Port Hedland Outer Harbour Development

SAMPLING AND ANALYSIS PLAN IMPLEMENTATION REPORT

- PREP-1210-G-12058
- Revision 3
- 11 February 2011

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Sinclair Knight Merz
7th Floor, Durack Centre
263 Adelaide Terrace
PO Box H615
Perth WA 6001 Australia

Tel: +61 8 9469 4400
Fax: +61 8 9469 4488
Web: www.skmconsulting.com

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Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
A	02/12/2008	PF Morrison J Lazorov M Sobczak	T Probst	02/12/2008	Draft for client review
B	05/02/2009	PF Morrison N Aurisch	T Probst	05/02/2009	Revised Draft
0	09/02/2009	PF Morrison	T Probst J Lazorov	19/02/2009	Final
1	23/06/2009	T Probst	R Burgess	03/07/2009	Revised Spoil Grounds
2	20/07/2009	T Probst	R Burgess	20/07/2009	Final
3	19/01/2011	PF Morrison	R Burgess	09/02/2011	Revised Final
	11/01/2011	T Kaveney			Client review

Distribution of copies

Revision	Copy no	Quantity	Issued to
A	1	1 electronic	BHP Billiton Iron Ore (S Mavrick)
B	1	1 electronic	N Aurisch (Editorial Review); PF Morrison (Technical Review)
0	1	1 electronic	BHP Billiton Iron Ore (S Mavrick)
1	1	1 electronic	BHP Billiton Iron Ore (S Mavrick)
2	1	1 electronic	BHP Billiton Iron Ore (S Mavrick)
3	1	1 electronic	BHP Billiton Iron Ore (S Mavrick)

Printed:	8 April 2011
Last saved:	8 April 2011 02:17 PM
File name:	I:\WVES\Projects\WV05024\Technical\160 Live PER Document\A Appendices\Appendix A8 SAP M19\PREP-1210-G-12058, Rev 3 080211.doc
Author:	Andrew Tennyson
Project manager:	Fiona Rabone
Name of organisation:	BHP Billiton Iron Ore
Name of project:	Port Hedland Outer Harbour Development
Name of document:	Sampling and Analysis Plan Implementation Report
Document version:	Rev 3
Project number:	WV03759.160

1. Executive Summary

In accordance with the National Ocean Disposal Guidelines for Dredged Material (NODGDM) (EA 2002), a Sampling and Analysis Plan (SAP) is required to assess the suitability of dredge material for disturbance and disposal in offshore spoil grounds. This SAP Implementation Report presents the results of SAP investigations and is one study in a co-ordinated approach designed to meet assessment criteria under Western Australian (Public Environmental Review) and Commonwealth (EPBC Act) Environmental Impact Statements. The SAP Implementation Report also supports application for a Sea Dumping Permit through the Commonwealth Department of Environment, Heritage, Water and the Arts (DEWHA), recently renamed the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC).

As part of the SAP investigations, a Pilot Study was conducted to characterise sediments associated with proposed dredging works for BHP Billiton Iron Ore's Outer Harbour development offshore of Port Hedland harbour.

This report presents the combined results of the Pilot Study, SAP and Supplemental SAP submitted to DEWHA in August and November 2008, respectively.

A total of 213 surficial samples of marine sediments were collected offshore of Port Hedland, Western Australia, and analysed for contaminants of concern. Sites were sampled in this chronological order:

- 60 sites within a Pilot Study 'footprint'
- 8 sites within two Pilot study 'potential spoil grounds'
- 25 sites within five now discounted potential spoil grounds
- 50 sites within the proposed berthing area and channel dredge footprint
- 33 sites within six potential spoil grounds related to the proposed berthing area and channel dredge footprint
- 27 sites within a revised berthing area not previously sampled
- 10 sites within potential spoil ground expansion areas related to the revised berthing area.

To determine the vertical extent of contaminants of concern, material was also analysed from the geological strata of ten geotechnical boreholes drilled to the proposed dredge depth.

The main findings of the marine sediment characterisation and contaminant investigations were:

- The 95% Upper Confidence Level (UCL) for arsenic (As) exceeded the NODGDM screening level (20 mg/kg) in surficial material in all areas investigated;

- The 95% UCL for arsenic (As) exceeded the NODGDM screening level to a depth of 4 metres in boreholes;
- The 95% UCL for chromium (Cr) exceeded the NODGDM screening level (80 mg/kg) to a depth of 10 metres in boreholes, but not in surficial material;
- The 95% UCL for nickel (Ni) exceeded the NODGDM maximum level (52 mg/kg) to a depth of 19 metres in boreholes, but not in surficial material;
- Tributyltin (TBT) did not exceed NODGDM screening levels (5 µg Sn/kg) in any surficial samples or borehole samples;
- Potential spoil grounds were suitable receiving environments for spoil; and
- Sediment was characterised by medium to coarse grain sizes, with ≤ 10% of material in any area being under 100 µm in diameter.

Based on the results described in this report, any exceedances of NODGDM screening levels can be associated with naturally occurring levels, and as such, the sediment within the proposed dredge footprint is considered suitable for unconfined disposal to sea (sea dumping).

2. Introduction

2.1. Overview of this Document

This document is an Implementation Report for the combined results of a Sampling and Analysis Plan (SAP) and Supplemental SAP submitted to the Department of Environment, Water, Heritage and the Arts (DEWHA), recently renamed the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), in August and November 2008, respectively. The SAP and Supplemental SAP documents outlined a methodology to characterise sediment chemistry from potential footprint and spoil ground locations proposed for BHP Billiton Iron Ore's development offshore of Port Hedland harbour, Western Australia.

Initiation of the environmental assessment process for the proposed Outer Harbour Development, including the submission of the SAP and Supplemental SAP, was undertaken in accordance with the current dredging assessment guidelines at the time; the National Ocean Disposal Guidelines for Dredged Material (NODGDM) (EA 2002), released in 2002.

BHP Billiton notes that it is familiar with the current assessment guidelines (the National Assessment Guidelines for Dredging (NAGD)), released in 2009 and acknowledges the recommended processes therein; however the environmental assessment process for the proposed Outer Harbour Development had progressed substantially prior to the NAGD being released. Although the Proponent has the option of resubmitting a SAP under revised guidelines, they are not required to revise and resubmit a SAP and/or SAP Implementation Report in the event that revised guidelines are released during an assessment process. This was the case for BHP Billiton Iron Ore for the proposed Outer Harbour Development dredging and disposal activities. As a result, BHP Billiton Iron Ore's request for a Sea Dumping Permit for ocean disposal of dredged material and associated documentation will be assessed under the NODGDM.

This SAP Implementation Report details the sampling process undertaken and the results of sediment contaminant analysis. It discusses any identified potential contaminants of concern and necessary management plans as based on the results.

2.2. Background to Proposed Development

BHP Billiton Iron Ore is one of Australia's largest iron ore producers with mine, rail and port operations located in the Pilbara region of Western Australia (see **Figure 2-1**). BHP Billiton Iron Ore exports its products to steelmakers in Japan, Korea, Taiwan, China, Europe and Australia through Port Hedland, which is one of the busiest commodity ports in the world.

BHP Billiton Iron Ore's current port operations consist of processing, stockpiling and ship-loading facilities on opposite sides of the Port Hedland Harbour at Nelson Point and Finucane Island in an area generally referred to as the Inner Harbour, (see **Figure 2-2**).

BHP Billiton Iron Ore is in a phase of significant growth and has been focused on growing the business via a phased approach to meet market demand. This has been, and continues to be, achieved by a series of Rapid Growth Projects (RGP) which enable BHP Billiton Iron Ore's capacity to be increased incrementally (that is, RGP 1, 2, 3, 4, 5 and 6).

BHP Billiton Iron Ore's expansion program will continue to grow with market demand for iron ore, which is expected to remain strong for some time as China continues its urbanisation phase. This growth will also have a flow-on effect to other steel producers in the Asian region and will underpin the current and proposed expansion activities.

To meet the expected global demand for iron ore, BHP Billiton Iron Ore is embarking on a development program to achieve a target of 350 million tonnes per annum (Mtpa) of installed capacity by 2015 at its Western Australia Iron Ore operations.

Maximising the output from the Inner Harbour is an essential step in this program. Additional iron ore loading and berthing facilities within the Port Hedland Inner Harbour are currently being constructed as part of RGP5, and further capacity is being investigated as part of feasibility studies for RGP6.

The Outer Harbour Development will be located adjacent to BHP Billiton Iron Ore's existing operations at Port Hedland and includes the construction of stockyards within the vicinity of the decommissioned Hot Briquetted Iron (HBI) plant at Boodarie and jetty and wharf structures offshore from Finucane Island (**Figure 2-3**).

In pursuing ongoing growth plans, BHP Billiton Iron Ore is committed to working with local communities to support sustainable development in the region and ensure their needs are incorporated into growth plans.

2.3. Proposed Outer Harbour Development

The proposed Outer Harbour Development will provide an export capacity of approximately 240 Mtpa of iron ore. Details of the modular incremental expansions or staging options to reach the 240 Mtpa capacity are still under consideration.

The project description outlined below is based on the current engineering design concept and details may change as the project design is further defined and finalised. Accordingly, the Outer

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Harbour Development comprises the following major components (from terrestrial to marine environment) (see **Figure 2-3**):

Terrestrial

- rail connections and spur from the existing BHP Billiton Iron Ore mainline to proposed stockyards at Boodarie;
- rail loops at Boodarie;
- stockyards at Boodarie;
- an infrastructure corridor (including conveyors, access roadway and utilities) from the stockyards to the proposed marine jetty;

Marine

- an access jetty structure, including abutment works;
- a deck for the transfer station where the jetty meets the wharf;
- a wharf structure;
- berthing and mooring dolphins;
- ship access gangways and conveyor cross-overs and cross-unders;
- aids to navigation;
- a ship arrestor barrier structure; and
- berth pockets, departure basins, swing basins, link channels, new departure channel and tug access channel.

In accordance with the NODGDM (EA 2002), administered by DEWHA, a SAP is required to assess the suitability of dredge material for disturbance and disposal in offshore spoil grounds. The results of this SAP will be used to support an application to DEWHA (now DSEWPaC) for a Sea Dumping Permit under the *Environment Protection (Sea Dumping) Act 1981* (the Sea Dumping Act).

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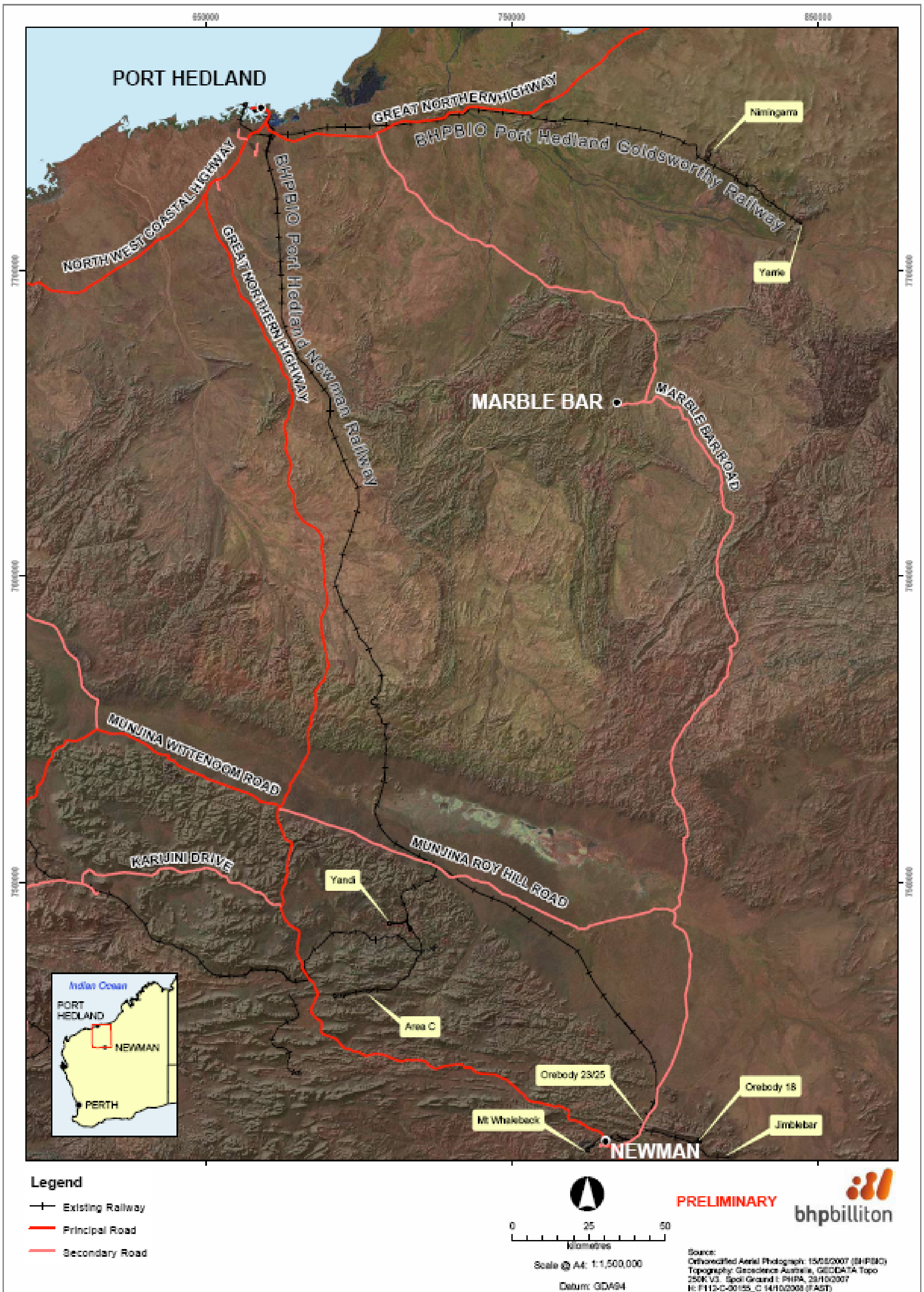

Figure 2-1 BHPBIO existing operations

- **Figure 2-1: BHPBIO's existing operations**

Figure 2-2: Port Hedland Inner Harbour existing and approved operations

- **Figure 2-2: Port Hedland Inner Harbour existing and approved operations**

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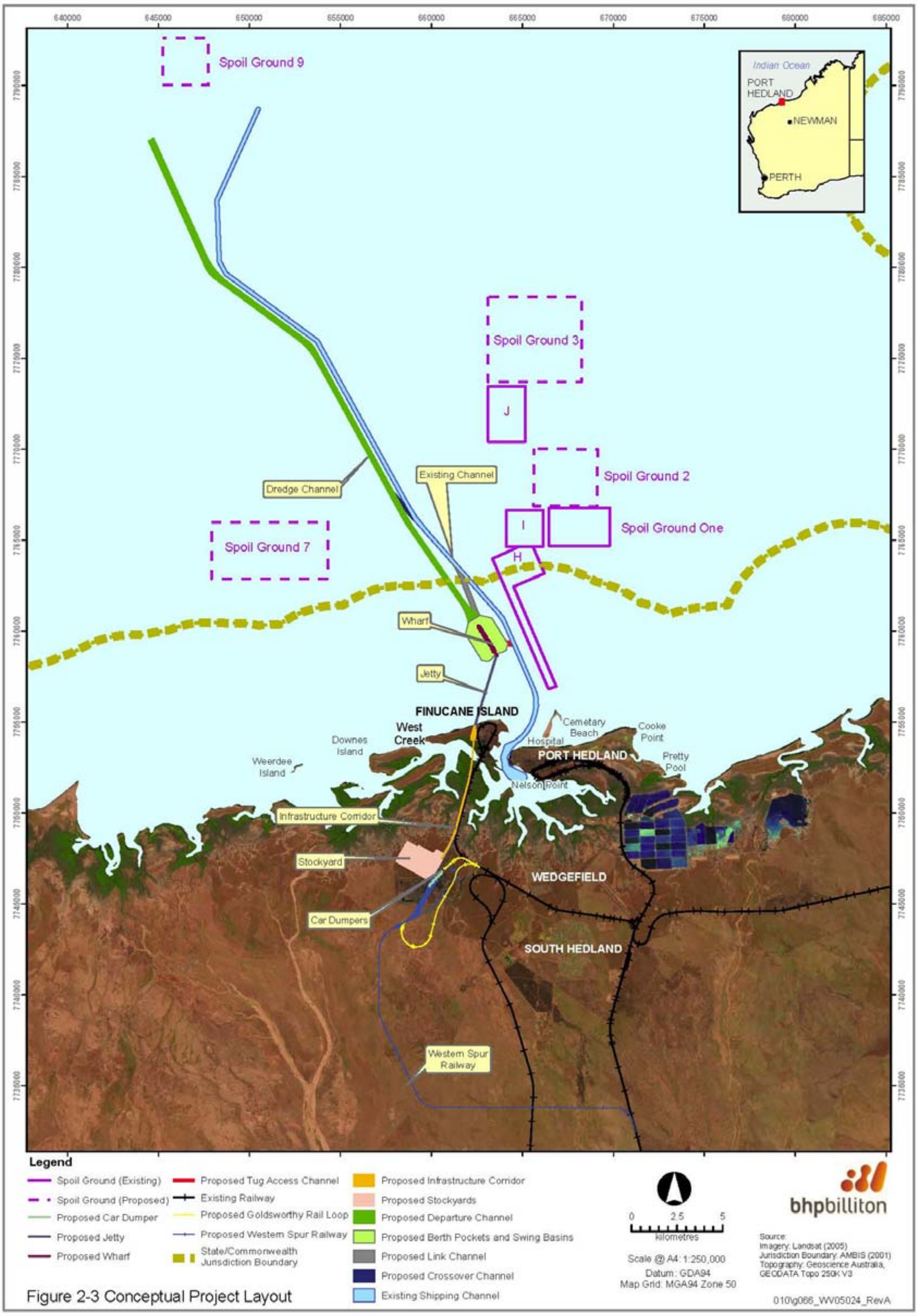

- **Figure 2-3: Conceptual project layout**

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3. Nature of Proposed Dredging

The area of proposed capital dredging is remote from existing developments (**Figure 2-3**) and remains in a largely unaltered state apart from the present shipping channel. Therefore it is likely that the sediments are 'probably clean' as per the definition given in NODGDM Section 3.11.1 (EA 2002) which states:

"In Australia there are likely to be many isolated locations that contain essentially pristine sediments, that is, no urban development, industry or transport corridors or agriculture."

The proposed location is situated well offshore (>4 km) from Port Hedland Inner Harbour and as such has no urban or industrial development that could potentially contaminate the area. Whilst the adjacent shipping channel is a transport corridor, historical sampling results (Koskela Group 2007) indicate that it is clean and it is logical to assume the area bordering it would also be clean.

The total volume of dredged material is estimated to be approximately 54 Mm^3 (inclusive of any over-dredging) for construction of Stages 1, 2 and 3 (**Figure 3-1**). There is no dredging proposed for Stage 4. A range of material types are present within the proposed dredge footprint, requiring the use of a trailing suction hopper dredger (TSHD) for unconsolidated materials. Harder materials will first require cutting and/or crushing using a cutter suction dredger (CSD) with the crushed material being left on the seabed for subsequent removal with a TSHD.

Dredge spoil will be placed in a number of offshore spoil grounds, with potential locations identified and investigated (**Figure 5-4**). The dredge footprint will be approximately 34,200 m long and on average 230 m wide for a new departure channel but this will be wider in the region of the berth pockets and turning basins. The total footprint area is estimated at 14,169,098 m^2. The layout and widths of channels, arrival and departure basins and berth pockets have been designed for the proposed vessel types in accordance with international standards.

The required depths will be approximately -22 m chart datum (CD) for the berth pockets, -23 m CD for the wharf area, -11 m CD for the arrival basin and -16 m CD for the departure basin, based upon a 250,000 dead weight tonnes (DWT) vessel. The basins, berth pockets and up to 3 km of the departure channel will be located in State waters, with the remainder of the departure channel being in Commonwealth waters. The depths along the new 34 km departure channel will range from -15.2 m to -16.7 m CD.

Dredging operations will be conducted on a 24 hours per day, 7 days per week basis. It is proposed that dredging will occur in a staged manner (as shown in Figure 2.7), as follows:

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- Stage 1 – dredging of berth pockets, eastern swing and departure basins, a tug access channel and a link channel to the existing channel to provide two loading berths;
- Stage 2 – dredging of the western swing and departure basins to provide two additional loading berths. This stage also includes the dredging works for the new 34 km departure channel and the crossover link channel;
- Stage 3 – dredging for the extension of the wharf with additional berth pockets and the swing and departure basins to accommodate another four loading berths; and
- Stage 4 – there is no dredging activity proposed for this stage.

The approximate duration of the dredging stages and respective volumes of dredged material, is summarised in **Table 3-1**. The dredging volumes shown in **Table 3-1** are approximate only, and include allowances for over-dredging, while the dredging periods account for down times for maintenance, weather related interruptions and include allowances for potential coral spawning periods where dredging activities may be affected.

- **Table 3-1: Summary of Construction Dredging Activities, their Timing and Associated Volumes**

Stage	Year	Area(s) to be Dredged	Duration (months)	Area (m^2)	Volume Dredged (Mm^3)
1	1–2	Berth pockets, eastern swing and departure basins, tug access channel, link channel	24	2,253,840.36	22
2	3–4	Western swing and departure basins, departure channel, crossover link channel	25	10,852,285.82	25
3	5	Extension of the wharf, additional berth pockets, and departure swing basins for four loading berths	7	1,062,971.37	7
4		No dredging planned	N/A	–	N/A
Total			**56**	**14,169,097.55**	**54**

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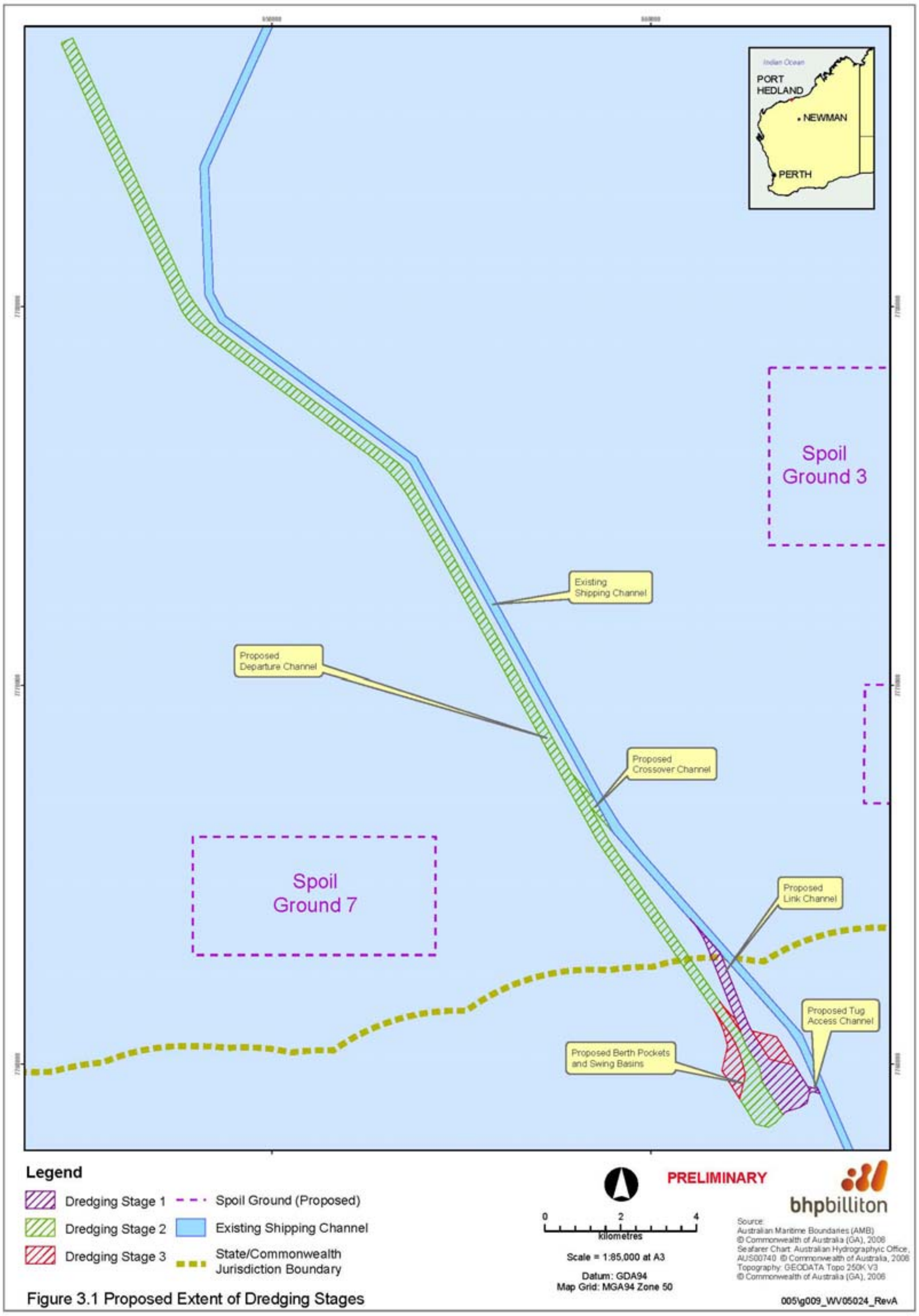

- **Figure 3-1: Proposed extent of dredging stages**

A single line seismic refraction survey carried out in the vicinity of the proposed dredge footprint in March 2006 has identified a range of material strengths in the layer of material within 8 m below the existing seabed (Fugro 2006). The nature of materials within this range and their dredging characteristics are summarised in **Table 3-2**. Based on the likely characteristics of the dredge material, dredging is likely to be conducted using a combination of cutter suction dredge (CSD) and trailing suction hopper dredge (TSHD). A cross section of the proposed dredge footprint seabed profile illustrates that the bulk of dredge material will originate from the wharf head and berth pocket areas (**Figure 3-2**). Additionally, geotechnical bores have demonstrated that unconsolidated sand and shell is generally restricted to the upper 2 m of sediment (**Figure 3-3**). The soil units identified in the geotechnical bores are summarised as follows:

- **Unit 2a – Holocene sands and gravels:** This unit consists of loose dark brown to grey, fine to coarse (though mainly coarse) quartz sands, with varying amounts of shell and coral debris, fine to medium gravel, clay and silt. This layer is typically calcareous, with a very loose to medium dense consistency. The calcareous component is largely composed of eroded calcarenite and water-worn calcrete nodules.
- **Unit 2b – Holocene marine muds:** This unit typically comprises black, dark brown, grey-brown, silty and sandy clays, which are very soft to firm in consistency and commonly malodorous.
- **Unit 4b –Siliceous calcarenile:** This unit generally consists of siliceous calcarenite, which is lithified beachrock comprising quartz sand, whole shells, shell fragments and ooliths (sand-size concretions of carbonate material). Preliminary laboratory testing indicates that the siliceous calcarenite contains up to 40% quartz grains. The unit is generally very weak to moderately weak, decreasing in strength with depth.
- **Unit 6a – Upper red beds:** This unit generally comprises relatively uniform red brown clayey sand, silty sand and sandy clay, ranging from medium dense to very dense and stiff to hard in consistency. In contrast to the underlying, and more cemented, Unit 6b, the consistency of Unit 6a is the consequence of compaction by self-weight, rather than by cementation. Although cemented layers may be encountered within Unit 6a, the majority of this unit is uncemented.
- **Unit 6b – Lower red beds:** This unit generally comprises very weak to moderately weak clayey sandstone, sandstone, calcareous sandstone and conglomeratic sandstone towards the base of the layer. The sandstone and clayey sandstone can be very weakly cemented in places. The quartz content of the lower red beds has been estimated as being up to 90%, though 30–60% is more common.
- **Unit 7 – Sandstone Breccia, Silcrete Breccia and Calcareous Breccia:** This unit generally comprises sandstone breccia, silcrete breccia and calcareous breccia, which are distinguishable by the nature of the cementing material (silcrete/ferricrete/ calcrete). Unit 7 tended to be the hardest, most rock-like material encountered.

Note that Unit 2a is 'alluvial sand and shell'; other categories are rock or heavily consolidated material that would be extremely unlikely to contain sediment contamination.

Figure 3-3 is inclusive of the innermost 6 km of the proposed dredge footprint, but is characteristic of the entire footprint.

- **Table 3-2: Dredging material characteristics identified from early seismic works**

Seismic Wave Velocity (m/s)	Generic Description	Dredging Characteristics	Location where material is found
< 1,900	Unconsolidated sediments[1]	Easily dredged with a TSHD	Generally limited to upper 2 m^2
1,900–2,500	Weakly consolidated sediments	Easily dredged with a CSD	Variable
2,500–4,000	Medium strength rock	Dredged with difficulty with a CSD	Variable

[1] Note that this is a geotechnical definition of 'unconsolidated sediment' which is not necessarily equivalent to the definition for surficial sediment sampling purposes.

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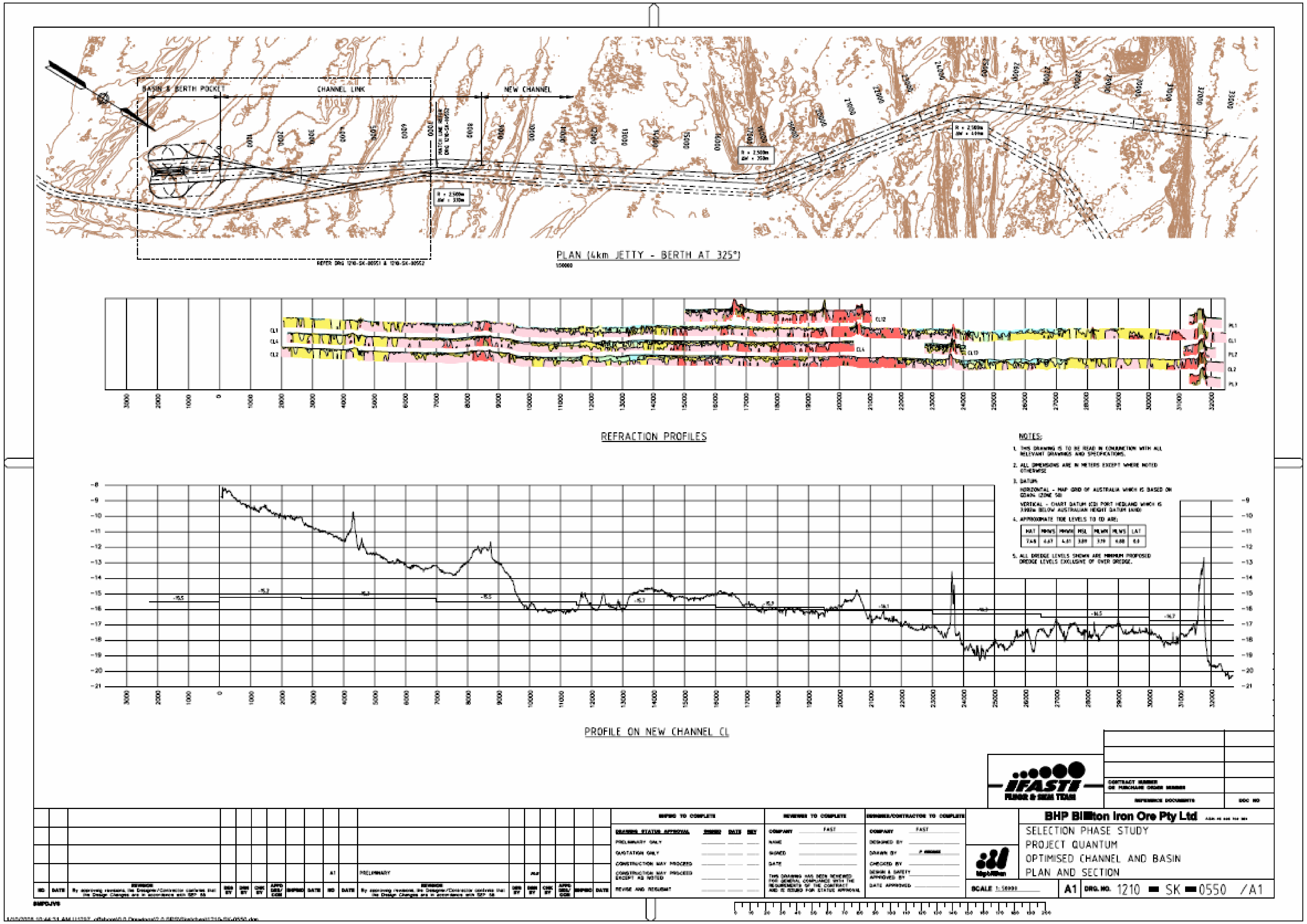
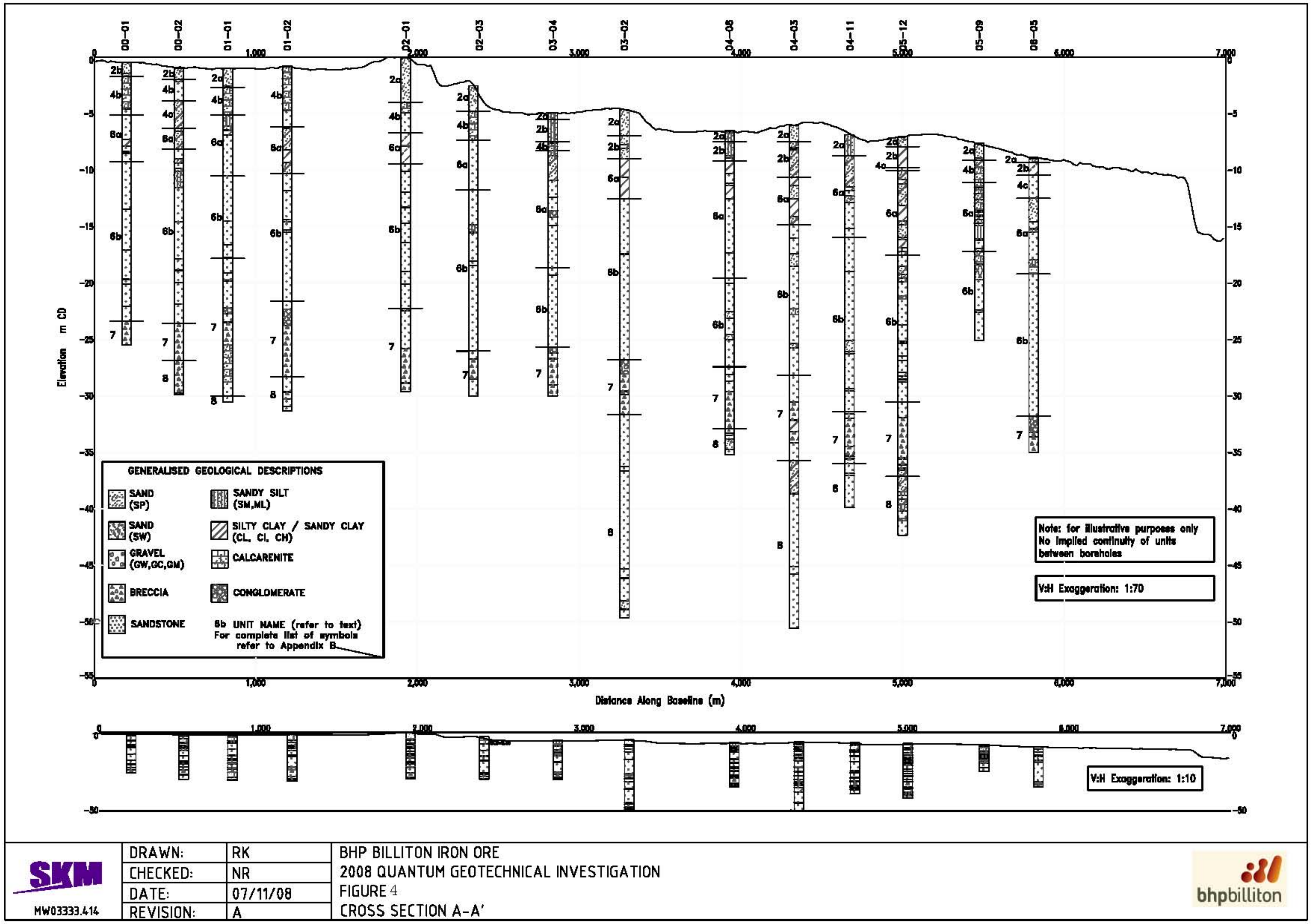


■ **Figure 3-2: Longitudinal cross section of proposed dredge footprint seabed profile**



■ **Figure 3-3: Sediment depth profile along part of the proposed dredge footprint**

4. Description of Existing Information

4.1. Contaminants of Concern

Contaminants of concern are defined in NODGDM (EA 2002) as:

> "Those chemical substances for which sources are known or suspected in the dredge area or its catchment, based on historical data. Where good chemical data are available on the sediments, the contaminants of concern are those substances that are present at levels greater than the relevant Screening Level."

4.1.1. Previous Studies of Contaminants of Concern in the Region

Port Hedland Inner Harbour

The sediments of Port Hedland Inner Harbour have been extensively analysed over recent years and previous studies have shown homogeneity of contaminant levels throughout the Port, with the exception of some results described below. A summary of sediment chemistry data collected in the Inner Harbour in commissioned studies since 1990 for BHP Billiton Iron Ore, Port Hedland Port Authority (PHPA) and Fortescue Metals Group Limited (FMG) is detailed in **Table 4-1**.

Outside Port Hedland Harbour - Shipping Channel

In May 2006 the PHPA analysed sediment samples that were collected at 24 locations in the existing shipping channel outside of Port Hedland (Koskela Group 2007). Of the contaminants of concern analysed in that channel, only nickel (Ni) generated results that exceeded the NODGDM screening levels (EA 2002). . The report concluded that although the 95% Upper Confidence Limit (UCL) for nickel (21.6 mg/kg) marginally exceeded the NODGDM screening level of 21 mg/kg, it could be explained as being a natural occurrence. It should be noted that as the material was collected from the channel at a deeper strata than the surrounding seabed with a Van Veen grab, there is a strong possibility that the analysed samples contained at least some sediment from this deeper strata, as opposed to only sediment that had washed into the channel from the adjacent seabed.

Geotechnical boreholes to a minimum depth of -25m CD were analysed for environmental parameters in the BHP Billiton Iron Ore Outer Harbour Development SAP and exhibited levels of nickel exceeding NODGDM screening levels. The results from these samples, coupled with a lack of known anthropogenic inputs, indicate a strong likelihood that elevated nickel (Ni) levels in the offshore region are naturally occurring. Results from these boreholes also indicated that levels of arsenic (As) at depth were in exceedance of NODGDM screening levels.

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Table 4-1: Summary of sediment chemistry analyses in Port Hedland Inner Harbour

Proponent, Consultant and Study Date	Study Outcomes
PHPA (Koskela Group 2007)	Analysed sediment samples that were collected from 14 sites adjacent to the PHPA No. 1, 2 and 3 berth pockets at Nelson Point (see **Figure 2-2**) indicated that the 95% UCL of the mean for copper (74.1 mg/kg), nickel (36.4 mg/kg) and TBT exceeded NODGDM screening levels. From 14 sites adjacent to BHP Billiton Iron Ore Nelson Point berths A and B, the 95% UCL for chromium (96.2 mg/kg) and nickel (46.2 mg/kg) exceeded NODGDM screening levels. From 10 sites adjacent to BHP Billiton Iron Ore Finucane Island berths C and D, the 95% UCL for chromium (83.8 mg/kg), nickel (39.8 mg/kg) and TBT exceeded NODGDM screening levels. From 18 sites within the Inner Harbour maintained channel, the 95% UCL for nickel (33.8 mg/kg) exceeded NODGDM screening levels. From the 4 reference sites sampled, the 95% UCL of the mean for arsenic (48.1 mg/kg) exceeded NODGM screening levels with one sample exceeding the maximum screening level of 70 mg/kg recording a maximum concentration of 74 mg/kg.
FMG (Oceanica 2005)	Sampled sediments for heavy metals within FMG's proposed dredging location at Anderson Point. Concluded that the top metre of sediment was uncontaminated by metals or TBT. Concentrations of nickel (40 mg/kg) and chromium were above NODGDM screening levels. Oceanica (2005) postulated that this related to the naturally high concentrations of these metals in the region as concentrations of nickel and chromium have previously been found to be elevated at locations remote from the harbour (URS 2004). Bioavailability testing conducted on samples elevated in nickel and chromium found that the bioavailability of these elements was found to be acceptably low against ANZECC/ARMCANZ (2000) guidelines. Based on these results, Oceanica stated the spoil could be classified as suitable for unconfined sea disposal based on the criteria provided in the NODGDM.
BHP Billiton Iron Ore's Products and Capacity Expansion (PACE) projects (SKM 2002; SKM 2004)	Nickel and chromium were above NODGDM screening levels from samples taken in the harbour near the port facilities. Elevated concentrations were linked to naturally elevated concentrations of the metals in the region. Iron levels were also elevated in 2004, apparently as a result of iron ore loading in the harbour (SKM 2004; Dr Peter Morrison pers. comm.).
PHPA (PHPA 1990 – 2002)	Tested harbour sediments for numerous metals (on average every two years). Levels of arsenic, cadmium, chromium, copper, lead, nickel and TBT exceeded NODGDM screening levels at times in that period. Sites exceeding screen levels were predominantly near the wharves, the tug slip way or in Stingray Creek with lower concentrations found in the channel and a side branch of South East Creek.
PHPA (URS 2003)	Sampling and analysis of 14 metals, TBT and total petroleum hydrocarbons (TPH) for sediments from sites surrounding Anderson Point in the channel and intertidal zone. Iron, manganese, nickel and zinc levels were elevated.
BHP Billiton Iron Ore (BHP Billiton Iron Ore 1993-1996)	Analysis of water and sediment quality in the harbour found concentrations of metals comparable to regional values, except for elevated levels of iron adjacent to iron ore export berths. Iron occurs at naturally high geological levels in the region.

4.1.2. BHP Billiton Iron Ore Outer Harbour Pilot Study

In December 2007, a SAP pilot study offshore of Port Hedland was conducted by SKM on behalf of BHP Billiton Iron Ore. The location of the sampling sites was designed to be representative of the current proposed dredge footprint. Sixty sites distributed along 15 one kilometre transects (four sites per transect) were sampled along a theoretical dredge 'footprint'. Transects were aligned perpendicular to the footprint (**Figure 4-1**). Core sampling by divers met resistance at ≤ 50 cm at all sites. The pilot study 'footprint' results demonstrated that of all potential contaminants of concern described in the following sections, only arsenic (As) had a 95% UCL above NODGDM screening levels. The pilot study analysed samples for certain unlikely contaminants at one-third of sites, such as polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCs) and polychlorinated biphenyls (PCBs). The 95% UCL for all of these potential contaminants of concern were below NODGDM screening levels.

The main points of interest from the pilot study results were:

- One sample contained levels of silver (Ag; 5 mg/kg) exceeding the NODGDM maximum level (3.7 mg/kg) and all other samples were below the detection limit of 0.1 mg/kg;
- 54 samples contained levels of arsenic (As) exceeding NODGDM screening levels (20 mg/kg) but below NODGDM maximum levels (70 mg/kg);
- One sample contained levels of nickel (Ni; 34.3 mg/kg) exceeding NODGDM screening levels (21 mg/kg) but below NODGDM maximum levels (52 mg/kg); and

Power analysis undertaken on the pilot study 'footprint' results using Systat v12 Software (Systat Software Inc.) and 80% cut off for type 2 analysis, demonstrated that it would be necessary to sample only 5.1% of the normally proscribed sample sites in the main SAP in order to adequately characterise the material from the proposed footprint. The power analysis calculations are presented in **Appendix A**.

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- **Figure 4-1: Location of pilot study sampling sites**

4.1.3. Currency of Data

Data currency is defined in NODGDM (EA 2002) as follows:

> *"Where there is existing chemical or toxicity data from the dredging site sediments, of quality acceptable to the Determining Authority, it will have a maximum currency of five years. Where contamination of the waterway is ongoing, or new pollution sources are present (such as a new industry or accidental spill) recent data will be required."*

Data currency for available data from sites adjacent to the proposed Outer Harbour Development footprint and potential spoil grounds is less than five years old (e.g. Koskela Group, 2007). As there have been no known spills or new industrial inputs in the vicinity of those sampling sites, the data sets are considered to be valid for use in determining the contaminant status of material in the proposed footprint and potential spoil grounds.

4.1.4. Potential Contaminants of Concern in this SAP Study

The proposed dredging footprint for the BHP Billiton Iron Ore Outer Harbour Development is in an area distant from known potential land based and industrial contaminant inputs. The nearest potential source of contaminants is Port Hedland shipping channel, followed by the Inner Harbour, the entrance being approximately 4 km in a straight line from the nearest point of proposed dredging (**Figure 2-3**). The area of proposed activity is on a stretch of coastline devoid of out flowing terrestrial river systems, reducing the potential source input of many contaminants. It is also a high energy environment (large tide differentials and summer cyclonic activity) which results in thorough mixing of sediments in the offshore environment and reduces the likelihood of 'hot spot' formation where contaminant levels are elevated in highly localised areas.

Sediment sampling surveys that have been previously undertaken in the existing Port Hedland Port Authority shipping channel (Koskela Group 2007) indicated that the sediments would likely be classified as 'probably clean' with the exception of naturally occurring levels of nickel (Ni).

A pilot study conducted in December 2007 (see **Section 4.1.2)** demonstrated that of the potential contaminants of concern listed below, only arsenic (As) had a 95% UCL exceeding NODGDM screening levels. As explained in **Section 4.1.1**, elevated levels of nickel and arsenic were also encountered at depth in geotechnical boreholes analysed for environmental parameters, indicating natural influences.

Despite evidence to date and possible exemption from further testing as described in NODGDM Section 3.1, a conservative sampling approach was taken in the SAP and Supplemental SAP investigations as the proposed dredge footprint is located parallel to an existing shipping channel

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which, although demonstrated to be 'probably clean', could be a source of introduced shipping related contaminants of concern such as tributyltin (TBT).

The potential contaminants of concern that were analysed in the SAP and Supplemental SAP investigations included:

- Metals (Sb, As, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, Ag, Zn);
- Tributyltin (TBT);
- Total organic carbon (TOC);
- Particle size distribution (PSD) and Moisture content; and
- PAHs, OCs and PCBs in approximately one third of the samples.

These were the potential contaminants that were analysed from surficial samples collected by divers. Material was also collected to dredge depth from ten geotechnical cores for analysis of the metals listed above (see **Table 6-7**).

4.1.5. Benthic Habitat of Dredge Footprint and Potential Spoil Grounds

Habitat mapping undertaken by marine scientists and commercial divers to date has indicated the benthos of the dredge footprint and potential spoil grounds to be dominated by medium to coarse grain sands and shell fragments. Medium to coarse grain sediment was also encountered at sampling sites during the pilot study. Geotechnical cores have demonstrated the upper 2 m (approximately) of seabed to be dominated by sand and shell (**Figure 3-3**). Below this depth, the geotechnical cores encountered consolidated material or rock.

These observations are consistent with a marine technical report released by the Western Australian Department of Environment and Conservation (DEC 2006). The DEC's survey measured grain size from the top 2 m of sediment at four sites offshore from Finucane Island (to the west of the proposed dredge footprint) and reported that sediment grain sizes of <63 µm comprised <1% of the sediment volume at each site. Sediment grain size has a strong correlation with contaminant binding potential. This is particularly true for metals and sediment particles <2 µm such as clay (DEC 2006).

The sparse biota within the proposed dredge footprint and potential spoil grounds is comprised of soft corals, sponges, ascidians (sea squirts), *Halimeda* (calcareous green algae) and a variety of mobile epifaunal invertebrates, predominantly echinoderms (sea stars, urchins, crinoids and sea cucumbers). At a small number of survey sites in the vicinity of ridge lines, divers observed scleractinian corals (hard coral). These corals were predominantly small colonies of *Turbinaria* spp (<50 cm diameter).

5. Sampling and Analysis Plan Execution

5.1. Sampling Design and Rationale

In reference to the procedures outlined in the NODGDM (EA 2002), special consideration was given to sampling design in this SAP for three reasons:

- The sediments to be dredged in the proposed area are 'probably clean' as a result of the remote and unaltered nature of the proposed area of development;
- The presence of contaminants was not expected to vary spatially throughout the area of proposed dredging due to high sediment mixing by wave action; and
- The dredge footprint encompasses an extremely large area that would require an excessive number of sampling sites when consideration is given to points 1 and 2 above.

In consideration of the above, sediment was sampled from a reduced number of sites than that which would normally be required. Guidance taken from NODGDM Appendix 4: *London Convention – Waste specific guidelines for assessment of dredged material*, indicates that this approach was appropriate. In **Section 4.2** of this appendix, sediment can be exempt from detailed characterisation if it meets one of three criteria:

1) Dredged material is excavated from a site away from existing and historical sources of appreciable pollution, so as to provide reasonable assurance that the dredged material has not been contaminated;
2) Dredged material is comprised predominantly of sand, gravel and/or rock; and
3) Dredged material is comprised of previously undisturbed geological materials.

The material in the proposed dredge footprint meets all three of these criteria, as described earlier in the document in **Sections 3** and **4.1**.

5.2. Number of Sample Sites

Surficial sediment samples have been collected and analysed from a total of 213 sites offshore of Port Hedland (**Table 5-1**). Of these, 50 were within the proposed berth and channel dredge footprint and 33 were in preferred spoil grounds. After analysis of samples from those 83 sites, design modifications re-located the berthing area closer to the coastline, necessitating sediment analysis from an additional 27 sites in the re-located berth area and from 10 potential spoil ground sites related to the new berth area. At every site, surficial cores met refusal < 50cm, which means that there is only one sample per site (other than field triplicate and split samples).

Sediment was also analysed for metal concentrations from 4–6 geological strata of ten geotechnical bore holes which were drilled to the proposed dredge depth (see **Figure 5-1** and **Table 6-7**).

- **Table 5-1: Summary of sediment sample numbers and trip dates**

Sample type	Number of samples	Collection start	Collection finish
Pilot study ‘footprint’	60	18/12/2007	23/12/2007
Pilot study ‘spoil grounds’	8	18/12/2007	23/12/2007
Potential spoil ground sites (1)	25	11/01/2008	12/01/2008
Footprint sites (6 km design)	50	06/02/2008	11/02/2008
Potential spoil ground sites (2)	33	02/05/2008	17/05/2008
Footprint sites (4 km design)	27	22/09/2008	23/09/2008
Potential spoil ground sites (3)	10	22/09/2008	23/09/2008
Total surficial sites	**213**		
Geotechnical bore holes (A)	6	29/03/2008	04/04/2008
Geotechnical bore holes (B)	4	24/07/2008	25/07/2008
Total boreholes	**10**		

Details of surficial sampling site collection dates, times, co-ordinates and water depths are provided in **Appendix E**.

5.2.1. Dredge Footprint

According to NODGDM (EA 2002) the appropriate number of samples sites for screening of sediments is based on the volume of spoil to be dredged. NODGDM (EA 2002) also states that anthropogenic contamination of seabed sediments is generally accepted to occur in the upper mobile sediment layers down to one metre, which makes this the material of potential concern. Therefore, the volume of material (VoM) that was to be sampled for this proposed dredge activity was calculated as the volume of the top metre of the proposed footprint, calculated by the following formula:

VoM = Area of footprint × 1 m

Geographical Information System (GIS) analysis determined that the dredge footprint of the area was approximately 11,974,320 m^2

Therefore, the VoM = 11,974,320 m^3

The number of sample sites was based on the number of sites to appropriately screen the volume of material removed from the top metre of substrate within the proposed area of dredging. This approach has been approved in recent years by DEWHA for capital dredging SAP projects including Albany Port Expansion (2007), Bunbury Port Authority (2008), Dampier Port Upgrade A (2004), Dampier Port Upgrade B (2007), Fremantle Port Inner Harbour (2007) and Shark Bay Salt (2007).

Contaminant analysis of samples from the ten geotechnical boreholes taken from representative sites across the dredge footprint, to the maximum dredge depth, was also undertaken. These sites were chosen to best represent the proportion of material to be dredged along the proposed footprint, so that eight boreholes were analysed from within or near the wharf head and turning basins, where the majority of material will be dredged, and one each from mid way along the footprint and at the outer regions of the footprint (**Figure 5-1**). As a result of the remote location and 'probably clean' nature of the sediments to be dredged, these geotechnical boreholes were considered adequate to verify the sampling volume assumptions presented above.

The volume of surface material to be dredged from the proposed development is greater than 500,000 m^3; therefore NODGDM required the total number of sample sites for the proposed dredging to be based on the extrapolation shown in **Figure 5-2** using the equation:

Sample sites = $[2.447 \times 10^{-5}$ (VoM m^3 spoil)] + 15.55

The total number of sample sites required by NODGDM was therefore calculated as

Sample sites = $[(2.447 \times 10^{-5}$*11,974,320 m^3 spoil) + 15.55]
= 309 sites

The NODGDM provides the following advice for dredging programs similar to that proposed for this project:

"For very large proposals, involving millions or tens of millions of cubic metres, the number of samples should be determined statistically."

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- **Figure 5-1: Location of geotechnical bore holes designated for environmental testing**

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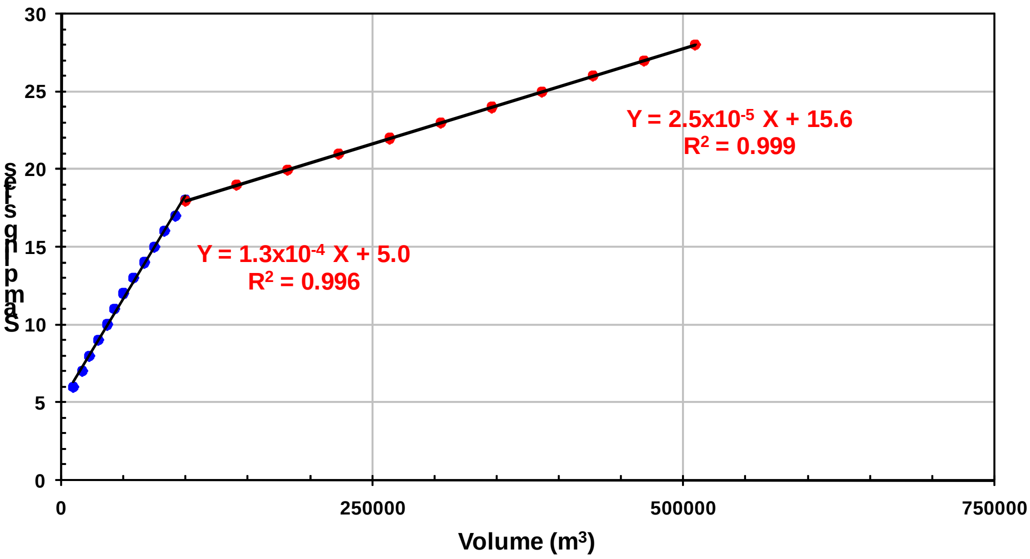
To determine a suitable number of sampling sites for the SAP study along the proposed dredge footprint, a power analysis was undertaken on existing data obtained during the pilot study. The analysis (using Systat v12 Software and 80% cut-off for type 2 analysis) demonstrated that as little as 5.1% of the number of samples normally required would be sufficient to characterise contaminants of concern (see **Appendix A**). This estimate was based on a sample of 60 sediments samples collected several kilometres to the west of the proposed channel alignment and the selection of the most variable metal arsenic which was found to occur in relatively high (above NODGDM screening) levels. These same data are intended to be used as background values for subsequent comparisons if required.

Given the extremely large area of proposed dredging, the remote nature of the proposed development and the 'probably clean' classification of sediments (see **Section 5.1**) it was proposed that 15% of the normally required sampling sites from a footprint this size would be adequate.

The total number of sample sites was therefore calculated as follows:

Sample sites $= [(2.447 \times 10^{-5} * 11{,}974{,}320 \text{ m}^3 \text{ spoil}) + 15.55] * 0.15$
$= 47$ sites
Rounded up $= 50$ sites



- **Figure 5-2: Number of sample sites required for chemical testing as per NODGDM**

Despite the fact that the material was 'probably clean' throughout the footprint, the proposed dredge footprint was considered as being three areas: wharf area (sites 1–10), inner channel (11–31) and outer channel (32–50). This design was considered appropriate to demonstrate any possible stratification of contamination levels from nearshore versus offshore areas (see **Figure 5-4**). In accordance with NODGDM (EA 2002), the proposed 50 sampling sites were randomly assigned to a grid of equally sized cells (five times the number of sampling sites) along the footprint on a pro rata basis for each of the three areas.

After these samples were collected (and the original SAP was submitted to DEWHA), design modifications re-located the berthing area of the dredge footprint closer to land. Sites were assigned within the area of the re-located berth footprint not previously sampled. This area equated to 3,557,381 m^2. The number of sample sites was calculated as for the SAP, resulting in 16 sample sites. An additional 11 sites (for a total of 27 sites, labelled 101 - 127) were assigned to allow for any minor realignments of the footprint (**Figure 5-4** and **Figure 5-5**).

5.2.2. Potential Spoil Grounds

Selection criteria for the potential spoil grounds were based on requirements outlined in NODGDM Section 4 (EA 2002) and considered:

- the potential for environmental impact (that is proximity to sensitive habitats);
- adequacy of water depth (to limit re-suspension); and
- potential conflicts with current and future use of the area (in regards to shipping channels and anchorages).

After completion of pilot study sampling and confirmation of the proposed dredge footprint, samples were collected and analysed from 25 sites within five potential spoil grounds in January 2008 (**Figure 5-3**). These spoil grounds were discounted after subsequent environmental investigations and engineering inputs/constraints.

A further 33 sites were sampled in May 2008 from six potential spoil ground areas, labelled Areas 1–3 and 7–9 (**Figure 5-4**). Five sites were sampled in each potential area, other than Area 3. Sampling of eight sites was considered suitable for characterising Area 3 due to its relative size compared with the other areas. Coordinates of all sampling sites and spoil ground corner points are supplied in **Appendix E.**

As described in **Section 5.2**, design modifications reduced the jetty length which brought the berth area dredge footprint nearer to shore (see **Figure 5-5**). Concurrently, the size of Area 7 increased. To allow for this increase, an additional three sites were assigned to Area 7 in the Supplemental SAP (Sites 202 -204 in **Figure 5-5**). In consideration of the design modification, an additional seven sites were investigated in the Supplemental SAP to the north and west of Area 7 to allow for a greater percentage of dredge material to be dumped closer to the dredge area, if required (Sites 201 and 205 – 210 in **Figure 5-5**). Sampling procedures at all spoil ground sites were identical to those employed to assess material in the proposed dredge footprint so as to allow comparison of physical properties and contaminant levels.

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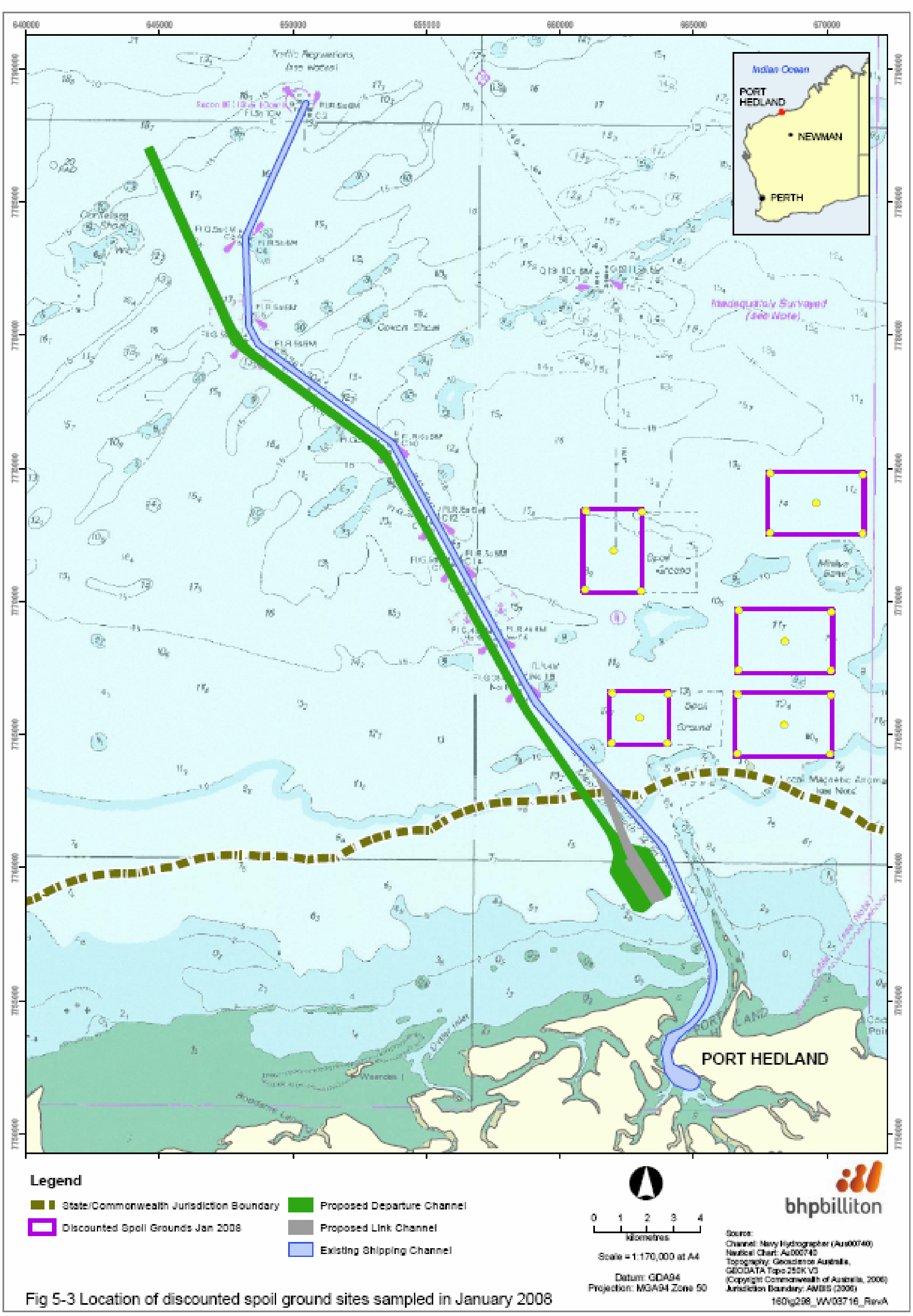

Figure 5-3: Location of discounted spoil ground sites sampled in January 2008

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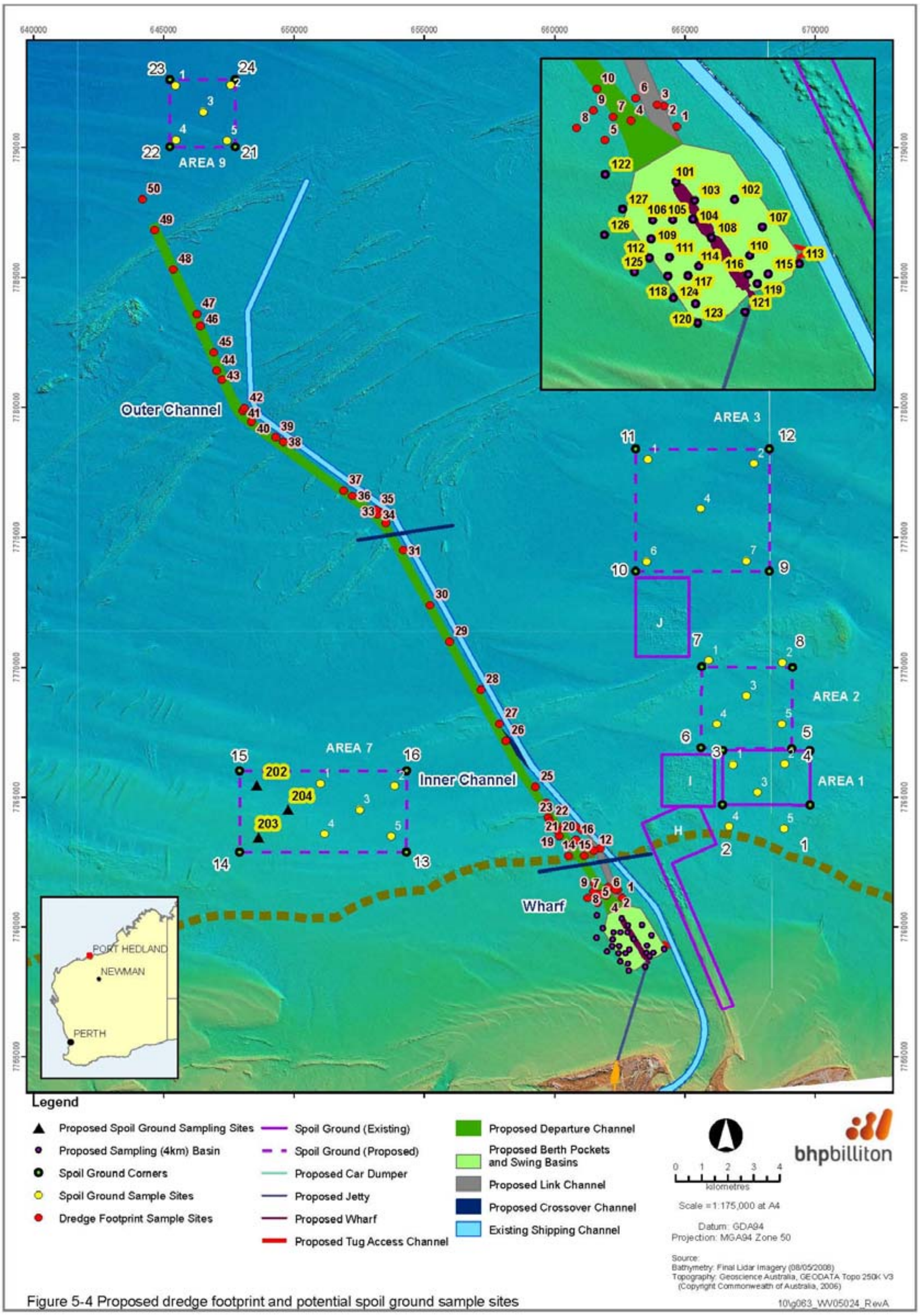

■ **Figure 5-4: Proposed dredge footprint and potential spoil ground sample sites**

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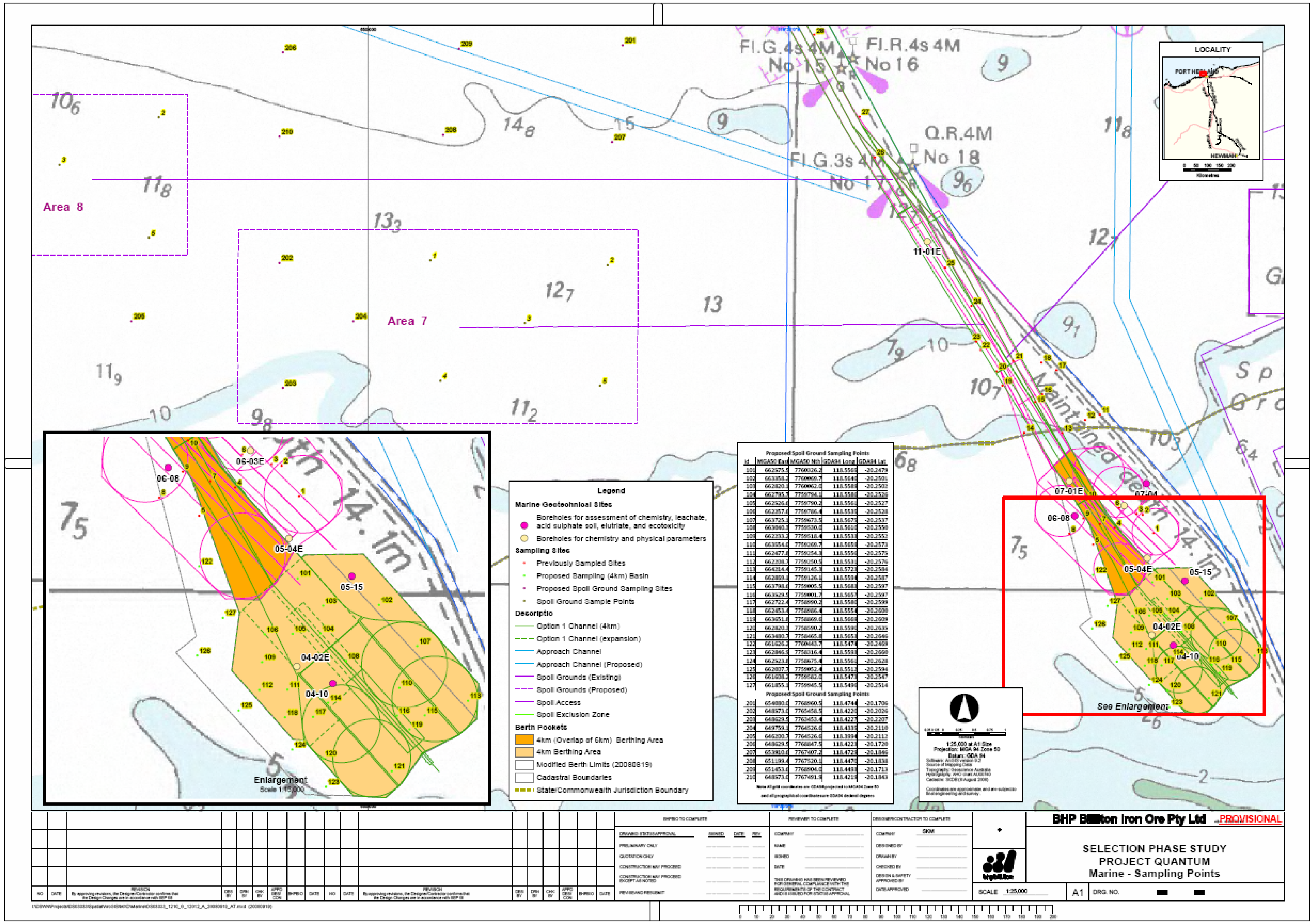

■ **Figure 5-5: Sites in re-located berthing and potential footprint enlargement area**

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5.3. Sampling Procedures

5.3.1. Hand Core Sediment Collection

Surficial sediment samples were collected using polycarbonate cores by marine scientists. Seafloor sediments within the proposed footprint and potential spoil grounds were predominantly comprised of a shallow layer of medium to coarse grain sand and shell fragments over pavement or rubble. This resulted in core refusal of ≤ 50 cm at all sites. At all sites, divers attempted to push or tap in cores vertically, but the physical characteristics of the sediment frequently necessitated oblique coring or surface grabs in order to get sufficient material.

When returned to the surface, cores were photographed and a visual description of the sediment core colouring and contents including biota (e.g. molluscs and macroalgae) was recorded. Records were made of the time, date, and prevalent environmental conditions when samples were collected from each site. Between sites, the sediment cores and mixing utensils were thoroughly cleaned using Decon 90 and rinsed using seawater from each site.

5.3.2. Geotechnical Bore Sample Collection

Material was analysed for environmental characteristics from the predominant geological strata of ten geotechnical bores, taken to dredge depth. Due to scarcity of unconsolidated sediment above the uppermost 1–2 m of seabed, there was an inadequate amount of material to allow longitudinal splitting of each core for environmental testing, as recommended in NODGDM Section 3.3.3 (EA, 2002). There were 2–3 strata in each core from which adequate volumes of suitable material was present for environmental analysis. Material was collected and homogenised from various locations within each of the strata to create one sample per strata. Material was then placed into suitable containers as advised by a NATA accredited laboratory, and were sent by priority freight for analysis at NATA accredited laboratories in Perth and Sydney.

The location of boreholes is illustrated in **Figure 5-1**; the six black dots indicate sites that had material analysed for standard chemical and physical characteristics as listed in **Section 4.1.3**, while the pink dots represent sites where material was analysed for standard chemical and physical characteristics as well as acid sulphate soils, leachates, elutriates and ecotoxicity. These additional tests were included so as to facilitate any potential land based disposal if it becomes a viable option, and the results are not discussed in this report.

5.3.3. Sample Handling, Preservation, Storage and Transportation

Immediately post collection and description of cores, samples were transferred to individual containers sourced from the laboratory for sample analysis so as to comply with NODGDM guidelines and Appendix 7 therein (**Table 5-2**). Marine scientists wore clean, non powdered latex gloves at all times when processing samples to minimise the risk of contamination. Gloves were replaced before each sample was processed to prevent possible cross contamination. Samples were stored below 4°C and in the dark in a refrigeration unit (chest freezer) in accordance with facilities provided on the vessel used for sampling logistics. Thermally insulated containers with cooling blocks to maintain temperatures below 4°C were on hand as a contingency and for temporary storage during transport. Samples were transported by air freight or priority road freight to ensure they were received by the laboratory in suitable condition for each physical and chemical parameter to be analysed. Samples were consigned using a chain of custody to the laboratory for analysis. Only one NATA approved laboratory was contracted to analyse samples (other than ecotoxicity; which is not discussed in this report) as the contaminants of concern were routine in nature and results would be highly unlikely to vary between laboratories.

- **Table 5-2: Summary of sample containers, preservation and storage**

Analytical parameter	Container	Preservation technique & holding time
Metals (Sb, As, Cd, Co, Cr, Cu, Mn, Hg, Pb, Ni, Ag, Zn)	250 mL glass jar, Teflon lined lid.	180 day holding time – chilling to 4ºC
TBT and moisture content	150 mL glass jar, Teflon lined lid	<4°C; Dark TBT – 120 day holding time if frozen.
TOC	150 mL glass jar, Teflon lined lid	<4°C; Dark; 14 day holding time for extraction – chilling to 4ºC
PSD	150 g in a plastic zip lock bag	<4°C; No specific holding time. Freezing not required
PASS	150 g in a plastic zip lock bag	<4°C or freeze; 24 hour holding time if chilled, indefinite if frozen
PAHs	250 mL glass jar, Teflon lined lid	Freeze; Dark; 14 day holding time for extraction – chilling to 4ºC
OCs	250 mL glass jar, Teflon lined lid	<4°C; Dark; 14 days if refrigerated
PCBs	250 mL glass jar, Teflon lined lid	<4°C; Dark; 14 days if refrigerated

Note: Advice on sample containers, use, storage and transport was sought from the NATA certified laboratory to be used (ALS Perth). Moisture content/TBT/TOC was obtained from one 150 mL jar; organics from one 250 mL jar.

5.3.4. Health and Safety Precautions

Sediment samples were collected by qualified divers appropriately trained in occupational SCUBA procedures (AS2815.1) and SSBA (AS2815.2), in accordance with Australian Standards (AS2299.1:2007) and following a detailed safety plan. Despite harm from contact with contaminated sediments being considered unlikely, adequate exposure protection was used by all divers. The safety plan included a definition of hazards, a risk assessment, risk mitigation measures and an emergency plan. Activities aboard the vessel were subject to a job safety environment analysis (JSEA) which was undertaken before work commenced. Thereafter, activities were monitored by the skipper and/or dive supervisor for compliance.

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5.3.5. Analytical Laboratory

The method and analytical PQLs for the sediment analyses are provided in **Table 5-3**. Analyses were undertaken by Australian Laboratory Services (ALS) Perth, who are accredited under NATA for the analyses performed (NATA 825).

- **Table 5-3: Analytical methods and PQLs for sediment analyses**

Parameter	Sites	Method	NODGDM PQL	Analytical Laboratory PQL	Units
Antimony	All Sites	ICP-MS	0.5	0.1	mg/kg
Arsenic	All Sites	ICP-MS	1.0	0.1	mg/kg
Beryllium[1]	Supplemental	ICP-MS	–	0.1	mg/kg
Cadmium	All Sites	ICP-MS	0.1	0.1	mg/kg
Chromium	All Sites	ICP-MS	1.0	0.1	mg/kg
Cobalt	All Sites	ICP-MS	0.5	0.1	mg/kg
Copper	All Sites	ICP-MS	1.0	0.1	mg/kg
Lead	All Sites	ICP-MS	1.0	0.1	mg/kg
Manganese	All Sites	ICP-MS	10	0.1	mg/kg
Mercury	All Sites	FIMS	0.01	0.01	mg/kg
Molybdenum[1]	Supplemental	ICP-MS	–	0.1	mg/kg
Nickel	All Sites	ICP-MS	1.0	0.1	mg/kg
Selenium[1]	Supplemental	ICP-MS	–	0.1	mg/kg
Silver	All Sites	ICP-MS	0.1	0.1	mg/kg
Zinc	All Sites	ICP-MS	1.0	0.1	mg/kg
PSD	All Sites	Wet sieving - SUBCON	NA	0.1	%
Moisture content	All Sites	Drying at 65 °C	0.1	0.1	%
TOC	All Sites	LECO after acid treatment	0.1	0.02	%w/w
TBT	All Sites	GCMS	1.0	0.5	µg Sn/kg
PAHs (individual)	Selected Sites	GC/MS-SIM	5.0	5.0	ug/kg
PAHs (total)	Selected Sites	GC/MS-SIM	100.0	100.0	ug/kg
OCs (individual)	Selected sites	GPC/Florasil/GCµECD	1.0	0.5	ug/kg
PCBs (total)	All sites	GPC/Florasil/GCµECD	5.0	5.0	µg/kg

[1] Only analysed in samples proposed in Supplemental SAP

5.3.6. QA/QC Procedures

The laboratory (ALS) used for analysis is NATA certified (NATA 825) for the parameters measured and undertook required blanks, tests of standards and replicate tests to the satisfaction of NATA requirements. SKM is certified to ISO9001 and has ensured documentation and procedures adhere to ISO9001 standard.

As part of the quality control process proscribed by NODGDM in Section 3.3.7, 10% of sites randomly allocated within the dredge footprint were designated as 'triplicate' sites. At these sites, three cores were collected instead of one and the contents of each 50 cm increment (only 0–50 cm in this SAP) was analysed as an individual sample. The purpose of analysing triplicates was to assess the variability of samples collected from the same site – it may indicate localised discrepancies that need to be accounted for (that is, flakes of TBT may have dramatically increased TBT levels in one of the triplicates). The criterion for acceptance of 'triplicate' data is the relative standard deviation (RSD) of 50% and was calculated as follows:

$$RSD = \frac{\frac{Standard\ deviation}{n-1}}{Average} \times 100$$

Where: n = number of replicates

Additionally, 5% of sites were designated as 'split' sites as per NODGDM Section 3.3.7. At these sites, a single core was collected and the contents thoroughly mixed. Two samples (splits) were obtained the bowl of sediment. The purpose of splitting samples was to assess variation arising from sub-sampling techniques. If the results from the splits were not within a certain range, it would indicate poor mixing of sediments in the field before they were placed into containers. The criterion for acceptance of 'split' data is the relative percent difference (RPD) of 35% and was calculated as follows:

$$RPD = \frac{Absolute\ value\ of\ (A-B)}{Average} \times 100$$

where: A is split 1
B is split 2

5.3.7. Data Management Procedures

Data management adhered to ISO9001 standards. All data was validated prior to reporting. Sediment TBT and other organics were normalised to 1% TOC prior to any analysis. Normalisation involved division by the percent TOC when in the range 0.2–10%. TOC levels outside of the lower range resulted in division by 0.2 (effectively multiplying the organic contaminant level by 5). No values were found to be outside of the maximum range but if they had they would have been normalised by dividing by 10. Analytical data for the dredging area and each potential spoil ground was analysed separately as per NODGDM. Data was tested for normality using the Shapiro-Wilks Test and depending upon the results (normal or log-normal), the 95% UCL was calculated as follows:

(1) Normal Data: $$UCL \quad average = \overline{X} + t_{\alpha, n-1} \frac{s}{\sqrt{n}}$$

where: $\overline{X}$ is the arithmetic average of the sample measurements

α is the level of significance of 0.05

n is the number of sample measurements

s is the standard deviation of the sample measurements

$t_{\alpha,n-1}$ is the test statistic (Student's t for α and n-1 degrees of freedom)

(2) Non-normal data: Non-normal data will be statistically analysed by normalising the data (transforming it with log, square root or inverse transformations, which ever provides the best normalisation) and then using the formula (singular) in Equation (1) to calculate the 95% UCL. The 95% UCL would then be reverse-transformed to allow comparison with the NODGDM. Alternatively, the Bootstrap method using Monte Carlo re-sampling techniques (i.e. by randomly selecting values from the original sample set) can be used, should the transformation process prove unsuccessful (i.e. data is not successfully normalised via any of the transformations available).

The resulting 95% UCLs will be compared to the guideline values as per NODGDM. Statistical comparisons with background values derived from adjacent sites and the proposed spoil grounds will be made should the screening value be exceeded in any of the dredge areas.

5.3.8. Equipment

The following equipment was used during collection of sediments in the SAP:

- MV '*Sea Sprint'* and MV '*Serious Fun'* for diving operations and a clean sample handling work space;
- GPS for position fixing;
- SCUBA and SSBA equipment;
- 50 mm diameter × 50 cm long polycarbonate cores;
- Digital camera with underwater housing;
- Sample containers provided by the laboratory (ALS, NATA 825);

- Refrigeration units (chest freezers) and thermally insulated containers and freezer blocks, all aboard the vessel;
- Miscellaneous items for sediment handling, sampling and cleaning of sampling utensils (e.g. non powdered latex gloves, Decon 90 cleaning solution); and
- Data forms for logging sample collection information.

5.3.9. Contingency Plan

Contingency time was built into the dive plans to allow for delays resulting from adverse weather. Equipment required for sampling was not complex and spares of diving equipment, GPS units, and other more technical equipment was carried as backup. Had weather conditions forced fieldwork to cease, arrangements were in place to re-schedule as soon as reasonably possible.

The NATA lab requested to undertake sample analysis was requested to retain samples in storage after initial analysis. Had the 95% UCL for any potential contaminants of concern reported above screening levels identified in NODGDM, then additional investigations would have been undertaken as required.

6. Results for Pilot Study and SAP

The laboratory data that supports the results in this section are supplied in **Appendix B** and **Appendix C,** respectively, for the Pilot Study and SAP.

6.1. Particle Size Distribution

Grain sizes of samples in the Pilot Study and SAP were assigned to nine categories ranging from < 38 µm to > 2000 µm. The particle descriptions and grain sizes for each category were:

Particle Description	Grain size (µm)
Very fine gravel	> 2000
Very coarse sand	1000–2000
Coarse sand	500–1000
Medium sand	250–500
Fine sand	180–250
Very fine to fine sand	90–180
Very fine sand	63–90
Coarse silt	38–63
Medium silt	< 38

6.1.1. PSD of Pilot Study Footprint sites

Particle size distribution (PSD) data was collected from 60 sites, with four sites allocated to each of 15 transects (**Figure 4-1**). For each transect, the mean of the four sites was calculated for the grain size classes. Transects were then allocated to an area, as in **Section 6.1.1**, so that transects 1–3 were the 'wharf' zone, transects 4–8 the 'inner channel', and transects 9–18 the 'outer channel.'

For each zone, the mean of relevant transects were plotted against the nine grain size classes (**Figure 6-1** and **Table 6-1**). Less than 10 % of material from each of the zones was fine sand (≤ 250 µm) or of smaller diameter. The similarity of PSD in each area has resulted in the 'wharf' PSD curve being predominantly covered by the 'outer channel' curve.

Sediment grain size has a strong correlation with contaminant binding potential, particularly for metals and sediment particles <2 µm (DEC 2006). The PSD results illustrated in **Table 6-1** indicate a low potential for contaminant binding with material from the proposed dredge footprint. Sediment size also relates to the potential for suspension and re-suspension of particles in the water column — larger particles are less likely to remain in suspension than smaller particles (that is, reduced potential plume impact).

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6.1.2. PSD of SAP Footprint and Spoil Ground Sites

PSD was analysed from samples at 44 of 50 sites along the proposed dredge footprint. Six sites had inadequate volume of material for analysis. Results from the sites were allocated to three areas as described in **5.2.1** to generate a mean and standard deviation value for each size category in each area (**Table 6-2**). The PSD class size averages for each area were then cumulated to illustrate the distribution of sediment sizes within each zone (**Figure 6-2**). Less than 10% of material from any area was fine sand (< 250 µm) or smaller.

Particle size distribution information was calculated for the six potential spoil grounds sampled in **Figure 5-4**. Data points for each spoil ground (area) in **Figure 6-3** represent the mean value of all sites within each spoil ground. For this figure, there were five sites in Spoil Grounds 1, 2, 7, 8 and 9 and eight sites in Spoil Ground 3. Particles <180 µm accounted for ≤ 10% by weight of the means within each spoil area (**Table 6-3**).

Representative photos of intact cores collected from sites within the three SAP footprint areas are provided in **Figure 6-4**.

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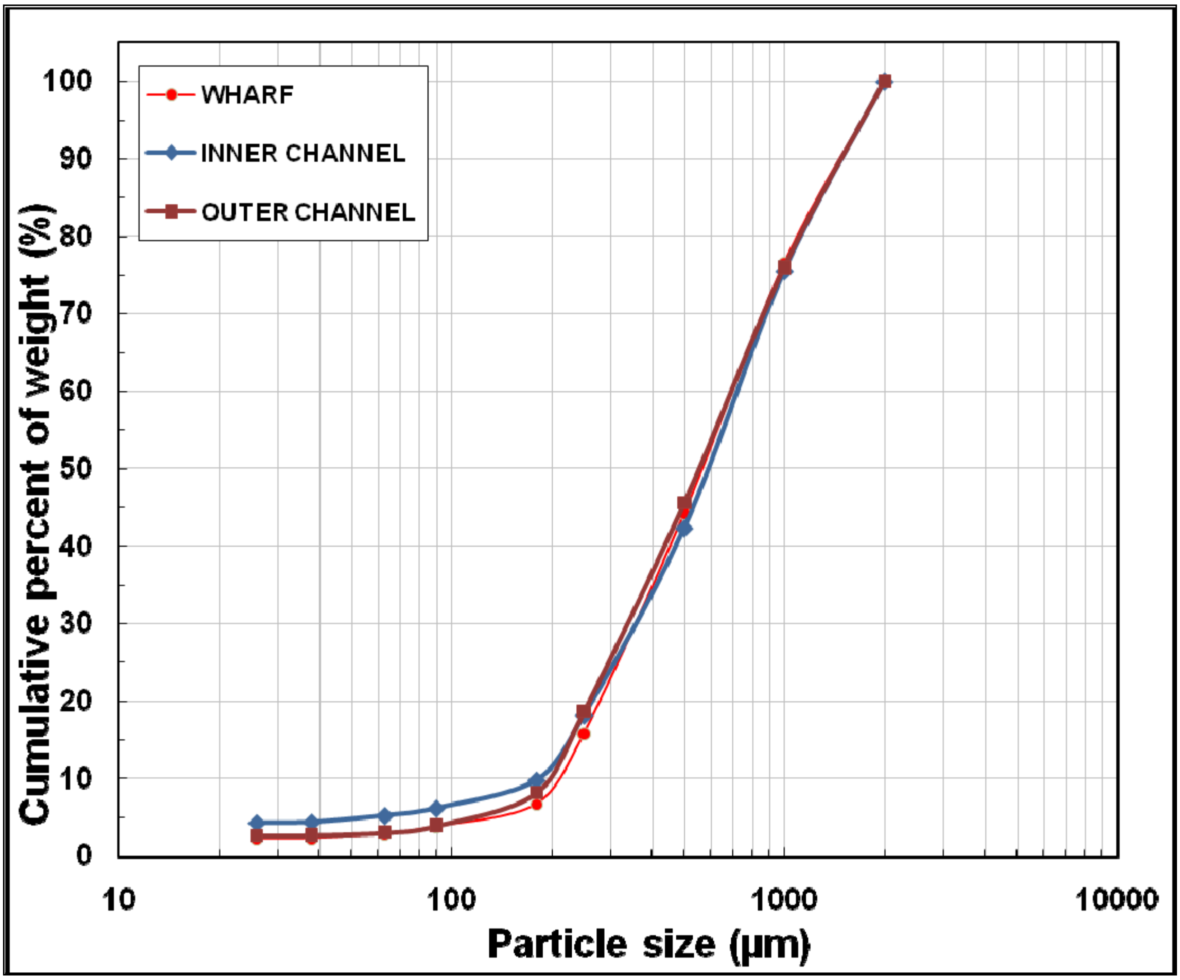

- **Figure 6-1: Mean PSD of sites in three sections of pilot study 'footprint'**

- **Table 6-1: Mean percentage of sediment by grain size class (Pilot Study)**

Classification	Grain Size (µm)	Pilot Study 'Footprint' Area		
		Wharf	Inner Channel	Outer Channel
Very fine gravel	> 2000	23.48±4.7	24.46±5.1	24.01±5.9
Very coarse sand	1000–2000	32.3±9.6	33.19±4.6	30.45±4.97
Coarse sand	500–1000	28.36±6.7	24.13±7.2	26.88±5.2
Medium sand	250–500	9.14±5.2	8.41±2.1	10.5±4.29
Fine sand	180–250	2.92±1.3	3.62±2.3	4.28±1.3
Very fine to fine sand	90–180	0.88±0.8	0.96±0.51	0.89±0.3
Very fine sand	63–90	0.62±0.6	0.85±0.5	0.34±0.1
Coarse silt	38–63	0.03±0.2	0.08±0.01	0.06±0.01
Medium silt	< 38	2.26±0.2	4.3±1.2	2.6±0.1

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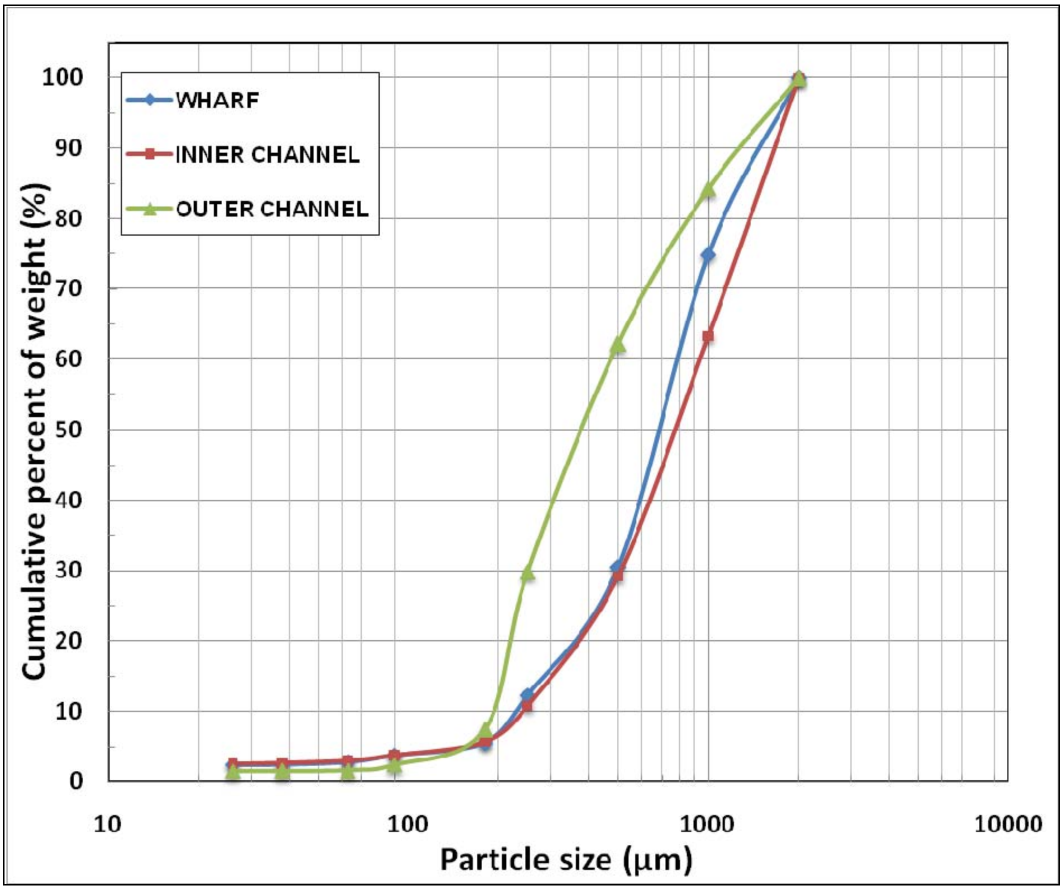
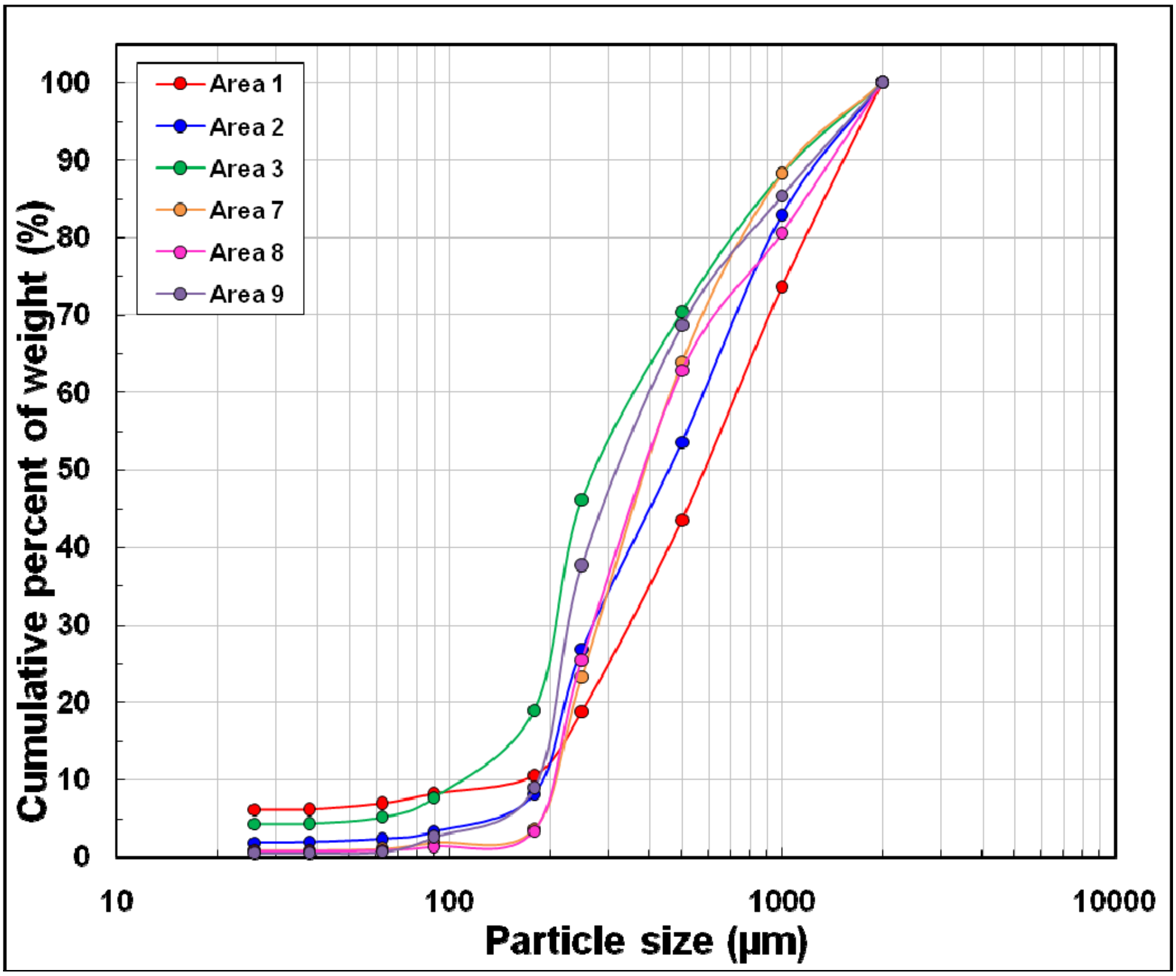


- **Figure 6-2: Mean PSD of sites in three sections of SAP footprint**

- **Table 6-2: Mean percentage of sediment by grain size class (SAP Footprint)**

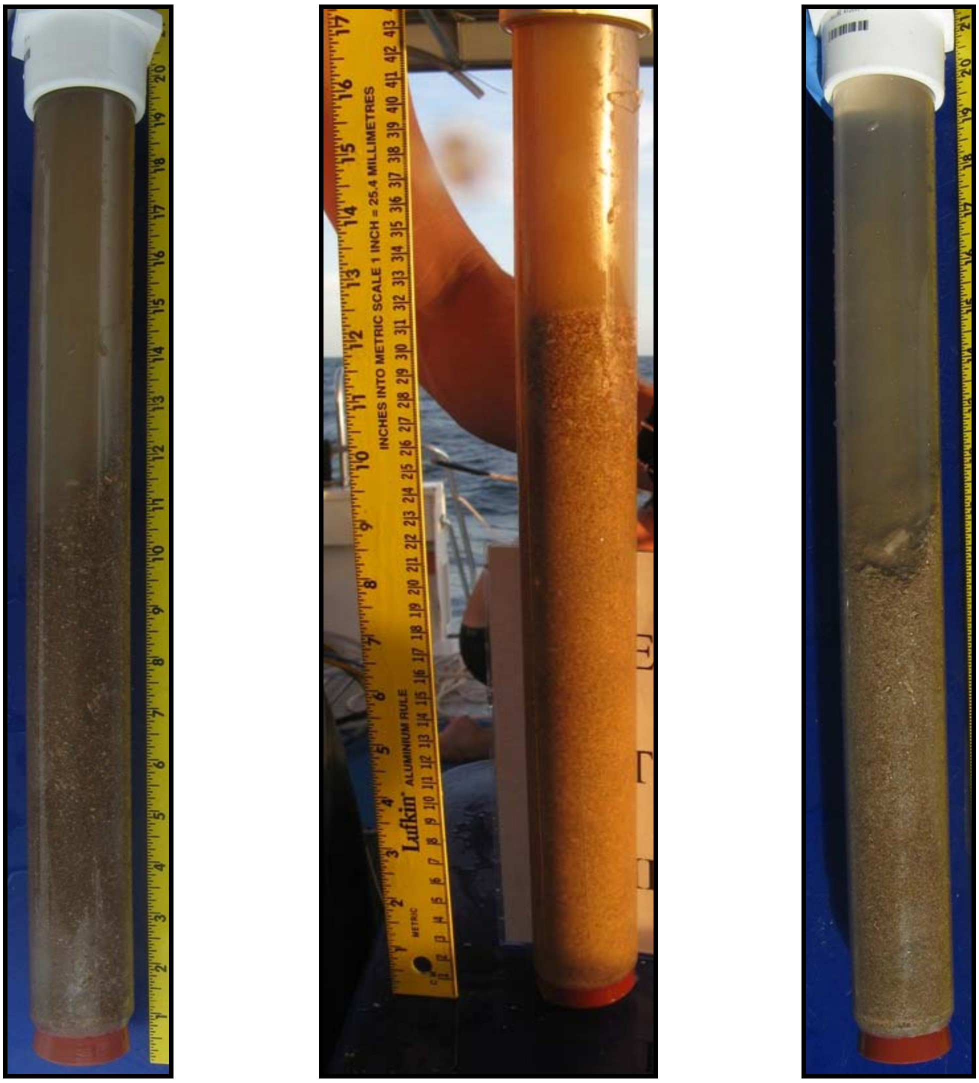
Classification	Grain Size (µm)	Proposed SAP Footprint Area		
		Wharf	Inner Channel	Outer Channel
Very fine gravel	> 2000	25.11±8.27	36.64±16.21	27.32±15.29
Very coarse sand	1000–2000	44.45±13.47	34.16±10.19	32.29±14.97
Coarse sand	500–1000	18.14±11.16	18.38±9.54	21.79±12.19
Medium sand	250–500	6.77±6.71	5.17±3.00	10.19±9.29
Fine sand	180–250	1.81±1.43	1.88±1.15	2.69±2.63
Very fine to fine sand	90–180	0.96±0.61	0.77±0.51	0.80±0.53
Very fine sand	63–90	0.35±0.25	0.35±0.18	0.28±0.19
Coarse silt	38–63	0.07±0.07	0.14±0.45	0.09±0.31
Medium silt	< 38	2.34±0.88	2.51±1.72	2.15±1.50



- **Figure 6-3: Mean PSD of sites in SAP potential spoil grounds**

- **Table 6-3: Mean percentage of sediment by grain size class (SAP spoil grounds)**

Classification	Grain Size (µm)	Proposed SAP Spoil Grounds					
		Area 1	Area 2	Area 3	Area 7	Area 8	Area 9
Very fine gravel	> 2000	26.34±10.1	17.08±9.7	11.74±12.4	11.74±10.4	19.4±15.6	14.64±12.5
Very coarse sand	1000–2000	30.1±11.1	29.37±23.6	17.90±13.6	24.4±6.2	17.77±10.1	16.69±10.0
Coarse sand	500–1000	24.71±10.9	26.77±18.9	24.23±19.0	40.56±8.96	37.45±10.7	31.01±11.3
Medium sand	250–500	8.25±5.6	18.67±21.6	27.2±22.2	19.67±7.4	22.06±13.2	28.74±12.8
Fine sand	180–250	2.33±1.2	4.86±4.7	11.3±12.7	1.73±0.59	2.04±1.4	6.31±3.31
Very fine to fine sand	90–180	1.24±1.0	0.91±0.7	2.53±2.5	0.81±0.24	0.48±0.23	1.90±1.4
Very fine sand	63–90	0.79±0.7	0.43±0.4	0.84±0.7	0.19±0.15	0.11±0.1	0.15±0.1
Coarse silt	38–63	0.03±0.1	0.08±0.01	0.03±0.02	0.01±0.00	0.01±0.00	0.01±0.0
Medium silt	< 38	6.22±2.4	1.84±1.23	4.25±2.9	0.87±0.7	0.7±0.6	0.56±0.6



Site 10 (Wharf) Site 21 (Inner Channel) Site 49 (Outer Channel)

- **Figure 6-4: Sediment cores from sites within the proposed SAP dredge footprint**

6.1.3. PSD of Borehole Samples

The particle size distribution based on samples collected from six boreholes and grouped according to soil units is provided in **Table 6-4** and **Figure 6-5**.

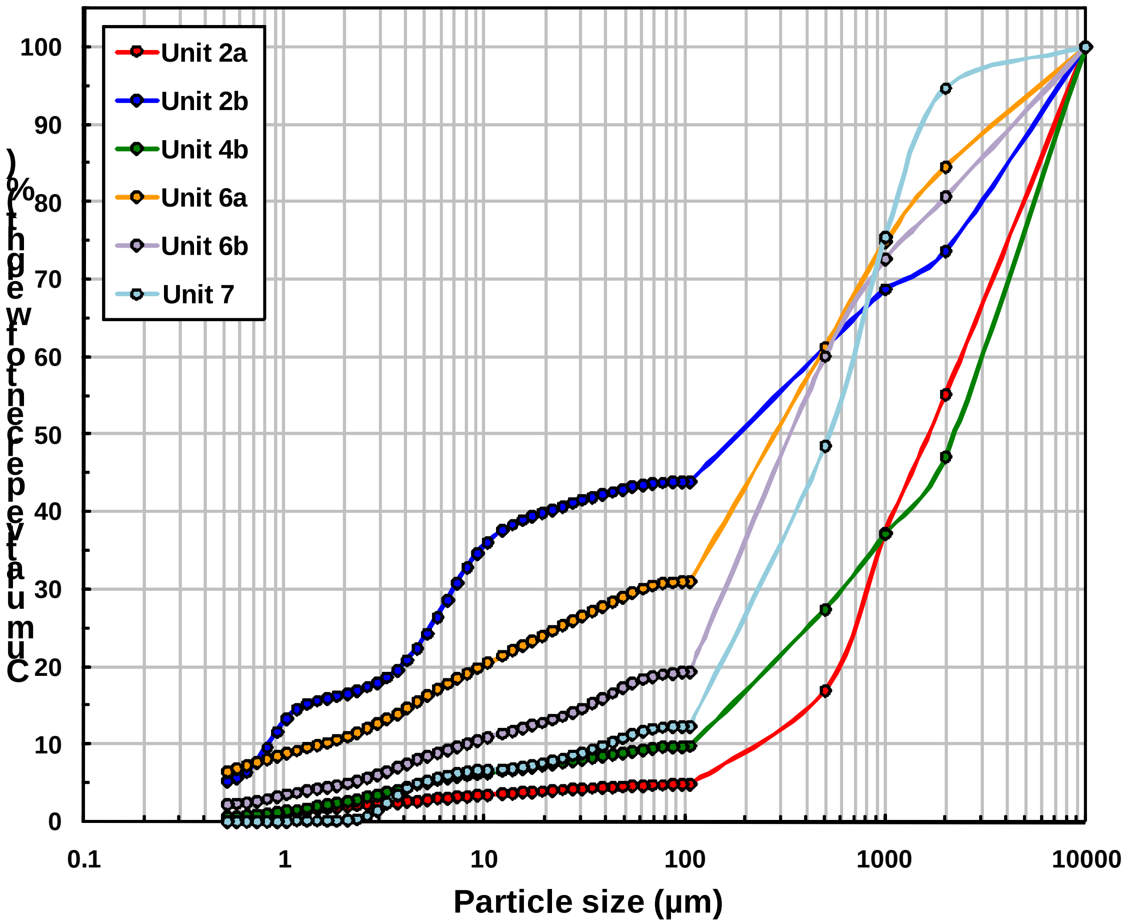
The size groupings provided in **Table 6-4** indicate that with the exception of soil units 2b and 6a, the material is predominantly coarse sand with a low fraction (<10%) of very fine silt. Soil units 2b and 6a have a very fine silt fraction of 22.46% and 15.37% respectively.

The size groupings were chosen because they represent settling behaviour when released into the water column. Material with a particle size diameter less than 5 µm will not settle out of the water column until they are well offshore in very deep water, where the hydrodynamic conditions do not continually resuspend the particles. The size classes between 5 µm and 500 µm will drop out of suspension over distances ranging from 10 km to 100 m respectively if suspended in the water column as a result of dredging and disposal activities. Particles larger than 500 µm will drop out immediately at the point of release (dredge or spoil ground).

- **Table 6-4: Particle size distribution for borehole samples by size groupings**

Soil Unit	Particle Size Classification (%/w)				
	Very Fine Silt (<5 µm)	Fine Silt (5–20 µm)	Silt (20–100 µm)	Sand (100–500 µm)	Coarse Sand (>500 µm)
	Never drops	Drops over 10 km	Drops over 1 km	Drops over 100 m	Drops over 1 m
Unit 2a	2.65	1.28	0.82	12.14	83.11
Unit 2b	22.46	17.42	4.01	17.30	38.80
Unit 4b	4.79	2.48	2.47	17.66	72.59
Unit 6a	15.37	8.53	7.02	30.26	38.81
Unit 6b	8.03	4.82	6.48	40.71	39.97
Unit 7	4.97	2.64	4.76	36.12	51.51

The percentage of fine material in soil units 2b and 6a is clearly seen in **Figure 6-5** when the data is expressed as a cumulative percentage of the total sample weight. Soil units 2a, 4b, 6b and 7 are subtly different in percentage composition of material less than 100 µm, and more variable when over 100 µm, but they are very similar in the fraction less than 5 µm.



- **Figure 6-5: Particle size distribution of borehole samples**

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6.2. Sediment Metals

As for PSD, sediment metal data from the proposed SAP footprint and the pilot study 'footprint' were both separated into three zones to allow for interpretation of nearshore versus offshore contaminant levels, if necessary.

The 95% Upper Confidence Limits (UCLs) for metals were calculated for each of these regions in both the proposed dredge footprint and the pilot study 'footprint', which were considered to be reference sites (**Table 6-5**). The 95% UCL for metals was also calculated for the 33 potential spoil ground sites described in **Section 5.2.2** (**Table 6-6**). In addition, environmental samples were analysed from ten geotechnical boreholes collected within the proposed dredge footprint, or in the immediate vicinity (**Figure 5-1**). These samples consisted of material combined from a given soil strata (matrix) within a borehole. There were a maximum of three strata in any borehole that had adequate and suitable material for environmental analysis. A total of six strata were combined between the ten boreholes to generate adequate data for interpretation (**Table 6-7**).

The sediment metal data can be summarised as follows:

- The 95% UCL for metals in the 0 – 0.5 m range within the proposed SAP dredge footprint were similar to, or lower than those in the reference area;
- The 95% UCL for all metals in the 0 – 0.5 m range within the proposed SAP dredge footprint and potential spoil grounds (other than arsenic) were below NODGDM screening levels;
- The 95% UCL arsenic levels in the 0 – 0.5 m range within all areas of the pilot study 'footprint' were above the NODGDM screening level and are believed to be naturally occurring in the region (**Table 4-1**). In addition, the 95% UCL for arsenic in the wharf area of the proposed dredge footprint is significantly higher than the wharf area of the pilot study footprint, but within the range observed for other areas;
- The 95% UCL for silver in the 0 – 0.5 m range exceeded the NODGDM screening level in the 'wharf' area of the pilot study 'footprint';
- The 95% UCL for arsenic exceeded the NODGDM screening level to a depth of 4 m in boreholes;
- The 95% UCL for nickel exceeded the NODGDM maximum level within one soil matrix from the 0 - 4 m range, and one matrix from the 4 - 19 m range;
- The 95% UCL for nickel exceeded the NODGDM screening level within one soil matrix from the 4 - 19 m range; and
- The 95% UCL for chromium exceeded the NODGDM screening level within one soil matrix from the 0 – 4 metre range, and one matrix from the 4 – 19 metre range

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6.3. Sediment Organotin

Sediment tributyltin (TBT) and total organic carbon (TOC) results from within the proposed dredge footprint and pilot study ‘footprint’ are presented in **Table 6-8**. Results of TBT and TOC analysis from the six potential spoil grounds are presented in **Table 6-9**. Material from six soil matrices within ten boreholes was also analysed for TBT and TOC (**Table 6-10**).

The data can be summarised as follows:

- The 95% UCL for normalised TBT in all areas of the proposed SAP dredge footprint and pilot study ‘footprint’ reference sites were below the NODGDM screening level;
- The 95% UCL for normalised TBT at all sites in the six proposed spoil grounds were below the NODGDM screening level; and
- TBT and TOC levels in borehole samples exceeded the NODGDM screening level from one matrix each within the 0 – 4 m and 4 – 19 m range

6.4. Sediment PAH, PCB and OC

Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and organochlorines (OCs) were analysed in the proposed dredge footprint at five sites in the wharf area, seven sites in the inner channel, and six sites in the outer channel. Additionally, one transect (comprising four sites) was analysed within each of the wharf, inner channel and outer channel areas in the pilot study ‘footprint’ (T1, T6 and T12). The means of the four sites in each transect were calculated and these values were then used to calculate the 95% upper confidence limits (UCL). Results of PAH, PCB and OC 95% UCL values are presented in **Table 6-11**. The data can be summarised as follows:

- The 95% UCL for PAHs, PCBs and OCs in all areas of the proposed dredge footprint and pilot study ‘footprint’ were below the NODGDM screening level or the laboratory PQL, which was less than the NODGDM screening level.

However, halving of OC values below the PQL[1] and normalisation to 1% TOC[2] meant that OC concentrations in most samples were 1.25µg/kg (0.25µg/kg multiplied by 5; as the TOC concentrations were < 0.2%). This exceeds the NODGDM screening level for individual OCs despite not being measurable in the samples. As 19 OC’s were analysed, the total OC values in the results section are mostly 23.8µg/kg (19 x 1.25µg/kg).

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[1] As per NODGDM Section 3.10.5

[2] As per NODGDM Table 5

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Table 6-5: Sediment metal data of Pilot Study and SAP sites (95% UCL)

Parameter	Units	Guidelines [a]		Proposed SAP Dredge Footprint			Pilot Study 'Footprint'		
		Screening	Maximum	Wharf Area (1-10)	Inner Channel (11 – 31)	Outer Channel (32 – 50)	Wharf Area (T1 – T3)	Inner Channel (T4 – T8)	Outer Channel (T9 – T18)
Antimony	mg/kg	2	25	0.3	0.3	0.3	0.6	0.4	0.4
Arsenic	mg/kg	20	70	**42.7**	**41.7**	**22.2**	**27.2**	**46.1**	**21.7**
Cadmium	mg/kg	1.5	10	0.1	0.1	0.1	0.1	0.1	0.1
Chromium	mg/kg	80	370	18.1	17.6	16.4	12.7	24.1	13.2
Cobalt	mg/kg	—	—	6.4	5.9	4.0	3.5	6.7	3.3
Copper	mg/kg	65	270	4.1	3.3	3.2	2.0	6.6	2.2
Lead	mg/kg	50	220	5.0	4.6	3.2	2.9	5.9	2.8
Manganese	mg/kg	—	—	249.3	649.0	494.5	259.0	731.1	389.4
Mercury	mg/kg	0.15	1	0.005	0.005	0.005	0.005	0.005	0.005
Nickel	mg/kg	21	52	7.0	8.3	6.2	4.6	11.7	4.5
Silver	mg/kg	1	3.7	0.1	0.1	0.1	**1.2**	0.1	0.1
Zinc	mg/kg	200	410	7.8	8.1	5.8	3.9	8.4	3.6

a National Ocean Disposal Guidelines for Dredge Material (EA 2002).

Note: Bold values exceed screening levels.

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Table 6-6: Sediment metal data of potential SAP spoil grounds (95% UCL)

Parameter	Units	Guidelines [a]		Potential Spoil Areas					
		Screening	Maximum	Area 1	Area 2	Area 3	Area 7	Area 8	Area 9
Antimony	mg/kg	2	25	0.3	0.4	0.3	1.6	0.7	0.32
Arsenic	mg/kg	20	70	**42.9**	**40.8**	**43.1**	**70.1**	**50.1**	**27.6**
Cadmium	mg/kg	1.5	10	0.05	0.1	0.17	0.19	0.16	0.1
Chromium	mg/kg	80	370	20.5	23.6	24.8	45.7	39.2	25.2
Cobalt	mg/kg	–	–	6.4	6.5	7.5	8.9	6.8	3.9
Copper	mg/kg	65	270	4.5	4.7	10.0	5.4	4.8	2.8
Lead	mg/kg	50	220	4.0	4.1	4.9	6.8	5.0	3.2
Manganese	mg/kg	–	–	369.5	599.7	1296.3	634.4	651.3	514.4
Mercury	mg/kg	0.15	1	0.005	0.005	0.005	0.11	0.06	0.03
Nickel	mg/kg	21	52	6.9	9.1	10.1	9.2	8.0	4.2
Silver	mg/kg	1	3.7	0.05	0.05	0.07	0.15	0.05	0.05
Zinc	mg/kg	200	410	13.7	13.9	14.9	8.9	7.7	6.2

a National Ocean Disposal Guidelines for Dredge Material (EA 2002).

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Table 6-7: Sediment metal data in soil matrices from boreholes (95% UCL)

Parameter	Units	Guidelines [a]		Soil Matrices*					
		Screening	Maximum	Unit 2a	Unit 2b	Unit 4b	Unit 6a	Unit 6b	Unit 7
Antimony	mg/kg	2	25	0.4	0.6	0.2	0.1	0.1	0.1
Arsenic	mg/kg	20	70	**68.1**	**29.5**	**20.7**	9.8	11.0	7.5
Cadmium	mg/kg	1.5	10	0.4	0.1	0.1	0.2	0.1	0.1
Chromium	mg/kg	80	370	23.7	**128.5**	22.2	**81.1**	46.9	74.9
Cobalt	mg/kg	–	–	9.8	26.9	3.7	10.5	5.8	7.9
Copper	mg/kg	65	270	8.4	27.1	5.2	16.4	9.9	19.1
Lead	mg/kg	50	220	9.0	42.2	3.8	9.1	5.1	9.8
Manganese	mg/kg	–	–	1617.4	288.0	219.9	263.2	224.1	68.5
Mercury	mg/kg	0.15	1	0.02	0.06	0.01	0.01	0.01	0.01
Nickel	mg/kg	21	52	14.7	**100.2**	7.81	**44.6**	23.1	**64.7**
Silver	mg/kg	1	3.7	0.3	0.1	0.1	0.1	0.1	0.2
Zinc	mg/kg	200	410	12.7	67.7	7.6	25.1	12.7	26.7

a National Ocean Disposal Guidelines for Dredge Material (EA 2002).
* Soil matrices were refined since **Figure 3-3** was created. Units 2a, 2b and 4b in the table above are equivalent to ≤ 4 metres sediment depth and Units 6a, 6b and 7 are all 4–19 metres sediment depth.
Bold values exceed screening and/or maximum levels.

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Table 6-8: Sediment TBT and TOC data of Pilot Study and SAP sites (95% UCL)

Parameter	Units	Guidelines [a]		Proposed SAP Dredge Footprint			Pilot Study 'Footprint'		
		Screening	Maximum	Wharf Area (1-10) [c]	Inner Channel (11 – 31)	Outer Channel (32 – 50)	Wharf Area (T1 – T3)	Inner Channel (T4 – T8)	Outer Channel (T9 – T18)
TBT	µg Sn/kg	–	–	0.25	0.25	0.25	0.25	0.25	0.25
Normalised TBT[b]	µg Sn/kg	5	70	1.25	1.25	1.25	1.25	1.25	1.25
TOC	%	–	–	0.13	0.18	0.16	0.11	0.12	0.16

Table 6-9: Sediment TBT and TOC data of potential SAP spoil grounds (95% UCL)

Parameter	Units	Guidelines [a]		Potential SAP Spoil Ground Sites					
		Screening	Maximum	Area 1	Area 2	Area 3	Area 7	Area 8	Area 9
TBT	µg Sn/kg	–	–	0.25	0.25	0.25	0.25	0.25	0.25
Normalised TBT[b]	µg Sn/kg	5	70	1.29	1.25	1.25	1.25	1.25	1.25
TOC	%	–	–	0.20	0.13	0.15	0.13	0.11	0.14

Table 6-10: Sediment TBT and TOC data in soil matrices from boreholes (95% UCL)

Parameter	Units	Guidelines [a]		Soil Matrices *					
		Screening	Maximum	Unit 2a [c]	Unit 2b	Unit 4b	Unit 6a	Unit 6b	Unit 7
TBT	µg Sn/kg	–	–	0.25	1.90	0.25	0.35	0.03	1.90
Normalised TBT[b]	µg Sn/kg	5	70	1.25	**9.50**	1.30	1.75	0.31	**9.48**
TOC	%	–	–	0.16	0.05	0.17	0.02	1.57	0.07

a National Ocean Disposal Guidelines for Dredge Material (EA 2002). b. Normalised to 1% TOC. c. Results are the mean of all sites within the given area/matrix.
* Soil matrices were refined since **Figure 3-3** was created. Units 2a, 2b and 4b in the table above are equivalent to ≤ 4 metres sediment depth and Units 6a, 6b and 7 are all 4–19 metres sediment depth
Bold values exceed screening and/or maximum levels.

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▪ Table 6-11: Sediment PAH, PCB and OC data of Pilot Study and SAP sites (95% UCL)

Parameter	Units	Guidelines [a]		Proposed SAP Dredge Footprint [c]			Pilot Study 'Footprint'		
		Screening	Maximum	Wharf Area (1-5)	Inner Channel (13, 21, 26–30)	Outer Channel (32, 41-45)	Wharf Area (T1)	Inner Channel (T6)	Outer Channel (T12)
Total PAH[b]	µg /kg	4, 000	45, 000	215	222.9	215.0	215.0	215.0	215.0
Total PCB[b]	µg /kg	23	—	12.5	12.9	12.5	12.5	12.5	12.5
Total OC[b]	µg /kg	—	—	23.8	24.5	23.8	23.8	23.8	23.8

a National Ocean Disposal Guidelines for Dredge Material (EA 2002).
b Normalised to 1% TOC.
c Numbers in brackets indicate sites analysed for these parameters

6.5. Sediment Quality Control

6.5.1. Laboratory Quality Control Analyses

Analytical quality control data (blanks, duplicates and spiked samples) for the various sediment and elutriate analyses are contained in the laboratory reports in **Appendix B** and **Appendix C** for the Pilot Study and SAP, respectively.

6.5.2. Field Quality Control Samples

The quality control data for field samples (triplicates and split samples) are provided as relative standard deviation (RSD; triplicates) and relative percent difference (RPD; splits) of each metal for the proposed pilot study 'footprint' and SAP footprint in **Table 6-12** and **Table 6-13**, respectively. Section 3.6 of the NODGDM indicates that the RSD for a series of triplicates samples should be <50% whereas the RPD for spilt samples should be <35%. There was inadequate material in boreholes to allow collection of triplicate and split samples.

The results of the field quality control samples were as follows:

- All RSDs for parameters measured in triplicates from the proposed dredge footprint and pilot study 'footprint' material were below the acceptance criteria of 50%.
- All RPDs for parameters measured in splits from material were below the acceptance criteria of 35% except in the following instances:
  - Antimony, arsenic and copper at Site 6 in the proposed dredge footprint;
  - Cadmium and TOC at Site 21 in the proposed dredge footprint;
  - Antimony averaged over the three sites in the proposed dredge footprint;
  - Antinomy and Cadmium at Site T7-4 in the pilot study 'footprint';
  - TOC at Site T10-2 in the pilot study 'footprint'; and
  - TOC averaged over the three sites in the pilot study 'footprint'.

These data indicate that the sampling program and subsequent analysis of parameters were within specification and agreed level of variability for replicates (triplicates) but split samples were more variable. The instances of RPD exceedance were related to levels of contaminants that were near the Practical Quantitation Limit (PQL) for the relevant parameters. This means that very small differences in contaminant levels produced large variability in RPD values. Parameters with values further from their respective PQLs (e.g. cobalt, chromium and manganese) had RPD calculations well below 35% at each site and when averaged overall. For this reason, the sampling and analytical methods are considered to be appropriate and within NODGDM expectations for Quality Assurance.

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Table 6-12: Quality control data for RSD and RPD analyses of Pilot Study sites

Parameter	Units	PQL	Criteria	Pilot Study 'Footprint' Area					Criteria	Pilot Study 'Footprint' Area			
			RSD (%)	Site T5-1	Site T7-1	Site T9-1	Site T11-1	Mean	RPD (%)	Site T5-2	Site T7-4	Site T10-2	Mean
Antinomy	mg/kg	0.1	50	6.7	7.9	10.8	10.0	8.8	35	0.0	**40.0**	0.0	13.3
Arsenic	mg/kg	0.1	50	6.4	4.0	22.0	2.9	8.8	35	20.9	6.6	21.6	16.4
Cadmium	mg/kg	0.1	50	17.3	17.3	0.0	0.0	8.7	35	0.0	**66.7**	0.0	22.2
Chromium	mg/kg	0.1	50	6.3	4.6	8.4	2.5	5.5	35	22.5	14.8	22.4	19.9
Cobalt	mg/kg	0.1	50	8.2	3.4	16.4	4.8	8.2	35	26.6	13.1	10.5	16.7
Copper	mg/kg	0.1	50	4.2	5.1	8.7	16.2	8.5	35	23.4	10.2	4.4	12.7
Lead	mg/kg	0.1	50	6.3	4.3	11.3	3.5	6.4	35	21.8	15.7	3.9	13.8
Manganese	mg/kg	0.1	50	8.9	4.0	14.4	10.2	9.4	35	12.5	8.5	11.8	10.9
Mercury	mg/kg	0.1	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0	0.0
Nickel	mg/kg	0.1	50	7.2	5.1	12.3	4.1	7.2	35	27.8	9.8	24.0	20.6
Silver	mg/kg	0.1	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0	0.0
Zinc	mg/kg	0.1	50	6.3	4.4	9.2	2.4	5.6	35	29.5	12.2	15.0	18.9
TOC	%	0.02	50	5.0	7.4	13.0	14.5	10.0	35	26.1	30.8	**66.7**	**41.2**
Tributyltin	µg Sn/kg	0.5	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0	0.0

Bolded values exceed criteria.

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▪ Table 6-13: Quality control data for RSD and RPD analyses of SAP sites

Parameter	Units	PQL	Criteria	Proposed Dredge Footprint Area					Criteria	Proposed Dredge Footprint Area			
			RSD (%)	Site 1	Site 11	Site 13	Site 29	Mean	RPD (%)	Site 6	Site 21	Site 32	Mean
Antinomy	mg/kg	0.1	50	0.0	20.8	17.3	10.8	12.2	35	**66.7**	0.0	**40.0**	**35.6**
Arsenic	mg/kg	0.1	50	1.5	11.0	6.1	8.6	6.8	35	**40.8**	26.5	30.3	32.5
Cadmium	mg/kg	0.1	50	0.0	0.0	10.8	28.9	9.9	35	0.0	**66.7**	0.0	22.2
Chromium	mg/kg	0.1	50	3.5	1.2	4.3	4.7	3.4	35	18.9	5.2	1.9	8.7
Cobalt	mg/kg	0.1	50	2.5	6.3	5.1	15.1	7.3	35	4.9	3.8	11.0	6.5
Copper	mg/kg	0.1	50	4.8	9.4	5.4	14.2	8.5	35	**41.2**	23.3	6.6	23.7
Lead	mg/kg	0.1	50	1.4	4.8	6.8	7.5	5.1	35	0.0	4.3	22.6	9.0
Manganese	mg/kg	0.1	50	2.8	8.6	6.4	29.4	11.8	35	2.1	22.8	10.6	11.8
Mercury	mg/kg	0.1	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0	0.0
Nickel	mg/kg	0.1	50	3.2	1.3	6.4	12.5	5.9	35	17.7	26.1	13.8	19.2
Silver	mg/kg	0.1	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0	0.0
Zinc	mg/kg	0.1	50	1.1	2.4	2.7	4.8	2.8	35	28.6	14.1	5.6	16.1
TOC	%	0.02	50	2.3	0.0	12.9	6.2	5.4	35	24.0	**40.0**	8.0	24.0
Tributyltin	µg Sn/kg	0.5	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0	0.0

Bolded values exceed criteria.

7. Results for Supplemental SAP

The laboratory data that supports the results in this section are supplied in **Appendix D**.

7.1. Particle Size Distribution

Grain sizes of samples were assigned to categories ranging from < 75 µm to > 2360 µm.

In the Supplemental SAP, grain sizes were measured in eight slightly different categories as it was not considered necessary to measure to such a fine scale based on results from the Pilot Study and SAP PSD results. The grain size categories used for Supplemental SAP samples were:

Particle Description	Grain size (µm)
Fine gravel	>2360
Very coarse sand	1118–2360
Coarse sand	600–1118
Medium sand	425–600
Medium sand	300–425
Fine sand	150–300
Very fine sand	75–150
Medium silt	< 75

Particle size distribution (PSD) of sediment samples were analysed from 27 sites within the relocated berthing area (Sites 101–127 in **Figure 5-5**). An additional 10 PSD samples were analysed from potential spoil ground areas (sites 201–210 in **Figure 5-5**).

Results from the berthing area and the spoil expansion area were processed to generate a mean and standard deviation value for each size category in each area (**Table 7-1**). The PSD class size averages for each area were then cumulated to show the distribution of sediment sizes within each zone (**Figure 7-1**).

Similarly to PSD results in the Pilot Study and SAP, <150 µm particles accounted for ≤ 10% by weight of the means within each area. This would suggest a low potential for contaminant binding with material from these areas.

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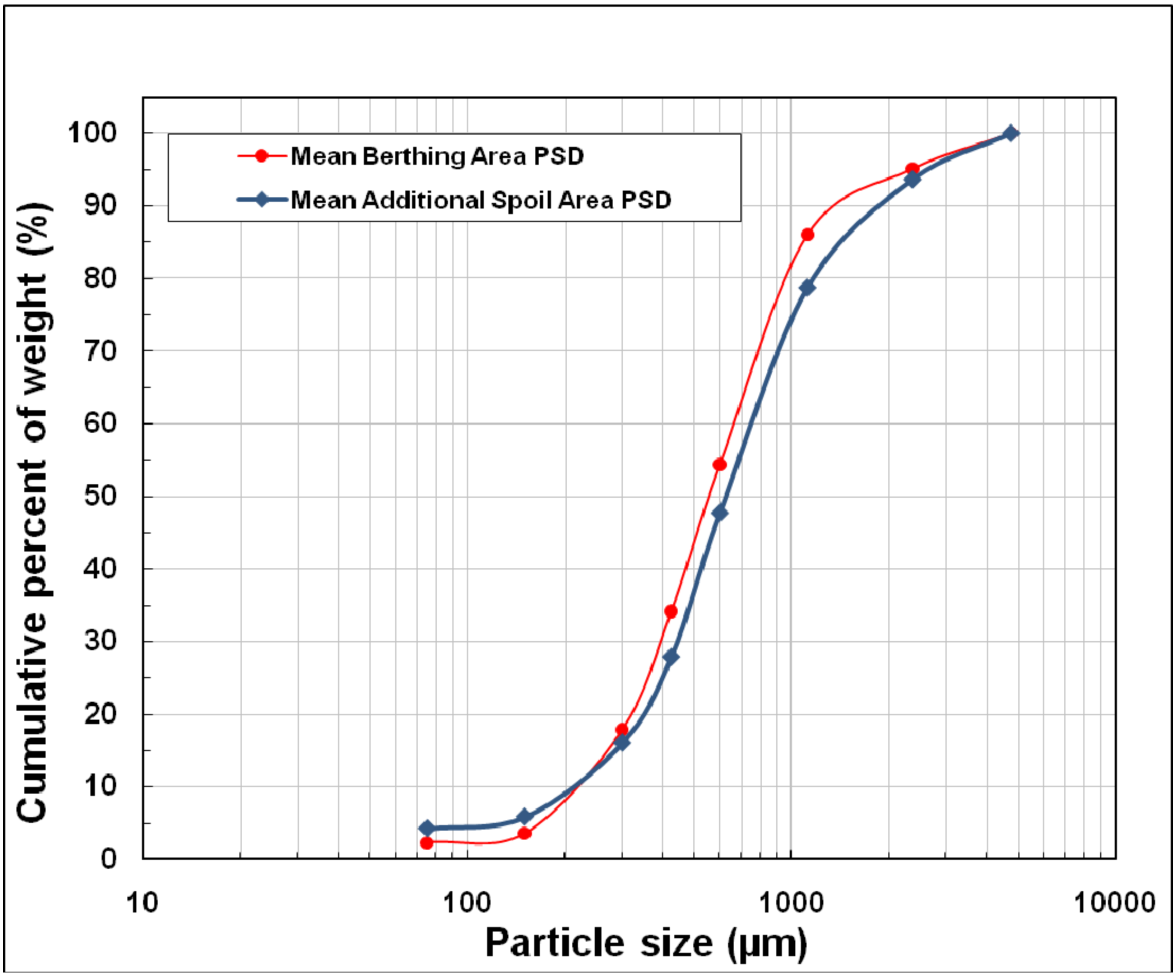

- **Figure 7-1: Mean PSD curve for re-located berthing and additional spoil areas**

- **Table 7-1: Mean percentage of sediment by grain size class (Supplemental SAP)**

Classification	Grain Size (µm)	Supplemental SAP Areas	
		Berths	Spoil Expansion
Fine gravel	>2360	4.88±5.7	6.36±4.3
Very coarse sand	1118 – 2360	9.1±7.8	14.91±6.8
Coarse sand	600–1118	31.66±20.6	31.04±8.7
Medium to coarse sand	425 – 600	20.17±7.3	19.82±6.4
Medium sand	300 - 425	16.33±10.3	11.82±4.7
Fine sand	150 - 300	14.28±4.5	10.19±6.0
Very fine sand	75–150	1.24±0.9	1.61±2.0
Medium silt	<75	2.35±0.8	4.25±1.72

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7.2. Sediment Metals

The 95% Upper Confidence Limits for metals were calculated for the 27 sites in the re-located berthing area and 10 sites in the potential spoil expansion area, respectively (**Table 7-2**).

The laboratory reports that support these data are provided in **Appendix D**. The data can be summarised as follows:

- The 95% UCL for all metals in the re-located berthing area and potential spoil expansion area (other than arsenic) were below NODGDM screening levels.

7.3. Sediment Organotin

The 95% Upper Confidence Limits for tributyltin (TBT) and total organic carbon (TOC) were calculated for the 27 sites in the re-located berthing area and 10 sites in the potential spoil expansion area, respectively (**Table 7-3)**.

The laboratory reports that support these data are provided in **Appendix D**. The data can be summarised as follows:

- The 95% UCL for TBT in the re-located berthing area and potential spoil expansion area were below NODGDM screening levels.

7.4. Sediment PAH, PCB and OC

Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and organochlorines (OCs) were analysed at 5 sites in the re-located berthing area. Results of PAH, PCB and OC analyses are presented in **Table 7-4**.

The laboratory reports that support these data are provided in **Appendix D**.

- The 95% UCL for PAHs, PCBs and OCs in the re-located berthing area dredge footprint were all below the NODGDM screening levels.

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Table 7-2: Sediment metal data of Supplemental SAP sites and related previous SAP data

Parameter	Units	Guidelines [a]		Sampling Areas		Previous SAP data	
		Screening	Maximum	Re-located Berth	Spoil Expansion	Pilot Study 'Footprint' Wharf Area (T1 – T3)	Proposed SAP Dredge Footprint Wharf Area (1-10)
Antimony	mg/kg	2	25	0.5	0.4	0.6	0.3
Arsenic	mg/kg	20	70	**30.4**	**42.3**	**27.2**	**42.7**
Beryllium	mg/kg	—	—	0.2	0.1	-	-
Cadmium	mg/kg	1.5	10	0.1	0.1	0.1	0.1
Chromium	mg/kg	80	370	17.7	20.0	12.7	18.1
Cobalt	mg/kg	—	—	2.7	6.2	3.5	6.4
Copper	mg/kg	65	270	2.0	4.0	2.0	4.1
Lead	mg/kg	50	220	2.2	4.9	2.9	5.0
Manganese	mg/kg	—	—	147.9	628.9	259.0	249.3
Mercury	mg/kg	0.15	1	0.01	0.01	0.005	0.005
Molybdenum	mg/kg	—	—	0.3	0.4	-	-
Nickel	mg/kg	21	52	4.2	8.4	4.6	7.0
Selenium	mg/kg	—	—	0.3	0.1	-	-
Silver	mg/kg	1	3.7	0.3	0.1	**1.2**	0.1
Zinc	mg/kg	200	410	0.1	6.5	3.9	7.8

a National Ocean Disposal Guidelines for Dredge Material (EA 2002).
Note: Bold values exceed screening levels.

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Table 7-3: Sediment TBT and TOC data of Supplemental SAP sites

Parameter	Units	Guidelines [a]		Sampling Areas	
		Screening	Maximum	Re-located Berth [c]	Spoil Expansion
TBT	µg Sn/kg	–	–	0.25	0.25
Normalised TBT[b]	µg Sn/kg	5	70	1.25	1.25
TOC	%	–	–	0.07	0.10

a National Ocean Disposal Guidelines for Dredge Material (EA 2002).
b Normalised to 1% TOC.
c Results are the mean of all sites within the given area.

Table 7-4: Sediment PAH, PCB and OC data of Supplemental SAP sites

Parameter	Units	Guidelines [a]		Re-located Berth Area [c] (101, 102, 109, 114, 117)
		Screening	Maximum	
Total PAH[c]	µg /kg	4, 000	45, 000	215
Total PCB[c]	µg /kg	23	–	12.5
Total OC[c]	µg /kg	–	–	23.8

a National Ocean Disposal Guidelines for Dredge Material (EA 2002).
b Normalised to 1% TOC.
c Numbers in brackets indicate sites analysed for these parameters

7.5. Sediment Quality Control

7.5.1. Laboratory Quality Control Analyses

Analytical quality control data (blanks, duplicates and spiked samples) for the various sediment analyses from the re-located berth area are contained in the laboratory reports in **Appendix D**.

7.5.2. Field Quality Control Samples

Relative standard deviation (RSD; triplicates) and relative percent difference (RPD; splits) of each metal for the re-located berth area are summarised in **Table 7-5**.

The results of the field quality control samples in the re-located berth area were as follows:

- All RSDs for parameters measured in triplicates were below the acceptance criteria of 50% except TOC at site 110
- All RPDs for parameters measured in splits were below the acceptance criteria of 35%

The exceedance of RSD for TOC at Site 110 was because two of the three samples were below detection limits. The halving of these values (as per NODGDM recommendations) exaggerated the RSD value at this site. The overall RSD for all four triplicate sites was < 50% for TOC.

For this reason, the sampling and analytical methods are considered to be appropriate and within NODGDM expectations for Quality Assurance.

Triplicates and duplicates for organics were found to be consistently below detection limits making the calculation of RPD and RSD impossible.

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Table 7-5: Quality control data for RSD and RPD analyses of Supplemental SAP sites

Parameter	Units	PQL	Criteria	Field Triplicates					Criteria	Field Splits		
			RSD (%)	Site 104	Site 110	Site 113	Site 120	Mean	RPD (%)	Site 109	Site 116	Mean
Antinomy	mg/kg	0.1	50	3.4	0.0	0.0	0.0	0.8	35	6.5	0.0	3.2
Arsenic	mg/kg	0.1	50	2.5	2.6	3.9	2.7	2.9	35	5.0	7.5	6.2
Cadmium	mg/kg	0.1	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0
Chromium	mg/kg	0.1	50	2.1	4.2	1.2	2.9	2.6	35	1.9	17.8	9.8
Cobalt	mg/kg	0.1	50	5.3	7.7	1.6	3.1	4.4	35	3.3	22.2	12.8
Copper	mg/kg	0.1	50	18.2	46.0	10.7	9.2	21.0	35	23.3	6.5	14.9
Lead	mg/kg	0.1	50	7.6	7.5	3.3	3.1	5.4	35	8.3	22.2	15.3
Manganese	mg/kg	0.1	50	3.4	3.2	3.5	3.3	3.4	35	18.6	29.1	23.9
Mercury	mg/kg	0.1	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0
Nickel	mg/kg	0.1	50	9.3	11.0	4.3	6.2	7.7	35	10.8	13.7	12.2
Silver	mg/kg	0.1	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0
Zinc	mg/kg	0.1	50	10.0	17.7	4.3	5.4	9.4	35	11.5	20.0	15.7
TOC	%	0.02	50	14.3	**54.1**	25.0	6.7	25.0	35	15.4	0.0	7.7
Tributyltin	µg Sn/kg	0.5	50	0.0	0.0	0.0	0.0	0.0	35	0.0	0.0	0.0

Bolded values exceed criteria.

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8. Summary

The results of the implementation of the Pilot Study, SAP and Supplemental SAP can be summarised as follows:

- Particle size distributions within sediment matrix 2a:
  - Similar distributions across all areas of the Pilot Study, SAP and Supplemental SAP;
  - Predominantly coarse sand (500–1000 µm) or larger diameter; and
  - Section 2a was represented in all samples by less than 0.5 m of material
- Sediment metals:
  - The 95% UCL for all metals in the 0 – 0.5 m range within areas of the Pilot Study, SAP and Supplemental SAP were below the NODGDM guideline screening levels other than arsenic (As);
  - The 95% UCL for metals in the SAP and Supplemental SAP areas were similar to, or lower than those in the Pilot Study areas;
  - Arsenic exceeded NODGDM screening levels within reference areas and to a depth of 4 m in boreholes, and as such is considered to be naturally occurring in the region; and
  - Chromium and nickel exceeded NODGDM screening/maximum levels in the 0 – 4 m range and the 4 – 19 m range in boreholes, but not within any surficial samples in the 0 – 0.5 m range, and as such is considered to be naturally occurring in the region
- Organotins:
  - The 95% UCL for normalised TBT in the all areas of the Pilot Study, SAP and Supplemental SAP were below the NODGDM guideline screening level; and
  - The 95% UCL for normalised TBT exceeded the NODGDM screening level in one matrix each within the 0 – 4 m range and the 4 – 19 m range in boreholes. The 95% UCL exceedances were due to low sample numbers and TOC levels < 0.2%, and the normalised TBT values for the individual sites in the soil matrices were all below the NODGDM screening level.
- PAHs, PCBs, OCs:
  - The 95% UCL for PAHs, PCBs and OCs in the Pilot Study, SAP and Supplemental SAP areas were below the NODGDM guideline screening level
- QA/QC:
  - There were a total of 25 exceedances of QC laboratory test parameters as per NATA criteria. The majority of these were only slightly over accepted relative percent deviation (RPD) and involved contaminant concentrations nearing the Practical Quantitation Limit (PQL), exaggerating small differences in concentrations.

- All RSDs for parameters measured in triplicates from proposed dredge footprint and pilot study ‘footprint’ material were below the acceptance criteria of 50% other than TOC at Site 110 in the Supplemental SAP (54.1 %), which was exaggerated as two of the three triplicates were below the detection limit.
- All RPDs parameters measured in splits from proposed dredge footprint and pilot study ‘footprint’ material were below the acceptance criteria of 35% except in the following instances:
  - Antimony (Sb) at Site 6 and Site 32 in the proposed dredge footprint and Site T7-4 in the pilot study ‘footprint’;
  - Arsenic (As) at Site 6 in the proposed SAP dredge footprint;
  - Cadmium (Cd) at Site 21 in the proposed SAP dredge footprint and Site T7-4 in the pilot study ‘footprint’;
  - Copper (Cu) at Site 6 in the proposed SAP dredge footprint;
  - Total Organic Carbon (TOC) at Site 21 in the proposed SAP dredge footprint and T10-2 in the pilot study ‘footprint’; and
  - The QA/QC data indicate that the sampling program and subsequent analysis of parameters were within specification and agreed level of variability for replicates (triplicates) but split samples were more variable. This would normally be an issue; however, samples exceeding the RPD acceptance criteria of 35% involved concentrations nearing the PQL, exaggerating small differences in concentrations.

- Suitability of dredge material and receiving environment:
  - The material to be dredged in the proposed SAP and Supplemental SAP dredge footprints is clean with no contaminants of concern above NODGDM screening levels other than Arsenic (As), which we contend is naturally occurring as it occurs in unconsolidated material to a depth of 4 m throughout the region including the proposed spoil grounds;
  - The six spoil grounds illustrated in **Figure 5-4** meet the selection criteria of **Section 5.2.2** and do not contain contaminants of concern above NODGDM screening levels; therefore
  - The material is suitable for unconfined disposal to sea at any of the designated spoil grounds.

9. References

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Appendix A Pilot Study Power Analysis

A.1 Raw Data

Collected from pilot study alignment at 60 sampling locations, to a depth of ≤50 cm.

Site	Arsenic	Chromium	Copper	Lead	Nickel	Zinc
T1-1	28.7	13.2	1.9	3.1	4.9	4.0
T1-2	28.6	11.2	1.6	2.7	3.8	3.5
T1-3	26.7	10.6	1.6	2.5	3.4	3.6
T1-4	29.9	11.5	1.8	2.7	4.3	3.8
T2-1	24.3	11.7	2.0	2.7	4.2	4.0
T2-2	23.2	10.4	1.3	2.5	3.3	2.9
T2-3	22.2	12.2	1.9	2.7	4.3	3.8
T2-4	24.0	12.5	1.9	2.8	4.4	4.4
T3-1	26.0	13.4	2.3	3.3	4.4	3.4
T3-2	19.7	12.9	1.8	3.0	3.8	3.5
T3-3	26.0	12.5	2.1	2.8	5.2	3.8
T3-4	28.3	13.8	2.3	2.8	5.1	3.9
T4-1	14.0	53.9	21.6	10.9	34.3	24.5
T4-2	35.3	31.0	10.4	6.8	16.3	10.5
T4-3	30.0	30.9	8.4	6.6	15.4	10.1
T4-4	43.2	24.7	5.9	6.4	12.0	7.9
T5-1	48.8	14.2	3.5	5.2	6.4	5.0
T5-2	50.5	15.0	3.4	5.3	6.8	5.2
T5-3	65.3	19.3	5.2	6.6	9.9	7.3
T5-4	49.0	37.2	4.1	5.6	8.3	6.1
T6-1	56.0	15.0	4.3	5.5	7.6	5.9
T6-2	49.1	16.1	3.9	5.0	7.8	5.8
T6-3	47.7	15.0	2.4	4.3	5.4	4.5
T6-4	42.5	14.4	2.4	4.1	5.3	4.4
T7-1	39.3	13.8	3.0	4.2	6.1	4.6
T7-2	52.4	15.3	3.9	4.9	7.2	5.2
T7-3	38.0	14.0	2.5	4.2	5.4	4.0
T7-4	40.9	14.4	2.8	4.1	5.8	4.6
T8-1	21.6	10.3	1.7	2.7	3.4	2.7
T8-2	29.5	11.6	2.0	3.2	4.2	3.2
T8-3	17.0	12.5	2.1	2.5	4.7	3.8

Site	Arsenic	Chromium	Copper	Lead	Nickel	Zinc
T8-4	21.8	12.5	2.3	2.8	4.8	3.8
T9-1	8.7	9.0	1.6	1.7	3.1	2.7
T9-2	11.2	9.0	1.5	1.9	3.0	2.7
T9-3	15.0	11.6	1.6	2.2	3.8	3.0
T9-4	17.1	13.4	1.8	2.4	4.5	3.8
T10-1	24.7	13.2	2.5	2.8	4.8	3.9
T10-2	19.5	11.5	2.2	2.6	4.4	3.7
T10-3	24.6	12.6	2.6	3.2	5.1	3.7
T10-4	18.8	15.0	2.9	2.8	5.2	4.4
T11-1	26.6	14.9	2.0	3.4	4.6	3.2
T11-2	22.8	13.6	1.8	3.1	4.2	3.1
T11-3	16.8	14.4	2.5	2.8	5.4	4.0
T11-4	12.7	14.7	2.4	2.6	4.9	3.8
T12-1	18.8	10.0	1.4	2.6	2.8	2.2
T12-2	19.4	11.1	1.4	2.6	2.9	2.3
T12-3	29.6	10.7	1.5	2.6	3.2	2.6
T12-4	21.1	10.0	1.4	2.3	2.6	2.3
T16-1	62.2	18.1	4.1	6.7	8.4	6.4
T16-2	60.8	17.5	4.0	6.2	8.2	6.1
T16-3	62.3	18.8	4.3	6.6	9.0	7.0
T16-4	46.2	16.6	3.6	4.9	7.4	5.5
T17-1	42.5	15.5	3.6	4.9	7.2	5.1
T17-2	43.7	16.7	3.1	4.8	6.4	5.2
T17-3	26.5	14.3	3.2	3.4	4.3	3.3
T17-4	24.0	13.5	1.8	3.0	3.9	3.0
T18-1	15.7	14.4	2.3	2.5	5.6	4.3
T18-2	16.7	12.4	2.2	2.6	5.0	3.9
T18-3	22.8	12.1	2.2	2.6	4.9	3.6
T18-4	55.1	21.1	6.6	7.3	11.1	8.6

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A.2 Basic Statistics

Site	Arsenic	Chromium	Copper	Lead	Nickel	Zinc
N	60	60	60	60	60	60
Min	8.70	9.00	1.30	1.70	2.60	2.20
Max	65.30	53.90	21.60	10.90	34.30	24.50
Mean	31.42	15.38	3.17	3.86	6.23	4.79
SD	14.69	7.21	2.94	1.75	4.60	3.12

A.3 Power Analysis Inputs

Site	Arsenic	Chromium	Copper	Lead	Nickel	Zinc
Mean	31.42	15.38	3.17	3.86	6.23	4.79
SD	14.69	7.21	2.94	1.75	4.60	3.12
Test	20	80	65	80	21	200
α	0.05	0.05	0.05	0.05	0.05	0.05
β	0.80	0.80	0.80	0.80	0.80	0.80

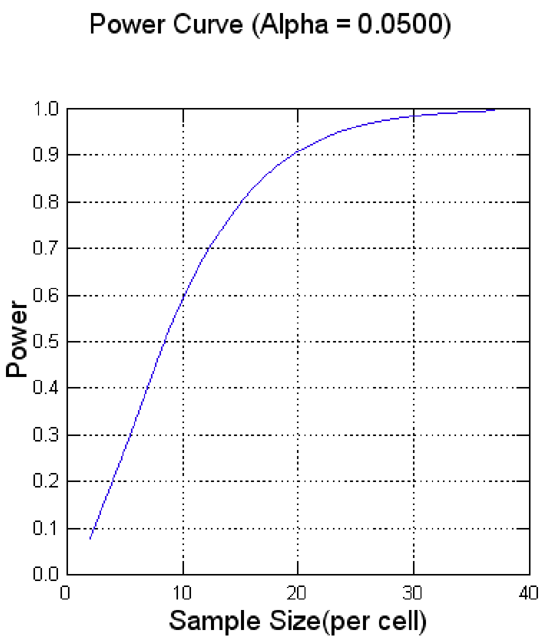
A.4 Power Analysis Outputs

Based on 80% cut-off for type 2 analysis, using

Arsenic

Noncentrality Parameter = 0.7775 * sqrt(sample size)

Sample Size (per cell)	POWER
12	0.6892
13	0.7304
14	0.7670
15	0.7994
16	0.8279



Chromium

Noncentrality Parameter = -8.9626 * sqrt(sample size)

Sample Size (per cell)	POWER
2	0.6837
3	1.0000

Copper

Noncentrality Parameter = -21.0306 * sqrt(sample size)

Sample Size (per cell)	POWER
2	1.0000

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Lead

Noncentrality Parameter = -43.5086 * sqrt(sample size)

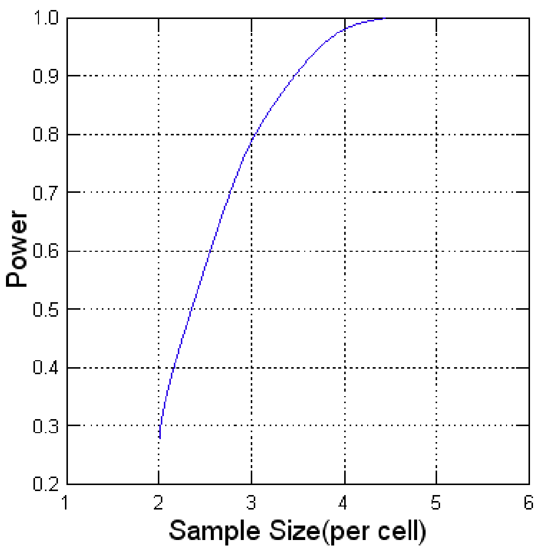
Sample Size (per cell)	POWER
2	1.0000

Nickel

Noncentrality Parameter = -3.2109 * sqrt(sample size)

Sample Size (per cell)	POWER
2	0.2784
3	0.7897
4	0.9809

Power Curve (Alpha = 0.0500)



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Zinc

Noncentrality Parameter = -62.5673 * sqrt(sample size)

Sample Size (per cell)	POWER
2	1.0000

A.5 Sample Size Requirements

According to the NODGDM (EA 2002) the appropriate number of samples sites for screening of sediments is based on the volume of spoil to be dredged. NODGDM (EA 2002) also states that anthropogenic contamination of seabed sediments is generally accepted to occur in the upper mobile sediment layers down to 1m, which makes this the material of potential concern. Therefore, the proposed volume of material (VoM) to be sampled is calculated as the volume of the top 1m of the development footprint, calculated by the following formula:

VoM = Area of footprint × 1 m

Geographical Information System (GIS) analysis has determined that the dredge footprint is approximately 11,974,320 m^2

Therefore, VoM = 11,974,320 m^3

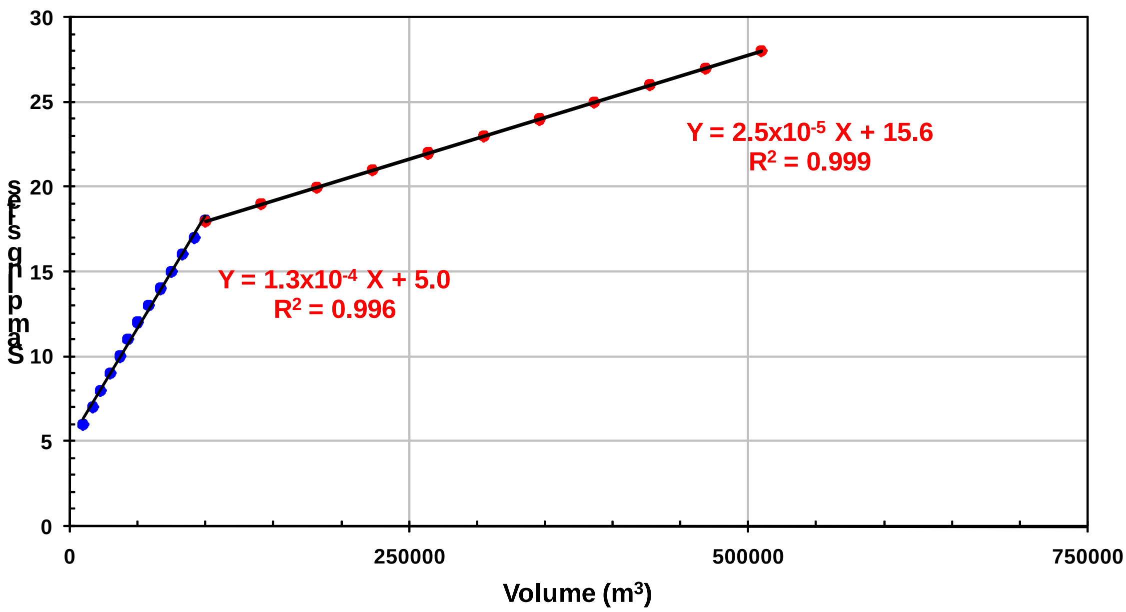
The volume of surface material to be dredged from the proposed development is greater than 500,000 m^3, therefore the NODGDM require the total number of sample sites for the proposed dredging to be based on the extrapolation shown in **Figure 9-1** using the equation:

Sample sites = [2.447 × 10^{-5} (VoM m^3 spoil)] + 15.55

The total number of sample sites required by the NODGDM is therefore calculated as:

Sample sites = [(2.447 × 10^{-5}*11,974,320 m^3 spoil) + 15.55]

= 309 sites



▪ **Figure 9-1: Sample sites required for chemical testing**

This calculation of sampling sites assumes that there is no recent (<5 year old) data available.

Power analysis using the pilot data provided above would suggest that Arsenic is above the NODGDM screening and has the greatest variability thus using it as a predictor of sample site numbers in power analysis is warranted.

An appropriate level of power was obtained to differentiate the sample mean from screening level with only 16 samples. This equates to 5.1% (16/309) of the number prescribed by the NODGDM. Therefore the use of 15% is more than sufficient to characterise the sediments in the proposed dredge footprint. This equates to 47 sites; this SAP proposes to sample 50 sites for conservatism.

Appendix B Pilot Study Laboratory Reports

Appendix C SAP Laboratory Reports

Appendix D Supplemental SAP Laboratory Reports

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Appendix E Field Sampling Information

Site	Date	Time	Water depth in metres (at time)	Sediment description	GDA94 co-ordinates	
					Latitude	Longitude
Pilot Study 'footprint'						
T1-1	19/12/07	12:00	14	Coarse sand	S 20°13.60'	E118°29.80'
T1-2	19/12/07	12:15	14	Coarse sand	S 20°13.56'	E118°29.90'
T1-3	19/12/07	10:30	15	Coarse sand	S 20°13.52'	E118°30.02'
T1-4	19/12/07	10:45	15	Coarse sand	S 20°13.46'	E118°30.17'
T2-1	19/12/07	14:30	14	Coarse shelly sand	S 20°13.35'	E118°29.53'
T2-2	19/12/07	14:45	15	Coarse shelly sand	S 20°13.29'	E118°29.68'
T2-3	19/12/07	13:15	15	Coarse shelly sand	S 20°13.25'	E118°29.79'
T2-4	19/12/07	13:30	15	Coarse shelly sand	S 20°13.20'	E118°29.94'
T3-1	19/12/07	17:15	15	Gravel, shell, sand	S 20°13.16'	E118°29.31'
T3-2	19/12/07	17:30	16	Gravel, shell, sand	S 20°13.09'	E118°29.51'
T3-3	19/12/07	16:15	16	Coarse shelly sand	S 20°13.06'	E118°29.58'
T3-4	19/12/07	16:30	16	Coarse shelly sand	S 20°13.04'	E118°29.66'
T4-1	20/12/07	08:00	20	Gravel over silt	S 20°12.13'	E118°28.11'
T4-2	20/12/07	08:15	19	Gravel over silt	S 20°12.10'	E118°28.21'
T4-3	20/12/07	09:00	19	Gravel over silt	S 20°12.06'	E118°28.36'
T4-4	20/12/07	09:15	19	Gravel over silt	S 20°12.00'	E118°28.55'
T5-1	20/12/07	09:30	20	Coarse & fine sand	S 20°10.75'	E118°26.37'
T5-2	20/12/07	09:45	19	Coarse & fine sand	S 20°10.69'	E118°26.59'
T5-3	20/12/07	10:00	19	Coarse sand	S 20°10.65'	E118°26.71'
T5-4	20/12/07	10:15	19	Coarse sand	S 20°10.63'	E118°26.79'
T6-1	20/12/07	15:00	20	Coarse sand over rock	S 20°10.05'	E118°25.41'
T6-2	20/12/07	15:15	20	Coarse sand over rock	S 20°10.01'	E118°25.51'
T6-3	20/12/07	16:00	21	Coarse sand over rock	S 20°09.96'	E118°25.67'
T6-4	20/12/07	16:15	21	Coarse sand over rock	S 20°09.93'	E118°25.77'
T7-1	20/12/07	17:00	22	Coarse sand over shell	S 20°09.16'	E118°24.80'
T7-2	20/12/07	17:15	22	Coarse sand over shell	S 20°09.13'	E118°24.98'
T7-3	20/12/07	18:00	22	Coarse sand and shell	S 20°09.11'	E118°25.10'
T7-4	20/12/07	18:15	22	Coarse sand and shell	S 20°09.10'	E118°25.22'
T8-1	20/12/07	18:30	23	Coarse sand and shell	S 20°08.10'	E118°24.38'
T8-2	20/12/07	18:45	23	Coarse sand and shell	S 20°08.05'	E118°24.51'
T8-3	21/12/07	16:30	22	Coarse sand over rock	S 20°07.99'	E118°24.67'
T8-4	21/12/07	16:45	22	Coarse sand over rock	S 20°07.95'	E118°24.78'
T9-1	21/12/07	14:30	20	Shell, sand over	S 20°06.68'	E118°24.22'
T9-2	21/12/07	14:45	20	Shell, sand over	S 20°06.59'	E118°24.35'
T9-3	21/12/07	14:00	20	coarse sand over	S 20°06.51'	E118°24.48'
T9-4	21/12/07	14:15	19	coarse sand over	S 20°06.44'	E118°24.57'
T10-1	21/12/07	12:45	19	Coarse sand, rubble, rock	S 20°05.17'	E118°24.37'
T10-2	21/12/07	13:00	20	Coarse sand, rubble, rock	S 20°05.12'	E118°24.47'
T10-3	21/12/07	11:30	19	Coarse shelly sand	S 20°05.05'	E118°24.59'
T10-4	21/12/07	11:45	19	Coarse shelly sand	S 20°05.00'	E118°24.67'
T11-1	21/12/07	10:00	23	Coarse sand and shell	S 20°04.17'	E118°24.43'

SKM

Site	Date	Time	Water depth in metres (at time)	Sediment description	GDA94 co-ordinates	
					Latitude	Longitude
T11-2	21/12/07	10:15	23	Coarse sand and shell	S 20°04.12'	E118°24.56'
T11-3	21/12/07	10:45	22	Coarse sand over rubble	S 20°04.04'	E118°24.72'
T11-4	21/12/07	11:00	22	Coarse sand over rubble	S 20°04.00'	E118°24.81'
T12-1	21/12/07	09:15	23	Coarse sand over rubble	S 20°03.33'	E118°24.50'
T12-2	21/12/07	09:30	22	Coarse sand over rubble	S 20°03.27'	E118°24.65'
T12-3	21/12/07	08:30	22	Coarse sand over rubble	S 20°03.20'	E118°24.79'
T12-4	21/12/07	08:45	22	Coarse sand over rubble	S 20°03.16'	E118°24.88'
T16-1	22/12/07	11:45	22	Coarse sand and shell	S 20°01.85'	E118°24.90'
T16-2	22/12/07	12:00	23	Coarse sand and shell	S 20°01.81'	E118°24.98'
T16-3	22/12/07	12:15	22	Coarse sand over rubble	S 20°01.73'	E118°25.17'
T16-4	22/12/07	12:30	21	Coarse sand over rubble	S 20°01.67'	E118°25.29'
T17-1	22/12/07	12:45	22	Coarse sand over rubble	S 20°00.53'	E118°25.58'
T17-2	22/12/07	13:00	23	Coarse sand over rubble	S 20°00.47'	E118°25.71'
T17-3	21/12/07	10:15	23	Coarse sand over rubble	S 20°00.41'	E118°25.83'
T17-4	21/12/07	10:00	24	Coarse sand over rubble	S 20°00.38'	E118°25.91'
T18-1	22/12/07	10:30	24	Coarse sand over rubble	S 19°59.72'	E118°25.89'
T18-2	22/12/07	10:45	24	Coarse sand over rubble	S 19°59.66'	E118°26.02'
T17-3	22/12/07	11:00	25	Coarse sand over rubble	S 19°59.62'	E118°26.11'
T18-4	22/12/07	11:15	25	Coarse sand over rubble	S 19°59.56'	E118°26.24'
Pilot Study 'spoil grounds'						
SG1-1	21/12/07	17:45	20	Gravel, shell over clay	S 20°09.39'	E118°28.61'
SG1-2	21/12/07	18:15	21	Fine and medium sand	S 20°10.06'	E118°29.36'
SG1-3	21/12/07	17:00	19	Medium sand over rock	S 20°10.59'	E118°28.07'
SG1-5	21/12/07	16:15	18	Coarse sand and shell	S 20°08.63'	E118°23.78'
SG3-1	22/12/07	09:00	19	Coarse sand and shell	S 20°06.96'	E118°23.15'
SG3-2	22/12/07	08:00	19	Coarse sand and shell	S 20°07.63'	E118°23.58'
SG3-4	22/12/07	07:15	18	Coarse sand and shell	S 20°07.70'	E118°22.88'
SG3-5	22/12/07	09:30	18	Coarse sand and shell	S 20°01.68'	E118°22.52'
Potential Spoil Ground Sites (1)						
SGA-1	11/01/08	10:30	18	Coarse sand	S 20°07.000'	E 118°38.350'
SGA-2	11/01/08	11:00	18	Fine sand and shell	S 20°07.000'	E 118°36.350'
SGA-3	11/01/08	11:30	19	Fine sand and shell	S 20°07.600'	E 118°37.350'
SGA-4	11/01/08	12:00	19	Coarse and fine sand	S 20°08.200'	E 118°36.350'
SGA-5	11/01/08	12:20	20	Coarse and fine sand	S 20°08.200'	E 118°38.350'
SGB-1	11/01/08	15:20	18	Coarse sand	S 20°09.800'	E 118°37.700'
SGB-2	11/01/08	15:45	19	Coarse sand	S 20°09.800'	E 118°35.700'
SGB-3	11/01/08	16:00	16	Coarse sand	S 20°10.400'	E 118°36.700'
SGB-4	11/01/08	16:30	17	Coarse and fine sand	S 20°11.000'	E 118°35.700'
SGB-5	11/01/08	16:50	16	Medium grain sand	S 20°11.000'	E 118°37.700'
SGC-1	11/01/08	17:10	16	Coarse and fine sand	S 20°11.500'	E 118°37.700'
SGC-2	11/01/08	17:30	16	Coarse and fine sand	S 20°11.500'	E 118°35.700'
SGC-3	12/01/08	11:00	16	Medium grain sand and	S 20°12.100'	E 118°36.700'
SGC-4	12/01/08	11:30	16	Medium grain sand and	S 20°12.700'	E 118°35.700'
SGC-5	12/01/08	11:50	14	Medium grain sand and	S 20°12.700'	E 118°37.700'
SGD-1	12/01/08	12:45	15	Coarse sand and rubble	S 20°07.800'	E 118°33.600'
SGD-2	12/01/08	13:10	17	Fine silt	S 20°07.800'	E 118°32.400'

SKM

Site	Date	Time	Water depth in metres (at time)	Sediment description	GDA94 co-ordinates	
					Latitude	Longitude
SGD-3	12/01/08	14:15	17	Medium grain sand	S 20°08.600'	E 118°33.000'
SGD-4	12/01/08	13:55	18	Coarse sand	S 20°09.400'	E 118°32.400'
SGD-5	12/01/08	13:35	18	Coarse sand	S 20°09.400'	E 118°33.600'
SGE-1	12/01/08	14:50	20	Coarse sand	S 20°11.500'	E 118°34.200'
SGE-2	12/01/08	15:20	20	Coarse sand	S 20°11.500'	E 118°33.000'
SGE-3	12/01/08	15:45	18	Fine sand and shell	S 20°12.000'	E 118°33.600'
SGE-4	12/01/08	16:00	18	Fine sand	S 20°12.500'	E 118°33.000'
SGE-5	12/01/08	16:30	17	Fine sand and shell	S 20°12.500'	E 118°34.200'
Dredge Footprint - 6km Design						
1	9/2/08	15:15	16	Sand, shell over rubble	S 20°14.443'	E118°33.393'
2	9/2/08	14:45	17	Sand, shell over rubble	S 20°14.283'	E118°33.294'
3	9/2/08	14:45	17	Sand, shell over rubble	S 20°14.275'	E118°33.239'
4	9/2/08	14:30	17	Medium sand over gravel	S 20°14.399'	E118°33.039'
5	9/2/08	15:30	17	Medium sand over rubble	S 20°14.548'	E118°32.840'
6	9/2/08	14:15	16	Medium sand over rubble	S 20°14.225'	E118°33.076'
7	9/2/08	14:00	16	Medium sand over rubble	S 20°14.368'	E118°32.901'
8	9/2/08	13:45	15	Gravel over rock	S 20°14.455'	E118°32.620'
9	9/2/08	13:30	16	Coarse sand over	S 20°14.319'	E118°32.749'
10	9/2/08	12:15	15	Coarse sand	S 20°14.155'	E118°32.775'
11	10/2/08	08:15	13	Gravel and fine sand	S 20°13.415'	E118°32.892'
12	10/2/08	08:15	13	Gravel and fine sand	S 20°13.462'	E118°32.756'
13	10/2/08	08:45	13	Coarse sand and gravel	S 20°13.578'	E118°32.547'
14	10/2/08	09:00	13	Coarse sand	S 20°13.578'	E118°32.196'
15	8/2/08	18:15	14	Coarse sand and shell	S 20°13.309'	E118°32.293'
16	8/2/08	18:15	14	Coarse sand and shell	S 20°13.241'	E118°32.359'
17	8/2/08	17:45	14	Coarse sand	S 20°13.029'	E118°32.487'
18	8/2/08	17:45	14	Coarse sand	S 20°12.966'	E118°32.349'
19	8/2/08	17:45	14	Coarse sand	S 20°13.170'	E118°31.991'
20	8/2/08	17:15	15	Coarse sand over clay	S 20°13.045'	E118°31.937'
21	8/2/08	16:45	15	Medium sand over	S 20°12.954'	E118°32.091'
22	8/2/08	16:15	20	Soft silt over clay	S 20°12.860'	E118°31.784'
23	8/2/08	16:00	18	Coarse sand	S 20°12.790'	E118°31.746'
24	8/2/08	16:00	18	Coarse sand	S 20°12.476'	E118°31.698'
25	8/2/08	15:30	18	Coarse sand and shell	S 20°12.146'	E118°31.453'
26	8/2/08	15:00	19	Medium grain sand and	S 20°11.191'	E118°30.796'
27	8/2/08	14:30	19	Shallow sand over rock	S 20°10.839'	E118°30.653'
28	8/2/08	14:00	21	Shallow sand over rock	S 20°10.128'	E118°30.229'
29	8/2/08	13:30	23	Coarse sand and shell	S 20°09.124'	E118°29.530'
30	8/2/08	13:00	22	Medium sand	S 20°08.372'	E118°29.096'
31	10/2/08	09:30	22	Coarse sand	S 20°07.227'	E118°28.487'
32	10/2/08	09:45	23	Sand, gravel over	S 20°06.672'	E118°28.102'
33	10/2/08	10:00	22	No sample – pavement	S 20°06.441'	E118°27.974'
34	10/2/08	10:15	23	No sample – pavement	S 20°06.484'	E118°27.910'
35	10/2/08	10:30	23	No sample – pavement	S 20°06.395'	E118°27.882'
36	10/2/08	10:45	23	No sample – pavement	S 20°06.113'	E118°27.360'
37	10/2/08	11:00	23	No sample - pavement	S 20°06.001'	E118°27.172'

Site	Date	Time	Water depth in metres (at time)	Sediment description	GDA94 co-ordinates	
					Latitude	Longitude
38	9/2/08	11:00	23	Coarse sand	S 20°04.995'	E118°25.825'
39	9/2/08	11:00	23	Coarse sand	S 20°04.901'	E118°25.659'
40	9/2/08	10:30	23	Coarse sand	S 20°04.585'	E118°25.127'
41	9/2/08	10:00	23	Sand, gravel over	S 20°04.358'	E118°24.929'
42	9/2/08	10:15	23	Sand, gravel over	S 20°04.298'	E118°24.971'
43	9/2/08	09:30	21	Coarse sand and shell	S 20°03.709'	E118°24.465'
44	9/2/08	09:00	20	Coarse sand and shell	S 20°03.524'	E118°24.355'
45	9/2/08	09:00	20	Coarse sand and shell	S 20°03.148'	E118°24.284'
46	7/2/08	10:00	22	Coarse sand over rock	S 20°02.589'	E118°23.988'
47	7/2/08	09:30	24	Sand over platform	S 20°02.340'	E118°23.915'
48	7/2/08	09:00	24	Coarse sand over	S 20°01.413'	E118°23.381'
49	7/2/08	08:30	24	Coarse sand over	S 20°00.604'	E118°22.962'
50	7/2/08	08:00	25	Coarse sand over	S 19°59.956'	E118°22.680'
Potential Spoil Ground Sites (2)						
1-1	03/05/08	13:45	15	Coarse sand	S 20°11.649'	E118°35.808'
1-2	03/05/08	14:00	15	Coarse sand	S 20°11.617'	E118°36.931'
1-3	03/05/08	14:30	15	Coarse sand and shell	S 20°12.213'	E118°36.347'
1-4	03/05/08	14:45	13	Medium grain sand and	S 20°12.928'	E118°35.729'
1-5	03/05/08	15:00	13	Shallow sand over rock	S 20°12.972'	E118°36.934'
2-1	03/05/08	12:00	17	Shallow sand over rock	S 20°09.468'	E118°35.242'
2-2	03/05/08	12:30	17	Coarse sand and shell	S 20°09.497'	E118°36.863'
2-3	03/05/08	12:30	17	Medium sand	S 20°10.204'	E118°36.083'
2-4	03/05/08	13:00	16	Coarse sand	S 20°10.800'	E118°35.441'
2-5	03/05/08	13:30	16	Coarse sand	S 20°10.787'	E118°36.864'
3-1	03/05/08	8:15	20	Coarse sand	S 20°05.296'	E118°33.866'
3-2	03/05/08	9:00	23	Sand, gravel over	S 20°05.356'	E118°36.203'
3-3	03/05/08	9:00	19	Sand, shell over rubble	S 20°05.278'	E118°37.992'
3-4	03/05/08	9:30	22	Medium sand over gravel	S 20°06.307'	E118°35.035'
3-5	03/05/08	10:15	21	Medium sand over rubble	S 20°06.277'	E118°36.994'
3-6	03/05/08	10:45	22	Medium sand over rubble	S 20°07.424'	E118°33.861'
3-7	03/05/08	11:00	20	Medium sand over rubble	S 20°07.392'	E118°36.055'
3-8	03/05/08	11:30	17	Gravel, shell, sand	S 20°07.399'	E118°37.969'
7-1	03/05/08	13:00	14	Gravel, shell, sand	S 20°12.121'	E118°26.713'
7-2	16/05/08	13:30	17	Coarse shelly sand	S 20°12.152'	E118°28.346'
7-3	16/05/08	14:00	15	Coarse shelly sand	S 20°12.660'	E118°27.586'
7-4	16/05/08	14:15	15	Medium grain sand and	S 20°13.170'	E118°26.815'
7-5	16/05/08	14:30	17	Coarse sand	S 20°13.201'	E118°28.286'
8-1	16/05/08	11:30	17	Coarse sand	S 20°10.887'	E118°22.557'
8-2	16/05/08	12:00	17	Coarse sand and shell	S 20°10.895'	E118°24.201'
8-3	16/05/08	12:15	18	Medium grain sand and	S 20°11.318'	E118°23.290'
8-4	16/05/08	12:00	18	Shallow sand over rock	S 20°11.869'	E118°22.705'
8-5	16/05/08	13:00	16	Shallow sand over rock	S 20°11.945'	E118°24.118'
9-1	16/05/08	8:45	28	Coarse sand and shell	S 19°57.581'	E118°23.402'
9-2	16/05/08	9:00	29	Medium sand	S 19°57.563'	E118°24.605'
9-3	16/05/08	9:30	29	Coarse sand	S 19°58.126'	E118°24.015'
9-4	16/05/08	10:00	27	Coarse sand	S 19°58.714'	E118°23.421'

SKM

Site	Date	Time	Water depth in metres (at time)	Sediment description	GDA94 co-ordinates	
					Latitude	Longitude
9-5	16/05/08	10:30	26	Coarse sand	S 19°58.722'	E118°24.543'
Dredge Footprint – 4km design (previously un-sampled for 6km design)						
101	22/09/08	13:45	15	Coarse sand	S 20°14.874'	E118°33.390'
102	22/09/08	13:55	15	Coarse sand	S 20°15.006'	E118°33.840'
103	22/09/08	14:00	16	Coarse sand	S 20°15.013'	E118°03.531'
104	22/09/08	14:10	15	Sand, gravel over	S 20°15.158'	E118°33.518'
105	22/09/08	14:23	15	Sand, gravel over	S 20°15.162'	E118°33.364'
106	22/09/08	14:33	14	Coarse sand and shell	S 20°15.165'	E118°33.209'
107	22/09/08	14:38	15	Coarse sand and shell	S 20°15.219'	E118°34.052'
108	22/09/08	14:45	16	Coarse sand and shell	S 20°15.300'	E118°33.660'
109	22/09/08	14:53	15	Coarse sand over rock	S 20°15.310'	E118°33.196'
110	22/09/08	15:08	15	Sand, shell over rubble	S 20°15.439'	E118°33.956'
111	22/09/08	15:18	16	Sand, shell over rubble	S 20°15.452'	E118°33.338'
112	22/09/08	15:26	16	Medium sand over gravel	S 20°15.456'	E118°33.184'
113	22/09/08	15:35	14	Medium sand over rubble	S 20°15.503'	E118°34.336'
114	22/09/08	15:45	14	Medium sand over rubble	S 20°15.520'	E118°33.564'
115	22/09/08	15:55	16	Medium sand over rubble	S 20°15.580'	E118°34.098'
116	22/09/08	16:00	15	Sand, gravel over	S 20°15.584'	E118°33.944'
117	22/09/08	16:05	14	Sand, shell over rubble	S 20°15.594'	E118°33.480'
118	22/09/08	16:14	15	Medium sand over gravel	S 20°15.598'	E118°33.326'
119	23/09/08	09:00	16	Medium sand over rubble	S 20°15.655'	E118°34.015'
120	23/09/08	09:34	15	Medium sand over rubble	S 20°15.811'	E118°33.539'
121	23/09/08	09:50	13	Sand, shell over rubble	S 20°15.875'	E118°33.919'
122	23/09/08	10:07	15	Sand, shell over rubble	S 20°15.279'	E118°32.837'
123	23/09/08	11:17	15	Medium sand over gravel	S 20°15.081'	E118°32.977'
124	23/09/08	11:15	14	Medium sand over rubble	S 20°14.'812	E118°32.843'
125	23/09/08	11:05	15	Medium sand over rubble	S 20°15.1959	E118°33.555'
126	23/09/08	10:55	15	Medium sand over rubble	S 20°15.2766	E118°33.368'
127	23/09/08	10:42	15	Coarse sand and shell	S 20°15.8564	E118°33.069'
Potential Spoil Ground Sites (3)						
201	23/09/08	12:10	20	Coarse sand	S 20°10.233'	E118°28.466'
202	23/09/08	12:40	16	Coarse sand	S 20°12.157'	E118°25.322'
203	23/09/08	13:00	18	Coarse sand	S 20°13.244'	E118°25.364'
204	23/09/08	12:50	16	Sand, gravel over	S 20°12.657'	E118°26.007'
205	23/09/08	13:25	15	Sand, gravel over	S 20°12.673'	E118°23.964'
206	23/09/08	14:00	15	Coarse sand and shell	S 20°10.320'	E118°25.338'
207	23/09/08	14:55	15	Coarse sand and shell	S 20°11.076'	E118°28.376'
208	23/09/08	14:30	15	Coarse sand and shell	S 20°11.028'	E118°26.819'
209	23/09/08	14:15	16	Coarse sand over rock	S 20°10.276'	E118°26.958'
210	23/09/08	13:40	17	Medium sand over rubble	S 20°11.056'	E118°25.312'

SKM

Corner co-ordinates of spoil grounds 1 – 3 and 7 - 9						
					GDA94 Co-ordinates	
Spoil Ground	Number	Corner		Sediment Description	Latitude	Longitude
1	13	SE		Not a sample location	S20°13.054'	E118°37.138'
1	14	SW		Not a sample location	S20°13.068'	E118°35.557'
1	15	NW		Not a sample location	S20°11.412'	E118°35.541'
1	16	NE		Not a sample location	S20°11.397'	E118°37.121'
2	17	SE		Not a sample location	S20°10.970'	E118°37.116'
2	18	SW		Not a sample location	S20°10.988'	E118°35.088'
2	19	NW		Not a sample location	S20°09.332'	E118°35.072'
2	20	NE		Not a sample location	S20°09.314'	E118°37.099'
3	1	SE		Not a sample location	S20°07.582'	E118°36.568'
3	2	SW		Not a sample location	S20°07.644'	E118°33.626'
3	3	NW		Not a sample location	S20°05.080'	E118°33.601'
3	4	NE		Not a sample location	S20°05.038'	E118°36.542'
7	9	SE		Not a sample location	S20°13.530'	E118°28.633'
7	10	SW		Not a sample location	S20°13.867'	E118°24.954'
7	11	NW		Not a sample location	S20°11.867'	E118°24.941'
7	12	NE		Not a sample location	S20°11.837'	E118°28.619'
8	21	SE		Not a sample location	S20°12.098'	E118°24.461'
8	22	SW		Not a sample location	S20°12.114'	E118°22.481'
8	23	NW		Not a sample location	S20°10.710'	E118°22.470'
8	24	NE		Not a sample location	S20°10.694'	E118°24.466'
9	5	SE		Not a sample location	S19°58.848'	E118°24.726'
9	6	SW		Not a sample location	S20°58.859'	E118°23.288'
9	7	NW		Not a sample location	S20°57.455'	E118°23.276'
9	8	NE		Not a sample location	S20°57.444'	E118°24.713'

Appendix F Geotechnical Environmental Sampling and Analyses