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Position Paper

Project Number: 279.01   Project Name: Karratha Back Beach Feasibility Study

Date: 16/12/2014   Doc Ref: P-279.01-1

Client: City of Karratha

Subject: **Preliminary Dredging Feasibility Study**

1 Introduction

The Back Beach boat ramp on Nickol Bay is a small craft facility servicing local recreational boaters in the Karratha area. The facility is maintained and administered by the City of Karratha (CoK), and consists of two ramps, static finger jetty and a groyne providing protection from prevailing wind and wave conditions from the west through north. Figure 1-1 shows the locality of Karratha Back Beach boat ramp.

Figure 1-1: Location of the site (GHD 2013)

The tidal window in which mariners area able to use the launching and retrieval facilities is limited. Breakwater reconfiguration works to be undertaken in the near future are expected to address excessive siltation within the facility, but even if the current +2.35 m CD design depth of the facility is maintainable (approximately equal depth to the surrounding tidal flat), the basin will remain unusable throughout much of the tidal cycle.

Rev	Issue	Prepared by	Submitted to	Date	Copies
A	Draft- Issued for Internal Review	Mahtab Moalemi	Jonathon McKay	11/12/14	1 elec
B	Draft- Second Review	JM	Tim Green	15/12/14	1 elec
0	Draft – Issued for Client Review	JM	Susan Batt (CoK)	16/12/14	1 PDF
1	Final – Issued for Use	JM	SB	23/12/14	1 PDF

CoK wishes to assess the feasibility of enabling greater access to the facility by deepening the ramp area and basin, dredging a navigable channel to deep water, upgrading the ramp jetties, and raising the staging area and car park to remain operable throughout a much greater tidal range. This Position Paper reports on Component 1 of the three component scope for which BMT JFA has been engaged to undertake, and presents a preliminary feasibility assessment of establishing a dredged channel to deeper water.

This Paper considers the following three key factors:

- The approximate level and quantity of rock within the proposed channel alignment
- Concept level cost estimate for dredging the volume of material required to be removed to established the proposed channel
- Environmental limitations of dredging the proposed channel.

The above considerations are limited, and further studies and assessment would be required to determine a sufficiently informed dredging design and works methodology if the project is to be further pursued. Recommended for further studies are also presented.

1.1 Information Collected

- BMT JFA commissioned Surrich Hydrographic to undertake a survey of the site which was carried out in mid-November 2014. This survey was effectively a simultaneous hydrographic bathymetry survey as well as geophysical Sub-Bottom Profile (SBP) survey. The results of this survey are presented in Appendix A.
- BMT Oceanica coordinated the collection of a number of surface sediment samples in the vicinity of the boat ramp, in order to undertake a preliminary assessment of the chemical and physical characteristics of the material to be dredged, as they relate to potential environmental impacts. The results of this study, which provides guidance as to further investigations that may be required and any likely limitations which have been detected at this early stage, can be found in Appendix B.

2 Concept Channel Design

2.1 Vertical Datum

The vertical Chart Datum (CD) adopted for this project is based upon an estimated Lowest Astronomical Tide (LAT) at the site. The adoption of estimated LAT for use as Chart Datum in marine works is standard industry practice, and enables designers, mariners and Contractors to easily understand how any given height in CD relates to its submergence characteristics as well as the present tide level at the site.

In lieu of historical water level measurement within the vicinity of the facility, the 2011 submergence curve produced by the Department of Transport for nearby Cape Lambert (Appendix C) is used to approximate the tidal characteristics of the site. This submergence curve is based upon measured water levels over a number of years, and is considered more conservative than the submergence curve of King Bay which has been used at the site previously. The Cape Lambert 2011 submergence curve is considered more conservative than that of King Bay as it has a greater tidal range, and is considered more appropriate for use at Back Beach as Nickol Bay is closer in distance over water to Cape Lambert than it is to King Bay.

In order to establish an approximate level for LAT at Back Beach, the relationship between Mean Sea Level and the Cape Lambert tidal range is used to transfer this submergence curve to Back Beach. As measured water level data is not available for Back Beach, the GDA Ellipsodal height of 0.0 m AHD at Back Beach is considered the best approximation available (as, theoretically, the AHD model approximates MSL throughout Australia). The same relationship between AHD and LAT at Cape Lambert is therefore adopted at Back Beach, resulting in a vertical datum which is 3.35 m below AHD at the site.

The Cape Lambert 2011 submergence curve is thus used in assessing the submergence characteristics of the Back Beach site. Care should be taken to differentiate between the vertical datum adopted for this project (and therefore used in all drawings produced during this project) and previously prepared drawings of facilities and surveys of the site which use a variety of different vertical datums. King Bay LAT, which appears to have been the datum used on some previous design drawings for the facility, is approximately 0.6 m higher than the Chart Datum (based on Cape Lambert LAT) being used for this project.

2.2 Basis of Design

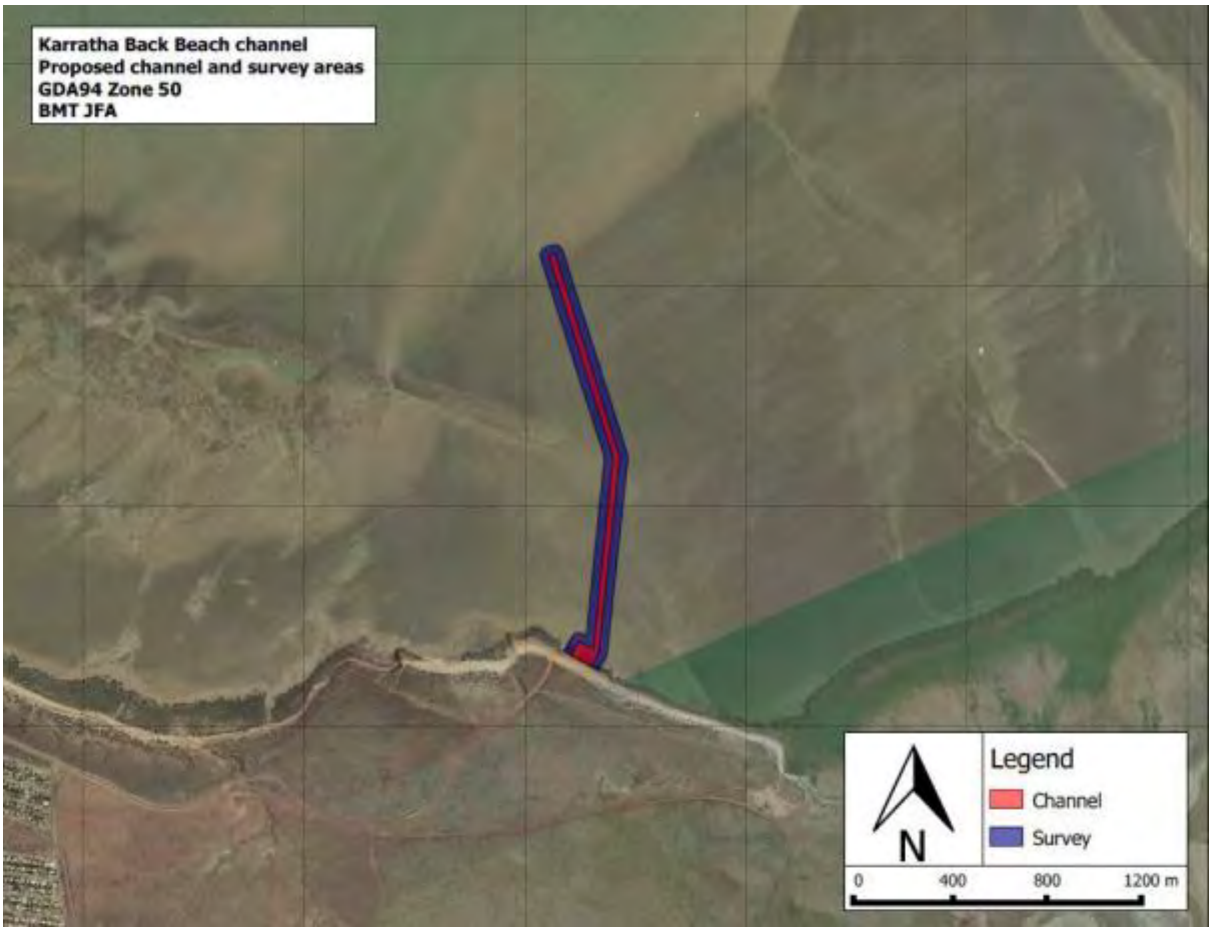

Figure 2-1: Concept channel layout

The concept channel design used in this feasibility assessment has been produced on the basis of the following key requirements and assumptions:

- *Channel alignment* – As no bathymetry data was available, historical aerial images were reviewed in order to estimate the shortest route to deep water that avoids visible signs of shallow outcropping rock. This alignment is shown in Figure 2-1, and represents a direct path to what visibly appears to be the end of the tidal flat (i,e. deep water) which bends mid-way to avoid a visible reef running parallel with the shore.
- *Channel width* – Section 3.1.2 of AS 3962 Australian Standard Guidelines for the Design of Marinas specifies minimum and preferred width of the lesser of 30m or six times the beam of vessels using the facility. 30m channel width is adopted as a conservative estimate, to provide ample width for two-way vessel traffic, navigation of the channel bend, and some allowance for siltation. This channel width could potentially be narrowed following future detailed channel design.
- *Channel Batter Slopes* – Batter slopes of 1:5 have been used for the purposes of this preliminary assessment, which is a batter slope typically specified for underwater channel slopes in unconsolidated material.
- *Channel Depth* – Following the receipt of breakwater design drawings, it was identified that the toe of the existing breakwater is likely to be founded at approximately +2.35 m CD. This means deepening of the facility adjacent to this breakwater to the full -1.0 m CD target depth desired by CoK would not be possible without substantial breakwater stabilisation works. It was agreed that the deepest depth that could feasibly be accommodated within the existing facility is +1.0 m CD. BMT JFA has therefore compared the feasibility of establishing a channel to +1.0 m CD and +1.7 m CD (an intermediate depth between +1.0 m CD and the +2.35 m CD design at present) in this Paper. Detailed channel design would still need to be undertaken to take into account specific site conditions and confirm breakwater stability at these depths.

2.3 Channel Availability

In order to assess improvements in channel availability for given increases in depth, a design vessel draft of 0.5 m is adopted, based on the vessel draft specified in Section 3.4.1 of the GHD 2013 report. Adding an allowance for 30cm under keel clearance (derived from Section 3.2.1 of AS 3962-2001), a total of 0.8 m of water is considered the requirement for vessel access. It should be noted that this selection of design draft and under keel clearance is preliminary and for the purpose of this desktop study only; these design parameters will be finalised during the detailed channel design phase of Component 2 of this project, should it proceed.

Using the Cape Lambert 2011 submergence curve (Figure 2-1):

- The present **+2.35 m CD** facility design depth requires a water level of +3.15 m CD, corresponding to a tidal availability of approximately **53%**
- A **+1.7 m CD** facility design depth requires a water level of +2.5 m CD, corresponding to a tidal availability of approximately **69%**
- A **+1.0 m CD** facility design depth requires a water level of +1.8 m CD, corresponding to a tidal availability of approximately **84%**

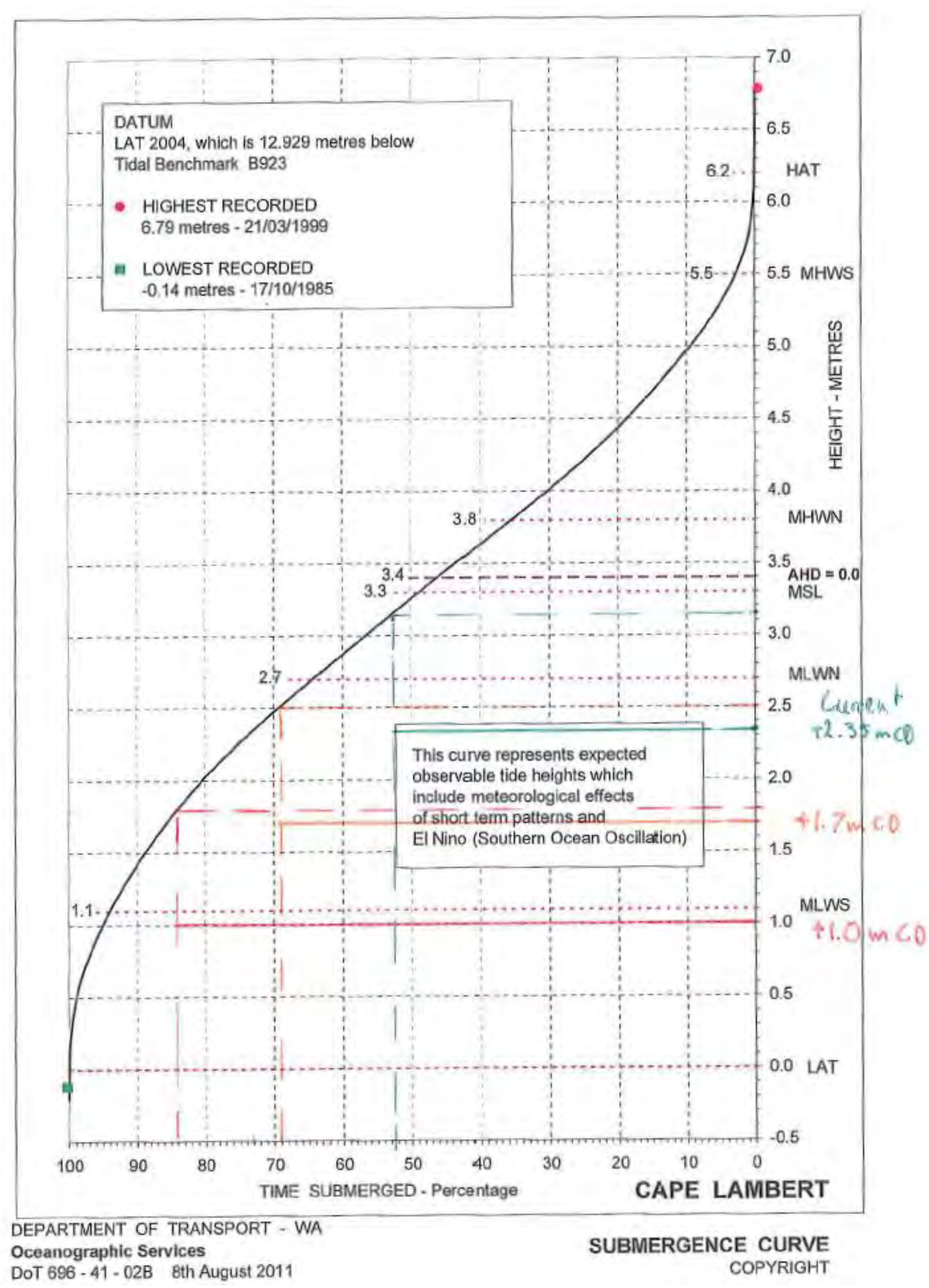

Figure 2-2: Submergence curve showing each depth considered (solid lines), with corresponding water level required for navigation (long dashed lines).

2.4 Siltation

Quantifying an estimate of channel siltation requires further hydrodynamic and sediment transport studies, which would be undertaken in Component 2 of this project should it proceed.

A previous report on siltation at the site (GHD 2013) discusses siltation rates within the breakwater area. The measured siltation rate within the breakwater area of 50mm/yr (2013a) is not directly applicable to a dredged channel, and is not considered representative of the true siltation rate as it does not take into account the removal of sediments during maintenance dredging/excavation at the boat ramp. A siltation rate of 50 mm/yr could therefore be considered a baseline ‘best case scenario’ for siltation in the channel.

Given the exposed location of the site, complete infilling of the channel during a cyclone event is considered a possibility, and is therefore used as a ‘worst case scenario’.

3 Dredging Scope

3.1 Rock Levels and Material to be Dredged

3.1.1 *Underlying Rock*

A bathymetric and geophysical survey of the channel route was undertaken by Surrich Hydrographics; an interpretive report for this survey can be found in Appendix A. This investigation identified the presence of underlying rock at varying levels along the channel route. This Sub-Bottom Profile (SBP) survey was able to detect the layer of harder material underlying the top sandy/silty layer at the site. The SBP was not able to differentiate between rock and coarse gravel layers in all areas, and therefore extensive ground probing was undertaken to verify the level of rock at areas of interest. Rock levels as shallow as +2.2 m CD were detected within the channel footprint.

Based on the interpreted results of the SBP survey and associated ground probing, drawings have been prepared showing the approximate surfaces of shallow rock relative to the two channel depths considered.

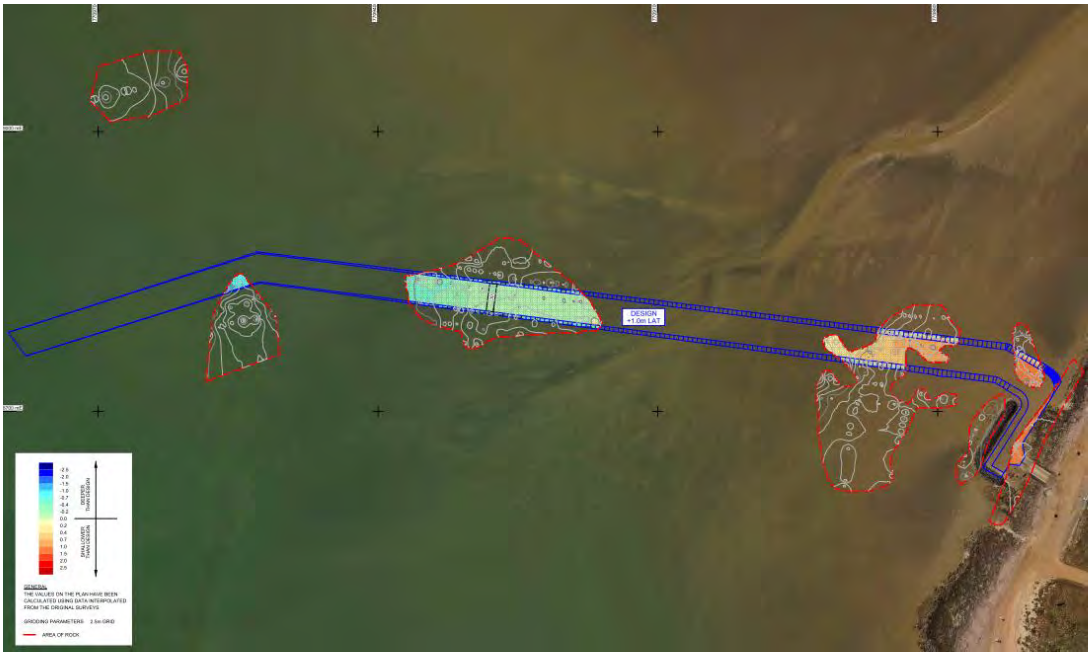

Figure 3-1: Location and depth of the rock layer below and above the design level (+1.0 m CD)

As can be seen on the attached drawings, nearly all shallow rock identified that would impact upon the channel route is within approximately 150m from the shore. It should be noted that due to the remote sensing nature of the rock survey undertaken, it does not provide 100% certainty of the true underlying rock surface below the seabed, nor does it make any assessment of the strength or 'dredgeability' of the rock. Further geotechnical investigation would be required before undertaking dredging to the depths outlined in this Paper.

3.1.2 *Material to be Dredged*

Based on results of the hydrographic survey undertaken by Surrich Hydrographics on 16 November 2014, the total volume of material required to be dredged is approximately 45,700m^3 to a design depth of +1.0m CD and 17,850m^3 to a design depth of +1.7m CD (both quantities include a 0.3 m overdredge allowance). These total volume estimates are presented in Table 3-1 below.

The volumes of underlying rock identified shallower than the design depths have been estimated and also presented in Table 3-1. Note that this rock would only require dredging during the initial capital dredging works, and would not need to be dredged during subsequent maintenance dredging campaigns.

Table 3-1: Volume of materials to be dredged (includes 0.3 m overdredge allowance)

Description	Design Depth	
	+1.0 m CD	+1.7 m CD
Total Dredging Volume (m^3)	**45,700**	**17,850**
Rock Volume (m^3)	5,920	1,763
Proportion of rock by volume	13%	10%

Based on site observations, the sediment near the boat ramp is generally very fine clayey sand which is largely unconsolidated. On the tidal flat, the sediment had a higher sand content and was firmer to walk on, with the occasional soft patch. The sediment on the tidal flat will have the fines removed through current and wave action, hence appearing firmer, while those same fines are then deposited in the lee of the breakwater.

Surrich Hydrographics undertook a test pit at the site, and reported on the nature of the unconsolidated materials within the dredging layer just outside the breakwater. At the time of writing no samples of this deeper layer had been laboratory tested, but they are reported to be typically fine grained sand with some coarser shell and gravel fragments in some layers. This material is typically dredgeable by most common items of dredging plant.

3.2 Dredging Method and Costs

3.2.1 *Dredging Equipment*

Two dredge types have been considered for the proposed works:

- A Backhoe Dredge (BHD) would likely be capable of dredging the consolidated material thought to be within the proposed dredge area; however a BHD will have a relatively slow production rate and may prove prohibitively slow and costly for such a large dredge area. A BHD may be able to continue working during perioids of low tide .A BHD would most likely require barges or similar to transport dredged material to the disposal location further adding to costs.

- A Cutter Suction Dredge (CSD) has a rotating mechanical cutting head which breaks up and loosens dredge material. This creates slurry which is retrieved by a suction pipe directly behind the cutting head. Dredged material is typically pumped in slurry along a pipeline to the disposal site.

A small Cutter Suction Dredge (CSD) has been used for the purposes of the cost estimates presented in this Paper, as it is considered most suited for this project at this stage for the following reasons:

- Rock dredging (depending on rock strength) is within the capability of a CSD
- A CSD would have a high production rate and would complete the works more quickly than a BHD
- Cutter Suction Dredge (CSD) is capable of pumping the dredged materials directly to the disposal location without barges etc being required
- A small CSD can typically be transported by road resulting in relatively affordable mobilisation rates.

A final decision on the preferred dredging equipment would be considered in Component 2 of this project should it proceed, and would be better informed by extra information on ground conditions on site and the anticipated time of the year in which the works would be proceeding.

A CSD in the “Small” size class (under 3,000kW total installed power) would have less rock cutting power than a larger CSD, however the shallow nature of the channel to be dredged would significantly limit the tidal windows within which large (deeper draft) plant could operate.

3.2.2 *Disposal site*

Selection of an appropriate disposal site is a decision that can strongly impact the general feasibility and cost of the entire project. Three alternatives are considered for disposal of dredged materials:

- Offshore disposal
- Onshore (land) disposal
- Side casting

Offshore disposal (i.e. outside the intertidal zone) would require a Sea Dumping Permit for the Commonwealth Department of Environment, which adds cost and typically requires at minimum six months to obtain.

Land disposal would involve the pumping of sediments ashore to a bunded area. This disposal method has the advantage of being able to reclaim land or build up the height of existing land, or alternatively material can be stockpiled or trucked off site for land disposal elsewhere. There are extra costs associated with management of the disposal site and material depending on the location selected.

Side casting onto the intertidal area is considered the most cost and time effective method to dispose the dredged material for this project. This would involve pumping of dredged material directly off to the side of the dredge area, disposing several hundred metres away from the channel. It is not anticipated that state government regulators would require a particular environmental approval to undertake this disposal method, however this would ultimately be dependent on the outcomes of further sediment sampling and an Environmental Impact Assessment undertaken in the next phase of works. Side casting has therefore been selected as the basis of the cost estimates presented in this Paper. If side casting is not possible, or reclamation onshore is desired, then land disposal is considered a feasible disposal option that could be investigated further.

3.2.3 *Key operational limitations*

The following key operational limitations have been identified for the proposed works:

- **Seastate/wind.** Seastate conditions have the propensity to significantly impact dredging works, resulting in significant downtime costs. The exposed nature of the site suggests that it would be susceptible to adverse wind-induced wave conditions. Analysis of wind and wave characteristics is not within the scope of this Paper, so an estimated allowance of 20% downtime for seastate conditions has been used. No safe harbour is within proximity to the site, so dredging works would need to be completed outside of the cyclone season.
- **Available working hours.** The large tidal range at the site limits the time within which the target channel depth will have sufficient water to enable to floating dredge to operate. The Contractor may be able to structure working hours around the available daily tidal windows, however for the purposes of this cost estimate it is assumed that paid standby costs will be applicable when the tide is too low for the dredge to work.

3.2.4 *Cost and Time Estimate*

A preliminary cost and time estimate for undertaking the proposed dredging work has been prepared for each design depth using the approximate volumes presented in Table 3-1. Rates have been based on the rates from recent projects using similar equipment in the region with which BMT JFA has had involvement. The estimates consider the following costs:

- Mobilisation and demobilisation of plant from Perth
- Typical preliminaries, overheads, site establishment
- Dredging and disposal works (assuming 82 m^3/hr unconsolidated material production rate)
- Paid standby during tide levels too low to work (assuming 1 m water depth required to operate and assuming full overdredge depth achieved) resulting in
  - 88% tidal dredging availability at +1.0 m CD design depth
  - 72% tidal dredging availability at +1.7 m CD design depth
- Paid standby for weather/seastate conditions (assumed 20% of operating time)

Given the very preliminary nature of the estimate, a 25% contingency allowance has been provisioned to cover unforeseen circumstances, variations in rates, etc.

Time and cost estimates for the proposed dredging work using a small CSD are presented in Table 3-2. Note that 0.3m over dredge has been included in the volumes for both dredging depths.

Table 3-2: Cost estimate for undertaking proposed dredging of loose materials. All amounts are based on a total volume including 0.3 m overdredge allowance. All figures exclusive of GST.

Parameter	Rate	Qty		App. Amount	
		Design depth: 1.0 m	Design depth:1.7 m	Design depth: 1.0 m	Design depth:1.7 m
Mobilisation	$125,000	1		$125,000	
Preliminaries, Insurances	$4,400	1		$4,400	
Demobilisation	$110,000	1		$110,000	
Dredging works	$897	557 hrs	218 hrs	$500,000	$195,000
Seastate down time + standby time (tidal condition)	$612	178 hrs	105 hrs	$109,000	$64,000
			Total	$850,000	$500,000
			15% engineering & environmental management	$127,000	$75,000
			25% contingency	$212,000	$125,000
			TOTAL ESTIMATE	$1,187,000	$700,000

The results presented in Table 3-2 show that dredging a channel to design depth of +1.0 m CD will cost in the order of $1.1M for a relative 58% increase in facility availability for vessels. Dredging a channel to design depth of +1.7 m CD has a cost in the order of $650K for a relative 30% increase in facility availability for vessels.

As noted in Section 2.2, there may be scope to further reduce the width of the channel following the detailed channel design study. If the AS 3962 minimum channel width of 20m was able to be adopted, a corresponding reduction in channel volumes (and dredging costs) would be expected. An approximation of these cost differences is presented in Table 3-3.

Table 3-3: Cost estimate for undertaking proposed dredging of loose material for different channel width.

	Dredging depth of +1.0m CD		Dredging depth of +1.7m CD	
Channel width	Approximate Vol	Cost	Approximate Vol	Cost
30m	45,700	$1,187,000	17,850	$700,000
20m	34,000	$967,000	15,000	$636,000

Note that these cost estimates are representative of dredging *unconsolidated sediments* (i.e. not rock), and are what could be expected during a maintenance dredging campaign to restore the channel to depth. The extra cost of dredging the portion of material in the dredge volume that is rock must be considered for the initial capital dredging works. This extra cost could be highly variable depending on the properties of the rock, and in lieu of this specific site information, quantifying these costs is not possible at this stage of the project.

As a guide, if the rock encountered is considered 'dredgeable' and it takes three times as long to dredge rock than other sediments, this results in an extra ~$130K to dredge the rock in the channel to +1.0 m CD, compared to an extra ~$40K to dredge to +1.7 m CD. *These figures are not based on any specific information,* could be considered a 'best case scenario' for rock dredging and are included for discussion only. Further geotechnical investigations may determine that the rock is not 'dredgeable' or prohibitively expensive.

3.2.5 *Maintenance Costs*

For the comparison of dredging costs, the cost of re-dredging the entire channel volume is considered. The 'best case scenario' siltation rate of 50 mm/yr corresponds to the channel requiring re-dredging every 20 years for +1.7 m CD depth, and re-dredging every 34 years for +1.0 m CD depth. The corresponds to a 'best case scenario' of $28,000 - $35,000 average annual maintenance costs, and a 'worst case scenario' (i.e. annually) of $600,000 - $1.2M average annual maintenance costs.

This can be better defined during siltation assessment undertaken in Component 2 of this project, but it is expected that the true figure would lie somewhere in between these numbers and is likely to vary from year to year.

3.3 Environmental Considerations

A preliminary study undertaken by BMT Oceanica presents the findings of initial site sediment sampling and analysis in the vicinity of the boat ramp (Appendix B). This memorandum includes preliminary interpretations of the laboratory results and recommendations for the Component 2 sediment sampling and analysis and environmental impact assessment are also presented.

Five sediment sampling collection points were investigated. Sediments sampled within the Boat Ramp area were dominated by clay and silt sized particles and consequently had relatively long settling times. The samples collected were all surface samples, within the silty boat ramp basin, and coarser sediments are expected outside of this area where the majority of the dredging volume exists. Therefore, turbidity generation will need to be considered but is expected to be manageable.

On visual inspection sediments at three sites contained black particles; however the total organic carbon concentrations of the sediments were relatively low. Testing for acid sulfact soils is recommended, and if potential for acid sulphate soils is detected then monitoring and management measures would likely need to be implemented.

The contaminants tested (metals, organotins and hydrocarbons) were all below the relevant guideline levels with some exceptions. Elevated levels of Nickel and Chromium were detected, meaning that further testing is required to investigate their potential impacts on water quality, and monitoring measure could be required.

The preliminary sampling and analysis of sediments does not suggest that there will be any cost-prohibitive environmental implications for the project, however this would be further refined during the Environmental Impact Assessment phased of Component 2 of this project should it proceed.

4 Conclusions

Between 15,000 m^3 and 46,000m^3 of material would need to be dredged to establish the channels considered in this assessment. Capital and maintenance costs are still considered variable and dependant primarily on rock properties and expected siltation rates.

4.1.1 *Findings*

The estimates provided in this paper are concept (order of magnitude) level only, and need to be considered carefully in light of a number of assumptions made. The key findings of this paper are summarized below:

- Underlying rock levels along the channel alignment at the site have been detected as high as +2.2 m CD, however levels are variable along the channel route
- Dredging a channel to a depth that avoids all rock would offer very little navigational benefit relative to the capital costs of mobilising equipment, etc
- A channel dredged to a design depth of +1.0 m CD would require 34,000 – 46,000 m^3 to be dredged, of which approximately 13% is rock.
- A channel dredged to a design depth of +1.7 m CD would require 15,000 – 18,000 m^3 to be dredged, of which approximately 10% is rock.
- The dredging works are considered best suited to a small Cutter Suction Dredge, with side casting of material on to the adjacent tidal flat the most cost effective disposal option.
- Dredging a channel to design depth +1.0 m CD would be expected to cost in the order of \$1.0M – \$1.2M for a relative 58% increase in tidal availability for vessels using the facility.
- Dredging a channel to design depth +1.7 m CD would be expected to cost in the order of \$600,000 – \$700,000 for a relative 30% increase in tidal availability for vessels using the facility.
- The cost for dredging the rock within the channel alignments has not been estimated. This rock may or may not be dredgeable. If weakly consolidated, it may be feasible to establish a channel at this depth however a geotechnical investigation is required to pursue this further. If small volumes of rock near to the shore are not dredgeable, using a land based rock breaking excavator may be feasible.
- The dredging campaign to establish the channel discussed could range from 8 to 22 weeks depending on depth selected, channel dimensions and material encountered.
- Total cost and time of the capital dredging works (the first dredging campaign) is highly dependent on geotechnical properties of the rock layer (i.e. density, strength, permeability). Without further geotechnical information more accurate cost and time estimation is not possible.
- Maintenance dredging of the channel could be required as frequently as annually, or as infrequently as every 34 years (for +1.0 m CD channel). This corresponds to an annual average maintenance cost of \$28,000 - \$1.2M depending on the siltation rate in the channel. Costs would be expected to be toward the upper end of this range and may vary from year to year.

4.1.2 *Recommendations*

- The further feasibility studies and assessments that consist of Component 2 of this project should be undertaken if the establishment of this channel is to be pursued further
- A geotechnical investigation to assess rock properties should be undertaken, as dredging will require the removal of some rock. A simple test pit investigation may be suitable to collect samples of the rock surface to determine its properties.
- Further environmental sampling in addition to that already planned for Component 2 should be completed to investigate potential for acid sulphate soils and particular samples be re-tested for elutriate nickel, chromium III and chromium VI to better assess potential environmental impacts.

5 References

GHD (2013) Karratha Back Beach Boat Ramp Study – Concept Options Report, January 2014.

DRAWINGS

APPENDIX A:
KARRATHA BACK BEACH SURVEY REPORT

Surrich Hydrographics

KARRATHA BACK BEACH

GEOPHYSICAL SURVEY REPORT

For

BMT JFA Consultants

SURRICH HYDROGRAPHICS JOB NO. SH20141006

Client:	BMT JFA Consultants Level 3, 20 Parkland Rd, Osborne Park Perth WA 6017 Australia
Date:	November 2014

REVISION HISTORY				
REV	DATE	REVISION DESCRIPTION	BY	APPROVED
A	25/11/2014	Issued for client comment	AMR	JA
B	27/11/2014	Issued for client comment	AMR	JA
C	30/11/2014	Geophysics added to report	JA	AMR
D	13/12/14	Final after client review	JA	AMR

DISTRIBUTION LIST	
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 ABBREVIATIONS

The following abbreviations may be used in this document

AHD	Australian Height Datum
BM	Bench Mark
CD	Chart Datum
C-O	Calculated Minus Observed
DGPS	Differential Global Positioning System
GDA94	Geocentric Datum of Australia 1994
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS80	Geodetic Reference
HAT	Highest Astronomical Tide
HDOP	Horizontal Dilution of Precision
IHO	International Hydrographic Organisation
ITRF	International Terrestrial Reference Frame
kHz	Kilohertz
LAT	Lowest Astronomical Tide
MBES	Multi Beam Echo Sounder
MGA	Map Grid of Australia
MRU	Motion Reference Unit
MSL	Mean Sea Level
PDOP	Position Dilution of Precision
COG	Centre of Gravity
IMU	Inertial Motion Unit
HIPS	Hydrographic Processing Software
POSMV	Position Orientation System for Marine Vessel
PPK	Post Processed Kinematic
RINEX	Receiver Independent Exchange Format
RTK GPS	Real Time Kinematic Global Positioning System
SBES	Single Beam Echo Sounder
SSM	Standard Survey Mark
SBP	Sub Bottom Profiler
TBM	Tidal Bench Mark / Temporary Benchmark
THU	Total Horizontal Uncertainty
TPU	Total Propagated Uncertainty
TVU	Total Vertical Uncertainty
UPS	Uninterruptible Power Supply
UTM	Universal Transverse Mercator
VDOP	Vertical Dilution of Precision
WA	Western Australia
WGS84	World Geodetic System of 1984

Table 1. Abbreviations

2 REFERENCE

a. Geoscience Australia – www.ga.gov.au

b. IHO Special Publication 44 (Version 5)

c. Manual On Hydrography Publication C-13

d. Guidelines for the Planning, Execution and Management of Hydrographic Surveys in Ports and Harbours, FIG Commission 4, Working Group Hydrographic Surveying in Practice.

3 INTRODUCTION

Surrich was contracted by BMT JFA to provide a bathymetric and geophysical survey of an area adjacent to the existing boat ramp at Karratha Back Beach.

Access to the ramp is severely limited to mid-tides and above.

The aim of the survey is to provide information to assist the analysis of various channel dredging scenarios.

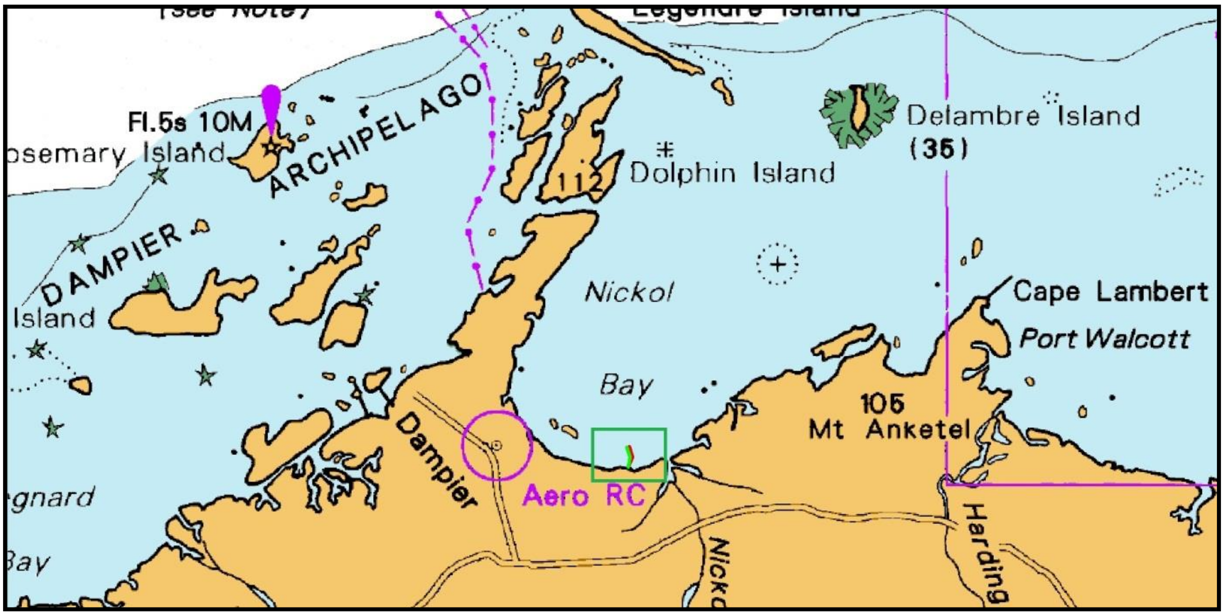


Figure 1. Location Diagram

4 METHODOLOGY

The scope of work and nature of the seabed made single beam echo-soundings an effective choice for the bathymetry.

Two sub bottom profiling (SBP) systems were considered for this work:

1. Pinger type system offering high resolution but lower penetration energy.
2. Boomer type system offering higher penetration energy but lower resolution.

The pinger type 'Innomar SES-2000 Compact' instrument was chosen for the following reasons:

- Penetration. Although the SES-2000 has less penetration than a boomer, the required depth of investigation is estimate to be no more than 4m.
- Vertical resolution. The seabed response from a typical boomer system spans a vertical distance about 1 to 1.5 metres in the SBP profile, effectively masking shallow layers in this range below the seabed. The seabed response from the SES-2000 is only ~35cm at 12kHz making it more suitable for shallow investigations.
- High positional accuracy (the unit is mounted below the GPS antenna as opposed to a boomer which is towed behind the vessel and GPS antenna.
- High ping rates 15-20 pings per second for the SES-2000 compared to 0.3 pings per second for a boomer system.
- Ability to acquired accurate SBES and SBP from the SES-2000 simultaneously.

On commencement of work, the main and proposed alignments were to be surveyed, and the alignment which became deeper quicker was to be surveyed in detail.

5 OPERATIONS

5.1 SURVEY PERSONNEL

The survey was conducted by the following personnel:

- Andrew Richardson; senior hydrographic surveyor/ party chief
- Justin Anning; operator/geophysicist

5.2 SUMMARY OF OPERATIONS

The following is a summary of operations conducted for the Karratha back beach survey

Activity	Dates
A. Richardson and J. Anning arrive in Port Hedland	12th November 2014
Mobilise vessel	12th November 2014
Establish RTK base station at Karratha HRE 109A	13th November 2014
Commence calibration and equipment testing onsite	13th November 2014
Carry out ground truth probing over survey Area	15th November 2014
Carry out survey	16th November 2014
Demobilise vessel and depart back to Port Hedland	16th November 2014
Depart Port Hedland back to Perth	17th November 2014
J Anning departs Perth to Karratha	21st November 2014
Further ground truthing probes carried out over survey site	22nd November 2014
J. Anning departs Karratha back Perth	23rd November 2014

Table 2. Key dates

5.3 INCIDENTS

No incidents to report

6 EQUIPMENT

6.1.1 VESSEL

The following is a list of equipment installed on the vessel

- Innomar SES-2000 compact parametric sub bottom profiler (SBP), with a 4° beam width.
- Acquisition PC' s
- Valeport mini SVP
- Trimble SPS851 with internal radio

6.1.2 RTK BASE STATION

Survey critical components of the RTK Base Station established on the rear lead tower in Port Hedland.

- Trimble SPS851 with internal radio
- 1 x Zephyr Geodetic Antenna Model 2

6.1.3 SOFTWARE

Survey critical software and version number in use:

- PDS2000 Version 3.8.1.0
- Valeport DataLog Express SVP Software

6.1.4 VESSEL

Cervan vessel 'Polki'

Figure 2. Survey vessel

7 POSITIONING AND DATUM

7.1 HORIZONTAL CONTROL

Final horizontal control for the survey was GDA 94, the base station transmitted corrections in GDA94.

Parameter	Value
Datum	GDA 94
Ellipsoid	GRS 80
Projection	Transverse Mercator
Latitude of Origin	0° N
Longitude of origin	117° 00'E
False Easting	500000.00
False Northing	10000000.00
Scale Factor	0.9996

Table 3. GDA 94 parameters

7.2 VERTICAL CONTROL

As per client request all depths from the sounder were relative to chart datum (CD), which is defined by estimation of the lowest astronomical tide (LAT) at the site. This is derived applying the same AHD/MSL and LAT separation at tidal Bench mark BM B923 located at Cape Lambert.

Fixing the AHD/MSL plane from Cape Lambert to the base station bench mark HRE 109A gives a separation of 10.399m between the GDA ellipsoid and LAT, compared to 9.34 at Cape Lambert.

8 BATHYMETRY SURVEY

8.1 SURVEY CHECKS

8.1.1 RTK POSITION CHECK

A GPS base station was established at HRE 109A in Karratha. The base transmitted corrections via radio for real time position and height corrections.

Position and height checks were conducted with an independent RTK on a local mark in Karratha. See **Appendix A** for the base Station setup worksheet.

To confirm validity of the Roving GPS antennae on the vessel and the validity of the base station HRE 109A a series of checks were carried out. Checks on HRE 108 were carried out prior to commencement of the survey. All checks were within tolerance.

GDA94 MGA50					
HRE 108 E	HRE 108 N	RTK Rover E	RTK Rover N	E Diff	N Diff
486507.200	7708335.496	486507.2098	7708335.496	0.010	0.000

Table 4. RTK position check on HRE 108, 13/11/2014

GDA94 MGA50		
HRE 108	RTK Rover	Diff
10.395m	10.3982	0.003m

Table 5. RTK height check on HRE 108, 13/11/2014

HRE 109A validity was also checked using AUSPOS. A Total of 21 hours of raw observed RINEX data was used to derive the solution. The AUSPOS report for HRE 109A is contained in **Appendix C** and a summary detailed below.

GDA94 MGA50					
HRE 109A E	HRE 109A N	AUSPOS E	AUSPOS N	E Diff	N Diff
488035.909	7708595.001	488035.927	7708594.991	-0.018	0.010

Table 6. AUSPOS position check on HRE 109A, 15/11/2014

GDA94 MGA50		
HRE 109A	AUSPOS	Diff
7.928m	7.908m	0.020m

Table 7. AUSPOS height check on HRE 109A, 15/11/2014

Figure 3. SSM HRE 109A

Figure 4. SSM HRE 108

8.1.2 HEADING CHECK

The vessel antenna was located directly over the single beam sonar head negating the need for a heading device.

8.1.3 SINGLE BEAM BAR CHECK

The single beam was checked using a plate suspended by graduated wire below the Transducer head.

An initial bar check was conducted on the SBES as a standalone system to check the operation of the system

Bar check depth	ES raw	Draft	ES draft corrected	Difference
1.00m	0.64	0.38	1.02	-0.02m
1.50m	1.10	0.38	1.48	-0.02m

Table 8. SBES bar check

8.1.4 LEAD LINE

A steel weight was tied to a graduated rope and the distance from a fixed known point on the vessel to the seabed was measured. Results of this observation are below.

There was almost no tide movement at the time of the check and the seabed was very flat.

The average of all the observations were used in the final check calculations

7 Readings from the top of the SES-2000 pole to the seabed were taken the average of these observations was 4.07m

Distance from the top of the pole to the phase centre of the GPS was 1.23m

The average offset z position of the of the SBP in the PDS2000 software log files was 2.38m

Distance from the SBP acoustic centre to the GPS Phase Centre (PC) was measure to be 2.299

The LAT height of the top of the SES-2000 pole was 4.508m LAT.

Derived by using the calculation: 3.439(LAT of SBP) + 2.299(Distance from SBP to GPS PC) – 1.23 (Distance from GPS PC to Top of Pole) = 4.508

Calculated LAT depth = 4.508 (LAT of top of pole) – 4.07 (Distance from top of pole to seabed)

= 0.438m

Actual measure depth = 0.359

A misclose of 0.079m was record

This figure was within tolerance for the project but not ideal. Further refinement of the method will be undertaken before next carried out.

This check was coupled with a further check comparing the RTK heights of the seabed when the tide was out with bathy points that lay close to the RTK records. Results of this are in the next section.

8.1.5 RTK TOPO CHECK AGAINST BATHYMETRY RECORDS

A total of 7 records were acquired out on the seabed when the tide was out.

Results are detailed below.

	Topo point LAT				Closest adjacent point on bathymetry		
	Easting	Northing	Z LAT		Easting	Northing	Z LAT
1	488639.25	7708768.37	2.38		488638.40	7708771.80	2.35
2	488666.40	7708771.13	2.36		488662.50	7708769.50	2.34
3	488691.49	7708763.16	2.36		488695.50	7708762.80	2.31
4	488729.86	7708795.92	2.28		488739.50	7708792.80	2.27
5	488754.00	7708844.98	2.25		488742.60	7708845.70	2.21
6	488769.71	7708892.54	2.19		488770.50	7708892.60	2.15
7	488764.88	7708920.96	2.16		488756.50	7708920.40	2.11

Table 9. Topo check compared to bathy

Below details the distance each check point was from the actual bathy data.

Average misclose between these checks point is 0.04m. This provides good evidence that the bathy records are reliable.

	Check point distance from bathy		Bathy LAT depth misclose
	Easting	Northing	Z misclose
	0.85	-3.43	0.03
	3.90	1.63	0.02
	-4.02	0.36	0.05
	-9.64	3.12	0.01
	11.40	-0.72	0.04
	-0.79	-0.06	0.04
	8.38	0.56	0.05
Average	1.44	0.21	0.04
Standard dev	6.67	1.88	0.01

Table 10. Topo - bathy comparison results

8.2 DATA PROCESSING

All bathymetry data was logged in the PDS2000 acquisition package and logged in the .raw proprietary format. This data was then processed inside the PDS2000 software.

All noise data was methodically removed and checked with the Echogram data to ensure no points erroneously removed. The steps below detail the complete processing flow

- Review and edit PDS2000 log file
- Use RTK Tide method
- Apply heave correction
- Clean soundings
- Create grid of data in PDS
- Grid using Grid Model application.
- Bin Size 1m
- Look for any major anomalies that may need addressing
- Create chart in Plot application in PDS2000
- Use Mean dataset for chart representation
- Export final gridded data using mean dataset for client use

8.3 DATA QC

Data quality control was conducted by Andrew Richardson upon completion of processing.

All soundings were cleaned and each line compared to the Sonar echogram to ensure the bottom trace was accurately determining the seabed.

Cross-lines were carried out over the whole survey area, all lines correlated very well with the main survey lines. Results of this analysis is further explained in section 9.

All positions were filtered to ensure only those that had RTK fixed GPS codes were used in the representation of the bathymetry. This is of particular importance as the depths rely heavily on the on the GPS altitude.

8.4 VERTICAL UNCERTAINTY

8.4.1 STATISTICAL UNCERTAINTY

Total Vertical Uncertainty for the survey can be determined using a statistical analysis of the acquired data to show the repeatability of the data.

To further validate the RTK tide corrected bathymetric data cross lines were carried out the whole survey area. Results of this analysis are detailed below .

Average depth difference between cross-lines and mainlines	0.012m
Standard deviation of the depth difference between cross-lines and mainlines	0.025m

Table 11. Bathymetric data cross line analysis

8.5 HORIZONTAL UNCERTAINTY

8.5.1 THEORETICAL UNCERTAINTY

An assessment of the Total Horizontal Uncertainty can be determined by combining the errors of survey systems that directly affect the measurement of the position of each sounding. The errors associated with this survey have been assessed and are included at **Appendix B**.

The Innomar SES-2000 compact transducer has a beam width of 4° and in 3m of water (max raw sounder depth encountered on site) equating to a 0.210m diameter beam footprint. This makes up the bulk of the horizontal uncertainty. This figure is seen in the TPU sheet in **Appendix B**.

All single beam records have been beam steered to account for the roll of the vessel during operations. This correction angles the beams in the direction of the roll therefore positioning the data record closer to its actual position.

8.5.2 STATISTICAL UNCERTAINTY

As this is a single beam survey, performing a statistical analysis of the horizontal uncertainty in limited. RTK position checks will make up the majority of the horizontal check for uncertainty. Throughout the survey the GPS remained positioned directly over the sonar head; this removed the effects of heading change.

9 SUB BOTTOM PROFILING

9.1 SES-2000 ACQUISITION SETTINGS

- Configured for simultaneous acquisition of 5kHz and 12kHz.
- Heave corrected.
- Ping rate was configured to maximum. The 12kHz data used in the interpretation has a station spacing of approximately 10cm.

9.2 DATA PROCESSING

- The 5kHz and 12kHz low frequency data are pre-processed by the manufacturers software.
- Data converted to segy format.
- Data loaded into Cheaspeak Technologies Sonarwiz software
- The seabed bottom track is derived.
- A vertical gain function is applied.
- A light horizontal 3-trace averaging filter is applied.
- On initial analysis it was decided to utilize the higher resolution 12kHz data. The 5kHz data gave no extra penetration in the area of interest.
- SBP profiles are visualized in 3D against the processed bathymetry to ensure correct heights are applied (QC check).
- Sediment probe results loaded into the Sonarwiz database.
- Geological model is created/interpreted.
- 1st reflector picked and exported to csv file.
- Rock boundaries picked and exported to dxf file.
- 1st reflector grid created and the interpreted rock sections extracted as grids.
- 1st reflector and rock grids visualized in 3D against the SBP and bathymetry to ensure correct heights are applied (QC check).

9.3 SEDIMENT PROBES AND RESULTS

A 10mm rod with a rounded end and a heavy duty tee-piece welded on was utilized to probe the seabed at low tide to assist developing the geological model. The tee-piece allowed the rod to be hammered in through the gravelly layers. The rod could reach a maximum depth of 2.3m from the rounded tip to the tee-piece.

At low tide the seabed is typically hard enough to walk on, the exception being inside the groyne area and the immediate entrance to the groyne and to the north for 50m where vessels have disturbed the seabed creating very soft sediments in which a person typically sinks down 50cm.

Figure 5. Sediment probe and hammer

A typical probe was performed as follows.

1. Press the rod into the soft surface silts by hand until the first resistance is felt. Note the depth to the base of the soft material.
2. Manually ram or hammer through the harder material. This harder material typically extends continuously or in closely spaced layers until either a positive rock intercept was made (logged as 'rock'), or the resistance is too great to continue, upon which the final depth would be noted and the unit below the soft silt logged as 'hard unconsolidated'. 'Resistance too great to continue' means avoiding damage to probe from repeated hammering with little gain in depth.

The hard material (not rock) encountered beneath the soft silt layer is considered to be unconsolidated gravels in a silt matrix as identified in a sample recovered by digging.

Rock was mostly identifiable as an extremely hard 'ringing' cap-rock like surface when impacted with the probe, and no further penetration after repeated hammering. It is possible that a boulder floating in the unconsolidated gravels may be misidentified as rock, therefor it is required that many probes be performed to reduce the effect of spurious logs on the interpretation.

Probes were performed along a SBP traverse in the N-S direction, and along one of the tie lines in an E-W direction.

9.4 SEDIMENT SAMPLING

At MGA 488696E 7708769N, a hole was dug to investigate the nature of the 'hard unconsolidated' layer as identified in the sediment probing. Samples of the upper soft silt layer (20-30cm deep) and underlying harder layer (50-60cm deep) were also collected for the client.

The figure below shows the sample from the 'hard unconsolidated' layer after being washed of the silty matrix (estimated 50% matrix in this sample). It consists of sub-angular gravels and shell fragments, as well as larger sub-angular cobbles and unbroken shells. There was no evidence of cementation in this location and the hardness encountered during probing is due to the gravelly material.

Figure 6. Remaining material after washing out the silt from the "hard unconsolidated" layer

9.5 DISCUSSION OF RESULTS

Only the 12kHz SBP data was used in the interpretation. The lower resolution 5kHz data did not have any greater penetration through the strongly attenuating first reflector. The 5khz data did show greater penetration towards the seaward end of the grid, however this information was outside the scope of this survey. It does suggest the nature of the first reflector is becoming less 'gravelly' and therefore less attenuating with increasing distance from the coast.

In the following figures, vertical scale is positive down. Datum is LAT. Horizontal scale is metres and numbers are increasing to the North (to seaward). Data displayed by “pings” resulting in some distortion of the horizontal scale.

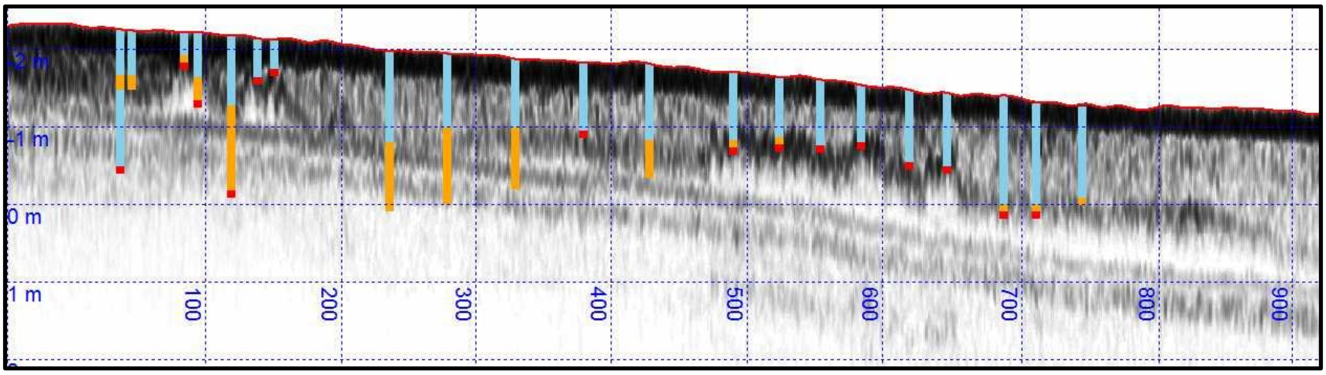


Figure 7. Section of the N-S traverse immediately east of the centreline, with probe results.

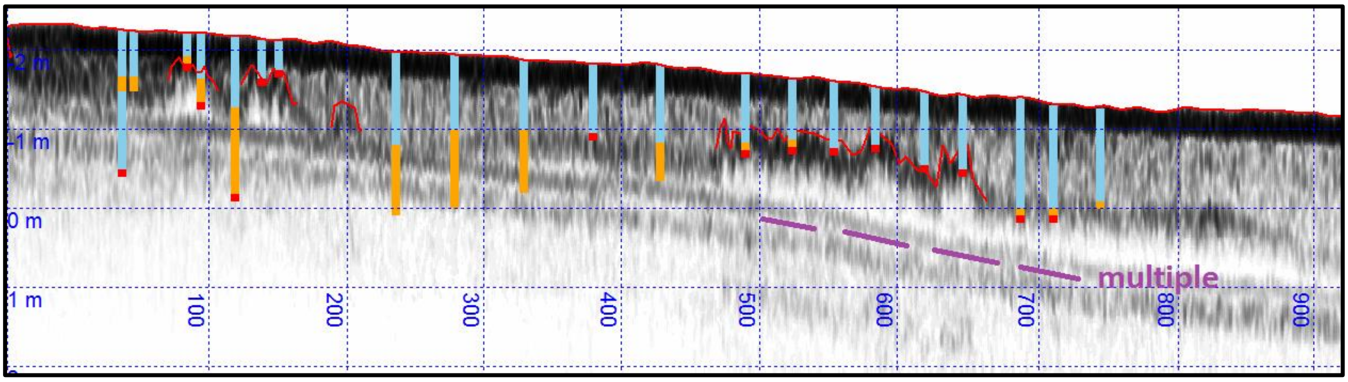


Figure 8. As previous image but with digitized rock interpretation (red line).

The SBP data merged with the probe data in the figures above, shows the following basic features:

1. Reflection from the seabed (top dark layer)
2. A single main subsurface reflector which either represents:
   a. The gravel layer
   b. Rock
3. The seabed multiple <u>not to be confused with a true sub-surface reflector</u>. This is (simplistically) identified as 2 feint dark parallel bands which are ~2x the water depth during acquisition. Be aware there are other features associated with the multiple.

In addition to the masking effect of the seabed multiple, there is poor penetration below the main reflector and it is <u>not possible to identify the rock layer beneath this reflector</u>, even though it may exist. Gravels are recognized as being a strong attenuator of SBP signal.

The two probes at approximately 690m and 710m in the previous figure were field logged as terminating in rock; however they have now been interpreted as ending in gravels. The field notes show indecision deciding to log these as ‘hard unconsolidated’ or ‘rock’. Because the reflector is quite flat and diffuse it is strongly considered to represent the unconsolidated gravels which have undergone extra compaction because of their depth compared with their shallower counterparts.

The figure below shows the shoreline at approximately mid tide. It is possible the buried rock surfaces being mapped would have previously been through a similar weathering process as the present shoreline shown in the photo, including infilling of the cavities with sediment and reef building processes.

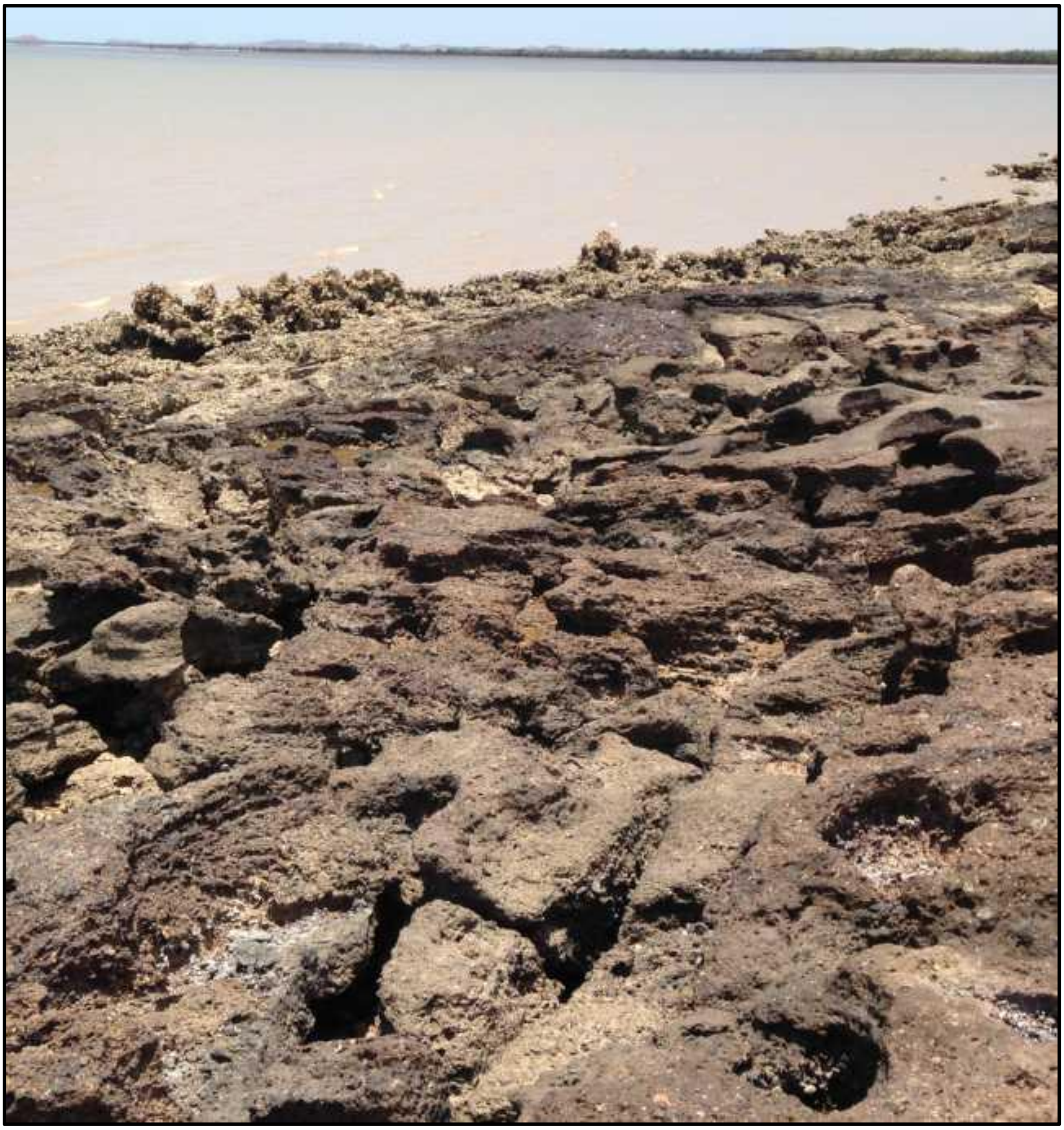


Figure 9. Shoreline adjacent to survey area

In the following figure, vertical scale is positive down. Datum = LAT. Horizontal scale is metres and numbers are increasing to the East.

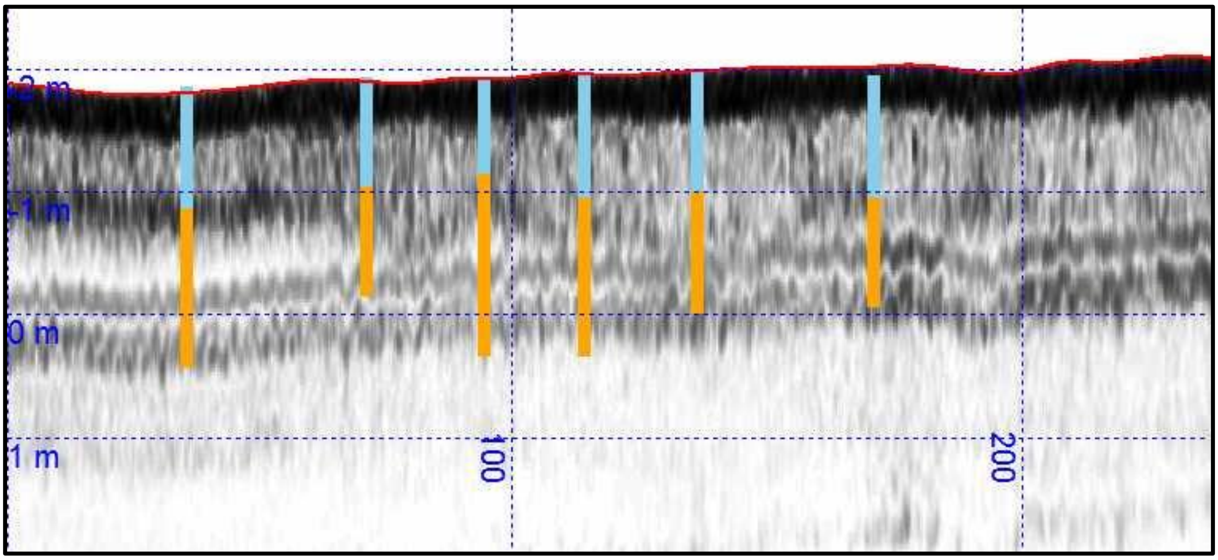


Figure 10. Section of an W-E tie-line, with probe results.

A series of probes were performed along one of the EW tie lines which showed a variable first reflector surface (Figure XX). According to the model being defined, this reflector does not have the attributes of rock. The probes were performed to confirm this and gain a better understanding of the non-rock first reflector.

These probes confirmed that the hard gravels may be well defined or poorly defined by the SBP. The well defined gravels with a relatively strong reflector are flat lying, unlike the rock surface which is undulating. The poorly defined gravels also show an undulating surface, however unlike rock, the reflector is very weak and the gravels are interpreted as being disturbed, for example reworked by a drainage channel.

9.6 MODEL SUMMARY

Silt	Silt layer extends from the seabed down to the gravel layer or rock. Sound Velocity 1900m/s
Unconsolidated gravels in a silt matrix	Generally a weaker reflector than rock. Where it is a relatively strong reflector, it is because of a well defined flat surface (unlike the rough rock signature). Where the reflector undulates it also becomes very weak (unlike the rock signature) as a result of its surface being ill defined, possibly through being reworked. Sound velocity used for processing is not applicable as no reflectors require depth corrections below this layer.
Rock	Strong reflector with a rough surface which undulates over a 0.5m range where it exists above the gravel layer. Appears to be a terraced landform, with upper surfaces becoming progressively deeper towards seaward. May represent a significant rock unit or a caprock of unknown thickness. The SBP had no penetration below the gravel layer, so the depth of rock beneath the gravel layer is unknown. Probing suggests the rock is certainly capable of dropping off to 1m below its upper surfaces within 10's of meters horizontally, however it is no known if the elevation changes are undulating or in steps.

Table 12. Summary of the geological-geophysical model units

9.7 DIGITIZATION OF REFLECTORS

The first reflector was digitized from the SBP. The elevation grid of this surface is shown in figure 11a below. This represents the limit of penetration of the SBP in this environment. The first reflector may represent either the rock or gravel layer interface buried beneath soft unconsolidated silts. The reflector was exported as a text file and extra observations were appended to the file where there was no SBP data, but manual probing had provided extra information for the depth to rock. The surface was then gridded and the file name is referred to as the 'first reflector'.

Rock was also digitized from the SBP and boundaries drawn around the rock in plan view, separating them into 6 areas denoted A to G. Be aware these boundaries are interpretative.

The areas were then extracted from the 'first reflector' grid resulting in a separate grid for each rock area A to G. Figure 11b shows the extracted 'rock' grids from the 'first reflector' grid, with the height in brackets representing the highest elevation of the surface.

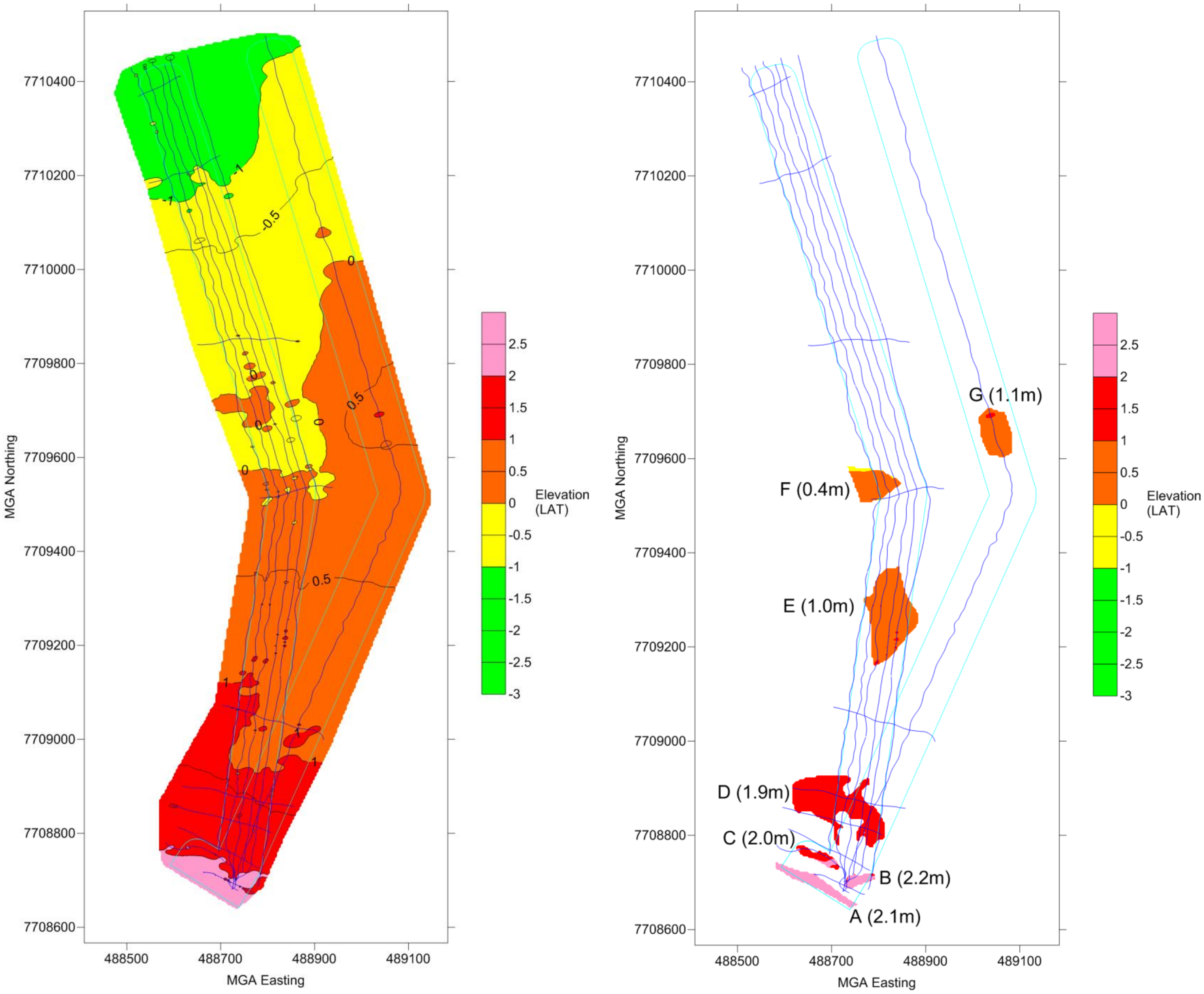


Figure 11. Left image (a) is the surface of the first reflector. Right image (b) is the location of rock surface extracted from first reflector surface. Rock elevations (highest points) are indicated in brackets relative to LAT.

10 CONCLUSIONS

The bathymetry indicated the primary proposed channel route encountered deeper water quicker than the alternate proposed route.

The SBP indicated both the proposed routes encounter rock elevations up to 2m above LAT in the proposed channel alignments in the immediate vicinity of the groyne area.

It is unknown if the rock encountered is a caprock or a hard rock unit.

11 RECOMMENTATIONS

The results indicate it may be possible to optimize a winding channel route around the rock.

If further geotechnical information is required to determine the depth to the bedrock below the gravel layer a detailed marine seismic refraction survey and boomer survey might be considered.

Regarding the boomer survey, careful consideration should be made to the power and configuration to optimize the survey for the extremely shallow target, and to ensure good positioning.

Alternatively the ‘probe’ equipment and procedures could be further utilized, with some minor improvements, to conduct a targeted survey to locate the best channel that can be achieved without dredging through rock. Positions and elevations recorded with RTK GPS.

12 DATA DELIVERABLES

12.1 REPORT

- This survey report is provided in digital format as a PDF file.

12.2 BATHYMETRY DATA

- ASCII points of mean 1m binned data

12.3 SBP RESULTS

- Geotiffs
    - First reflector contours
    - Rock contours
- DXF
    - Survey Lines
    - Rock boundaries in plan view

12.4 CHARTS

ID	Title	Scale	Size	Description
SH20130110_01	Bathymetry Soundings	1/2500	A1	Survey Extents, with Aerial Photo Overlay

Table 13. Chart List.

13 LETTER OF APPROVAL

This report and the accompanying plans are respectfully submitted.

This report and the accompanying survey plans have been closely reviewed and are considered complete and adequate as per the job specification.

Compiled By:

Andrew Richardson, BSc

Certified Professional Hydrographic Surveying Level 2

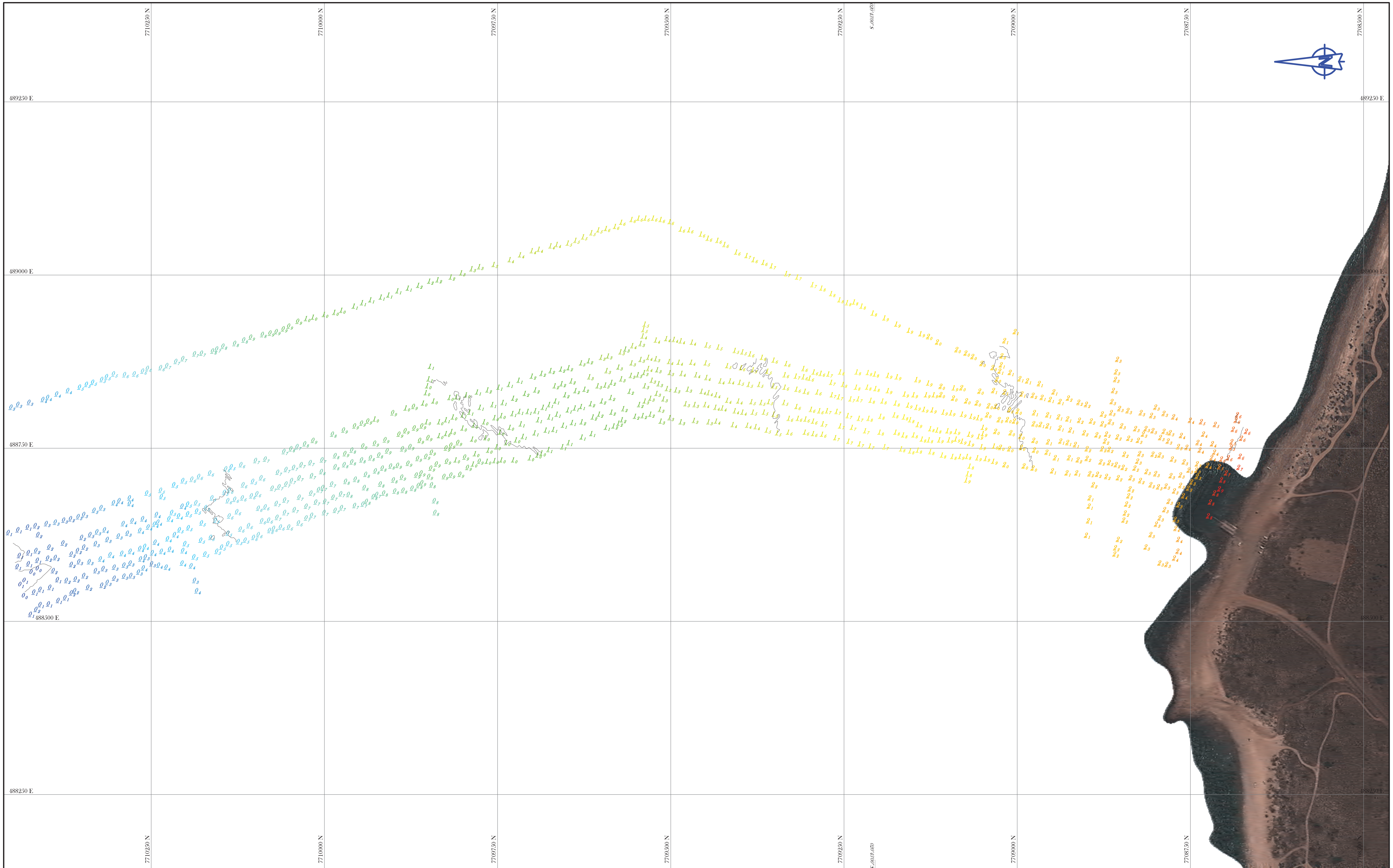
Surrich Hydrographics Pty Ltd

APPENDIX A
Base Station Descriptions

APPENDIX B
SBES TPU

APPENDIX C
AUSPOS Results

APPENDIX D
Charts



Revision	Date	Description	Surveyor	Drawn	Checked	
A	22/11/2014	Final Survey - For Client Perusal	AMR	AMR	JA	

PROJECT NOTES

Survey Date: 16 November 2014

Survey Class:

Total Horizontal Uncertainty 95% CI: +/-0.73m

Total Vertical Uncertainty 95% CI: +/- 0.128m

Datasets have been checked and approved by Andrew Richardson director of Surrich Hydrographics Pty. Ltd.

Signed:____________________

EQUIPMENT

Survey Vessel	Response
SBES	ODOM EchoTrac CVM
MRU	TSS 335B
Positioning	Trimble RTK
Tide Gauge	N/A
SVP	Valeport Mini SVS
Acqusition	PDS2000
MBES Processing	Reson PDS2000

HORIZONTAL DATUM

Spheroid: GRS80
Datum: GDA94
Semi Major Axis (a): 6378137.0
Inverse Flattening (1/f): 298.257222101

Projection: Universal Transverse Mercator
UTM Zone: MGA Zone 50
Central Meridian (CM): 117° 00' 00"
Latitude of Origin: 0° 00' 00"
False Easting: 500,000m
False Northing: 10,000,000
Scale Factor on CM: 0.9996
Units: Metre

DATUM TRANSFORMATION

No Transformations Required

Method: Bursa/Wolfe(7 Parameters)

Shift X(m): 0.00000
Shift Y(m): 0.00000
Shift Z(m): 0.00000
Rotation X(sec): 0.0000000
Rotation Y(sec): 0.0000000
Rotation Z(sec): 0.0000000
Scale factor[ppm]: 0.0000000

VERTICAL DATUM

Depths relative to Lowest Astronomical Tide (LAT)

All Depths were recorded relative to the GDA Ellipsoid using RTK heighting techniques and shifted to LAT using the known Separation between AHD/MSL and LAT at BM B923

The GDA Ellispoid is higher at the chosen base Station HRE 109A. This equates to a 10.399m separation between the GDA ellipsoid and LAT at HRE 109A, compared to the separation of 9.34m at BM B923

Scale 1:2500

0 m 50 m 100 m 150 m 200 m 250 m 300 m 350 m 400 m 450 m

LOCATION PLAN

BMT JFA CONSULTANTS

KARRATHA
GEOPHSICAL SURVEY

BATHYMETRIC SOUNDINGS

Client: BMT JFA Consultants "Where will our knowledge take you?"

BMT JFA Consultants

Contractor: Surrich Hydrographics

SCALE: 1/2500	SH20141006_1	A1

APPENDIX B:
MEMORANDUM: PRELIMINARY SEDIMENT SAMPLING AND ANALYSIS RESULTS AND RECOMANDATIONS

BMT Oceanica

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MEMORANDUM

ATTN:	Jonathan McKay	**CC:**	
ORGANISATION:	BMT JFA	**FROM:**	Katharine Thorne
PROJECT NO:	1170_001	**DATE:**	15 December 2014
SUBJECT:	Karratha Back Beach Dredging Feasibility Study – Component 1: Preliminary Sediment Sampling and Analysis Results and Recommendations		

1. Scope

This memorandum presents the findings of the preliminary site investigation in the vicinity of the Karratha Back Beach Boat Ramp undertaken to inform a feasibility study for the dredging of an entrance channel to the boat ramp. Preliminary interpretations of the data documented herein and recommendations for the Component 2 sediment sampling and analysis and environmental impact assessment are also presented.

2. Sediment Sampling and Analysis

2.1 Sediment sampling methods

Surface sediments within the Karratha Back Beach Boat Ramp area (hereafter the Boat Ramp) were sampled by representatives from BCH Hyder Pty Ltd on 14 November 2014. The sediments were collected at five sites within the proposed dredge footprint for the Boat Ramp area and Entrance Channel (Figure 2.1 and Table 2.1). A sixth site (K6) was proposed to be sampled in the footprint, but was inaccessible by foot on low tide, and relocated immediately adjacent to the dredge boundary (within ~1.8 m). For this preliminary investigation, sampling sites were positioned in areas considered to have the highest risk of sediment contamination due to higher vessel traffic.

For this preliminary site investigation, the sampling methods were designed based on the *Cockburn Sound Manual of Standard Operating Procedures* (EPA 2005). These guidelines were originally developed for Cockburn Sound, however the monitoring procedures for sediments are routinely adopted throughout the state.

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MEMORANDUM

ATTN:	Jonathan McKay	**CC:**	
ORGANISATION:	BMT JFA	**FROM:**	Katharine Thorne
PROJECT NO:	1170_001	**DATE:**	15 December 2014
SUBJECT:	Karratha Back Beach Dredging Feasibility Study – Component 1: Preliminary Sediment Sampling and Analysis Results and Recommendations		

1. Scope

This memorandum presents the findings of the preliminary site investigation in the vicinity of the Karratha Back Beach Boat Ramp undertaken to inform a feasibility study for the dredging of an entrance channel to the boat ramp. Preliminary interpretations of the data documented herein and recommendations for the Component 2 sediment sampling and analysis and environmental impact assessment are also presented.

2. Sediment Sampling and Analysis

2.1 Sediment sampling methods

Surface sediments within the Karratha Back Beach Boat Ramp area (hereafter the Boat Ramp) were sampled by representatives from BCH Hyder Pty Ltd on 14 November 2014. The sediments were collected at five sites within the proposed dredge footprint for the Boat Ramp area and Entrance Channel (Figure 2.1 and Table 2.1). A sixth site (K6) was proposed to be sampled in the footprint, but was inaccessible by foot on low tide, and relocated immediately adjacent to the dredge boundary (within ~1.8 m). For this preliminary investigation, sampling sites were positioned in areas considered to have the highest risk of sediment contamination due to higher vessel traffic.

For this preliminary site investigation, the sampling methods were designed based on the *Cockburn Sound Manual of Standard Operating Procedures* (EPA 2005). These guidelines were originally developed for Cockburn Sound, however the monitoring procedures for sediments are routinely adopted throughout the state.

Figure 2.1 Sampling sites

Table 2.1 Sampling site coordinates

Sampling site	Coordinates[1]	
	Easting	Northing
K1	488654	7708745
K2	488655	7708723
K3	488677.5	7708729
K4	488697	7708715
K5	488719	7708719
K6	488689	7708697

Notes:
1. Coordinates in UTM50; GDA94).

Sampling was undertaken at low tide when field personnel could access them on foot. At each site, sediment was sampled within a 1 x 1 m area. The top 2 cm of material was scraped from each of the four corners and the centre of the 1 x 1 m area and composited into one sample (Figure 2.2).

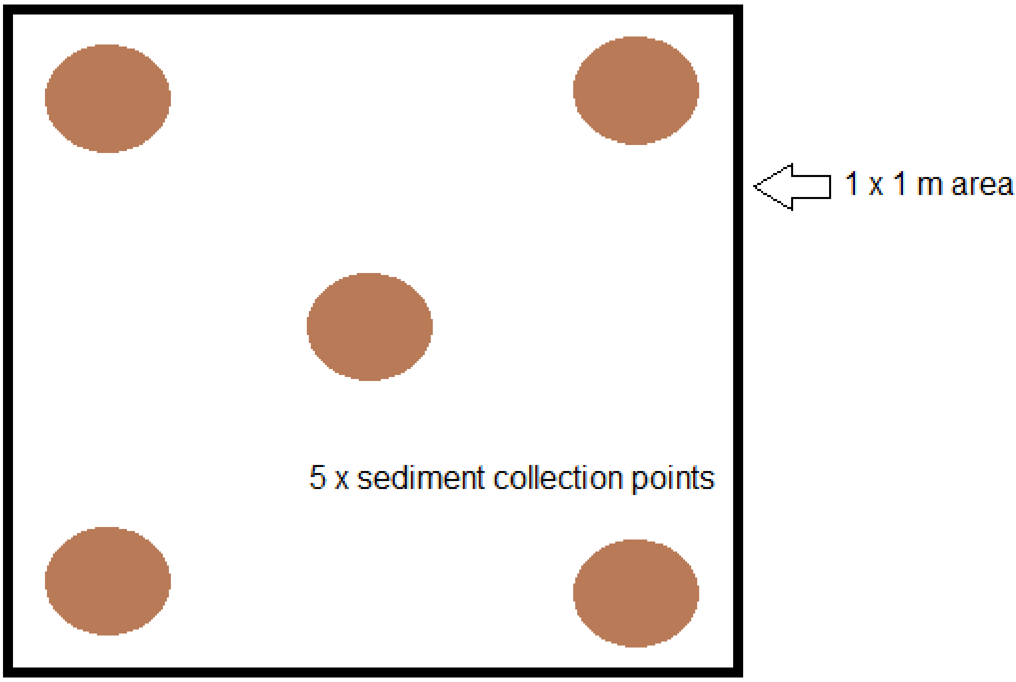

Figure 2.2 Sediment collection schematic

2.1.1 Sampling quality assurance and quality control

All samples were collected according to written procedures provided by BMT Oceanica and to the requirements of analytical laboratories. Facilities for the preservation and transport of samples were provided and Chain of Custody documented. Standard field collection sheets and check lists were used for the work. No quality assurance/quality control samples were collected for inter- or intra-laboratory comparison.

2.2 Sediment analysis methods

2.2.1 Particle size analysis

All sediment samples were analysed for particle size distribution. The particle size distribution and settling velocity of the samples were analysed to assess the potential intensity and duration of turbidity resulting from dredging and disposal. MicroAnalysis Australia Pty Ltd completed the particle size measurement, using laser diffraction for particles 0.02–500 µm and wet screening for particles 500–10 000 µm.

2.2.2 Contaminant analysis

Concentrations of contaminants within the sediment samples were determined via chemical analyses, using standard methods in National Association of Testing Authorities accredited laboratories. The National Measurement Institute undertook the contaminant analyses detailed in Table 2.2. These contaminants were selected based on the identified potential sources of contamination due to the location and use of the Boat Ramp.

Table 2.2 Contaminants analysed in the Boat Ramp sediment samples

Contaminant type	Contaminant analysed	Likely source	Potential impact
Organic carbon	Total organic carbon (TOC)	Organic matter	Affects the biological availability of organic contaminants and can indicate risk of hypoxia within waters
Metals	Total metals: • arsenic (As) • cadmium (Cd) • chromium (Cr) • copper (Cu) • lead (Pb) • mercury (Hg) • nickel (Ni) • zinc (Zn)	Vessel and other sources	High concentrations harmful to humans/flora/fauna
Organotins	Total tributyltin (TBT)	Vessel antifoulant paint (prior to 2008)	High concentrations harmful to fauna, particularly molluscs
Hydrocarbons	• Total recoverable hydrocarbons (TRHs) • Polycyclic aromatic hydrocarbons (PAHs) • Benzene, toluene, ethylbenzene and xylene (BTEX)	Fuels and lubricants	High concentrations harmful to humans/flora/fauna

2.2.3 Laboratory QA/QC

As part of their standard procedures, each of the laboratories complete testing of blanks, spikes and standards and complete laboratory duplicates.

Laboratory blanks

Laboratory blanks are samples (usually reagent water or clean matrix similar to that of the test sample) that are processed and analysed in the same way as the submitted sediment samples. The blanks are used to detect contamination arising in the laboratory as a result of sample preparation, extraction or analysis (CA 2009). Blanks should ideally be at or near the detection limit of the method used (CA 2009).

Standard samples

Standard samples are sediments of known and certified composition that are included in each analysis batch to assess analysis accuracy (CA 2009). The values of standards should be close to the certified value for the individual standard (typically 80–120% of the certified value; CA 2009).

Matrix spikes

Matrix spikes are used to prove that an analyte can be added to and then detected in sediment samples (CA 2009). Recovery rates should be within the limits specified for the analysis method, which are typically 75–125% (CA 2009). When the recovery of a spike is below that expected for the performance of the analytical method, this could indicate matrix interference or heterogeneity of the sediment sample (CA 2009).

2.3 Data analysis methods

2.3.1 Particle settling times

Particle settling times were calculated using Stokes' Law, which estimates the particle settling velocity based on the diameter and density of the particles. Settling velocities were then used to estimate the time taken for sediment to settle through 1 m of water.

2.3.2 Normalisation of organics

Concentrations of organic contaminants (tributyltin (TBT), total recoverable hydrocarbons (TRHs), polycyclic aromatic hydrocarbons (PAHs) and benzene, toluene, ethylbenzene and xylene (BTEX)) were normalised to 1% total organic carbon (TOC) prior to reporting. TOC is the main binding constituent for organic substances and normalisation provides a measure of contaminant bioavailability (CA 2009). Where TOC is significantly greater than 1%, the additional binding capacity will result in organics being less biologically available and therefore normalisation reduces the measured value proportionally (the reverse also applies). In samples where the TOC was less than 0.2% or greater than 10%, these limit values (i.e. 0.2% or 10%, respectively) were used.

2.3.3 Assessment against guidelines

Guidelines relevant to this preliminary site investigation have been applied assuming onshore disposal of dredged material. If offshore disposal of dredge material is required, different methods and guidelines will be applied during the Component 2 assessment. The guidelines relevant to the preliminary assessment of material are outlined below.

Marine sediment guidelines

Sediment contaminant concentrations were compared to ANZECC & ARMCANZ (2000) Interim Sediment Quality Guidelines (ISQG)-Low and -High, to assess whether the sediments pose a threat to the ecological health of the marine environment. This is in-line with recommendations within the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPC 2013), see section below for further details. Data were assessed individually as there were not enough samples collected to calculate statistics from the data.

Contaminated sites guidelines

The *National Environment Protection (Assessment of Site Contamination) Measure* guidelines to assess the ecological and human health risks associated with the material once disposed to land (NEPC 2013).

The NEPC (2013) guidelines are an updated version of the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC 1999)—the source of many of the contaminant criteria within the Western Australian (WA) *Contaminated Sites Management Series* (DEC 2010) (Department of Environment and Conservation, now Department of Environment Regulation (DER)). The DER is presently working to incorporate the amended NEPC (2013) into the WA guidelines. In the interim, the DER requires all contaminated sites assessments to be in-line with NEPC (2013) (DER 2014).

Data were assessed against the Ecological Investigation Levels (EILs), Ecological Screening Levels (ESLs) and the Health Investigation Levels (HILs). As the disposal area has not yet been confirmed it has been assumed that disposal shall be to a public open space e.g. side casting as beach nourishment, therefore data shall be assessed against the EILs and ESLs for "areas of ecological significance" and HIL Level 'C', appropriate for "public open space such as parks, playgrounds, playing fields " (NEPC 2013). The data were assessed against the guidelines individually as there were not enough samples collected to calculate statistics from the data.

The EILs prescribed by the NEPC (2013) guidelines require addition of ambient background analyte concentrations (determined from reference site data) to define contaminant limits for ecological investigation. The proposed disposal site for dredged sediments has not yet been confirmed; therefore reference site data from the disposal site was not collected as part of this preliminary investigation. In the absence of known ambient background concentrations, EILs specified in DEC (2010) were used for assessment (which do not require addition of background analyte concentrations).

3. Nature of the Material to be Dredged

3.1 Physical sediment characteristics

3.1.1 Visual and olfactory characterisation

A visual inspection of sediment samples from the Boat Ramp indicated that sediments to be dredged ranged in colour from brown to grey/black and were composed mainly of clay/silt size particles (Table 3.1). Some organic matter noted at site K2 and black particles were observed in samples collected from sites K1 and K6 potentially indicating the presence of organic matter. Descriptions and photographs of sediment at each site are presented in Table 3.1.

Table 3.1 Field log of the Boat Ramp sediment samples

Site	Description	Photograph
K1	Grey/black clay/silt, no algae	
K2	Grey clay/silt, small amount of organic matter, green algae on surface	

Site	Description	Photograph
K3	Grey clay/silt, no algae	
K4	Grey clay/silt, some sand present	
K5	Brown silt	
K6	Grey/black silt	

3.1.2 Particle size distribution

The sediments sampled within the Boat Ramp area were fine grained, dominated by clay, silts and very fine sand sized particles (Table 3.2 and Figure 3.1). The largest component in the sediments at all sites was coarse silt (19.85–33.95%), with the exception of site K2 where sediments were dominated by medium silt (19.26%). Sediments at site K2 (closest to the Boat Ramp) contained the highest total sit and clay fractions (68.73% and 19.88%, respectively), sediments at site K4 contained the highest gravel fraction (6.92%) and sediments at site K5 contained the highest total sand fraction (32.68%). The distribution of the sites indicates that the sediments contain a greater component of sand with distance offshore.

Table 3.2 Particle size distribution of the Boat Ramp sediment samples

Wentworth size category (µm)		Proportion of sample by volume (%)					
		K1	K2	K3	K4	K5	K6
Total gravel	**>2000**	**0.02**	**0.48**	**0.13**	**6.92**	**0.00**	**1.67**
Very coarse sand	1000–2000	0.18	0.80	0.07	2.89	0.12	0.86
Coarse sand	500–1000	0.50	0.35	0.26	1.80	0.10	0.79
Medium sand	250–500	2.21	0.62	0.83	1.27	0.00	1.61
Fine sand	125–250	6.49	1.46	3.48	4.15	4.33	3.26
Very fine sand	63–125	16.34	7.69	15.53	17.00	28.14	12.56
Total sand	**63–2000**	**25.72**	**10.92**	**20.18**	**27.11**	**32.68**	**19.09**
Coarse silt	31–63	19.85	17.14	23.03	23.81	33.95	21.17
Medium silt	16–31	15.44	19.26	16.98	14.54	13.09	16.88
Fine silt	8–16	12.47	16.96	12.21	8.51	5.85	12.33
Very fine silt	4–8	11.18	15.37	11.22	7.88	6.01	11.80
Total silt	**4–63**	**58.94**	**68.73**	**63.44**	**54.75**	**58.90**	**62.18**
Total clay	**0–4**	**15.32**	**19.88**	**16.25**	**11.23**	**8.42**	**17.06**

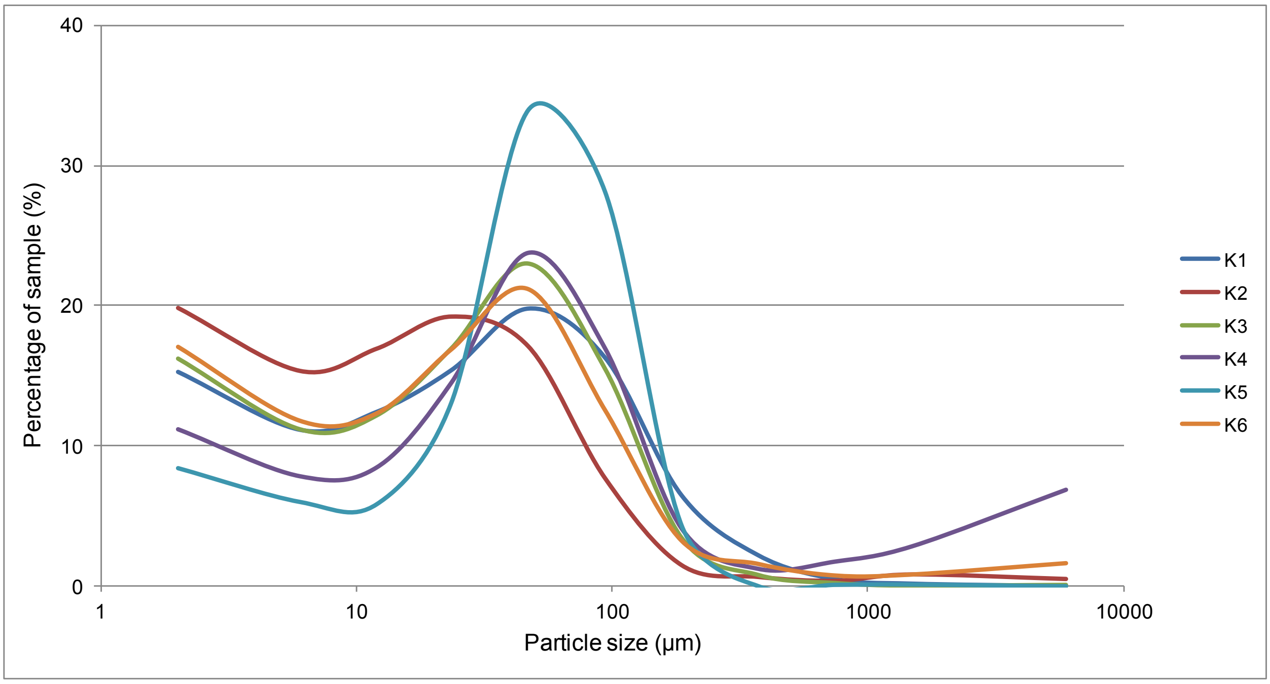

Figure 3.1 Particle size distribution of the Boat Ramp sediment samples

3.1.3 Settling times

The settling velocity was calculated for all sediment samples collected from the Boat Ramp and is presented in Table 3.3. The time for 50% of particles to settle through 1 m of water ranged between 0.2 hrs (i.e. 12 minutes for sediment at site K4) and 1.6 hours (for sediment at site K2). The time for 90% of particles to settle through 1 m of water ranged between 14.3 hours (K5) and 68.8 hours (K2). The relatively high settling times observed for sediments at site K2 are the result of the higher proportion of silt and clay (total 88.61%; Section 3.1.2).

Table 3.3 Settling time of the Boat Ramp sediment samples

	K1	K2	K3	K4	K5	K6
Minimum settling velocity of 50% of particles (mm/s)	0.585	0.176	0.521	1.351	1.770	0.463
Time for 50% of particles to settle over 1 m (hours)	0.475	1.579	0.534	0.206	0.157	0.599
Minimum settling velocity of 90% of particles (mm/s)	0.006	0.004	0.005	0.010	0.019	0.005
Time for 90% of particles to settle over 1 m (hours)	46.968	68.779	53.472	26.846	14.287	57.447

Note:

1. The setting time was calculated using the geometric mean of the particle sizes, the 90^{th} and 50^{th} percentiles of particle sizes and Stokes' Law, which is dependent on the diameter and density of the particles.

3.2 Total organic carbon

The TOC content of sediment sampled within the Boat Ramp area was low, ranging from 0.49% at K5 to 1.20% at K2 (Table 3.4). These TOC values correlate with the particle size distribution data - samples containing higher clay sized particles also contained higher TOC.

Table 3.4 Total organic carbon of the Boat Ramp sediment samples

Sample	TOC (mg/kg)	%TOC
K1	8600	0.86
K2	12 000	1.20
K3	9300	0.93
K4	6500	0.65
K5	4900	0.49
K6	9300	0.93

3.3 Metals

Sediment metal concentrations collected from the Boat Ramp are presented in Table 3.5. Note that the NEPM (2013) EILs for zinc, copper, nickel, lead and chromium III are additive contaminant limits (i.e. based on the addition of ambient background concentrations). In the absence of known ambient background concentrations of these contaminants, for this preliminary site investigation the DEC (2010) EILs have be used for assessment (as specified in Section 2.3.3).

Arsenic, cadmium, copper, lead, mercury and zinc concentrations were below ISQG-Low, EIL and HIL guidelines at all sites.

Chromium concentrations were below ISQG-Low at all sites except site K2. At site K2 the sediment chromium concentration exceeded the ANZECC & ARMCANZ ISQG-Low value but met the ANZECC & ARMCANZ ISQG-High value. The speciation of chromium concentration is required for an assessment against EIL (chromium III) and HIL (chromium VI) guidelines; however, only total chromium concentration was determined in this preliminary investigation. The total chromium concentrations (and thus the chromium III and chromium VI concentrations) at all sites were below the respective EIL and HIL guidelines.

Nickel concentrations were below the ISQG-Low ,ISQG-High, EIL and HIL guidelines at sites K4 and K5. At sites K1, K2, K3 and K6, nickel concentrations exceeded the ISQG-Low value but below the ISQG-High, EIL and HIL guidelines.

Similar to TOC, metal concentrations correlated with the particle size distribution data – samples containing higher clay sized particles also contained higher metal concentrations. Additionally, sediments with higher metal concentrations, and exceedances in chromium and nickel, appear to be closer to the shore/Boat Ramp.

Table 3.5 Metal concentrations in the Boat Ramp sediment samples

Metals (mg/kg)		As	Cd	Cr III	Cr VI	Total Cr	Cu	Pb	Hg	Ni	Zn
ANZECC & ARMCANZ Sediment Guidelines[1]	ISQG Low	20	1.5	-	-	80	65	50	0.15	21	200
	ISQG High	70	10	-	-	370	270	220	1	52	410
NEPM Soil Guidelines	EILs: Area of ecological significance[2]	20	-	25–50[3]	-	-	15–60[3]	110[3]	-	1–25[3]	7–130[3]
	HILs: C[4]	300	90	-	300	-	17 000	600	80	1200	-
DEC Assessment levels for Soil	EILs[5]	20	3	400	1[6]	-	100	600	1	60	200
K1		13	<0.4	n/a	n/a	70	13	4.8	<0.1	**27**	30
K2		13	<0.4	n/a	n/a	**95**	18	7.3	<0.1	**36**	62
K3		12	<0.4	n/a	n/a	69	12	4.8	<0.1	**27**	28
K4		9.1	<0.4	n/a	n/a	51	8.9	3.5	<0.1	20	20
K5		8.9	<0.4	n/a	n/a	41	6.7	2.6	<0.1	16	15
K6		10	<0.4	n/a	n/a	69	12	4.1	<0.1	**27**	28

Notes:
1. Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000)
2. Ecological Investigation Levels (EILs) in the National Environment Protection (Assessment of Site Contamination) Amendment Measure (No. 1) (NEPC 2013).
3. NEPM (2013) EILs for Zn, Cu, Ni and Pb are added contaminant limits based on added concentrations to ambient background concentration. In the absence of known ambient background concentrations of these contaminants, the DEC (2010) EILs shall be used for assessment.
4. Health Investigation Levels (HILs) in the National Environment Protection (Assessment of Site Contamination) Amendment Measure (No. 1) (NEPC 2013).
5. Ecological Investigation Levels (EILs) in the Contaminated Sites Managements Series: Assessment Levels for Soils (DEC 2010).
6. It is not considered necessary to assess against the DEC (2010) EIL as an EIL for chromium VI has not been specified in the NEPM (2013) guidelines.
7. Red values indicate exceedance of the ANZECC & ARMCANZ (2000) ISQG-Low values.
8. "-" indicates where no guideline value exists.
9. n/a: chromium III and chromium VI were not analysed during this preliminary investigation.

3.4 Organotins

The organotin results for all samples collected from the Boat Ramp (Table 3.6) were below the laboratory LoR (0.5 µg.Sn/kg) and were therefore also below the ISQG-Low and ISQG-High values. Note that as all the results were below LoRs, it was not necessary to normalise the values to 1% TOC.

Table 3.6 Organotin concentrations in the Boat Ramp sediment samples

Organotins (µg.Sn/kg)		Monobutylitin	Dibutylin	Tributyltin[1]
ANZECC & ARMCANZ Sediment Guidelines[2]	ISQG Low	-	-	5
	ISQG High	-	-	70
K1		<0.5	<0.5	<0.5
K2		<0.5	<0.5	<0.5
K3		<0.5	<0.5	<0.5
K4		<0.5	<0.5	<0.5
K5		<0.5	<0.5	<0.5
K6		<0.5	<0.5	<0.5

Notes:
1. Normalised to 1% total organic carbon. All the results were below LoRs, it was not necessary to normalise the values to 1% TOC.
2. Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000)
3. "-" indicates where no guideline value exists.

3.5 Hydrocarbons

The total recoverable hydrocarbon (TRH) results for all samples collected from the Boat Ramp (Table 3.7) were below the laboratory LoRs. The TRH concentrations were therefore also below the NEPM ESLs[1]. Note that as all the results were below LoRs, it was not necessary to normalise the values to 1% TOC.

Table 3.7 Total Recoverable Hydrocarbon concentrations in the Boat Ramp sediment samples

Total Recoverable Hydrocarbons (mg/kg)		Total TPH	C6 – C10 less BTEX (Coarse/Fine)	>C10 – C16 less naphthalene (Coarse/Fine)	>C16 – C34 (Fine)	>C34 – C40 (Fine)
NEPM Soil Guidelines	ESLs: Area of ecological significance[1]	-	125	25	-	-
	ESLs: Urban residential/public open space[1]	-	180	120	1300	5600
K1		<275	<25	<50	<100	<100
K2		<275	<25	<50	<100	<100
K3		<275	<25	<50	<100	<100
K4		<275	<25	<50	<100	<100
K5		<275	<25	<50	<100	<100
K6		<275	<25	<50	<100	<100

Notes:

1. Ecological Screening Levels (ESLs) in the National Environment Protection (Assessment of Site Contamination) Amendment Measure (No. 1) (NEPM 2013). The ESL for urban residential/public open space are also presented here as there are no EILs for areas of ecological significance for TRH chain fractions $>C_{16}$.
2. "-" indicates where no guideline value exists.

The Polycyclic Aromatic Hydrocarbon (PAH) results for all samples collected from the Boat Ramp (Table 3.8) were below the laboratory LoRs. The PAH concentrations therefore met the ISQG-Low, EIL, ESL and HIL guidelines[2].

[1] *Please note that the LoR for the TRH chain fraction $>C_{10}$–C_{16} was 50 mg/kg, and thus greater than the NEPM ESL for areas of ecological significance (25 mg/kg). Therefore, it cannot not be definitively stated that the guidelines were met for this analyte. The NEPM ESLs for urban residential/public open space are also presented here as there are no ESLs for areas of ecological significance for TRH chain fractions $>C_{16}$, and these guidelines were met.*

[2] *Please note that the LoRs for acenaphthalene, acenaphthene, fluorene, anthracene and dibenzo(a,h)anthracene are greater that the ANZECC & ARMCANZ ISQG-low values. Therefore, it cannot not be definitively stated that the guidelines were met for these analytes. However as the total PAH concentrations met the ANZECC & ARMCANZ ISQG-low values, it is unlikely that any of the individual PAH concentrations would have exceeded their respective ISQG-low values. The concentrations of these individual PAHs were below the ANZECC & ARMCANZ ISQG-high values.*

Table 3.8 Polycyclic Aromatic Hydrocarbon concentrations in the Boat Ramp sediment samples

Polycyclic Aromatic Hydrocarbons (mg/kg)		Total PAH	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a) anthracene	Chrysene	Benzo(b+k) fluoranthene	Benzo(a) pyrene	Indeno(1,2,3-c,d) pyrene	Dibenzo(a,h) anthracene	Benzo(g,h,i) perylene
ANZECC & ARMCANZ Sediment Guidelines[1]	ISQG Low	4	0.16	0.044	0.016	0.019	0.24	0.085	0.6	0.665	0.261	0.384		0.43		0.063	
	ISQG High	45	2.1	0.64	0.5	0.54	1.5	1.1	5.1	2.6	1.6	2.8		1.6		0.26	
NEPM Soil Guidelines	EILs: Area of ecological significance[2]	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	ESLs: Area of ecological significance[3]	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-
	HILs: C[4]	300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K1		<1.6	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10
K2		<1.6	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10
K3		<1.6	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10
K4		<1.6	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10
K5		<1.6	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10
K6		<1.6	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10

Notes:

1. Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000)
2. Ecological Investigation Levels (EILs) in the National Environment Protection (Assessment of Site Contamination) Amendment Measure (No. 1) (NEPM 2013).
3. Ecological Screening Levels (ESLs) in the National Environment Protection (Assessment of Site Contamination) Amendment Measure (No. 1) (NEPM 2013).
4. Health Investigation Levels (HILs) in the National Environment Protection (Assessment of Site Contamination) Amendment Measure (No. 1) (NEPM 2013).
5. "-" indicates where no guideline value exists.

The Benzene, Toluene, Ethylbenzene and Xylene (BTEX) results for all samples collected from the Boat Ramp (Table 3.9) were below the laboratory LoRs. The BTEX concentrations were therefore below EIL guidelines.

Table 3.9 Polycyclic Aromatic Hydrocarbon concentrations in the Boat Ramp sediment samples

		Benzene (fine grained)	Toluene (fine grained)	Ethylbenzene (fine grained)	Xylenes (fine grained)	Total BTEX
NEPM Soil Guidelines	**EILs: Area of ecological significance[1]**	**10**	**65**	**40**	**1.6**	**-**
K1		<0.50	<0.50	<0.50	<1.0	<2.5
K2		<0.50	<0.50	<0.50	<1.0	<2.5
K3		<0.50	<0.50	<0.50	<1.0	<2.5
K4		<0.50	<0.50	<0.50	<1.0	<2.5
K5		<0.50	<0.50	<0.50	<1.0	<2.5
K6		<0.50	<0.50	<0.50	<1.0	<2.5

Notes:

1. Ecological Investigation Levels (EILs) in the National Environment Protection (Assessment of Site Contamination) Amendment Measure (No. 1) (NEPM 2013).
2. "-" indicates where no guideline value exists.

3.6 Summary

Sediments sampled within the Boat Ramp area were dominated by clay and silt sized particles and consequently had relatively long settling times. On visual inspection sediments at three sites contained black particles; however the total organic carbon concentrations of the sediments were relatively low. The contaminants tested (metals, organotins and hydrocarbons) were all below the relevant guideline levels with the exceptions of: chromium which exceeded the ISQG-Low value at one site; and nickel which exceeded the ISQG-Low value at four sites. The TOC and metal concentrations in the sediments appear to correlate with the sediment grain size and the distance offshore – with higher concentrations in sediments with higher fines content and closer to the shore and/or Boat Ramp.

4. Interpretations and Recommendations

Based on the results of the sediment sampling and analyses, BMT Oceanica makes the following interpretations and recommendations for future sampling and analyses prior to the commencement of any dredging and disposal works (which may have cost implications for Component 2 of these works):

1. The particle size distribution data and corresponding settling rates indicate that the proposed dredging will potentially generate relatively high levels of turbidity. However the surface samples analysed herein represent only a small proportion of the material to be dredged. Testing of the deeper sediments, to be undertaken as part of Component 2, will allow a full assessment of the potential turbidity generated from this project. Coarser sediments are expected and have been anecdotally reported in the underlying layers and therefore there may be less turbidity generation. Nonetheless, it is recommended that the benthic habitat and/or the presence of sensitive receptors in addition to natural background turbidity levels in the area be assessed prior to the commencement of any dredging works as part of the Environmental Impact Assessment. If sensitive benthic primary producer habitat is present in the area surrounding the proposed dredge footprint or if there is a risk of a significant social impact, additional turbidity monitoring and management will be required during dredging and disposal. Turbidity monitoring may comprise the capture of plume sketches, site photographs

and aerial photographs during dredging and disposal. Management actions may include contingency measures such as a revision of the dredging methods and the cessation of dredging whilst the unacceptable levels of turbidity dissipate. Actual monitoring and management actions will be confirmed during the preparation of the Environmental Impact Assessment as part of Component 2.

2. The sediment colour at three sites indicates the potential presence of acid sulfate soils. It is recommended that samples collected prior to dredging be analysed for the presence of acid sulfate soils, as part of Component 2 of the works. If acid sulfate soils are present, their disturbance could release acid which would then potentially mobilise any metals in the sediment and make them more bioavailable. Therefore monitoring and management actions would be required during the dredging and disposal works. Monitoring may include in situ acidity measurements of the dredge plume and the return water. Management actions may include contingency measures such as a revision of the dredging methods, the cessation of dredging to allow unacceptable levels of acidity to dissipate and management of the return water. Actual monitoring and management actions will be confirmed during the preparation of the Environmental Impact Assessment as part of Component 2.

3. As nickel and chromium concentrations exceeded the ANZECC & ARMCANZ ISQG-Low values in some sediment samples, it is recommended that those samples be retested for elutriate nickel, chromium III and chromium VI. Elutriate analysis of sediment samples is designed to simulate the potential release of contaminants from the sediment during dredging and disposal (CA 2009) and therefore will give an estimate of the amount of bioavailable contaminant released as a result of dredging and disposal. These would be assessed against the water quality guidelines defined in ANZECC & ARMCANZ (2000). If they are found to exceed the water quality guidelines, appropriate management and monitoring will be required during dredging and disposal; these may include water quality monitoring of the dredge plume and return water and also management of the return water. Actual monitoring and management actions will be confirmed during the preparation of the Environmental Impact Assessment as part of Component 2. Should sea dumping be the preferred mode of disposal, these sediment samples should also be tested for bioavailable nickel and chromium. For the analysis as part of Component 2, it is recommended that all sediment samples be tested for chromium III and chromium VI to allow direct assessment against the NEPM (2013) and DEC (2010) EIL and HIL guidelines and therefore appropriate environmental impact assessment of the land disposal of the dredge material.

Future sediment sampling to inform an Environmental Impact Assessment ahead of the proposed dredging project will be designed following confirmation of the dredging footprint and disposal area. The methods for sampling and guidelines used for assessment will be established in a formal sampling and analysis plan. On completion of the Environmental Impact Assessment it is recommended that the project, the Environmental Impact Assessment and the proposed dredging monitoring and management plan be presented to the Department of Environment Regulation and the Office of the Environmental Protection Agency to ensure their acceptance of the project as low-risk (dependant on the outcomes of the Environmental Impact Assessment) and confirm that there is no requirement for further approvals. If there is no evidence of potential contaminant release or impact to sensitive receptors there may be no requirement for further approvals. Alternatively, a formal referral of the project to the Office of the Environmental Protection Agency may be requested which will have additional time and cost implications for the project.

5. References

ANZECC & ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1: The Guidelines. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT, October 2000

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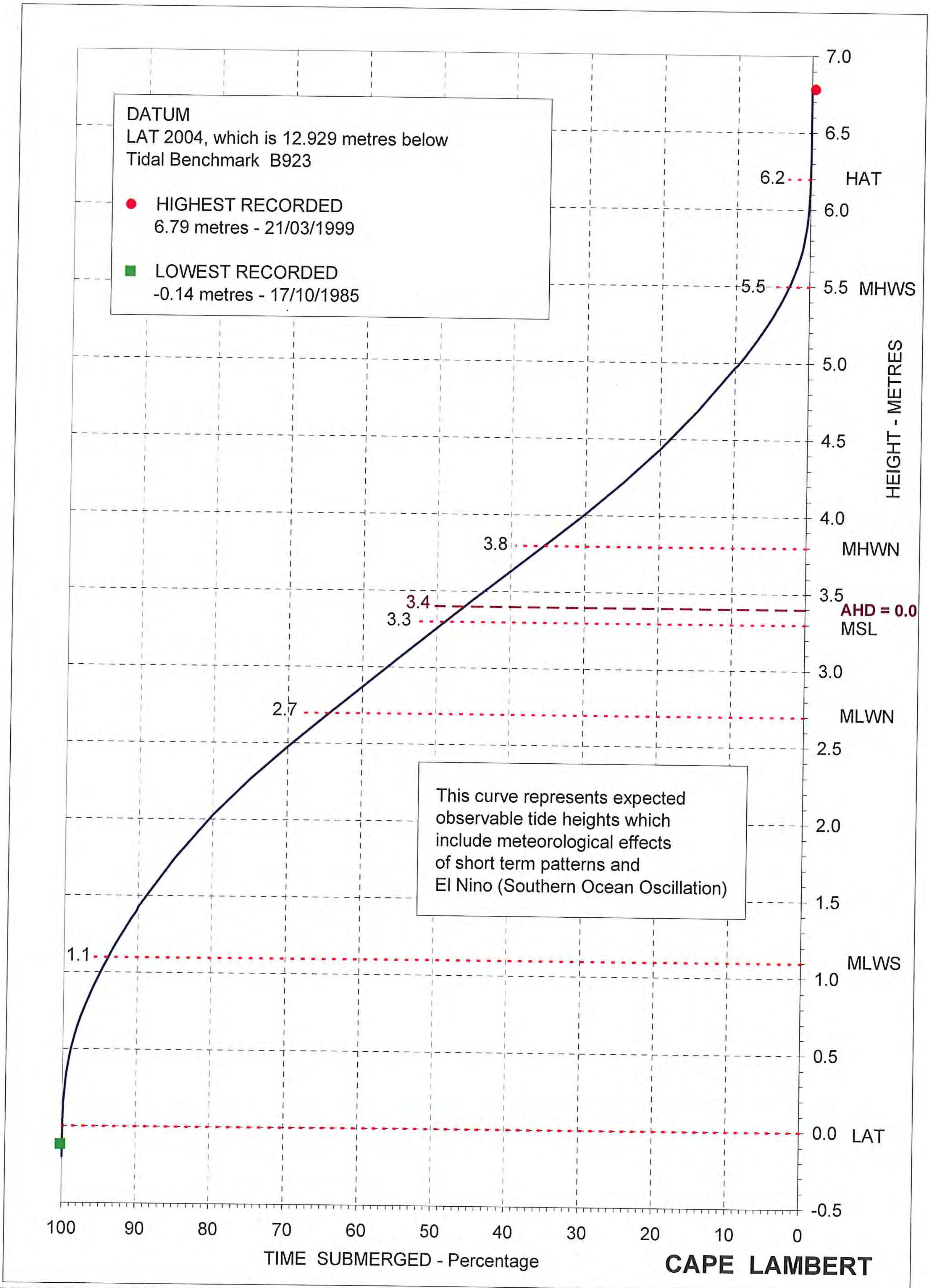
DER (2014) Contaminated Sites Guidelines – Management Series Guidelines. Department of Environment Regulation, Government of Western Australia, Perth, Western Australia. Available from <http://www.der.wa.gov.au/your-environment/contaminated-sites/61 contaminated-sites-guidelines> [Accessed 2 December 2014]

EPA (2005) Manual of Standard Operating Procedures – For Environmental Monitoring against the Cockburn Sound Environmental Quality Criteria (2003–2004) – A Supporting Document to the State Environmental (Cockburn Sound) Policy 2005. Environmental Protection Authority, Report No. 21, Perth, Western Australia, January 2005

NEPC (1999) National Environment Protection (Assessment of Site Contamination) Measure 1999. National Environment Protection Council

NEPC (2013) National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1) National Environment Protection Council, 2013

APPENDIX C:
CAPE LAMBERT SUBMERGENCE CURVE



DEPARTMENT OF TRANSPORT - WA
Oceanographic Services
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SUBMERGENCE CURVE