APPENDIX H11

Assessment of bow waves and propellar wash

BHP Billiton

Olympic Dam EIS Project

Assessment of Waves and Propeller Wash Associated with Shipping: Final Report

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EXECUTIVE SUMMARY

AMOG Consulting was engaged by BHP Billiton under Contract 85200/AKH/VLA to conduct studies to address the level of impact of vessel generated waves and propeller-induced turbidity on the nearby environment imposed by transit of commercial vessels to be used for Olympic Dam Expansion Project in the Upper Spencer Gulf (USG).

The following activities were conducted in order to provide an assessment of the commercial vessel impacts:

1. Vessel generated waves
    - An evaluation was made of the magnitude and number of vessel generated waves in proximity of the shore-line.
    - The magnitudes of waves due to transition of commercial vessels in USG were compared against the magnitudes of waves due to other potential users of the waterway, such a recreational speed boats.
    - The breaking of vessel generated waves was investigated. The magnitude of breaker heights, the breaker water depth and their distance to shoreline was also assessed.
    - The wave run up on the shore was assessed to investigate the risk to shore infrastructure and bathers.
    - A comparison was made for the estimated magnitude and number of vessel generated waves against the expected magnitude and number of waves caused by a 25kt wind (a typical naturally occurring environmental condition in the USG).
2. Propeller-induced wash
    - An estimation was made of the magnitude of jets induced by the action of propellers of commercial vessels and other potential users in USG.
    - The level of sediment transport due to estimated jet velocities were calculated and compared for each vessel.
    - The erosion induced by the action of propellers of commercial vessels was compared against the erosion induced by tidal currents in USG.
    - An evaluation was made of water turbidity levels due to action of propellers of the commercial vessels.
    - The turbidity levels were compared against the environmental limits for seagrass.

Based on the results of the assessment, it was found that:

I. The highest waves due to commercial vessels are of the order of 0.3m. Based on the estimation of vessel-generated wave heights when they approach the shore and break (0.2m), their type and distance to the shore, it is unlikely for commercial vessels to cause severe waves that would be of danger to the bathers and near-shore infrastructure;

II. The highest vessel generated waves are likely to be smaller (about 50%) than the waves due to natural causes like a 25kt wind. In addition, the occurrence of vessel generated waves is likely to be much less than the occurrence of similar or larger height waves due to natural processes, such as waves generated by a 25kt (12.9m/s, 45km/h) wind. As such, the potential risk due to vessel generated waves is of less significance compared to the waves induced by natural causes.

III. The run-up due to vessel-generated waves is expected to be negligible and as a result, the induced potential risk on shore infrastructure is insignificant.

IV. The maximum wave heights due to transit of commercial vessels was found to be slightly higher than the ones created by the recreational vessels in the area.

V. The maximum expected amount of seabed sediment mobilised by the action of propellers of commercial vessels was found to be approximately 2mm per each vessel transit.

VI. For similar water depths at the commercial vessels' track (7.5m) the amount of seabed sediment mobilisation by other users in USG was found to be negligible. However, considering the typical water depths within the range of operation of the recreational vessels in USG (1m-2m), the amount of sediment mobilised by these users would be similar to that produced by commercial vessels.

VII. Considering the duration of flow actions, the rate of erosion induced by commercial vessels was found to be at most about half of the erosion rate induced by tidal currents in USG.

VIII. Considering the finite boundary of action for the propeller induced jets, it is unlikely that the propeller wash would cause any damage to the sea-grass patches and mangroves close to the shoreline (i.e. tugs and heavy lift vessels operate too far from mangroves and seagrass beds for the propeller wash turbidity to impact them). This includes at the landing facility location, where due to water depth limitations on vessel navigation, and the geometry of the landing facility, the large commercial vessels would not be able to approach the seagrass beds sufficiently closely for the propeller-induced jets to directly impinge on the seagrass beds.

IX. Turbidities induced by propellers of commercial vessels are unlikely to cause any significant issues for the viability of seagrass in USG.

TABLE OF CONTENTS

1 INTRODUCTION

This report presents the findings of the studies made to assess the impact of the commercial vessels transiting the Upper Spencer Gulf.

The report is arranged as follows:

- Section 1 describes the project background and the scope of work;
- Section 2 presents the results of the assessments on the vessel-generated waves;
- Section 3 presents the results of the assessments on the propeller wash;
- Section 4 summarised the conclusions from the findings of the studies; and
- Section 5 lists the references used in the studies.

1.1 BACKGROUND

BHP Billiton is intending to expand the existing Olympic Dam copper, uranium, gold and silver mine and processing plant, including associated infrastructure. Olympic Dam is located approximately 570 km NNW of Adelaide in South Australia. As part of the prospective expansion, BHP Billiton is intending to develop an offloading facility in Upper Spencer Gulf (USG) to enable Pre-Assembled Modules (PAMs) to be received from some vessels and then dispatched from the facility to a nearby lay-down yard or directly to the mine site.

This prospective site is located on the western side of Upper Spencer Gulf, about 10 km to the south of Port Augusta.

The Olympic Dam Expansion Draft Environmental Impact Statement 2009 (Draft EIS) was released for public comment during 2009. A number of responses were received in relation to the operational activities of commercial vessels operating in the waters of the USG.

Submissions received to the Draft EIS suggest that bow waves as well as propeller wash associated with tugs and barges moving to and from the landing facility in USG are of concern to the public. These concerns are related to the potential for propeller induced flows and vessel generated waves to cause coastal erosion with damage to mangroves, seagrass and shoreline infrastructure (coastal homes, jetties etc).

The impacts of commercial vessel bow waves and propeller wash along the channel heading to and from the proposed landing facility needs to be further investigated and better understood for inclusion in the Supplemental EIS (SEIS).

In order to address these concerns, AMOG Consulting was engaged by BHP Billiton under Arup subcontract 85200/AKH/VLA to conduct studies to assess the level of impact of vessel generated waves and propeller-induced wash and turbidity on the nearby environment.

1.2 SCOPE

The overall aim of this project work was to conduct an assessment to identify and characterise the effects of

- Vessel-generated waves; and
- Propeller-induced wash and turbidity;

from vessels associated with the Olympic Dam Expansion project and other users in the USG.

2 VESSEL-GENERATED WAVES

A vessel will create a pressure disturbance as it moves in the water, whereby it creates a system of diverging and transverse waves (see Figure 1). The results presented in this section cover the analysis of diverging waves generated by the vessels, which is referred to hereafter as the vessel generated waves.

Evaluation of the diverging vessel generated waves is described in Appendix B. A summary of findings from these studies is presented in the following sections.

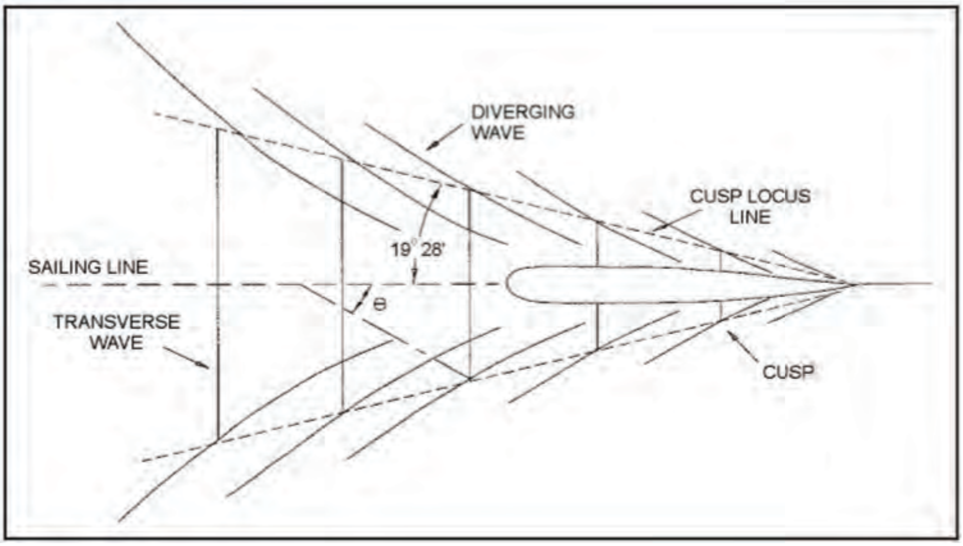

Figure 1 : Wave Crest Pattern Generated at a Vessel Bow Moving Over Deep Water
Ref [8]

2.1 VESSELS CONSIDERED

The following vessel types, associated with the Olympic Dam expansion project were considered for the assessment of vessel generated waves.

- "Sea Baron" Ro-Ro Heavy Lift Vessel (HLV);
- A Tug; and a
- A Barge.

In addition, the following vessels typical of current USG usage were assessed to provide a comparison:

- A fishing vessel; and
- A recreational speed boat.

Table 1 presents a summary of the specifications assumed for the above vessels.

Table 1: Vessels Considered for the Study of Vessel-Generated Waves

Parameter	Vessel Types				
	"Sea Baron" HLV	Tug	Barge	Fishing Boat	Recreational Speed Boat
Length [m]	153	37.8	163	17.5	5.2
Beam [m]	32.2	11.3	41.2	4.6	2.2
Draft [m]	5	4.5	4	2	0.4
Service Speed [knots]	5	5	6	10	30

Notes:
1. This is the percentage of engine power during the service operation of the vessel to the total engine power.
2. The barge was assumed to be towed by the tug.

2.2 MAGNITUDE OF VESSEL-GENERATED WAVES

Table 2 presents the results of the assessment for the maximum vessel-generated wave heights for the vessels described in Section 2.1. The results presented are based on the available analytical formulations in the literature and publications considering similar vessels at different locations to USG.

The estimated maximum wave heights due to passage of commercial vessels in USG is in the order of 0.3m. In contrast, the waves generated by recreational vessels would be around 0.1-0.2m (about 20-40% smaller).

Table 2: Estimated Heights for Vessel-Generated Waves

Parameter	Vessel Types				
	Sea Baron HLV	Tug	Barge	Fishing Vessel	Recreational Speed Boat
Expected Maximum Wave Height Near-Shore [m]	0.3	0.3	0.3	0.2	0.2

Notes:
1. An average water depth of 7.5m along the vessel route was assumed. The initial vessel generated wave height is strongly related to vessel speed, but only weakly related to water depth.

2.3 EFFECTS OF VESSEL-GENERATED WAVES

An important aspect of vessel-generated waves is their likely interaction with near-shore infrastructure and bathers, when they approach shore and make land. Assessment of wave effects involves understanding

- Local bathymetry;
- Continuous wave attenuation along the progression track;
- Number of occurrence of vessel generated waves;
- Wave breaking; and
- Wave run up.

Charts of a bathymetric survey in the Upper Spencer Gulf are provided in Appendix A.

As a background to the discussion of vessel-generated wave heights, it should be understood that the main factor driving the height of waves generated by vessels operating at sub-critical speeds (such as commercial vessels associated with the project) is the vessel speed. The vessel speed is a primary factor in determining the vessel-generated wave celerity (speed) and, following the wave dispersion equation, the wave length (distance between successive wave crests). For the purpose of this assessment, waves have assumed to be at the maximum steepness for the calculated wave length, and are therefore the maximum height that can be generated for a given vessel speed (higher waves will break by spilling, limiting their height). This is a conservative (worst case) assumption, and in practice the wave height generated by different vessel hull forms could be expected to be less than predicted by this method.

The water depth is less significant in determining the initial vessel-generated wave height, and the the wave height would be largely invariant over the range of water depths in the navigable channel of the USG. Changes in wave height due to shoaling, breaking and run-up as the wave passes over shallows near the shore are more significant when assessing the vessel-generated wave effects.

As indicated in Section 2.2, The highest vessel-generated waves for the commercial vessels in USG were found to be of the order of 0.3m. Based on the available information in [2], the highest waves induced by a 25kn wind were found to about 0.7m high within the vicinity of the shoreline. Therefore, the highest near-shore vessel-generated waves are expected to be considerably smaller than the near-shore waves caused by the 25kn wind.

To compare the relative impact of vessel generated waves from construction related activities to the waves caused by natural causes, a study was made of the waves that would commonly occur in the area (waves generated by a 25kt wind as per [2]) at the same shore location. The study indicated that the number of occurrences of wind-generated waves with heights above the highest vessel-generated waves was of the order of 30 times the occurrence of the vessel generated waves. This indicates that the waves generated by natural causes like a 25kt wind are expected to be of higher impacts on the shoreline infrastructure (see Appendix E).

Based on the results presented in Appendix B, given the flat slope of the shoreline and the waters inshore of the channel (on both the eastern and western sides of the USG), it was estimated that the vessel-generated waves would break in a water depth of approximately 0.3m. The breaking waves were estimated to be of spilling type with a height around 0.2m. As such, it is expected that the vessel-generated waves would lose most of their energy before even reaching the shoreline. An analytical assessment of the wave run-up confirms the significant attenuation of waves at the beach. As such, no impact on coastal homes, infrastructure, or bathers is expected from vessel generated waves.

3 PROPELLER WASH

A rotating ship propeller generates a turbulent continuous stream of fast moving water flow known as the propeller-induced jet (see Figure 2). This jet acts on a certain area on the seabed before it looses its strength. Propeller-induced jets can impinge directly on the bottom and move the bed sediments and cause erosion. This can also physically damage benthic vegetation, such as seagrass, by scouring the seabed around them. This is also known as propeller wash.

As one of the objectives of this project work, assessments have been made with regards to propeller-induced erosion caused by the commercial vessels transiting the USG. Appendices C and D provide the estimations of propeller wash and turbidity. A summary of findings from these studies is presented in the following sections.

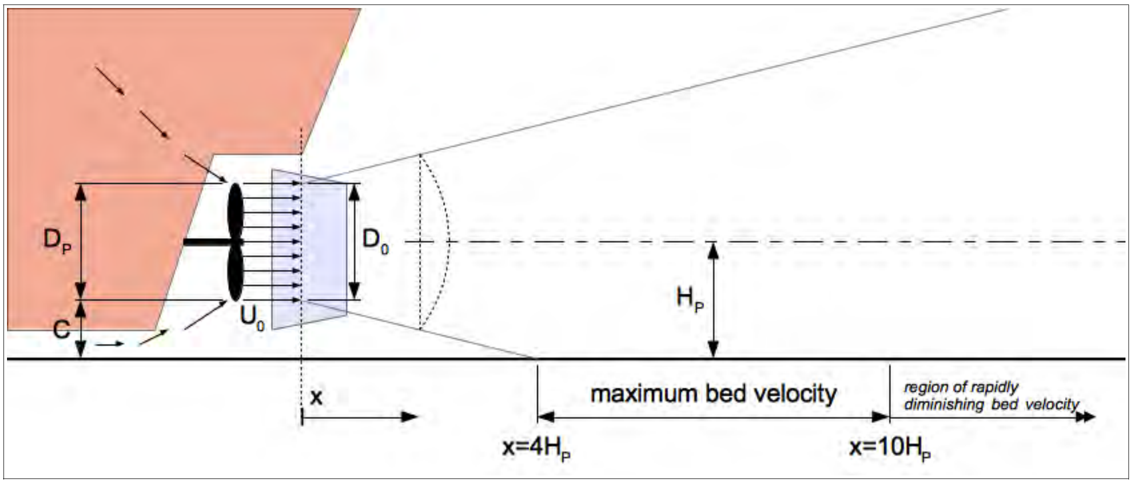

Figure 2: Simplified Diagram of Propeller-Induced Jet
Based on Prosser [1] as reproduced in [5]

3.1 VESSELS CONSIDERED

The following vessel types associated with the Olympic Dam Expansion Project were considered for propeller wash assessment:

- "Sea Baron" Ro-Ro Heavy Lift Vessel (HLV);
- A Tug;

For purpose of comparison, the following vessels typical of current USG usage were also considered:

- A fishing vessel;
- A recreational vessel;
- A recreational speed boat; and
- A Jet-ski.

Table 3 presents a summary of the specifications assumed for the above vessels.

Table 3: Parameters of Vessels Considered for Propeller Wash Assessment

Parameter	Vessel Types					
	"Sea Baron" HLV	Tug	Fishing Boat	Recreational Vessel	Speed Boat	Jet-ski
Length [m]	153	37.8	17.5	10.7	5.2	3.4
Beam [m]	32.2	11.3	4.6	3	2.2	1.2
Draft [m]	5	4.5	2	1	0.4	0.2
Propeller Type	Non-Ducted	Ducted	Non-Ducted	Non-Ducted	Non-Ducted	Non-Ducted
Number of Propellers	2	2	1	1	1	1
Propeller Diameter [m]	3.7	3.4	0.6	0.4	0.35	0.16
Engine Power [kW]	2580	2290	-	90	68	-
Service Power Ratio (%)[1]	10	50	-	-	-	-
Propeller RPM	-	-	800	-	5500	6500
Service Speed [knots]	5	6	10	8	30	20

3.2 MAGNITUDE OF PROPELLER WASH

Table 4 presents the results of the expected sand transport rates per width of the bed for the vessels in USG assuming similar water depths of operation equal to 7.5m (approximate water depth along the transit route of the commercial vessels in the northern USG). The results indicate that only the HLV and the Tug will have a significant bed velocities. However whilst these commercial vessels would mobilise greater amounts of seabed sediment compared to other users in USG, the depth of sediment mobilised per passage are negligible (less than 2mm depth per passage).

Table 4: Calculated Bed Jet Velocities and Bed Sediment Mobilisation

Parameter	Vessel Types					
	"Sea Baron" HLV	Tug	Fishing Vessel	Recreational Vessel	Speed Boat	Jet-ski
Near-bed Jet Velocity[1] [m/s]	2.4	3.8	0.3	Nil.[2]	Nil.[2]	Nil.[2]
Expected Sand Transport Per Width of Bed [$m^3/(ms)$]	3.5	14.6	Nil.[2]	Nil.[2]	Nil.[2]	Nil.[2]
Estimated Depth of Mobilised Sediment[3] [mm]	0.5	1.8	Nil.[2]	Nil.[2]	Nil.[2]	Nil.[2]

Notes:
1. The average water depth at the vessel propeller was assumed to be about 7.5 m for the HLV, Tug and Fishing Vessel. These vessels have a relatively deep draft and would have insufficient under keel clearance to regularly operate in shallower water depths. Maximum near bed velocity occurs in region 18m to 45m from vessel stern for "Sea Baron" HLV and the Tug.
2. Nil implies the calculated values are insignificant.
3. Depth of sediment on bed mobilised per vessel transit, but before consideration of resettlement of sediments.

3.3 EFFECTS OF PROPELLER WASH

3.3.1 Direct Impingement Of Propeller Jet On Seagrass

The maximum propeller jet velocities at the seabed occur at a distance of 4 to 10 times the propeller height from the seabed (as per Figure 2). This equates to 18m to 45m for the "Sea Baron" HLV and the Tug. Beyond this distance, the velocity at the seabed decays rapidly. As due to bathymetric constraints at the proposed offloading terminal, the HLV cannot approach closer than 90m to the identified seagrass beds at transects L1. L2 and L3 (per Appendix O1 of the Draft EIS [1]), and the tug no closer than 70m when applying high thrust, then there is negligible risk of the propeller jet impinging directly on these seagrass beds.

3.3.2 Erosion

Erosion assessment shows that the total depth of sediment mobilised by the propeller action of the commercial vessels would be below 2mm per each transit. For the typical commercial vessels considered, the longest widths and lengths of jet action would not exceed 28m and 75m, respectively.

Based on the prospective vessel shipping route, it can be assumed that the commercial vessels would operate at a distance of at least 350m from the shoreline. This implies that the turbulent flows excited by the action of the propellers of the commercial vessels would be settled well before reaching the sea-grass patches, mangroves and the beach infrastructure. As such, the propeller wash from the commercial vessels in USG is not expected to cause any impact on the near-shore infrastructure.

3.3.3 Turbidity

Turbidity is the cloudy appearance of water which is caused by suspended material. One of the objectives of this work was to assess the level of turbidities caused by the action of the propellers of the commercial vessels and to compare them against the environmental limits imposed for the viability of sea-grass.

Turbidity is strongly correlated to settlement time of the scoured sediments and the grain sizes. As such, it is very site specific and without laboratory measurements of samples drawn from the specific site, the estimation of relationship between the turbidity levels (NTU) and the total suspended sediments (mg/L) in the USG is uncertain. For this assessment, typical values of the relationship between suspended sediment and turbidity levels have been used, however for additional certainty site specific testing is required.

The Port of Melbourne Corporation (PoMC) [4] provides a turbidity limit for sea-grass of 25NTU based a 6-hour averaged data. Ref [6] states that even for some sensitive species of seagrass to die, light deprivation (absolutely no ambient light) needs to persist for 38 days.

The level of suspended sediments is a function of sediment settlement duration. In absence of interference from the environmental effects such as waves, suspended sand sediments would normally settle in period of one minute, extending to a couple of hours if larger scale environmental actions (i.e. storm seas) retard the settlement of sediments.

Based on still water conditions, the lower bound of the settlement time was estimated as 1.5 minutes. At this settlement time, the magnitude and duration of the calculated turbidity levels induced by the commercial vessels propellers were, on a pro-rata basis, within the 6 hour environmental limit recommended by PoMC [4] for sea-grass.

The upper limit of the settlement time is harder to estimate, as it is dependent on the particular wave and current conditions that would cause resuspension of sediments, and the flocculation and settlement properties of the sediments at the site. Insufficient detail on these factors was available to draw specific conclusions as to this limit for the USG, however general guidance on typical sediment times for the similar sediments to those present in the USG gives 2 hours as an upper limit on the settlement time [7].

Turbidity estimations showed that for propeller-induced turbidities to satisfy the 6 hour limit of 25NTU ([4]) when adjusted pro-rata for the initial turbidity levels and settlement duration, the equivalent sediment settlement duration to stay within the PoMC recommended limit is approximately 4 minutes.

However, when interpreting this guidance, the following factors should be considered:

- The PoMC limits on turbidity were based upon studies of light deprivation on the seagrass species *Halophila ovalis*. This species has been noted for its low tolerance to light deprivation. The seagrass species endemic at the site of the proposed offloading facility is *Posidonia australis*, a larger and more robust seagrass species that would presumably be more tolerant of short term shading events (although no specific data on short term shading events could be sourced).
- The PoMC limits are based on ongoing turbidity causing prolonged light deprivation due to significant turbidity causing events such as dredging. The durations of light deprivation causing morbidity in the studied seagrass species (*H. ovalis)* was 38 days. These were then scaled to a six hour duration limit as a indicator of severe light deprivation occurring that could induce morbidity if further prolonged, rather than as in indicator of the immediate onset of morbidity.
- The turbidity induced by vessels operating at the offloading facility would be pulse events, where the turbidity would be induced by a vessel movement, but these vessel movements would be intermittent. As such, there is an opportunity for the turbidity to settle between vessel movements, such that light deprivation over the seagrass would not be prolonged.

As the turbidity caused by the vessels will be intermittent in nature, and the calculated times for settlement are relatively short (much less than 6 hours, even when based on the worst case settlement time estimate), and the induced light deprivation would be far below the critical limits from Ref [6] (complete light deprivation for 38 days), the vessel generated turbidity at the offloading facility are assessed of being a low risk of impact on the viability of the seagrass species in USG.

3.3.4 Comparison With Existing Vessels

The results of the sand transport studies conducted for a water depth of 7.5m (average water depth at the commercial vessel tracks) shown in Table 4 indicated that the level of sand transport due to the action of propellers of commercial vessels is large compared to the recreational vessels in USG. However, another study (see Appendix B) suggests that similar levels of erosion to the commercial vessels is expected for the recreational vessels at shallower water depths (about 1.5m) which is normally quite likely to be the case for the recreational vessels.

3.3.5 Comparison With Natural Processes

The estimated sand transport level estimated from the results published in [2] is about 0.015kg/m·s per unit width of seabed. As such, the mass rate of erosion per width of seabed due to tidal currents is considerably lower than the rate of erosion induced by the the propellers of the commercial vessels.

However, tidal currents would normally act on a considerably larger seabed area than the propeller induced flows (in the order of minimum 20 times). Moreover, tidal flow effects are typically of significantly larger duration as opposed to the propeller induced flow effects (in the order of a day compared to a few hours). Based on the results of sand transport (100 $m^3/(m \cdot yr)$) in [2], it is estimated that the erosion per width of bed due to the tidal currents would be of the order of 2 times the highest erosion per width of bed caused by the action of propellers of the commercial vessels in the USG.

4 CONCLUSIONS

Based on the results of the assessment, it was found that:

I. The highest waves due to commercial vessels are of the order of 0.3m. Based on the estimation of vessel-generated wave height heights when they approach the shore and break (0.2m), their type and distance to the shore, it is unlikely for commercial vessels to cause severe waves that would be of danger to the bathers and near-shore infrastructure;

II. The highest vessel generated waves are likely to be smaller (about 50%) than the waves due to natural causes like a 25kn wind. In addition, the occurrence of vessel generated waves is likely to be much less than the occurrence of similar or larger height waves due to natural processes, such as waves generated by a 25kt (12.9m/s, 45km/h) wind. As such, the potential risk due to vessel generated waves is of less significance compared to the waves induced by natural causes.

III. The run-up due to vessel-generated waves is expected to be negligible and as a result, the induced potential risk on shore infrastructure is insignificant.

IV. The maximum wave heights due to transit of commercial vessels was found to be slightly higher than the ones created by the recreational vessels in the area.

V. The maximum expected amount of seabed sediment mobilised by the action of propellers of commercial vessels was found to be approximately 2mm per each vessel transit.

VI. For similar water depths at the commercial vessels' track (7.5m) the amount of seabed sediment mobilisation by other users in USG was found to be negligible. However, considering the typical water depths within the range of operation of the recreational vessels in USG (1m-2m), the amount of sediment mobilised by these users would be similar to that produced by commercial vessels.

VII. Considering the duration of flow actions, the rate of erosion induced by commercial vessels was found to be at most about half of the erosion rate induced by tidal currents in USG.

VIII. Considering the finite boundary of action for the propeller induced jets, it is unlikely that the propeller wash would cause any damage to the sea-grass patches and mangroves close to the shoreline (i.e. tugs and heavy lift vessels operate too far from mangroves and seagrass beds for the propeller wash turbidity to impact them). This includes at the landing facility location, where due to water depth limitations on vessel navigation, and the geometry of the landing facility, the large commercial vessels would not be able to approach the seagrass beds sufficiently closely for the propeller-induced jets to directly impinge on the seagrass beds.

IX. Turbidities induced by propellers of commercial vessels are unlikely to cause any significant issues for the viability of seagrass in USG.

5 REFERENCES

[1] **BHP Billiton (2009)**. "Marine Ecological Surveys*", Olympic Dam Expansion Draft Environmental Statement.* Appendix O1.

[2] **BHP Billiton (2009)**. "Coastal Processes Modelling*", Olympic Dam Expansion Draft Environmental Statement.* Appendix O13.

[3] **PIANC (1997)** *Guidelines for the Design of Armoured Slopes Under Open Piled Quay Walls.* Report of Working Group 22 Supplement to Bulletin No. 96. Permament International Association of Navigation Congresses, Brussels.

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[5] **Prosser, M J. (1986)** *Propeller Induced Scour.* Report RR 2570. BRHA.

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APPENDIX A - BATHYMETRY OF UPPER SPENCER GULF

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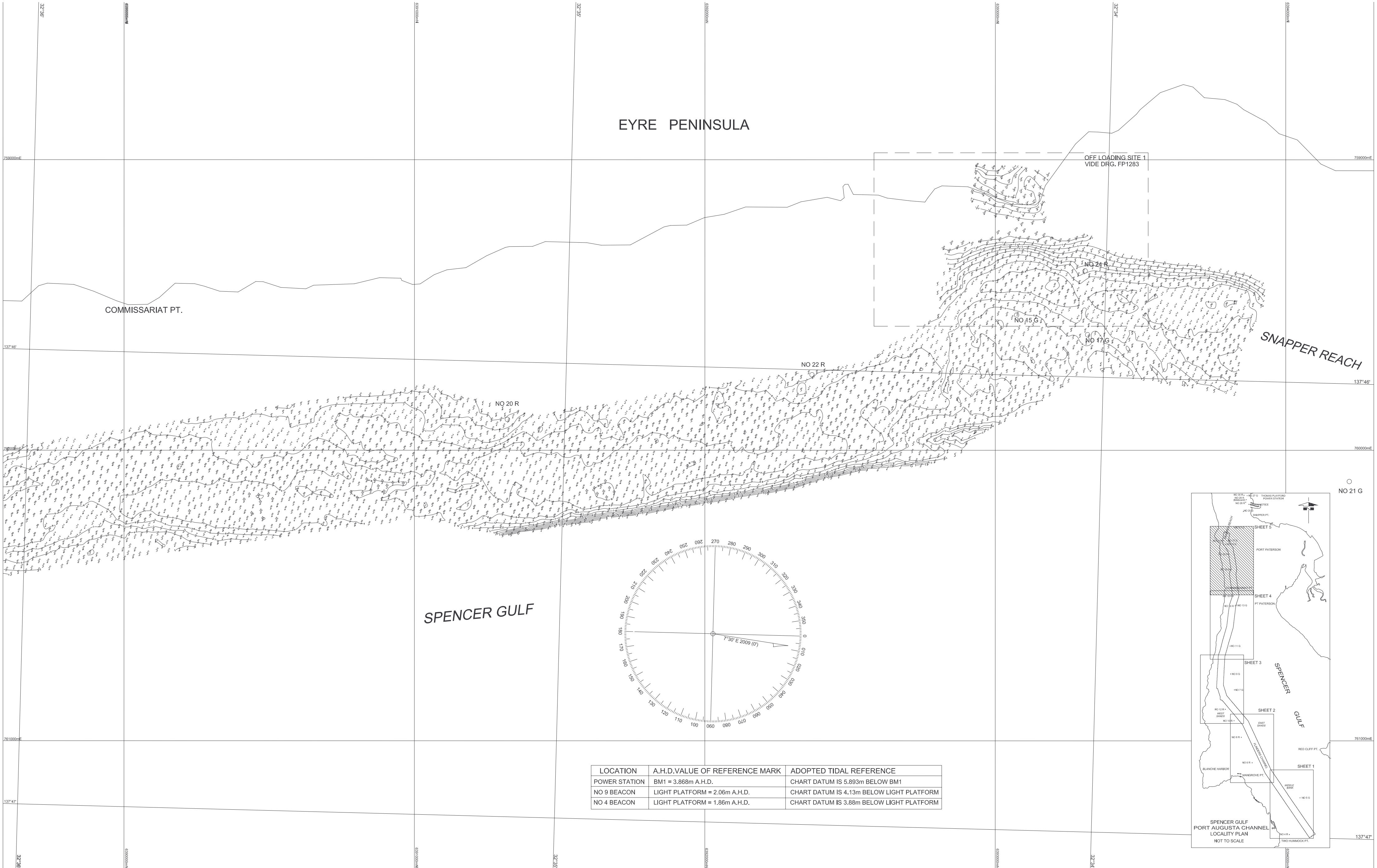

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NO 9 BEACON	LIGHT PLATFORM = 2.06m A.H.D.	CHART DATUM IS 4.13m BELOW LIGHT PLATFORM
NO 4 BEACON	LIGHT PLATFORM = 1.86m A.H.D.	CHART DATUM IS 3.88m BELOW LIGHT PLATFORM

REV	DESCRIPTION OF REVISION	ALTERED / DATE / CHECKED	SURVEYOR / C.H.S. / M.S.

DRAWN	Add	DATE	20/07/07
CHECKED	pwh	DATE	20/07/07
SURVEYOR		DATE	

CHIEF HYDROGRAPHIC SURVEYOR

MANAGER SURVEY

THIS SURVEY HAS BEEN CARRIED OUT USING A GEOSWATH INTERFEROMETRIC WIDE SWATH SURVEY SYSTEM TO I.H.O. S44 STANDARD FOR SPECIAL ORDER SURVEYS AND THAT:

(A) FULL SEARCH AREA (ie TOTAL BOTTOM COVERAGE) HAS BEEN ACHIEVED OVER SURVEY AREA

(B) A DEPTH ACCURACY FOR REDUCED DEPTHS (95% CONFIDENCE LEVEL) OF ± 0.25m HAS BEEN ACHIEVED

(C) DATA PROCESSING AND MODELLING HAS BEEN CARRIED OUT USING A 2m GRID

(D) SELECTED SOUNDINGS SHOWN ON THIS PLAN ARE MINIMUM DEPTHS WITHIN A 40m CIRCLE OF INFLUENCE

VERTICAL DATUM
REFER TABLE

HORIZONTAL DATUM
MGA ZONE 53, USING GDA 94 DATUM (WGS 84 GRID ALSO SHOWN)

EQUIPMENT
SURVEY LAUNCH: PATHFINDER
GEOACOUSTICS GS+ SURVEY SYSTEM
TRIMBLE AG132 DGPS SYSTEM
TSS DMS05 MOTION SENSOR
S G BROWN MERIDIAN GYRO COMPASS

REFS
HYDRO/REFS

CAD
PORT AUGUSTA07
FP1282_19-21JUN 07_SHT5.dwg

GIS
AUGUSTA07.002

NOTES
SOUNDINGS & LEVELS TAKEN 19 - 21 JUNE 2007.

SCALE
BEFORE REDUCTION 1:5000
METRES 0 100 200 300 400 500 METRES

Flinders Ports
SOUTH AUSTRALIA

PORT AUGUSTA
OVE ARUP PTY LTD
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SUPERSEDES DRG.

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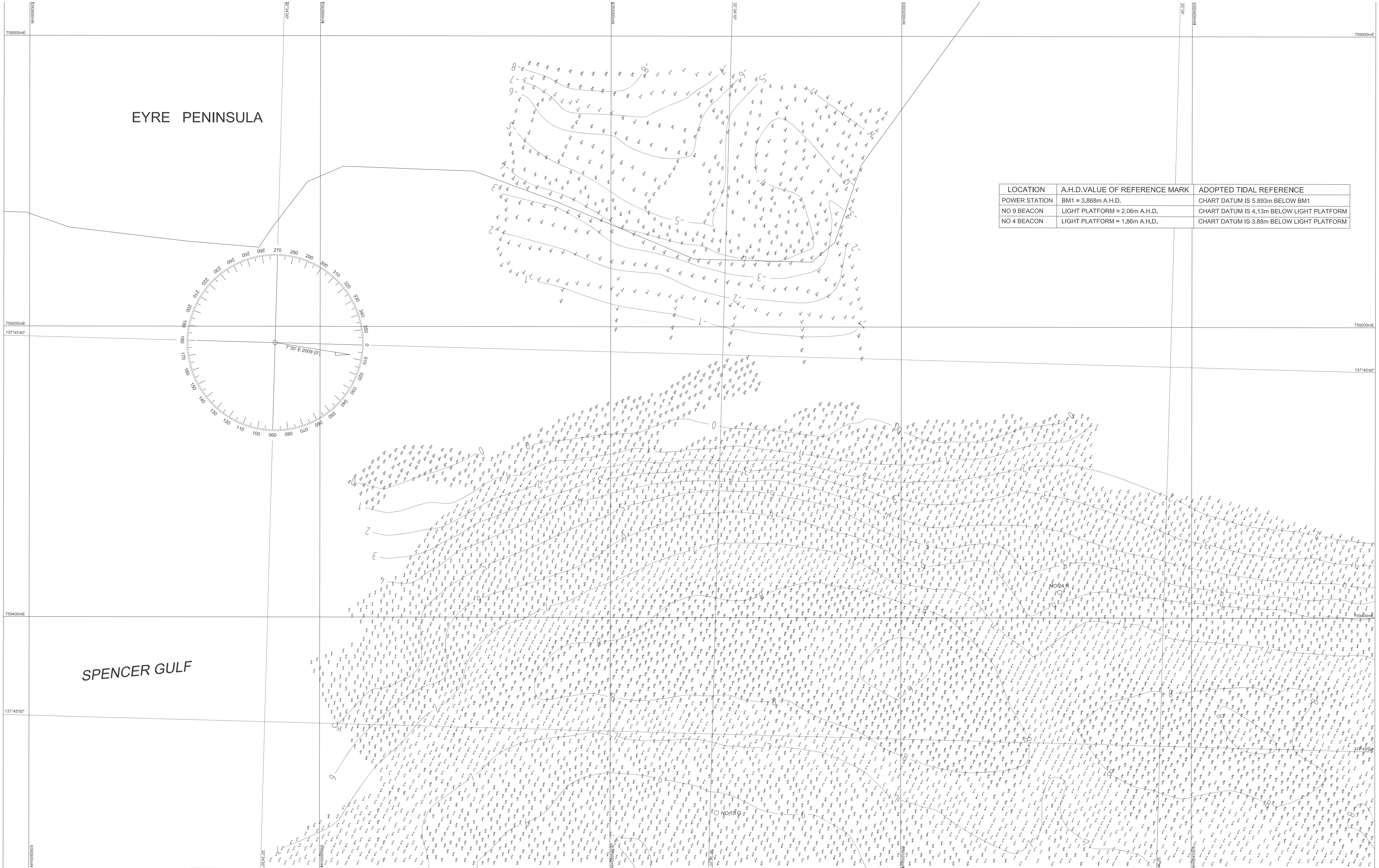

LOCATION	A.H.D.VALUE OF REFERENCE MARK	ADOPTED TIDAL REFERENCE
POWER STATION	BM1 = 3.868m A.H.D.	CHART DATUM IS 5.893m BELOW BM1
NO 9 BEACON	LIGHT PLATFORM = 2.06m A.H.D.	CHART DATUM IS 4.13m BELOW LIGHT PLATFORM
NO 4 BEACON	LIGHT PLATFORM = 1.86m A.H.D.	CHART DATUM IS 3.88m BELOW LIGHT PLATFORM

REV	DESCRIPTION OF REVISION	ALTERED	SURVEYOR
		DATE	C.H.S.
		CHECKED	M.S.

DRAWN	Add	DATE	20/07/07
CHECKED	pwh	DATE	20/07/07
SURVEYOR		DATE	

CHIEF HYDROGRAPHIC SURVEYOR

MANAGER SURVEY

THIS SURVEY HAS BEEN CARRIED OUT USING A GEOSWATH INTERFEROMETRIC WIDE SWATH SURVEY SYSTEM TO I.H.O. S44 STANDARD FOR SPECIAL ORDER SURVEYS AND THAT:

(A) FULL SEARCH AREA (ie TOTAL BOTTOM COVERAGE) HAS BEEN ACHIEVED OVER SURVEY AREA

(B) A DEPTH ACCURACY FOR REDUCED DEPTHS (95% CONFIDENCE LEVEL) OF ± 0.25m HAS BEEN ACHIEVED

(C) DATA PROCESSING AND MODELLING HAS BEEN CARRIED OUT USING A 2m GRID

(D) SELECTED SOUNDINGS SHOWN ON THIS PLAN ARE MINIMUM DEPTHS WITHIN A 8m CIRCLE OF INFLUENCE

VERTICAL DATUM
REFER TABLE

HORIZONTAL DATUM
MGA ZONE 53, USING GDA 94 DATUM
(WGS 84 GRID ALSO SHOWN)

EQUIPMENT
SURVEY LAUNCH: PATHFINDER
GEOACOUSTICS GS+ SURVEY SYSTEM
TRIMBLE AG132 DGPS SYSTEM
TSS DMS05 MOTION SENSOR
S G BROWN MERIDIAN GYRO COMPASS

REFS
HYDRO/REFS

CAD
PORT AUGUSTA07
FP1283_19-21JUN
07_SITE1.dwg

GIS
AUGUSTA07.003

NOTES
SOUNDINGS & LEVELS TAKEN 19 - 21 JUNE 2007.

SCALE
BEFORE REDUCTION 1:1000
METRES 0 20 40 60 80 100 METRES

Flinders Ports SOUTH AUSTRALIA

PORT AUGUSTA
OVE ARUP PTY LTD
OFF LOADING SITE 1

SUPERSEDES DRG.

JOB NO.	HA2AAG
SHEET	1 OF 3
LOC 450	TYPE 13
DRG. No. FP1283	REV

APPENDIX B - VESSEL-GENERATED WAVE CALCULATIONS

B.1 METHODOLOGY

Evaluation of vessel-generated waves is performed in the following manner:

1. Calculation of Depth Froude Number knowing vessel speed and water depth as per [B.1].
2. For sub-critical Froude regimes, estimations are made for diverging wave direction, celerity, period and length from analytical expressions in [B.3]. Also calculations are compared against available measurement data in [B.2], [B.3], [B.4], and [B.5].
3. For other Froude regimes, estimation of wave heights are made based on the available vessel measurement data in [B.2], [B.3], [B.4], and [B.5].
4. Calculations regarding breaking wave heights, breaker depth, and wave run-up at the shore are based on [B.3] and [B.6].

B.2 ASSUMPTIONS

- It was assumed that the barge is towed by the tug. Therefore, the barge speed is taken the same as the tug i.e. 5 knots.
- To be conservative, vessel-generated waves were assumed to have a steepness close to the breaking limit (~1/7).
- The water depth at the vessel shipping line was assumed to be 7.5m.
- Seabed slope near-shore was taken equal to 1/500.

B.3 RESULTS

Table 5 presents the key results of the vessel-generated wave calculations.

Table 5: Estimated Heights for Vessel-Generated Waves

Parameter	Vessel Type				
	"Sea Baron" HLV	Tug	Barge	Fishing Vessel	Recreational Speed Boat
Vessel Speed [knots]	5	5	6	10	30
Depth Froude Number	0.3	0.3	0.3	0.6	1.8
Regime	sub-critical	sub-critical	sub-critical	sub-critical	supercritical
Expected Maximum Wave Height Near-Shore [m]	0.3	0.3	0.3	0.2	0.2

Notes:
1. The average water depth at vessel sailing line was assumed to be about 7.5m.

B.4 REFERENCES

[B.1] **PIANC (2003)**. "Guidelines for Managing Wake Wash from High-Speed Vessels*".*

[B.2] **Gates E T (1989)**. *"Maritime Accidents: What Went Wrong?".* Gulf Publishing Company, Houston, Texas.

[B.3] **U.S. Army Corps of Engineers. (2002).** "Coastal Engineering Manual" . Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).

[B.4] **Das M M and Johnson J W, (1970)**. "Waves Generated By Ships and Small Boats*", Twelfth Coastal Engineering Conference*, *Washington DC*.

[B.5] **Sorensen R M and ASCE A M, (1967)**. "Investigation of Ship Generated Waves*", Journal of the Waterways and Harbours Division, Vol 93, no WW1, Proceedings of ASCE*.

[B.6] **U.S. Army Corps of Engineers. (1984).** "*Shore Protection Manua*l" U.S. Army Corps of Engineers, Washington, D.C, Government Printing Office.

APPENDIX C - PROPELLER WASH CALCULATIONS

C.1 METHODOLOGY

Evaluation of the propeller-induced erosion and turbidity is made in the following manner:

1. Calculations for initial jet speed and diameter, and reduced flow velocity close to seabed and the area of jet action are made based on [C.1].
2. Bed erosion calculations are conducted based on [C.2], [C.3], and [C.4].
3. Erosion rates were estimated based on Nielsen's method in [C.2].
4. Sediment settlement duration has been calculated based on [C.2].

C.2 ASSUMPTIONS

- The seabed was taken to be nearly flat.
- Jet velocity was assumed to decay with distance following an inverse quadratic relation.
- The bottom was considered to be of sandy type. Sediment characteristics were taken as presented in Table 6 .
- The jet is a assumed to act on an area with with width equal to 4 times the initial jet diameter and length equal to 15 times the distance between propeller axis to seabed.
- It was assumed that commercial vessels would transit the channel once per day.
- It was assumed that tidal current would occur four times a day, with maximum tidal current speed (taken equal to 1m/s) occurring 70% of each interval.

Table 6: Sediment Characteristics

Parameter	Value	Dimension
Average Grain Size	1	[mm]
Material Density	2650	[kg/m^3]
Porosity	0.4	[-]
Relative Density	1.65	[-]
Grain Drag Coefficient	0.0026	[-]

C.3 RESULTS

Table 7 presents the key results of the propeller-induced erosions assuming all vessels at 7.5m water depth.

Table 7: Key Results for Propeller Induced Erosion in 7.5m Water Depth

Parameter	Vessel Type					
	"Sea Baron" HLV	Tug	Fishing Vessel	Recreational Vessel	Speed Boat	Jet-ski
Initial Jet Velocity [m/s]	6.5	8.5	12.7	16.5	46	25
Initial Jet Diameter [m]	2.6	3.4	0.43	0.28	0.25	0.16
Near-bed Flow Velocity [1][m/s]	2.4	3.8	0.3	Nil.[2]	Nil.[2]	Nil.[2]
Induced Shear-Stress [Pa]	15.5	39	0.2	Nil.[2]	Nil.[2]	Nil.[2]
Critical Bed Shear-Stress [Pa]	0.5	0.5	0.5	0.5	0.5	0.5
Does Erosion Occur?	Yes	Yes	No	No	No	No
Expected Sand Transport Per Width of Bed [$m^3/(ms)$]	3.5	14.6	Nil.[2]	Nil.[2]	Nil.[2]	Nil.[2]
Effective Jet Area	21m × 73m	27m × 75m	-	-	-	-
Estimated Depth of Erosion [mm]	0.5	1.8	Nil.[2]	Nil.[2]	Nil.[2]	Nil.[2]

Notes:
1. The average water depth at the vessel sailing line was assumed to be about 7.5 m.
2. Nil implies the calculated values are insignificant.

Table 8 presents the key results of the depth study at which the speed boat propeller jet have similar effect to the HLV and Tug vessels in the channel.

Table 8: Key Results for Depth Sensitivity Study for Speed Boat

Speed Boat Parameters	Erosion Rates similar to:	
	"Sea Baron" HLV in 7.5m	Tug in 7.5m
Expected Sand Transport [kg/s]	73.7	396.6
Initial Jet Diameter [m]	0.25	0.25
Initial Jet Velocity [m/s]	46	46
Effective Jet Width [m]	1	1
Critical Bed Shear-Stress [Pa]	0.5	0.5
Induced Shear-Stress [Pa]	121	353
Near-bed Flow Velocity [1][m/s]	6.7	11.5
Water Depth	1.3	1

C.4 REFERENCES

[C.1] **PIANC (1997)**. “Guidelines for the Design of Armoured Slopes Under Piled Quay Walls*”.* International Navigation Association.

[C.2] **Soulsby, R (1997)**. “Dynamics of Marine Sand*”* Telford.

[C.3] **Hoffmans and Verheij(1997)**. *“Scour Manual”.* Balkema, Rotterdam.

[C.4] **Van Rijn, L (1993)**. “*Principles of Sediment Transport In Rivers, Estuaries and Coastal Seas*”. Aqua publications, Netherlands.

APPENDIX D - TURBIDITY CALCULATIONS

D.1 METHODOLOGY

POMC [D.1] provides a turbidity limit for sea-grass of 25NTU based a 6 hour averaged data.

Turbidity is strongly correlated to settlement time of the scoured sediments and the grain sizes. As such, it is very site specific and without laboratory measurements, the estimation of relationship between the turbidity levels (NTU) and the total suspended sediments (mg/L) in the USG is uncertain.

AMOG is unaware of any expression between the turbidity and total suspended solid levels in USG. Among other expressions that were found for other locations, the following relation was used (from [D.2]) that is believed to be relatively conservative:

$$1\,TSS\,[mg/L] = 7.5\,NTU \qquad \text{Equation 1}$$

This then gives the environmental limit for the total suspended solids of 3.3 mg/L. It is used as a provisional limit for suspended solids until the actual relationship for the USG can be determined by testing.

D.2 ASSUMPTIONS

- Water depth was assumed to be 7.5m.
- It was assumed that all the suspended mass is concentrated above the effective jet area and the sediments are mixed uniformly with the water within the entire depth of channel.
- It was assumed that the total suspended solid concentration decays linearly with time.
- For estimation of settlement time, it was assumed that sediments would begin to fall from the still water level.
- Two different maximum settlement times of 1.5 minutes (based on calculated data) and 2 hours (based on typical values given in [D.3] and taking account of some environmental resuspension of sediment) were considered.

D.3 RESULTS

Table shows the key results of the turbidity calculations for the "Sea Baron" HLV and the Tug.

Table 9: Key Results of Turbidity Calculations

Speed Boat Parameters	Vessels	
	"Sea Baron" HLV	Tug
Jet Length [m]	73	75
Scour Time For one Length of Jet [sec]	28	24
Total Suspended Mass [kg]	2086	9595
Volume of Water [m^3]	11475	15300
Total Suspended Solids [mg/L]	180	630
Calculated Settlement time in the absence of disturbance from environmental effects	1.5min	1.5min
6Hr-Averaged TSS Assuming 1.5min Settlement Duration [mg/L]	0.4	1.31
POMC Limit Satisfaction	Yes	Yes
6Hr-Averaged TSS Assuming 2Hrs Settlement Duration [mg/L]	30	105
POMC Limit Satisfaction	No	No
Maximum Settlement Time to Satisfy the POMC Limit	13min	4min

D.4 REFERENCES

[D.1] **Port of Melbourne Corporation (2008)**. *“Turbidity-Detailed Design”* p1-45.

[D.2] **Hanna Instruments (2004)**. *“Turbidity Meters”* p1-6.

[D.3] **Soulsby, R (1997)**. “Dynamics of Marine Sand*”* Telford .

APPENDIX E - WIND WAVE CALCULATIONS

E.1 METHODOLOGY

Estimations regarding the number of storm (wind) generated waves from wave period and significant wave heights are based on [D.1].

E.2 ASSUMPTIONS

- The significant wave height of the wind generated waves were taken to be 0.4m as per [D.2].
- The zero up-crossing period of the wind-generated waves were assumed to be 4.5s.
- The duration of wind was assumed equal to 3 hours (standard assumption for period of persistence of a storm condition in offshore engineering).
- It was assumed that the peak waves from storm (wind) generated waves follow a Rayleigh distribution [D.1].

E.3 RESULTS

Table 10 presents the key results of the assessment for wind generated waves.

Table 10: Calculated Occurrence and Number of Wind Waves Exceeding 0.4m

Parameter	Estimated Value
Total Number of Waves	2400
Probability of Exceedance of Wave Height of 0.4m	13.5%
Number of Waves Exceeding the 0.4m Wave	324

E.4 REFERENCES

[D.1] **Faltinsen O M (1999)**. *"Sealoads on Ships and Offshore Structures".* Cambridge University Press, UK.

[D.2] **BHP Billiton (2009)**. "Coastal Processes Modelling*",* Olympic Dam Expansion Draft Environmental Statement , *Appendix O13*.