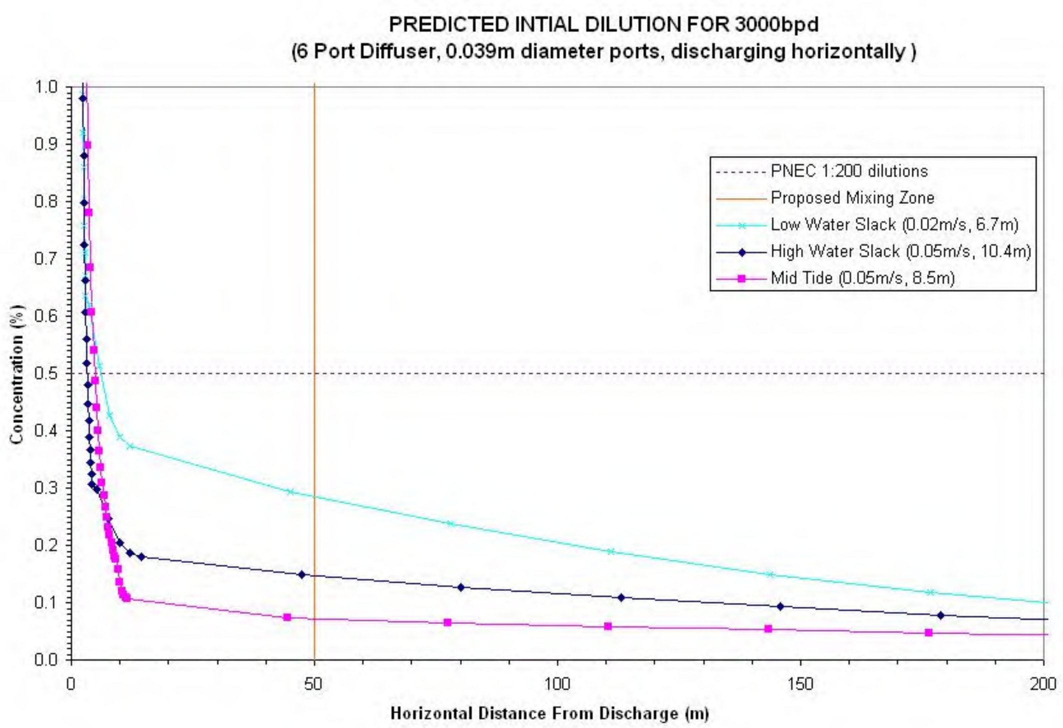
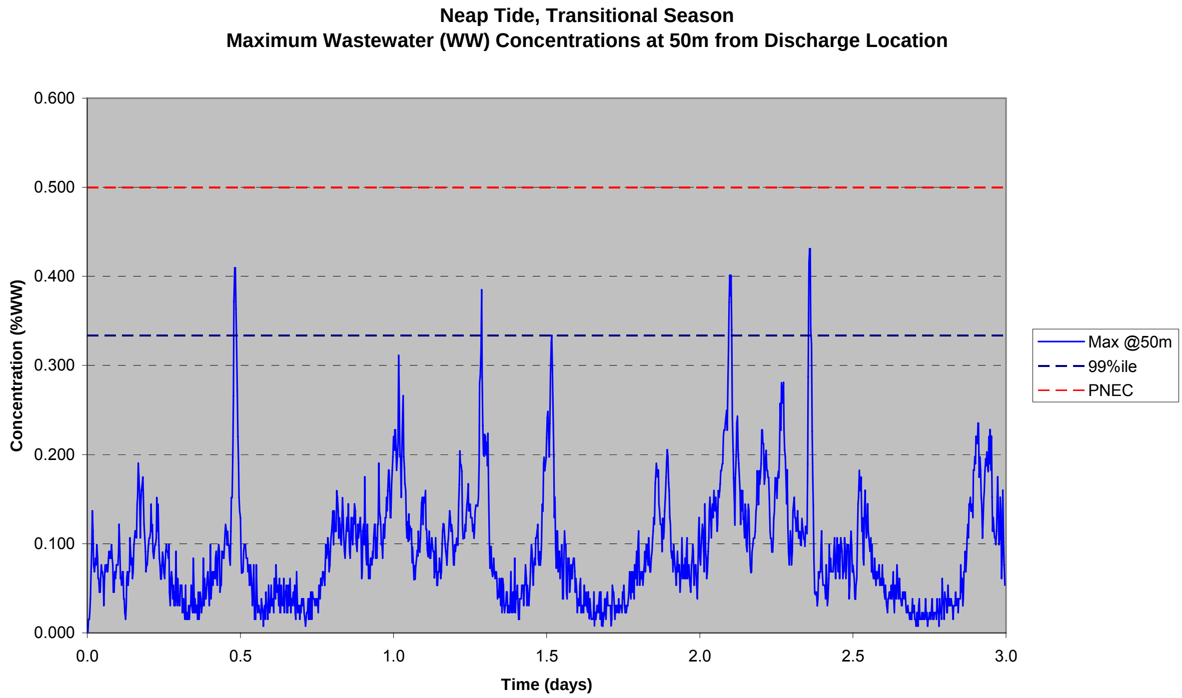
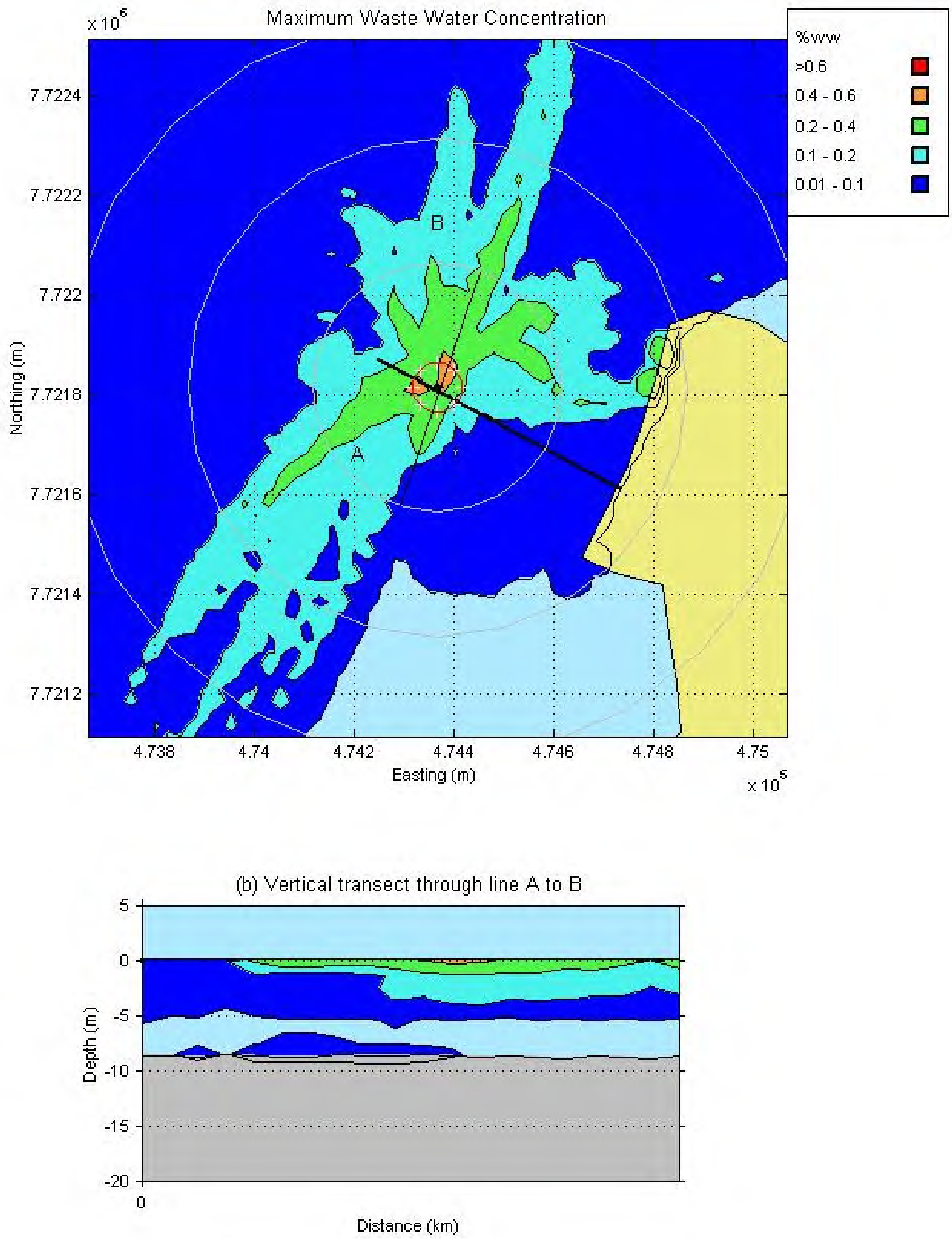


Figure 3: Comparison Between Near Field Dilution for Various Discharge Options



- **Figure 4: Predicted Maximum Wastewater Concentrations for Typical Conditions During the Transition Season for a Neap Tide (Worse Case Scenario)**



- **Figure 5: Time Series of Maximum Wastewater Concentration at 50 m from the Discharge Location for a Neap Tide During the Transition Simulation**

Note: range rings are 250 m apart; red ring denotes the proposed 50 m mixing zone; white crosses are locations where time series are extracted.

3. Response to Submissions

Thirteen government and public submissions have been received on the Draft PER for the proposed Pluto LNG Development (**Table 2**). This section contains Woodside's formal responses to the issues raised in these submissions.

- **Table 2: Public and Government Submissions on the Draft PER**

No.	Submission
1	International Federation of Rock Art Organisations (Robert Bednarik)
2	Russell Clemens
3	Conservation Council of Western Australia
4	Department of Fisheries
5	Dampier Port Authority
6	Western Australian Museum
7	Anna Vitenbergs
8	GetUp! (Brett Solomon)
9	EPA Service Unit
10	Department of Environment and Conservation
11	Ngarluma Aboriginal Corporation
12	Department of Health
13	Jeannine Gan and Christopher Malcolm

<u>Environmental Approvals Process</u>

5.11 It is noted a supply base has not been included for assessment in this document, although the DPA is aware that Woodside are considering establishing a base in the port area.

Woodside is currently assessing options for a supply base to service the Pluto LNG Development and potentially other Woodside operations in the North West Shelf region. This includes the option of potentially expanding the existing King Bay Supply Base or development of a stand-alone supply base elsewhere within King Bay area. The preferred supply base option will be subject to an additional environmental assessment and approval process.

<u>Stakeholder Engagement</u>

1.8 Item 2.1, Consultation of Stakeholders to Date: Numerous false claims are made. For instance the consultation of Traditional Custodians has been a farce in every possible respect. In Table 2-1, we, the International Federation of Rock Art Organisations, are listed as having been consulted. We have never, in any form or fashion, been consulted by Woodside.

Woodside has been in contact with IFRAO both via written correspondence and telephone discussions, and is aware of IFRAO's concerns regarding development on the Burrup

Peninsula. These concerns have been addressed in the Draft PER. In particular a description of the potential impacts to and management of Aboriginal cultural heritage within the proposed development area is provided in Section 10.3 and Section 11.4 of the Draft PER.

Comprehensive consultation has been undertaken with the Traditional Custodians in regards to cultural heritage.

11.1 Woodside has not consulted at all with us [the Ngarluma Aboriginal Corporation] about the Pluto project, despite its comments in the draft PER, its policies and obligations to us under the BAMIEA, the Burrup Agreement that we made with the State government.

11.2 Woodside [has failed to] involve us in any heritage site surveys, sharing of information in survey reports and not providing us with any documentation about the proposed Pluto project nor the Pluto Site A and B section 18 Aboriginal Heritage Act (AHA) applications.

11.4 Woodside's decision makers have refused to meet with us [the Ngarluma Aboriginal Corporation] as Traditional Owner decision makers.

11.14 Table 2.1 lists 'Ngarluma people' as 'stakeholders contacted by Woodside'. NAC is the corporate spokesperson for the Ngarluma people and our Country and we have not been 'contacted.'

11.12 we have not been involved in 'cultural heritage induction' nor any heritage surveys nor monitoring

11.13 we have not been involved in any development of 'Environmental Management Plans' nor any 'Cultural Heritage Management Plan'

Woodside has consulted with representatives nominated by the Ngarluma, Yindjibarndi, Yaburarra, Mardudhunera and Wong-Goo-Tt-Oo groups. The Ngarluma Aboriginal Corporation is a Prescribed Body Corporate established under the Native Title Act to hold and manage Native Title interests for the Ngarluma native title claimant group. Native Title has been found not to exist over the Burrup Peninsula.

Woodside has offered to discuss the Pluto LNG Development with the Ngarluma Aboriginal Corporation. The Ngarluma Aboriginal Corporation has declined to meet with Woodside for that purpose. Further, in June 2006 at a meeting attended by the Aboriginal Cultural Material Committee, representatives from Woodside and representatives from each of the Indigenous groups who participated on the heritage surveys, the Ngarluma elders clearly said that Ngarluma representation on heritage surveys is a matter for the Ngarluma community to agree and resolve. As such, the Chairperson of the Ngarluma Aboriginal Corporation, who was present at this meeting, was asked to organise a Ngarluma community meeting at which the community would discuss and conclude Ngarluma heritage survey representation. Woodside, until advised otherwise by the Ngarluma community and elders, will not change the way that it conducts heritage surveys including who participates on those surveys.

Comprehensive heritage surveys have been conducted over the Pluto LNG Development leases. These surveys involved archaeologists, anthropologists and senior members of the Indigenous community who have been identified by the community. This included senior Ngarluma elders.

11.3 All aboriginal groups oppose the proposal.

11.15 Woodside acknowledges that "none of the Indigenous groups of the area are supportive of the development on the Burrup Peninsula". Yet Woodside wishes to proceed anyway, flying in the face of its own publicly declared 'Indigenous Community Policy'

1.14 [We recommend that the EPA request the following from Woodside]…To provide written evidence that the senior Traditional Custodians of the local Indigenous groups agree to the placing of this plant on their traditional land.

1.2 The further destruction of the Dampier monument is strenuously opposed by the Wong-Goo-Tt-Oo, the Ngarluma and the Mardudhunera-Yaburrara.

In 2003 the Ngarluma/Yindjibarndi, Yaburarra/Mardudhunera and Wong-Goo-Tt-Oo groups agreed with the State Government of Western Australia, under the Burrup and Maitland Industrial Estates Agreement, to the establishment of an industrial estate on the Burrup Peninsula. The Burrup LNG Park, the onshore component of the Pluto LNG Development, is proposed to be constructed within this agreed industrial estate.

Woodside understands that the Indigenous groups of the area do not support further development on the Burrup Peninsula and that in the event that development is to occur, the groups wish to be involved in heritage management consultations and surveys so as to influence how development proceeds with a view to minimising impact and protecting their interests.

Woodside's approach to heritage management is one of heritage site avoidance where practicable which is not inconsistent with any of the Company's policies or the requirements of any State or Commonwealth legislation. Woodside has applied for relevant approvals to progress the proposed Pluto LNG Development on that basis.

Development Alternatives

1.7 The most suitable site for the Pluto Project is at Onslow, where even construction costs would be significantly lower.

1.18 [We recommend that the EPA request the following from Woodside]…To explain in detail why Onslow is not a realistic option for the siting of the Pluto plant.

The site selection process and the factors that led to the selection of the Burrup Peninsula as the preferred onshore location for the Pluto LNG Development are described in detail in Section 3 of the Draft PER.

As described in the Draft PER, the site selection process included investigation of 12 potential development locations, including Onslow. Onslow and the Burrup Industrial Estate option were carried as alternative locations after other sites had been discounted. Significant engineering work and assessment of cost, technical, environmental and socio-economic factors was undertaken for these development options.

Onslow currently carries a range of uncertainties that are considered to present a significant risk to Woodside's development timeframe for the Pluto LNG Development. Onslow presents technical and cost challenges for the Development particularly with regard to capital and operational costs associated with marine facilities (length of jetty and shipping channel) and marine operability (sea-state) off Onslow. Other uncertainties include the unresolved status of industrial sites south of Onslow, existing Native Title claims which have not yet been determined, limited existing community infrastructure and lack of government support for a development of this size in this area and timeframe.

8.4 The economic grounds for this proposed site [Burrup Peninsula] have always been weak. The Council of the Shire of Roebourne, where the majority of the area's North-West Shelf workers reside, has previously stated in 2002: 'There are only limited areas for further expansion on the Burrup...It is a false economy to squeeze developments into relatively small, disconnected valleys...The Shire of Roebourne urges the State government, in conjunction with the Federal Government, to encourage relocation of these industries, through the provision of common use infrastructure'.

The industrial land allocated to Woodside for the Pluto LNG Development provides sufficient space suitable for development. The Pluto LNG Development site is located in the proximity of significant industrial and community infrastructure and existing public port facilities and shipping channels. Significant common user infrastructure has been installed in the Burrup Industrial Estate by the Government of Western Australia to support industrial development.

3.1 In response to this PER the Conservation Council of WA reiterates our extreme disappointment in Woodside's decision not to use previously cleared industrial land, existing port facilities and existing dredged channel at the NWS Joint Venture facility. This disappointment has been made clear to the proponent during a number of public consultation meetings. Relocating the project to the JV site would avoid all of the significant damage to very high conservation value terrestrial and marine flora and fauna as well as the internationally significant Burrup rock art. It appears the only barrier to using the existing facility is an unwillingness to engage with other Joint Venture partners to negotiate a suitable arrangement. This is completely unacceptable given the sensitivity of the receiving terrestrial, marine and cultural environments.

8.5 It makes far more, long-term economic sense to capitilise on the newly discovered natural gas fields from one of two locations: in the already destroyed and flattened land on the Burrup, close to the North-West Shelf Joint Venture, or further down the coast, around Onslow – where flat expanses of featureless spinifex, devoid of any obstacles to industrial construction, abound. Each of the Joint-Venture partners have stated a willingness to negotiate the inclusion of the Pluto plant on the already destroyed land – letters to this effect have been included at the end of this submission.

The North West Shelf Venture (NWSV) site is not leased by Woodside alone but by a joint venture of which Woodside is a one-sixth participant. In 2006 Woodside put forward a proposal to the joint venture participants to construct the Pluto LNG Development onshore facilities within the NWSV lease area. The joint venture chose not to accept this proposal.

Consequently, Woodside has proceeded with its own development proposal on alternative industrial sites. Given the progress already made with the detailed engineering and design studies, the current proposal at Site A and Site B represents the only option that can satisfy customer requirements for LNG supply from late 2010.

As described in the Draft PER the site selection process included investigation of 12 potential development locations, including Onslow. The site selection process and the factors that led to the selection of the Burrup Peninsula as the preferred onshore location for the Pluto LNG Development are described in detail in Section 3 of the Draft PER.

11.8 We [Ngarluma Aboriginal Corporation] note that alternative sites were primarily considered only 'from an engineering feasibility perspective'. Woodside clearly prioritises this purely technical perspective above more important social and cultural perspectives, perspectives that would say the proposal should not occur where Woodside wants it to.

The site selection process and the factors which led to the selection of the Burrup Peninsula as the preferred onshore location for the Pluto LNG Development are described in detail in Section 3 of the Draft PER.

Woodside has applied a range of environmental and socio-economic considerations to site selection and these supported the decision to locate the Pluto LNG Development on the Burrup Peninsula. Detailed environmental and socio-economic criteria were developed in consultation with stakeholders, and are presented in Table 3-4 of the Draft PER.

5.13 Trunkline route Option B is not supported by the DPA, as it is considered a sub-optimal use of the area in relation to future development of the port.

10.5 Given that the gas trunkline is a key component of the Pluto LNG Development the proponent should provide supplementary data and discussion on the potential terrestrial and marine environmental impacts of route Option B if this option is to be considered for impact assessment and/or possible approval.

Trunkline route Option B is no longer being carried as an alternative trunkline route and Woodside is not progressing environmental or cultural heritage assessments and approvals for this option.

Emissions Discharges and Waste

8.2 We are also still unaware of the effect CO_2 emissions from the new Pluto plant will have on surrounding petroglyphs in the long-term – no scientific evidence can conclusively say what will happen either way.

1.6 The high concentration of acidic atmospheric emissions is destroying the rock art, further acidic emissions (a doubling of current 12000 t/yr NOx plus others) need to be located elsewhere.

1.16 [We recommend that the EPA request the following from Woodside]…To provide technical details of the effects of the acidic pollution on the ferruginous rock accretion, bearing in mind that Woodside has already lowered ambient pH from 7.2 to 4.6 causing acidic precipitation 50 weeks in the year.

1.17 [We recommend that the EPA request the following from Woodside]…To provide a documented and reliable prediction of how much further the precipitation pH will be lowered by the Pluto plant.

13.3 This section [Emissions, Discharges and Waste] to include the significance and the effect of any emissions on the Indigenous rock art in the vicinity of the Pluto plant.

13.16 There is a lack of correlation between the field studies outcomes and Woodside's assertions that there is no clear evidence of change in condition of the rock art as the field studies were not done where the emissions suitably simulated either the current baseline (based on Karratha gas plant or similar) or forecasted air quality as stated in other sections of the PER.

13.17 Why have no international standards been identified and applied to assess the impact of emissions on the rock art? Why is there inconclusive evidence from the analysis undertaken, and was additional assessment and monitoring not undertaken until conclusive evidence had been established?

13.24 Similarly, if Woodside is operating in accordance with its Environmental Policy, why has it not published the impact of NO2 and CO2 emissions on the rainfall pH, and why has it not advised the affect of this on the rock art?

The potential impacts of atmospheric emissions on rock art are discussed in Section 11.4 of the Draft PER.

As discussed in the Draft PER, the presence of heavy industry on the Burrup Peninsula has generated concerns that industrial emissions may lead to an accelerated deterioration of rock art. These concerns centre on the issue of potential acid deposition which can occur when sulphur dioxide (SO_2), carbon dioxide (CO_2) or nitrogen dioxide (NO_2) react with water, oxygen and other oxidants in the atmosphere to form acidic compounds.

In 2002 the Government of Western Australia appointed the Burrup Rock Art Monitoring Management Committee to assess whether there has been any change to the petroglyphs over and above that due to natural weathering. The Committee has commissioned CSIRO Atmospheric Research to conduct an air pollution monitoring programme. The Committee has also commissioned several studies into rock art appearance, with the work primarily done by CSIRO Manufacturing and Infrastructure Technology and some input from CSIRO Exploration and Mining.

Interim results from this work indicates that current levels of air pollution on the Burrup Peninsula are low (well below national and international environmental and health standards and at least one-tenth of what is found in Perth) and are not resulting in accelerated rock art weathering or damage to the rock art.

All known sources of air emissions on the Burrup Peninsula have been included in a cumulative air quality assessment for the Pluto LNG Development. The results of this work are presented in Section 5.1.2 and Section 9.5 of the Draft PER.

1.13 [We recommend that the EPA request the following from Woodside]…To provide firm estimates of the quantities of CO_2, NOx, SOx and benzene to be emitted by the Pluto plant once operational.

Estimates for the quantities of CO_2, NOx, SOx and benzene emissions from the operation of the gas processing facility are provided in the Draft PER. Estimated emissions of CO_2 and other greenhouse gases are described in Section 5.1.1 and estimates for NOx, SOx, benzene and other combustion products are provided in Section 5.1.2.

4.7 The proponent should be encouraged to adopt one of the land-based options for the discharge of waste water.

5.3 The DPA does not support discharge of any wastewater to Mermaid Sound and would encourage Woodside to consider reuse opportunities such as freshwater requirements of offshore exploration drilling programs.

Since publication of the Draft PER Woodside has revised the reference case for wastewater treatment and disposal to allow for extensive treatment of all wastewater streams to meet plant service water specifications. This will result in a high level of wastewater treatment and substantially reduced discharge volumes to Mermaid Sound. This strategy would also reduce consumption of regional potable water that would otherwise be provided by Water Corporation.

Woodside is continuing to investigate options to provide the remainder of treated wastewater to a third party, thereby negating the need to routinely discharge wastewater to Mermaid Sound. A discharge line to Mermaid Sound and ability to source service water needs from Water Corporation will need to be retained in the event of treatment system upsets and/or low produced water/runoff rates.

5.5 Prior consultation with the DPA is required should there be a need to discharge pipeline hydrotest water within port limits.

This comment is acknowledged. Woodside will consult with all relevant stakeholders, including the Dampier Port Authority, prior to disposal of hydrotest water.

12.3 An Air Quality Management Plan (AQMP) is recommended to address air emission issues that could arise from the commissioning and the operation of the LNG plant. Specifically the AQMP should include a program of stack emission monitoring to verify current emission estimates. The AQMP should also include compliance monitoring and reporting requirements to be undertaken.

Air emissions from the Pluto LNG Development will occur during commissioning and normal operations of the gas processing facility and for some hours over the course of a year during non-routine operations. The most significant emissions are generated by the combustion of fuel gases from gas turbines and by flaring associated with the gas processing facility. Air emissions have been estimated through an air quality assessment and are presented in Section 5.1 of the Draft PER.

Where applicable, emissions may be further managed by works approvals and licence conditions set by the DEC under the *Environmental Protection Act 1986*.

12.4 It is the preferred option that all human sewage waste generated by onshore activity is treated by a packaged wastewater treatment plant with associated land based disposal area that complies with the requirements of the Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974, and that application to construct or install this system is made to the local government.

During operations, Woodside plans to treat sewage generated by onshore activity in a packaged wastewater treatment plant. Woodside intends to use the treated effluent onsite, and plans to dispose of treated sludge at a licensed landfill. Woodside will seek relevant approvals to undertake those activities.

12.8 To ensure appropriate protection of people during recreational use of natural estuarine and ocean waters, water quality should be assessed against the National Health and Medical Research Council's Guidelines for Managing Risks in Recreational Waters.

The primary objective of the *National Health and Medical Research Council's Guidelines for Managing Risks in Recreational Waters* is to protect human health from threats posed by the recreational use of coastal, estuarine and fresh waters including natural hazards such as surf, rip currents and aquatic organisms, and those with an artificial aspect, such as discharges of wastewater. The guidelines are not mandatory; rather, they have been developed as a tool for state and territory governments to develop legislation and standards appropriate for local conditions and circumstances.

The relevant characteristics of the guidelines in relation to the Pluto LNG Development are *Chemical Hazards* and *Aesthetic Aspects* and are discussed below:

Chemical Hazards: Current recreational activity levels within the area of the proposed wastewater discharge location are not significant and will be limited as a result of the presence of the proposed jetty. As stated in the Draft PER (Section 11.11 p. 404), public access to Holden Point via road is currently prohibited and the beach is visited by few recreational visitors. Public access by boat will be restricted (as described in Section 5.2.15 of the Draft PER) in the interests of health and safety.

In areas where significant recreational activity takes place, (for example, around Conzinc Island and at Conzinc Bay) it is considered highly unlikely, based on wastewater dispersion modelling, that chemical hazards from treated wastewater will be an issue (refer to response to **Comment 9.3** for details on chemical constituents and their concentrations and to Section 7.8.13 of the Draft PER for discussion on potential impacts from treated wastewater discharge). Water quality monitoring at the boundaries of a localised mixing zone, which is proposed as part of the Pluto LNG Development Wastewater Management Plan, will confirm that contaminants are within the Pilbara Environmental Quality Management Framework guidelines for recreational waters.

Aesthetic Aspects: Aesthetic issues associated with dredging induced turbidity (reduction in water clarity) will be assessed in accordance with the Pilbara Environmental Quality Management Framework. The 'National Health and Medical Research Council's Guidelines for Managing Risks in Recreational Waters' states that 'No guideline values have been established for aesthetic aspects' .

Refer to the response to **Comment 9.11** for further discussion of dredging impacts on recreation and aesthetic values and for proposed criteria for assessing turbidity impacts.

Impacts associated with water clarity will be managed according to **Section 7.9.15** of the Draft PER and the Framework Dredging and Spoil Disposal Management Plan (**Appendix I**).

12.9 Management Plans for the discharge of the produced water will also need to meet the requirements of the Radiological Council and, as appropriate, the Petroleum Division of the Department of Industry and Resources and/or the National Offshore Petroleum Safety Authority.

The requirements of the Western Australia Radiological Council and the Petroleum Division of the Department of Industry and Resources will be considered in the finalisation of a comprehensive Wastewater Management Plan.

13.6 What monitoring will be included in the forthcoming Management Plans both during construction and for the normal operation phases?

Regular monitoring of stack emissions will be carried out in compliance with Works Approval and Operating Licence Conditions under Part V of the *Environmental Protection Act 1986* (WA).

Dust emissions during construction will be minimised through the development and implementation of a Dust Management Plan. A Framework Dust Management Plan was provided in Appendix G of the Draft PER.

13.19 What avenues for recourse and restitution will the community and the custodians of the rock art have once the plant has been constructed and is found to be causing direct and irreparable damage to the rock art?

Woodside has provided its assessment of the likely impacts of the proposed Pluto LNG Development in the Draft PER.

The plant will be designed, built and operated in accordance with the environmental approval conditions established by the Western Australian and Australian Governments. Air-borne emissions will be managed within licence limits and exceedences will be reported to authorities. Woodside is supporting the work currently being undertaken by the Burrup Rock Art Monitoring Management Committee.

Woodside's approach is to avoid impact and our performance will be monitored by government regulators.

13.23 What records can Woodside provide of data associated with the pH of natural rainfall from the area surrounding the Karratha LNG facility as an indication of the likely atmospheric changes in the Dampier area?

Wet deposition is not believed to be a significant exposure pathway for acidic emissions on the Burrup Peninsula (CSIRO 2006). The Burrup Rock Art Study currently being conducted by CSIRO for the Department of Industry and Resources has found to date that the local vegetation and land surfaces (including rock art) are not considered sensitive to the acid deposition impacts. Consequently Woodside does not anticipate monitoring of rainfall pH to be separately undertaken for the Pluto LNG Development.

Marine Impacts and Management

3.2 The Council also recommends to the EPA that any approval for this project (in either location) be coupled with a condition that Woodside engage an appropriate independent consultant to fully assess the cumulative impacts of their operations on the marine and terrestrial environments of the Burrup before any development is commenced.

Woodside is currently conducting a cumulative environmental impact assessment of its operations in the North West Shelf region. This study is being undertaken with the participation of the Department of Environment and Conservation and independent scientists.

3.3 Woodside should be required to conduct a full baseline survey of any areas likely to be affected by Woodside's operations on the Burrup and permanent monitoring sites should be established to ensure the protection of the Burrup's rich biodiversity.

In line with the Environmental Scoping document for the Draft PER, baseline studies have been planned and undertaken for both onshore and offshore environments in which development activities are proposed. The results of field surveys are described in the Draft PER and supporting technical appendices and form the basis for assessment and management of predicted environmental impacts of the proposed Development.

Environmental management plans that outline specific environmental monitoring requirements will be developed in consultation with relevant regulatory authorities. In some cases further surveys and studies will be undertaken as part of Woodside's commitment to manage the likely environmental impacts of the proposed Pluto LNG Development identified by this impact assessment process. For example, a regional-scale marine environmental baseline of fixed monitoring stations was established and implemented in 2006 and will provide physical and biological data to support management and monitoring of effects of marine construction activities. It is expected that the findings of this baseline study will contribute significantly to a better understanding of local and regional physical processes as well as to various aspects of the biological communities in Mermaid Sound.

4.2 The PER should contain a comprehensive NIMS [non-indigenous marine species] risk assessment that, at a minimum, should examine the type of vessel/equipment, where and when the vessel/equipment has come from (i.e. last port of call) and the type of surfaces on the vessel/equipment that may be at risk from carrying NIMS. For example, all vessels should be examined for their risk profile in relation to NIMS including tending vessels, blast barges, structures and equipment such as floating docks, platforms etc. The Department of Fisheries can be contacted to provide advice on developing a comprehensive risk management plan.

4.3 Inspection requirements should include examination of internal systems, including internal strainers. Precautionary treatment of these systems prior to arrival should also be considered. This may include freshwater treatment of dredge ballast tanks, although this is not mentioned within the PER.

4.4 The Quarantine Act 1908 *and Regulations 2000 (Cwth) mentioned in the PER (Table 13-1) only apply to ballast water management requirements. Hull and internal fouling should also be identified as issues within the PER.*

4.6 Reference is made in relation to the preparation and implementation of a Marine Pest Management Plan. Current management strategies in relation to external and internal hull fouling are insufficient. Such a plan should include both prevention and response *provisions. Prevention requirements such as pre-arrival inspection and treatment option[s] should include incident response plans that would be implemented if any non-endemic or pest species were identified on any project vessels, structures or equipment.*

Woodside will comply with all relevant legislation and regulations in respect of managing the risk of introducing non-indigenous marine species (NIMS) associated with the proposed Development.

The risks and potential impacts associated with marine pest species, including those associated with vessel ballast water, hull fouling and residual sediments contained on dredges and in ballast tanks were identified and discussed in Section 7.7 of the Draft PER along with a summary of mitigation and control measures.

Woodside recognises the importance of having a robust management plan in place to manage risks of introducing non-indigenous marine species. As outlined in the Draft PER, the focus of environmental management will be on prevention, with proposed management measures as outlined in the context of the Framework Management Plan (Appendix G of the Draft PER). This framework is the basis for development of a detailed management plan that will be developed in consultation with the Department of Fisheries and other relevant stakeholders.

4.5 Impacts to be avoided or minimised in relation to NIMS also relates to the introduction of exotic parasites and diseases that may affect endemic species. This is currently not identified in the PER (Table ES-1 or section 7.7).

Woodside would expect to have to satisfy the same requirements that apply to other regional port users in respect of managing risks of introducing exotic parasites and diseases. Woodside is not aware of evidence showing that diseases and parasites have been introduced and impacted endemic species through the types of construction activities proposed.

5.1 A recent survey of the spoil grounds has confirmed there has been a substantial loss of dredged material from the Northern Spoil Ground. This highlights the incompatibility of disposing fine material at this location. This spoil ground has more capacity for coarse material than estimated during the initial discussions with Woodside and hence it is unlikely there is a need to extend the existing spoil ground to the north. The disposal of fine material at this location is not supported. Further consultation with the Dampier Spoil Management Committee is required.

This comment is acknowledged. Woodside will consult with the DPA and the Dampier Spoil Management Committee in relation to appropriate means of disposing material generated from marine construction and dredging work. Woodside is investigating the feasibility of locating more material to the deep water spoil ground (i.e. spoil disposal ground 2B).

5.6 It is DPA's preference that dredged material of engineering quality be disposed at a location from where it can be readily retrieved and reused.

5.7 For backfill of trenches in port limits, it is DPA's preference to utilise dredge material of engineering standard stored in the southern spoil ground rather than sourcing from land or dredging a borrow area that is outside the footprint of the dredge program.

This comment is acknowledged. Woodside's preference, wherever practicable, is to dispose of spoil material at sites in reasonable proximity to construction works as this avoids additional environmental and operational constraints associated with long haulage distances and additional vessel movements.

Woodside is investigating options to re-use some of the coarser clean spoil material located in the existing Northern Spoil Ground and similar materials generated during the proposed inshore dredging of the turning basin and shipping channel. The spoil and dredged material from these locations is considered suitable fill for stabilising sections of the proposed trunkline. The use of pre-existing, clean spoil is viewed as, overall, a more attractive option environmentally as it eliminates risks and impacts associated with the alternative option of sourcing large quantities of rock from onshore sites that would require additional blasting and quarrying and with the attendant impacts associated with removal, transport and offloading of material to site.

6.1 In this section [4.6.5 Dredging], a maritime archaeological survey is required for areas proposed for dredging and blasting.

Woodside is required to notify the Aboriginal Cultural Material Committee if the company believes that its activities will damage Aboriginal heritage sites and to seek consent to use land for a required purpose in that instance. Woodside has no reason to believe that it will disturb Aboriginal heritage sites during maritime operations associated with the Pluto LNG Development.

5.2 Where relevant, the DPA expects Woodside to comply with DPAs existing and planned port wide environmental management control measures such as the DPA Environmental Management System, Contractors Handbook, Dampier Cargo Wharf Terminal Handbook, local Marine Notices etc. These are available on the DPA website (www.dpa.wa.gov.au).

In undertaking its activities, Woodside will comply with all relevant laws and regulations, including those that fall under the jurisdiction and responsibility of the DPA in administering and enforcing its legal obligations and requirements on port users.

5.9 The DPA encourages research in the region to support improved environmental management. Any planned research in the marine environment should be undertaken in consultation with the DPA who maintains a coordinated approach.

5.10 The DPA is currently investigating the potential for a port wide common marine monitoring program. It would be expected that Woodside contribute to this program.

Woodside supports the DPA position of taking a coordinated approach to marine research and will consult with DPA and other relevant regional stakeholders in relation to proposed research it may be considering where this has potential mutual benefits in managing areas of common environmental risk. In that regard, Woodside has recently engaged in preliminary discussions with other regional users, including DPA, with the purpose of seeking to identify potential opportunities for coordinating aspects of marine environmental monitoring.

5.12 The DPA would expect Woodside to consult with DEC regarding design of lighting to minimise impacts to turtles.

This comment is acknowledged. The DEC will be consulted regarding strategies to minimise impacts on turtles during the development of detailed Environmental Management Plans.

7.1 This Pluto report makes specific mention of turtle safety during construction (i.e. dredging etc.) however, I am unable to find any specific plan, future strategy, or research programme that addresses the long-term potential impacts of this project on the marine reptile species classified as endangered and vulnerable (see 6.3.8 Table 6-5) and, to date, largely ignored in the Dampier Archipelago.

A Framework Sea Turtle Management Plan was provided in Appendix G of the Draft PER, and a Framework Dredging and Spoil Disposal Management Plan was provided in Appendix I of the

Draft PER. Both of these management plans will be further developed in consultation with the DEC and other relevant government agencies to minimise potential impacts on turtles.

7.2 Recommendation: that Pluto commits to a long-term, appropriately structured turtle research programme in the Dampier Archipelago addressing, inter alia, the impacts of:

- *artificial lighting (onshore and offshore)*
- *flare towers*
- *construction activities (spoil dumping, dredging, blasting etc)*
- *habitat destruction (nesting and foraging)*
- *vessel impacts*
- *waste disposal*
- *increased recreational impacts.*

Additional research to identify:

- *definitive turtle habitat mapping of the Dampier Archipelago including:*
    - *mating and nesting sites*
    - *nesting beaches and nest success rates*
    - *aggregation sites*
    - *migratory routes*
    - *feeding and internesting grounds*
    - *population numbers and trends*
    - *hatchling orientation.*

Potential impacts to sea turtles will be managed through engineering design where required (for example, design of lighting to reduce light spill) and management plans including a Sea Turtle Management Plan, a Dredging and Spoil Disposal Management Plan and a Waste Management Plan. Management plans will be developed in consultation with the DEC and other relevant authorities.

Woodside is supportive of research programs, and will consider funding appropriate investigations into sea turtle ecology.

9.1 No information on the toxicity of the hydrotest fluids and consequently the concentration threshold in marine waters considered to be safe to biota has been provided. This information is essential for assessing the potential risk to marine ecosystem and should be provided along with any necessary management strategies that will be implemented to prevent any impacts in the response to submissions(e.g. method of discharge, flow rate and calculated zone of effect (if any)).

Hydrotest fluids from the trunkline, flowlines and services lines will be discharged near the offshore platform, in water depths of approximately 80 to 85 m. Seawater is likely to be used to hydrotest the onshore storage tanks and it is likely that this will be discharged nearshore.

Offshore Discharge of Hydrotest Fluids: The trunkline, flow lines and service lines will be hydrotested with filtered seawater containing leak detection dye and treated with oxygen scavengers and biocides. The dosage rates for oxygen scavenger, biocide and leak detection dye shall be sufficient to prevent internal corrosion and bacterial attack for the entire period that the water will be resident in the pipelines.

To ensure these chemicals do not present a significant threat to the offshore marine environment, only those chemical brands with a minimum Hazard Quotient (HQ) category of 'Silver' or 'Gold' or Categories D or E (for non-CHARM assessed chemicals) under the United Kingdom Offshore Chemical Notification Scheme will be used. All chemicals will either be included on the CEFAS List of Notified Chemicals in accordance with the HOCNF format and the above categories, or Woodside will ensure that sufficient information exists to support an HOCNF application in line with the above categories.

The OCNS conducts hazard assessments on chemical products that are used offshore. Products not applicable to the CHARM model (that is, inorganic substances, hydraulic fluids or chemicals used only in pipelines) are assigned an OCNS grouping A – E, with A being the greatest potential environmental hazard and E having the least potential for environmental harm.

Products that only contain substances termed PLONORs (Pose Little or No Risk) are given the OCNS E grouping (LINK to PLONOR list). The United Kingdom Offshore Chemical Notification Scheme requires toxicity data from three trophic levels (Algae, Crustacea and Fish) to predict the potential ecosystem risk, and in turn, rank the product by Hazard Quotient (HQ).

The exact chemicals to be used for offshore hydrotesting have not yet been determined as the Pluto LNG Development is still in the design phase and chemical selection will take place during selection of a trunkline installation contractor. However, **Table 3** indicates chemicals which would typically be used for hydrotesting as an example of the types of additives that may be used. The data and OCNS categorisation is preliminary at this stage.

Table 3: Typical Chemicals for Offshore Hydrotesting

Chemical	**Primary Constituent**	**Typical OCNS Category[1]**
Oxygen scavenger	Ammonium bisulphite	D
Biocide	Phosphonium salts	D
Dye	Fluorescein	E

Note 1: OCNS - Onshore Chemical Notification System. Category E chemicals are low toxicity, readily biodegradable and non-bioaccumulative.

Glycol slugs will be used during dewatering of the trunkline and pipelines to condition the pipelines and suppress hydrate formation during the introduction of hydrocarbons. Monoethylene glycol (MEG) is on the OSPAR List of Substances / Preparations Used and Discharged Offshore which are Considered to Pose Little or No Risk to the Environment (PLONOR).

All Hydrotesting and pre-commissioning chemical additives will be listed in the Pipeline Flooding and Hydrotesting Procedure and referenced within the Pipelay Environment Plan. This plan will be submitted to the Department of Industry and Resources, in accordance with the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999. The Environment Plan will include the:

- chemicals selected
- dose rates
- a risk assessment of the discharge to the marine environment.

The Environment Plan must be approved by the regulator prior to pipelay commencing. It is important to note that disposal of treated hydrotest water and MEG slugs to the offshore marine environment is standard industry practice, as there are both few alternatives and the operation presents a negligible risk to biota in deeper water.

Nearshore Discharge of Hydrotest Fluids: Woodside is nearing selection of a contractor to build and test the onshore storage tanks. It is currently planned to test the onshore LNG and other storage tanks using seawater. A short residence time in each vessel is planned to ensure low internal corrosion from using this source. Using seawater has both environmental and economic benefits, as it reduces demand on the local potable water system, presents little risk of marine impact on discharge and enables faster completion of the hydrotest activities. An active or passive cathodic protection system may be employed on selected elements of the tanks to aid in reducing corrosion. On the completion of hydrotesting this water will be returned to the sea, via a discharge line located on the jetty. As the water used is untreated (that is, no chemicals will be added), biological effects from this operation will be negligible, although it is likely that a diffuser or energy dissipation device will be added to the end of the discharge line to ensure physical impacts of discharge (for example, stirring up sediments) is minimised.

In the event that the planned hydrotest methodology for the onshore storage tanks is modified and treatment to hydrotest water (potable or seawater) is required, a risk assessment will be undertaken to ensure discharge presents a low risk to the nearshore marine environment. Selection of low toxicity chemicals will be a pre-requisite for any treatment additives. As discharge of tank hydrotest water will be in shallower water, if chemicals are added, discharge will require careful control to ensure adequate dilution (matched to the concentration, biodegradability and toxicity of chemicals selected) is achieved within a small area of influence around the jetty structure.

9.2 The reasons for not utilising the Burrup multi-user brine disposal pipeline for the discharge are not well argued and do not appear to be sufficient reason for dismissing the option. Introducing this additional outfall into Mermaid Sound will result in another mixing zone within a high ecological protection area that is likely to require a low level of ecological protection. There is a strong argument on environmental protection grounds to discharge the waste water from this proposal through the multi-user pipeline.

As discussed in Section 3.6 of the Draft PER, the concept of using the multi-user brine disposal pipeline has been considered by Woodside, but was not the favoured approach for managing and disposing of wastewater generated by the Development.

Modeling demonstrates that, based on a high level of treatment, treated wastewater discharge into Mermaid Sound will result in a localised mixing zone (as discussed in Section 7.8.13 of the Draft PER). Woodside remains committed to undertaking both ecological testing of treated wastewater and operational monitoring of the discharge location as outlined in the Framework Wastewater Management Plan (Table G-3, Appendix G of the Draft PER and the revised version presented in response to **Comment 9.12**), which will ensure that impacts on the marine environment, outside of a localised mixing zone, are negligible and acceptable within this mixing zone.

It is envisaged that in the vicinity of proposed nearshore marine infrastructure (including jetty, turning basin and berth pocket) a moderate level of ecological protection will be allocated, commensurate with the level allocated to existing industrial development areas in Mermaid Sound, as per the approach outlined in the *Pilbara Coastal Water Quality Consultation Outcomes* report (March 2006). Siting of the wastewater disposal line adjacent to the turning basin (from a diffuser system located at the end of the jetty) already presents synergies with this area of proposed lower environmental protection (refer to **Figure 6** in the response to **Comment 9.12** which shows low LEP mixing zone area located within the moderate LEP surrounding the nearshore infrastructure). Whilst it is recognised that the multi-user brine outfall area is categorised as an area of 'low' environmental protection, compared with inner port areas, which may be considered either 'low' or 'moderate', other environmental and commercial factors must be taken into consideration.

The short and long term risks and commercial aspects of the disposal option were also critical in the decision to include a stand-alone wastewater outfall line into the Pluto LNG Development proposal. In addition to mitigating the risks (commercial and environmental) associated with sharing a multiple user disposal line over which Woodside would have little control (outlined in the Draft PER), adoption of a stand-alone option within the development footprint ensures Woodside:

- always has priority access to the line and can schedule maintenance and inspection activities accordingly
- is clearly accountable for managing and monitoring discharges.

The ability to continually treat and dispose of produced water coming ashore is critical to the Pluto LNG Development. On this basis, Woodside has included within the wastewater treatment system a variety of redundancies, to allow maintenance of portions of the system whilst the system is still operational. On the same basis, a reliable disposal line is a pre-requisite for a successful and stable ongoing operation.

Woodside is continuing to explore re-use options for highly treated wastewater generated by the Development. It is Woodside's intent to minimise any discharges to Mermaid Sound, through use of wastewater within the gas processing facility and by local industry. Not only would this result in a reduced potential for impact in Mermaid Sound, but it would have the additional benefit of reducing the overall pressure on the potable water supply in the Pilbara region by replacing potable water with highly treated wastewater from the Development.

9.3 The actual chemical constituents (contaminants) and the concentrations expected to be present in the effluent are not listed. Some effort is required to better characterise the wastewater to be discharged into Mermaid Sound so that potential toxicity can be assessed and hence the degree of mixing necessary to protect the environmental values of the Sound can be estimated.

Table 4 presents estimated constituents and concentrations of treated wastewater. Concentrations are provided for end of pipe and at the edge of the mixing zone (50 m from point of discharge) where a predicted 250 dilutions is achieved. Where values for 99% species level of protection are available in ANZECC/ARMCANZ (2000) these are also provided; all predicted constituents meet these guidelines at the edge of the mixing zone. Concentrations of those constituents with a potential to bioaccumulate (benzene and mercury) meet 99% species level of protection at the end of pipe as per ANZECC/ARMCANZ (2000).

- **Table 4: Predicted Chemical Constituents and Concentrations in Treated Wastewater Discharge**

Constituent	Expected Concentration at End of Pipe (mg/L)	Expected Concentration at 50 m (edge of mixing zone) (based on 250 dilutions) (mg/L)	99% Species Level of Protection (ANZECC/ARMCANZ 2000) (mg/L)
Total free/dispersed hydrocarbons	<0.1	0.0004	N/A
Total dissolved hydrocarbons (including BTEX)	<0.1	0.0004	N/A
Benzene*	<0.05	0.0002	0.5
MEG	<1	0.004	N/A
Other production chemicals including corrosion inhibitors	<1	0.004	N/A
aMDEA	<1	0.004	N/A
PAHs, total	<0.1	0.0004	Napthalene = 0.05
Chromium, Lead, Nickel and Zinc	<0.5	0.002	0.0022 - 0.0077
Cadmium	<0.175	0.0007	0.0007
Copper	<0.075	0.0003	0.0003
Mercury*	0.0001	0.0000004	0.0001
Silver	<0.2	0.0008	0.0008

** These constituents are recognised as bioaccumulators and are predicted to meet 99% species protection limits at end of pipe.*

Concentrations of chemical constituents presented in **Table 4** are predicted concentrations based on the current design reference case. These estimates may be subject to some change as engineering design progresses.

9.4 *Apart from an expectation that the wastewater treatment plant will achieve <5 mg/L, the performance characteristics of the wastewater treatment plant have not been provided. For example many of the contaminants in the water to be treated will be water soluble (e.g. BTEX, many PAHs, metals) and may not be removed by the treatment plant. If the combined concentration of many of these contaminants was 5mg/L or greater then the effluent could be expected to be toxic and would require substantial dilution to achieve safe levels.*

Proposed onshore wastewater treatment facilities will ensure that the combined concentration of BTEX, PAHs and metals will be extremely low. Expected chemical constituents and concentrations, including BTEX, total PAHs and metals are provided in **Table 4**. The proposed wastewater treatment process is described below.

The system to treat produced water (i.e. condensed water) and non routine and accidentally oil contaminated water will be a combined system and will include the following phases:

- salt removal
- removal of dissolved and free hydrocarbons through a macro porous polymer
- biological treatment via a membrane bioreactor
- micro filtration and UV/ ozone treatment to remove ions (this allows treated wastewater to be used as process water in the onshore gas processing facility).

It should also be noted that non routine and accidentally oil contaminated water will be fed through a gravity separation system before it is commingled with condensed water for treatment.

Sewage and grey water will be treated in a sewage treatment plant and will follow the following steps:

- separation
- biotreatment (membrane bioreactor)
- chlorination
- nutrient removal.

9.5 *WET testing of the Goodwyn Alpha produced water is used to give some indication of the toxicity of the Pluto wastewater discharge. Unfortunately these tests are almost all acute tests, many with mortality related end-points and the range of species tested does not meet the minimum dataset requirements for deriving a moderate reliability guideline (five species from four different taxonomic groups, including a fish, invertebrate and alga) (ANZECC & ARMCANZ, 2000). Given the low reliability of the dataset, significant assessment (safety) factors need to be applied to derive a low reliability guideline trigger value, as outlined in ANZECC & ARMCANZ (2000).*

See response to **Comment 9.6**.

9.6 *The proponent has estimated a dilution factor of 200 to apply to the wastewater outfall for the protection of marine biota (page 154). There is no logical basis for the derivation of this dilution factor. Using the recommended approach from ANZECC & ARMCANZ (2000) on the inadequate dataset for Goodwyn Alpha, an estimated low reliability guideline for dilution of the wastewater would be either the lowest chronic NOEC value (algal growth inhibition test) divided by 200, or the lowest acute LC50 or EC50 value divided by 1000, whichever is the lowest. This gives a required dilution factor of at least 6400. If the dataset was assumed to be adequate then a different approach would be taken to deriving a dilution factor, for example, using the algal growth inhibition data the dilution factor would be 320. Even so, these dilutions are based on toxicity data for untreated Goodwyn Alpha produced formation water with no other added waste streams and therefore of little relevance to this proposal.*

The MEG recirculation system proposed for the Pluto LNG Development cannot tolerate any significant saline produced formation water ingress. For design purposes a nominal allowance is made for a small quantity of 'nuisance' formation water ingress; the balance of the offshore produced water being non-saline water condensed from the hydrocarbon gas phase. The small formation water allowance is made to ensure design robustness and in practice there may actually be little or no formation water produced. Wells that produce large quantities of formation water will be shut-in until future offshore facilities are installed that can remove and treat the formation water offshore.

The Draft PER states that the Pluto gas field will be managed to avoid large quantities of formation water and it was conservatively assumed that 20% of the produced water coming to shore would be formation water with the remainder comprising condensed water. In practice this is a design allowance and the expectation is that there will be negligible formation water produced.

The Goodwyn Alpha produced formation water and associated WET testing was used as highly conservative comparison case. As stated in Section 7.8.13.3 of the Draft PER the Goodwyn Alpha produced water ecotoxicology assessment was used in the absence of toxicity information for produced water (i.e. formation and condensed water) from the Pluto gas field. Goodwyn Alpha produced water was chosen as the best available analogy in terms of toxicity given it is also a gas/ condensate facility located on the North West Shelf and uses the same types of chemicals that the Pluto LNG Development will most likely use.

Based on predicted chemical constituents and concentrations of the treated wastewater as outlined in response to **Comment 9.3**, toxicity is likely to be very low.

9.7 PFW and Condensate water will also contain MEG that will mostly be separated from the wastewater for re-use. However, a quantity of MEG will still be discharged with the wastewater. Information is required on the actual concentration of MEG anticipated to be discharged and on its toxicity.

The Draft PER (**Section 7.8.13.3**, p.152) states that prior to treatment, the concentration of MEG could be as high as 100 mg/L. However, with the wastewater treatment system proposed (as outlined in the response to **Comment 9.4**), the MEG concentration is expected to be less than 1 mg/L (refer to **Table 4**).

It is considered unlikely there will be any environmental impacts associated with discharge of MEG into Mermaid Sound as is stated in the Draft PER (**Section 7.8.13.3**, p.153):

"A review of eco-toxicity data (Hinwood et al. 1994) found MEG to be slightly toxic (1000-10 000 LC50 (mg/L)) to almost non-toxic (10 000 – 100 000 LC50 (mg/L)). The MEG is readily bio-degradable in water with degradation likely to occur through aerobic bacterial activity. No acute or chronic impacts on marine organisms resulting from discharge of MEG are expected given its low toxicity and that all wastewater streams will be bio-treated then filtered."

9.8 Statements such as 'Sedimentation of hydrocarbon compounds and heavy metal precipitates from PFW is not generally thought to be a problem in terms of impact on sediment quality as suspended particles are spread over a wide area' and 'heavy metals (and other potential bioaccumulators) associated with Pluto wastewater are likely to be very low and dilution in the receiving environment will reduce them to background levels' need to be backed up with data on discharge concentrations and modelling data.

Table 4 contains expected concentrations of hydrocarbons and heavy metals in the treated wastewater. Given the expected low concentrations of these constituents, impacts resulting from sedimentation are considered unlikely. A reduction in volume of discharged treated wastewater (refer to project update in **Section 2.3** for further details) will further ensure that impacts from sedimentation are unlikely. Model outputs show that the plume is rapidly diluted within the first 10 m of discharge. Concentrations of potential bioaccumulators will be within 99% species protection levels (ANZECC/ARMCANZ 2000) at end of pipe, to ensure the risk of bioaccumulation from discharged contaminants is negligible. A comprehensive monitoring programme will be put in place to ensure contaminants are not bio-accumulated by marine organisms. This will include agreed ‘trigger values’ for initiation of further studies and remedial actions as necessary (as stated in Table G-3, Appendix G of the Draft PER).

9.9 A 100m x100m mixing zone is proposed for the outfall within a ‘high ecological protection area’ (DoE, 2006). Very little data has been provided to justify such a large mixing zone for this relatively small outfall (mixing zone is same approx. size as for the multi-user pipeline) and consideration needs to be given to reducing its size.

Woodside acknowledges that the 100 m x 100 m mixing zone is conservative as it is based on a PNEC derived from WET testing undertaken on untreated Goodwyn Alpha produced water which, as discussed in response to **Comment 9.6**, provides a highly conservative assessment of wastewater that will actually be discharged into Mermaid Sound.

It should also be noted, as stated in Section 7.8.13.3 (pg. 156) of the Draft PER, that the mixing zone accounts for worse case wind and tide scenarios and that approximately 70% of the time required dilutions are likely to be met within a much smaller mixing zone (likely to be within 10 m).

Further wastewater modeling has been undertaken since completion of the Draft PER to assess discharge of a revised volume of 3000 bpd of treated wastewater (as discussed in **Section 2.3**) As discussed the revised modeling shows an improvement in dilution at 50 m.

It should also be noted that the mixing zone accounts for worse case wind and tide scenarios and that even during this worse case scenario it is likely that a dilution of >500 would be achieved within 10 m of discharge approximately 70% of the time. Improved dilutions in the near-field and far-field are predicted during other seasons and tidal conditions.

9.10 The outfall must also be considered within the context of impacts on the social environmental values (e.g. recreation and aesthetics, fishing and aquaculture) as well as ecosystem health.

Refer to the response to **Comment 9.11**.

9.11 The environmental values (EVs), environmental quality objectives (EQOs) and levels of ecological protection (DoE, 2006) that apply to the marine waters affected by this proposal are not well described. The response to submissions needs to clearly describe the impact of the development on the EVs, EQOs and levels of ecological protection and the EQOs and levels of ecological protection that the proponent is committing to achieve, including the proposed mixing zone (note: strong technical arguments are required to justify a change in EQOs or levels of protection).

The Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives was released in June 2006 (DoE 2006a). This document establishes an Environmental Quality Management Framework (EQMF) and presents the EPA’s interim set of environmental goals (environmental values and environmental quality objectives) and spatially allocates these goals (levels of ecological protection) for state waters of the Pilbara coast. The table below provides an assessment of Pluto LNG Development activities against the environmental values (EVs), environmental quality objectives (EQOs) and levels of ecological protection that apply to the marine waters of Mermaid Sound. It includes an assessment of potential impacts on ecological and social values associated with the following development components:

- treated wastewater discharge
- the nearshore infrastructure such as the turning basin and jetty
- dredging and spoil disposal activities.

▪ **Table 5: Assessment of Development Activities Against Environmental Values, Environmental Quality Objectives and Levels of Ecological Protection**

Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed Indicators	Potential Impacts and Management for Treated Wastewater Discharge	Potential Impacts and Management for Nearshore Infrastructure (Jetty and turning basin)	Potential Impacts from dredging and spoil disposal	Relevant EQCs
Ecosystem Health	Maintenance of ecosystem Integrity	Physical and Chemical Stressors: ▪ Turbidity and Sedimentation ▪ Dissolved Oxygen ▪ pH Toxicants in water and sediments including the following: ▪ Metals/metalloids ▪ Non-metallic inorganics ▪ Organics	A localised mixing zone (100 x 100 m) is proposed at the wastewater discharge location as shown in Error! Reference source not found.. A low LEP is proposed in this mixing zone. Within this mixing zone elevated levels of some chemical constituents may be expected (refer to response to **Comment 9.3** for details on predicted constituents and concentrations). Outside of this mixing zone a moderate level of protection will be achieved at all times. It should be noted that in terms of chemical constituent concentrations of the treated wastewater, a high level of protection will be achieved at the edge of the mixing zone and that the moderate LEP relates to nearshore infrastructure and associated shipping during operations as discussed in	In the vicinity of the proposed nearshore marine infrastructure a moderate level of ecological protection (LEP) will be allocated, commensurate with the level allocated to existing industrial development areas in Mermaid Sound (as shown in Error! Reference source not found.). A moderate LEP would allow for elevated levels of turbidity and sediment mobilisation resulting from shipping movements, associated with operations, at these facilities. Other indicators including: metals, pH and dissolved oxygen are unlikely to be impacted by the proposed nearshore infrastructure.	There are likely to be impacts within Mermaid Sound resulting from elevations in turbidity and sedimentation, as a result of dredging. These impacts and management measures proposed are presented in detail in Section 7.9 of the Draft PER and in various responses to comments in this document Impacts on pH and dissolved oxygen levels are unlikely; however, these indicators will be monitored as described in the DSDMP. Impacts on water and/or sediment quality resulting from mobilisation of toxicants during dredging are considered unlikely given sediments in the area of dredging were found to be clean.	Physiochemical baseline data that is currently being collected by the Woodside will be used together with Australian and New Zealand Water Quality Guidelines (ANZECC & ARMCANZ 2000) to develop appropriate physiochemical EQCs for Mermaid Sound. Water and sediment quality baseline data that has been collected by the DoE will be used together with Australian and New Zealand Water Quality Guidelines (ANZECC & ARMCANZ 2000) to develop appropriate EQCs for Mermaid Sound

Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed Indicators	Potential Impacts and Management for Treated Wastewater Discharge	Potential Impacts and Management for Nearshore Infrastructure (Jetty and turning basin)	Potential Impacts from dredging and spoil disposal	Relevant EQCs
			column five of this table). Discussion of discharge of treated wastewater into Mermaid Sound and the associated mixing zone is discussed in Section 7.8.13.3 of the Draft PER. Management and monitoring of the treated wastewater and potential impacts is described in Section 7.8.13.4 of the Draft PER and in the response to **Comment 9.4**.			
Fishing and Aquaculture	Seafood for Human Consumption	Biological contaminants: ▪ Thermotolerant faecal coliforms in water Thermotolerant faecal coliforms in fish flesh ▪ Metals and organics in fish flesh	Pluto wastewater will be treated to a very high level so that biological contaminants, metals, organics and other potential contaminants are highly unlikely to bioaccumulate or otherwise impact on the quality of seafood for human consumption. Volumes of sewage and grey water will be low further reducing potential for risk from biological contaminants.	Impacts on seafood for human consumption as a result of the presence of the proposed nearshore infrastructure are considered highly unlikely.	Impacts on seafood for human consumption as a result of dredging activities associated with dredging for the Pluto LNG Development are considered highly unlikely.	Thermotolerant faecal coliform bacterial concentration guidelines as per the Australian and New Zealand Water Quality Guidelines (ANZECC & ARMCANZ 2000) will be used as the basis for EQCs within Mermaid Sound.

Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed Indicators	Potential Impacts and Management for Treated Wastewater Discharge	Potential Impacts and Management for Nearshore Infrastructure (Jetty and turning basin)	Potential Impacts from dredging and spoil disposal	Relevant EQCs
	Aquaculture	Toxicants – a range of metals, inorganics and pesticides. Physio-Chemical Stressors: ▪ Dissolved Oxygen ▪ pH	There are presently no active aquaculture leases in Mermaid Sound; nevertheless, outside the proposed localised mixing zone it is unlikely treated wastewater discharge will exceed EQCs associated with aquaculture. Dissolved oxygen and pH levels are highly unlikely to vary significantly as a result of Pluto treated wastewater discharge outside the mixing zone.	Presence of nearshore infrastructure is highly unlikely to impact upon possible future aquaculture activities within Mermaid Sound.	Impacts on future aquaculture activities in Mermaid Sound associated with mobilisation of toxicants are highly unlikely, given sediments to be dredged are clean. Potential for impacts from turbidity and sedimentation associated with dredging will be transient; considered very unlikely there will permanent impacts that may affect future aquaculture activities.	EQCs to be developed for the maintenance of ecosystem integrity will be used to maintain aquaculture values.
Recreation and aesthetics	Primary contact recreation values (for example, swimming and diving)	Biological: • Faecal Pathogens • Toxic Algae Physical : ▪ pH ▪ Water clarity Radiological: • Toxic Chemicals – a range of chemicals including inorganics,	Outside a localised mixing zone, it is considered unlikely biological, physical and chemical indicators relating to primary contact recreation will be exceeded. It is highly unlikely primary contact recreation activities will occur inside the mixing zone which includes the proposed jetty and associated berthing facilities. Radiological – see response to **Comment 9.19** for	It is considered unlikely indicators associated with primary contact recreation activities will be impacted by the presence of the nearshore infrastructure. Limited primary contact recreation activities currently occur in the vicinity of the proposed nearshore infrastructure.	Water clarity as an indicator in primary contact recreation serves to enable swimmers to estimate depth and see subsurface hazards easily. Given swimming rarely occurs in the vicinity of the dredge operations impacts are considered highly unlikely. Impacts on water clarity will be mitigated against through a variety of	EQCs to be developed for the maintenance of ecosystem integrity will be used to maintain primary contact recreation values. See Aesthetic Values section of this table for water clarity related EQC. Radiological – see response to **Comment 9.19** in this document.

Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed Indicators	Potential Impacts and Management for Treated Wastewater Discharge	Potential Impacts and Management for Nearshore Infrastructure (Jetty and turning basin)	Potential Impacts from dredging and spoil disposal	Relevant EQCs
		organics, pesticides.	discussion of NORMs and discharge of radioactive material into Mermaid Sound. Treated wastewater discharge will managed according to Section 7.8.13.3 of the Draft PER and the updated Framework Wastewater Management Plan provided as part of the response to **Comment 9.13**.		measures as detailed in the DSDMP. Water clarity is further discussed in the Aesthetic Values section of this table.	
	Secondary contact recreation values (includes boating and recreational fishing)	Biological: • Faecal pathogens • Toxic Algae Physical and chemical: • pH • Toxic Chemicals	Limited secondary contact recreation activities will occur within the vicinity of the wastewater outfall, nevertheless the treated wastewater is highly unlikely to contain chemicals at concentrations that can irritate the skin of the human body. No impact from treated wastewater on secondary contact recreation values is expected.	No impact from the presence of the proposed nearshore infrastructure on secondary contact recreation values is expected.	No impact from dredging activities on secondary contact recreation values is expected.	No impacts expected. EQCs to be developed for the maintenance of ecosystem integrity will ensure secondary contact recreation values are maintained.
	Aesthetic Values	Water Clarity Fish Tainting Substances – large range of chemicals implicated in fish tainting – related to concentration in water	It is highly unlikely that treated wastewater will result in impact on water clarity or fish flesh quality relevant to aesthetic values given the high level of treatment of the wastewater	Presence of nearshore infrastructure is highly unlikely to impact upon water clarity or fish flesh quality. For further discussion on aesthetic impacts from the Pluto LNG Development,	Dredging activity is likely to result in exceedances of the EQCs for water clarity within some areas of Mermaid Sound. A figure showing the area where water clarity will be reduced by more than	As per the Australian and New Zealand Water Quality Guidelines (ANZECC & ARMCANZ 2000) – the natural visual clarity of the water should not be reduced

Environmental Value (EV)	Environmental Quality Objective (EQO)	Proposed Indicators	Potential Impacts and Management for Treated Wastewater Discharge	Potential Impacts and Management for Nearshore Infrastructure (Jetty and turning basin)	Potential Impacts from dredging and spoil disposal	Relevant EQCs
		column.	proposed.	including nearshore infrastructure, refer to Section 11.12 of the Draft PER.	20% will be provided once re-modelling has been completed and appropriate background data has been collected and analysed. It should be noted that impacts on water clarity are transient and will not result in long term changes. Impacts on water clarity will be mitigated against through management measures and controls detailed in the DSDMP. Fish tainting substances are highly unlikely to of issue given sediments to be dredged are clean.	by more than 20%.
Cultural and Spiritual	Maintenance of cultural and spiritual values		No Impacts are predicted	No Impacts expected	No Impacts expected	No impacts expected
Industrial Water Supply	Maintenance of industrial water supply values		No impacts are expected from the treated Pluto wastewater discharge on industrial water supply values.	No impacts are expected from the treated Pluto wastewater discharge on industrial water supply values.	No impacts are expected from the treated Pluto wastewater discharge on industrial water supply values.	No impacts expected

9.12 A map showing the benthic habitats within the vicinity of the outfall is needed.

Figure 6 shows benthic habitats within the vicinity of the wastewater discharge point and the proposed Moderate Level of Ecological Protection (LEP) around the nearshore infrastructure, commensurate with the level allocated to existing industrial development areas in Mermaid Sound. A moderate LEP would allow for elevated levels of turbidity and sediment mobilisation resulting from shipping movements, associated with operations, at these facilities.

9.13 A comprehensive management plan would be required for an outfall such as this. It would need to address issues such as (but not limited to):

- *Management of the different waste streams that make up the wastewater discharge*
- *Wastewater discharge rate*
- *Wastewater contaminant monitoring program*
- *Whole effluent toxicity testing of the wastewater*
- *Diffuser performance monitoring*
- *Environmental/ecological impact monitoring around the outfall to confirm 'no impact'.*

A Framework Wastewater Management Plan in Table G-3 in Appendix G of the Draft PER which covers the issues suggested in the above comment (with the exception of 'Wastewater discharge rate'), and is provided below. Proposed revisions are highlighted in red below.

Table 6: Framework Wastewater Management Plan

Wastewater Management Plan Format	
Management Issues	The discharge of wastewater may result in marine physical and ecological effects including reduced water quality and toxicity effects to marine biota.
Objectives	To comply with applicable legislation and guidelines. To minimise the potential for adverse impacts on water quality.
Performance Indicators	Performance indicators will be developed consistent with relevant regulatory, local and Development requirements
Management Strategies	▪ The residual total hydrocarbon in water concentration of wastewater discharge will be less than 5 mg/l as an annual average for water discharged to Mermaid Sound. ▪ Other measures employed to reduce the potential for environmental impact associated with wastewater disposal are process design, procedures for chemical selection, dosing rates and operational maintenance and control of production equipment. ▪ Woodside will put in place reduction targets and mitigation measures should the results of monitoring and/or investigations indicate a potential or actual unacceptable impact. ▪ Whole Effluent Toxicity (WET) testing on actual treated wastewater will be undertaken as soon as first water becomes available and periodically thereafter. Routine monitoring to ensure discharged wastewater meets specified criteria. ▪ Construction amenities will be regularly inspected and maintained, and effluent will be disposed of offsite at an appropriate facility. ▪ During operation, approved sewage systems will be provided at Site B. ▪ An appropriate monitoring and maintenance schedule for the sewage treatment system at Site B will be developed and implemented. ▪ The oil-in-water meter will be regularly tested and calibrated as per acceptable standards to ensure its accuracy. ▪ The concentration of total hydrocarbon in wastewater discharged to Mermaid Sound will be measured daily. ▪ A contingency plan will be developed to manage wastewater in cases where unexpected volumes and/or quality of wastewater are produced.
Monitoring	Monitoring of wastewater will occur at source prior to commingling and at the discharge point. Wastewater will be monitored in accordance with regulatory requirements and will include monitoring of discharge rates. A comprehensive monitoring programme will be put in place to confirm the prediction of

	no significant impact to nearshore communities and to ensure contaminants are not bio-accumulated by marine organisms. This will include agreed 'trigger values' for initiation of further studies and remedial actions as necessary. Monitoring will confirm that an appropriate level of ecological protection is being achieved at the edge of the agreed mixing zone. The concentration of total hydrocarbon in wastewater discharged to Mermaid Sound will be measured daily. Routine monitoring to ensure treated wastewater meets the EQMF social use values at end of pipe or within a distance, from point of discharge, agreed with the relevant authorities.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

9.14 Coral habitat has been mapped in some detail on the eastern side of Mermaid Sound for predicting the effects of the turbidity plume (e.g. Figures 7-36 to 7-40 and 7-44 to 7-51) and for this the proponent should be commended. However, it is noted that coral habitat on the western side of Mermaid Sound has not been well mapped and should be rectified. Maps showing macroalgal habitat are less detailed, and sponge/soft coral habitat and seagrass habitat have not been mapped at all. It is accepted that seagrass distribution in this area is patchy and seasonally variable; nevertheless, Figure 7-32 is not an acceptable level of detail for a seagrass habitat map.

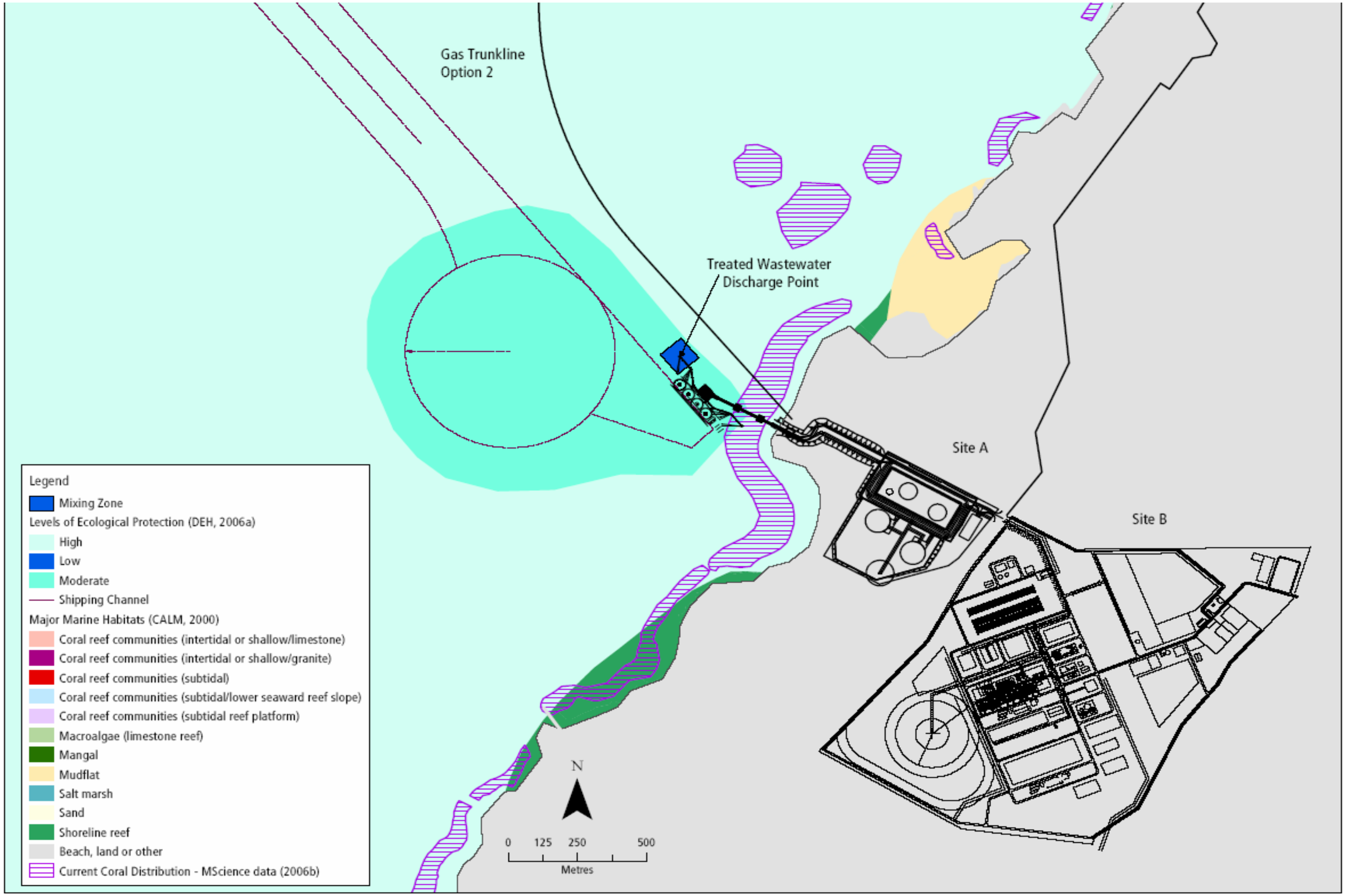
Coral habitat distribution within DPA limits on the eastern side of Mermaid Sound is shown in **Figure 7**.

Figure 7-31 and **Figure 7-32** of Section 7.9.9.2 the Draft PER have been revised to include information from studies of the marine biodiversity of the Dampier Archipelago (WA Museum 2004). The data included in the revised figures is sourced from two diving expeditions (Morrison 2004, data collected in 1998 and 1999) and a dredging expedition (Hutchins et al 2004, data collected in 1999).

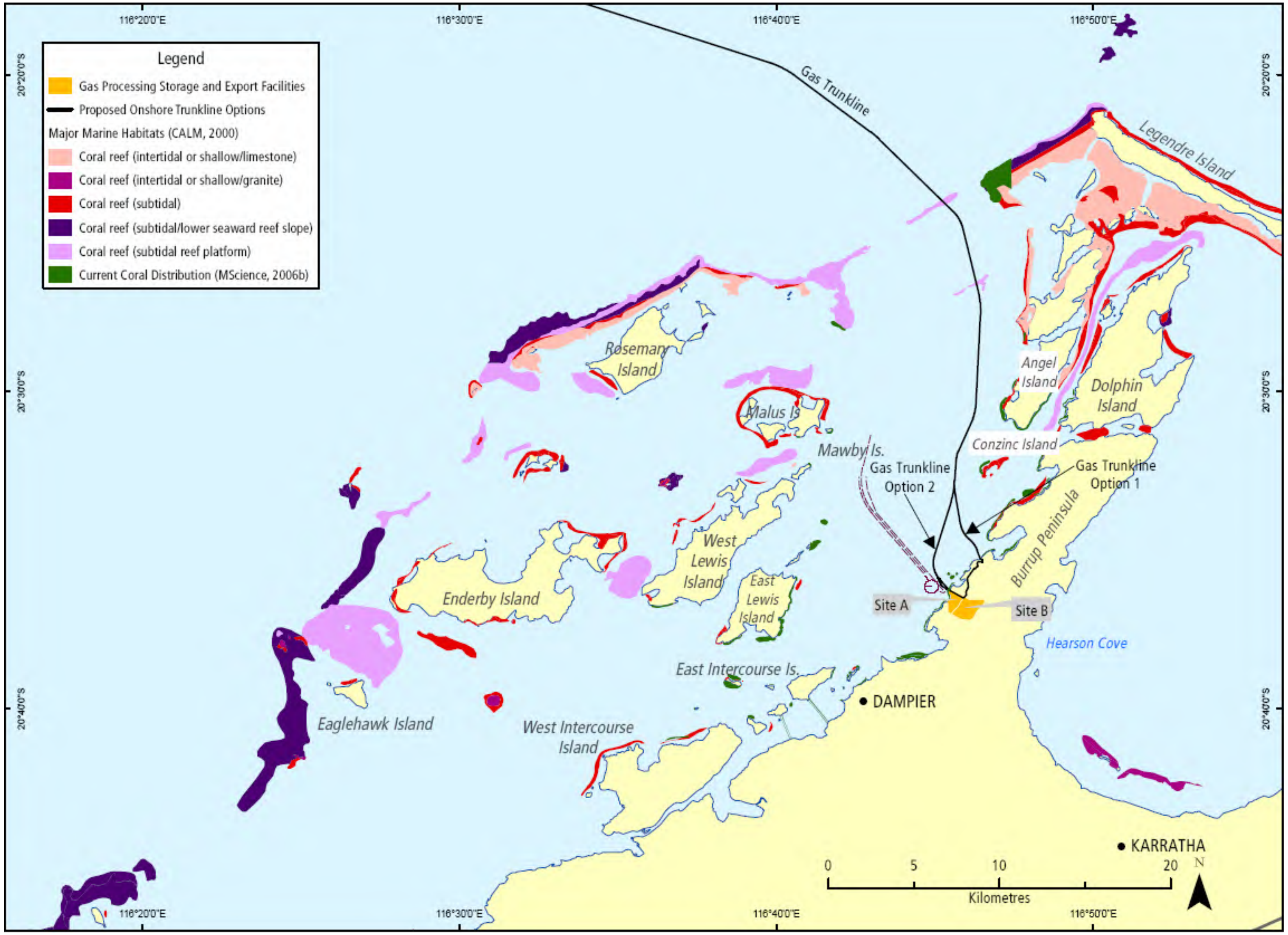
In **Figure 7-31** macroalgae data from the diving expeditions is quantitative and includes approximate percentage cover at each sample site. The dredging expedition data has records of occurrence during each dredge. Stations where no macro-algae were observed are included to provide an indication of the areas of occurrence.

Similarly, **Figure 7-32** now includes stations where no seagrasses were observed to provide an indication of the areas of occurrence. Information on seagrass from the Dampier Archipelago generally does not include information on percent cover. The information consistently report seagrass as sporadic and occurring in low density. The most common species are *Halophila sp*., which are generally ephemeral and is known for its ability to colonise new areas.

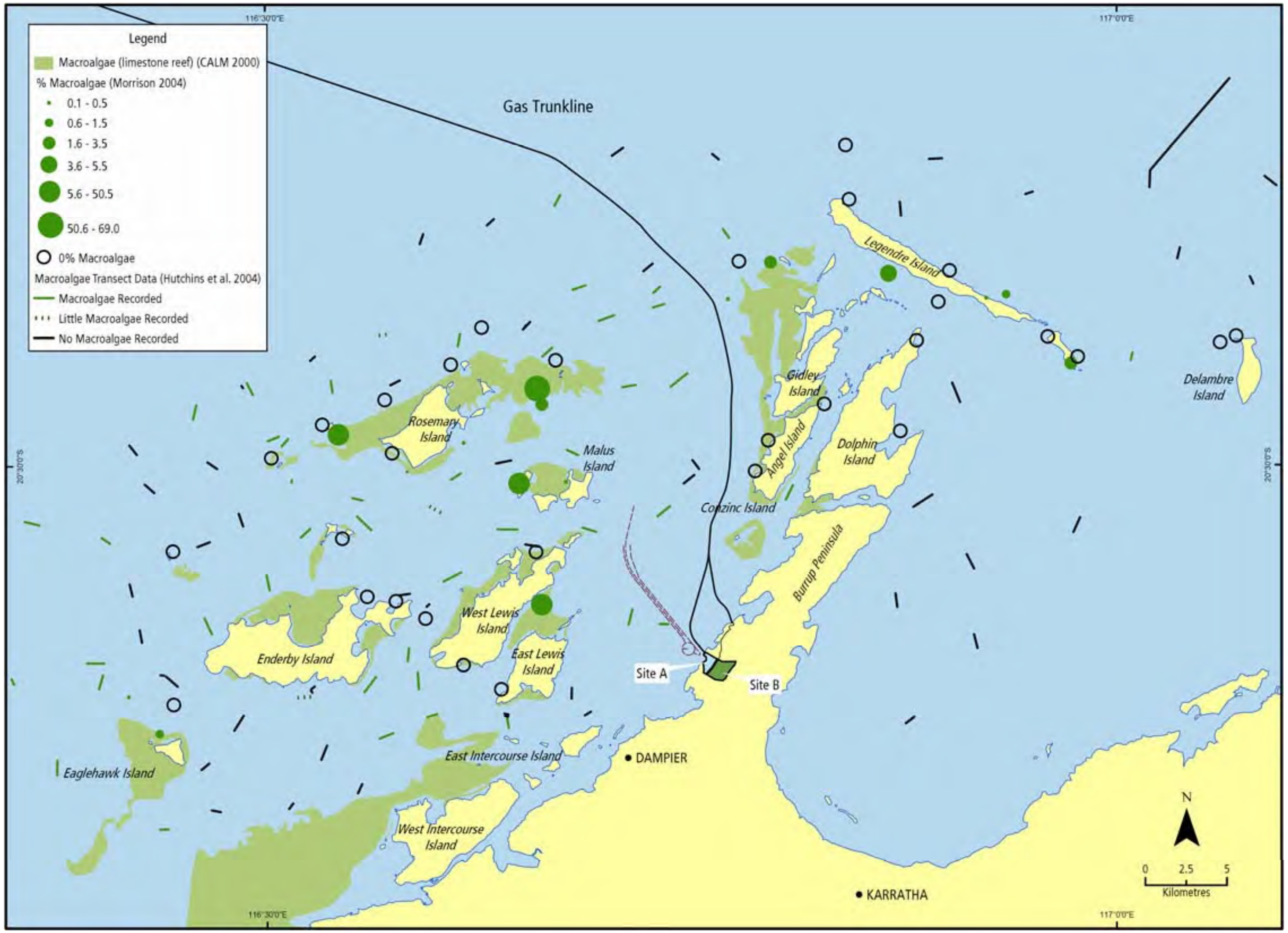
For further discussion on the predicted impacts on macro-algae and seagrass please refer to the response to **Comment 9.22.**



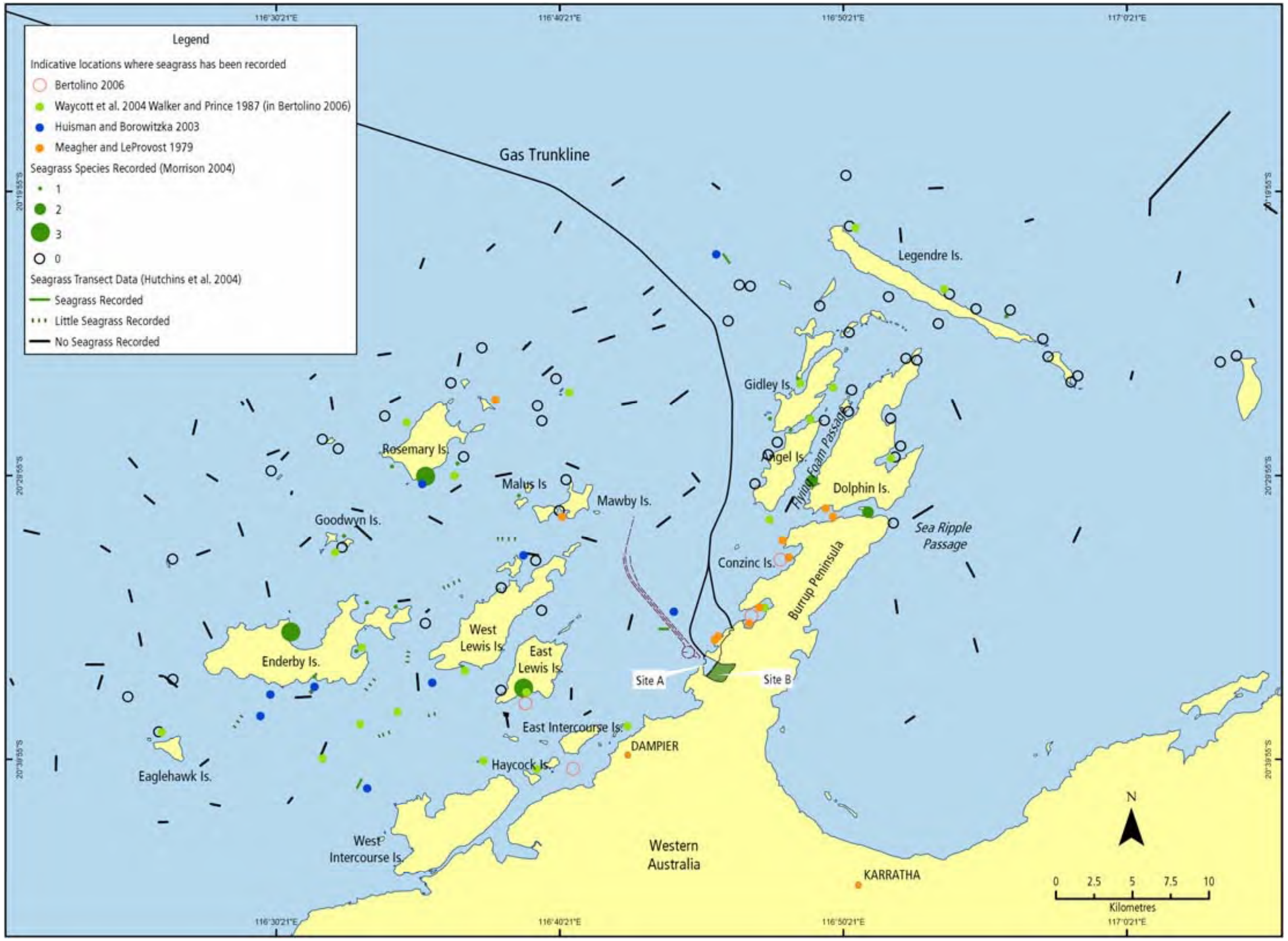
- **Figure 6: Benthic Habitats in the Vicinity of Wastewater Discharge Location**



■ **Figure 7: Revised Coral Distribution inside DPA limits in Mermaid Sound**



■ **Figure 7-31: Revised Macroalgae Distribution in Mermaid Sound**



■ **Figure 7-32: Revised Seagrass Distribution in Mermaid Sound**

10.1 That the proponent develops a detailed quantitative benthic habitat map that encompasses the 'zone of influence' of the project's marine works to allow an informed assessment of the nature and scale of potential environmental impacts. Given that the proposal has potential to impact on a proposed marine park, a quantitative habitat survey is considered necessary. This recommendation is consistent with comments made by the former CALM to both the EPA and proponent dated 5 May 2006.

For discussion of the 'zone of influence' please refer to the response to **Comment 9-24**.

For revised benthic habitat maps please refer to the response to **Comment 9-14**.

9.15 Please provide a copy of references IRCE (2004a) and Bertolino (2006).

Both references will be provided to the EPA and DEC.

9.16 When describing background suspended solid levels the median suspended solid concentration should be provided as well as the range. Just providing the range does not give an indication of typical background concentrations.

Woodside agrees that the range of suspended solids observed does not specify typical background rates (such as the median). However, for a median value to provide information on typical levels, the dataset itself must reflect the levels in Mermaid Sound in relation to the frequency with which they occur.

To illustrate this, monitoring before and after the Trunkline System Expansion Project (TSEP) installation showed no influence on the background TSS levels as rough weather caused suspension of solids across the Sound (IRCE 2004). The range of all recordings was 1–19 mg/L with a median of 10 mg/L (unpublished data from IRCE 2004).

In 1985 the DEC recorded surface and bottom TSS values at six sites to set a 'background level'. The surface values had a range of 0.88–8.64 mg/L and a median of 2.74 mg/L (as recorded in LSC 1987).

The problem is illustrated with the relatively high number of samples (54 in total) obtained during rough weather by IRCE, versus the relatively low number (17 in total) obtained by the DEC. It is clear that the higher number of samples taken during rough weather will bias the median in this example. Other factors influence the TSS levels as well, for example, the large tidal regime in Mermaid Sound. The ability of a median to describe a 'typical' situation thus depends on the representativeness of the dataset from which is calculated.

At the time of writing the Draft PER the data available on the levels of the suspended solids in Mermaid Sound consisted of spot measurements (as described above) taken over several years during a variety of conditions but with no corresponding time-series recording tidal cycles and sea states. In recognition of the need for corresponding time series data Woodside commenced a baseline study in August 2006 deploying five loggers continuously logging turbidity. Site-specific calibrations both in the field and in the laboratory provide estimations of continuous TSS levels at five sites in Mermaid Sound. This data will provide a solid basis for calculating statistics (such as the median) to support the understanding of the sediment flux within Mermaid Sound. This will provide information on general values as well as time series data of TSS variation over time and the temporal persistence of elevated levels.

9.17 Natural sedimentation levels are described to be as high as 240 mg/cm^2/day. This is extremely high and DEC suspects only occurs over unusual circumstances. Typical sedimentation rates in Mermaid Sound are generally in the 2 – 20 mg/cm^2/day.

Typical sedimentation rates in Mermaid Sound are lower than 240 mg/cm^2/d and this rate was not used to describe typical background sedimentation rates in the Draft PER.

The value of 240 mg/cm^2/d was used specifically in the impact assessment to determine a possible threshold value where intense mortality would occur in line with community and habitat loss as defined by EPA Guidance Statement No. 29 (EPA 2004). The observed rate of 240 mg/cm^2/d occurred following rough weather (IRCE 2004) and is not referred to in the Draft PER as a 'typical sedimentation rate'. However, the observed rate is not considered unusual, as the observation period did not occur after cyclonic influence, a situation when even higher rates are expected to occur.

For a discussion of background sedimentation rates, please refer to the response to **Comment 10.2**.

9.18 The models used to predict movement and fate of suspended sediment plumes do not appear to take into account on-going settlement and re-suspension of particles. This would seem to be a very significant process for a 2 year dredging and disposal program and could result in a significant underestimation of the influence of the dredging program if not adequately taken into account. Could the proponent please clarify how this process has been addressed through the modelling.

The sediment dispersion model used in the Draft PER follows a particle generated by either dredging or spoil disposal until first settlement on the seafloor. Therefore, suspension is accounted for up until first settlement and after that it 'drops' out of the model. Sedimentation patterns predicted by this model give an estimate of cumulative sedimentation, that is, how much sediment is predicted to accumulate on the seabed in each model cell without accounting for re-suspension. This is not seen as a limiting factor as the validity of the impact which can be predicted with this model output depends on the interpretation of both model output and observed sedimentation flux patterns in Mermaid Sound.

Observations from previous dredging programmes in Mermaid Sound suggest that impacts from sedimentation (possibly in synergistic effect with TSS, but not from TSS alone) generally occur within 1 and 1.3 km from the uplift area. In this area sedimentation rates can be very high inundating the coral community and causing long-term losses (Blakeway 2005). Peaks in TSS alone have not been observed to have a similar level of impact and has not been observed to cause losses of coral communities (Blakeway 2005.). This indicates that the near-field impacts are coupled to sedimentation but exactly how much is unknown. Outside the near-field footprint impacts are most likely coupled with increased TSS levels reducing light levels below a critical point for coral survival. Impacts such as these have not been recorded in Mermaid Sound from previous dredging programmes.

The model outputs predict conservatively high rates of accumulating sedimentation, with near-field rates of such proportions that the coral community is likely to become inundated and suffer intense mortality to the extent that the benthic primary producer community can be considered 'lost'. However, it is understood from the preliminary baseline monitoring results that the high rate of re-suspension in Mermaid Sound will cause re-suspension of at least parts of the settled particles soon after settling, thereby assisting in the removal of particles from the affected coral community.

The coral losses stated in the Draft PER were estimated using cumulative sedimentation predictions and theoretical thresholds which define an area in the near-field where corals are at risk of experiencing high sediment deposition. Resuspension of a proportion of the settling particles in the near-field will lesson the strain on the affected coral community by removing landing particles. Not taking re-suspension into consideration in the model predictions of sedimentation rates will over-estimate the accumulation of sediment and thereby possibly overestimate near-field estimate of losses. It is not clear where sediment goes once it is re-suspended and lifted from the surface of the corals. This is a complex issue and background baseline monitoring does not give a clear indication of the drift path of the suspended solids.

Woodside is currently scoping a revised model where wave energy is added and where particles are allowed to re-suspend depending on their size and the ambient energy field. This will provide further information on the fate of particles after re-suspension including migration to further afield areas where they may result in an increase in turbidity and light attenuation, and therefore indirect impacts on benthic primary producers from light deprivation.

Woodside believes that the impact assessment and specifically the coral community loss estimations caused by the first-time settlement of particles in the near-field area, close to both the uplift area and spoil disposal area, provide a realistic estimate of coral loss without re-suspension being accounted for in the model. Reference should be made to Table 7-34 of the Draft PER where the coral community loss estimates have been compared to previous observations.

9.19 In figure 7-15 the measured current speeds are generally significantly greater than the modelled current speeds. What effect is this likely to have on the predicted extent of the suspended sediment plumes?

The current meter is mounted near the bottom of the seabed where the influence of local topography and seabed is greatest; the current meter data itself only gives an estimate which is representative of that particular location and depth. The instrument is at a precise depth (1 m above seabed) while the current prediction is for a band spanning from the seabed to a position above the depth of the meter and hence is depth averaged over a 2 m depth. Because this band is near the seabed, where drag is maximised, this would tend to diminish peak speed predictions.

Having said that, the comparison shows that the north–south current is being well represented for 70–80% of the time during each tidal period (that is, has precisely the same current speed and timing throughout most of each tidal cycle). Where currents are under-represented, it is only for a short period (< 1 hour in any six hours) spanning the peak and given the magnitude of the current speeds (0.1–0.2 m/s) would not lead to vastly larger migrations on any one tidal cycle.

Under-representation of the short-lived peak current speeds is likely to affect the spread of finer particles but not as a long-term migration in one particular direction. Rather, by leading to a marginally smaller deposition footprint in the north–south direction (that is, a bit narrower towards both the north and south) because a tidally-driven particle can only migrate in one direction as far as a tidal migration before it gets carried back. For a discrepancy of this nature along the channel, the under-representation that could have occurred is estimated at about 50–60 m in the width of the deposition footprint but only if this had not been corrected for.

The circulation in Mermaid Sound is strongly tide-affected during spring tides and more wind-affected during neap tides. To account for wind forcing, the dispersion modeling used current data that was predicted using wind data measured concurrently at Karratha and LeGendre Island (either end of the study area) – using distance-weighting to account for variations along Mermaid Sound. This wind data was not available for the comparison to the current meter. Hence, wind data from a hind-casting atmospheric model (NCEP/NCAR Reanalysis) that used a generalised topography and that lacked sea/land breeze effects had to be used. Despite the less accurate wind data, the model data shows a similar response to wind systems during the neaps.

Recognising that the modeled currents may not account for all sub-scale transport processes and could be under-representative of the tidal or wind-driven magnitudes, Woodside included conservative horizontal and vertical dispersion allowances in the dispersion modeling. This had the effect of increasing the spatial spread of particles by at least the same magnitude, and therefore avoided under-representing the potential for sediments to affect sites to the north or south (as well as east–west) of the suspension source. This is standard quality control practice in sediment dispersion modeling, that is, to start with the understanding that errors are likely to be present in the forcing data. Sensitivity tests were then carried out for these errors to determine their significance.

9.20 The modelling results in Table 7-29 suggests that resettled sediment particles from the dredging process will be of the same particle size distribution as native sediment composition. In practice this does not appear to be the case for Mermaid Sound sediments. Both DEC (2006) and environmental consultants (MScience, 2007) have found a layer of fresh fine sediment overlaying the original sediments in the vicinity of recent dredging programs.

Table 7-29 of the Draft PER compares receiving sediment particle size composition with the likely composition of 'produced' sediments from sidecasting and overflow. While the composition is similar Table 7-29 does not state the compositions will be 'the same'. For example, there is 0% and 4% coarser particles (>100 µm) in the TSHD overflow and side-cast material from the CSD, respectively, compared to 7% in the receiving sediment. As described in Section 7.9.12 of the Draft PER finer particles are generally predicted to drift further away from the source of suspension than coarser material before settling, therefore there is some scope for a change in the seabed particle size distribution.

Despite this, a thick layer of yellow fines, as depicted in DEC (2006), is not predicted to arise as a result of dredging from the Pluto LNG Development. There may be other causes for the previous deposition of fines in the inner Mermaid Sound such as an alteration of the local hydrodynamics from coastline modification.

9.21 It is not clear over what time period many of the model outputs cover (e.g. Figures 7-11 and 7-12). Outputs should be for a sufficient time period to show cumulative effects over many tidal cycles (e.g. Figure 7-16 only shows cumulative effects of propeller wash for a 100 minute period).

Figures 7-11, 7-12a-c, 7-19a-c, 7-20a-b, 7-21, (p.174–195) in the Draft PER were not intended to be cumulative plots, but were intended to show examples of the levels of suspended solids caused by an isolated activity or concurrent activities (as described in each of the figures). These figures show how suspended solids are being generated from each type of activity, with each image captured after a number of days into the simulation of that activity or activities. The extent of the plumes shown is therefore the result of the balance between delivery of sediments at the source and the expected settling and dispersal at distance under particular example conditions. Woodside acknowledges that to accurately interpret the example figures the period of simulation is needed. **Table 7** provides clarification of how long dredging had been occurring before each image was captured. Note that in each case there was ample time for the plume to develop.

- **Table 7: Dredging Duration Prior to Image Capture**

Figure No. (Draft PER p.174–195)	Number of Days into Simulation	Time of Image Capture
7-11	5	2 pm
7-12a	5	2 pm
7-19a	31	8 am
7-20a	17	2 pm
7-21	21	4 pm
7-12b	5	2 pm
7-12c	5	2 pm
7-19b	19	5 pm
7-19c	18	4 pm
7-20b	15	2 pm

The predicted TSS levels at adjacent coral habitats throughout the proposed dredging programme (phase 1 as described in Figure 7-25) is summarised in the Technical Appendix D, Volume 2 of the Draft PER. The mean and range of predicted TSS levels during each month from the dredging and spoil disposal activities are summarised in box-whisker plots. It should be noted, however, that these box-whisker plots are inclusive of the TSS associated with the Phase I spoil disposal programme, where all spoil was to be disposed into spoil ground A/B. The currently preferred option is for disposal of the majority of spoil into the offshore spoil ground 2b, thus decreasing the TSS exposure near spoil ground A/B. Monthly predictions of maximum TSS rates from limited spoil disposal into spoil ground A/B is shown in Figures 7-23 to 7-25 in the Draft PER, with predicted daily maximum levels at selected locations of coral habitat in Figure 7-35 of the Draft PER.

In summary, Figures 7-11, 7-12, 7-19, 7-20, 7-21 of the Draft PER are not meant to be cumulative plots. These plots are presented in Technical Appendix D, Volume 2 of the Draft PER, with Figure 7-42 in the Draft PER presenting the cumulative plots closest to Holden Point where coral losses are predicted due to dredging activities.

9.22 Potential impacts on seagrass and macroalgal meadows should be addressed in more detail. The statement 'Habitat for macroalgae is mainly found in the outer Mermaid Sound, and indirect impact from dredging or spoil disposal is considered unlikely' is contradictory to the information in the benthic habitat map Figure 7-34.

As discussed in Section 7.9.9.1 (p.210–211) of the Draft PER the anticipated impacts on seagrass are low, with no loss of seagrass habitat predicted. The assessment is based on the following observations:

- No seagrass was found during seabed surveys of the proposed navigation channel, and proposed spoil ground 2b (described in Section 7.9.9.1 p.211, and Section 7.9.5.2, p.168 in the Draft PER). Spoil ground A/B is currently in use. No direct impact (removal of seagrass habitat) is therefore anticipated from the Pluto LNG Development.
- As described in Section 6.3.1 (p.109) and Section 7.9.9.1 (p.210-211) of the Draft PER there are no records of dense seagrass beds found in the Dampier Archipelago, all records are of sporadic and low density presence, often of seasonal species like Halophila sp, which are able to colonise new areas well. Potential indirect impacts on sporadic occurrence of low cover seagrass may arise from sedimentation or light attenuation stress, however such impacts will not be long-lasting as the habitat will not be removed, and re-colonisation can occur as soon as conditions allow.

As discussed in Section 7.9.9.1 (p.210–211) the anticipated impacts on macro-algae are low, with no loss of macro-algae habitat predicted. The assessment is based on the following observations:

- No macro-algae of parts of macro-algae were found during seabed surveys of the proposed navigation channel (described in Section 7.9.9.1 p.211). Only very sparse macro-algae were observed during one survey of the proposed spoil ground 2b (Section 6.3.1 p.109) while another survey did not record any macro-algae at this location (Section 7.9.5.2 p.168). No direct impact (removal of macro-algae habitat) is therefore anticipated from the Pluto LNG Development.

- As described in Section 6.3.1 p.109 and Section 7.9.9.1 p. 210-211 of the Draft PER the presence of macro-algae in the Dampier Archipelago is most predominant around the islands of the archipelago, with little marco-algae recorded from the west coast of the Peninsula. The occurrence is seasonal and the life cycle of macro-algae makes them resistant to permanent indirect impact. Potential indirect impacts may arise from sedimentation or light attenuation stress, however such impacts will not be long-lasting as the habitat will not be removed, and re-colonisation can occur as soon as conditions allow.

The statement 'Habitat for macroalgae is mainly found in the outer Mermaid Sound, (Section 7.9.9.2 and Figure 6-13) and indirect impact from dredging or spoil disposal is considered unlikely' refers to the outer Mermaid Sound. Whilst not specifically defined, for the purposes of the Draft PER the outer Mermaid Sound is considered to be the northern half of Mermaid Sound, extending northwards from Mawby and Conzinc Islands (Figure 6-13). The inner Mermaid Sound is considered to be the area extending south from Mawby and Conzinc Islands. **Figure 7-32** shows some macroalge within the inner Mermaid Sound, however most of the macroalgae habitat shown in **Figure 7-32** occurs in the outer Mermaid Sound (included in the outer Mermaid Sound is the macroalgae around Conzinc Island, Angel Island and further north).

9.23 Table 7-31 provides predicted sedimentation thresholds for scleractinian coral in Mermaid Sound. It provides Acute, Medium-term and Chronic thresholds for resilient coral species associations, but only Acute thresholds for vulnerable species associations. Since both resilient and vulnerable scleractinian coral species associations will be exposed to turbid plumes and additional sedimentation from the dredge and dredge spoil disposal program it is not clear why medium-term and chronic thresholds have not also been used in the modelling to predict potential impacts on vulnerable coral communities. This could have resulted in an under-estimation of the effect on the corals.

The thresholds for resilient species were developed to capture impacts caused by prolonged dredging activities in the vicinity of Holden Point. Here continuous dredging activities are predicted to elevate the risk of many acute events occurring close together. The findings of Stoddart et al (2005) and Blakeway (2005) indicate that sites within 1 km of the uplift area were exposed to a significant decrease in water quality associated with continuous dredging.

However, sites close to the spoil disposal were not influenced in the same way. For example, water quality (TSS and turbidity) at the three closest monitoring sites to the spoil disposal ground A/B (impact site ‘CONI’ and ‘COBN’ and near-reference site ‘ANGI’) did not experience elevated TSS and turbidity levels, and the water quality was similar to that of the far-reference sites (Stoddart and Anstee 2005). Furthermore, the model predicted occasional spikes in sedimentation but no low, chronic elevation. It was therefore considered appropriate for the Pluto LNG Development impact assessment to develop only an acute threshold level to capture potential impacts from sedimentation for corals near the spoil disposal area.

Spoil ground A/B has been in use for a number of years, and has had more than 31 million m^3 of spoil disposed to it. When comparing the predicted coral community losses from the proposed Pluto LNG Development spoil disposal programme into spoil ground A/B with that of previous programme the predicted losses appear to be of a conservative nature as no intense mortality and loss of coral community has been observed during any of previous disposal programmes (**Table 7-34** of the Draft PER).

Current observations from aerial photography in Mermaid Sound confirm that the plume associated with spoil disposal into A/B during January and February (summer months) is relatively confined to the site of disposal. It does not appear to spread eastward towards Angel Island and Conzinc Island causing chronic elevation in turbidity.

The proposed spoil disposal programme is currently being revised and is aimed at limiting the disposal of spoil into spoil ground A/B to only coarse sediments. This will reduce the impact on the coral communities at Angel Island and Conzinc Island – hence the current plume prediction is deemed a worst case scenario.

For further discussion on the coral thresholds refer to the response to **Comment 9.26**.

9.24 Maps showing the zone of direct and indirect effect on benthic primary producers also need to show the boundary at which no effect (including short-term reversible physiological effects) are expected to occur. This zone is likely to be based on water quality achieving background conditions.

Table 7-32 is fundamental to the interpretation of the impact assessment presented in the Draft PER.

The impact zones identified in the Draft PER consist of loss of coral community due to either direct removal of the primary producer habitat, or loss of the community itself due to sedimentation, in accordance with the Guidance Statement No 29 (EPA 2004). No losses are anticipated from suspended solids alone on the grounds that the model does not predict plume persistence and hence prolonged periods of light attenuation. This prediction is supported by prior observations (Stoddart and Anstee 2005) and interpretation of baseline data (see also the response to **Comment 9.18**).

While the impact assessment in the Draft PER has indicated the location and extent of likely losses; this does not include areas of 'low impact' as identified in Table 7-32 in the Draft PER.

Woodside recognises that the identification of this zone is paramount to management and the development of the DSDMP to aid in the establishment of appropriate impact and reference sites. The zone at risk of low impact is closely linked to the deterioration of water quality and the reaction of the benthic primary producers over time. This link is not well understood, and a cautionary approach is suggested in the *Revised Environmental Quality Criteria Reference Document for Cockburn Sound* and the *Pilbara Water Quality Management Framework*. Here a deterioration of water quality above natural variation identifies the area at risk of impact to the biological receptors. Different protection levels identifies the accepted level of deterioration from background levels before further monitoring and possibly management is needed.

The *Pilbara Water Quality Management Framework* has established the protection level of the majority of Mermaid Sound as 'high' to achieve set Environmental Quality Criterias (EQCs) for this level of protection, Environmental Quality Guidelines (EQGs) are developed for relevant stressors, such as for example suspended solids. An exceedence of an EQG indicates that an area is at elevated risk of impact to the ecosystem and that monitoring of the biological indicators themselves is needed. In turn set Environmental Quality Standards (EQSs) for the biological indicators must not be exceeded. If they are, management measures must be put in place.

According to the *Revised Environmental Quality Criteria Reference Document for Cockburn Sound*, the EQG for suspended solids for a high protection area stipulates that when the median of the observed TSS level over a certain period exceeds the 80% percentile of the natural background variation there is an elevated risk of impact to the environment, and relevant biological indicators must be monitored to ensure that the EQS is not exceeded.

Woodside is committed to implementing a detailed DSDMP reflecting this approach. However, to establish the zone of influence based on exceedance of the 80% percentile of background levels, these background levels need to be established. The baseline survey currently being undertaken is collecting continuous information on the background levels of sedimentation, light levels and turbidity (in NTU, this is converted to TSS via site specific and reliable relationships determined in situ and in the lab). Data is being collected over nine months during both summer and winter periods. Different background levels are likely to exist between seasons.

During the development of the DSDMP zones of influence can be established by identifying areas where monitoring of biological indicators (corals) is needed to trigger management measures and ensure these areas do not sustain an unacceptable impact.

As discussed in response to **Comment 10.6** a similar approach of monitoring biological indicators with coral cover decrease trigger levels for management measures is currently in use by the DPU dredging programme. The DSDMP for the proposed Pluto LNG Development dredging programme will take the same approach.

In summary, in the Draft PER Woodside has established zones of predicted coral community loss, which cannot be avoided due to the proximity of dredging and spoil disposal to sensitive habitat, and the direct removal of habitat off Holden Point.

Woodside acknowledges that zones of influence based on water quality have not been established. However, these zones can be better established during development of the DSDMP for management of the areas where losses are seen as preventable with management measures. The baseline monitoring programme will provide the data needed for the establishment of these zones.

9.25 Model outputs of the suspended sediment plume and the cumulative sedimentation pattern associated with dredging the outer portion of the shipping channel, including propeller wash and dredge spoil disposal, should also be provided to give an indication of potential impact on benthic primary producer habitat around northern West Lewis Island and Malus Island. It is noted that coral communities along East Lewis Island and West Lewis Island have not been mapped.

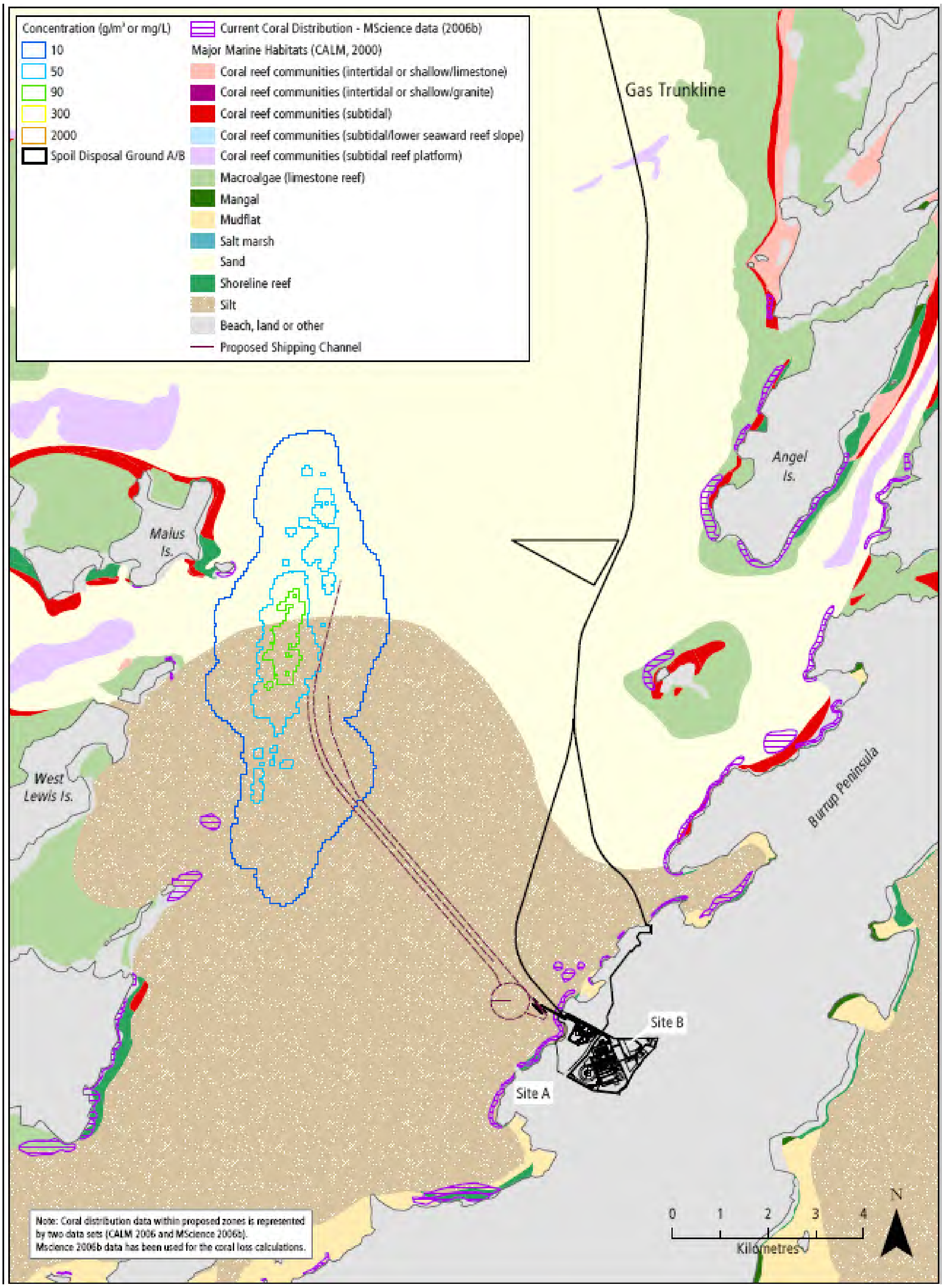
Modeling of the TSHD operations was undertaken during the Phase 1 modeling, as described in Section 7.9.7.2 (p.176-177) in the Draft PER. This included the outer end of the proposed navigation channel, with allowances for propeller wash by the TSHD (the only type of dredging expected at this location). Total suspended sediment plume plots were not included in the Technical Appendix D, Volume 2 for this specific location; however, TSS concentrations over time were reported in box-whisker plots for coral habitats along East and West Lewis Islands (Appendix D, Volume 2 of the Draft PER). These TSS concentrations included TSS from all sources including TSHD activity along the channel and dredging in other areas in accordance with the Phase 1 modeling. Note that propeller wash expected from transiting over the outer channel was much reduced because the water is deeper and hence under keel clearance is greater.

Revision of the spoil disposal programme shifted the main spoil disposal from A/B to the proposed spoil ground 2b, thus making the whisker-box plots obsolete as these were inclusive of all TSS sources (including spoil disposal into A/B). **Figure 8** shows the highest TSS concentration predicted at any location/depth during the month of TSHD operation at the outer end of the proposed navigation channel in accordance with the Phase I modeling but without concurrent spoil disposal activities. The maximum predicted TSS levels at the areas of coral communities are low, from 3–5 mg/L to 5–10 mg/L. Revised modeling of spoil disposal into A/B during the Phase 3 modeling predicted low TSS levels at Malus Island (Figure 7-35a of the Draft PER).

Woodside acknowledges that the model outputs presented in the Draft PER and in this document do not include the cumulative effects of dredging the outer end of the navigation channel while also disposing of spoil into A/B. However, these cumulative effects will be investigated further during the remodeling proposed to undertaken in conjunction with development of the DSDMP ; if impacts are predicted management measures to avoid those can be put in place (such as disposing into 2b while dredging the outer end of the channel).

Appendix A (of this document) contains a complete summary of the monthly predicted cumulative sedimentation patterns from dredging the proposed navigation channel and turning basin, according to the Phase 1 modeling. These figures are also shown in Technical Appendix D, Volume 2 of the Draft PER, however on the figures presented in this document the sedimentation pattern from the Phase 1 modeled spoil disposal into A/B are not included. Although the schedule and methodology for dredging the proposed navigation channel and turning basin may vary from the conceptual programme, these plots are indicative of the final dredging programme and predicted impacts.

The areas of coral community above the sedimentation thresholds predicted to suffer loss of coral communities due to excess sedimentation are shown in the Draft PER in Section 7.9.10.4 (p.224–230).



- **Figure 8: Highest Predicted TSS Level During One Month of TSH Dredging in the Outer End of the Proposed Navigation Channel**

9.26 The proponent has placed a great deal of confidence in the modelling and the coral sedimentation thresholds. The proponent has assumed that corals will only be impacted where modelled sedimentation in a polygon exceeds the thresholds (Figures 7-44 to 7-51). Given the level of uncertainty in the data it would be more appropriate to draw a generalised line around the modelled zone of threshold exceedances that included most of the impact polygons and assume this to be the predicted impact area.

Presentation of Areas of Loss: Woodside has not assumed that coral will only be impacted where modeled sedimentation in a polygon exceeds the thresholds. The areas above thresholds are defined as areas of indirect loss of habitat, as defined in Table 7-32 in the Draft PER. These areas above the thresholds are taken as having received sedimentation above a level at which the coral community will be inundated as was seen during dredging in Mermaid Sound in 2004 (the site 'SUPB' – Blakeway 2005). Here intense mortality caused the overall community to deteriorate to a level where recovery will take an unknown number of years. The substrate is covered with sediments, preventing settlement of larvae until cleared.

Woodside acknowledges that a theoretical model is only an indicative tool in the impact assessment process, and refers to further investigation of the predicted losses in Table 7-32 of the Draft PER.

The polygons marked as losses reflect the output of a stochastic model, where two adjacent model cells are not necessarily predicted to experience the same sedimentation regime. While Woodside acknowledges that in reality impacts are not expected to happen in these exact square model cells as marked on Figure 7-53 of the Draft PER, the outputs are meant to highlight the general areas where impacts are predicted to occur. While a general line around these areas is a valid way of presenting the losses, the pixilated method is an alternative way of conveying the estimates but with the same output, that is, both in effect draw a line where on one side impacts are predicted and on the other not. The pixilated output of the model is meant to reflect the boundary between predicted 'solid' areas of coral community loss, and areas without losses; they better represent the transition areas which are likely to be patchy.

Thresholds: The limitations of the theoretical thresholds have been acknowledged in the Draft PER (Section7.9.10.3 page 221) and in Technical Appendix G, Volume 2. The complexities involved in linking water quality to various degrees of impact on different coral species, morphologies, sizes and community types results in uncertainty in the predictions of 'coral habitat loss' as needed for the calculation of percentage loss within management zones in accordance with EPA Guidance Statement No. 29 (EPA 2004). It is acknowledged that the sedimentation thresholds are only theoretical, giving a generalised indication of impacts, and should not be applied in management (p.220 of the Draft PER).

The acute threshold was developed so that for the inner harbor a cumulative sedimentation load of 500 mg/cm^2/d (including a conservative background level, refer to response to **Comment 9.17**) would cause intense mortality and a subsequent loss of coral habitat and/or community. Such a load would cause a layer of less than 5 mm to form on a flat seabed. The coral communities in Dampier are generally not flat, with many growth forms protruding greatly from the seabed. If such an event was predicted to happen once at any one time, the area in question was considered as loss of coral community in line with EPA Guidance Statement No. 29 (EPA 2004). For the mid and outer harbor the threshold was halved (250 mg/cm^2/d for any one day) while the conservative, high background was kept at 55 mg/cm^2/d so that the model was interrogated with the threshold (250–55 = 195 mg/cm^2/d for any one day).

Sensitivity analysis of the coral sedimentation thresholds are shown in **Figure A1** to **Figure A-19** (**Appendix A**, this document). The thresholds were halved before subtraction of the conservative background sedimentation rate, as outlined in **Table 8** below. The figures indicate that halving the acute thresholds does not have a dramatic effect on the extent of the area of predicted coral loss. This is due to the nature of the increased sedimentation pattern observed repeatedly during dredging operations specifically in Mermaid Sound (Woodside acknowledges that it may be different in other areas of Australia). Here increased sedimentation rates are observed in proximity to the uplift area, but decreases rapidly with distance away from the dredge. This was observed by LSC (1989) and again during the current DPU dredging programme. This rapid decrease in sedimentation rates makes the impact assessment more robust than at first assumed from the limitations of using theoretical thresholds developed from literature values and in situ observations in Mermaid Sound.

Sensitivity analysis of the medium-term and chronic thresholds for the inner harbor likewise show that the estimated area of loss do not vary much by halving the thresholds (before subtraction of the background), nor by changing the duration from 5 and 15 consecutive days, respectively, to any 5 days out of 15, and any 15 days out of 30 for medium-term and chronic, respectively. The details of the sensitivity analysis are given in **Table 8**.

- **Table 8: Sensitivity Analysis of Medium-term and Chronic Thresholds**

	Threshold as in Draft PER*		**Threshold used for sensitivity analysis***		**Figure Ref**
Description	**Level**	**Duration**	**Level**	**Duration**	
Acute for resilient species	500 (445) mg/cm^2/d	Any 1 day	250 (195) mg/cm^2/d	Any 1 day	**Figure A1** to **Figure A19** **(Appendix A,** this document**)**
Medium-term for resilient species	300 (245) mg/cm^2/d	Any 5 consecutive days	300 (245) mg/cm^2/d	Any 5 days of any 15 day period	
			150 (95) mg/cm^2/d		
Chronic for resilient species	200 (145) mg/cm^2/d	Any 15 consecutive days	200 (145) mg/cm^2/d	Any 15 days in a 30 day period	
			100 (45) mg/cm^2/d		
Acute for vulnerable species	250 (195) mg/cm^2/d	Any 1 day	125 (70) mg/cm^2/d	Any 1 day	**Figure A20** to **Figure A22** **(Appendix A,** this document**)**

**values in parenthesis are minus the background level of 55 mg/cm^2/d and are the values used to interrogate the model*

The relationship between sedimentation, light deprivation and coral impact is problematic and not well understood (Gilmour et al. 2006). Woodside acknowledges that there is uncertainty in using a theoretical model and theoretical threshold levels to predict impacts. This is why Table 7-34 in the Draft PER was developed, to verify the estimates against the observed outcomes of numerous previous dredging programmes in the area. Though the Pluto LNG Development dredging programme is long, it is reasonable to gauge predicted impacts from programmes that have already taken place in the study area. The programme for the dredging of the LNG channel in the 1980s is a good example. Here the near-field impacts were observed within 1.3 km of dredging, and has subsequently seen coral recruitment along the coast (LSC 1989), thus not loosing the impacted coral habitat indefinitely.

9.27 It appears that a fundamental assumption for the modelling has been that sediments with a high proportion of silts and clays will be dredged during winter and coarser sediments will be dredged during summer and transition seasons. This is likely to have a significant impact on the extent of predicted suspended sediment plumes and sedimentation patterns.
Is the proponent committing to only dredge these respective sediments at the modelled times of year? If not, the modelling should be run to show the effect of dredging each sediment type at each time of year.

Table 7-25 (p.178) in the Draft PER provides a summary of the scenarios that were run to assess impacts from the conceptual dredging programme (Phase 1 and 2) and the revised spoil disposal plan (Phase 3).

Phase 1 and 2: The modeling of the dredging operation itself (not including spoil disposal) assumes particle size distributions as described in Section 7.9.7.4, (p.181) in the Draft PER. '…For the cutter suction dredging data from Geraldton (GEMS 2003) were used to represent sediments suspended form cutter suction dredging into limestone, and data from Dampier (SKM 2004) was used to represent sediments suspended from trailer suction dredging overflows. A conceptual sediment profile for the dredging channel was used to establish the depths of different sediments, and represented a basis for determining material composition along the navigation channel'.

The impact predictions from dredging the proposed navigation channel and turning basin are based on outputs from the conceptual modeling (phase 1 and 2), with particle size distribution assumptions as described above. The seasonal variation in weather pattern might influence the final sedimentation patterns but the indicative plume migration, spread and sedimentation will be representative of the finalised dredging programme.

Phase 3: Figures 7-23, 7-24, 7-25, 7-36, 7-37, 7-38 in the Draft PER explore selective spoil disposal (in terms of spoil coarseness) into distinct parts of spoil ground A/B and the northern extension during different seasons, as per the phase 3 modeling. As described in Section 7.9.7.9, page 195 of the Draft PER the phase 3 modeling assumed fine sediments disposed into spoil ground A/B during winter, where dispersion would be limited due to generally calm weather patterns. However, current revisions of the proposed spoil disposal programme are limiting the disposal of spoil into spoil ground A/B to coarse sediments only. This will reduce the impacts, in terms of coral community loss, at Angel and Conzinc islands where the predicted plume as shown is now deemed a worst case scenario – coarse material is generally subject to less drift before settlement than fines.

9.28 The impact of the dredging and spoil disposal program on the environmental value of recreation and aesthetics needs to be addressed (e.g. water clarity)

Refer to the response to **Comment 9.11**.

9.29 The presence of Naturally Occurring Radioactive Material in produced water is discussed in Section 7.8.11. The response to submissions needs to include what the radioactive constituents are, the expected concentrations, the environmental fate of these radioactive materials and how these will be managed in accordance with APPEA 2002 Guidelines for Naturally Occurring Radioactive Materials. Since discharge would be from a shallow nearshore outfall, this is a potentially significant issue.

Formation water within the Pluto gas reservoir may contain minimal quantities of Naturally Occurring Radioactive Materials (NORMS). It is too early to accurately assess the likely extent or nature of potential constituents of NORMS that could be present in the formation water that will flow from the production wells.

However, if NORMS is present in formation water, the quantity transported to the onshore system will be minimised by firstly limiting formation water ingress and secondly managing accumulation of NORMS.

The MEG recirculation system proposed for the Pluto LNG Development cannot tolerate any significant saline formation water ingress. For design purposes a nominal allowance is made for a small quantity of 'nuisance' formation water ingress the balance of the offshore produced water being non-saline water condensed from the hydrocarbon gas phase. The small formation water allowance is made to ensure design robustness and in practice there may actually be little or no formation water produced. Wells that produce large quantities of formation water will be shut-in until future offshore facilities are installed that can remove and treat the formation water offshore. This inherently limits the quantity of NORM that can be carried to the onshore facilities.

As described in the Draft PER (Section 7.8.11), the build up of scale in the offshore system, and hence, the risk of accumulating NORMS, will be controlled with the use of appropriate inhibitors and management of the MEG composition. In the onshore facilities the opposite approach will be used, with precipitation of salt/ carbonate scales (and possibly any NORMS) deliberately encouraged in the MEG pre-treatment system and in the MEG reclamation system. This ensures scaling occurs in a controlled fashion in locations where it can be managed.

Any NORMS present may precipitate at the same time (as RaCO3) and would be managed and disposed in accordance with the APPEA guidelines and legislative requirements at the time. Management of NORMS will be addressed in an environment management plan to be prepared for regulatory approval under petroleum legislation. Due to the active precipitation of salt/scale within the MEG system, the produced water recovered from the MEG system is not expected to contain any significant level of soluble NORM. Any solid NORM would be removed with other precipitated solids in the MEG system or the wastewater treatment system, thus minimising the accumulation of the NORM in the system.

9.30 The EPA's guidance on Benthic Primary Producer Habitat (BPPH) Protection specifies actions when the cumulative loss threshold is exceeded. Since these thresholds are greatly exceeded for Management Unit 1, and exceeded for Management Unit 2, the EPA expects:

- *an adequate environmental offset package to be developed to ensure "no net loss", or preferably a "net environmental benefit";*
- *a best practice approach to minimising the impacts; and*
- *the development of a comprehensive management plan.*

Adequate information has not been provided in the PER and further detail needs to be provided in the response to submissions.

Woodside is currently investigating options for environmental offsets. In particular, contribution to marine research programmes is being considered as a secondary offset. The following are examples of research topics that may be considered:

- investigations into artificial reef designs and materials that may be successful in the Dampier Archipelago
- feasibility studies to investigate the potential for coral rehabilitation/transplantation (as future offsets)
- investigation of coral-turbidity-light interactions in Mermaid Sound
- studies to better define coral spawning events and coral recruitment occurring in Mermaid Sound
- further studies defining local and/or regional metocean features that underpin the understanding of variables such as movement and fate of sediments, movement of coral recruits/propagules, and the movement and fate of discharged contaminants.

The development of environmental offsets will be undertaken in consultation with the EPA, DEC and other relevant authorities.

A Framework Dredging and Spoil Disposal Management Plan is provided in Appendix I, Volume 2 of the Draft PER. This Dredging and Spoil Disposal Management Plan will be further developed in consultation with regulatory authorities.

A comprehensive Dredging and Spoil Disposal Management Plan, including details of supporting monitoring programmes, will be developed before the start of the dredging programme. Management plans for other dredging programmes in the region (specifically in Mermaid Sound) will be used as a basis for the development of monitoring and management programmes for the Pluto LNG Development. Recent outcomes and lessons learnt from the Hay Point dredging programme on the east coast will also be used to develop the Dredging and Spoil Disposal Management Plan.

9.31 *The proponent has estimated that this project could potentially result in BPPH losses that exceed the thresholds of 10% and 1% for Management Units 1 and 2 respectively. In these circumstances, as outlined in the BPPH Guidance Statement No. 29, the EPA expects a substantial justification for the proposal, supported by technically defendable information that demonstrates understanding of the ecological role and value of the BPPH within the local context. The proponent is expected to determine the significance of any impacts on the ecosystem integrity of the area. The EPA also expects an adequate environmental offset package to counterbalance the damage/loss of BPPH with the goal of achieving 'no net loss' and preferably a 'net environmental benefit'. The proponent has not attempted to address these issues and hence has failed to provide an environmental argument for why these losses might be acceptable*

The Draft PER has been prepared using the most comprehensive information available to Woodside at the time of assessment. The environmental impact assessment presented in the Draft PER is the result of extensive literature reviews, consultation with marine and coral experts, modeling and studies by specialists. The level of information in the Draft PER has been presented to enable the reader to form an objective view of the potential impacts associated with the Pluto LNG Development.

It is acknowledged that the thresholds in Management Units 1 and 2 will potentially be exceeded. The acceptable cumulative loss criteria for Management Unit 1 is set at 10%, a difficult target to meet as Dampier is a major port. Direct loss of benthic primary producers within Management Unit 1 as a result of the proposed Pluto LNG Development dredging programme is estimated to be 2.7% whilst historical losses are estimated to be approximately 18.6%.

The coral species within Management Units 1 and 2 are common and widespread in other areas of the Dampier Archipelago; this widespread distribution offsets any potential loss of ecological integrity of the wider ecosystem even though localised impacts may arise. Recruitment into disturbed areas within Mermaid Sound is expected from other areas within Dampier Archipelago, and the integrity of substrate habitat will not be permanently altered in areas of indirect coral losses, therefore recovery of systems is anticipated.

Woodside is currently investigating options for environmental offsets – refer to the response to **Comment 9.30**.

10.2 *The proponent needs to provide the baseline data that are currently being collected on sedimentation, turbidity and light level, and develop a series of multiple impact thresholds (i.e. including frequency, intensity and duration of exposure to the physical variables) for corals that incorporate variation in tidal and sea state as opposed to just seasonal variation. These thresholds should then be used within the model as the basis for the environmental impact prediction. Given the length of the dredging campaign (i.e. 24 months) and the potential for impact on significant coral habitat, the environmental impact assessment needs to be based on the sedimentation and turbidity thresholds established using the methodology alluded to in Appendix A of the PER.*

Background Sedimentation Rate: In the absence of baseline data on the background sedimentation rates, the values used for setting the fixed background rate for use in the impact assessment were obtained from various studies where measurements were taken both during and before/after dredging and spoil disposal activities. Values obtained during dredging programmes were not excluded; rather all values were used in the formulation of the background sedimentation level as Mermaid Sound is believed to be chronically influenced by anthropogenic activities.

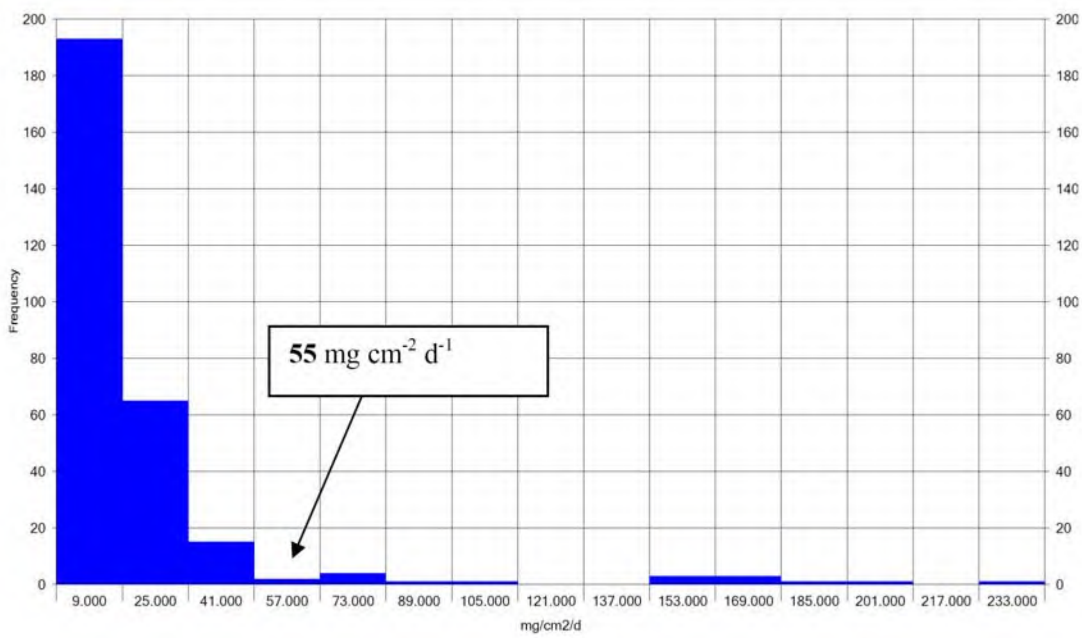
The theoretical conservative background rate was set so that over 90% of the measured sedimentation levels were below the fixed rate. Reference should be made to Figure 17 and Table 8 as presented in Appendix G, Volume 2 of the Draft PER.

The incorporation of a fixed, high background rate into the model introduces a degree of conservatism; by assuming that the background rate is always high the cumulative sediment load resulting from dredging and background will reach the coral mortality threshold even on days where the background rates will be much lower (**Figure 9**). This precautionary approach aids in creating a conservative impact assessment.

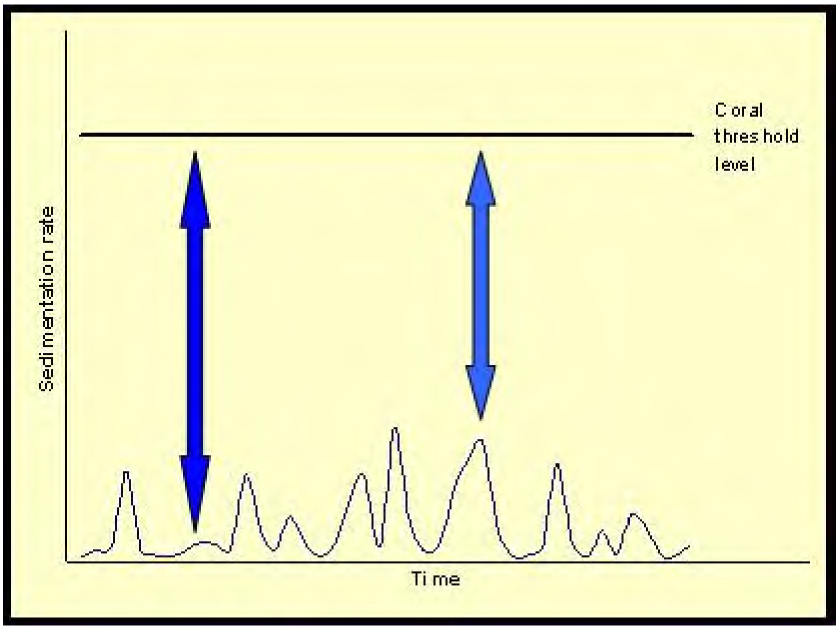
When a high rate of background sedimentation is assumed throughout the dredging programme, only the more extreme events will cause a background sedimentation rate higher than the assumed fixed rate incorporated into the model. In any case during any extreme events dredging is likely to stop for example, during cyclones. The predicted estimates of total sedimentation (background and dredging related) will therefore be conservative, that is, higher than what would be expected most of the time (**Figure 10**). This is emphasised even further in the outer harbor, where background sedimentation rates are generally lower. To address this, and as described in Section 7.9.10.3 of the Draft PER, a lower mortality threshold was derived for this area recognising that corals here live in regimes with generally lower sedimentation. Similarly, by using the high fixed background rate impacts are likely to be an over-estimate in the outer harbor.

Regardless of which corals (inner, mid or outer harbor) are most resilient to sedimentation, using the same conservative background rate for all areas will assist in avoiding an under-estimation of the impacts. The potential for over-estimating would give a worse-case scenario, which is preferable for impact assessment purposes.

The use of the same background sedimentation rate, which accommodates more than 90% of all the rates, is therefore considered a conservative approach in that this will yield a total sedimentation level above that expected the majority of the time during the proposed Pluto LNG Development dredging programme.



- **Figure 9: Compilation of Available Sedimentation Rate Data at the Time of Impact Assessment (from SKM 2006 – technical report Appendix G from the Pluto LNG Development draft PER).**



- **Figure 10: Thick black line represents the absolute coral threshold level, at which mortality will occur. The thin black line represents the background sedimentation level. The blue arrows represent the “allowable” sedimentation rate for dredging before the coral threshold level is reached. By assuming a constant high background level the total sedimentation level during the dredging programme is likely to be over-estimated.**

Trigger Levels versus Threshold Levels: McArthur et al 2002 outlines a methodology for determining trigger levels for benthic biota aimed at dredging management through water quality monitoring. Trigger levels can be developed based on the natural background variation and the assumption that corals are adapted to this regime and will be unable to cope with any significant increase in TSS or sedimentation levels. By basing the trigger levels on the frequency, intensity and duration of the observed background sedimentation and TSS time series it is possible to derive set levels at which corals are likely to become stressed.

However, a limitation in this method is the determination of the loss of coral habitat in accordance with the Benthic Primary Producer Guidelines; the trigger levels will not provide information on the level at which the coral community will suffer mortality to a degree where it is considered a loss in accordance with the guidance statement. As the link between physical stressors and the level of impact on corals is not well understood, mortality cannot be predicted using the trigger levels described in McArthur et al (2002). The intention of such trigger levels is to flag deterioration of water quality *before* impacts occur.

The theoretical mortality thresholds for the Pluto LNG Development Draft PER instead focused on setting a level at which an acute or semi-acute event would cause intense mortality to a similar extent as was observed during the 2004 dredging programme as is described in Blakeway (2005). Gilmour et al. (2006) has set indicative stress and mortality curves for sedimentation and turbidity; however, the authors emphaise that there is currently insufficient data to establish these levels with confidence. Woodside acknowledges this uncertainty in using theoretical mortality thresholds. Please refer to response to **Comment 9.26** for a discussion on threshold sensitivity analysis.

Sea state and Tide: Trigger levels developed on the basis of the baseline data will provide early warning indicators of conditions where the risk of impact to corals is increased. Such trigger levels are likely to vary with sea state and tide, as outlined in the responses to **Comment 10.2**. While a management programme relying mainly on water quality would need to develop trigger levels for varying conditions, it needs to be emphasised that the use of such detailed trigger levels for predictive purposes would be limited, as theoretical models are not able to predict weather during a two year period with the accuracy needed to investigate the impacts caused by the frequency of various intensities and the duration of these in relation to tidal and sea state. The theoretical model is a predictive tool which may give a general idea and prediction of the impacts based on average expected weather and tidal regimes within each season.

Baseline Data: The baseline survey has collected a large data set, which can be provided upon request in a specified format. The data set has not yet been analysed, as the baseline survey is still ongoing. A substantial amount of analysis is needed for interpretation of the data set, with the incorporation of weather and shipping data also required. This analysis is scheduled to be completed in May 2007.

Woodside concurs that the baseline data will be very valuable in establishing zones of influence based on the McArthur approach, which is commensurate with the *Pilbara Water Quality Framework Plan* and the *Revised Environmental Quality Criteria Reference Document for Cockburn Sound*. However, the use of trigger levels to determine the extent of coral community loss is limited.

Please refer also to the response to **Comment 9.24** for a discussion on how to establish zones of influence based on the Pluto LNG Development baseline data.

10.3 Appendix A of the PER (p. 494) outlines the methods used for determining baseline sedimentation and turbidity thresholds at which corals may become stressed (based on McArthur et al. 2002). It is recommended that the proponent provides the baseline data as discussed above, and develops a series of tolerance thresholds for corals to light (as opposed to TSS or Nephelometric Turbidity Units (NTU)) that represent tidal and sea state as opposed to just seasonal variation. The theoretical model should then be interrogated with these light thresholds to form the basis for the environmental impact prediction. Once impacts have been determined, the proponent can use this information to develop a monitoring and management framework.

In order to conduct an accurate environmental impact assessment, an understanding of the relationship between TSS and light attenuation for the limestone component of this projects dredging program is required. The proponent should discuss the potential chronic impact on benthic communities that may arise from any prolonged reduction in light associated with dredging.

Reference should be made to the response to **Comment 10.2** for details on disclosure of the baseline data, and a discussion on the use of trigger values based on the baseline data for impact assessment purposes.

Woodside recognises the enhanced risk of chronic impacts on corals in Mermaid Sound due to the length of the proposed dredging programme. Baseline monitoring has collected light data in situ which will provide an enhanced understanding of the light regimes within the coral habitat in Mermaid Sound. This dataset has been complemented with data collected by another proponent in Mermaid Sound during dredging and with concurrent coral monitoring. To address impacts from light attenuation during the Pluto LNG Development dredging programme this baseline light data and a revised model taking resuspension into consideration will be used.

From recent data collected during the DPU dredging programme data has become available on light attenuation in relation to TSS both at impact and reference sites. TSS values have been measured by taking water samples at the bottom and on the surface at both impact and reference sites. Light data has been collected concurrently using both a light meter (surface and bottom) and a secchi desk. The sediments liberated during the DPU dredging in proximity to Holden Point are representative of the sediments, which will be liberated through the proposed Pluto LNG Development dredging programme. This includes the limestone component liberated through CSD.

The identified relationship between TSS and light attenuation will be used to investigate the critical depth for coral communities in Mermaid Sound during the proposed Pluto LNG Development dredging programme.

10.4 Given the apparently dissipative nature of Northern Spoil Ground, the proponent should provide detailed information regarding the projected long-term fate and impacts of material disposed to all the proposed disposal grounds.

As indicated in Section 6, Appendix I of the Draft PER, spoil disposal will be managed to reduce potential impacts to as low as reasonably practicable. Proposed measures to mitigate impacts and to reduce the footprint associated with spoil disposal will be given effect through an approved Dredging and dredge spoil disposal management plan (DSDMP).

Section 7 of the Draft PER includes results of predictive modelling and assessment of the spoil disposal footprint. Further modelling will be undertaken during development of the DSDMP to further refine understanding of this footprint as further information becomes available about proposed activities, including materials relocation.

As indicated in Section 8.1.3 of the Draft PER, a post dredge survey will be conducted following completion of the dredging work to document the condition of affected benthic habitats following the cessation of dredging activities. Interpretation of the post-dredging survey findings will be supported by information that will be available from sites that have been established across the project area as part of the environmental baseline surveys now being conducted before dredging activities start.

Woodside notes the comment about the apparent dissipative nature of the Northern Spoil Ground and is aware that the Northern Material Relocation Site (NMRS) is a repository for disposed materials generated from activities by various port users, including Woodside.

Apparent losses from the NRMS have been evaluated recently in relation to disposal of dredged materials from works conducted at the turning basin for the LNG V Expansion Project. This suggested that a small proportion of material was lost during offloading mud and ooze while a similar proportion appeared to have been lost and dispersed during dredging. Some migration of materials was apparent around dump boxes. There was evidence of erosion of materials from dump areas and also from the remainder of the NRMS that included periods where the area had been subject to effects of tropical cyclones.

The NMRS is reserved for deposition of marine silts, mud and ooze contained within a bund of stable granular material. Because of its nature, some materials, such as mud and ooze, are difficult to quantify accurately. Theoretically, volume changes can be evaluated from survey information for the dredge area, in the dredge hopper, by sounding the solids and using derived factors to determine amount of material in suspension above solids, and by survey at the material relocation site.

Losses will occur at the dredging stage through the action of dragging the suction head through the material and causing some of it to become suspended and be dispersed due to current action. Propeller wash from the dredge will also cause a certain amount of loss. Such losses are impossible to measure accurately but can be estimated. Losses can also occur through current action when material is deposited at the relocation site before the material has had a chance to settle. These losses are also difficult to measure accurately.

Currents can also cause material to be eroded from the site over time, particularly during cyclonic events. An approximate value for such losses can be measured by comparison surveys, however, due to the sizes of the areas, unless losses are significant depth-wise, survey tolerances may render calculated volumes as unreliable.

Woodside would be supportive of opportunities to work with DPA and others using the spoil ground to improve collective understanding of the nature and extent of material dissipation. Woodside will consult with the DPA and the Dampier Spoil Management Committee in relation to appropriate means of disposing material generated from marine construction and dredging work. Woodside is investigating the feasibility of locating more material to the deep water spoil ground (i.e. spoil disposal ground 2B).

10.6 That the proponent develops threshold curves and a predetermined range of triggers for monitoring and managing impacts on corals. Pre-programmed management responses for the 80th percentile to the 95th percentile of natural variation for sedimentation and turbidity should be developed. A third tier of management would be introduced should the 'not to be exceeded value', being the 99th percentile, be reached at sensitive benthic systems.

A detailed monitoring and management response framework similar to the one currently being used for the Dampier Port upgrade should be developed (including the establishment of a Dredge Management Group).

Woodside welcomes the approach to setting water quality management trigger levels established above. As discussed in the response to **Comment 9.24** the *Revised Environmental Quality Criteria Reference Document for Cockburn Sound* and the *Pilbara Water Quality Management Framework* establish a similar approach to management and monitoring. Environmental Quality Guidelines (EQGs) for physical stressors developed for Cockburn Sound.

The baseline data collected will be used to enhance the understanding of the hydrodynamics and sediment flux in Mermaid Sound, and develop trigger levels following the methods of McArthur et al. 2002 or the *Revised Environmental Quality Criteria Reference Document for Cockburn Sound*. However, following on from the outcomes of the recent Hay Point dredging programme it is not believed that the dredging programme can be managed primarily from water quality data (such as sedimentation, turbidity, suspended solids and light attenuation). Such data is important to collect continuously during the dredging programme, and is proposed as part of the Pluto LNG Development monitoring programme. However, management decisions are to be based primarily on the outcomes of coral monitoring. During the Hay Point dredging programme water quality became important contextual information for the dredging management group with which to understand and interpret coral reports.

It is envisaged that the Pluto LNG Development establish a Dredging Management Group and develop a management plan in line with current monitoring undergoing in Mermaid Sound, where frequent coral monitoring forms the basis of management decisions, with water quality collected for the purpose of early warning indicators, and an enhanced understanding of coral health observations and the impacts from dredging.

10.7 The proponent should provide additional information on the characteristics of the potential light spill from the proposal, i.e. model zone of light influence. Additionally, the proponent should outline the proposed light reduction management measures and clearly demonstrate their effectiveness. The proponent should demonstrate that the project's light reduction and management practices are aligned with industry best practice.

Modeling the zone of light influence (light spillage modeling) was initially considered for the environmental impact assessment process, however investigations into available light modeling methodology indicated that it would be of limited benefit in the assessment of the Pluto LNG Development. Light modeling has a number of limitations preventing it from being used to translate the model outputs into impacts on fauna. Limitations of this approach include the following:

- Light modelling typically models light emissions in lux, which is an artificial unit of measurement used to measure the intensity of light spectrum visible to the human eye (Pendoley 2005). Lux is weighted for visible light pertinent to human vision (between 500 and 650 nm); it does not account for light emissions between 300 and 500 nm or above 650 nm. Turtles see light outside the range pertinent to human vision, for example green turtles are known to respond to light in the 350 to 450 nm range (Witherington and Bjorndal 1991). Therefore, light modelling does not model all the light that turtles react to.

- Light modelling does not account for various atmospheric conditions that affect light and light scattering, and therefore influence sea turtles' reactions to light. For example, an overcast sky can cause light to reflect off clouds thus increasing the influence of a light source (compared to the same light source during clear skies). Aerosols such as salt or dust in the atmosphere can also scatter light and light intensity.
- Light intensity is only one of several cues which direct nest site selection and seafinding behaviour in sea turtles. Modelling of light spillage would ultimately provide insight into only one dimension of a multi-faceted problem.
- Seafinding will occur even in the presence of artificial night lighting. Therefore any conclusions drawn from the modelling would be fraught with assumptions relating to the significance of light intensity as an influence on turtle behaviour.
- There is no single, measurable level of artificial brightness on nesting beaches that is acceptable for sea turtle conservation. The data obtained would therefore provide limited information in relation to impacts on sea turtles. Put simply, our limited appreciation of the influence of lighting impacts at different light intensities precludes a meaningful analysis of the data.
- The products of light spillage modelling would essentially be contour maps which indicate wattage at distance from source. Such modelling would not account for sky glow from sub-coastal development, light impacts from external sources, or the continuity (in silhouette) and elevation of the landward horizon.
- In the case of the Pluto LNG Development, it would prove impossible to isolate the impacts of proposed lighting from background light sources such as the existing Dampier Port Authority, NWSV Karratha Gas Plant and marine vessels in the wider locality. There are no published, scientifically valid means to measure light pollution in this context.

Since obtaining access to Site A in early 2007, Woodside has been undertaking visual monitoring for signs of turtle nesting activity at Holden Point Beach, directly adjacent to the Site A lease area. This monitoring is conducted each morning as a part of routine security checks along the site boundary. The purpose of this monitoring is to identify any signs of turtle activity including digs and tracks, and in the event that signs of activity are observed, to alert the Site Environmental Officer who is tasked with identifying type of turtle (if possible), determining whether nesting is likely to have occurred and recording this information.

To this date there have been no observed signs of turtle activity on Holden Point Beach. This is consistent with advice that the beach west of the Site A (i.e. Holden Point Beach) is not a significant site for sea turtle activity (Pendoley 2006). Hence, risk to nesting turtles from lighting associated with the Pluto LNG Development is considered low.

The DEC will be consulted regarding strategies to minimise impacts on turtles during the development of detailed Environmental Management Plans.

10.8 The proponent needs to discuss and address the potentially negative environmental consequences of the Pluto LNG Development resulting from the recreational requirements of additional people attracted to the West Pilbara region by the project. The proponent needs to develop strategies in consultation with DEC to assist in the avoidance and management of these impacts.

The workforce required for the construction of the Pluto LNG Development is in the order of that required for previous / existing developments including NWSV Phase V. There is no expectation that this will result in increased environmental impacts to the west Pilbara through increased recreational activity.

10.9 Given the unavoidable impacts and residual risks identified within the PER, if the Pluto LNG Development proceeds there will be a net environmental loss. Net environmental benefits cannot be achieved until all potential impacts are fully assessed, managed and offset as far as reasonably practicable. As such, DEC recommends that both the proponent and Government commit to ensuring that appropriate environmental offsets are provided for the impacts of the proposed development.

This comment is acknowledged. Consultation will be undertaken with the DEC and other appropriate authorities regarding environmental offsets for terrestrial and marine aspects of the Pluto LNG Development.

10.10 The scenarios modelled for dredging works tested a change from 15 hr/day to 24 hr/day (p. 176). It is understood that a 24 hour operation was applied to simulate worst case dredging operation impacts. DEC requests that the proponent outlines the differences in impacts between the two scenarios and comments on the effectiveness of using 'dredge resting phases' to reduce impact on significant coral systems potentially at risk.

Table 7-25 (p.178) in the Draft PER provides a summary of the scenarios that were run to assess impacts from the revised dredging and disposal programme (divided into Phase 1, 2 and 3).

As outlined in Section 7.9.7.4 (p.181) of the Draft PER, the simulations for the conceptual programme (phase 1) assumed operations for 15 hours a day, which were the basis for impact assessment from dredging of the proposed navigation channel. Both TSS and sedimentation sensitivities were later undertaken based on 15 hr operations (9 hr off) versus 24 hr operations (phase 2 modeling). Results indicated that there would not be a higher build up of TSS at distance from the dredging (that is, at Mermaid Sound scale) if dredging were longer each day. This was in line with the conclusion that there would not be a general build-up of TSS levels in Mermaid Sound over the course of the operation. Instead, elevations would be generated by the evolving movements of the plume. However, with 24-hour operations, the coral communities close to the dredging were predicted to receive more episodes of exposure over time and sometimes higher concentrations due to 'double-dosing' (that is, the plume passing over again before the remnants of the last exposure had dissipated). This phenomenon is due to the wider range of opportunities for exposure that arise from generating the plume for longer each day.

Evidence to support the findings that TSS levels are not predicted to build up over time at the Mermaid Sound scale, but will be patchy in distribution is given in Stoddart and Anstee (2005). Here, water quality, plume modeling and tracking before and during dredging in Mermaid Sound highlighted that previous dredge modeling that did predict a build up was grossly overestimating TSS levels.

The simulations for the revised spoil disposal programme (phase 3) assumed 24 hour dredging operations for the estimation of spoil disposal frequencies. While there may be increased levels of TSS and more frequent spikes during such a 24 hour operations programme in reality the effective dredging operations will not reach 24 hours due to periodic downtime for refueling, routine maintenance and repairs.

10.11 The presence of rock pinnacles found in 300-500 metres of water is noted in the PER (p. 107 & 111). These formations support deep water coral species such as Lophelia sp., and are a source of habitat, protection and nutrition for marine fish and other fauna. Similar rock pinnacle communities have been identified around the world supporting significant biodiversity and abundant marine life in areas that would otherwise be essentially barren and void of marine life. DEC supports the proponent's commitment to avoid placing project infrastructure or impacting on areas of sensitivity including rock pinnacles (p. 133).

This comment is acknowledged.

10.12 The PER states that marine vessels will anchor in prescribed areas within the port. DEC recommends that where possible moorings be installed and utilised to reduce the area of impact caused by anchorage. Consultation with the Dampier Port Authority and Government bodies will be necessary for the development and management of this strategy.

This comment is acknowledged. Woodside will consult with the DPA and other relevant regulatory agencies regarding operation of vessels within the Port of Dampier.

Terrestrial Impacts and Management

10.13 DEC considers weed management as a high priority on the Burrup Peninsula, especially preventing the establishment and spread of weeds within the non-industrial lands of the Burrup Peninsula. As such, DEC requests an opportunity to review and comment on the proposed Weed Management Plan (Appendix G).

In addition, DEC requests an opportunity to review and comment on the proposed Sea Turtle Management Plan, Marine Pest Management Plan, Blasting Management Plan, Vegetation and Flora Management Plan, Fauna Management Plan, and the Dredging and Spoil Disposal Management Plan.

The comment is acknowledged. Woodside will consult with the DEC when developing detailed environmental management plans.

10.14 DEC understands that there is a level of uncertainty in regard to the taxonomy of Rhagada species collected at both Site A and Site B (p. 320). As such, DEC recommends that the proponent commits to completing the short range endemic fauna survey by conducting further genetic investigations to resolve the issue. Given the taxonomic uncertainty and significance of short range endemic fauna on the Burrup Peninsula, the proponent needs to manage impacts and risks to land snails at Sites A and B.

Woodside is supportive of research, and will undertake studies to further understand the taxonomy of the *Rhagada* species collected at Site A and Site B.

In terms of managing impacts and risks to land snails, Woodside proposes to minimise impacts by avoiding land snail habitat where possible. Where land snail habitat cannot be avoided, management measures will be developed in consultation with the DEC and other regulatory bodies, and these management measures will be incorporated into the framework Fauna Management Plan (Appendix G of the Draft PER).

6.2 There should be concern for the two regionally significant vegetation associations that are likely to lose more than 50% of their area, as this would be highly detrimental to faunal assemblages, particularly invertebrates (as yet unsampled), that may be dependant on these associations. Some greater focus on the fauna of these should have been undertaken.

The two areas of regionally significant vegetation associations that are likely to lose more than 50% of their area are AcImTe/TeCa and AbCc'Te, as identified by Trudgen (2002).

Vegetation association AcImTe/TeCa is a mosaic community consisting of vegetation associations AcImTe (*Acacia coriacea*, *Indigofera monophylla*, *Triodia epactia* (Burrup form)) and TeCa (Triodia epactia (Burrup form), *Cymbopogon ambiguus*). A total of 140 occurrences of vegetation association AcImTe were recorded by Trudgen (2002) on the Burrup Peninsula with 73.9% of the vegetation association represented in the Burrup Conservation Zone; AcImTe is not considered regionally significant. Vegetation association TeCa has 97 occurrences (as mapped by Trudgen 2002) and 4.3% of its extent occurs in the Burrup Conservation Zone. The mosaic AcImTe/TeCa is considered significant due to the presence of TeCa, which has limited representation in the Burrup Peninsula Conservation Zone.

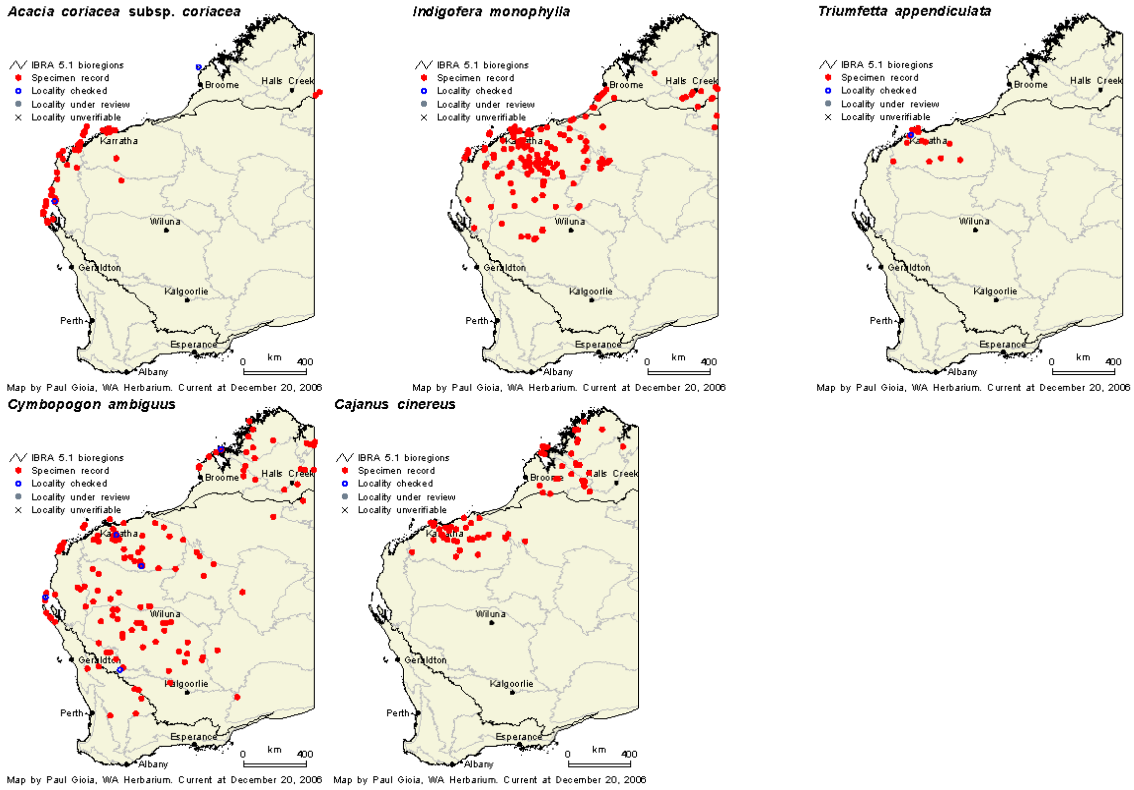
Vegetation association AbCc'Te was mapped twice on the Burrup Peninsula, and has 19% of its extent within the Burrup Peninsula Conservation Zone.

A desktop fauna assessment was undertaken for Site A and B; this is consistent with the advice provided by the DEC and the results (fauna species likely to occur in the site) are presented in Section 8.3 of the Draft PER. With regards to impacts on faunal assemblages that may be dependent on these vegetation associations, it is acknowledged that both vertebrate and invertebrate assemblages may utilise these two vegetation associations.

The broad habitat or landform that supports the two vegetation associations have been classified as upland stony plateau (ENV 2006) and upper undulating hills and slopes (Astron Environmental 2005), both of which are very common landforms on the Burrup Peninsula. The structure of the vegetation associations (shrublands over hummock grasslands, hummock grasslands) and the flora species comprising the vegetation associations are also found elsewhere on the Burrup Peninsula. Vertebrate fauna likely to inhabit these landforms, and therefore utilise the two vegetation associations, are broadly distributed and generally mobile species (Section 8.3 of the Draft PER). It is not anticipated that there would be any particular niche elements of these two vegetation associations that would be specifically utilised or depended upon by vertebrate fauna. Terrestrial vertebrate species on conservation significance (as discussed in Section 8.3.7 of the Draft PER), including species such as the fossorial skink *Notoscincus butleri*, and the Pilbara olive python (*Liasis olivacea baroni*), would not be restricted to these two vegetation associations. Loss of these associations is not considered to be likely to result in a loss of biodiversity at the species, or even the genetic level with respect to vertebrate fauna.

It is acknowledged that there is potential for the clearing of the two vegetation associations to impact upon biodiversity at the population or genetic level for invertebrate species, particularly as short range endemism can occur in some species over very short distances. However, the landforms and more importantly, the microhabitats within the landforms that invertebrates may depend upon (such as soil depth, rock type and detrital layers) are not expected to be disjunct or finite within the two vegetation associations. The landforms are very common and found throughout the Burrup Peninsula, including areas within the Burrup Peninsula Conservation Area (as identified by the Burrup Peninsula Land Use Plan and Management Strategy 1996). The upland stony plateau (ENV 2006) and upper undulating hills and slopes (Astron Environmental 2005) represent the connected interzone between isolated fauna habitats such as rockpiles and drainage lines that are much more likely to support short range endemic species. The connectivity of this basic landform, upon which the two vegetation associations occur, is evident in Figure 1 and Figure 2 of Astron Environmental (2005).

With respect to the potential loss of biodiversity resulting from clearing of these two vegetation associations, it is important to consider the potential dependence of invertebrate fauna on particular floristic taxon occurring within the associations. It is possible that unknown or as yet undescribed invertebrate taxa may specifically depend on a particular plant for its survival and persistence. In consideration of this, the structure and distribution of the main plant taxa within the two vegetation associations was considered. It was determined that the dominant taxa are well represented within the site, within the Burrup Peninsula and beyond the physiographic boundaries of the Burrup Peninsula. For example, the distribution maps of taxa within the two vegetation associations are presented below (Naturebase 2006). In all cases the taxa are distributed beyond the Burrup Peninsula. In cases of locally significant flora taxa within the associations, such as those described by Trudgen (2002) as being of conservation significance for the Burrup Peninsula, *Triodia epactia* is very broadly distributed across the Burrup Peninsula, and two other taxa with close affinities (*Triodia angusta* and *Triodia wiseanna*) are also very common in the area.



- **Figure 11: Distribution of Flora Taxa that Occur Within Vegetation Associations AclmTe/TeCa and AbCc'Te**

5.8 Should there be a requirement to quarry rock material from land it is DPA's preference that this be undertaken adjacent to existing Port land to extend available flat land for future potential Port uses in the area.

Should the Pluto LNG Development require rock other than that quarried from the Site A and Site B, then this is likely to be sourced from one or a number of existing quarries in the region. Quarries will be assessed based on the quality and quantity of rock they can supply under approvals, the location of the quarry, and other commercial considerations.

13.1 …how does Woodside justify the commencement of site preparation works at Burrup without developed Environmental Management Plans in place?

Site preparation works associated with Site A commenced in January 2007 after necessary environmental and heritage approvals were obtained and Environmental Management Plans for those works were in place. The EMPs were developed in consultation with the DEC and DEH: the Fauna Management Plan being formally approved by the DEH as a requirement under the Commonwealth EPBC Act approval.

Social and Economic Impacts and Management

4.1 Fisheries listed under section 10.7.3 of the PER should include reference to the Blue Swimmer Crab Fishery and the Marine Aquarium Fishery. The proposed live rock [lobster?] aquaculture site at Withnell Bay should also be listed under section 10.7.5 of the PER. These fisheries, in addition to those already listed in the PER, should be given warning of any proposed construction activities and the proponent should conduct information sessions for the affected fishing operators as required.

Sections 10.7.3, 10.7.5 and **11.8** of the Draft PER should be updated as follows with regard to the Northern Developmental Blue Swimmer Crab Fishery, the Marine Aquarium Fish Managed Fishery and the proposed live rock aquaculture site:

Western Australian State Managed Fisheries: The DFWA manages several fisheries on the North West Shelf, of which eight have boundaries that overlie or are in close proximity to part or all of the offshore area of the Pluto LNG Development, they include:

- the Pilbara Demersal Finfish Fishery comprising:
- the Pilbara Fish Trawl (Interim) Managed Fishery
- the Pilbara Trap Managed Fishery
- the Onslow Prawn Managed Fishery
- the Nickol Bay Prawn Fishery
- the Pearl Oyster Fishery
- the Western Australian Mackerel Fishery
- the North Coast Shark Fishery
- the Marine Aquarium Fish Managed Fishery
- the Northern Developmental Blue Swimmer Crab Fishery.

The Marine Aquarium Fish Managed Fishery: The Marine Aquarium Fish Managed Fishery operates in state waters spanning the entire Western Australian coastline. In recent years the fishery has been active in waters from Esperance to Broome with popular areas including the area from Karratha to Port Hedland (Newman and Cliff 2006). The Marine Aquarium Fish Managed Fishery is known to operate on coral reef around Conzinc and Angel islands.

The fishery targets more than 250 species of fish as well as coral, live rock and invertebrates. It is primarily a dive-based fishery that uses hand-held nets to capture target species from boats up to 8 m in length (Newman and Cliff 2006).

There are 13 licences in the fishery and in most years all licences are actively used. While the fishery operates throughout all Western Australian waters, catches are relatively low in volume due to the special handling requirements of live fish, with 28 936 fish being caught in 2005. Collectors can however, earn a high return from the capture of very small quantities of individuals (Newman and Cliff 2006).

The Northern Developmental Blue Swimmer Crab Fishery: The Northern Developmental Blue Swimmer Crab Fishery (NDBSCF) occupies waters out to the 200 m isobath between 115°E latitude and 120°E latitude, from approximately Onslow to Port Hedland. Two commercial fishers are authorised to operate in the NDBSCF with each exemption holder having slightly different fishing area boundaries. Exemption holder one being permitted to fish within the zone 115°6’60 E to 120°E, while exemption holder two is permitted to fish within the zones 115°E to 116°45’E and 117°E to 120°E (DEH 2006).

The fishery targets blue swimmer crab (*P. pelagicus*); however, operators are also permitted to retain coral crabs (*C. cruciata*) and sand crabs (*O. australiensis*) as by-product. Crabs are caught using approved crab traps and there is no closed season. In 2003, 49.1 tonnes of blue swimmer crab were taken with a total value of approximately $325 000 (DEH 2006).

10.7.5 Pearling and Aquaculture

Several land-based aquaculture sites exist in the vicinity of the Pluto LNG Development. There are currently no active pearling leases in the Dampier Archipelago. A live rock aquaculture site is also proposed at Withnell Bay. Live rock is substrate (usually rock or dead coral) that has been colonised by a range of flora and fauna such as bryozoans and coralline algae and is used by aquarium enthusiasts to enhance an aquarium's appearance and function

Preventative and Management Measures: As previously stated in Table 11-9 of the Draft PER, Woodside will ensure those stakeholders that could be potentially affected by construction activities are appropriately informed before the start of construction. Notification to Mariners and compliance with port authority regulations will be required under maritime and port legislation and regulations. Fisheries bodies, including the Marine Aquarium Fish Managed Fishery, the Northern Developmental Blue Swimmer Crab Fishery and the proposed aquaculture proponent at Withnell Bay, will be contacted by Woodside prior to commencement of construction activities and fishers provided with relevant information on timing of construction activities and related equipment and vessel movements. Where necessary, briefing sessions will be conducted with relevant fishers to ensure they are fully aware of proposed construction activities that could affect their activities.

6.3 Overall there is no mention of underwater cultural heritage (UCH) other than 'shipwrecks' in Section 10.4. UCH needs to be included in Section 10.3 Aboriginal Heritage as there is potential for submerged rock art in the area.

Woodside is required to notify the Aboriginal Cultural Material Committee if the company believes that its activities will damage Aboriginal heritage sites and to seek consent to use land for a required purpose in that instance. Woodside has no reason to believe that it will disturb Aboriginal heritage sites during maritime operations associated with the Pluto LNG Development.

6.4 Overall prior to construction phase of the Pluto development, a systematic desktop and field survey of the development area including the seabed should be made for Indigenous, historic and maritime cultural heritage sites by appropriately qualified archaeologists.

Prior to archaeological heritage surveys commencing over Site A and Site B detailed desktop analysis was completed to identify previously discovered Aboriginal heritage sites and to assess the extent of heritage surveys previously conducted over these areas of land. This work was completed to further Woodside's understanding of the heritage landscape, to assist the survey work and to comply with the heritage survey standards expected by the Department for Indigenous Affairs.

11.15 Woodside refers to the 'Burrup Land Use Management Plan' as if it is a final document. Our understanding is that it is still a draft only (and we have not seen or been consulted about it)

The Burrup Peninsula Land Use Plan and Management Strategy was endorsed by Cabinet in 1996, following public consultation.

In 2006, the Department of Environment and Conservation released the draft management plan for the Proposed Burrup Peninsula Conservation Zone. This draft management plan is a separate document, but refers to the Burrup Peninsula Conservation Zone outlined in the Burrup Peninsula Land Use Plan and Management Strategy (1996).

11.16 the 'Social Impact Management Plan' is proposed to be developed after the project is approved. This is too late: it needs to be developed, with input from organizations like ours, before any project approval is given so that findings and recommendations can be part of an application for the project approval

13.10 What is the timing for the publication of these [Social Impact Management Plan] documents? The draft PER states that the Social Impact Management Plan is due by early 2007. What is the intended review and comment process and procedures for these documents?

Woodside have been consulting with the Karratha Community Liaison Group to develop a social impact study and management plan that ensures Woodside maximises positive impacts, and minimises any negative impacts associated with the Pluto LNG Development. Independent consultants were engaged in the preparation of the Social Impact Management Plan.

The Social Impact Management Plan is due for release in the first half of 2007, prior to approval of the Development, and further consultation is planned on the management measures proposed by Woodside.

12.1 The nearest resident is 6 km away however the report has not clearly established whether workers living quarters are located on site.

The Pluto LNG Development workforce will be accommodated away from site, within existing towns.

12.2 …itinerant Indigenous communities were not considered in the document and further investigation is recommended to ascertain if they are potential sensitive receptors.

There are no itinerant Indigenous communities on the Burrup Peninsula and the representation of Indigenous people within the Shire of Roebourne and local workforce is well documented. Indigenous participation in the local community and the workforce has been captured in ABS census data and examined in a number of studies and reports and relevant aspects are addressed in the Pluto LNG Development Social Impact Assessment due for release in the first half of 2007.

Given the pre-existing scale of industrial development in the area and the absence of itinerant Indigenous communities, the issue of potentially sensitive receptors of this character does not apply. However, the local Indigenous community is of significance and is growing in terms of regional workforce demographics. The Pluto LNG Development will provide some opportunities for local and itinerant workers generally. Specific opportunities are being identified for the local, regional and national Indigenous community.

12.5 …an integrated mosquito management program to ensure that the risk of exposure to employees to mosquito-borne diseases is minimized will be an important OSH component for the site.

This comment is acknowledged. Risk of exposure of the workforce to mosquito borne diseases will be considered in health and safety management plans.

12.6 Woodside is advised that it is required to comply with the Health (Pesticides) Regulations 1956 made under Part VIIA Division 8 of the Health Act 1911 for pest controls. Any weed control must e conducted by either appropriately trained employees or contractors who have an appropriate licence.

This comment is acknowledged. The Weed Management Plan will be developed in consultation with regulatory authorities and will include reference to relevant legislation.

*12.7	The proponents are advised that they are required to develop a Drinking Water Quality Management Plan to be submitted to the Department of Health. This plan must demonstrate compliance with the 2004 Australian Drinking Water Guidelines.*

This comment is acknowledged. Woodside will consult with the Department of Health regarding management of drinking water quality.

Aboriginal Heritage

*1.9	The cultural contents of Site A, which are unique in the world, are considered only cursorily, there is no mapping of them, only an inadequate summary of previous surveys.*

*1.12	[We recommend that the EPA request the following from Woodside]…To provide fully documented evidence on the number of rock art motifs to be destroyed and moved, of the number of stone arrangements to be destroyed or disturbed, and on the number of both rock art items and arranged stones that will be located within 200 m of any plant components. This is required for both Site A and Site B.*

Woodside has described the cultural heritage environment in section 10.3 of the PER and its impacts on that environment in section 11.3. Detailed and specific information about the nature of Aboriginal heritage sites has been provided to the Department of Indigenous Affairs as part of Woodside's heritage approval application. Specific details about individual heritage sites will not be publicly released by Woodside due to confidentiality restraints and because much of this information is sensitive and gender specific to indigenous persons.

Woodside has clearly stated in the Draft PER the expected local and regional impact that the company will have on cultural heritage. Further to the statements made about the impacts on rock art, approximately 80% of the standing stones across the development fall outside of Woodside's disturbance zone. The most significant standing stone complex across the development which comprises 64% of the total number of standing stones is located at Site B. This site will be protected within a designated 'preservation zone' to ensure that these standing stones will be left undisturbed and in-situ within their existing environment.

No stone arrangements will be disturbed and Woodside estimates that it will have to retrieve and relocate approximately 150 individual engravings (motifs). 95% of the rock art on Site A and Site B will remain undisturbed.

Woodside has already successfully relocated all of the rock art and artefacts from within the Site A disturbance area without loss or damage. In total 42 engravings have been successfully moved to a pre-determined relocation zone where they remain barely discernable within the surrounding uncleared land.

*8.3	...considering the absence of the traditional custodians' knowledge of the site and lacking any completed inventory of the carvings, Woodside cannot be sure what significance any particular rock has in the context of the whole collection. It is unwise that Woodside continue preparing for development on Site A and applying for development on Site B until all these questions can be answered, especially when a location has not been confirmed and the plant has not been approved in full by their own board.*

*11.11	Woodside acknowledges that at the time of writing the PER, it does not have complete heritage survey results. In addition, it has no survey results from us as we were not invited to participate.*

Traditional custodians have participated on heritage surveys and Woodside has completed a detailed inventory of all heritage material on Site A and Site B. Archaeological heritage site significance ratings have considered the question of representation (please refer to response

13.20). Woodside's work program on Site A is being executed under all required approvals. Woodside's decision to proceed with site works prior to making a final investment decision on Pluto LNG Development has been considered carefully by the company and in the context of maintaining the ability to meet customer requirements for the supply of LNG by late 2010 and its decision to commit $1.4 billion to long lead items and the Front End Engineering Design phase of the Development.

At the time of writing the PER the Wong-Goo-Tt-Oo Group had not completed its heritage survey over Site B. This survey is now complete and the results have been submitted to the Department of Indigenous Affairs as part of Woodside's Site B heritage approval application. The results from the survey completed by the Ngarluma group have also been submitted to the Department of Indigenous Affairs as part of Woodside's heritage approval application for Site B. The matter of representation in these surveys raised by the Ngarluma Aboriginal Corporation has been addressed above.

1.10 The impact of the construction of the Pluto plant in this location will totally destroy the ambience of this sacred cultural precinct at Holden Point, and will result in the destruction of hundreds of rock art and stone arrangement sites. At the former, any boulders that can be transported will be, and already are presently, removed and dumped in a compound (we have thousands of boulders in such graveyards of rock art already, where they are of no value to either Aborigines or scientists). What cannot be moved, and that includes all stone arrangements, will be bulldozed.

8.1 Woodside's proposed Pluto expansion will cut through Site A of the Burrup Peninsula – one of the densest areas of rock carvings on the archipelago. Although Woodside has stated they aim to move 150 rocks and not destroy any carvings, the company has also admitted to GetUp that some of the rocks may have to be damaged in the process of moving, especially if they are too large or too difficult to move in any given particular place.

Woodside's response to point 1.10 above is as per the Company's response to points 1.9, 1.12, 13.2, 13.5, 13.8.

The retrieval and relocation of heritage sites, including rock art, at Site A rock has been 100% successful with no damage to rock art or any heritage site. No rock art has been destroyed. Woodside will apply the same relocation principles to Site B and aims to successfully relocate all heritage items.

1.1 Two weeks before the submissions commenting on the above application by Woodside closed, on 5 February 2007, Woodside began destroying rock art sites at the Pluto A Site at Dampier, i.e. without having obtained clearance from the EPA.

1.4 Woodside, in pre-empting your decision, has shown its contempt for the EPA's authority.

All preliminary site works on Site A, including the retrieval and relocation of artefacts and rock engravings, were conducted in accordance with the required statutory approvals, including that of the EPA and the Minister for Aboriginal Affairs. Those activities were not part of the Draft PER.

1.3 The Australian Heritage Commission has determined that Dampier should be on the World Heritage List, as well as on the National Heritage List.

The decision as to whether the Dampier Rock Art Precinct, including the Burrup Peninsula, should be placed on the National Heritage List is before the Commonwealth Minister for the Environment.

Woodside does not oppose the inclusion of the Burrup Peninsula on the National Heritage List.

Woodside's position in relation to this matter is conditional a gas precinct being established within an area of land already zoned for industrial development and that this area be excised from the boundary of the proposed NHL area. Woodside also believes that a suitable management framework should be in place before heritage listing occurs

11.5 sites to be destroyed in the Pluto Site B area include 'rare' and 'unusual' sites and sites of 'high' significance

11.10 We dispute the opinion that the sites to be disturbed 'are mostly of lower significance.' In our traditional law and custom, all sites at the Burrup are of highly sacred significance.

Significance assessments of heritage sites differed between the archaeological and ethnographic heritage surveys. Woodside acknowledges that the Burrup Peninsula and heritage sites within it are considered as highly significant by the Indigenous groups of the area and the broader community. The criteria for archaeological significance rating are discussed in Woodside's response to point 13.20 below.

No heritage sites given a high archaeological significance rating fall within Woodside's proposed disturbance zone at Site A. One site of high archaeological significance falls within the disturbance zone at Site B that Woodside intends to relocate and preserve. Woodside has also established designated preservation zones at Site B in which a significant standing stone complex and rock art depicting Thylacines will be protected. Successive Western Australian Ministers for Indigenous Affairs has approved Woodside proceeding with the Pluto LNG Development on Site A and Site B subject to conditions including the preservation of large numbers of heritage sites.

11.6 Given the heritage significance of our Country, Woodside has to 'demonstrate' that it has 'properly considered how to minimise any adverse impact by the proposal on heritage values'. Given its failure to consult with us, it cannot 'demonstrate' that any Aboriginal heritage matters have been considered or addressed.

Woodside has addressed these points in its responses to points 13.2 and 11.1, 11.2, 11.4, 11.14, 11.12, 11.13 and 8.3

11.7 …despite a pledge by Woodside given to the Department of Indigenous Affairs that it would not start any heritage destruction at Pluto Site A until an approval had been given to Site B, it has gone ahead and started shearing the front off sacred sites with a diamond saw.

No such pledge was given however it was Woodside's preference to wait for a decision on the Site B heritage approval prior commencing works on Site A. The time taken to finalise the approval process and Woodside's schedule for the Pluto LNG Development left the company with no choice but to commence works at Site A in January. Heritage approval for Site B was subsequently granted in February.

Diamond saws or similar equipment were not used on Site A. All rock art was successfully relocated to a designated relocation area identified in consultation with traditional custodians.

13.2 …what consideration does the PER commit to, to seriously address the impacts and provide alternatives to those key issues such as 'physical destruction or removal of cultural heritage'.

The Draft PER outlines the steps that Woodside has taken to minimise impacts to the Aboriginal heritage environment. For example, Woodside considered Aboriginal heritage when selecting a site on which to locate the Pluto LNG Development. This culminated in Woodside selecting areas containing large plateau style flat upland areas that typically contain less heritage sites, in particular rock art, than valley systems and watercourses.

A heritage site minimisation methodology was also employed by Woodside resulting in a Pluto LNG Development footprint that will avoid as many heritage sites as practicable. This process took into consideration advice from the indigenous groups of the area and the results of archaeological and ethnographic heritage surveys. This process has resulted in Woodside being able to avoid an estimated 95% of the rock art across the Pluto LNG Development. Discrete areas of land containing a vast majority of the heritage sites will be left un-disturbed and in-situ.

Where heritage sites fall within Woodside's proposed disturbance zone heritage sites cannot be left in-situ. Woodside aims to relocate all artefacts and rock engravings from within the development area to a designated relocation zone. This process is undertaken with the involvement of indigenous monitors, Woodside and contract archaeologists and in consultation with relevant agencies. The work has been completed at Site A with a 100% success rate.

13.5 …what is the likely impact of dust emissions (construction works, traffic, blasting etc.) and carbon emissions (LNG plant) and their probably sedimentation, on rock art?

There is expected to be no impact from dust emissions on rock art. Woodside's environmental management plans will address dust emissions and dust suppression measures will be implemented. Woodside will also apply active heritage site protection measures to all heritage sites (including rock art) situated in close proximity to any works or traffic. This may include covering, bolstering or strapping heritage sites to ensure they remain un-disturbed and in-situ during and after the completion of works. Specialist blasting techniques will also be used to ensure that heritage sites will not be damaged by fly rock or vibration.

Studies into the possible effects of chemical emissions on rock art are ongoing and preliminary results from the independent Burrup Rock Art Management Committee have concluded that there is no effect from emissions on rock art.

Dust suppression is exercised during construction activities and protection works are in put place during blasting activities. Small-charge blasting techniques are utilized, with little or no flyrock and dust. Vibration is kept to a minimum and protection works including sandbagging and geo-fabric covering are put in place to ensure protection of heritage sites.

Studies into the possible effects of chemical emissions on rock art are ongoing. Data collected by an independent, government-funded committee (Burrup Rock Art Management Committee) suggests that there is no link between current emission levels and effect on the rock art.

13.7 The Woodside draft PER is weak in its description of the aboriginal cultural heritage sites and its significance in terms of world anthropological history. Though Woodside reference their environmental and Indigenous community policies; they have been retrospective and casual with regards to a number of items: 'delay or stop activities where effective environmental controls are not in place', 'openly communicate our environmental performance with our workforce…and the wider community.'

Woodside has described the cultural heritage environment in Section 10.3 of the Draft PER and its impacts on that environment in Section 11.3. Detailed and specific information about the nature of Aboriginal heritage sites has been provided to the Department of Indigenous Affairs as part of Woodside's heritage approval application. Specific details about individual heritage sites will not be publicly released by Woodside for a number of reasons including:

- it was agreed with the Indigenous people who participated in surveys that survey information would not be made publicly available
- confidentiality restraints
- the majority of this information is culturally sensitive and gender specific.

Woodside has not provided information about the heritage landscape at Site A and Site B in terms of world anthropological history. The Company is not required to consider this question during the heritage survey process but has attributed archaeological heritage site significance ratings to international benchmarks. With the Pluto LNG Development footprint encompassing less than 1% of the total area of the Burrup Peninsula there remains opportunities for further anthropological research.

Specific procedures have been put into force on site to ensure all work is conducted in accordance with the relevant cultural heritage management plan. The Cultural heritage Management Framework and plans are published on Woodside's website at: http://www.woodside.com.au/Regions/Australia+and+Asia/Development+Opportunities/Pluto/Approval+Process/Cultural+Heritage+Management.htm

Woodside continues to comply with all of its policies in the pursuit of the Pluto LNG Development.

13.8 …what commitments does Woodside provide to ensure Woodside's ongoing accountability for the preservation of the rock art?

Woodside is committed to, where practicable:

- leaving rock art and other heritage sites undisturbed and in-situ
- implementing recommendations made by representatives of the Ngarluma, Yindjibarndi, Yaburarra, Mardudhunera and Wong-Goo-Tt-Oo groups; and to
- restricting the development footprint for the required onshore infrastructure.

At Site A, where site preparation activities have already commenced, the development footprint is limited to only 1/3 of the total area of the site. At Site B, Woodside's footprint will, in most part, be contained to the large plateau type flat upland areas. Apart from the required crossing points the integrity of the gully systems will be protected. This commitment is embedded within Woodside's heritage management approach which is to avoid impacts to the heritage environment as far as practicable.

Woodside's commitment and approach will result in approx 95% of rock art across Site A and Site B being left undisturbed and in-situ with Woodside's aim being to relocate the remaining 5% into a designated relocation zone(s). In containing its development footprint as far as practicable Woodside will also be leaving untouched large areas of land within which heritage sites will be left undisturbed and in-situ in their original current environment.

In addition to Woodside's commitments the company must comply with conditions set by the Minister for Indigenous Affairs under the consent that it has received to develop Site A and Site B.

To ensure Woodside's compliance with approval conditions and commitments all site activities are undertaken under a cultural heritage management framework and cultural heritage management framework plans. These documents are available to the public on Woodside's website and can be found at:

http://www.woodside.com.au/Regions/Australia+and+Asia/Development+Opportunities/Pluto/Approval+Process/Cultural+Heritage+Management.htm.

Woodside has dedicated Heritage Management staff to ensure the company's commitments and approval conditions are met.

13.9 'Aboriginal heritage sites left in situ where practical.' On what grounds/ criteria will the test of practicality be administered? How will this be monitored and assessments reviewed?

Woodside is still completing the detailed Front End Engineering and Design (FEED) phase for the Pluto LNG Development during which engineering planning, including the layout of infrastructure, will be finalised. Throughout this FEED phase planning and engineering staff will consider the location of Aboriginal heritage sites and embed in the final layout design heritage management conditions set by the State Minister for Indigenous Affairs. It is during this work, considering technical constraints and land access requirements, that heritage sites will be avoided as far as practicable.

Woodside's commitments will be monitored by the Department of Indigenous Affairs and representatives of the Indigenous groups of the area with whom Woodside meets regularly to provide heritage management updates.

13.11 Who are ACHM (Australian Cultural Heritage Management Pty Ltd) referenced to have conducted archaeological surveys according to Woodside PER? What constraints, if any, were there on their ability to conduct the archaeological surveys? Was their scope just for the Site A disturbance footprint?

Australian Cultural Heritage Management (ACHM) is an Aboriginal heritage management consultancy firm based in South Australia who Woodside contracts to provide independent heritage management advice. ACHM employs experienced archaeologists with particular expertise in the Burrup Peninsula and have been working on the Burrup Peninsula for some 6 years now.

Woodside placed no constraints on ACHM and made clear that company expected an extremely thorough survey exceeding the standards set by the Department of Indigenous Affairs. ACHM surveys have not been limited to the Woodside's proposed disturbance footprint as it was the results of the archaeological and ethnographic surveys over that the entire Site A and Site B lease areas that helped Woodside to shape the disturbance footprint to avoid heritage sites as far as practicable. ACHM will continue to work with Woodside to monitor initial ground disturbance works and the retrieval and relocation of heritage sites.

13.13 Woodside commit to retrieve and relocate approximately 150 rock art. What monitoring and extraction procedures apply to the removal and relocation of the rock art?

Woodside's aim is to retrieve and relocate all rock art from within the company's disturbance zone that is estimated to be approximately 5% of the rock art in place or around 150 single engravings (motifs). On industrial Site A this work has been completed with 100% success rate and with no damage to any rock art.

The retrieval and relocation of heritage material, including rock art, is monitored by representatives of the Indigenous groups of the area and is undertaken by a crew of professional riggers and crane operators, assisted by engineers and health and safety specialists. Prior to the works commencing a detailed retrieval and relocation method statement is written that outlines precisely how the work will be undertaken. This work instruction also records the wishes of the Indigenous representatives with respect to how and where heritage items should be handled and placed and is included to ensure that Woodside fully considers how to complete this work with sensitivity to Indigenous cultural considerations. Only after the work instruction has been approved can the retrieval and relocation works begin.

The process for the retrieval and relocation of heritage material includes clearing boulders around the heritage item to be relocated and in the case of rock art, wrapping the host boulder to protect it from damage caused by scraping or scratching, strapping it to ensure that fracturing will not occur and placing netting around it to create a hitching point for a crane to hoist it onto transport vehicle for transportation and then to gently place the item into a designated relocation area. Where possible, rock art is placed into this relocation area in the same aspect and orientation as its original environment context.

The retrieval and relocation of rock art and other heritage items at Site A has been completed successfully and with no damage to any heritage item or rock art.

13.14 Figure 11-1a and b clearly identify a connection point to Site E (LNG plant) on the southern boundary of Site A. Does this connection point fall within the 'do not disturb boundary'

This connection point does fall inside the "do not disturb area" identified by the Minister for Indigenous Affairs under the Site A heritage approval conditions. As illustrated in figures 11C-E this connection point is no longer required in a Site A and Site B development scenario. In effect this means that a large area of Site A (approximately two-thirds) will be left untouched so heritage sites can be left un-disturbed and in-situ in their original environmental context.

13.13 Rock art population estimates are inconsistent throughout the document and illustrate that extensive rock art surveys have yet to be completed

It is true that heritage surveys have not been completed across the entire Burrup Peninsula and to this extent only estimates are available as to the amount of rock art on the Peninsula. It has been estimated by the National Trust that up to 1 million pieces of rock art exist on across the Dampier Archipelago that includes the Burrup Peninsula.

Woodside has conducted very detailed archaeological and ethnographic heritage surveys across Site A and Site B to best understand the cultural heritage landscape. Woodside has found approximately 3 000 single engravings of which an estimated 150 or 5% will need to be retrieved and relocated from within the disturbance area that is required to build the onshore components of the Pluto LNG Development. Woodside expects to identify some additional archaeological material as planning and field work progresses ahead of the commencement of relocating heritage material on Site B; however, this is not expected to change the view that 95% of the rock art will remain undisturbed in situ.

13.15 What archiving methods are currently being employed and under what management plan is the rock art being removed, destroyed or relocated as part of the site preparation works?

During the archaeological and ethnographic heritage surveys of Site A and Site B detailed information pertaining to the location and nature of heritage sites was recorded and reported to the Department of Indigenous Affairs (DIA) in accordance with DIA standards and the *Western Australia Aboriginal Heritage Act*. Prior to the retrieval and relocation of heritage sites further recordings of each heritage site has been completed where required and detailed recording of the new location of each heritage site has been undertaken – this information will also be submitted to the Department of Indigenous Affairs.

The archiving of heritage sites has been very carefully managed by Woodside to ensure that all information pertaining to each heritage item has been captured and stored. The Department of Indigenous Affairs maintains the Register of Aboriginal Sites where some information about the location and nature of heritage sites is made available to the public.

All of Woodside's heritage management work, including the retrieval and relocation of heritage sites is executed under Woodside's Cultural Heritage Management Framework and specific Cultural Heritage Management Plans that have been written and implemented for each phase of work. These plans can be found at:

http://www.woodside.com.au/Regions/Australia+and+Asia/Development+Opportunities/Pluto/Approval+Process/Cultural+Heritage+Management.htm

13.18 Please advise the impact of blasting works and vibration on rock art? Particularly standing stone arrangements?

Blasting works and vibrations associated with construction and operation activities will have no impact on rock art or standing stones. Woodside has made a commitment that all heritage sites outside of the final designated disturbance area will remain undisturbed and in-situ. To achieve this outcome specialised small-charge blasting techniques will be used with the aim of producing little or no flyrock, vibration and dust.

Further, Woodside will also apply protection measures to heritages sites that lie in close proximity to the designated disturbance area. These protection measures will include placing protective matting on heritage material, bolstering it with sandbags, placing with wooden boxes over the top of heritage sites and / or placing protective screens around it.

13.20 How was the level of significance of the rock art determined? I.e. high level vs. low level? Table 11-7 Consequence D, E and F please provide the referencing key?

The criteria used to assign significance ratings to rock art was as follows:

Low Significance: Minimally altered places such as low-density artefact scatters or single/small groups of engravings of small size and simple composition, grinding patches or other Aboriginal site features which contain little information and/or are a common class of site.

Medium Significance: Sites that are relatively common and tend to have only moderate differentiation in information potential and character among them, and that have a good potential for recording and information recovery, (such as medium density artefact scatters, quarry/workshops, and open camp sites), or which have good potential for recording and relocation without significant loss of information, (e.g., a single engraving, or small groups of engraving boulders that are only moderately preserved and/or capable of salvage and relocation).

High Significance: Sites of a class that is considered to be rare or a site which has rare or unique research or educational qualities, sites which have a high/varied research and/or educational potential, including major archaeological deposits, quarry/workshops, most engraving sites – particularly larger and more varied sites.

13.21 'Any archaeological discoveries during site preparation work will be reported to the regulatory authorities..' Who are the regulatory authorities? Who is responsible for auditing this process?

Under the Western Australia Aboriginal Heritage Act Woodside must report the discovery of Aboriginal heritage material to the Registrar of Aboriginal Sites. The Department of Indigenous Affairs administers this Act and will audit this process and Woodside's compliance with heritage approval conditions set by the State Minister for Indigenous Affairs.

13.22 Given that the CHMP has yet to be written, are the current rock art extraction procedures being reported/ monitored/ recorded to any regulatory authorities?

Woodside, under conditions set by the Minister for Indigenous Affairs must report its heritage management activities, including the retrieval and relocation of rock art, to the Registrar of Aboriginal Sites. The Department of Indigenous Affairs audits and monitors Woodside's compliance with these and all other conditions set by the Minister for Indigenous Affairs.

The retrieval and relocation of heritage sites has and will be conducted under a Cultural Heritage Management Plan.

No works have commenced on Site B and will only commence when Woodside has obtained necessary approvals. As with Site A, specific CHMPs will be written for discrete work activities on Site B – no work on Site B will take place until the relevant cultural heritage management plan has been issued. Woodside's cultural heritage management plans for the Pluto LNG Development can be found at: http://www.woodside.com.au/Regions/Australia+and+Asia/Development+Opportunities/Pluto/Approval+Process/Cultural+Heritage+Management.htm

Safety Risk Assessment

5.4 It is noted the main flare on Site B is located in close proximity to DPAs security gatehouse operations. To avoid potential issues relating to noise impacts, the DPA strongly suggests that Woodside consider relocating the flare to an alternative location.

The noise assessment results for the gas processing plant at Site B conclude that the sound pressure level at the site boundary at the East West Service Corridor will be below the community noise level limit set at 65 dB(A) for an industry to industry boundary. The DPA's security gate house is approximately 250 m beyond the site boundary (and 500 m from the current flare location) so noise levels at the gate house will be somewhat lower than at the boundary. Optimisation of the plant layout is ongoing and if the opportunity to increase the distance between the flare and the DPA's security gate house arises then it will be taken advantage of, however other factors such as ensuring safe thermal radiation levels for site personnel and minimising environmental and heritage impacts limit the options available. It should be noted that moving the flare to any other location within Site B would only create a small reduction in noise levels at the DPA security gate house.

1.5 Already the equivalent of 100 Hiroshima bombs is stored in energy at the NW Shelf site, the Pluto project would add another 120 Hiroshima bombs equivalent and should therefore be built elsewhere because such concentration of volatile substances is dangerous.

Woodside is committed to ensuring the safety of our staff, contractors and the communities of Karratha and Dampier.

The estimation of the potential risk or hazard of LNG based on the relative energy content of a bomb does not consider thermodynamics and the behaviour of hydrocarbons.

Atomic bombs are designed to have the capability of releasing the energy contained within them in a matter of seconds or milliseconds. This is what makes them so destructive. Hydrocarbons (including LNG) do not have this same capability and explosions only occur under very defined and well-understood situations.

Only a fraction of energy can be released from the combustion of fuels such as LNG as it depends on the efficiency of combustion, the availability of oxygen, the energy of activation and how much fuel is left unburnt.

Liquefied natural gas is essentially no different from the natural gas used every day in homes and businesses around the world except that it has been chilled to minus 161 degrees centigrade at which point it becomes a liquid.

1.14 [We recommend that the EPA request the following from Woodside]…To provide firm estimates of the quantities of condensate, propane, butane, light oil, hydrogen and other flammable, toxic, volatile or explosive substances to be stored at the completed and operational Pluto plant..

At the current stage of design quantities of hazardous materials are still uncertain, and only coarse estimates are available, however the gas processing plant will contain sufficient quantities of hazardous materials to be classified as a Major Hazard Facility as defined in the *National Standard for the Control of Major Hazard Facilities* [NOHSC:1014(2002)]. Woodside is therefore required to comply with the requirements of the Standard, which include providing information to the regulatory authority and to the community regarding the nature of hazards at the facility. The information provided will include the maximum quantity of each hazardous material that is present or likely to be present at the facility.

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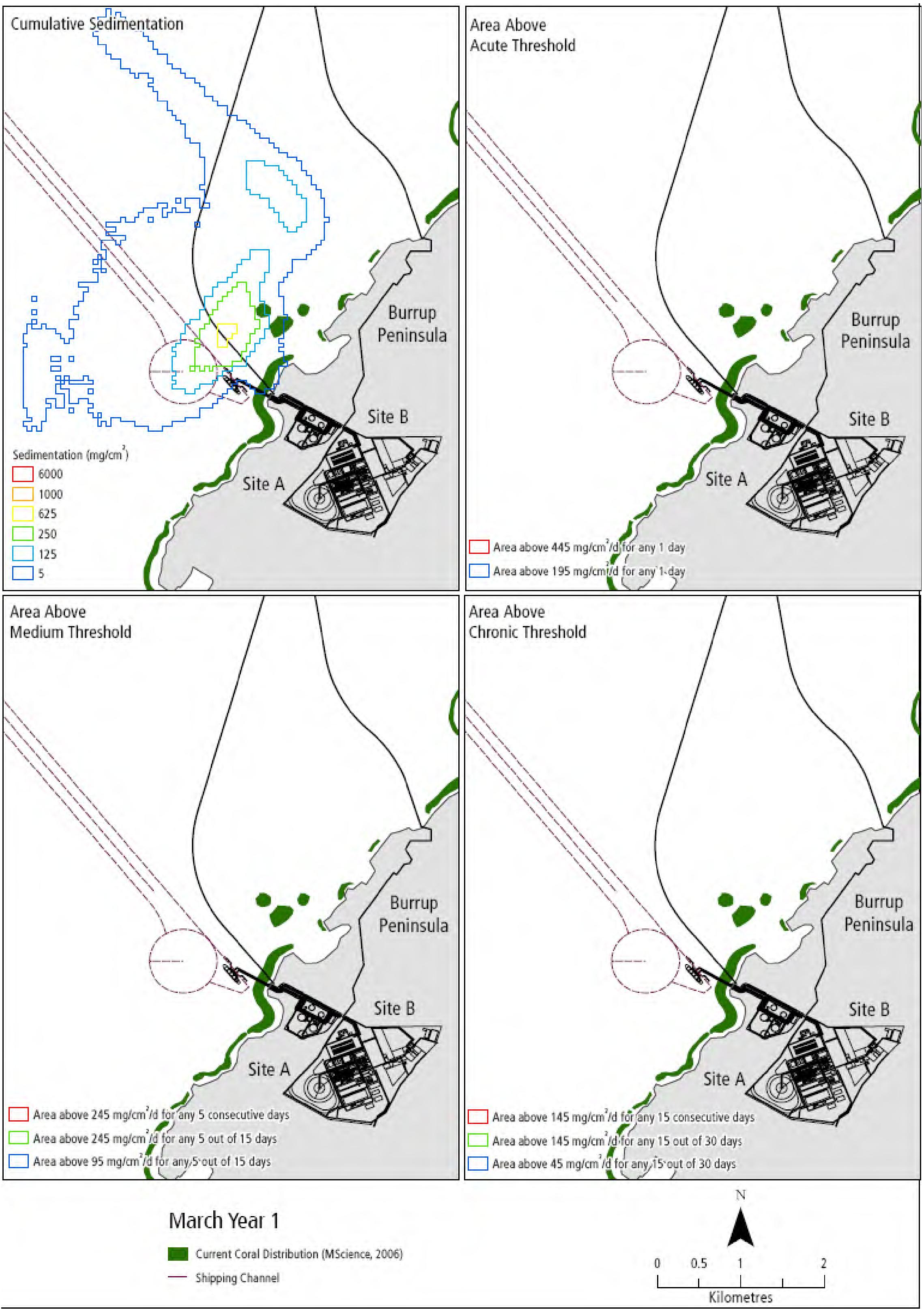
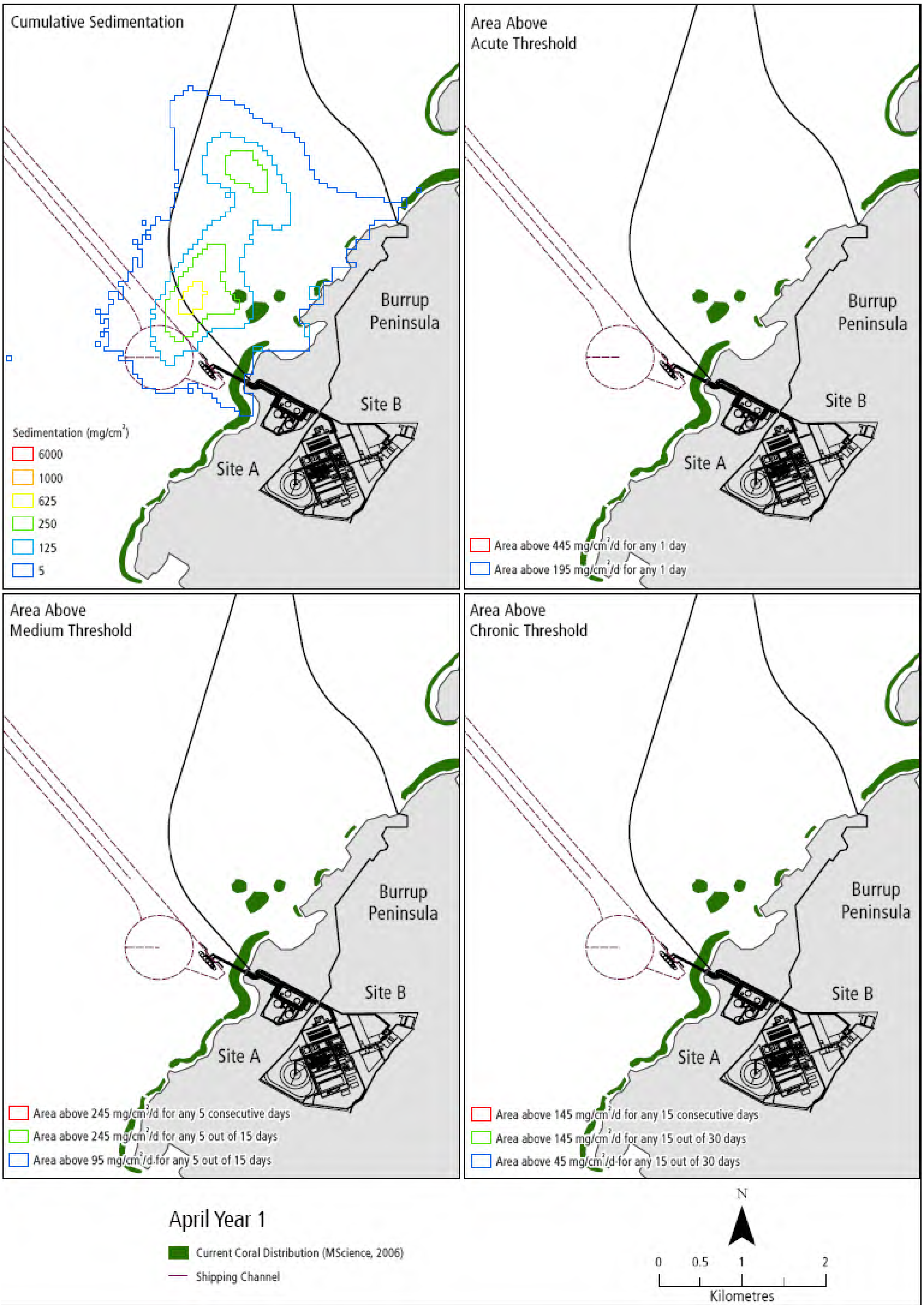
5. Appendix A - Cumulative Sedimentation and Threshold Sensitivity Analysis



- **Figure A 1 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for March Year 1.**



■ **Figure A 2 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for April Year 1.**

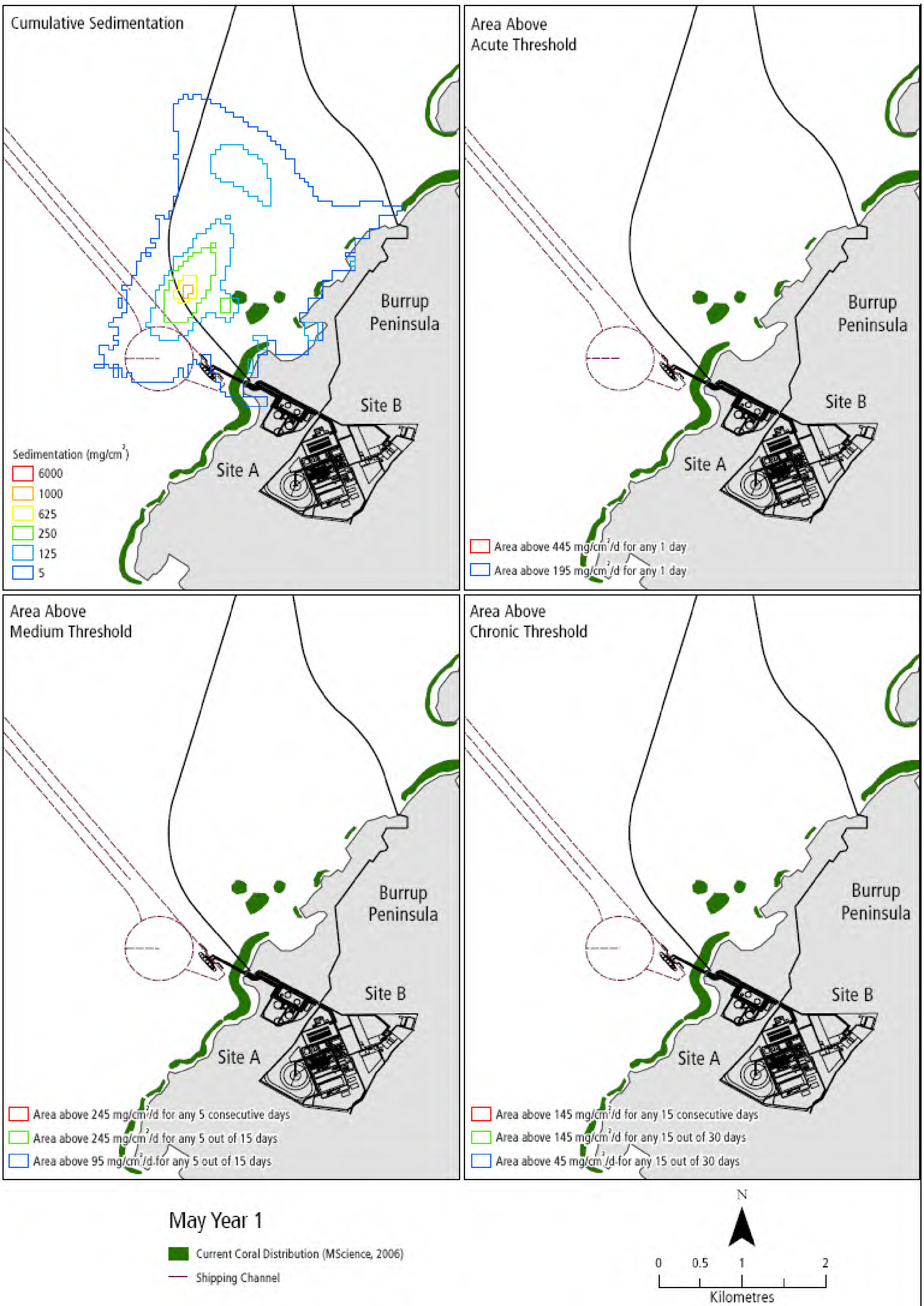


Figure A 3 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for May Year 1.

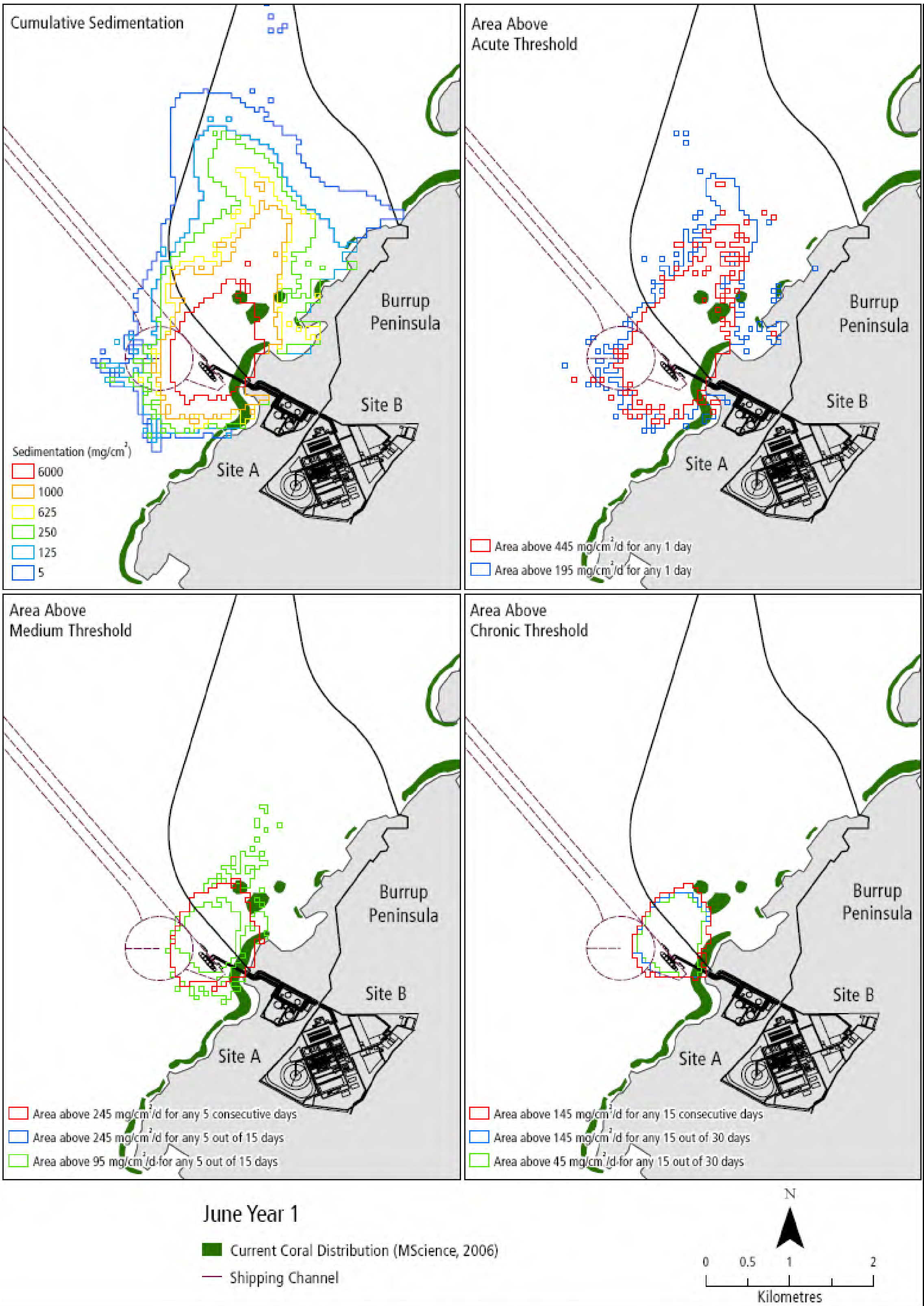
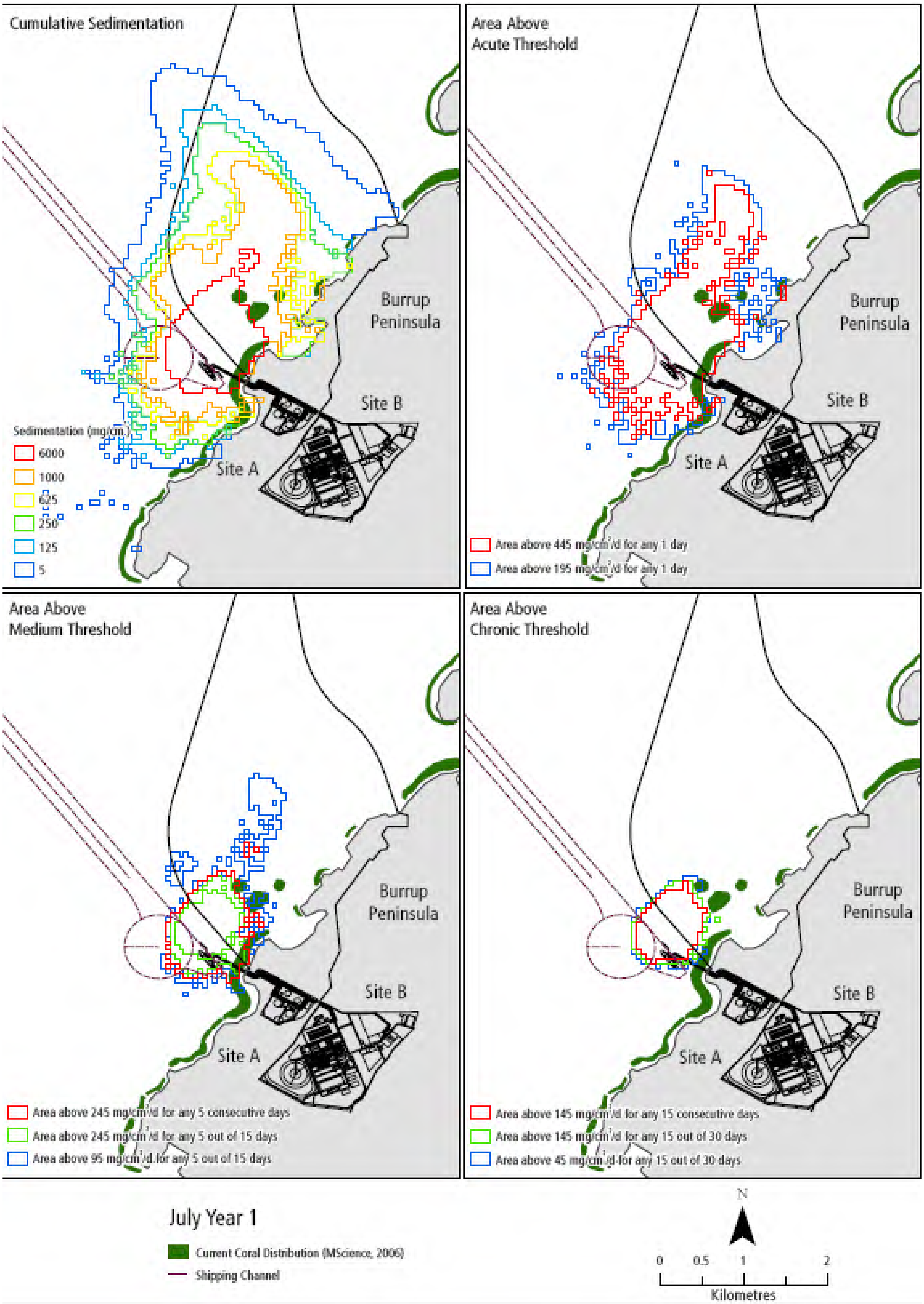
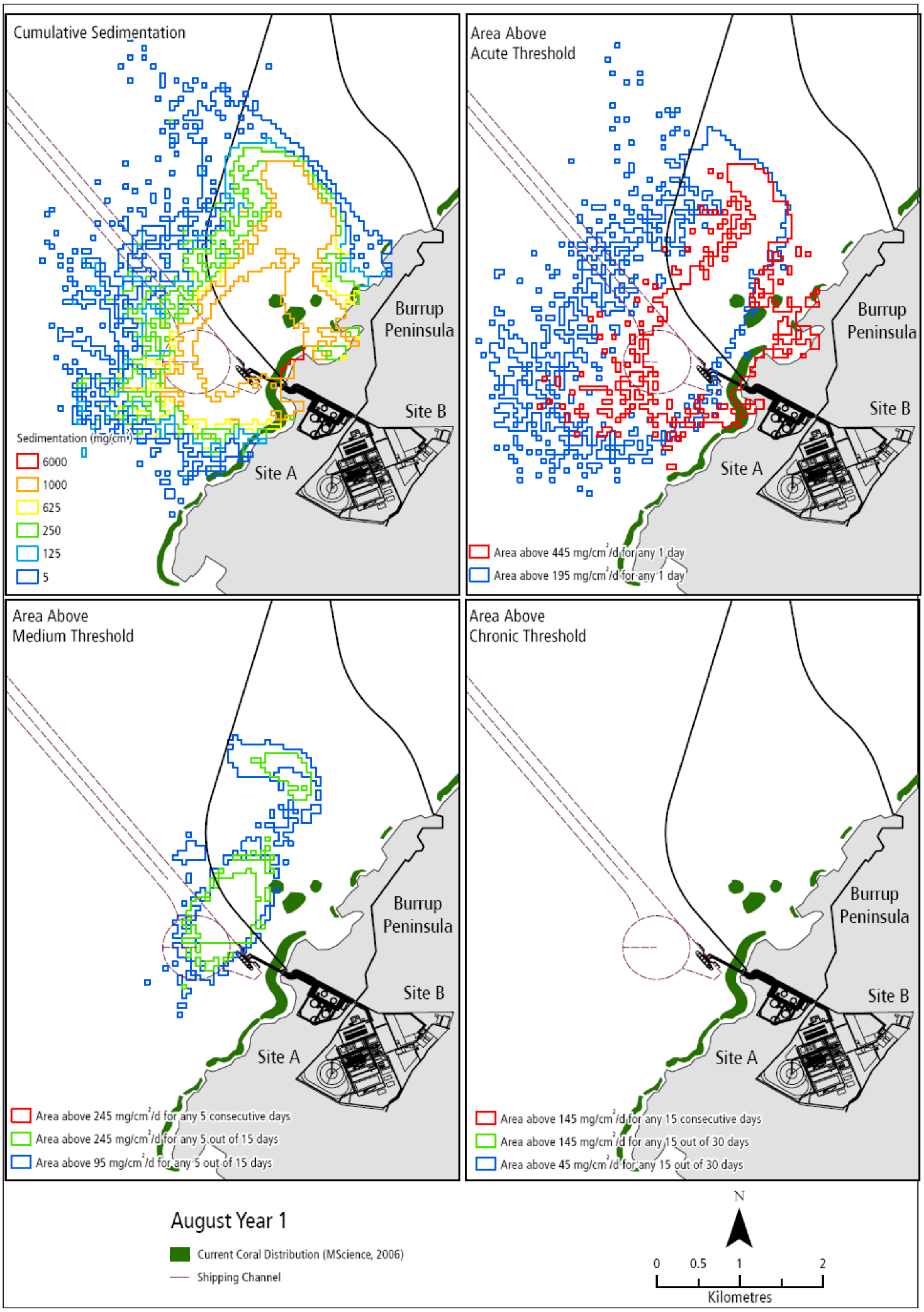


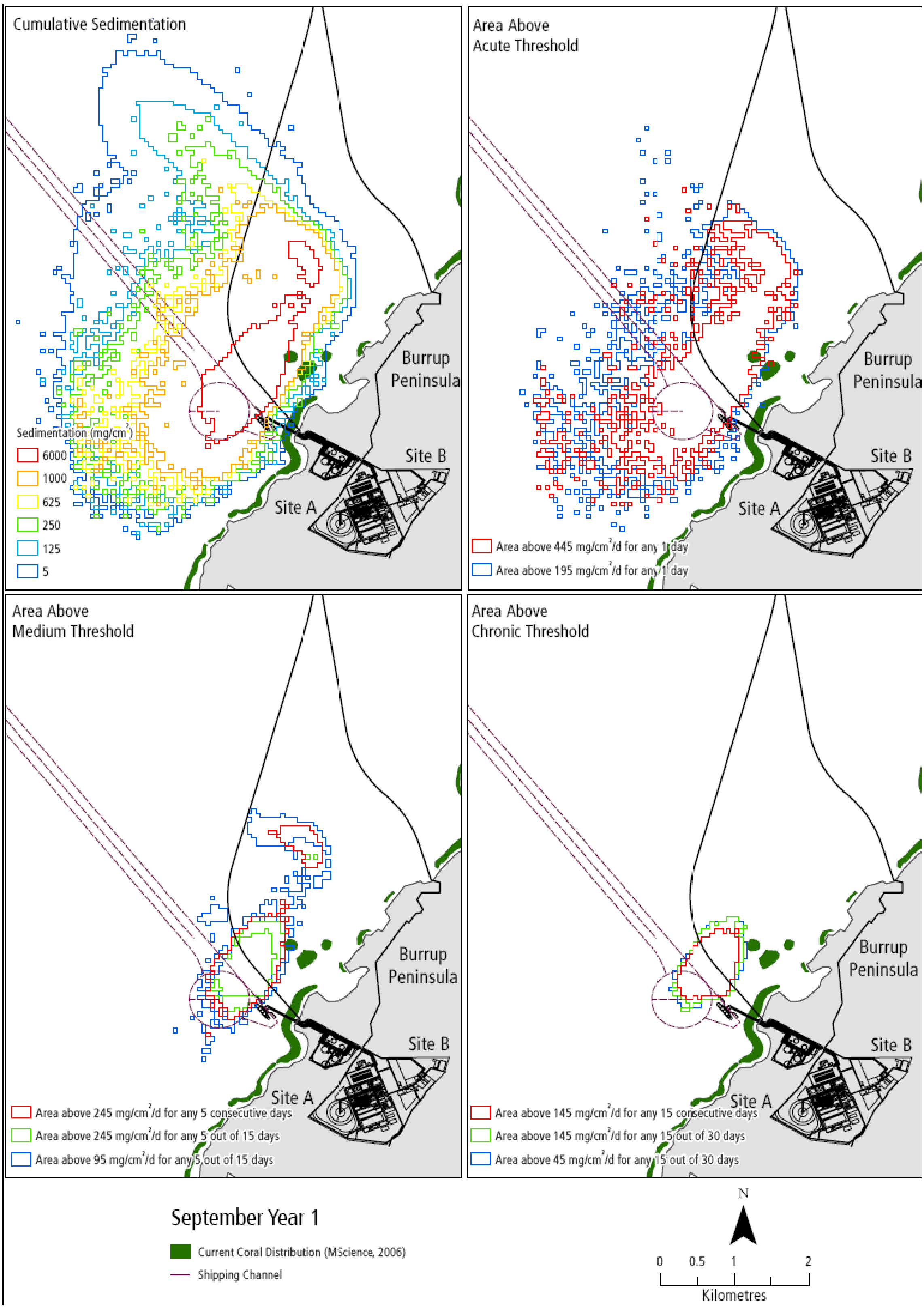
Figure A 4 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for June Year 1.



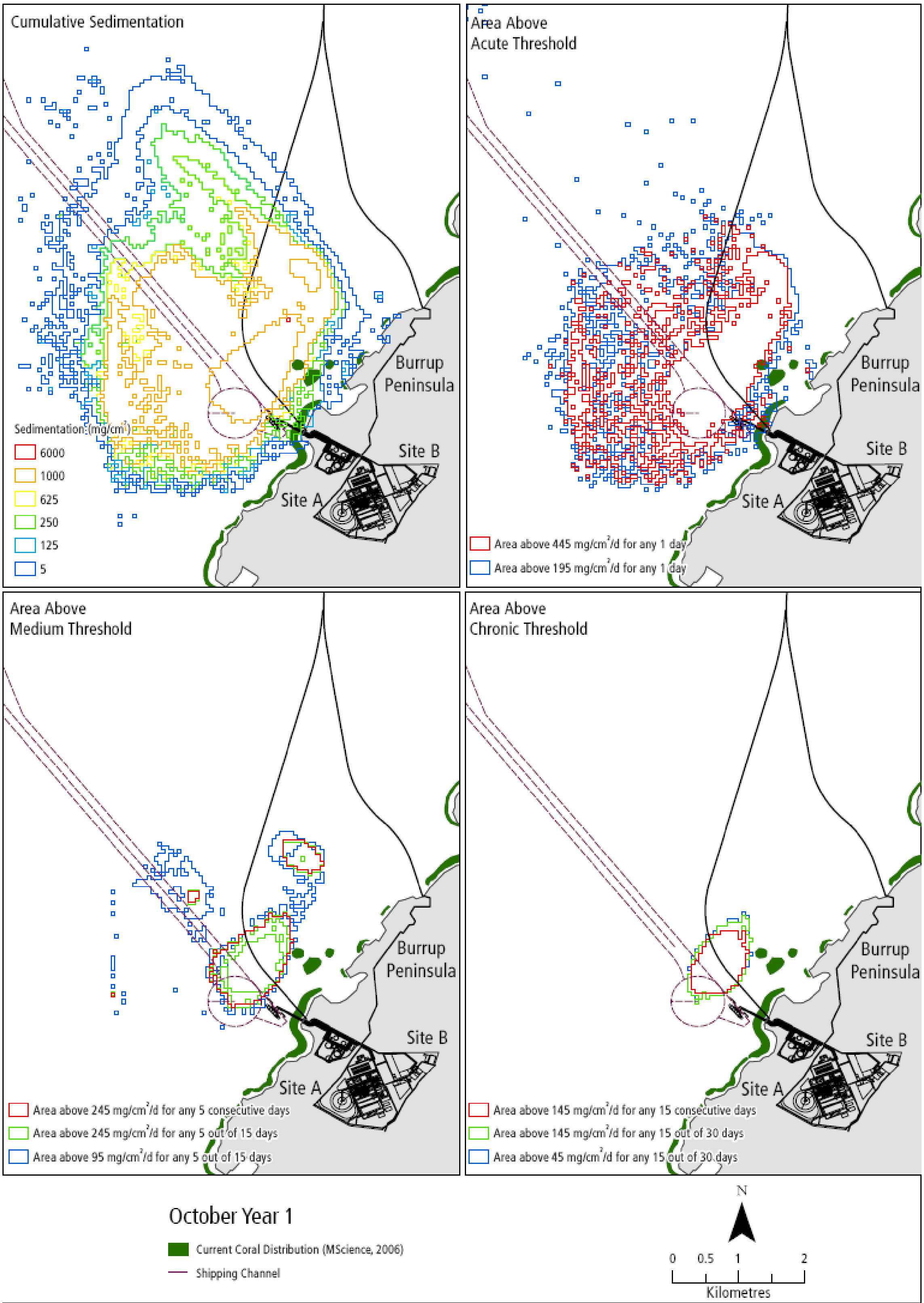
- **Figure A 5 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for July Year 1.**



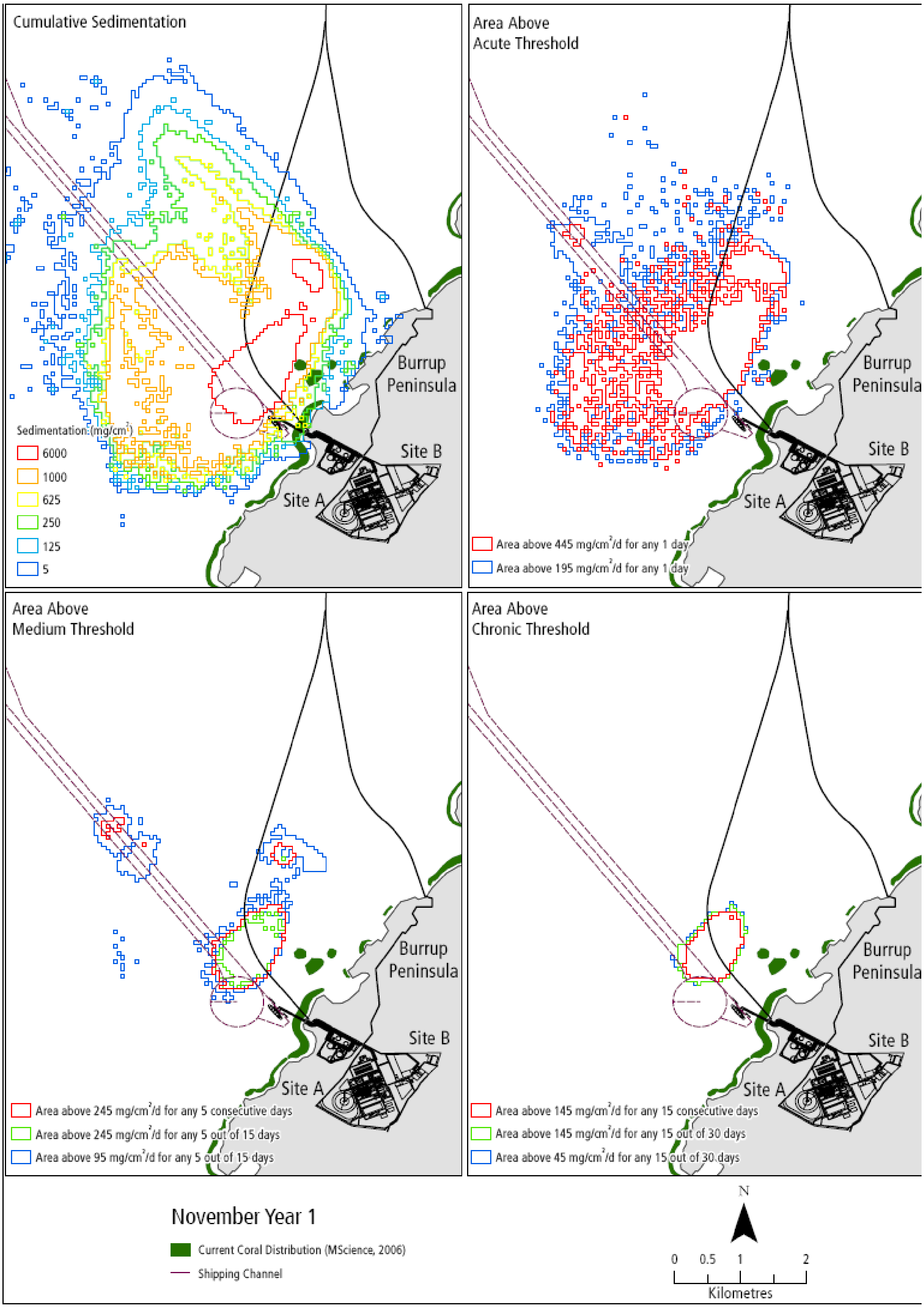
- **Figure A 6 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for August Year 1.**



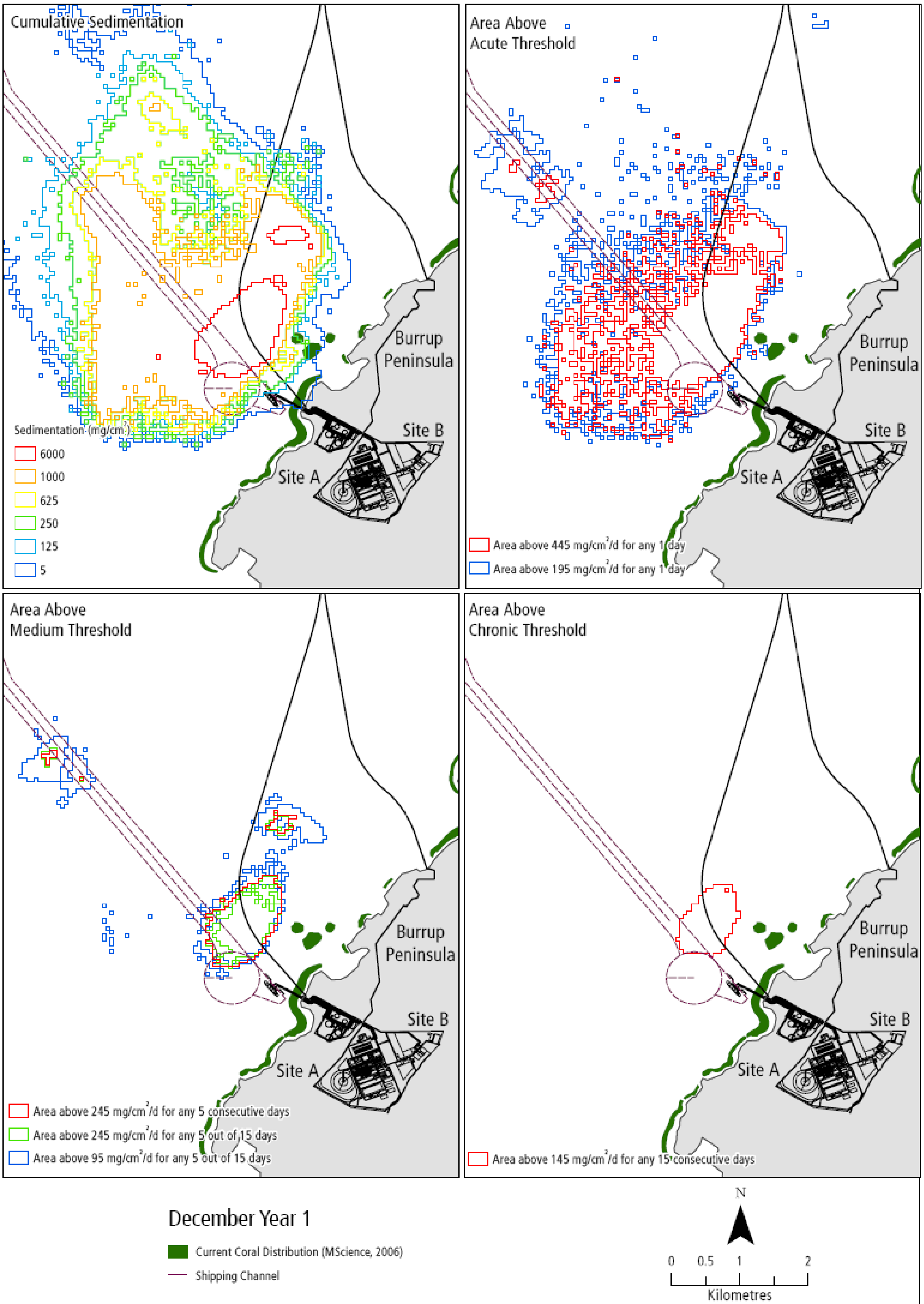
- **Figure A 7 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for September Year 1.**



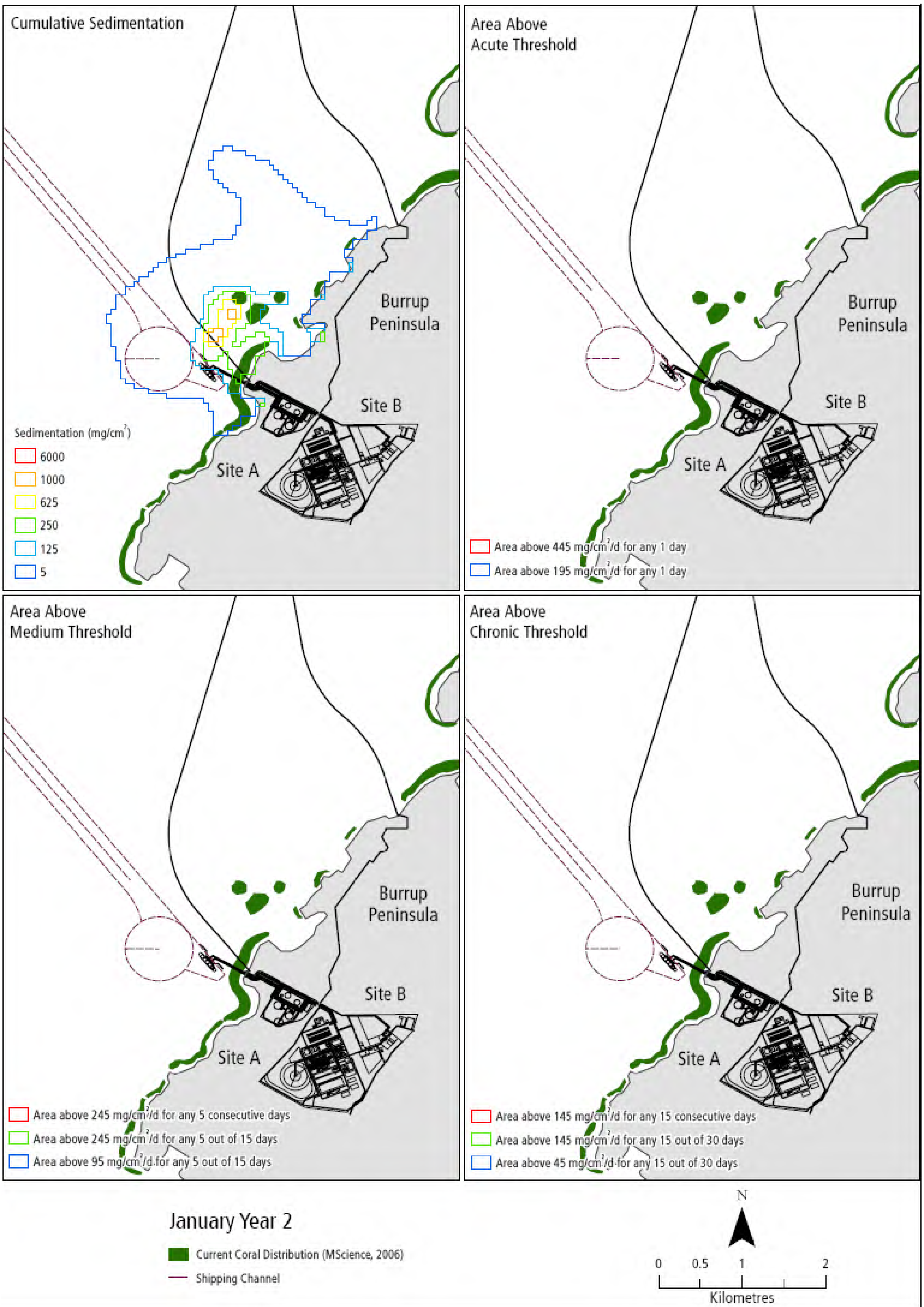
▪ **Figure A 8 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for October Year 1.**



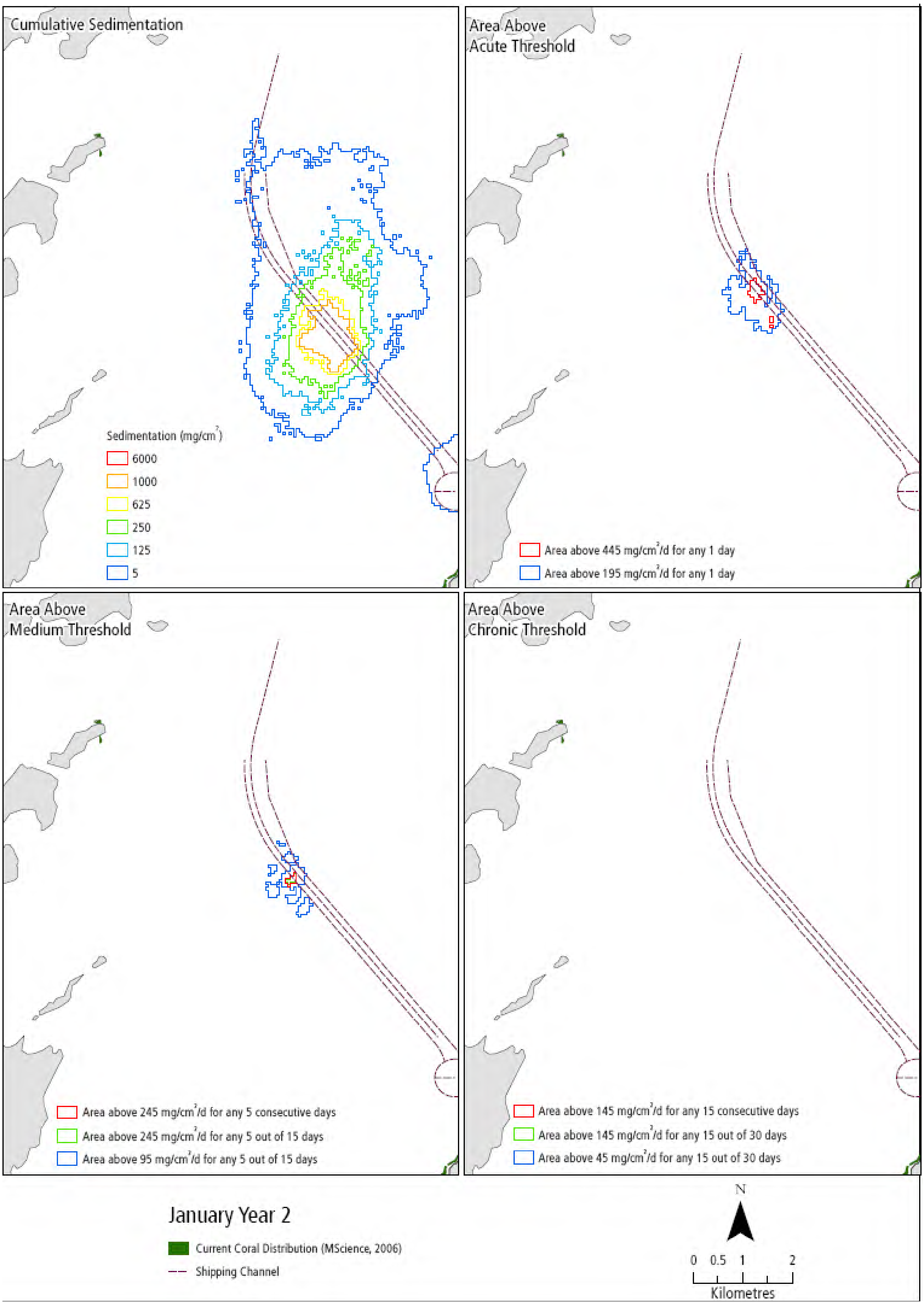
- **Figure A 9 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for November Year 1.**



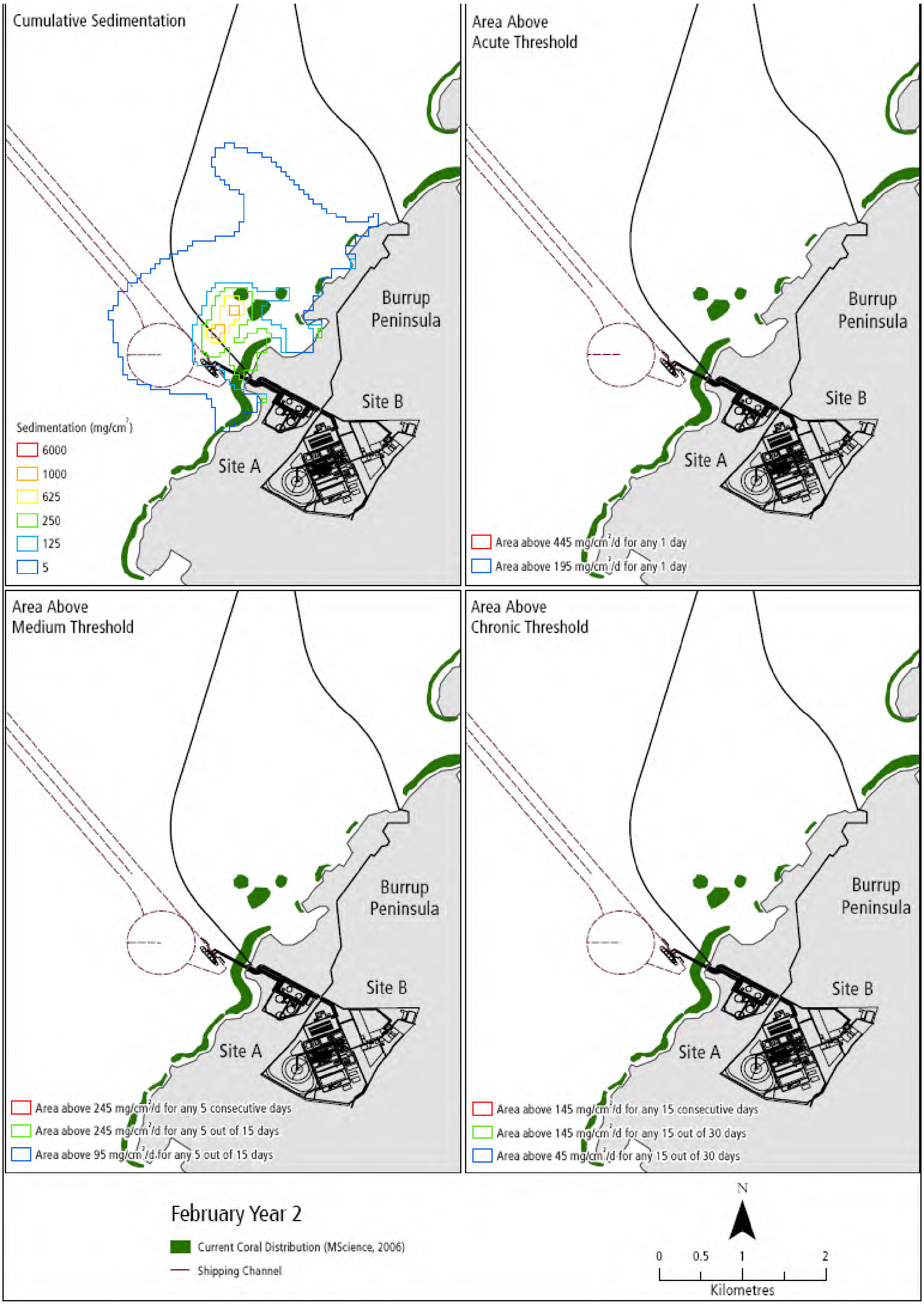
- **Figure A 10 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for December Year 1.**



- **Figure A 11 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for January Year 2.**



▪ **Figure A 12 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for January Year 2 – Dredging the Outer Channel.**



- **Figure A 13 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for February Year 2.**

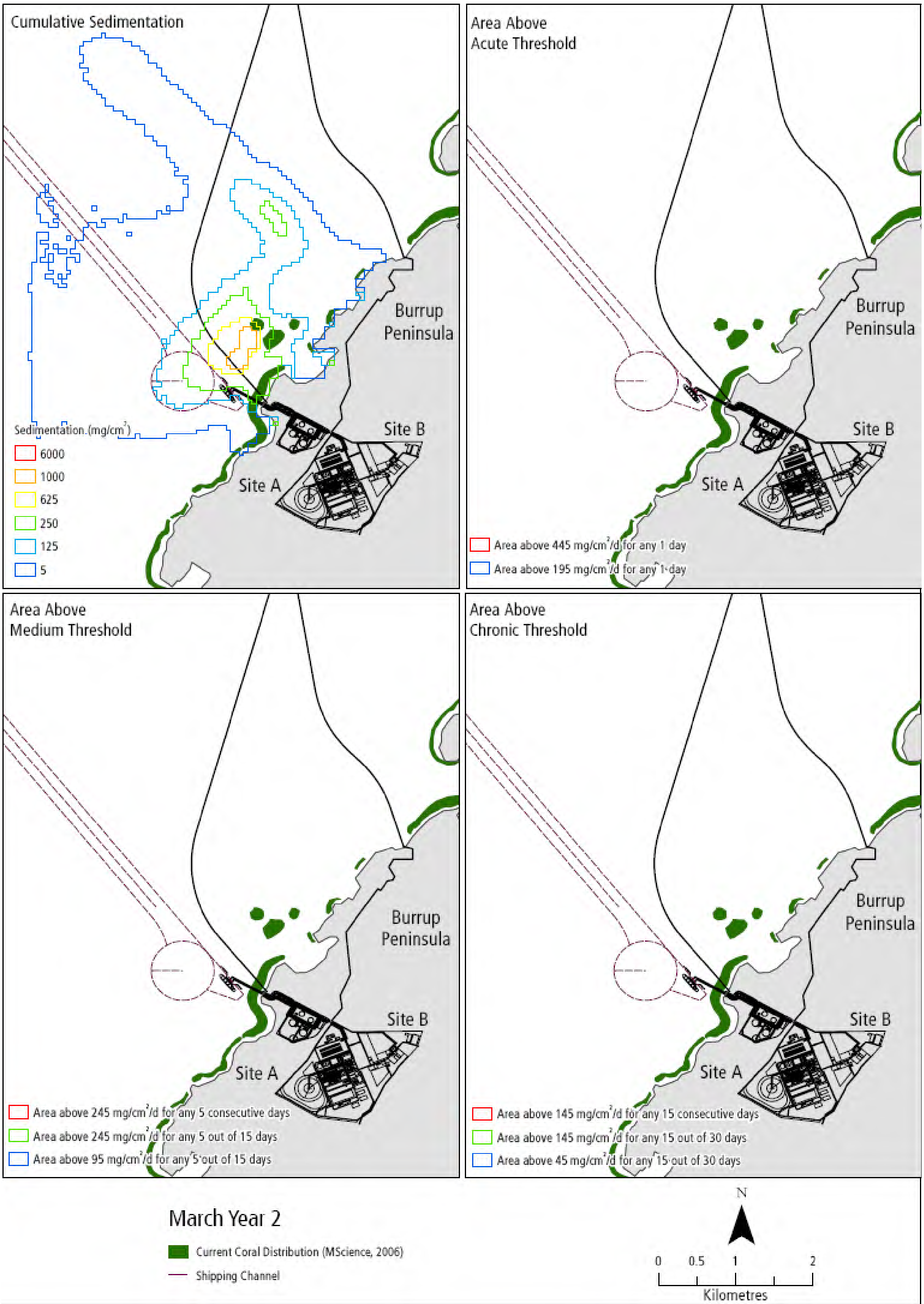
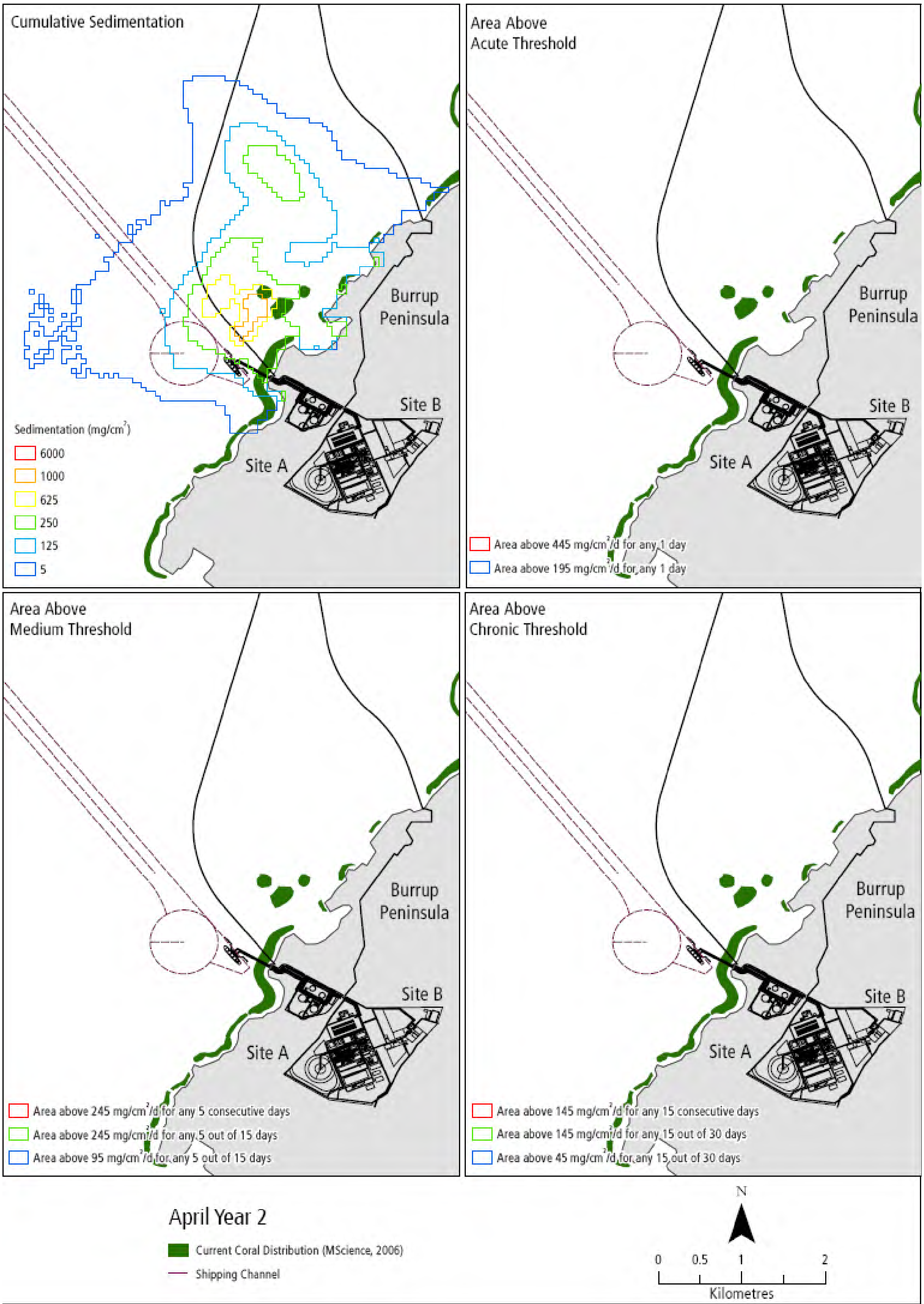


Figure A 14 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for March Year 2.



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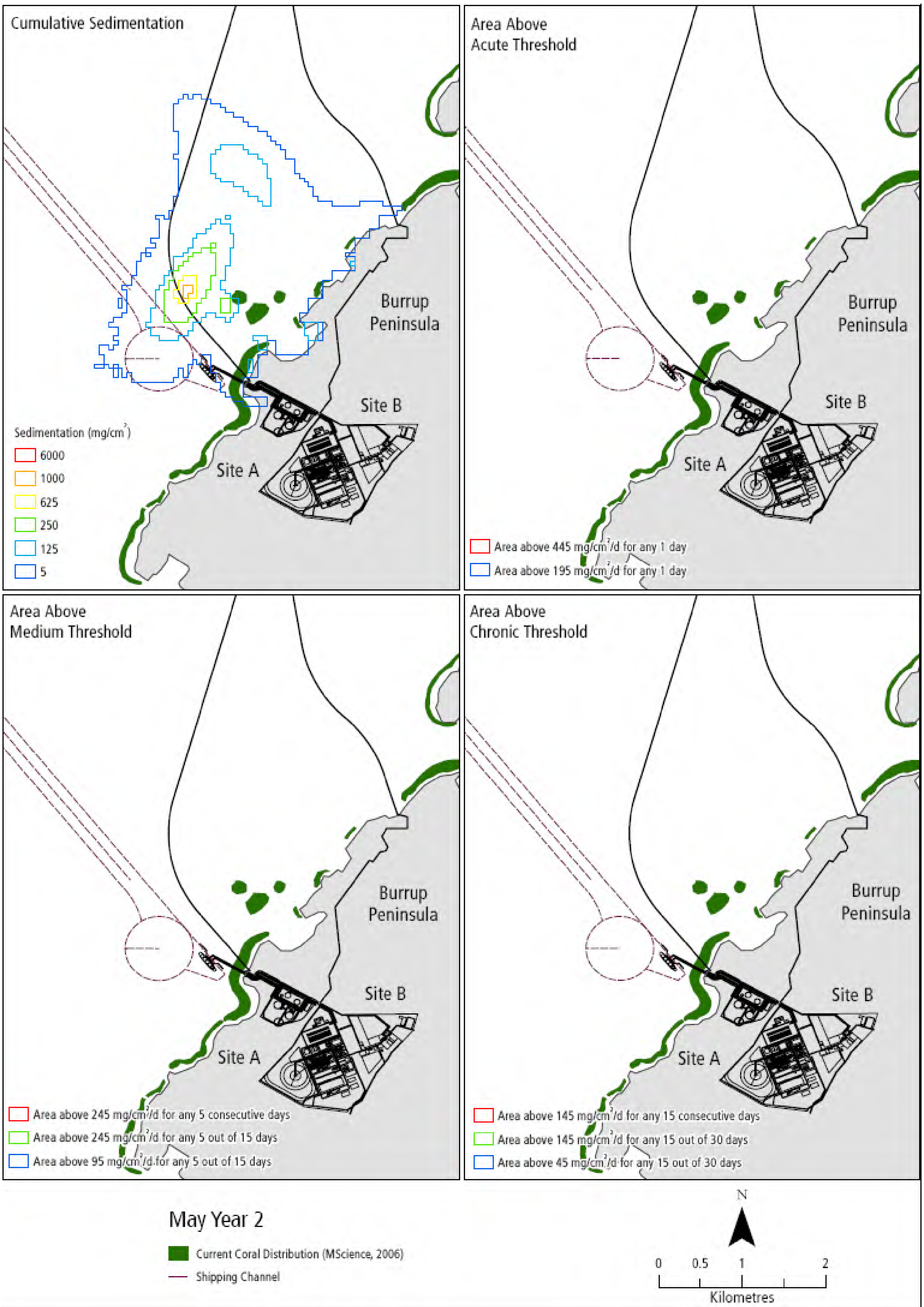
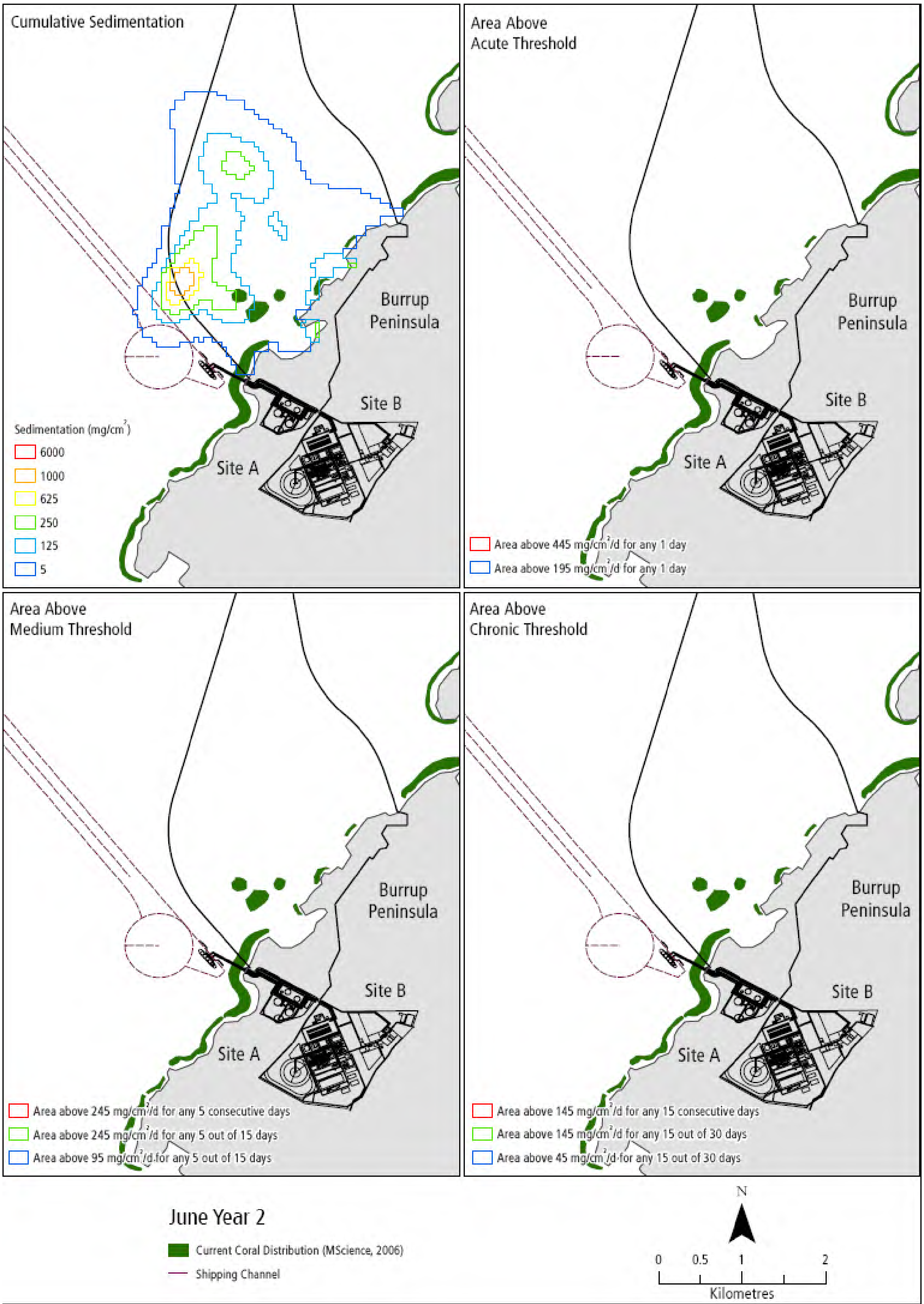


- **Figure A 16 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for May Year 2.**



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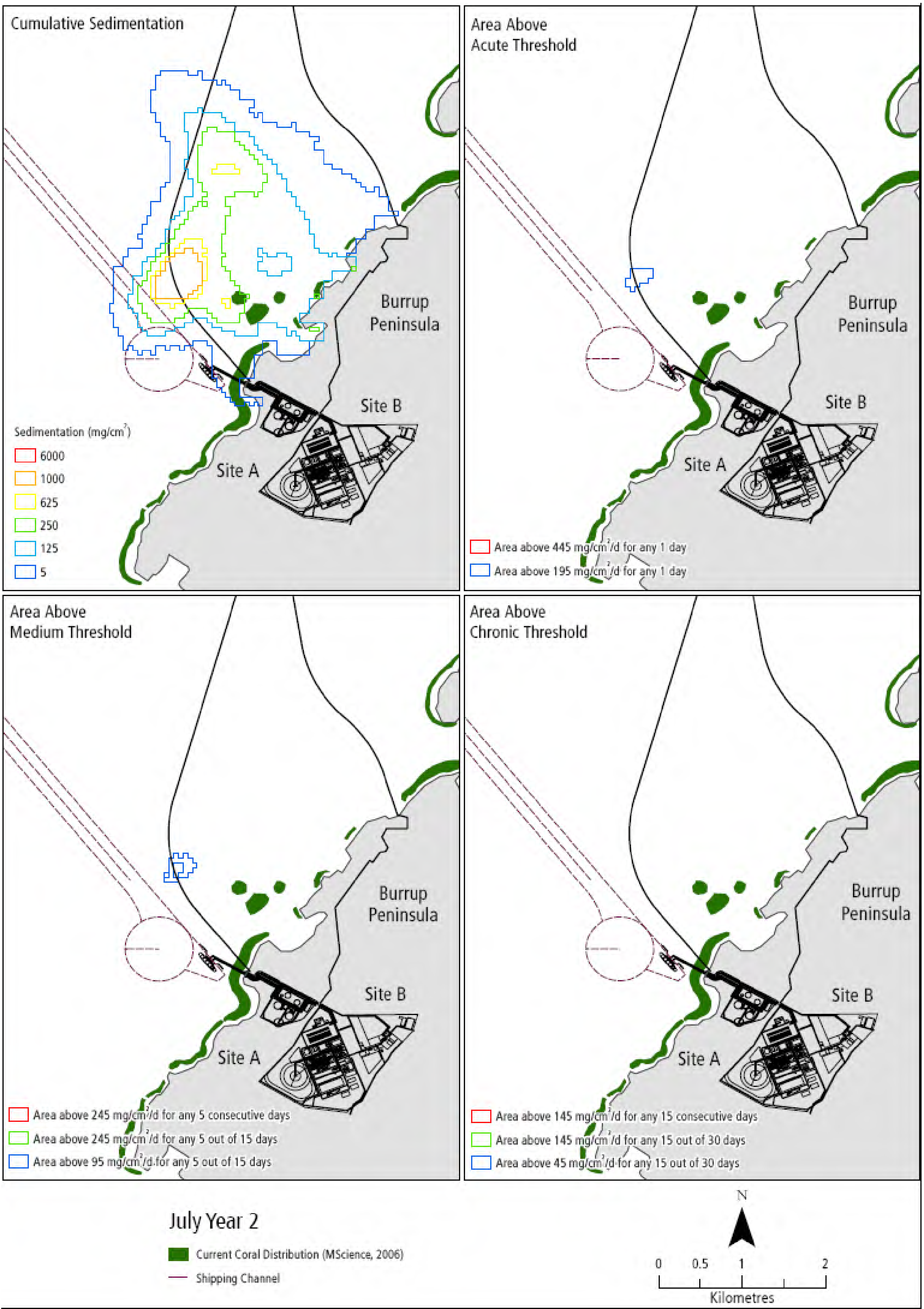

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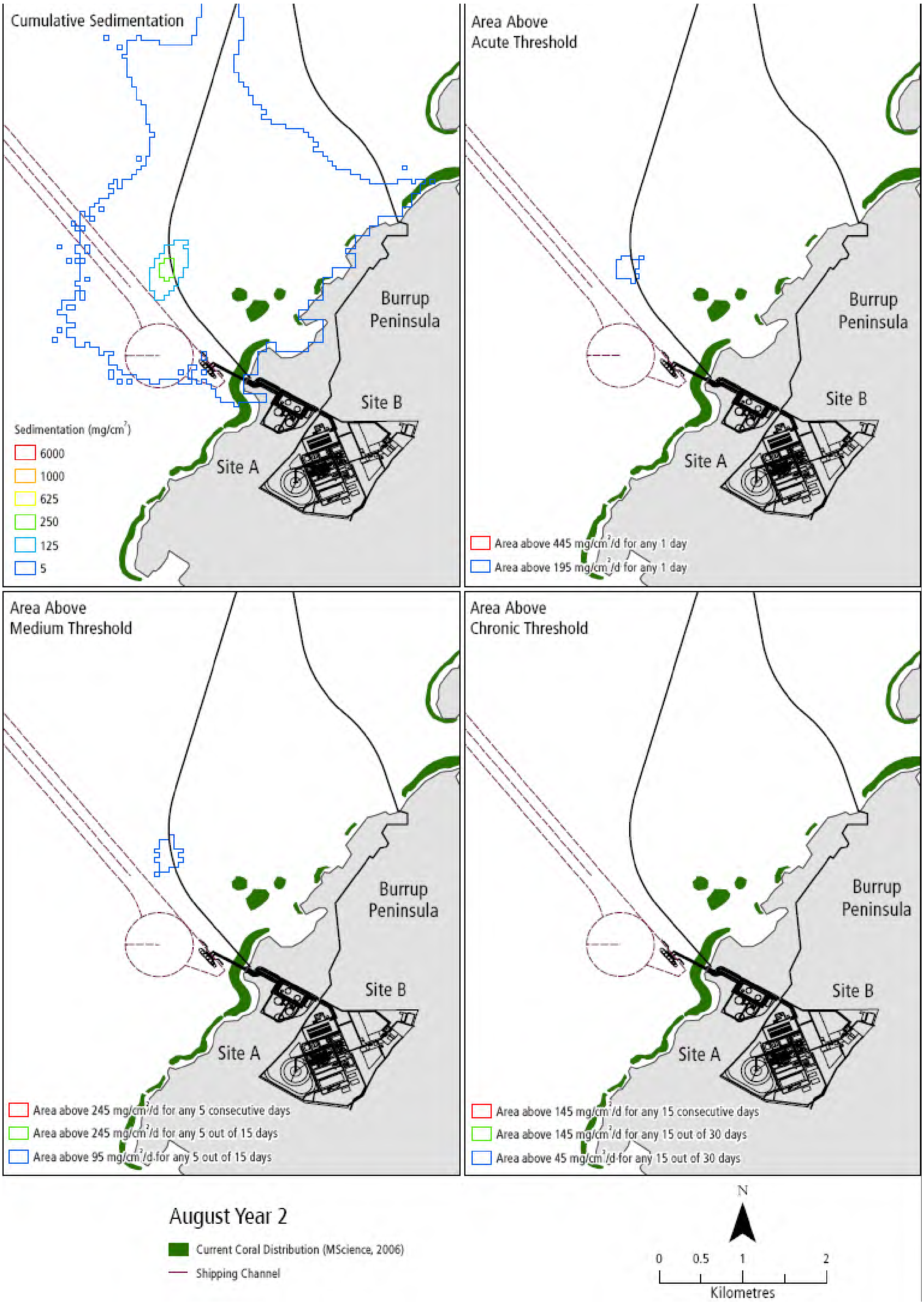
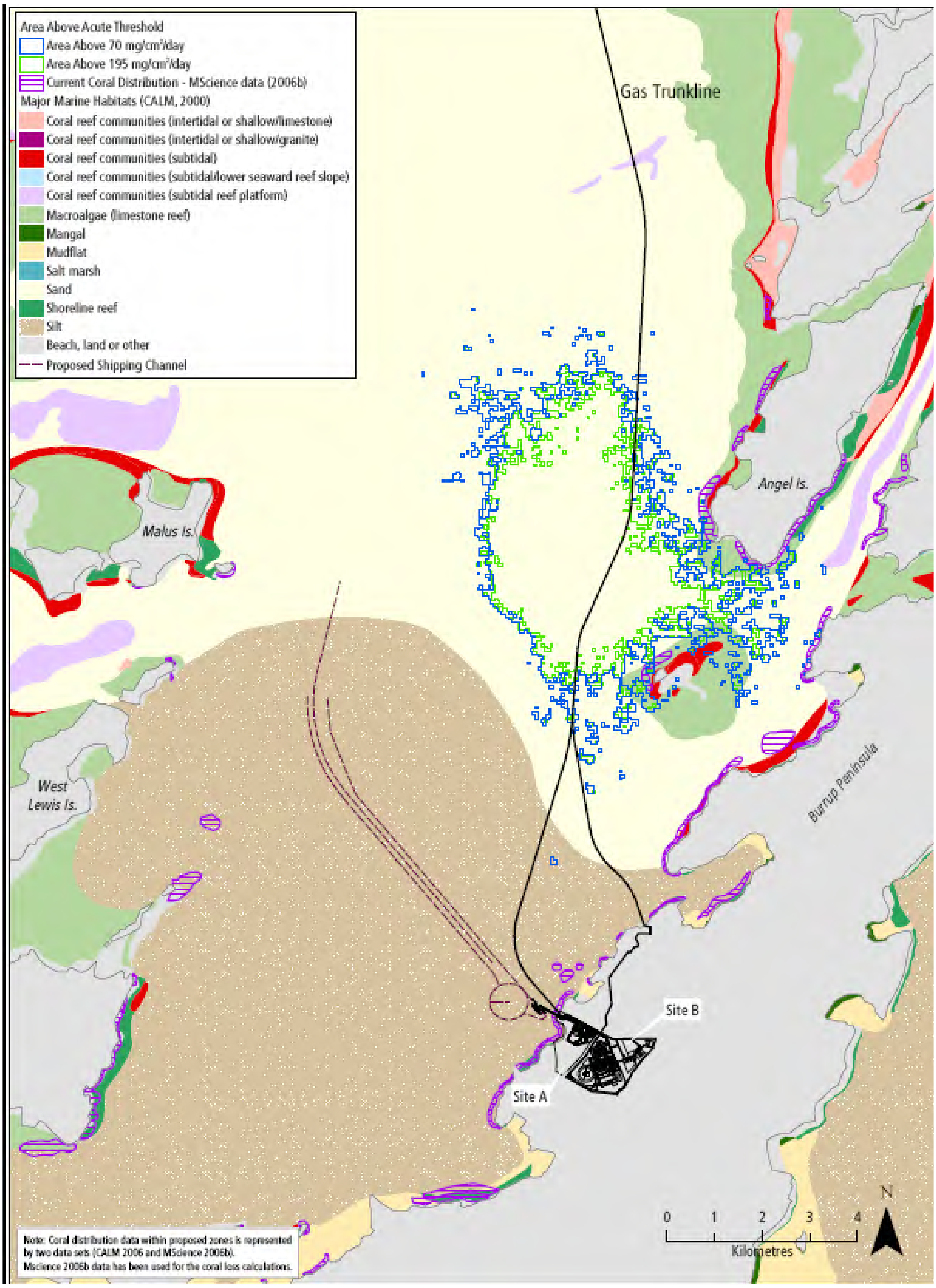
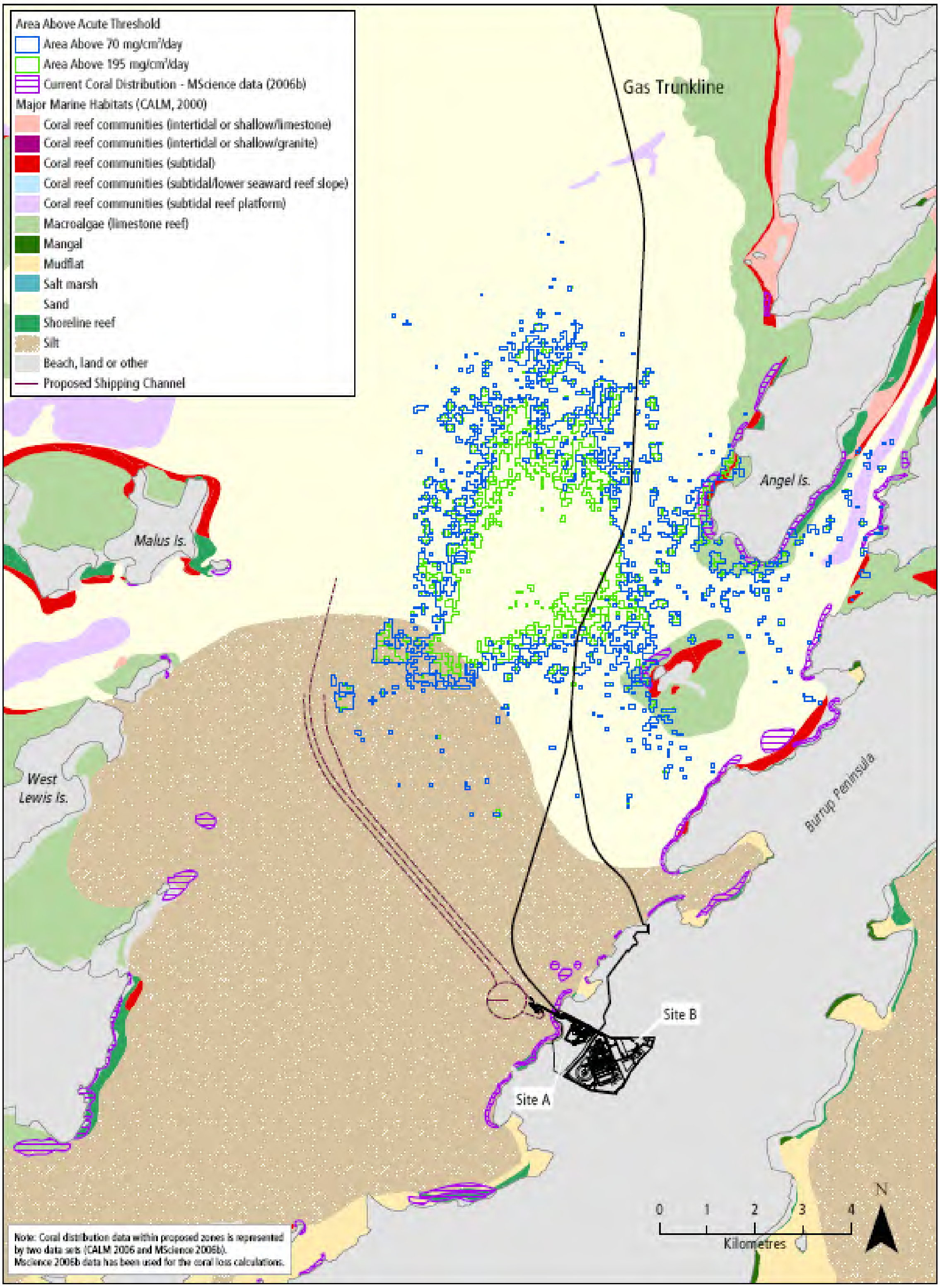


- **Figure A 19 Monthly Cumulative Sedimentation, Areas Above Thresholds and Threshold Sensitivity Analysis for August Year 2.**



- **Figure A 20 Sensitivity Analysis of the Sedimentation Threshold for Sensitive Species. Spoil Disposal into Spoil Ground A/B During Summer.**



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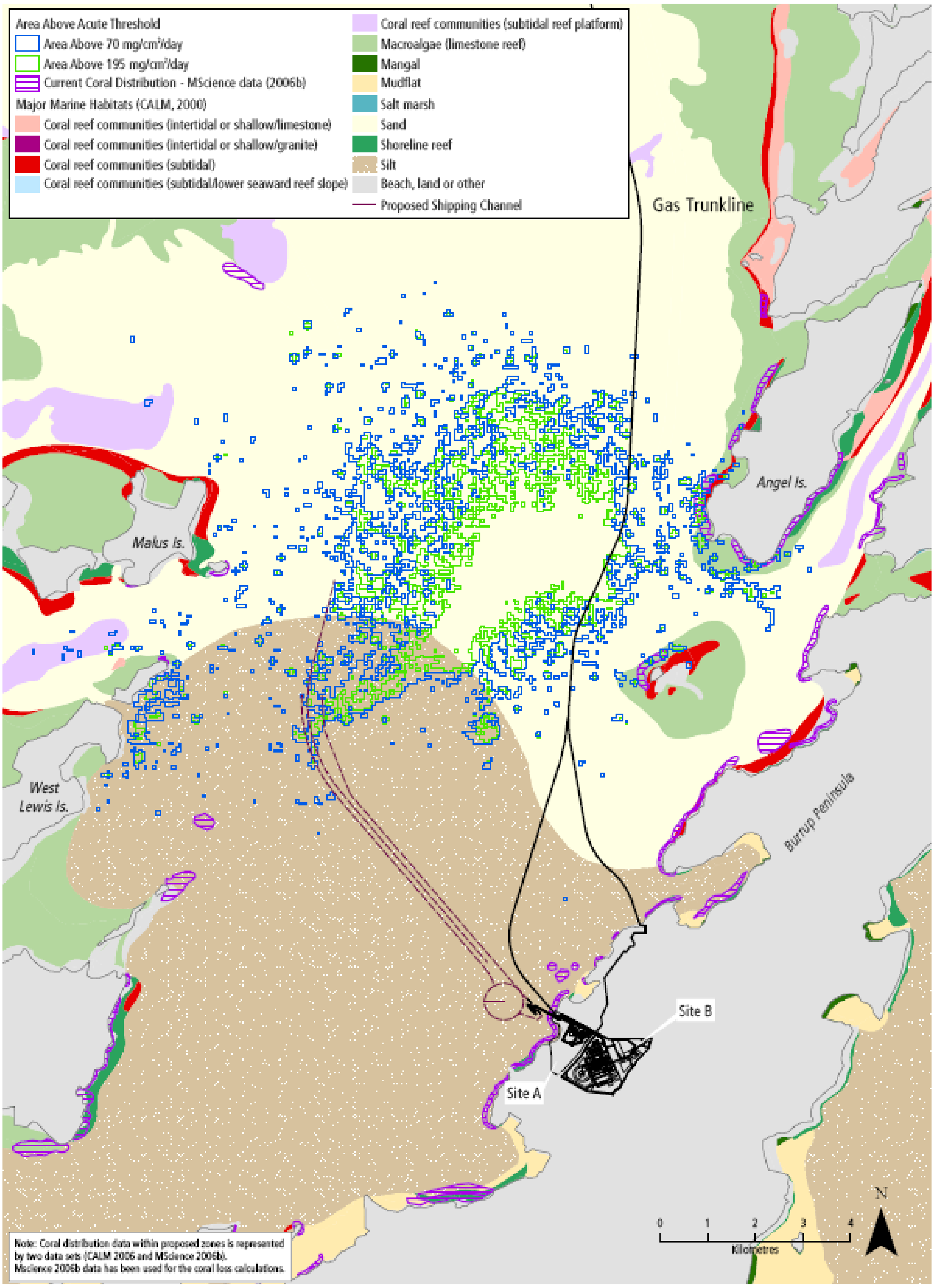

- **Figure A 22 Sensitivity Analysis of the Sedimentation Threshold for Sensitive Species. Spoil Disposal into Spoil Ground A/B During Winter.**

Pluto LNG Development

Public Environment Report / Public Environmental Review

Supplement and Response to Submissions

EPBC Referral 2006/2968
Assessment No. 1632

March 2007

Pluto LNG Development

REVISED PLUTO LNG DEVELOPMENT DREDGING SIMULATION AND IMPACT ASSESSMENT

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- 02 May 2007

Pluto LNG Development

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1. Introduction

Quantitative modelling has been applied to assess the consequences of dredging and sediment disposal operations associated with construction of the shipping channel and trunkline proposed for the Woodside Pluto LNG Development.

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2. Phase 1 Modelling

Previously presented studies undertaken by APASA focussed upon the cumulative plumes of suspended sediments, and associated sedimentation rates, generated by the operations. Simulations examined the progressive evolution of a relatively complex operation involving multiple types of dredging equipment. The cumulative outcomes of multiple simultaneous operations were investigated for a conceptual dredging program spanning two years. The source location and rates of movement (of the source) and production (hence sediment flux to the environment) were dictated by the conceptual plan. Among other factors, the simulations tested for the interaction of seasonal influences on circulation and the proposed location of the operations during different seasons.

Specifications for the discharge were based on the best available information from comparable operations – either from the international literature or from documentation of previous dredging operations in Western Australian waters, and to understand the potential influence of errors in this information, the study examined the sensitivity of the model outcomes to uncertainties. Sensitivity testing was undertaken to test the influence of sediment loss rates, size-distributions of sediments, vertical distribution of sediments set up by the discharges, the duration of daily operations (15 hr per day versus 24 hr per day) and the location of discharges. The model accounted for cohesion of the finer sediments to calculate realistic rates of sinking, due to clumping. The relevant background information can be found in sections 5,6 and 7 of the Draft PER, and reference should also be made to the PER Supplement and Response to Submissions.

The focus of the previous modelling was on the initial fate of sediments suspended by the various operations and followed multiple size-classes until first settlement to the seabed. The model accounted for cohesion of the finer sediments to calculate realistic rates of sinking due to clumping. Transport was calculated using modelled currents based on wind and tide forcing. Model currents were validated against measured currents in Mermaid Sound and Dampier Archipelago. In calculating settling from the lower layer of the water column to the seafloor, the model used estimates of current shear at the seabed to determine the probability that sediment of a given size-class would settle once they sank to the benthic layer. This approach, which is based on empirical evidence from previous comparisons to ADCP measurements of sediment distributions from similar dredging operations, was to account for the spread of fine sediments in the benthic layer if currents at the seabed exceed critical levels. Model results indicated that a high proportion of fines would remain suspended, given the current velocities predicted for the dredging and disposal locations. The model did not account for subsequent resuspension of settled material, leaving uncertainties about the additional contribution by such material.

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3. Phase 2 Modelling

3.1 Scope

Further modelling was undertaken to explore sensitivity of predictions made during Phase 1. The work specifically sought to:

- Examine the influence of resuspension of suspended sediments including the influence of waves.
- Place the model results in context with field measurements from within Mermaid Sound during and outside of other dredging operations.

In addition, the dredging programme has been altered from the original concept plan and the consequences of the new plan were tested for selected operations. Operations were selected on the basis that they were closest, or otherwise were likely to constitute the highest risk, to areas of concern.

Refer to **Table 1** and **Table 2** for changes in design to the proposed dredging programme that have occurred since the Draft PER was published.

- **Table 1 Changes in Design to the Proposed Dredging Programme since the PER was Published**

Item	Draft PER	Current position	Comment
Dredged channel length	10 km	Same	Bulk of dredging is over inner 8.5km; overall ship route is approximately 16km
Width of channel	250-275m	230-250m	-
Water depth in channel	12.5–13.5m	Same	-
Water depth in turning basin	Up to 13m	Up to 12.5m	-
Water depth in berth pocket	Up to 13.5m	Same	-
Dredging operations	24 hr basis	Same	-
Types of dredging vessels proposed	TSHD CSD	Same	-
Dredging approach	Use of a medium sized TSHD to remove unconsolidated material via suction pipe or drag arms; dredged materials pumped to hoppers; solids settle, overflow discharged at keel level; full hoppers move to	CSD initially works inshore berth pocket area with direct disposal of material to an interim rehandling pit located within the proposed turning basin; inshore dredged material removed directly via surface pipe to pit; TSHD removes material from pit to disposal grounds. Current proposal to use two TSHDs which are expected to reduce	Refer to Draft PER Section 4.6.5 and this report for further detail. Further changes to proposed approach may occur.

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Item	Draft PER	Current position	Comment
	spoil disposal site; CSD cuts harder material, which is deposited in situ and picked up later by TSHD for disposal to spoil ground.	overall operational time.	
Dredge spoil disposal	Coarse material from turning basin and berth pocket to spoil ground A/B and to offshore spoil ground 2B; finer material to spoil ground A/B; coarse and fine material from navigation channel to the offshore spoil ground 2B	Bulk of unconsolidated and fine material from navigation channel works to an extended offshore spoil ground 2B. Coarse and crushed materials from navigation channel works to northern section of spoil ground A/B and to northern section of offshore spoil ground 2B; some of the coarse material earmarked for possible re-use as fill for post lay trunkline stabilisation.	Refer to Draft PER Table 4-9 and this report for further detail.
Dredging duration	24 months	Same	Design, methods and operations continue to be investigated with the aim of optimising the programme and reducing works duration
Dredging start date	Q3 2007	Same	

- **Table 2: Summary of specifications and key changes to trunkline works**

Item	Draft PER	Current base case position	Comment
Trunkline length	~180 km	Unchanged	-
Trunkline route	Four route options, Options A,B,C and D, were presented from the offshore field to shore,	Revised – one option from the offshore field to a landing at Holden Point (or alternative landing at Karratha Gas Plant)	Refer to Figure 3-6 in Draft PER. The route has been selected to achieve shortest length between landfall and platform; lowest level of environmental impact; lowest risk for outside impact on trunkline and avoidance of existing permit blocks and oil & gas
Preferred landfall	Four landfall options considered – West Intercourse Island, and locations on the Burrup (Holden Point, Karratha Gas Plant, Cowrie Cove	Preferred option is Burrup Option A with landfall at Holden Point; Also still carrying second option of possible landfall to Karratha Gas Plant	Refer to Draft PER Section 3.4, Option B to West Intercourse Island was discounted earlier due to factors such as larger

Item	Draft PER	Current base case position	Comment
	and Conzinc South)		footprint; see Draft PER Supplement Section 2.2
Trunkline corridor with - inshore	1500 m	Unchanged	width required to accommodate anchor spread
Trunkline corridor width - offshore	1500 m out to 20 m depth; 3000 m beyond 20m and out to platform to accommodate pipelay vessel	Unchanged	Refer to Draft PER Figure 4-7 for drawings of trunkline corridor widths and Draft PER Section 4.5.3.2
Shore crossing construction	Backhoe dredge excavates trench; short section of onshore-offshore interface may require blasting; land-based excavators excavate trench between LAT to onshore end of near shore trench; a temporary groyne may be required for land-based excavators; rock backfilled	Unchanged	
Pre-lay construction	Pre-lay dredging of a trench using a TSHD, CSD and Back Hoe Dredge (BHD).	Pre-lay works scope amended to include new requirement beyond KP 50 for pre-lay sweeping or “pre-sweeping” to prevent scouring effects of unconsolidated material (if the layer thickness is proven to be more than 0.3 m). This will be removed with a TSHD and placed in spoil ground 5A.	Current proposal is similar to that in Draft PER up to Kilometre Point (KP) 50; current proposal indicates additional dredging and pre-sweeping requirement beyond KP50
Post-lay trunkline stabilisation at shore crossing	Quarry rock backfill and armour	Unchanged	
Post-lay trunkline stabilisation – offshore	From 8 m depth out to DPA port limits mix of no cover rock berm and use of backfill using coarse material such as sand, gravel or crushed calcarenite sourced from a suitable borrow site or from dredging	Similar to approach indicated in Draft PER; mix of no cover rock berm for areas where protection not an issue and coarse sand or crushed calcarenite rock as backfill for areas requiring protection; backfill sand to be sourced from pre-existing TSEP sand borrow area and coarse calcarenite from dredge spoil disposed in spoil ground A/B and in spoil ground	Refer to Draft PER Figures 4-8 and 4-9 for schematic drawings of no rock fill and no cover rock berm methods

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Item	Draft PER	Current base case position	Comment
		2B	
Rock dumping volume requirements	Maximum of order of 660 KM^3 sourced from onshore quarry (Draft PER Section 4.5.3.1)	Current base case is for 330 KM^3 (550kT)	
Spoil disposal	inside DPA port limits - to spoil ground A/B, northern extension and deepwater spoil ground 2B beyond DPA port limits – to deep water spoil ground 5A	inside DPA port limits – bulk of unconsolidated material and fines from work north of KP 18 up to boundary of DPA limit to spoil ground 2B rather than to spoil ground A/B beyond DPA port limits – same plan as before – into spoil ground 5A, running parallel with trunkline Extension proposed to spoil ground 2B to accommodate anticipated volumes	Refer to Draft PER Table 4-9
Estimated dredge spoil quantities	2.0 MM^3 inside DPA port limits 1.5 MM^3 beyond DPA port limits	1.1 MM^3 inside DPA port limits 1.9 MM^3 beyond DPA port limits 0.5 MM^3 provisional scope for CSD rock dredging in Mermaid Sound	Refer to Table 4-6 in Draft PER
Estimated sand and CCR quantities for backfill	No detail available; however, the need for sourcing suitable fill from a borrow area or from dredging material indicated in Draft PER; refer to Draft PER Section 4.5.3 and Table 4-9	1.4 MM^3 from spoil ground A/B and 2B inside DPA port limits 0.8 MM^3 from borrow ground outside DPA limits and spoil ground 2B	

3.2 Model Description

In contrast to the earlier modelling, the simulations took account of the non-cyclonic wave climate within Mermaid Sound to represent resuspension. The general methods were as follows:

- Circulation patterns due to wind and tide were modelled for a period of two years (2005 and 2006) using the existing hydrodynamic model (HYDROMAP).

- Wave patterns due to swells (originating from outside Mermaid Sound) and local winds were modelled for the same two year period using a widely recognised surface wave model (SWAN), based on archived swell data from the WaveWatchIII archive (source: NOAA), archived wind fields for the same times from the NCEP atmospheric hindcast (source: NOAA) and current and sea-level information from the hydrodynamic model (to account for influences of currents and local sea-level on wave propagation and magnitude).
- Wave predictions from the SWAN model were validated against wave measurements from within Mermaid Sound for a 19-month period of measurement, to confirm they were representative.
- The previously applied sediment model (SSFATE) was extended to include calculation of combined seabed stress as a time and space-varying field from the current and wave field supplied by the HYDROMAP and SWAN models and to apply bottom stress to calculate resuspension in response to seabed stress from the combined effect of waves and currents, using resuspension algorithms developed and tested by the US Army Corps of Engineers and other sources. The algorithms use a two-stage approach to account for the lower stress required to resuspend particles that have only recently settled (i.e. within hours). Thresholds are grain-size specific. A description of the model algorithms and supporting references can be supplied.
- SSFATE was applied to model specific operations, based on the updated dredge plan. As for previous modelling, deposition predictions were based on a probability function, responding to local seabed stress and the local sediment concentration. In contrast to previous modeling, dredged material was followed through ongoing deposition and resuspension cycles In response to seabed stress. Resuspended material was transported by the prevailing current field and followed through sinking and settlement.

The modelling investigated three key dredging related operations, located in different parts of Mermaid Sound:

- dredging of the turning basin/ship berth off Holden Point (multiple operations)
- dredging of the trunkline (Trailer Suction Hopper Dredge (TSHD) work only)
- disposal of sediments to the offshore disposal ground (area 2B).

Each operation was characterised by a unique pattern of discharge:

- rate and pattern of movement (of the suspension source)
- production rate
- % of production rate lost
- size distribution of discharged sediments
- vertical distribution (due to discharge)

- timing and duration of discharge.

Specifications were based on the most recently developed dredging programme, and used previously tested (conservative) settings for sediment grain-size distributions associated with each operation. Allowance for propeller-wash was included for all operations involving vessel movement over shallow ground. For example, the regular transit of TSHD vessels along the channel leading from the turning circle.

3.3 Outcomes

Wave model predictions closely represented the trends, magnitude and timing of waves measured by Metocean Engineers at the centre of Mermaid Sound in 2005–2006. Statistical analyses indicated a high correlation between modelled and measured wave heights, wave lengths and directions (other details here) at all times of year, indicating that wave inputs were correctly scaled.

Wave modelling indicated that the proposed location of the shipping channel is exposed to wind-waves but would be sheltered to a degree from the predominant swell direction (from the south-west), due to the islands of the Dampier Archipelago. Sheltering from swells varies along the sound (least at the entrance) and over time. The dredging areas are also exposed to northerly swells during occasional storm events. The consequence of these findings are that seabed stress will vary considerably within days (due to sea breeze cycles) and between days (due to general winds and swells) and, in general, there will be increased seabed stress moving from the back of the Sound to the entrance. As a result, resuspension potential will be low in the lower reaches of Mermaid Sound and higher towards the entrance.

Analysis of seabed stress also indicated that the contribution by waves (swells and seas) would be orders of magnitude larger than by wind and tide-driven currents. Seabed current speeds around the turning circle due to winds and tides alone are predicted to exceed critical speeds purported to resuspend clay-sized particles, but only during short periods, at peak tidal flows. In contrast, seabed stress from the combined influence of swells, waves and currents was predicted to exceed thresholds for resuspension of fines for a greater percentage of the time, and for coarser grain sizes at times.

Variations in seabed stress follow similar patterns to concentrations of suspended sediments reported by MScience, when no dredging was occurring in Mermaid Sound – consistent with the theory that wave resuspension of sediments is a primary driver of background suspended sediment loads.

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3.4 Scenarios

3.4.1 Dredging of the Turning Basin

As previously predicted, suspended sediment plumes generated by the various operations, inclusive of propeller-wash, are expected to be relatively high within 1–2 km of the operations and to decrease exponentially with distance along the tidal axis. Dredging of the turning basin will take up to 5 months beginning at the start of October, and simulation with October–November wind and waves resulted in a net northward trend in the extent of the plume and sedimentation footprint.

As previously predicted, the heavier sediments (down to fine sands and coarse silts) will settle locally but a proportion of the finer sediments (fine-silt and clay-size) drifted northward in the simulations to generate a plume ‘tail’ that extended along the eastern coast of Mermaid Sound. After the first few days of discharge, there was a notable contribution to the plume at the far northern extent due to resuspended clay and fine silt (recalling that seabed stress due to wave action is expected to be larger in this direction). Concentrations as high as 20–30 mg/l above-background suspended sediments were predicted for the near-seabed layer as far north as flying foam passage, on occasions. More frequently, concentrations were predicted to reach 10–20 mg/l above background in this area.

The distribution of the TSS plume due to dredging around Holden Point was similar to previously predicted but extended further north at times. The extension beyond the previous distribution was contributed by relatively low concentrations of clay.

The extent and concentration of the northward plume was predicted to vary with the prevailing wave conditions, rather than the duration of the discharge. A greater plume extent is expected during higher wave stress, because of resuspension of fines that have previously settled. This observation has two implications:

- Discharging for longer will not tend to raise background turbidity throughout the wider sound (outside the plume footprint) in the immediate term.
- Higher turbidity due to dredged fines is likely to occur at times when ‘back-ground’ turbidity is also higher (due to wave resuspension of fines that are already in the system).

The latter point suggests a synergistic relationship between the dredge plume TSS and background TSS (as opposed to background TSS being random relative to dredge TSS).

It also follows that, if the dredging contributes increased quantities of fine sediments to the seabed of Mermaid Sound, the long-term influence of this dredging program (and previous dredging undertaken by Woodside and others) could be increased turbidity response to wave action.

Habitats aligning the eastern coast are expected to be exposed at times to elevated TSS and sedimentation rates. The frequency and magnitude is expected to be greater for close sites, and chronically above background within 1 and 2 km. As previously predicted, exposure to more distant coral habitats was indicated to be as a series of short-lived episodes. Median concentrations at sites more than 2 km away remain low (<5 mg/l above background) but over time there are extreme events of the order of 25-50 mg/l above background expected. The more extreme events are very short-lived (~ one hour) but more moderate increases (~ 10 mg/l) are expected to last for 1–2 days.

These predictions are consistent with the field monitoring by MScience. Continuous monitoring of TSS, turbidity and sedimentation rates over months before and during the most recent dredging for Hamersley Iron indicated that median concentrations do not appreciably change, even at relatively close sites(~ 200 m from discharge sources) to the dredging and disposal. However, there is an increase in the magnitude of unusually high concentrations. Short-lived peak concentrations are raised by up to 50 mg/l. Analysis of the duration of the observed peaks indicates that 10 mg/l rises last up to 1 day and 50 mg/l rises last up to an hour.

3.4.2 Spoil Disposal into Spoil Ground 2B

The simulation of disposal to area 2B under the influence of wave energy and currents specified discharge for four weeks but the simulation was extended to two months to examine the stability of the spoil ground.

Results indicated that there would be sufficient wave energy to resuspend the finer sediments – clays to coarse silts. Heavier sediments were not resuspended, indicating stability of this material. Some capping of fines would be expected, once fines that are at the surface are winnowed off.

The fine sediments that either escape the disposal area during the initial disposal, or are subsequently resuspended were predicted to migrate through a series of suspension and resuspension cycles into Mermaid Sound and Dampier Archipelago where they will be subject to resuspension over time. The simulation was undertaken during late autumn to winter conditions, and there was a tendency for this material to be constantly resuspended due to the higher wave energy around the entrance of Mermaid Sound. There was a tendency for a net migration southwards, with dispersal onto the coral habitats on the east and west side of the entrance under these conditions. Lighter concentrations also migrated through the channel south of Rosemary Island and further south into Mermaid Sound.

Predicted TSS concentrations near seabed at coral habitats around the entrance indicated an elevated median concentration (10–30 mg/l) and short-lived extremes to 100 mg/l. Net sedimentation rates by contrast were relatively low, due to predicted instability of the sediments (resuspension rates close to sedimentation rates). MScience report a similar finding from

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monitoring at these sites using a sedimentation pan that allows for resuspension (in contrast to sediment traps).

There is some potential for resuspension of fine sediments on the sediment mound at the dump site as fine sediments dumped on the spoil grounds may be gradually reworked (resuspended) by northerly swells and some of this material may be moved from the spoil grounds into Mermaid Sound. .The current dredging programme for Dampier Port Upgrade has also indicated there may be some reworking of the material dumped on the spoil ground, and once that programme is complete and the data fully analysed, the information would be available for input into the dredge management plan for the dredging proposed here. If a substantive effect is considered to be likely through sediment resuspension of fines on the spoil ground then there are number of options that could be considered to mitigate any potential impact.

3.4.3 Trailer Suction Hopper Dredging of the Turning Basin

Simulation of plumes generated by TSHD overflow and propeller-wash during dredging of the trunkline indicated localised and short-lived extents. The median concentration calculated for each location over 6 weeks were low (<5 mg/l at any location), partly because the dredging operation will move quickly and therefore affect any one location for a small part of the time. Short-term extremes (any one hour) were of the order of 90–100 mg/l in the immediate area of the discharge (~ 1 km).

Predictions for TSS concentrations at coral habitats along the east coast of Mermaid Sound indicated plumes would effectively disperse before reaching these locations – extreme concentrations were low relative to the MScience monitoring values for these sites.

Likewise sedimentation along the adjacent reefs was predicted to be small, although there was an indication that fines deposited from the operation would migrate shoreward. – expected net sedimentation was predicted to be low (> 5 mg/cm2/d).

4. Coral Impact Assessment

4.1 Model Interrogation

For comparison with the Draft PER coral impact assessment the revised model outputs were interrogated using the same thresholds as were used in the submission to responses. These were slightly modified from those used in the Draft PER predictions to introduce an added degree of conservativeness (**Table 3**). Sensitivity analysis was also undertaken by halving the absolute sedimentation thresholds (that is, before background rate was subtracted), before interrogating the model to provide an indication of the loss footprint with a conservative threshold level. Levels for sensitivity analysis are provided in **Table 3.**

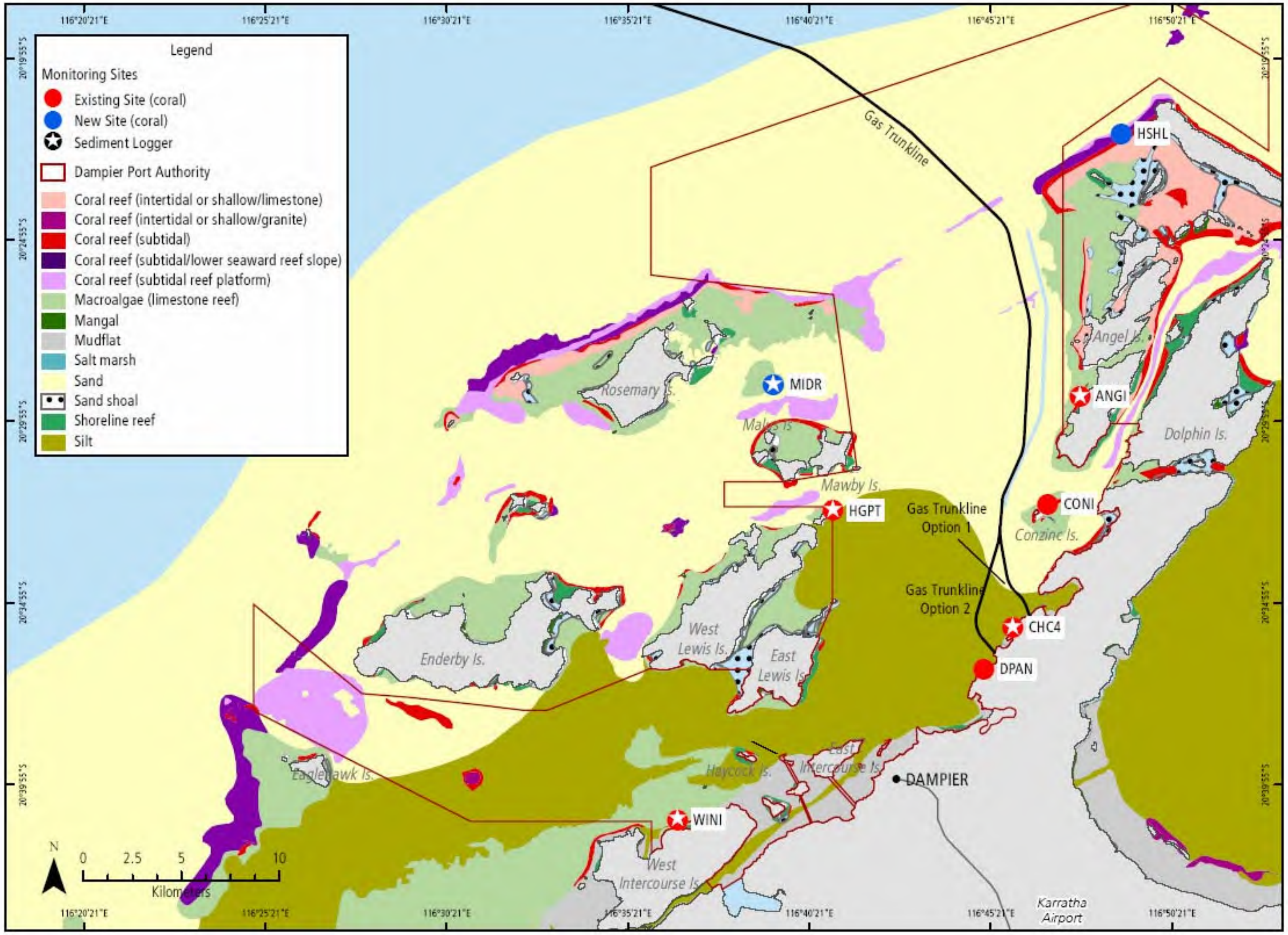
Table 3 Sedimentation Thresholds Used in Model Interrogation

	Thresholds*		Sensitivity analysis	
Description	**Level**	**Duration**	**Level**	**Duration**
Acute for resilient species	445 mg/cm^2/d	Any 1 day	195 mg/cm^2/d	Any 1 day
Medium-term for resilient species	245 mg/cm^2/d	Any 5 days of any 15 day period	95 mg/cm^2/d	Any 5 days of any 15 day period
Chronic for resilient species	145 mg/cm^2/d	Any 15 days in a 30 day period	45 mg/cm^2/d	Any 15 days in a 30 day period

The coral sedimentation threshold levels were developed using existing data on sedimentation rates recorded in Mermaid Sound, in conjunction with observations on coral health. This review provided an indication of sedimentation rates and associated level of impact. An extensive literature review was undertaken to compare sedimentation rates with experimental data obtained for relevant species.

Data collected by MScience as part of a pre-dredging baseline study (that is, during periods of no anthropogenic influence such as dredging) reflects only sublethal and most likely sub-stress levels of sedimentation and turbidity and was therefore not used to develop coral sedimentation threshold levels. Monitoring sites used for this baseline study are shown in **Figure 1**.

A preliminary analysis of data collected as part of the on-going Dampier Port Upgrade dredging programme shows no evidence of substantive coral mortality as a consequence of that dredging programme. There is some implication there may be an effect at on coral health at the Tidepole site, but that is confounded by considerable variation in the levels of mortality recorded at reference sites. A full analysis of the data collected from both the Pluto baseline corals monitoring programme and the Dampier Port Upgrade programme will not be possible until those programmes have been completed. When a full analysis of the data collected by each of these programmes is available it will be assessed with respect to the information that could be relevant to fine tuning of the respective thresholds proposed within the Draft PER for the Pluto corals monitoring programmes. At this stage it is premature to include any reference to the partial results from those studies.



■ **Figure 1 Sedimentation and Coral Health Site Locations for the Baseline Study**

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4.1.1 Zone 1 – Holden Point

The model outputs for Holden Point were interrogated using the sedimentation thresholds for resilient species, as defined in the Draft PER.

Model interrogation of the turning basin simulation with the acute sedimentation threshold yielded a footprint very similar to that in the Draft PER impact assessment. However, interrogation with the medium-term and chronic thresholds yielded slightly larger footprints than in the Draft PER assessment, reflecting the effects of resuspension in the revised model simulation.

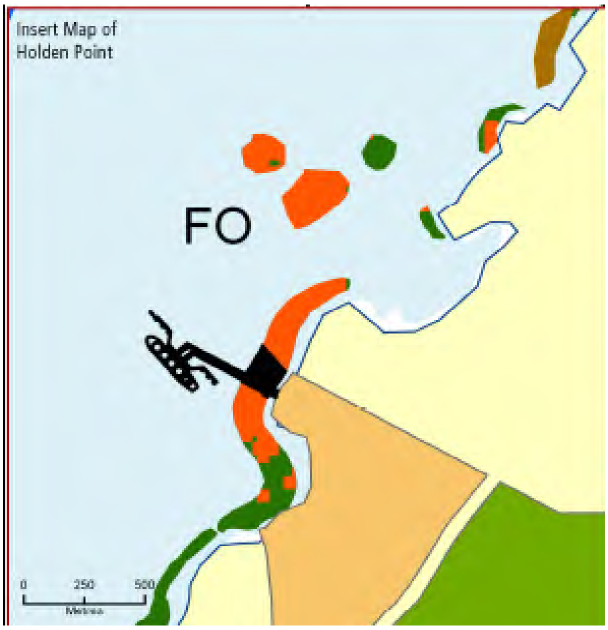
The reason for the increased loss footprint could be attributed to various factors:

- As described in **Section 3.3** settled particles resuspend when the seabed energy exceeds a certain threshold. The main contributor is wave energy, with tide and current causing resuspension to a lesser degree. The increase in the medium-term and chronic loss footprints were caused by the cycles of settlement and resuspension in close proximity to the dredging operation, with particles migrating outwards from the dredging operation over time.
- The increase in the loss footprint may also partly be attributed to the reposition of the turning basin closer to land than was the case in the Draft PER assessment.
- Also, the methodology was modified for the revised simulation, with operations increased from 15 to 24 hours a day.

Despite these changes, the revised loss footprint does not differ significantly from the Draft PER predictions. The Draft PER predicted cumulative impact was 42% (historical loss plus Pluto direct and indirect impact) in Management Zone 1 (Figure 2). Using the same baseline coral distribution data for the revised model output interrogation, the revised loss estimate for the same management zone is 43% (**Figure 3**).

Sensitivity analysis of the sedimentation thresholds was undertaken as described in **Section 4.1**. This caused the loss footprint to increase from 43 to 46% (**Figure 3**). The relatively small increase in the loss footprint shows that halving the thresholds does not yield a significantly larger footprint. As described in **Section 3.4.1** the sedimentation rates drop off exponentially along the tidal axis, and thus decrease quickly with distance away from operations. Using thresholds for impact assessment purposes is therefore relatively robust in that halving the thresholds will not cause the loss footprint to double in size, as might intuitively be expected.

The duration of the model simulation was six weeks; however, the dredging of the turning basin is estimated to take three months. As described in **Section 3.4.1** the model indicates that dredging for longer will probably not increase the level of sedimentation further than what is predicted during the six week simulation. Sedimentation and resuspension will tend to balance each other out over time. Simulating the construction of the turning basin for all three months may therefore not yield a larger loss footprint. However, chronic impacts from increased frequency of exposure to increased levels of TSS may cause impact outside the footprint of loss, but the exact level of impact is difficult to predict with any degree of certainty. The model output shows that a northward 'tail' will influence the eastern coast of the Burrup Peninsula, and impacts to coral communities here may occur; the influence could be chronic due to the extent of the dredging programme.



- **Figure 2 Draft PER Loss Predictions**

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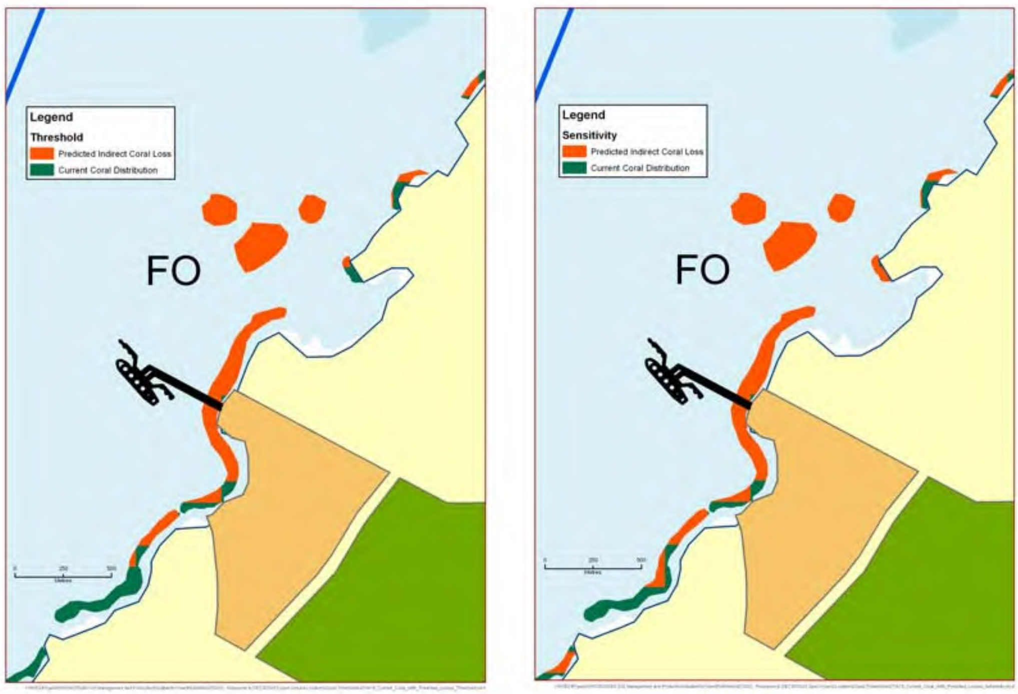

- **Figure 3 Revised Loss Predictions (left) and Loss Predictions from Sensitivity Analysis (right)**

4.2 Trunkline Installation

The model outputs for the TSHD for trunkline installation along Angel Island were interrogated using the sedimentation thresholds for resilient species, as defined in the Draft PER. Sensitivity analysis was also undertaken. The acute sensitivity threshold is equivalent to the acute threshold for sensitive species, and defined in the Draft PER.

Interrogation of the trunkline installation simulation indicated that predicted sedimentation rates were relatively low and confined to the area of operation. No losses were predicted when using the Draft PER sedimentation thresholds for resilient species.

Sensitivity analysis using halved thresholds, as described in **Section 4.1**, resulted in a small loss prediction at the south end of Angel Island. This is the same area in which losses were predicted in the Draft PER assessment from spoil disposal into spoil ground A/B. There is thus a potential for cumulative effects from trunkline installation and reuse/spoil disposal in spoil ground A/B.

The modelled trunkline installation scenario simulated the TSHD removing the upper layer of unconsolidated material prior to dredging the consolidated layer with a CSD. The period of time between these two activities is at present uncertain, but it is unlikely that the CSD will operate immediately after the cessation of the TSHD. Cumulative impacts due to chronic impacts over many weeks are therefore unlikely. However, as only the TSHD operation has been modelled the predictions of sediment flux from CSD operation may need to be considered to assess the possible cumulative effects of concurrent CSD operation and reuse/spoil disposal in spoil ground A/B.

4.3 Spoil Ground 2B

Modelling disposal of spoil into offshore spoil ground 2B during a four week period showed an increase in the sediment dispersion compared to the Draft PER model simulation. Resuspension and sediment transport into Mermaid Sound were shown to be particularly predominant during north-westerlies and high swell.

Interrogation of the simulated spoil disposal with the acute threshold for sensitive species did not yield any coral losses, neither did the sensitivity analysis where the threshold was halved. There may be a need to do further assessment on chronic impacts as the water quality in the outer harbour is generally high, and even low levels of suspended solids and sedimentation may have an impact over time.

As described in **Section 3.4.2** disposal into spoil ground 2B may cause sediments to disperse into Mermaid Sound. Though the levels of suspended solids are predicted to be low, the sediment plume of this resuspended material is predicted to reach the coral communities around Hamersley Shoal and along Gidley and Angel Island when wave and swell conditions move resuspended material in that direction. Given that spoil disposal is proposed over a duration of up to two years there is some potential for chronic impacts at some of these sensitive habitats. The level of resuspended sediments is predicted to be low and the consequent level of impact from this material is also expected to be low, and will also be influenced by the intensity and frequency of prevailing weather conditions in the Sound during the periods of release of dredge spoil over the spoil grounds.

There may also be a potential for cumulative impacts from disposal into spoil ground 2B, reuse/spoil disposal in spoil ground A/B, trunkline installation, and dredging of the turning basin. This will all depend on the timing of the operations, and the predominant weather patterns at the time.

5. General Conclusions

5.1 Holden Point

- Incorporating resuspension due to wave stress into predictions has indicated a relatively minor change in the near-field sedimentation rates at Holden Point.
- The loss footprint due to sedimentation has not increased significantly.
- The cumulative loss estimation in Zone 1 (Holden Point) has increased from 42% to 43%.
- The increase is mostly caused by an increase in the footprint due to medium-term and chronic sedimentation, reflecting the incorporation of resuspension into the model.
- The increase may also be a result of the minor relocation of the turning basin closer to Holden Point, and the increase in operations from 15 to 24 hours a day.
- The loss predictions did not increase significantly by halving the sedimentation thresholds, with cumulative loss estimates increasing only slightly from 43% to 46%.
- The model outputs show a tendency of the fines to disperse widely along the east shore of the Burrup Peninsula, and the coral communities here may therefore be at risk of impacts from light attenuation.

5.2 Spoil Ground 2B

- No losses due to sedimentation were predicted from the simulation of spoil disposal into 2B.
- The incorporation of resuspension in the model has indicated that the offshore spoil ground 2B may be unstable with finer sediments being washed out of the area. The model predicts this material will migrate into Mermaid Sound and disperse into the wider Dampier Archipelago.
- Though no losses were predicted due to sedimentation, the wide dispersion of fines from spoil disposal into 2B may cause impacts due to light attenuation, however the extent of this is unknown.

5.3 Trunkline

- The TSHD simulations along Angel Island did not predict any losses when interrogated with the thresholds for resilient species.
- A small area of loss at the south of Angel Island was predicted from interrogation with the acute threshold for sensitive species.
- This area is in the same general area where losses were predicted from spoil disposal into A/B in the Draft PER impact assessment.
- There may be a risk of cumulative effects from spoil disposal into A/B and dredging for trunkline installation, as a result of these activities occurring concurrently.