Technical Appendices Q2 to Q5

Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Wheatstone Project

July 2010

Wheatstone Project

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Appendix Q2 to Q5

Appendix Q2

Hydrocarbon Spill Modelling

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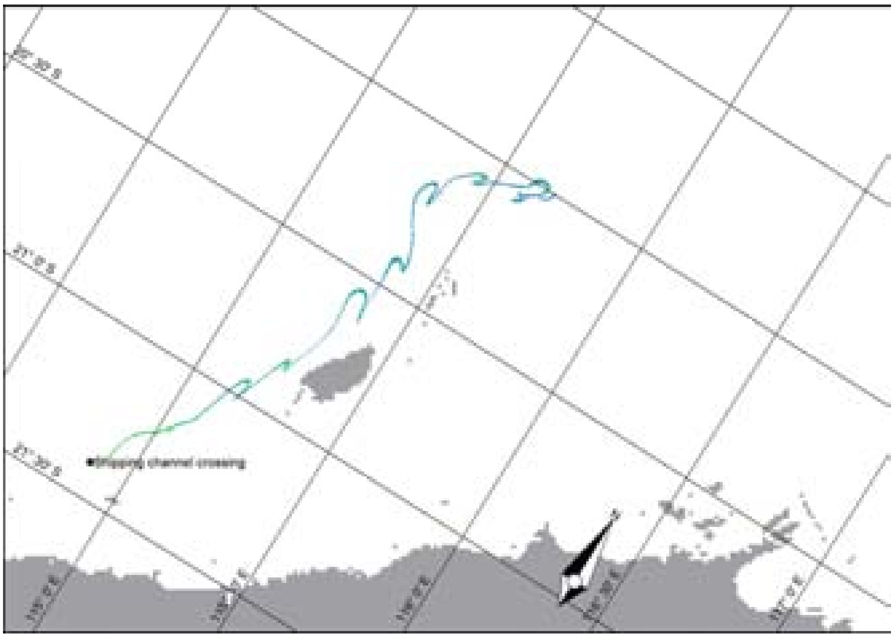
Wheatstone Project

Hydrocarbon Spill Modelling



Chevron Australia Pty Ltd **July 2010**

Wheatstone Project

Hydrocarbon Spill Modelling

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1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara coast. The LNG and Domgas plant will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin. The Wheatstone Project is referred to as the Project and the Ashburton North Strategic Industrial Area (Ashburton North SIA) is the proposed site for the LNG and Domgas plant. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land. The LNG plant will have a maximum capacity of 25 Million Tonnes Per Annum (MTPA) of LNG.

The Project has been referred to the State Environmental Protection Authority (EPA) and the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support the environmental impact assessment (EIA) process.

The potential for accidental hydrocarbon spills are rare events due to ever-improving technical solutions for offshore facilities and health, safety and environment in the oil and gas industry. However, the risk cannot be totally eliminated and therefore an analysis of the consequences of an oil spill needs to be undertaken as part of the EIA.

The aim of the hydrocarbon spill modelling is to provide an understanding of the trajectory of hydrocarbon spills from the Project for both nearshore and offshore components, using a range of conservative oil spill and climatic scenarios. This report provides details of the selected spill and climatic scenarios, the related assumptions, and a brief description of the modelling approach used. The approach for this study, including a description of the spill scenarios, is described in Section 2, while Section 3 provides a description of the applied oil spill model. The spill modelling results for all scenarios are presented in Section 4 and Appendix A to Appendix F.

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2 STUDY APPROACH

2.1 Spill Scenarios

Six spill scenarios have been identified for the EIA for the Project. These scenarios are:

- Scenario 1: Iago #1 Well - subsea spill of natural gas condensate (condensate) during drilling (due to loss of well control).
- Scenario 2: Wheatstone Platform (WP) - surface spill of diesel from leaking tanks.
- Scenario 3: Shipping channel crossing - subsea spill of condensate from leaking trunkline.
- Scenario 4: Product loading facility (PLF) - condensate spill to surface at loading
- Scenario 5: Materials offloading facility (MOF) - diesel fuel spill.
- Scenario 6: MOF - diesel fuel spill (with mitigation analysis of boom deployed across entrance).

Details for the identified spills are given in Table 2.1. Note that while a scenario number has been used to identify the individual scenario throughout this report, the scenario identification (Id), as provided in DHI (2010), is also listed in Table 2.1 for cross referencing purposes. The spill locations for the six scenarios are shown in Table 2.1 and Figure 2.1.

Table 2.1 Spill parameters for spill scenarios 1 to 6.

Scenario Number	**1**	**2**	**3**	**4**	**5**	**6**
Scenario Id	**A**	**E**	**F**	**G**	**H**	**I**
Location	Iago #1 Well	Wheatstone Platform	Shipping channel crossing	PLF	MOF	MOF (with mitigation)
	19° 55’ 54.48’’S 115° 20’ 2.89’’E	19º 56’ 34.80’’ 115º 22’ 55.20’’	21º 23’ 46.32’’ 114º 52’ 26.40’’	-	-	-
Type of oil / condensate	Iago condensate	Diesel	70/30 Wheatstone / Iago condensate	70/30 Wheatstone / Iago condensate	Standard diesel	Standard diesel
Water depth	100 m	At surface	30 m	Surface	At surface	At surface
Temperature	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient
Total spill	165 380 m^3	135 m^3	5568 m^3	100 m^3	2.55 m^3	2.55 m^3
Duration	90 days	10 minutes	5 days	1 minute	Instantaneous	Instantaneous
Flow rate	0.0212 m^3/s	0.225 m^3/s	0.0129 m^3/s	1.667 m^3/s	-	-

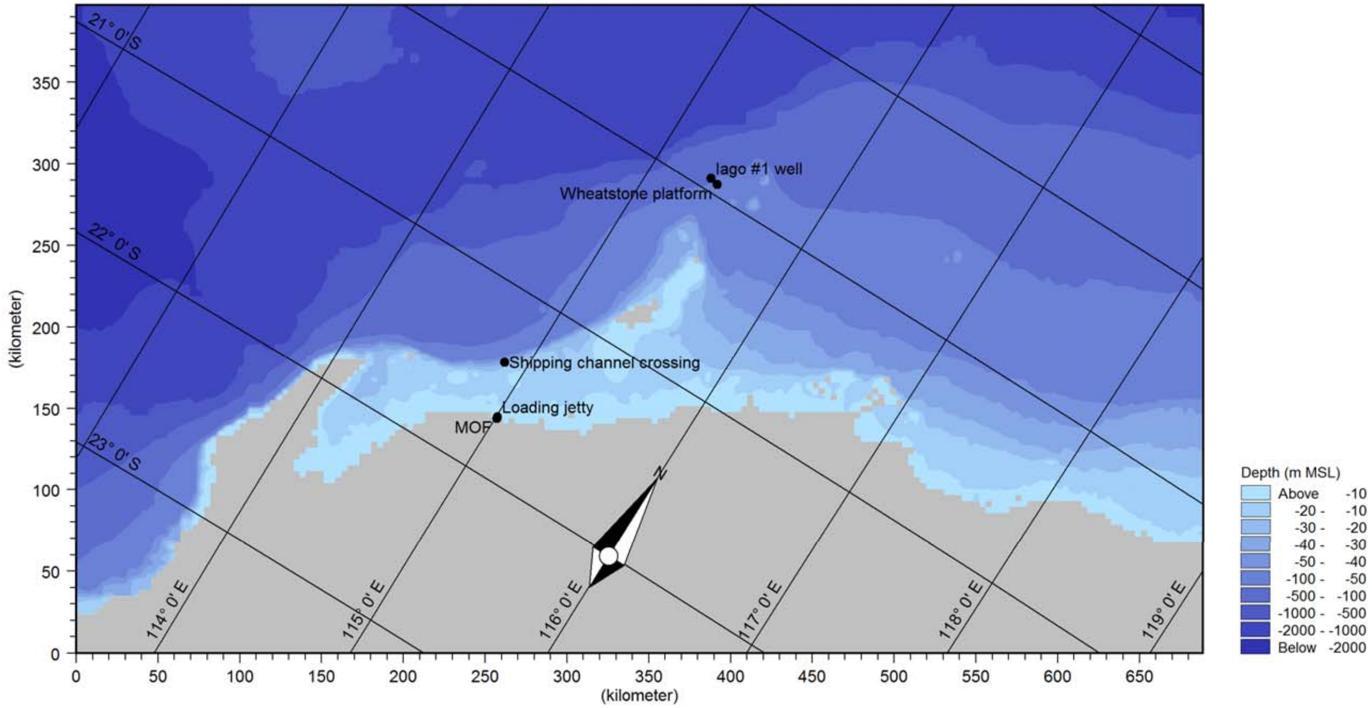

Figure 2.1 Spill locations.

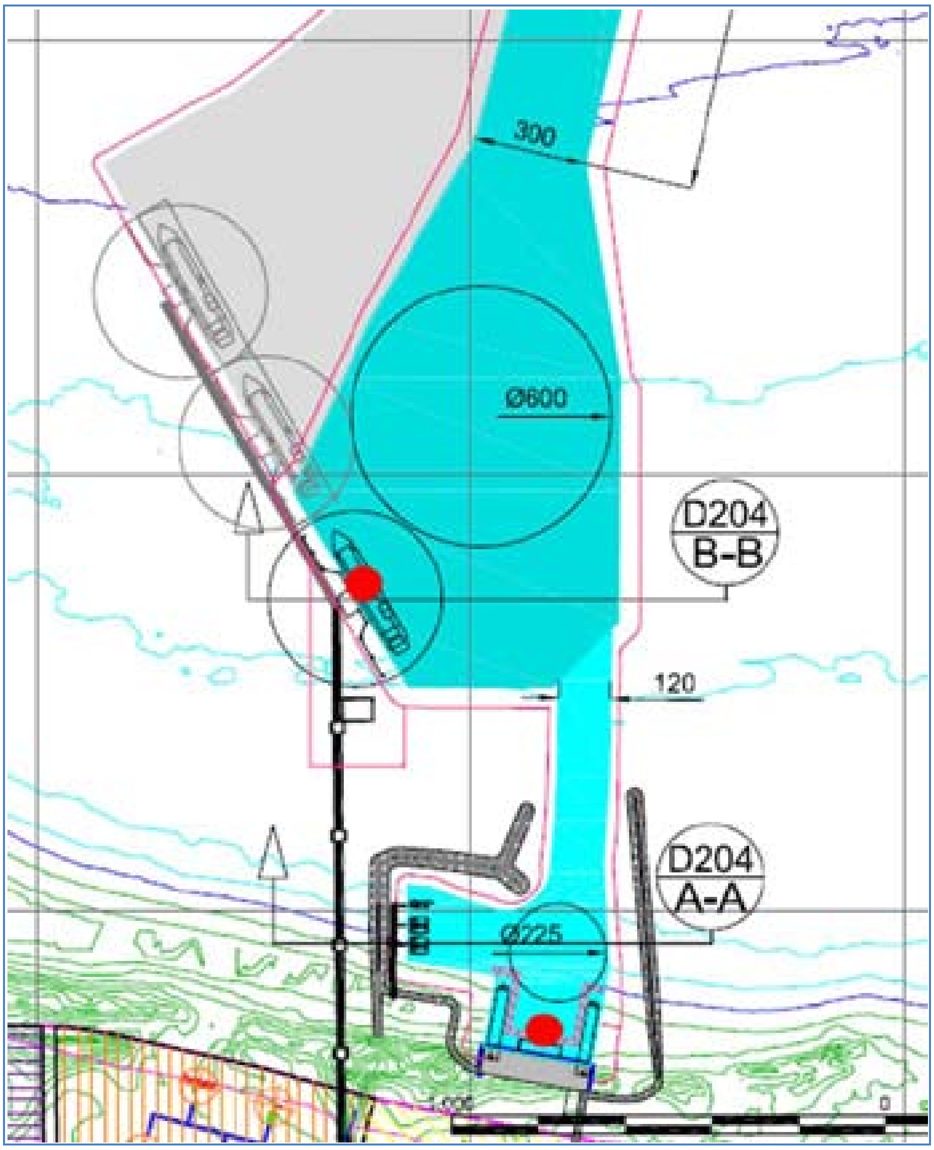

Figure 2.1 Spill locations at the PLF (upper red dot) and inside the MOF (lower red dot).

2.2 Modelling Approach

The oil spill modelling was carried out using a probabilistic modelling approach as described in Section 3.6. For each of the six scenarios and for each of the three seasons, described below (Table 2.2), a larger number of oil spill simulations were performed using the oil spill model described in Section 3.

Table 2.2 Definition of seasons for oil spill modelling.

Season	**Months**
Summer	September to February
Transition periods	March to April and August
Winter	May to July

The applied simulation periods, grid resolutions (DHI 2010) and number of simulations are listed for each scenario below (Table 2.3). For scenarios 1 to 5, and for each of the three seasons, the key results are presented as maps showing the following parameters:

- Maximum oil slick thickness (mm);
- Minimum time of arrival (hours); and
- Probability (percentage) of an oil slick of 0.001 mm or more reaching any given area.

The maps depicting these six scenarios are further described in Section 4 and provided in Appendix B to Appendix F. The results for scenario 6 are presented as a statistical analysis in Section 4.2.6.

Table 2.3 Overview of spill simulations.

Scenario Number	**1**	**2**	**3**	**4**	**5**	**6**
Scenario Id	**A**	**E**	**F**	**G**	**H**	**I**
Location	Iago #1 Well	Wheatstone Platform	Shipping channel crossing	PLF	MOF	MOF (with mitigation)
Spill Duration	90 days	10 minutes	5 days	1 minute	Instantaneous	Instantaneous
Simulation Duration	100 days	10 days	15 days	10 days	10 days	10 Days
HD model grid resolution	3645 m	3645 m	1215 m	405 m	15 m	15 m
Output grid resolution	405 m	405 m	405 m	405 m	15 m	15 m
Number of Simulations	36	324	324	324	324	324*

Note: * Simulations from scenario 5 have been applied to scenario 6.

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3 OIL SPILL MODELLING

3.1 Overview

The simulation of hydrocarbon spills was been carried out using DHIs oil spill model MIKE 21/3 SA (DHI 2009). In this model the oil is represented initially as buoyant Lagrangian particles being advected and dispersed while exposed to a range of weathering processes. The advection (drift) and dispersion of the individual particles is determined by the combined effects of current (tidal and/or wind driven), wind and bed drag. The model provides information on oil slick locations, the amount of oil left on the sea surface, the slick mobility and the evolution of the physicochemical properties of the oil.

The weathering processes included in the model are described below. A more detailed description of MIKE 21/3 SA including equations and key references for these is provided in Appendix A, while a full scientific documentation is available in DHI (2009).

3.2 Oil Spill Processes

The MIKE 21/3 SA model describes the spreading and weathering of oil spills in an aquatic environment under the influence of water movements (i.e. advection and the associated dispersion processes). The oil itself is defined according to its distillation properties and chemical structure.

The weathering processes may change the buoyancy of a particle, and particles may eventually settle on the seabed. Sedimentation, however, only occurs for very heavy oils in connection with mineral particles (sand/clay) and not for diesel and condensates as considered in the present study. Biodegradation and photooxidation only affect oil spills in the longer term (i.e. weeks to months or years) and therefore have not been considered. A schematic presentation of time scales for crude oil is shown in Figure 3.2.

The following processes are considered in the models (see Figure 3.1):

- Spreading (through advection and dispersion by tidal or wind-driven currents)
- Evaporation
- Emulsification
- Vertical dispersion (entrainment)
- Dissolution

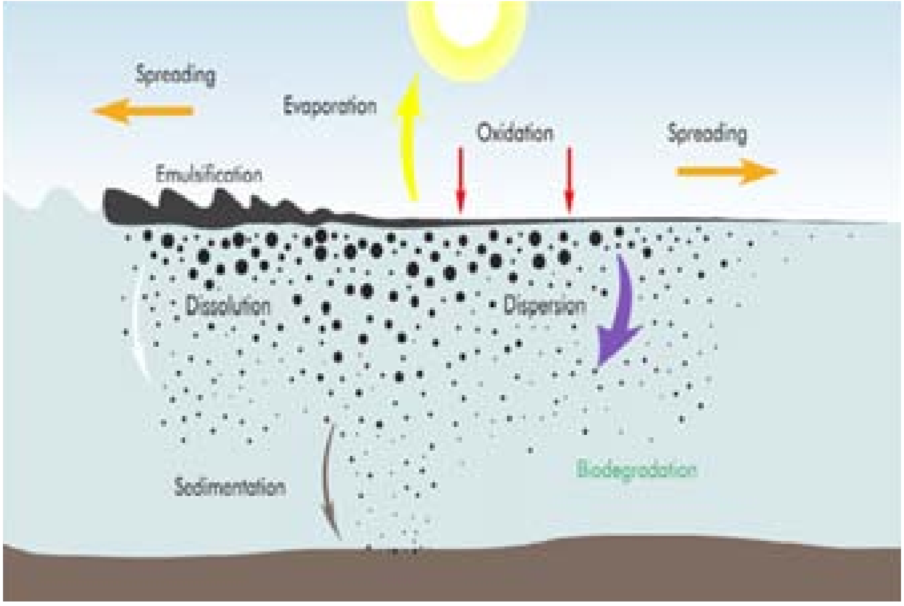


Figure 3.1 Weathering processes (from www.itopf.com)

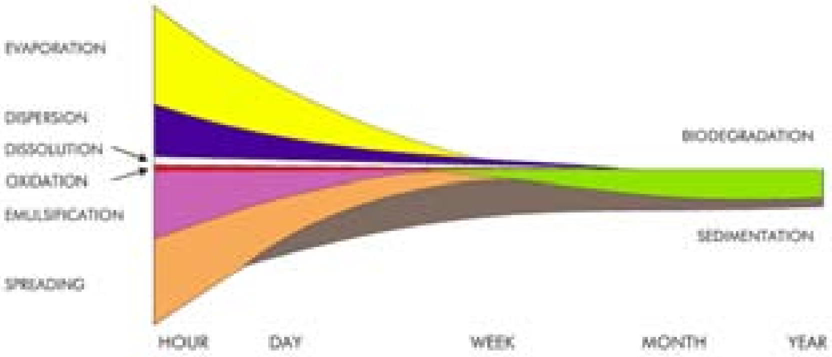


Figure 3.2 A schematic representation of the fate of a crude oil showing changes in the relative importance of weathering processes with time (the width of each band indicates the importance of the process) (from www.itopf.com)

3.3 Oil Spill Process Properties

The different parameters applied for the oil spill processes are listed below.

- Spreading: The currents define the water movement (advection) while the dispersion in the SA module is described using three dispersion coefficients that are proportional to the current in the longitudinal, transverse and vertical directions. Proportionality constants of 1.0 [m], 0.1 [m] and 0.01 [m] respectively were applied.
- Evaporation: Evaporation is given as a constant that is proportional to the amount of the evaporated oil. A default value of 0.0292 (dimensionless) has been applied.
- Emulsification: The emulsification process (water uptake) leads to a reduction in concentration, but also diminishes the evaporation of components from an emulsion. Emulsification is not included for either diesel or condensate (as specified by Chevron).
- Dispersion (called entrainment in MIKE 21/3 SA): The entrainment of oil (or vertical dispersion) into the water column is simulated using an interfacial tension parameter with a value of 20 dyne/cm (default value) valid for non-breaking waves.
- Dissolution: The volume of oil leaving the slick due to dissolution is calculated via a mass transfer coefficient set to a default value of $2.36 \cdot 10^{-6}$ (dimensionless).

Additionally the heat transport is considered in MIKE 21/3 SA with the following parameters used in the balance calculation:

- Albedo value: 0.14
- Emissivity of oil: 0.8
- Emissivity of water: 0.95
- Emissivity of air: 0.82

3.4 Oil Properties

Oil properties are described in MIKE 21/3 SA through the percentage of each of eight oil fractions given below:

- C6 - C12 (Paraffin)
- C13 - C25 (Paraffin)
- C6 - C12 (Cycloparaffin)
- C13 - C23 (Cycloparaffin)
- C6 - C11 (Aromatic)
- C12 - C18 (Aromatic)
- C9 - C25 (Naphteno-aromatic)
- Residual (including heterocycles)

Additionally the viscosity (in centistokes) and the reference temperature are required. The relative volumes for the eight fractions for diesel, Iago Condensate and 70/30 Iago/Wheatstone Condensate are given in Table *3.1*.

Table 3.1 Composition of diesel and condensates.

Composition	**Boiling Point**	**Diesel**	**100 % Iago Condensate**	**70% / 30% Iago / Wheatstone condensate**
C6 - C12 (Paraffin)	69 – 230 °C	11.30%	26.30%	18.70%
C13 - C25 (Paraffin)	230 – 405 °C	5.80%	23.00%	13.50%
C6 - C12 (Cycloparaffin)	70 – 230 °C	20.90%	20.70%	31.90%
C13 - C23 (Cycloparaffin)	230 – 405 °C	37. 8 %	20.20%	31.30%
C6 - C11 (Aromatic)	80 – 240 °C	10.30%	2.40%	1.10%
C12 - C18 (Aromatic)	240 – 400 °C	10.50%	3.50%	2.20%
C9 - C25 (Naphteno-aromatic)	180 – 400 °C	3.40%	0.00%	0.00%
Residual (including heterocycles)	> 400 °C	0.00%	3.80%	1.30%
Max water content from emulsification		0%	0%	0%
Asphaltene content		< 0.5 %	< 0.05 %	< 0.05 %
Wax content		5.80%	< 1 %	< 0.37 %
Density and viscosity				
Reference temperature		30 °C	30 °C	30 °C
Density		839 kg/m3	797.5 kg/m3	803.6 kg/m3
Kinematic viscosity		2.9 cS	1.518 cS	1.687 cS

For subsea spills the droplet diameter of the oil determines how fast the spill surfaces. Deep spill experiments with diesel show that droplet diameter varies from approximately 1 to 10 mm, with droplet diameters of 2 to 5 mm accounting for 70-75 per cent of the spill volume (Zheng and Yapa 2000). Condensate droplets with a diameter of 2 mm and 5 mm will surface within 12 minutes and 8 minutes respectively from a depth of 100 m., Even in strong currents, oil will surface within a few hundred metres from the spill location. Furthermore, with changing current and wind directions, the oil slick will pass the spill location and the surfacing of the spill will be of minor importance for the spreading potential.

3.5 Environmental Properties

3.5.1 Wind Data

The wind data applied in the oil spill model to describe the surface drift are for Scenario 2 to 6 identical to the wind data applied in the hydrodynamic simulations providing the currents for the oil spill simulations. For Scenario 1 wind fields have been applied to describe the surface drift, which is different from the wind applied for the hydrodynamic simulations (see section 3.5.3). A description of how the wind drift is combined with the hydrodynamic model currents are given in section (3.5.3).

3.5.2 Other Atmospheric Data and Current Data

A constant relative cloudiness of 0.4 and a time varying air temperature (taken from 3 hourly measurements covering several years) has been applied. For the present study existing 2D hydrodynamic results as described in DHI (2010) have been applied.

3.5.3 Current Data

Existing 2D hydrodynamic results as described in Ref /2/ have been applied for Scenarios 2 to 6. For Scenario 1 hydrodynamic results have been generated for an extending domain using an approach similar to that described in Ref /2/, but with a time series of wind conditions extracted at the well.

3.5.3.1 Combining wind drift and currents from hydrodynamic model

The drift profile applied in the oil spill simulations is derived using a combination of the theoretical bed shear profile (equivalent to a logarithmic profile of velocity) and wind acceleration of particles in near-surface layers directly exposed to the wind. Figure 3.3 illustrates how the MIKE 21 HD depth-averaged current is converted to the logarithmic profile (by maintaining the flux) which is added to the wind drift profile. The drift profile applied in the model is the sum of these two profiles.

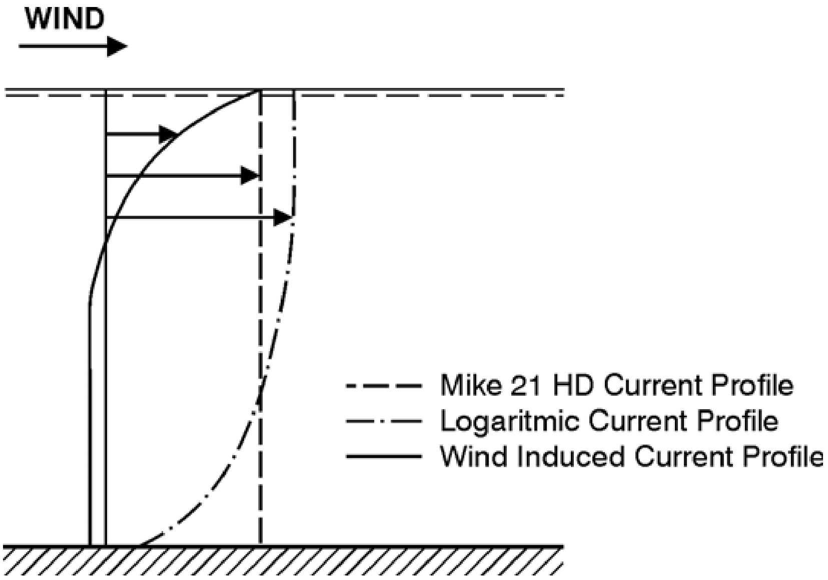


Figure 3.3 Logarithmic current profile (with the same depth integrated current speed as the MIKE 21 HD current profile) and wind induced current profile (with zero depth integrated current speed) are added in oil spill simulations

3.5.4 Other Oceanographic Data

A constant salinity of 33 psu and a time varying sea water temperature (taken from 3 hourly measurements covering several years) have been applied.

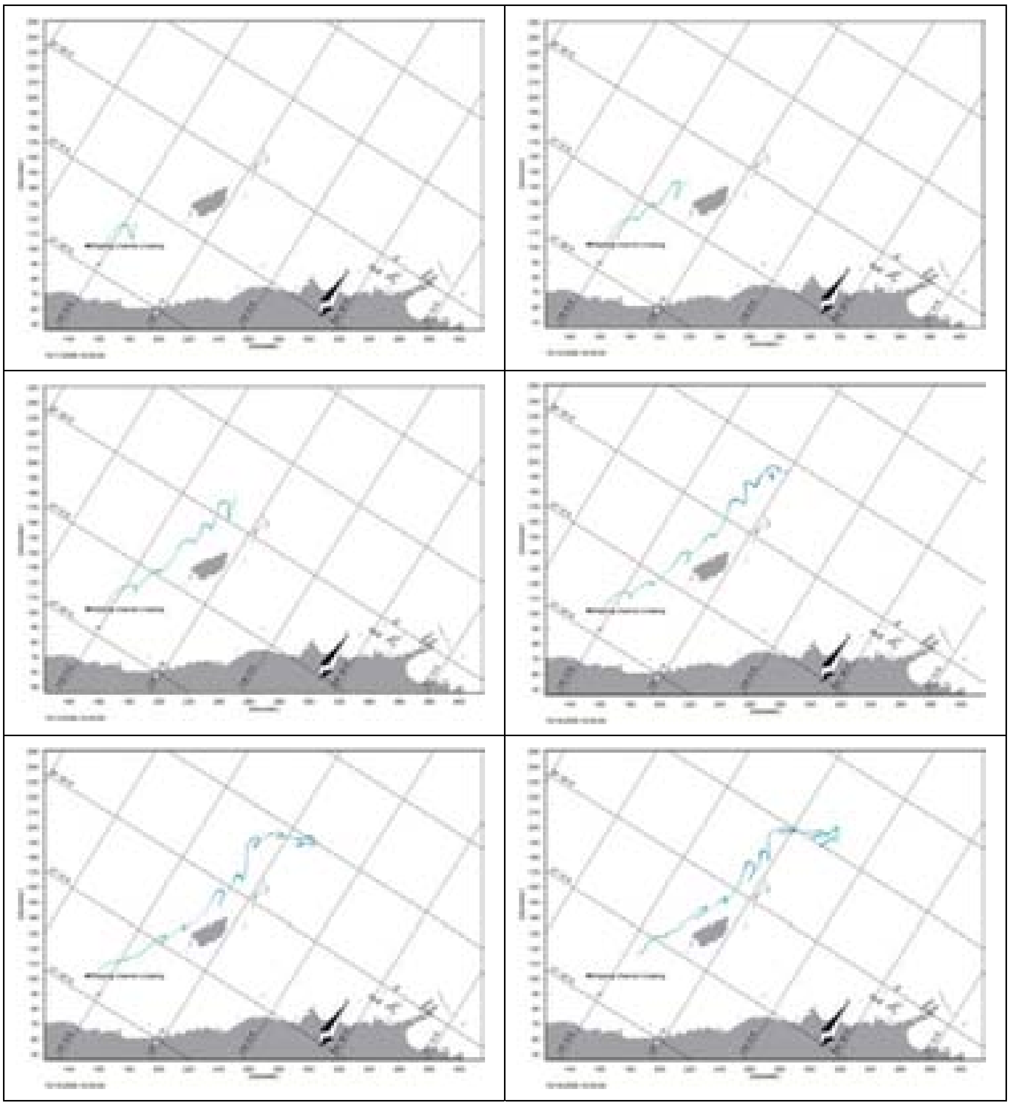
3.6 Probabilistic Oil Spill Modelling

An oil spill simulation using MIKE 21/3 SA describes the spreading and weathering of a spill taking place over a specific period (e.g. five days) and for a number of days after the spill has been stopped. The spill is subject to one set of environmental parameters (wind, currents etc.). A single simulation will thus only provide one possible outcome of the spill, while different environmental parameters would result in another outcome and thus impacted areas.

By running a large number of simulations with a large variety of environmental conditions it is assumed that all normally occurring combinations of wind, currents etc. are covered. Based on all these simulations an “envelope” of potentially affected areas is derived. This “envelope” is presented as a map providing information on the probability of a given area being impacted by a hydrocarbon spill. .

This probabilistic approach is illustrated in Figure 3.4 to Figure 3.10 for a condensate spill of 5568 m^3 taking place at the shipping channel crossing and lasting five days. The simulation period starts at 14:00 on 10/10-2006 and lasts for 15 days:

- Figure 3.4 and Figure 3.5 show model results (slick thickness) after 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12 and 15 days.
- Figure 3.6 shows the fate of the condensate during the 15 days simulation.
- Figure 3.7 shows the maximum oil thickness occurring during this single simulation, while Figure 3.8 shows the minimum time it takes for the oil slick to reach the area covered at any time during the 15 days simulation.
- Having carried out 108 individual simulations the maximum of all “maximum thickness maps” is computed. The result is shown in Figure 3.9.
- Likewise, the “minimum arrival time maps” for all 108 simulations are combined into one map providing the minimum for all simulations. This is shown in Figure 3.10.
- Finally, the probability of an oil slick reaching a given location can be computed based on all 108 simulations (Figure 3.11). For example, if a given location is reached by an oil slick with a thickness of more than 0.001 mm in 12 out of 108 simulations the probability amounts to 12/108*100 = 11 per cent for that location.



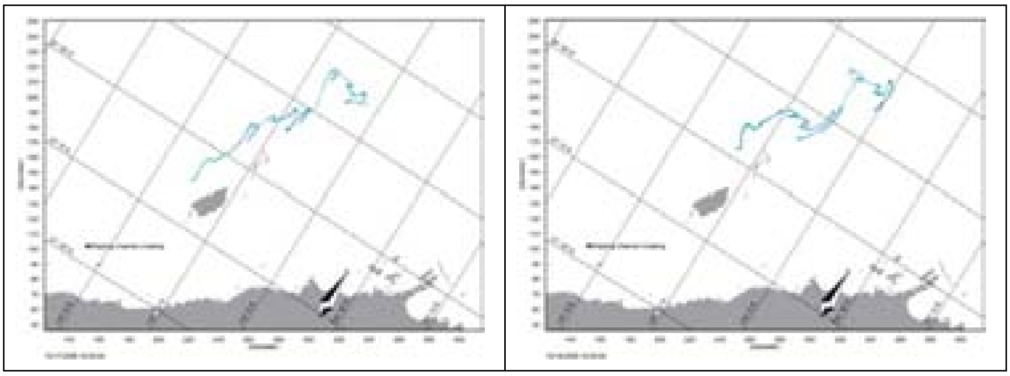


Figure 3.4 One individual oil spill from shipping channel crossing lasting five days with simulation results shown after 1, 2, 3, 4, 5, 6, 7, and 8 days.

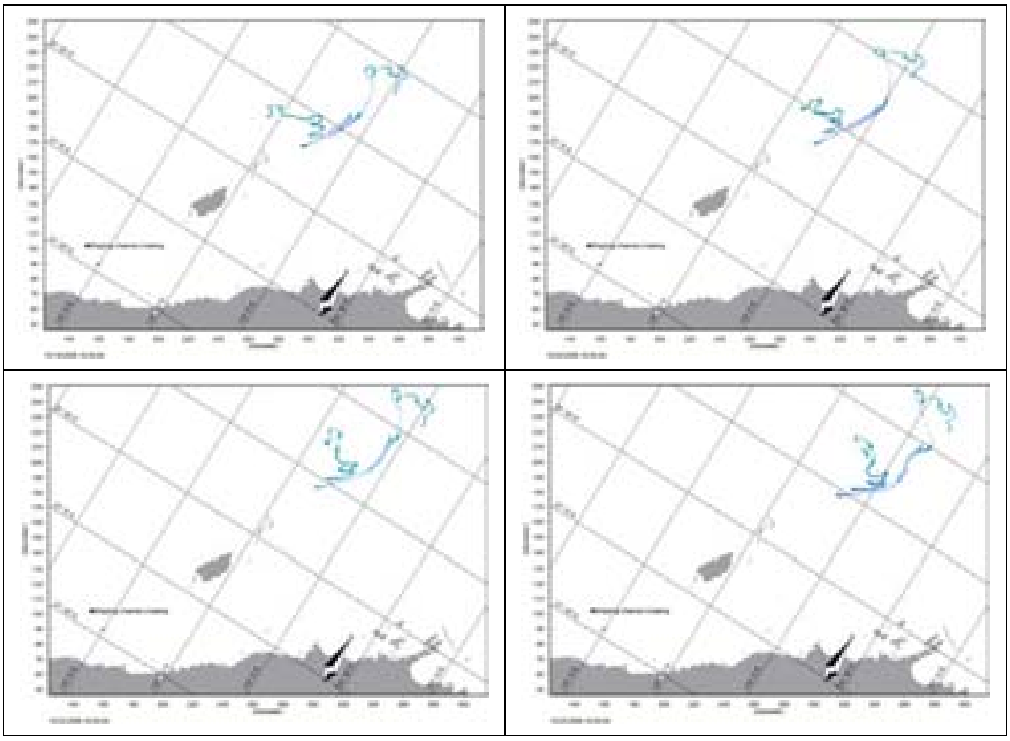


Figure 3.5 One individual oil spill from shipping channel crossing lasting five days with simulation results 9, 10, 12, and 15 days.

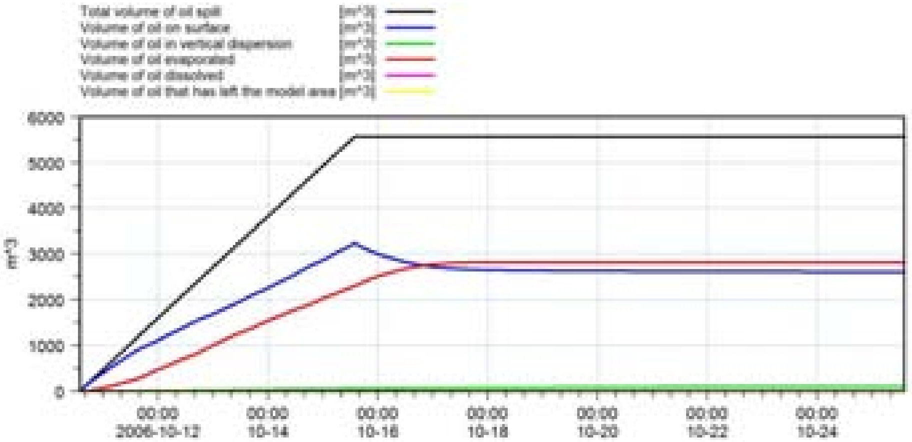


Figure 3.6 Fate of 5568 m^3 condensate spill during 15 days simulation.

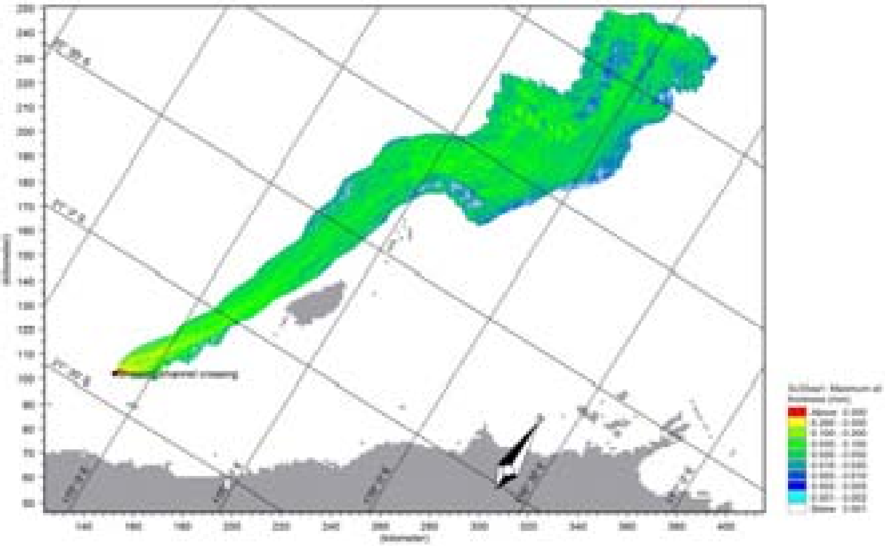


Figure 3.7 Maximum oil thickness during 15 days period from one simulation.

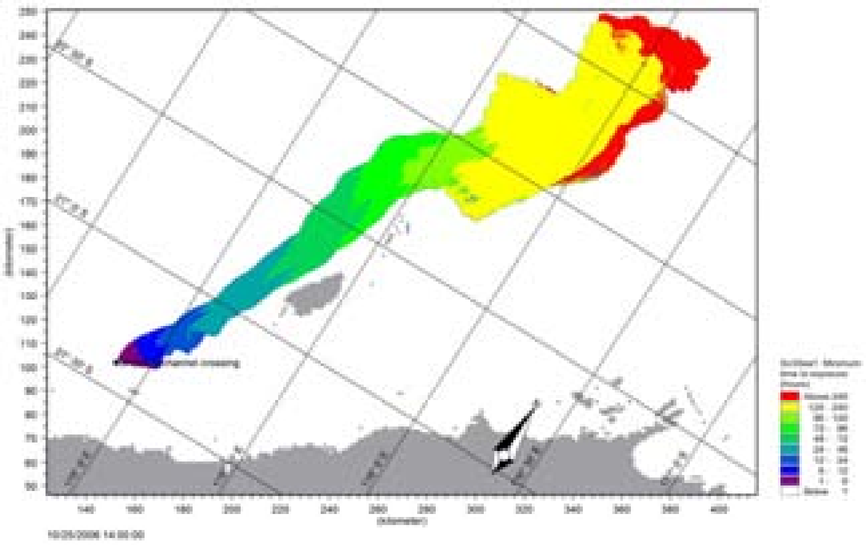


Figure 3.8 Minimum time of arrival of oil slick during 15 days period from one simulation.

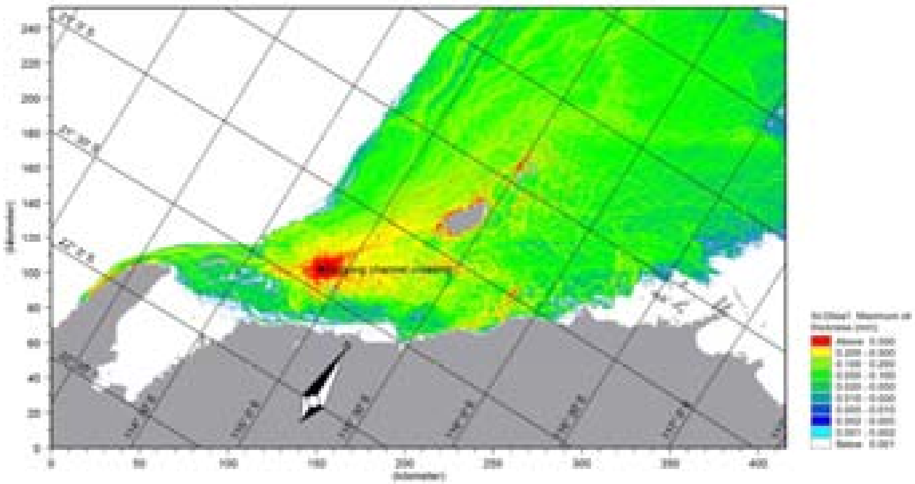


Figure 3.9 Maximum oil thickness during 15 days period from 108 simulations (note area shown is larger than in figures above).

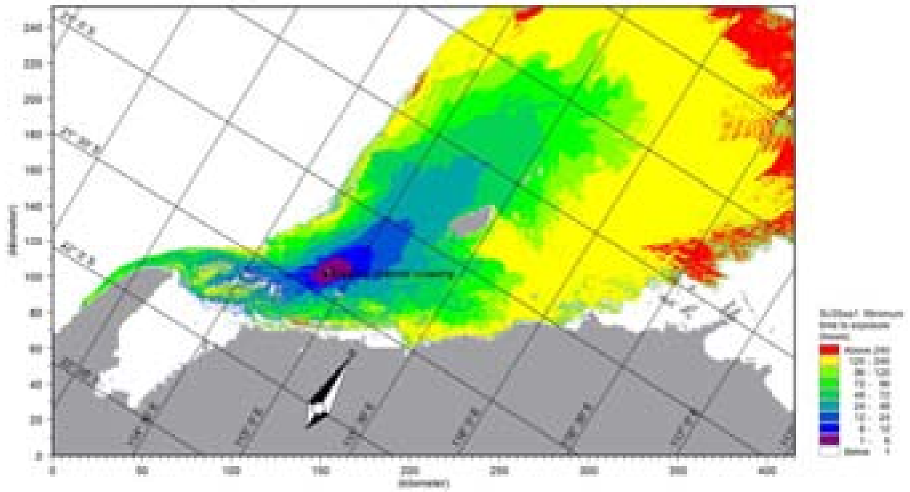


Figure 3.10 Minimum time of arrival of oil slick during 15 days period from 108 simulations (note area shown is larger than in figures above).

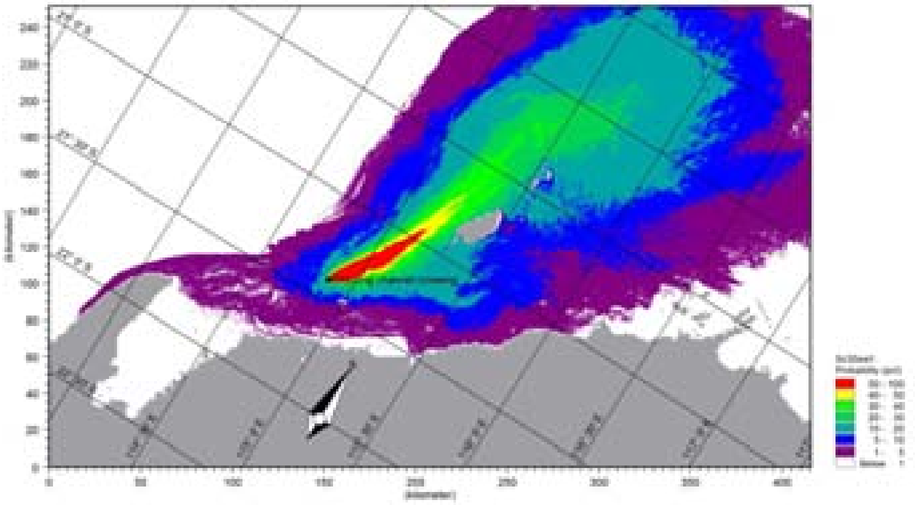


Figure 3.11 Probability (in percentage) of an oil slick with a thickness of 0.001 mm or above reaching a given area based on 108 simulations.

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4 OIL SPILL MODELLING RESULTS

4.1 General

Results from the six spill scenarios as described in Section 2 are provided in this section and in Appendix B to Appendix G. An overview of the spill simulations are provided in

Table *4.1*.

For each scenario and for each season the key results are presented as maps showing:

- Maximum oil slick thickness (mm);
- Minimum time of arrival (hours); and
- Probability (percentage) of an oil slick of 0.001 mm (the minimum) or more reaching any given area.

For the maps showing the probability of an oil slick reaching a given location an accuracy of 1 per cent is provided for all scenarios except scenario 1. In scenario 1 the accuracy is approximately 10 per cent as only 12 simulations have been carried out (see also Section 5).

For all simulations the effect of the seasonal variation of the wind is clearly seen in the results. During the summer the westerly to south westerly winds dominate forcing the oil slicks towards east and north east (see for example Appendix A Figure B-1). During the winter the easterly to south easterly winds force the oil slicks towards the west (see for example Appendix A Figure B-7). During the transition periods (April-May and August) the winds are variable and generally calmer than summer or winter. This is reflected in the relevant oil spill simulations which indicate the oil slicks may move in any direction (see for example Appendix A Figure B-4).

A discussion of the individual scenarios is not provided in the present report, however the results are presented in Appendix B to Appendix F.

Table 4.1 Overview of spill simulations.

Scenario Number	1	2	3	4	5	6
Scenario Id	**A**	**E**	**F**	**G**	**H**	**I**
Location	Iago #1 Well	Wheatstone Platform	Shipping channel crossing	PLF	MOF	MOF (with mitigation)
Spill Duration	90 days	10 minutes	5 days	1 minute	Instantaneous	Instantaneous
Simulation Duration	100 days	10 days	15 days	10 days	10 days	10 Days
HD model grid resolution	3645 m	3645 m	1215 m	405 m	15 m	15 m
Output grid resolution	405 m	405 m	405 m	405 m	15 m	15 m
Number of	3 (years) *	3 (years) *	3 (years) *	3 (years) *	3 (years) *	3 (years) *
Simulations	3 (seasons) * 4 = 36	3 (seasons) * 36 = 324	3 (seasons) * 36 = 324	3 (seasons) * 36 = 324	3 (seasons) * 36 = 324	3 (seasons) * 36 = 324*
Interval between start of individual simulations	1 month (summer), 15 days (transition), 10 days (winter)	95 hours	59 hours	11 hours	11 hours	11 hours*
Individual simulations started during these periods, summer	2006-Sep to 2007-Feb, 2007-Sep to 2008-Feb, 2008-Sep to 2009-Feb	2006-Sep to 2007-Feb, 2007-Sep to 2008-Feb, 2008-Sep to 2009-Feb	2006-Sep to 2007-Feb, 2007-Sep to 2008-Feb, 2008-Sep to 2009-Feb	2007-Jan/Feb 2008-Jan/Feb** 2009-Jan/Feb**	2007-Jan/Feb 2008-Jan/Feb** 2009-Jan/Feb**	2007-Jan/Feb 2008-Jan/Feb** 2009-Jan/Feb**
Individual simulations started during these periods, transition	2006 Mar, Apr, Aug, 2007 Mar, Apr, Aug, 2008 Mar, Apr, Aug	2006 Mar, Apr, Aug, 2007 Mar, Apr, Aug, 2008 Mar, Apr, Aug	2006 Mar, Apr, Aug, 2007 Mar, Apr, Aug, 2008 Mar, Apr, Aug	2007- Apr/May 2008- Apr/May** 2009-Apr/May**	2007- Apr/May 2008- Apr/May** 2009-Apr/May**	2007- Apr/May 2008- Apr/May** 2009-Apr/May**
Individual simulations started during these periods, winter	2006 May to Jul, 2007 May to Jul, 2008 May to Jul	2006 May to Jul, 2007 May to Jul, 2008 May to Jul	2006 May to Jul, 2007 May to Jul, 2008 May to Jul	2007- Jun/Jul 2008- Jun/Jul** 2009- Jun/Jul**	2007- Jun/Jul 2008- Jun/Jul** 2009- Jun/Jul**	2007- Jun/Jul 2008- Jun/Jul** 2009- Jun/Jul**

Note:: Simulations from scenario 5 have been applied to scenario 6*

***: Hydrodynamic model results from 2007 applied together with wind from actual year*

4.2 Key Modelling Results

4.2.1 Scenario 1 – Condensate Spill at Iago #1 Well

Key results are shown for season 1 (summer months), season 2 (transition months), and season 3 (winter months) in Appendix B. It is noted that part of the spilled condensate leaves the model domain at the northern boundaries (in summer conditions) and western boundaries (in winter) towards areas with no known environmental sensitive receptors.

4.2.2 Scenario 2 – Diesel Spill at Wheatstone Platform

Key results are shown for season 1 (summer months), season 2 (transition months), and season 3 (winter months) in Appendix C.

4.2.3 Scenario 3 – Condensate Leak at Shipping Channel Crossing

Key results are shown for season 1 (summer months), season 2 (transition months), and season 3 (winter months) in Appendix D.

4.2.4 Scenario 4 – Condensate Spill at PLF

Key results are shown for season 1 (summer months), season 2 (transition months), and season 3 (winter months) in Appendix E.

4.2.5 Scenario 5 – Diesel spill at MOF

Key results are shown for season 1 (summer months), season 2 (transition months), and season 3 (winter months) in Appendix F.

4.2.6 Scenario 6 – Diesel spill at MOF (with Mitigation)

The simulations carried out for scenario 5 have been analysed to illustrate the effect of deploying a boom across the entrance to the MOF to mitigate the spread of a diesel spill. Figure 4.1 shows the possibility of diesel escaping the MOF as a function of time. For example, if a boom is deployed 4 hours after a spill event (diesel of any given amount) will have escaped with a possibility of 20 per cent (i.e. in 20 per cent of all cases considered). The possibilities vary from season to season as shown in Figure 4.2 to Figure 4.4.

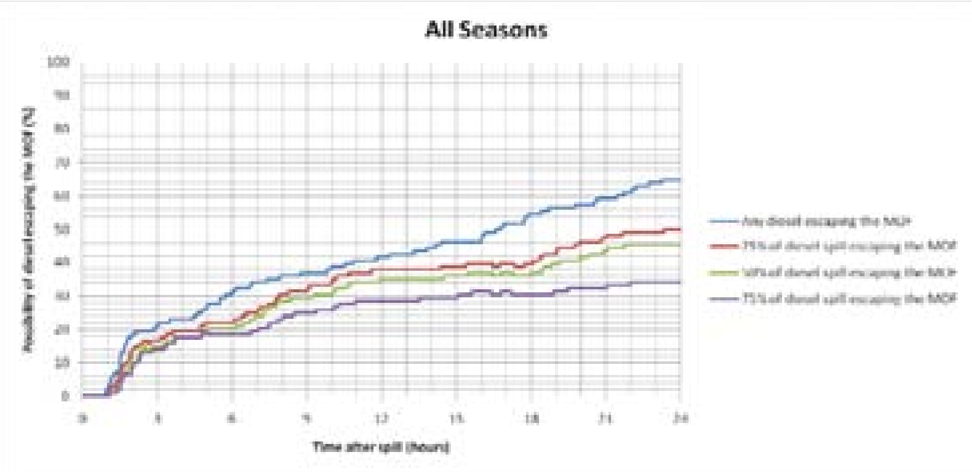

Figure 4.1 Possibility of diesel escaping the MOF as a function of time (all seasons).

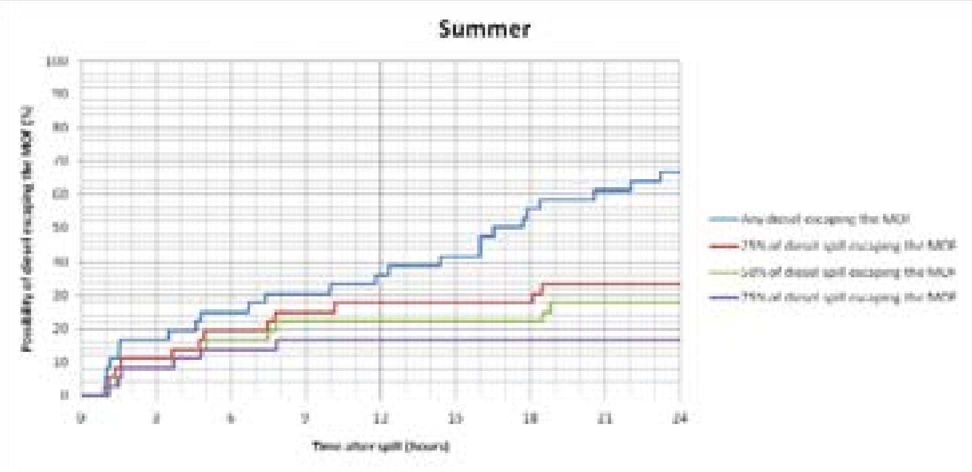

Figure 4.2 Possibility of diesel escaping the MOF as a function of time (summer).

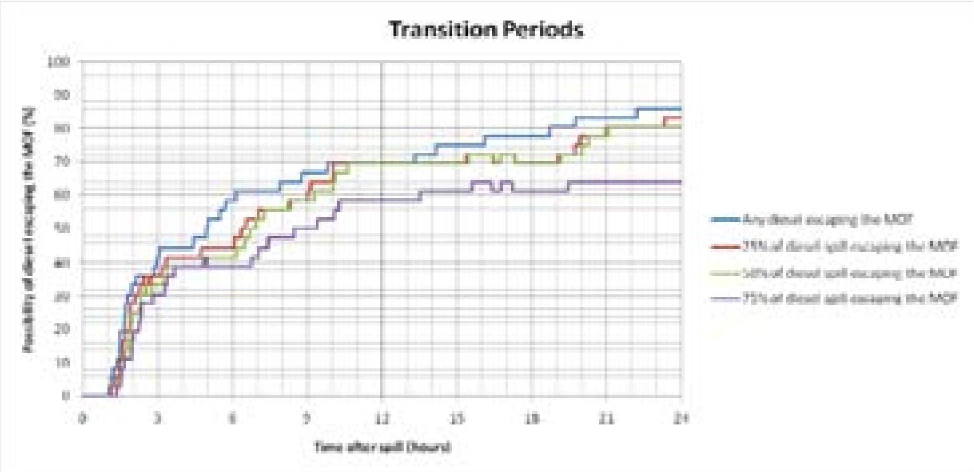

Figure 4.3 Possibility of diesel escaping the MOF as a function of time (transition periods).

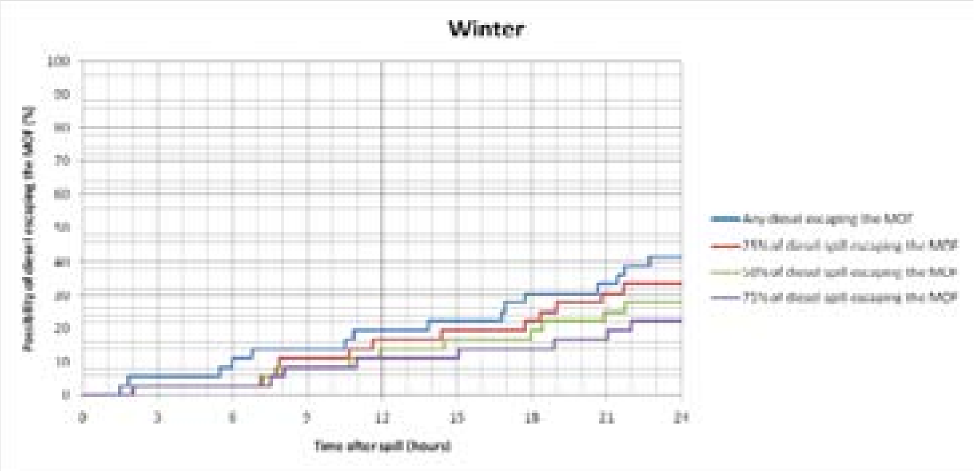

Figure 4.4 Possibility of diesel escaping the MOF as a function of time (winter).

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APPENDICES

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APPENDIX A

MIKE 21 & MIKE 3 SA, Spill Analysis

Short Description

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MIKE 21 & MIKE 3 SA

Spill Analysis

Short Description

MIKE 21/3 SA

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04 May 1999 / m21shortenv.doc/bgr

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MIKE 21 SA -
SPILL ANALYSIS MODULE

The Spill Analysis Module of MIKE 21 simulates the spreading and weathering of suspended substance in an aquatic environment under the influence of the fluid transport and the associated dispersion processes.

The substance may be an oil pollutant, defined according to its distillation properties and chemical structure (alkane or aromatic).

The pollutant is transported as discrete particles by a random walk tracking scheme calculating the displacement of each particle as the sum of an advective deterministic component and an independent, random Markovian component, which statistically approximates the random and/or chaotic nature of time-averaged tidal mixing.

Application Areas

The MIKE 21 SA module is an essential part in:

- online forecasting oil spill. Together with a hydrodynamic database and online measurements of currents the module can give information about oil slick locations, how much oil is left on the surface of the sea, the slick mobility and the evolution of the physicochemical properties of the oil
- risk analysis
- scenario studies of possible spills, which will assist in the development of contingency plans and assess likely environmental impacts
- guiding field data collection

Basic Equations

MIKE 21 SA solves the so-called Fokker-Planck equation for suspended oil-substances in two dimensions through the introduction of a consistent random walk particle method:

$$\frac{\partial f}{\partial t}+\frac{\partial}{\partial x_i}\left(A_i f\right)=\frac{\partial^2}{\partial x_i\, x_j}\left(\tfrac{1}{2} B_{ik} B_{jk} f\right)$$

A(f,t) is a known vector representing the deterministic forces which act to change f(t). B(t) is a known tensor characterising the random forces and f = c · h, where c is the concentration and h is the water depth.

The movement of each parcel is affected by the physicochemical processes. Once the parcels are released in the water body, their discrete path and mass are followed and recorded as a function of time relative to the reference grid system fixed in space.

Advection/Diffusion

The surface current velocity is based on a nearly logarithmic vertical velocity profile and the wind velocity component is added to the current velocity vectorially in order to determine the total surface drift velocity.

Horizontal diffusion due to turbulent fluctuation of the drift velocity is simulated, based on the random walk analysis, Fisher et al (1979). The formulas for the random longitudinal and transversal dispersions are:

$$\tfrac{1}{2}\, B\, B^T = \begin{vmatrix} D_{xx} & D_{xy} \\ D_{yx} & D_{yy} \end{vmatrix}$$

In the special case where $D_{xy} = D_{yx} = 0$, ie $D_l = D_{xx}$ and $D_r = D_{yy}$, the displacement in the horizontal and transversal directions are:

$$\Delta L = r \bullet \sqrt{(6 D_l \bullet t)},$$
$$\Delta T = r \bullet \sqrt{(6 D_r \bullet t)}$$

where r is a random number between -1 and 1.

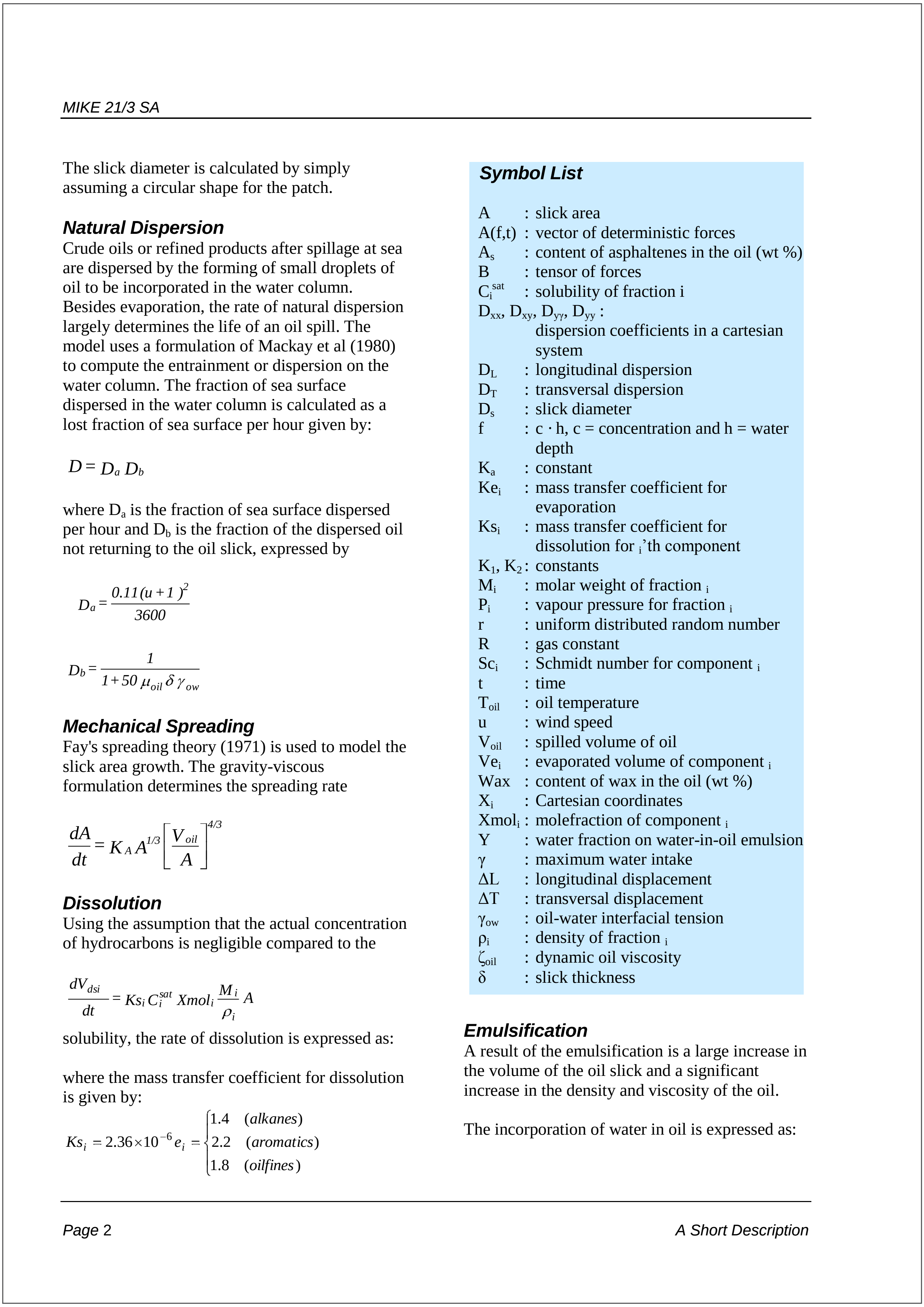
Evaporation

The evaporation process is modelled by a pseudocomponent approach in which oil is described by a set of fractions. The rate of evaporation can be expressed as:

$$\frac{dVe_i}{dt} = Ke_i \frac{P_i^{sat}}{RT_{oil}} Xmol_i \frac{M_i}{\rho_i} A$$

According to Mackay & Matsugu (1973) Ke_i is estimated by

$$Ke_i = 0.029\, D_s^{-0.11}\, Sc_i^{-0.67}\, u^{0.78}$$



The slick diameter is calculated by simply assuming a circular shape for the patch.

Natural Dispersion

Crude oils or refined products after spillage at sea are dispersed by the forming of small droplets of oil to be incorporated in the water column. Besides evaporation, the rate of natural dispersion largely determines the life of an oil spill. The model uses a formulation of Mackay et al (1980) to compute the entrainment or dispersion on the water column. The fraction of sea surface dispersed in the water column is calculated as a lost fraction of sea surface per hour given by:

$$D = D_a D_b$$

where D_a is the fraction of sea surface dispersed per hour and D_b is the fraction of the dispersed oil not returning to the oil slick, expressed by

$$D_a = \frac{0.11(u+1)^2}{3600}$$

$$D_b = \frac{1}{1+50\,\mu_{oil}\,\delta\,\gamma_{ow}}$$

Mechanical Spreading

Fay's spreading theory (1971) is used to model the slick area growth. The gravity-viscous formulation determines the spreading rate

$$\frac{dA}{dt} = K_A A^{1/3}\left[\frac{V_{oil}}{A}\right]^{4/3}$$

Dissolution

Using the assumption that the actual concentration of hydrocarbons is negligible compared to the

$$\frac{dV_{dsi}}{dt} = Ks_i\, C_i^{sat}\, Xmol_i\, \frac{M_i}{\rho_i} A$$

solubility, the rate of dissolution is expressed as:

where the mass transfer coefficient for dissolution is given by:

$$Ks_i = 2.36\times10^{-6} e_i = \begin{cases} 1.4 & (alkanes) \\ 2.2 & (aromatics) \\ 1.8 & (oilfines) \end{cases}$$

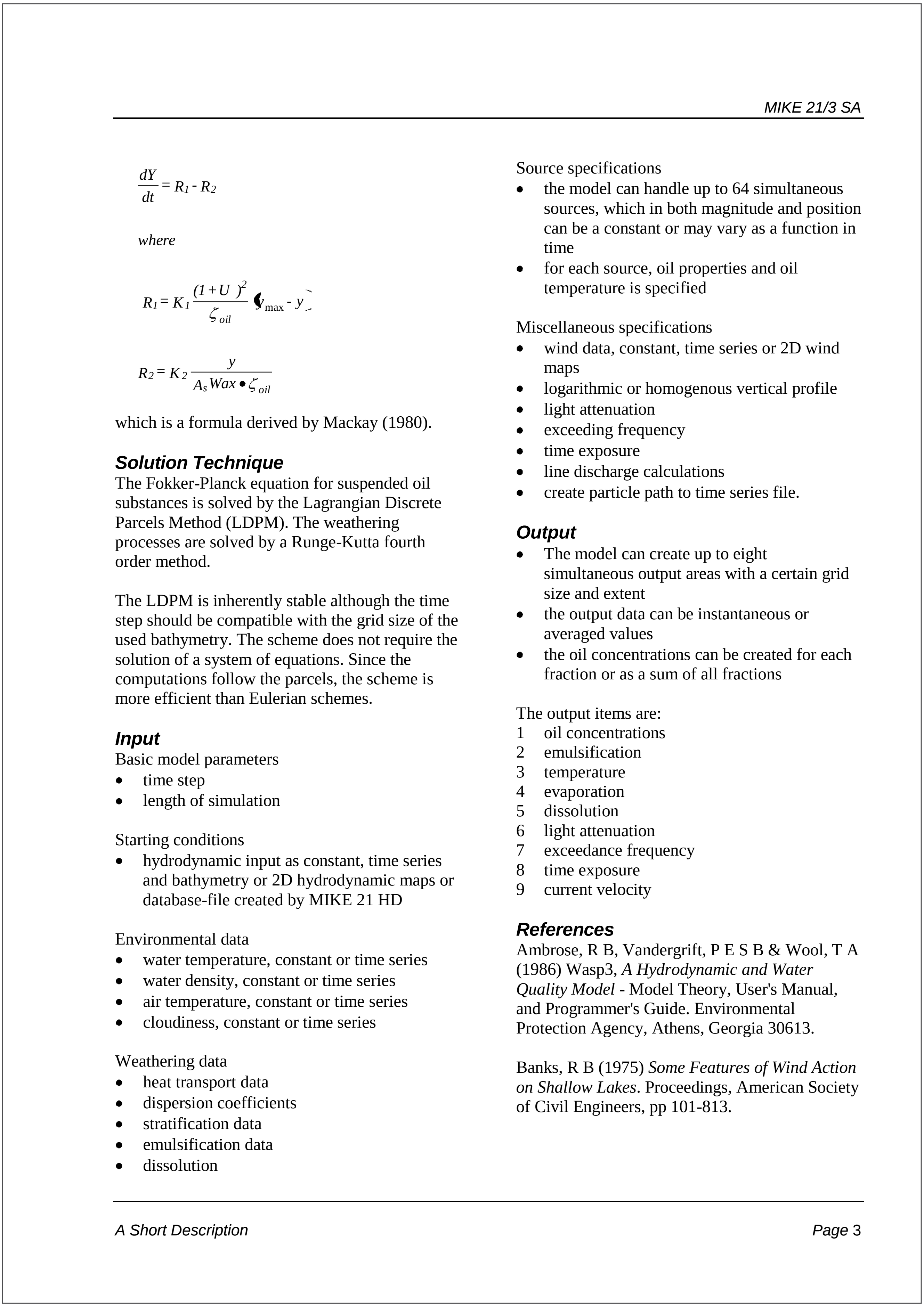
Symbol List

A	: slick area
A(f,t)	: vector of deterministic forces
A_s	: content of asphaltenes in the oil (wt %)
B	: tensor of forces
C_i^{sat}	: solubility of fraction i
D_{xx}, D_{xy}, $D_{y\gamma}$, D_{yy} :	dispersion coefficients in a cartesian system
D_L	: longitudinal dispersion
D_T	: transversal dispersion
D_s	: slick diameter
f	: c · h, c = concentration and h = water depth
K_a	: constant
Ke_i	: mass transfer coefficient for evaporation
Ks_i	: mass transfer coefficient for dissolution for $_i$'th component
K_1, K_2	: constants
M_i	: molar weight of fraction $_i$
P_i	: vapour pressure for fraction $_i$
r	: uniform distributed random number
R	: gas constant
Sc_i	: Schmidt number for component $_i$
t	: time
T_{oil}	: oil temperature
u	: wind speed
V_{oil}	: spilled volume of oil
Ve_i	: evaporated volume of component $_i$
Wax	: content of wax in the oil (wt %)
X_i	: Cartesian coordinates
$Xmol_i$	: molefraction of component $_i$
Y	: water fraction on water-in-oil emulsion
γ	: maximum water intake
ΔL	: longitudinal displacement
ΔT	: transversal displacement
γ_{ow}	: oil-water interfacial tension
ρ_i	: density of fraction $_i$
ζ_{oil}	: dynamic oil viscosity
δ	: slick thickness

Emulsification

A result of the emulsification is a large increase in the volume of the oil slick and a significant increase in the density and viscosity of the oil.

The incorporation of water in oil is expressed as:



$$\frac{dY}{dt} = R_1 - R_2$$

where

$$R_1 = K_1 \frac{(1+U)^2}{\zeta_{oil}} \left(y_{\max} - y\right)$$

$$R_2 = K_2 \frac{y}{A_s Wax \bullet \zeta_{oil}}$$

which is a formula derived by Mackay (1980).

Solution Technique

The Fokker-Planck equation for suspended oil substances is solved by the Lagrangian Discrete Parcels Method (LDPM). The weathering processes are solved by a Runge-Kutta fourth order method.

The LDPM is inherently stable although the time step should be compatible with the grid size of the used bathymetry. The scheme does not require the solution of a system of equations. Since the computations follow the parcels, the scheme is more efficient than Eulerian schemes.

Input

Basic model parameters
- time step
- length of simulation

Starting conditions
- hydrodynamic input as constant, time series and bathymetry or 2D hydrodynamic maps or database-file created by MIKE 21 HD

Environmental data
- water temperature, constant or time series
- water density, constant or time series
- air temperature, constant or time series
- cloudiness, constant or time series

Weathering data
- heat transport data
- dispersion coefficients
- stratification data
- emulsification data
- dissolution

Source specifications
- the model can handle up to 64 simultaneous sources, which in both magnitude and position can be a constant or may vary as a function in time
- for each source, oil properties and oil temperature is specified

Miscellaneous specifications
- wind data, constant, time series or 2D wind maps
- logarithmic or homogenous vertical profile
- light attenuation
- exceeding frequency
- time exposure
- line discharge calculations
- create particle path to time series file.

Output

- The model can create up to eight simultaneous output areas with a certain grid size and extent
- the output data can be instantaneous or averaged values
- the oil concentrations can be created for each fraction or as a sum of all fractions

The output items are:
1 oil concentrations
2 emulsification
3 temperature
4 evaporation
5 dissolution
6 light attenuation
7 exceedance frequency
8 time exposure
9 current velocity

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APPENDIX B

Scenario 1 – Condensate Spill at Iago #1 Well

Key Results

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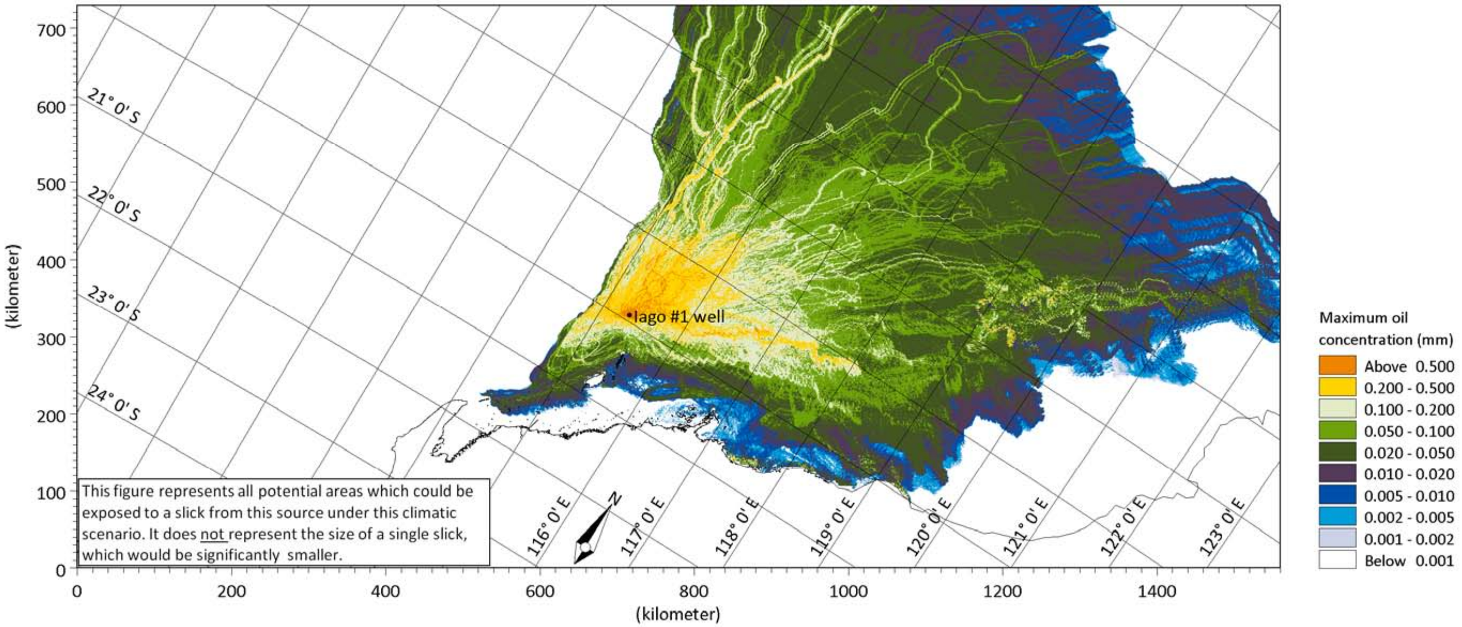
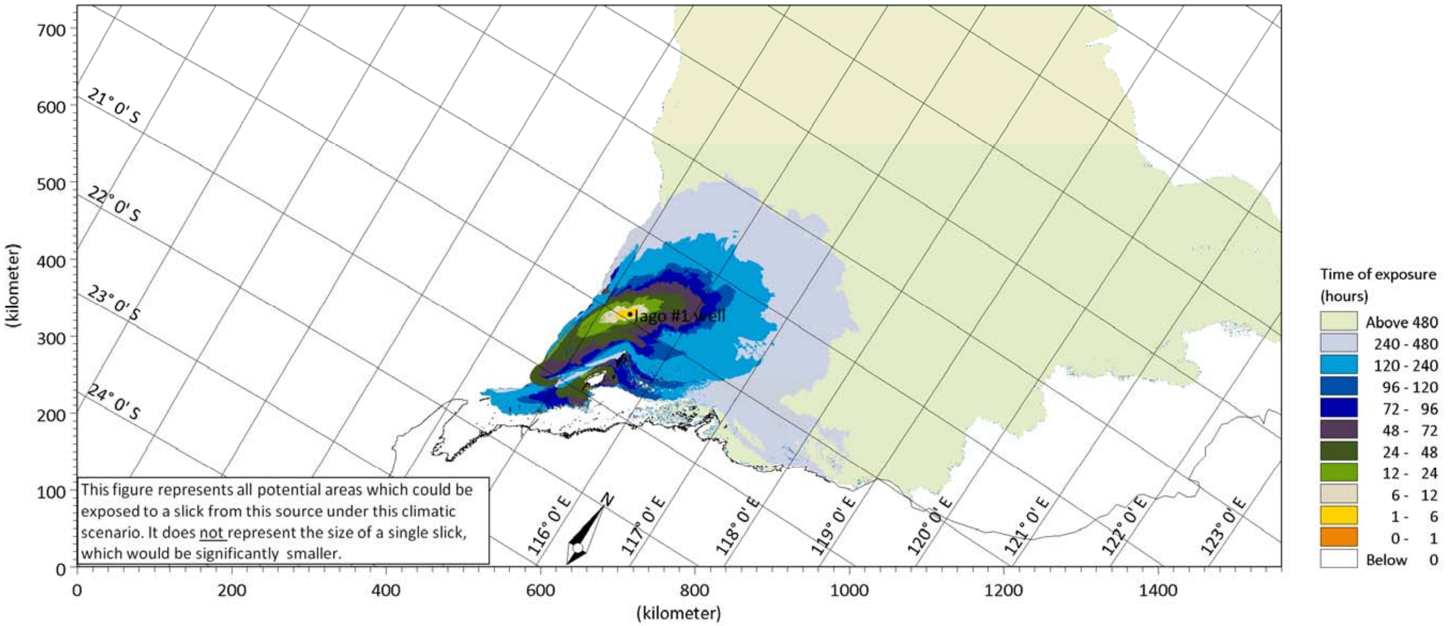


Figure B.1 Condensate Spill at Iago #1 Well, summer, maximum oil thickness



This figure represents all potential areas which could be exposed to a slick from this source under this climatic scenario. It does not represent the size of a single slick, which would be significantly smaller.

Figure B.2 Condensate Spill at Iago #1 Well, summer, minimum time to exposure

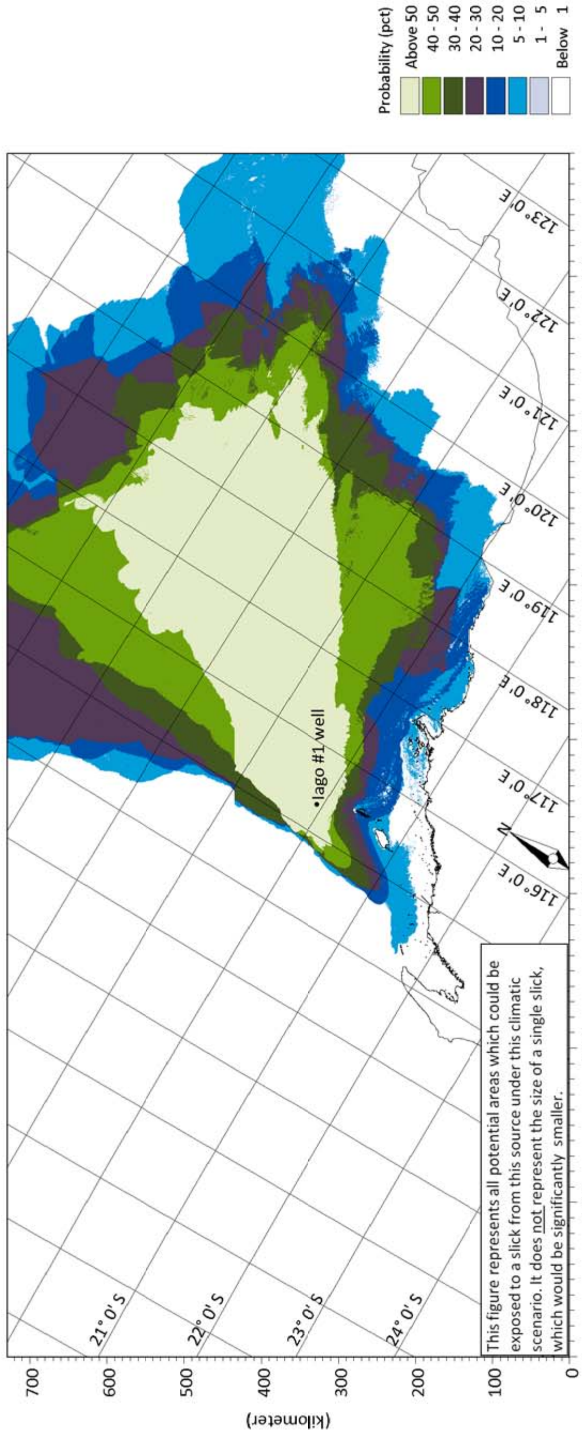
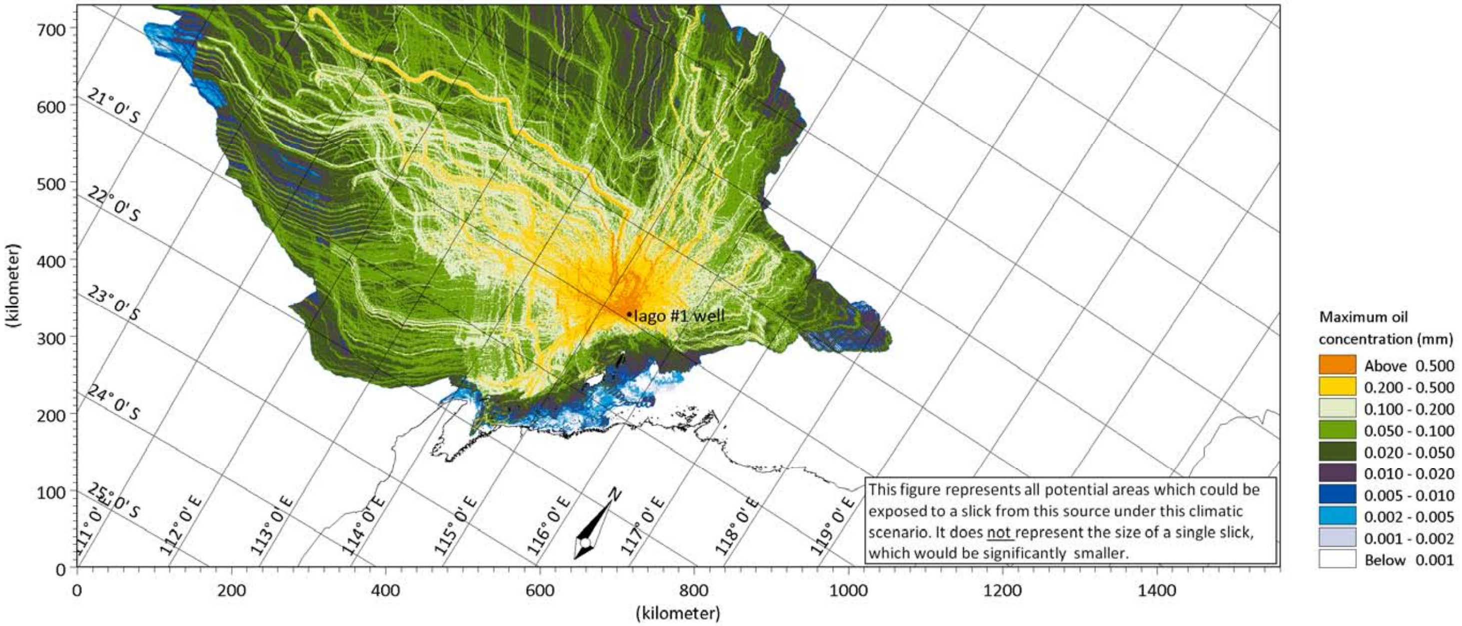
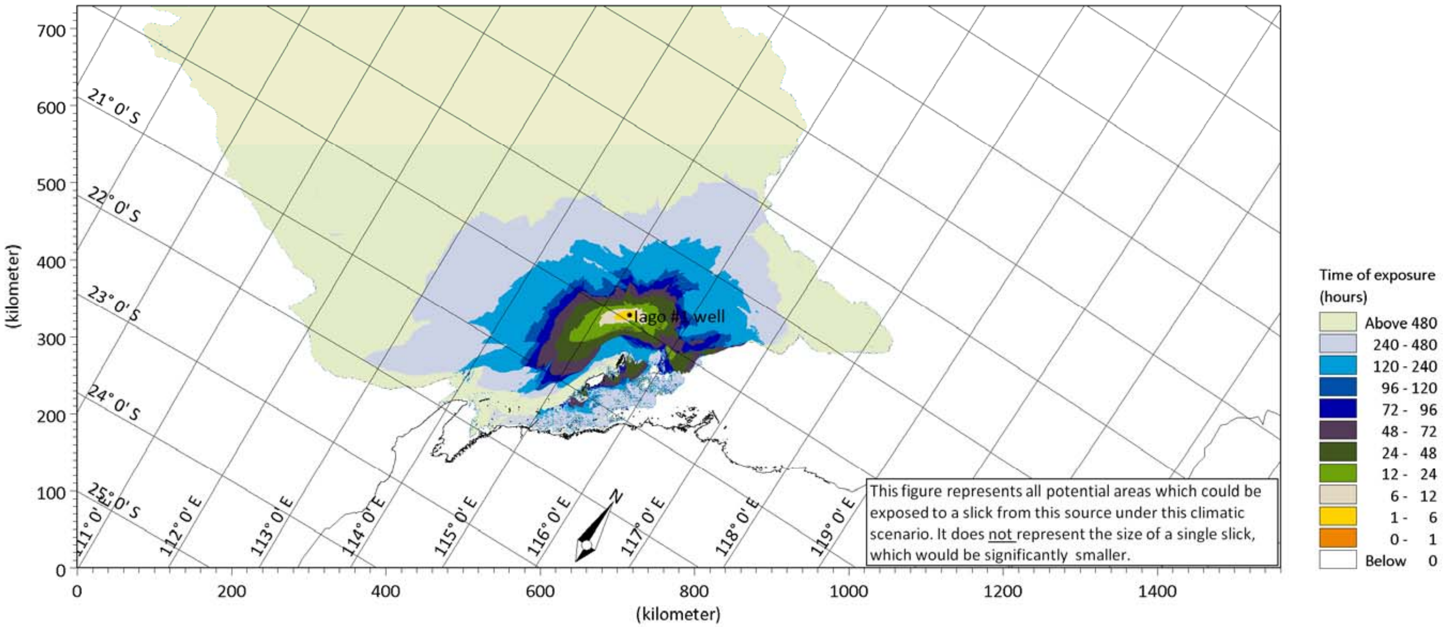


Figure B.3 Condensate Spill at Iago #1 Well, summer, probability of exposure



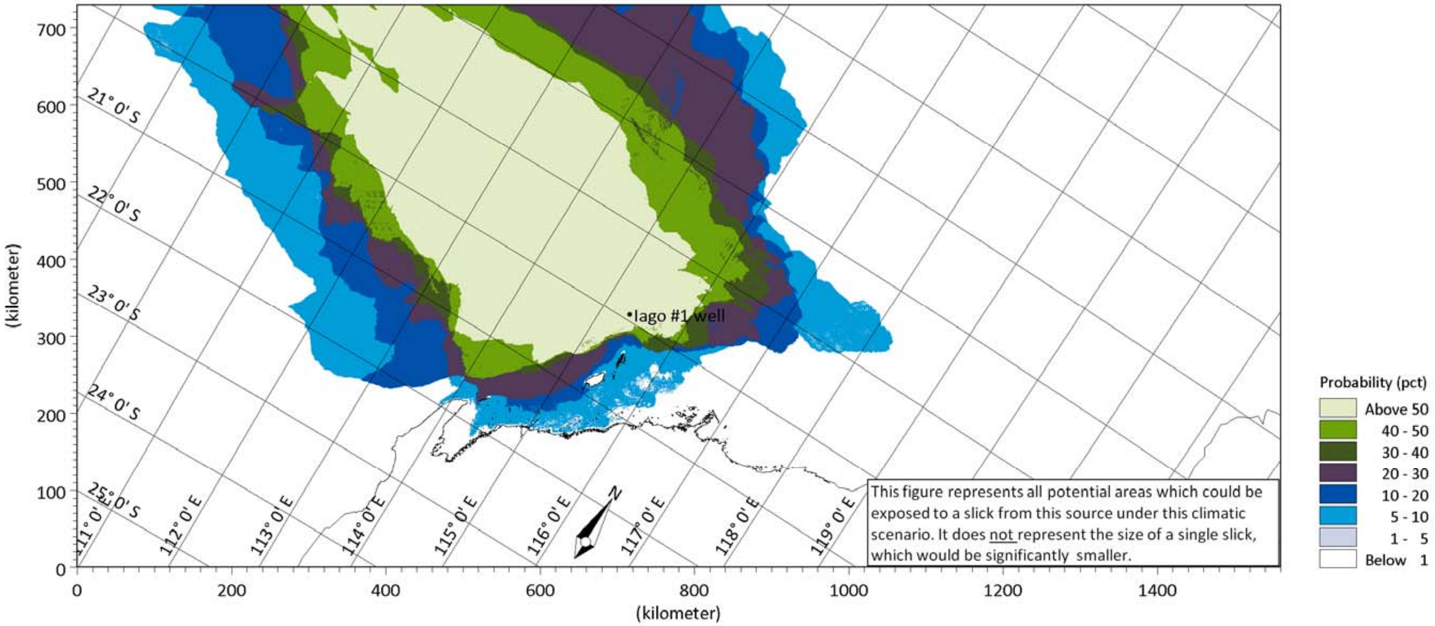
This figure represents all potential areas which could be exposed to a slick from this source under this climatic scenario. It does not represent the size of a single slick, which would be significantly smaller.

Figure B.4 Condensate Spill at Iago #1 Well, transitional periods, maximum oil thickness



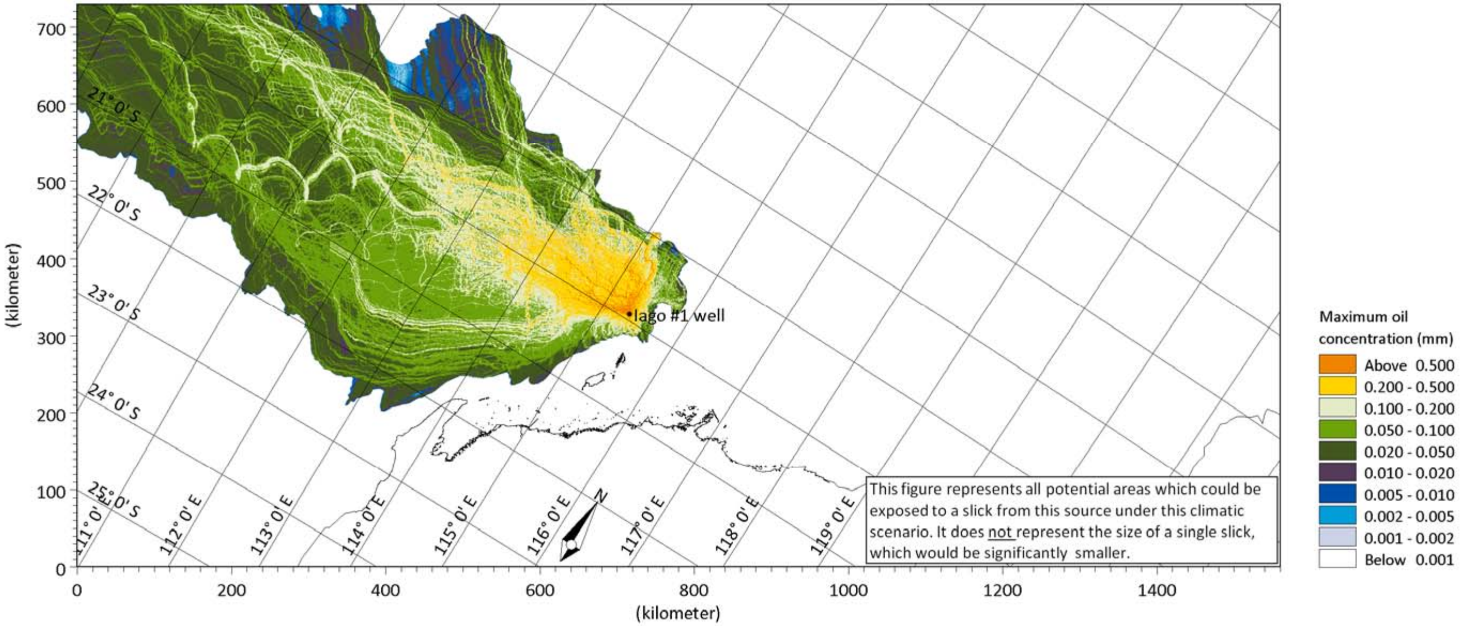
This figure represents all potential areas which could be exposed to a slick from this source under this climatic scenario. It does not represent the size of a single slick, which would be significantly smaller.

Figure B.5 Condensate Spill at Iago #1 Well, transitional periods, minimum time to exposure



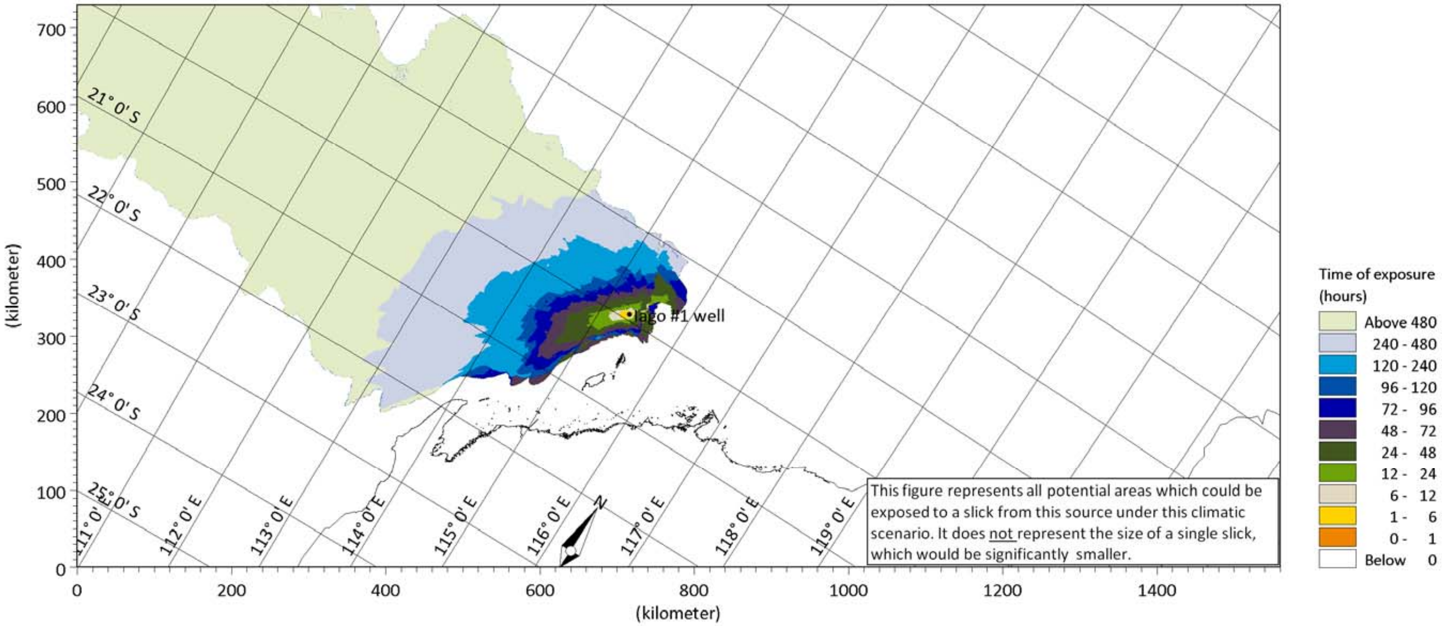
This figure represents all potential areas which could be exposed to a slick from this source under this climatic scenario. It does not represent the size of a single slick, which would be significantly smaller.

Figure B.6 Condensate Spill at Iago #1 Well, transitional periods, probability of exposure



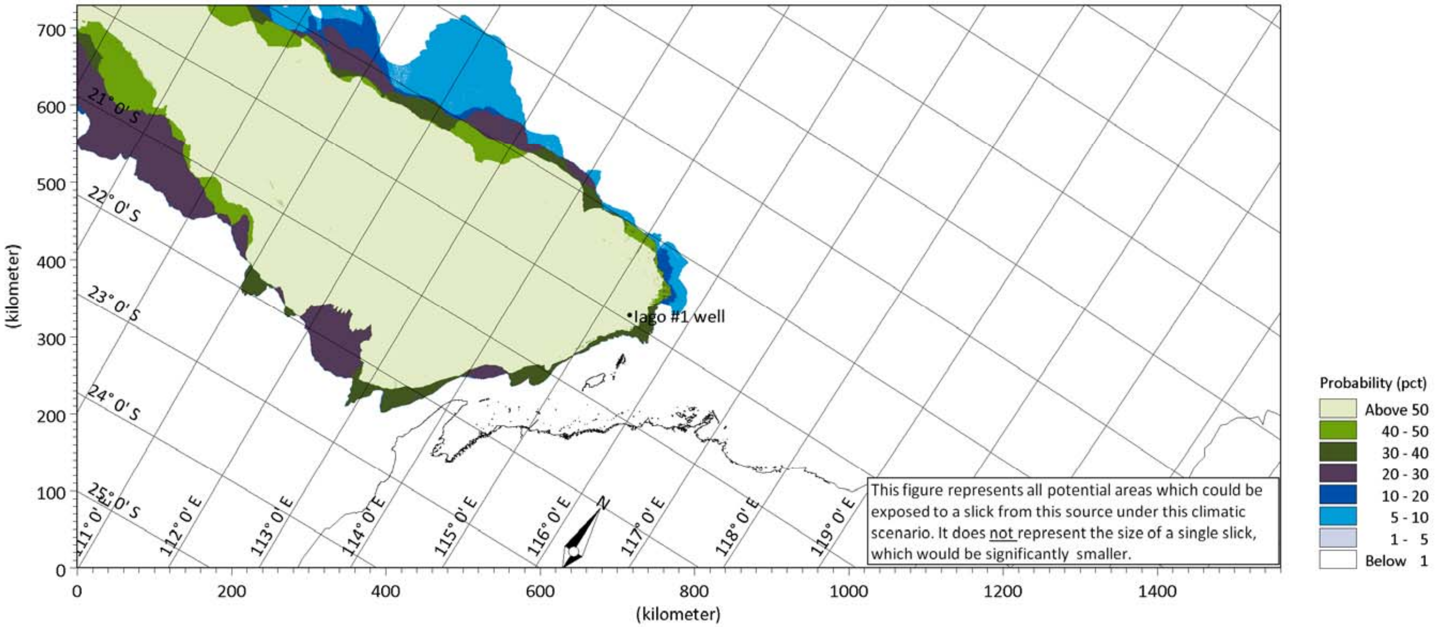
This figure represents all potential areas which could be exposed to a slick from this source under this climatic scenario. It does not represent the size of a single slick, which would be significantly smaller.

Figure B.7 Condensate Spill at Iago #1 Well, winter, maximum oil thickness



This figure represents all potential areas which could be exposed to a slick from this source under this climatic scenario. It does not represent the size of a single slick, which would be significantly smaller.

Figure B.8 Condensate Spill at Iago #1 Well, winter, minimum time to exposure



This figure represents all potential areas which could be exposed to a slick from this source under this climatic scenario. It does not represent the size of a single slick, which would be significantly smaller.

Figure B.9 Condensate Spill at Iago #1 Well, winter, probability of exposure

APPENDIX C

Scenario 2 – Diesel Spill at Wheatstone Platform

Key Results

C-1

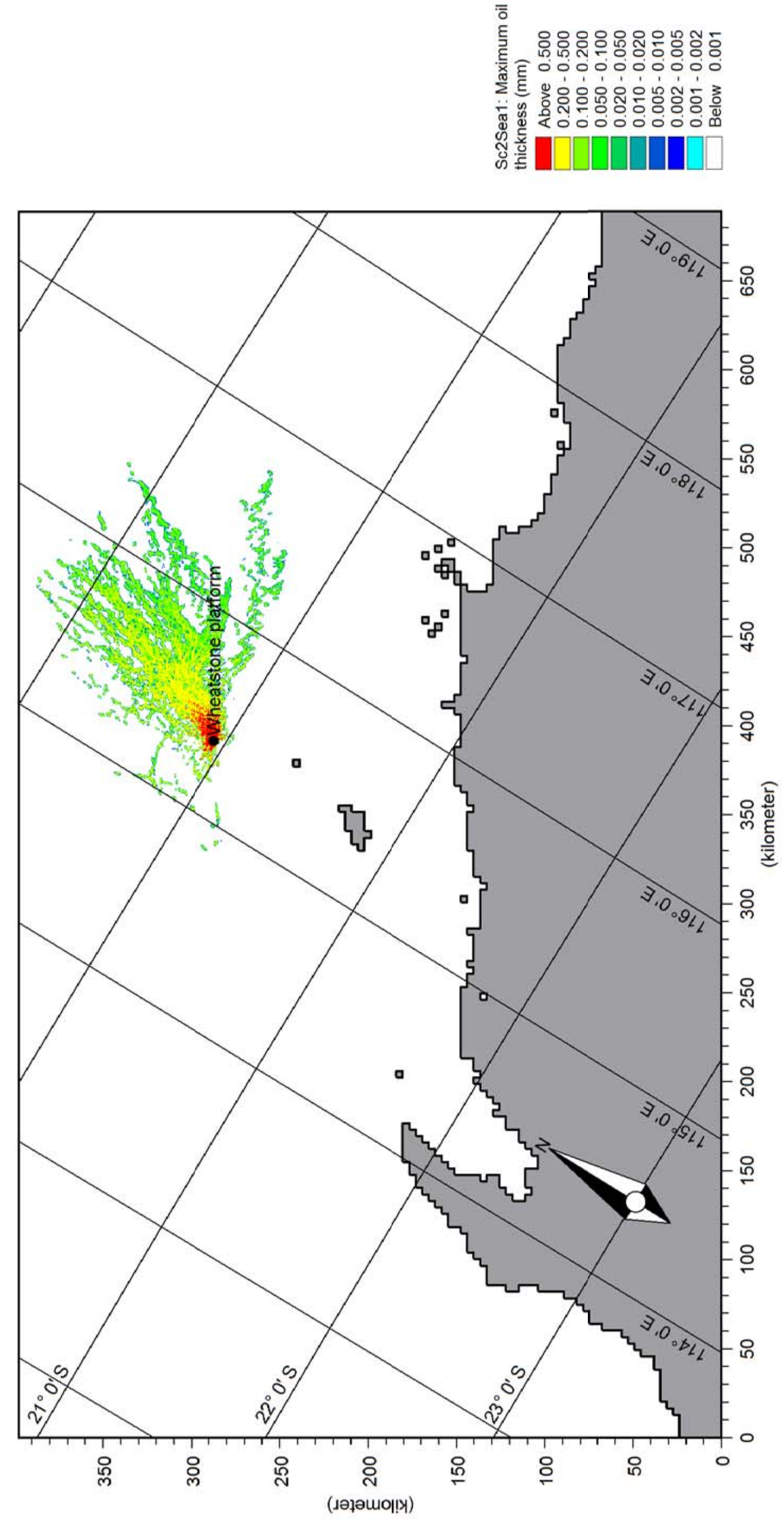


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Figure C.1 Diesel Spill at Wheatstone Platform, summer, maximum oil thickness

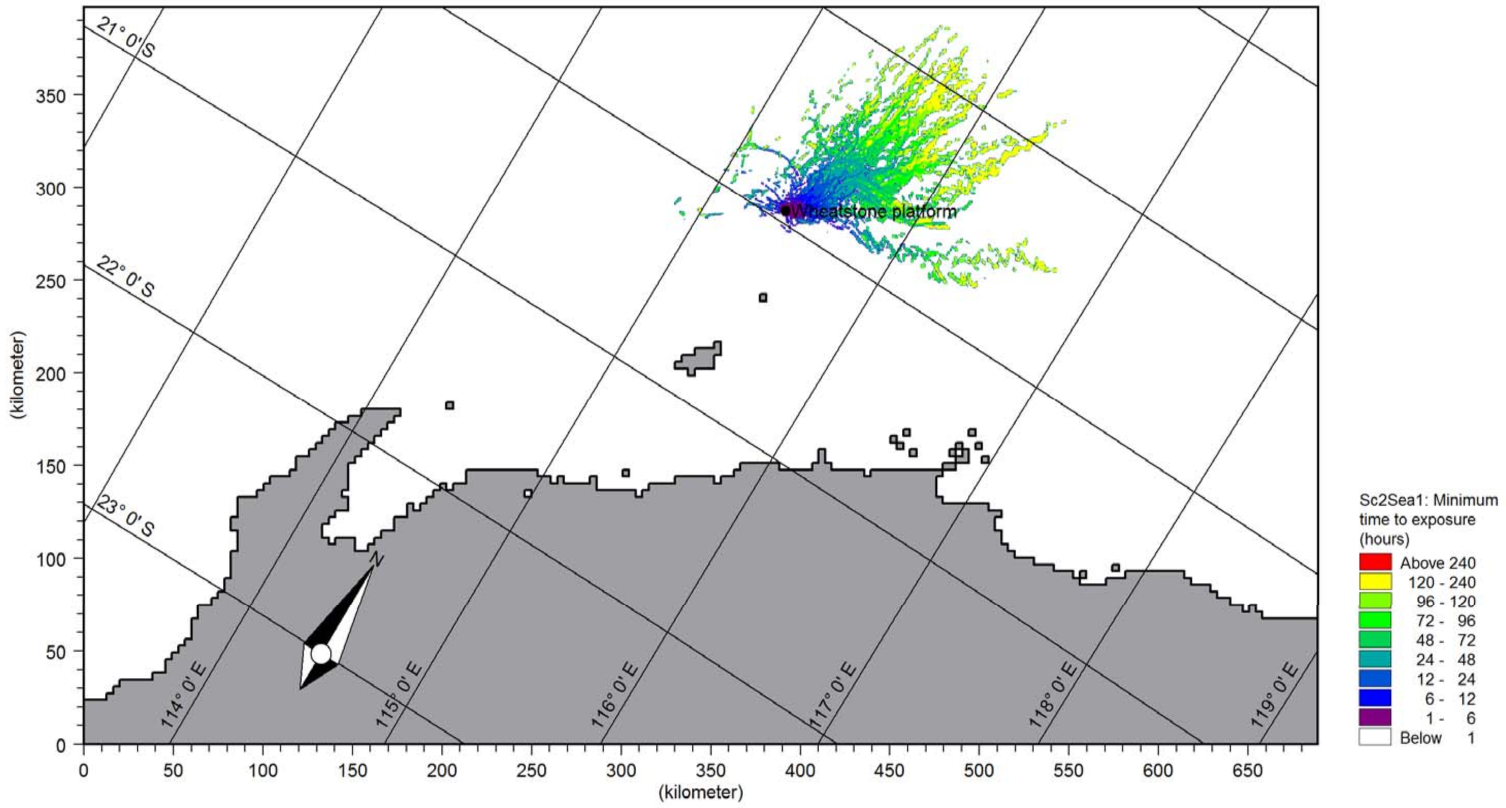

Figure C.2 Diesel Spill at Wheatstone Platform, summer, minimum time to exposure

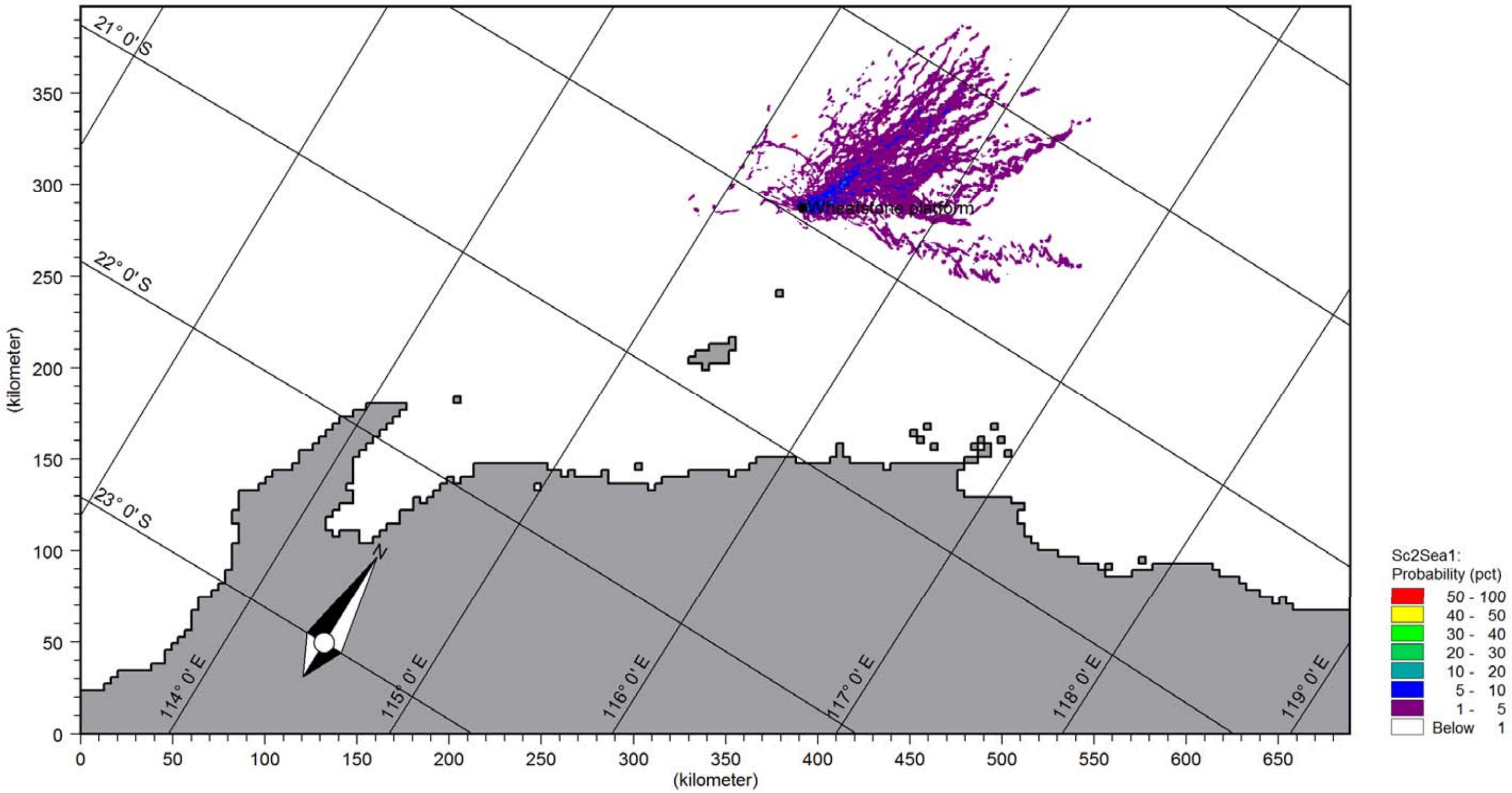

Figure C.3 Diesel Spill at Wheatstone Platform, summer, probability of exposure

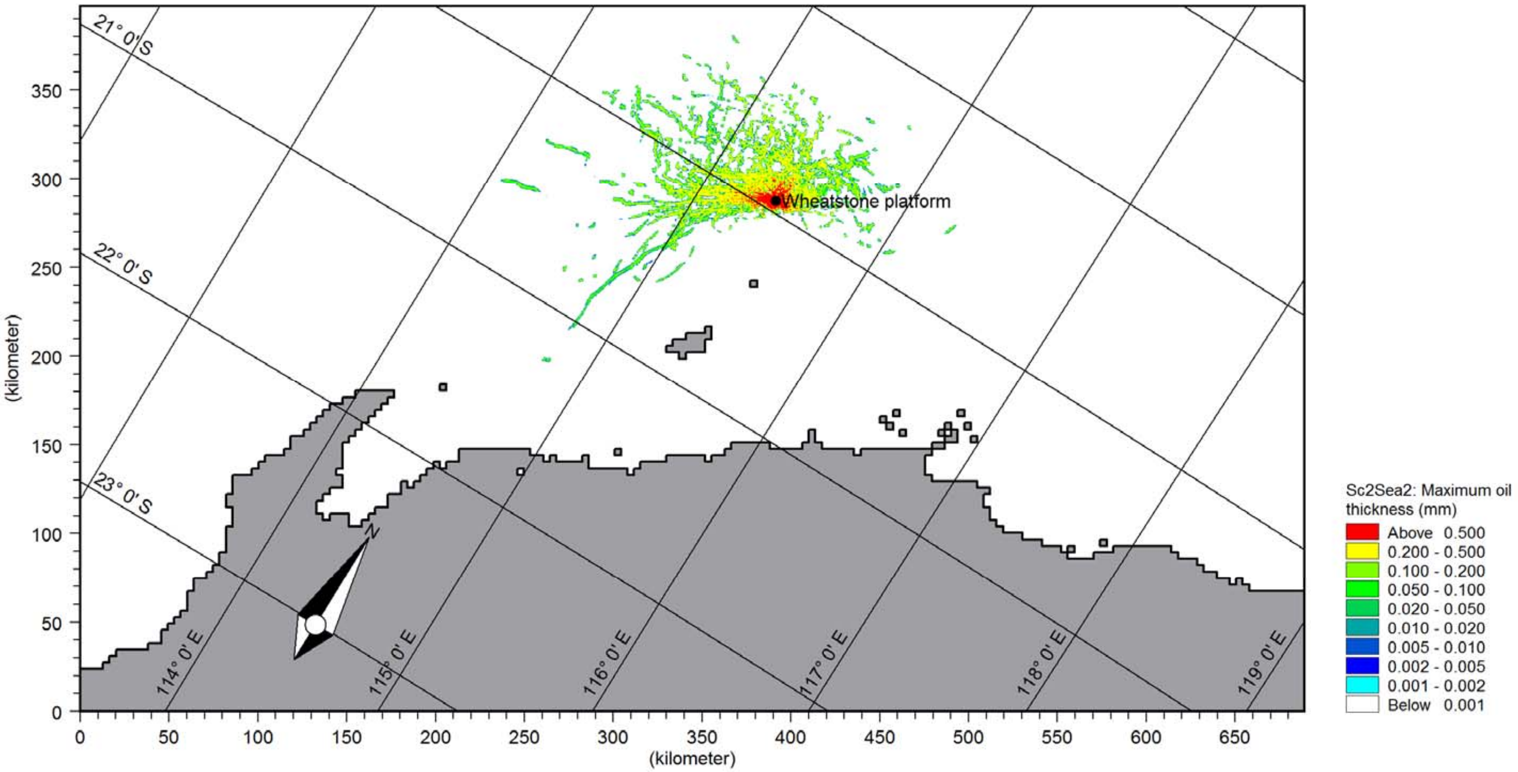

Figure C.4 Diesel Spill at Wheatstone Platform, transitional periods, maximum oil thickness

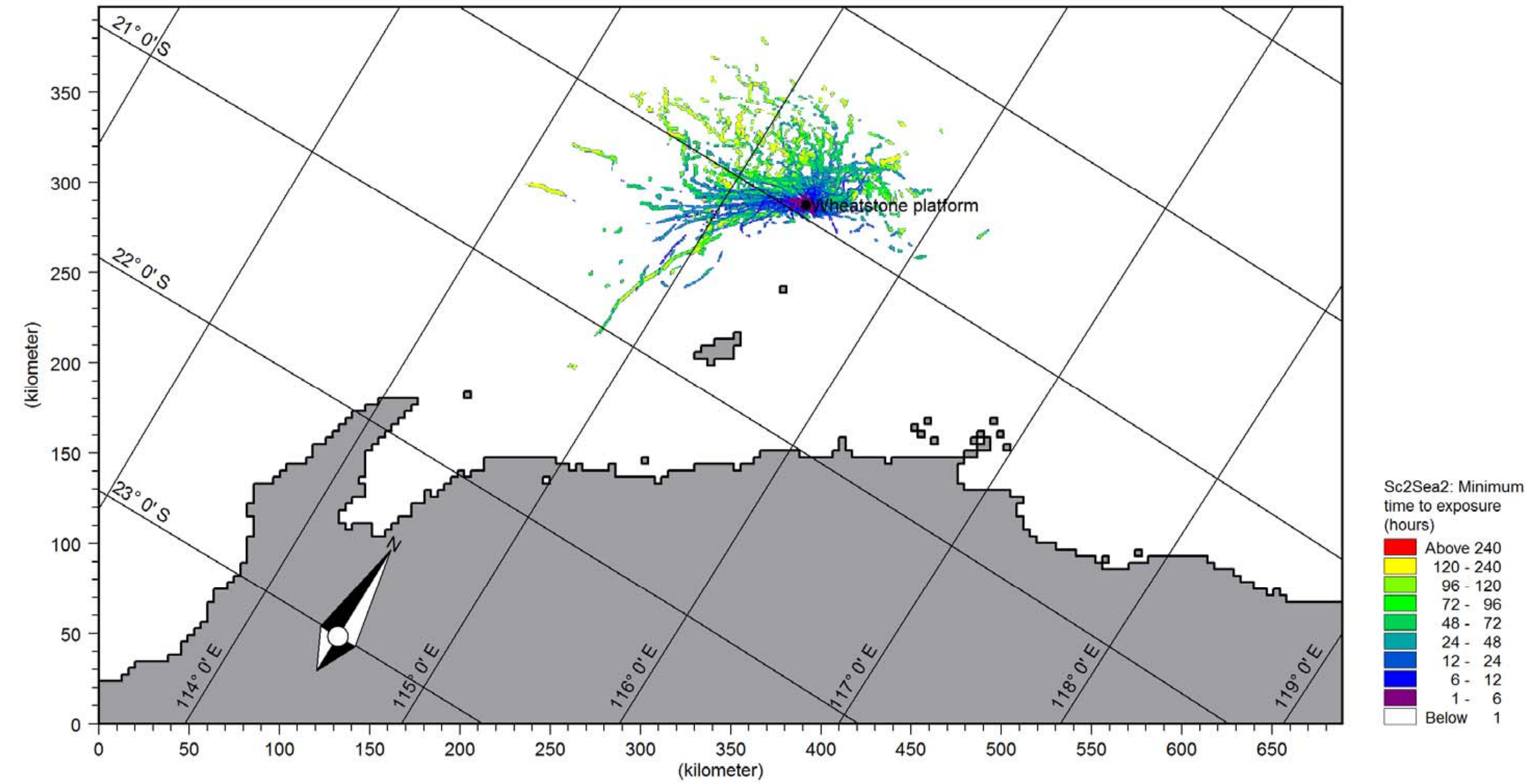

Figure C.5 Diesel Spill at Wheatstone Platform, transitional periods, minimum time to exposure

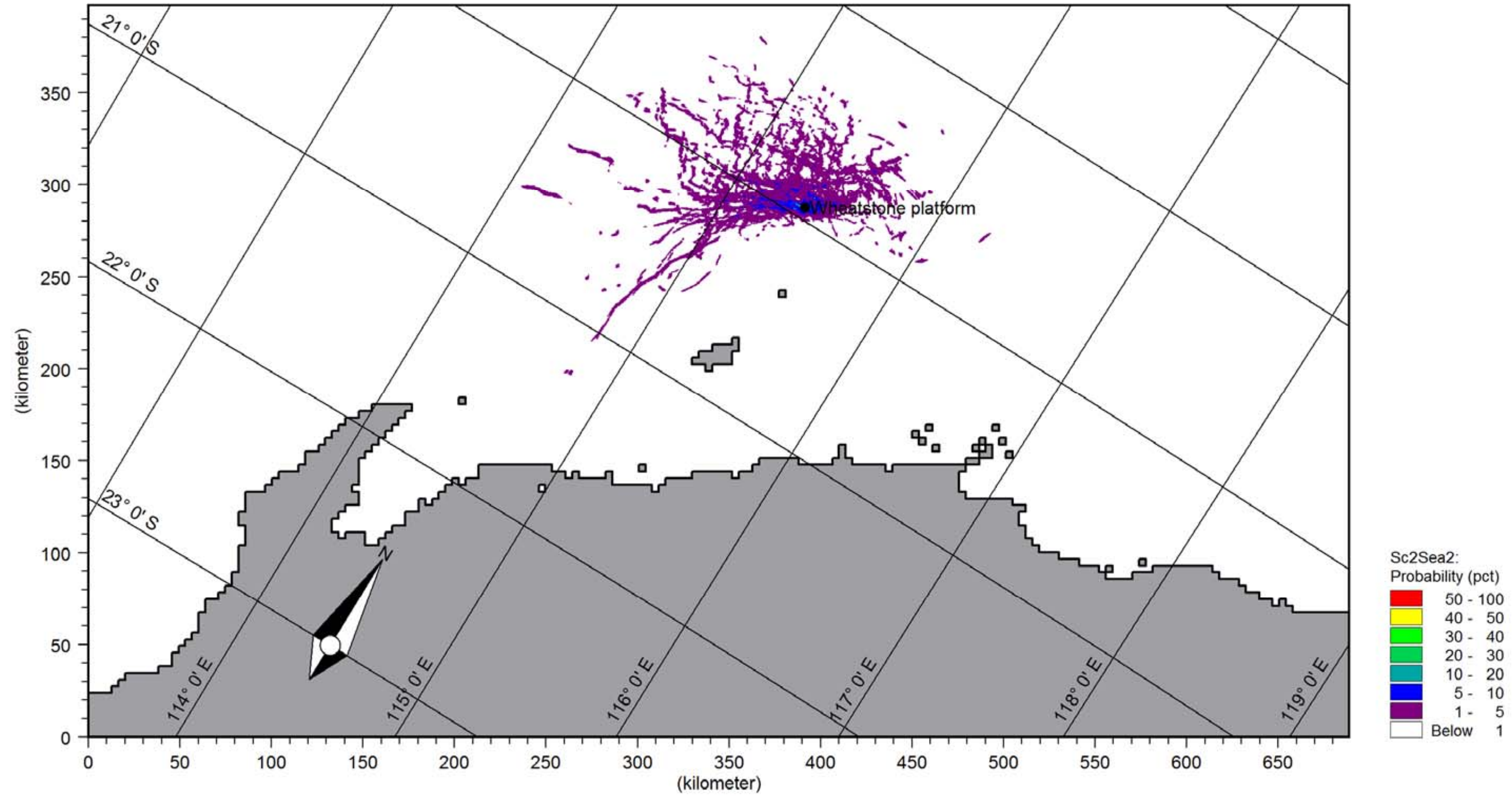

Figure C.6 Diesel Spill at Wheatstone Platform, transitional periods, probability of exposure

C-7

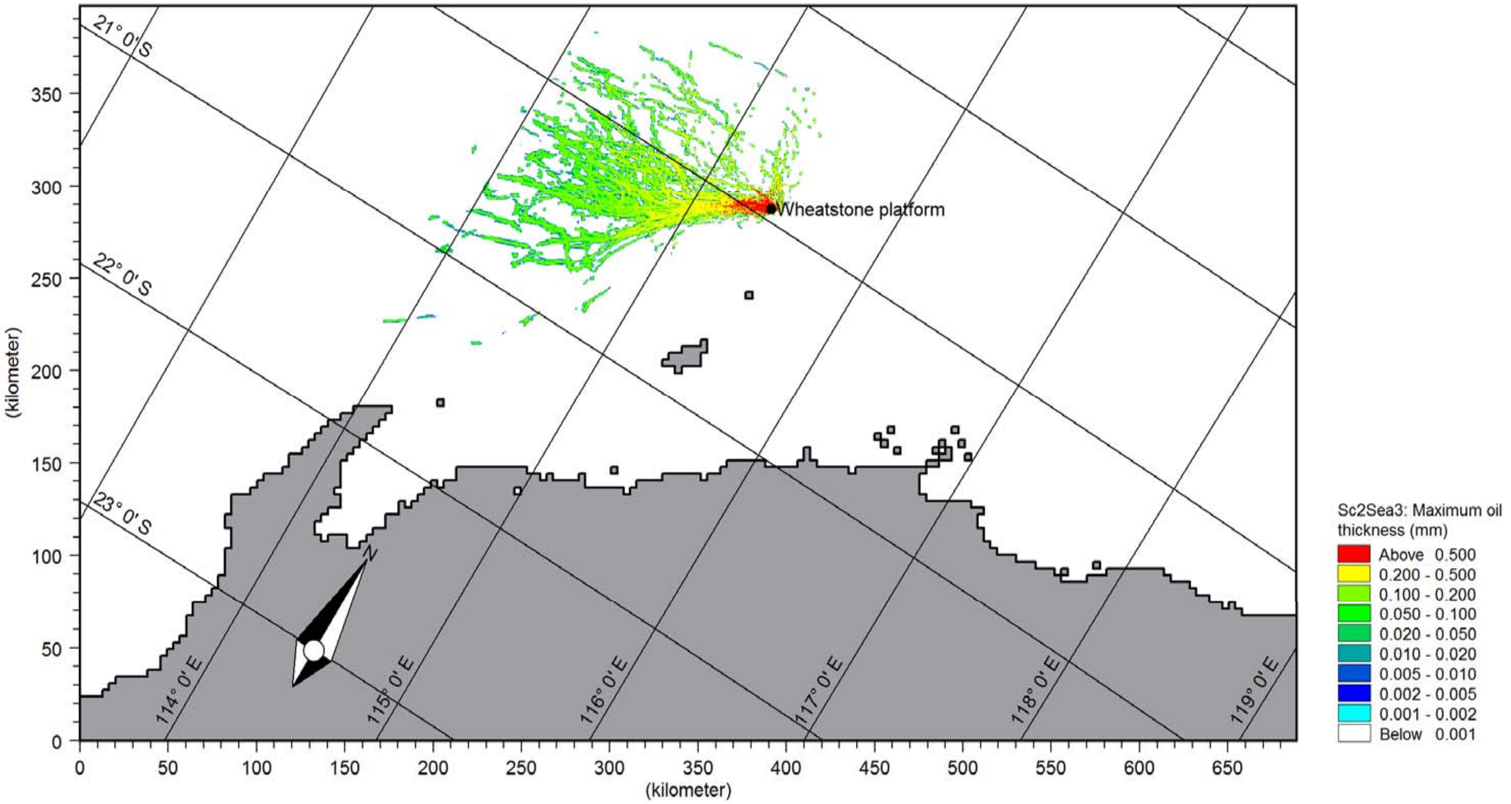

Figure C.7 Diesel Spill at Wheatstone Platform, winter, maximum oil thickness

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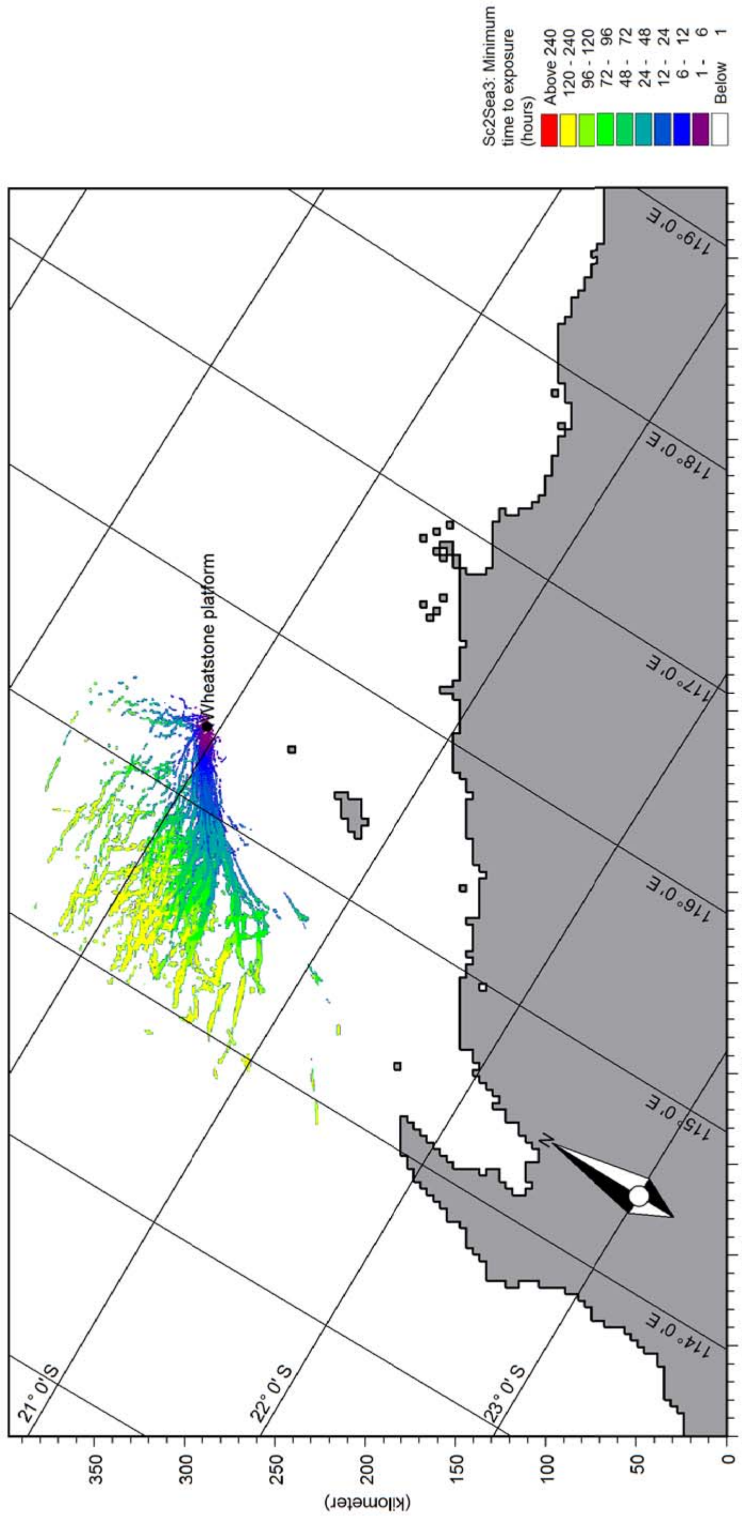

Figure C.8 Diesel Spill at Wheatstone Platform, winter, minimum time to exposure

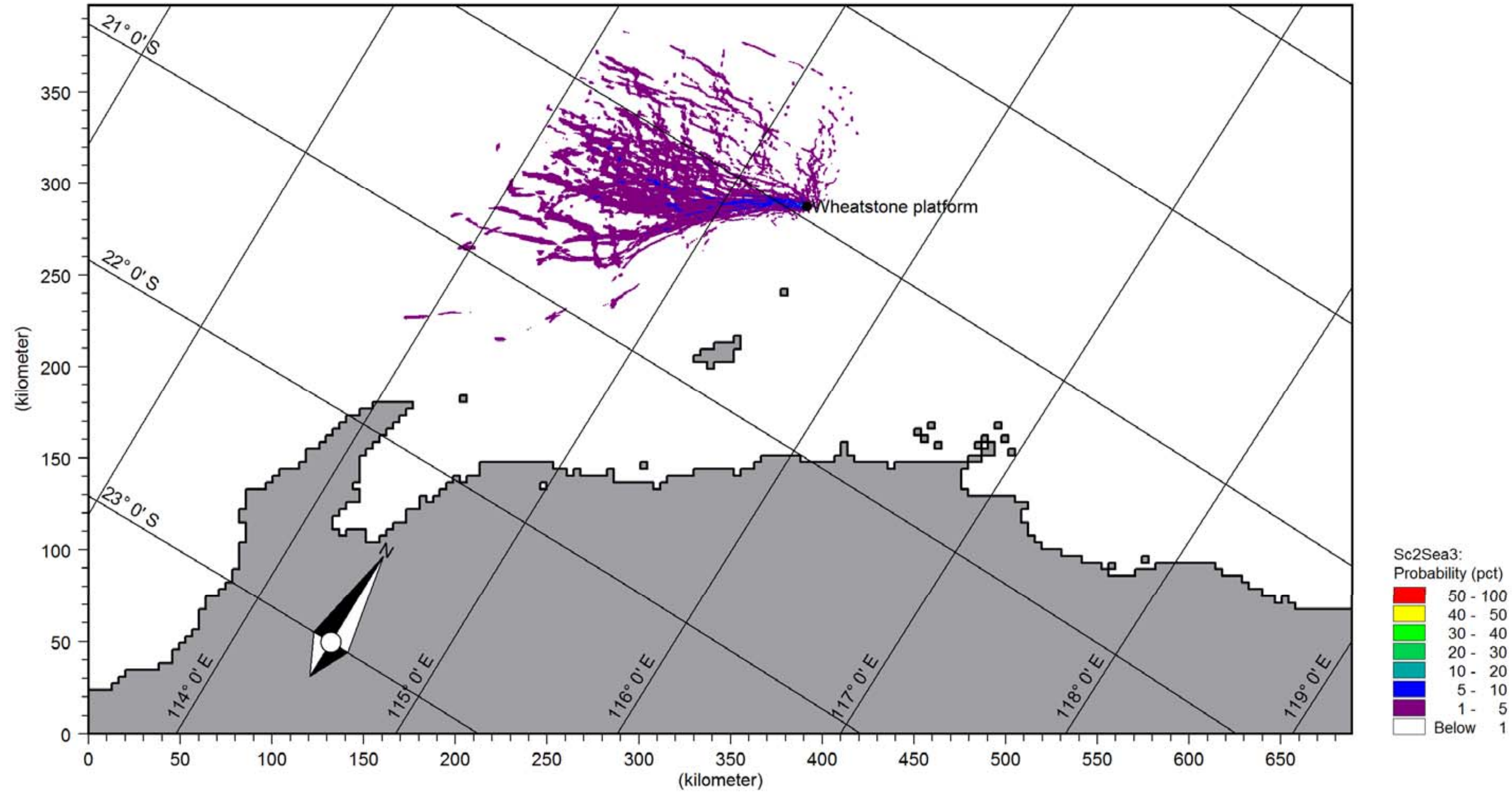

Figure C.9 Diesel Spill at Wheatstone Platform, winter, probability of exposure

APPENDIX D

Scenario 3 – Condensate Leak at Shipping Channel

Key Results

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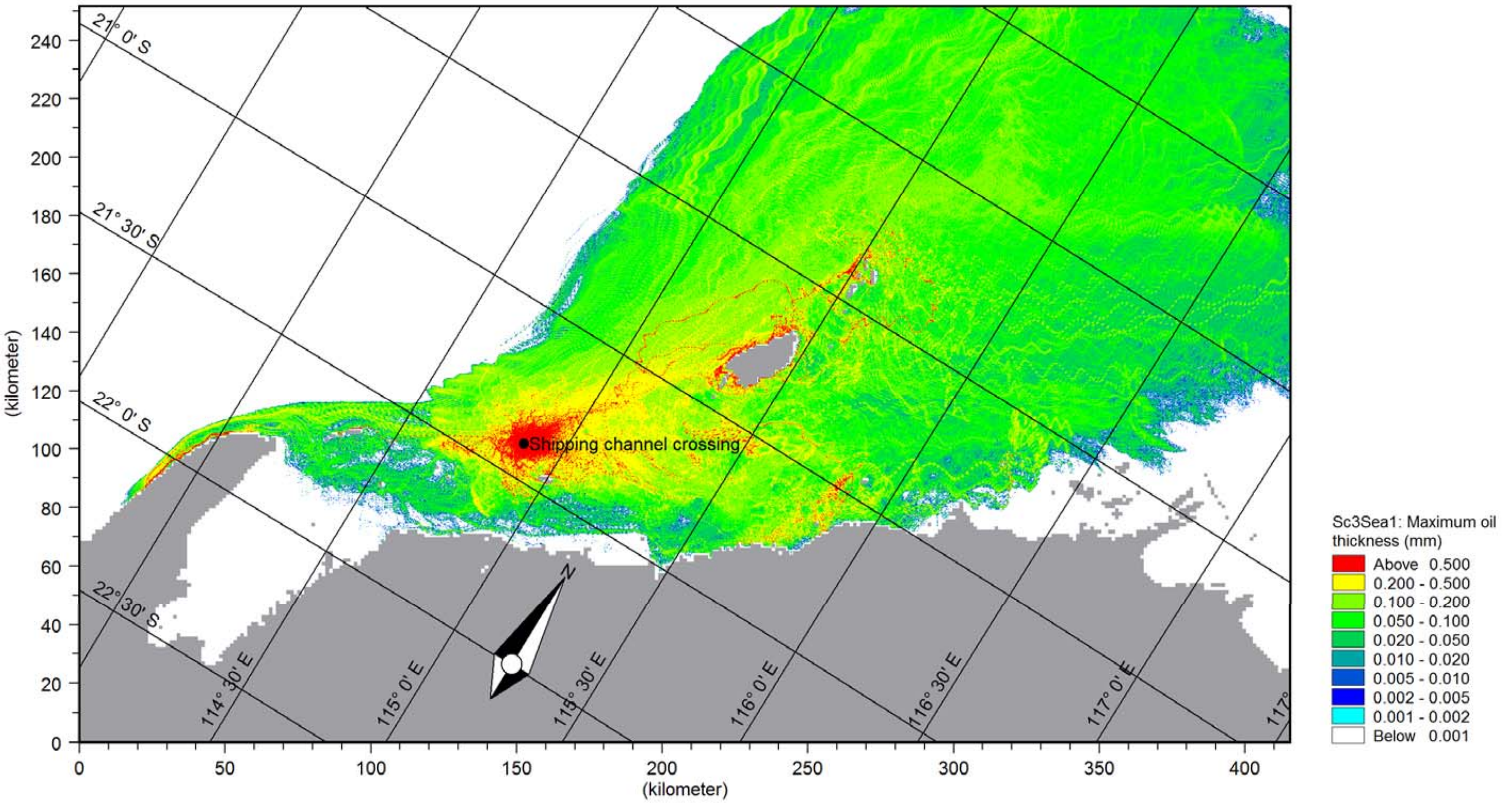

Figure D.1 Condensate Leak at Shipping Channel, summer, maximum oil thickness

D-2

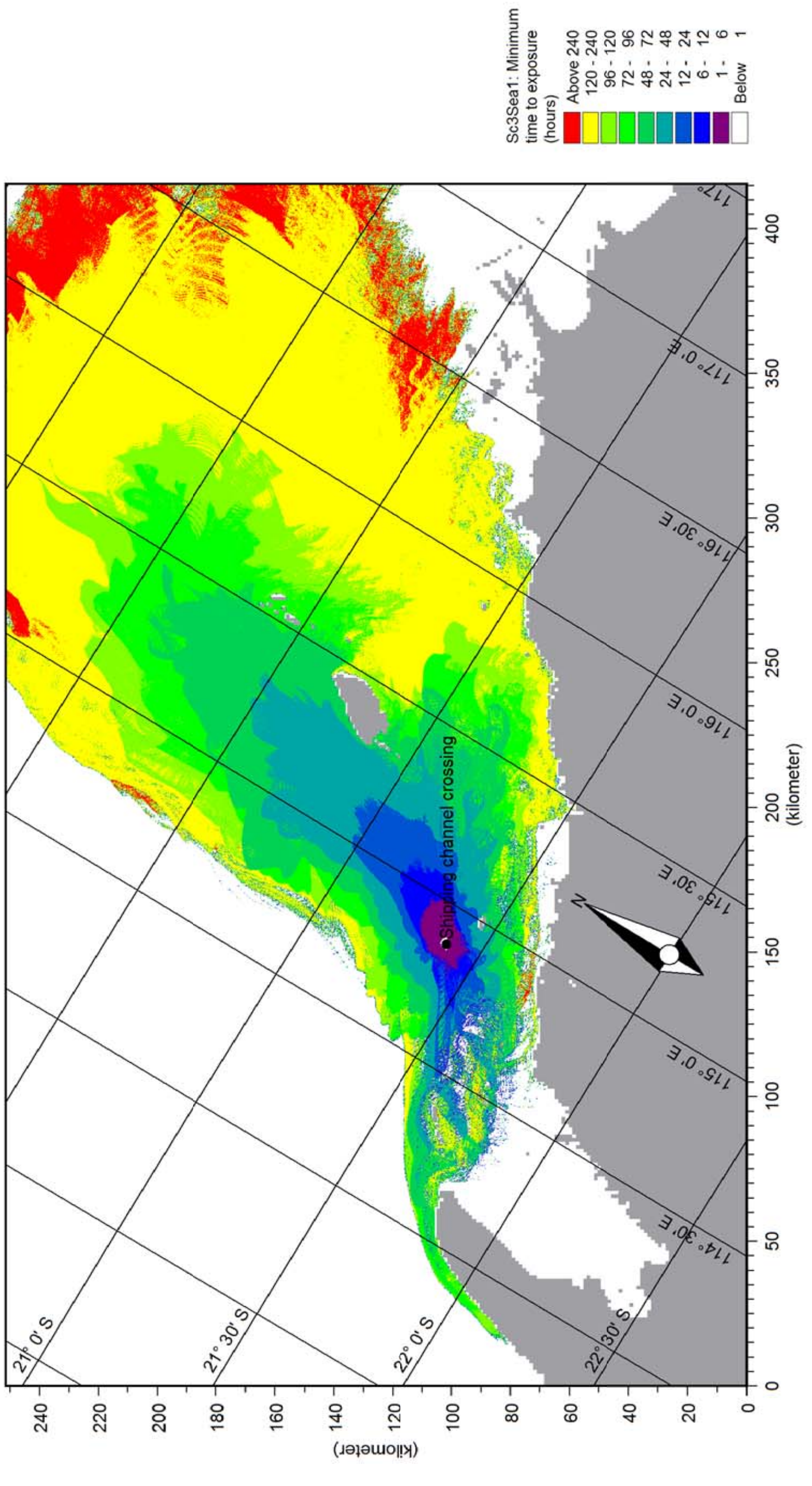

Figure D.2 Condensate Leak at Shipping Channel, summer, minimum time to exposure

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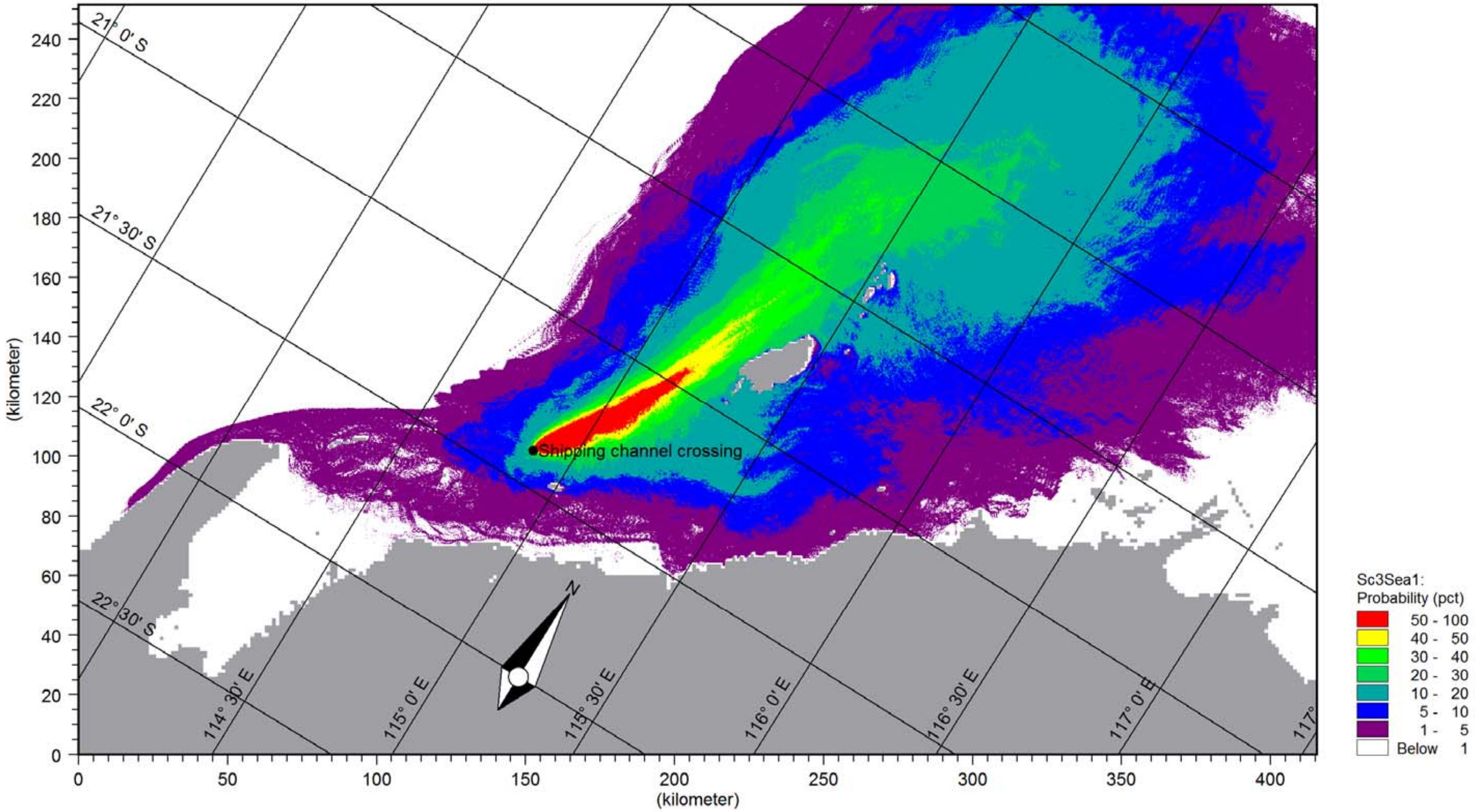

Figure D.3 Condensate Leak at Shipping Channel, summer, probability of exposure

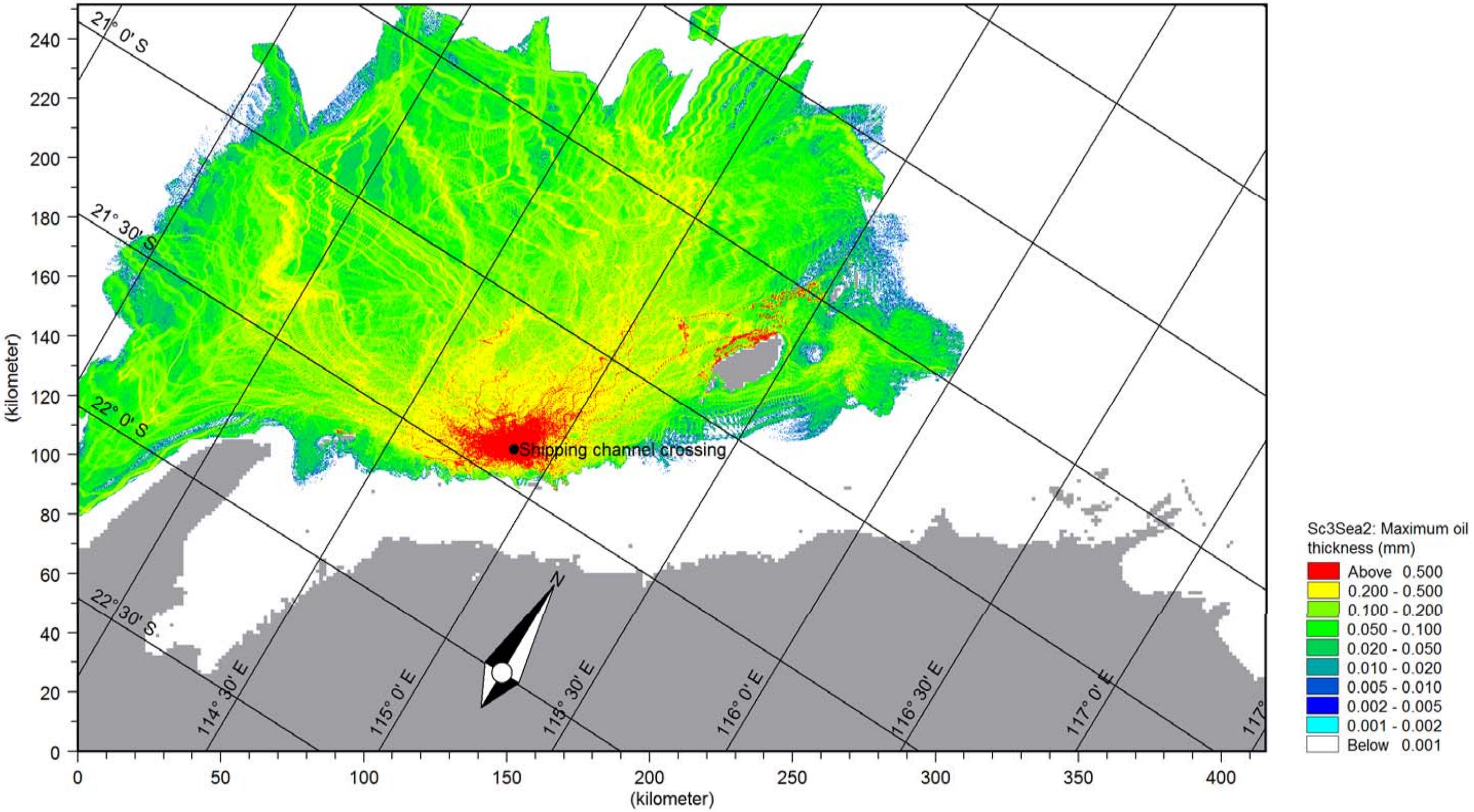

Figure D.4 Condensate Leak at Shipping Channel, transitional periods, maximum oil thickness

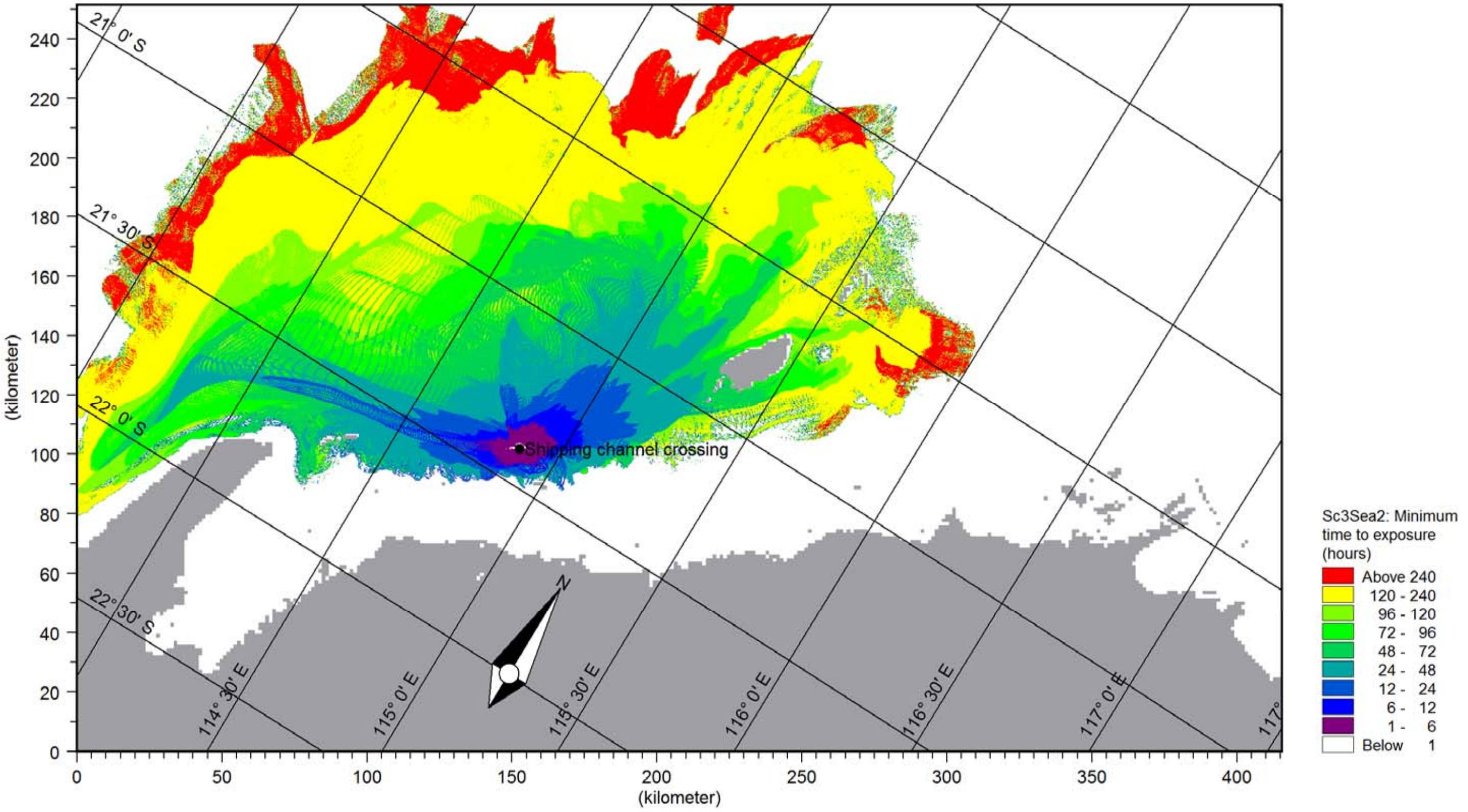

Figure D.5 Condensate Leak at Shipping Channel, transitional periods, minimum time to exposure

D-6

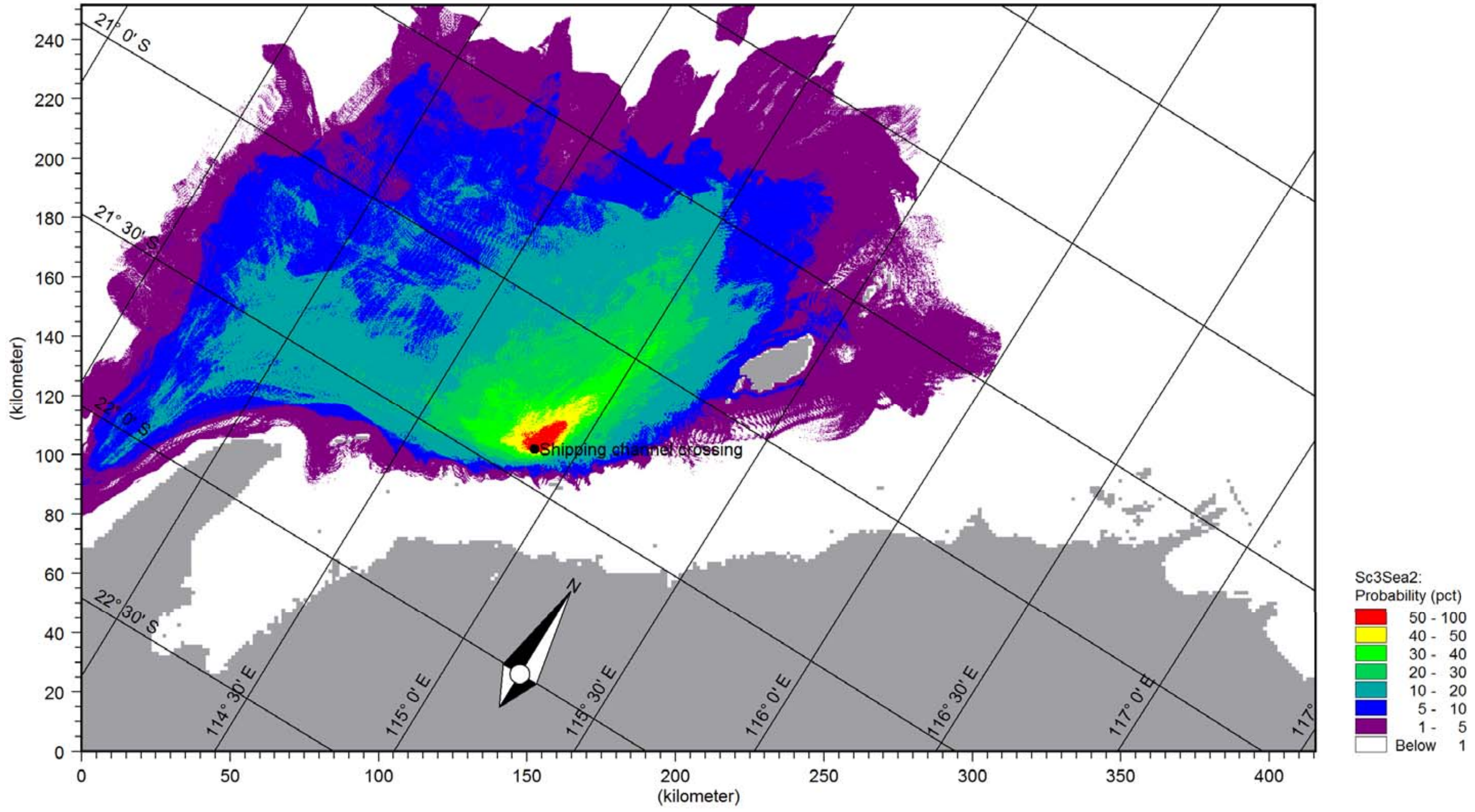

Figure D.6 Condensate Leak at Shipping Channel, transitional periods, probability of exposure

DHI Water & Environment

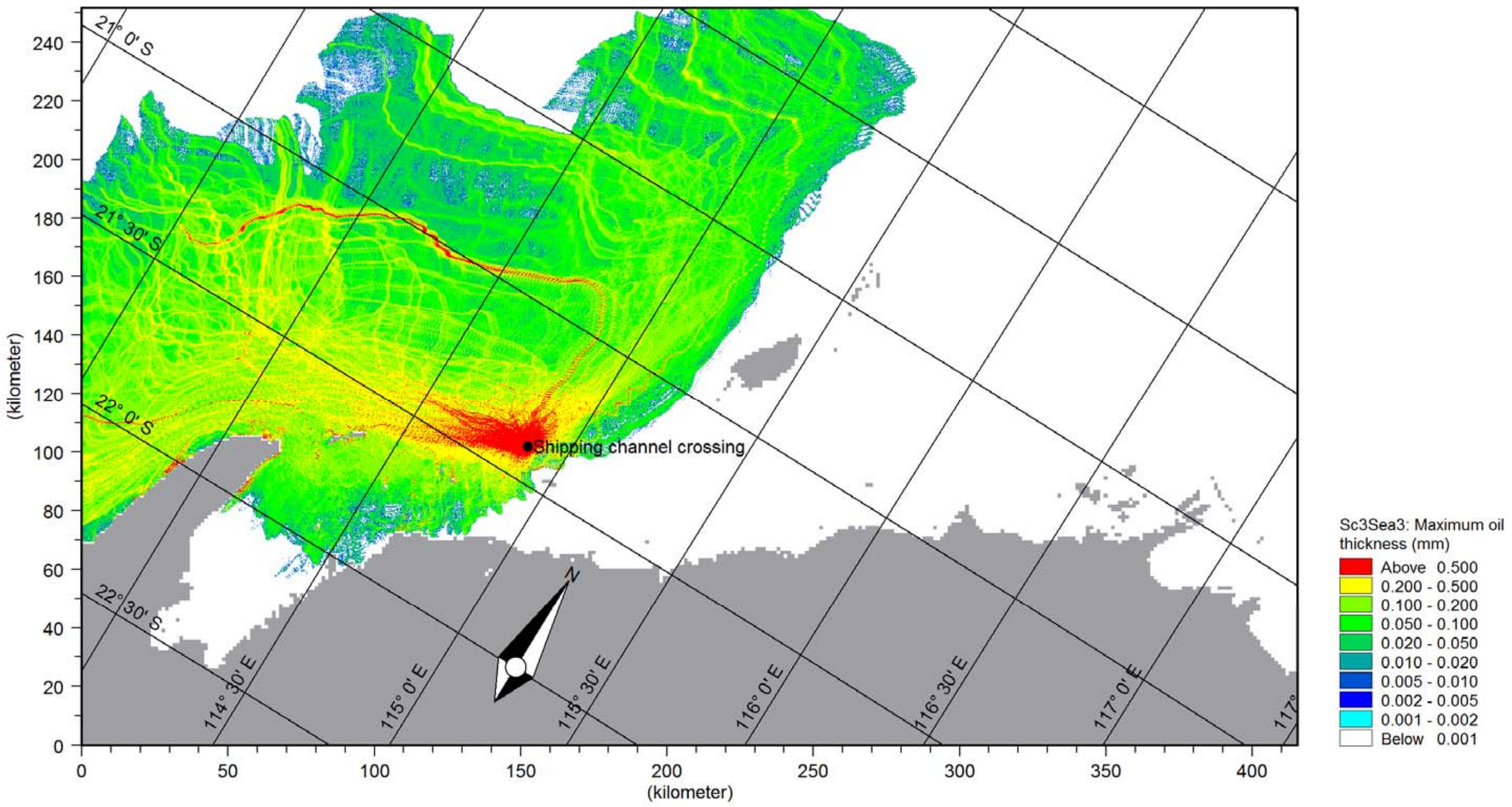

Figure D.7 Condensate Leak at Shipping Channel, winter, maximum oil thickness

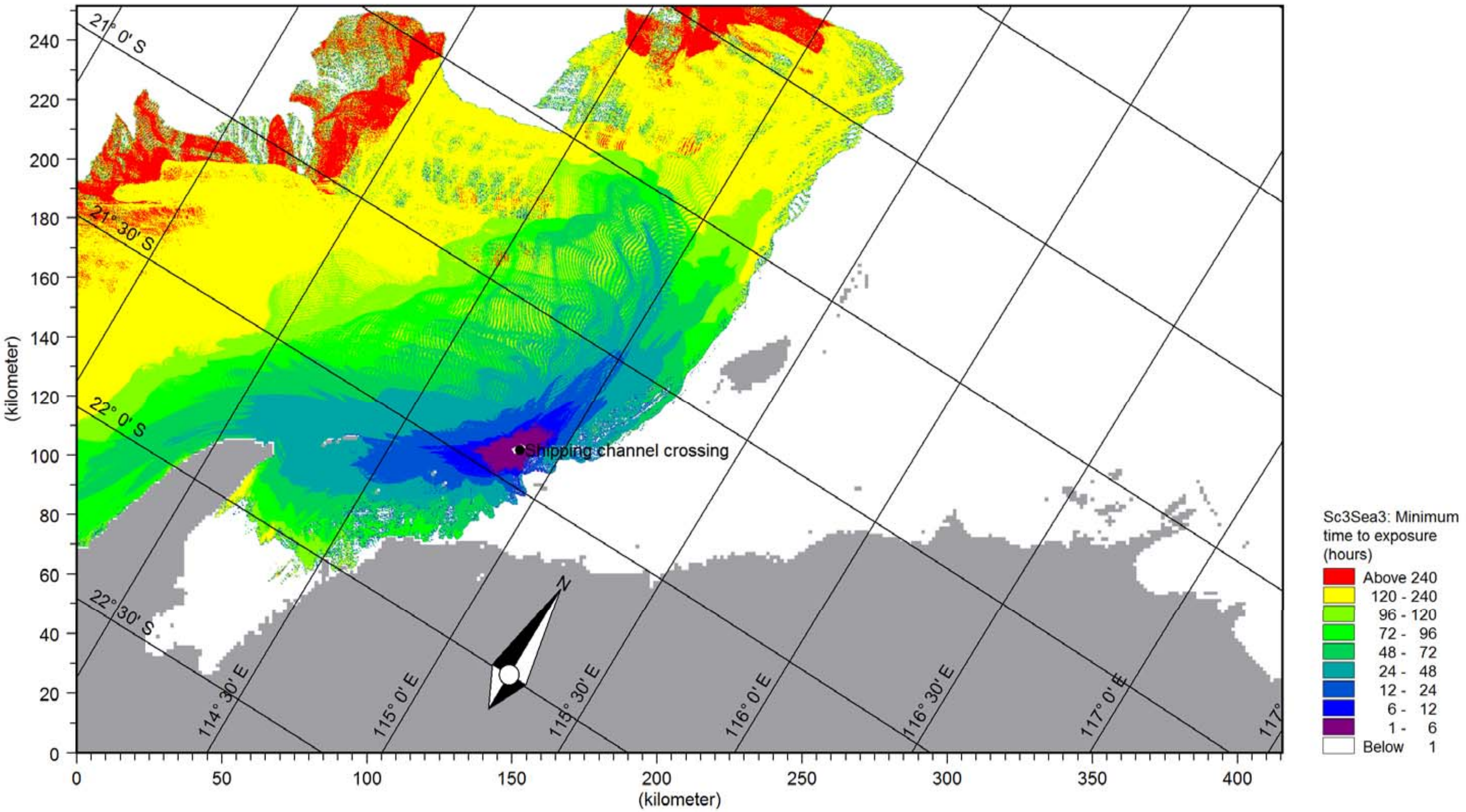

Figure D.8 Condensate Leak at Shipping Channel, winter, minimum time to exposure

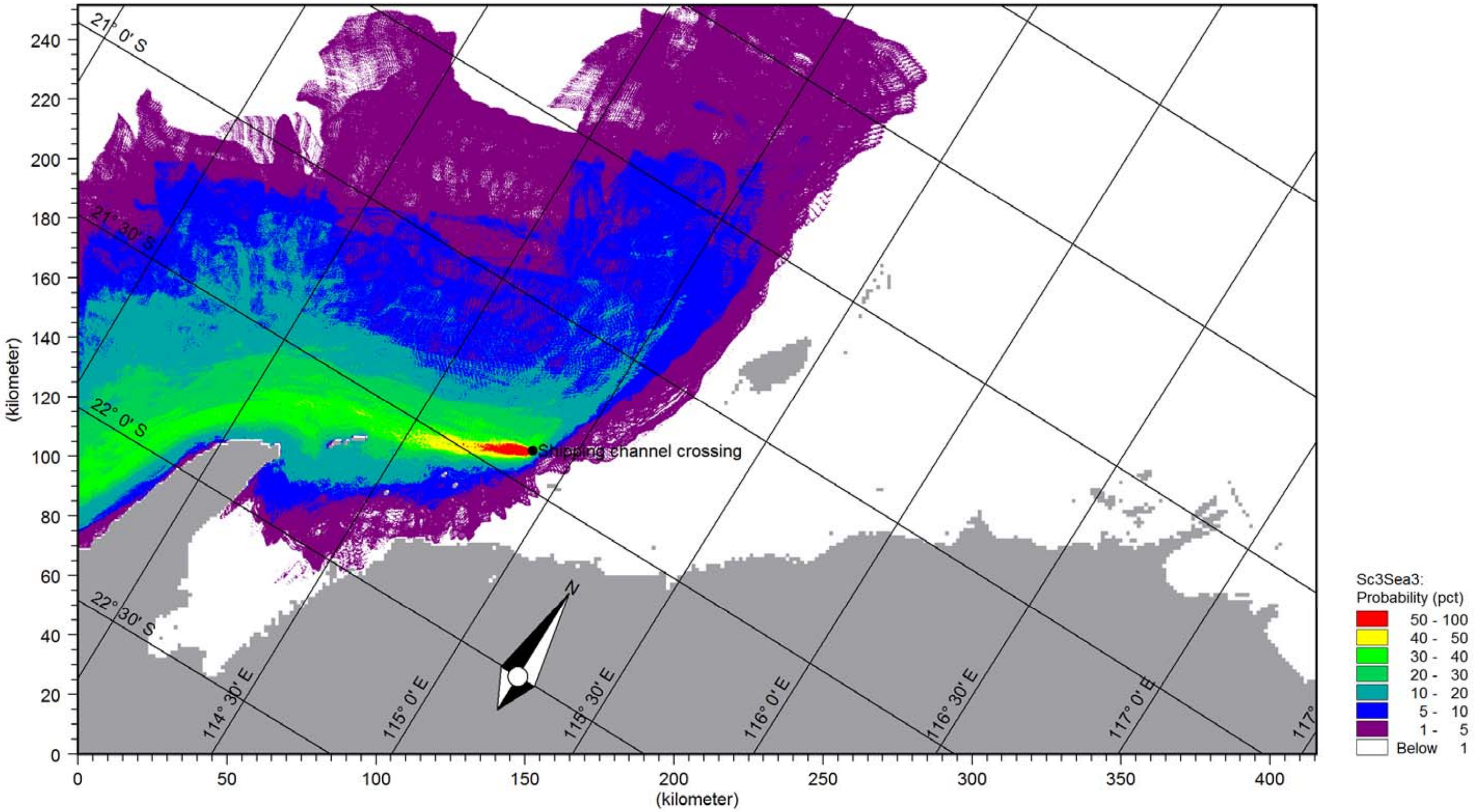

Figure D.9 Condensate Leak at Shipping Channel, winter, probability of exposure

APPENDIX E

Scenario 4 – Condensate Spill at PLF

Key Results

DHI Water & Environment

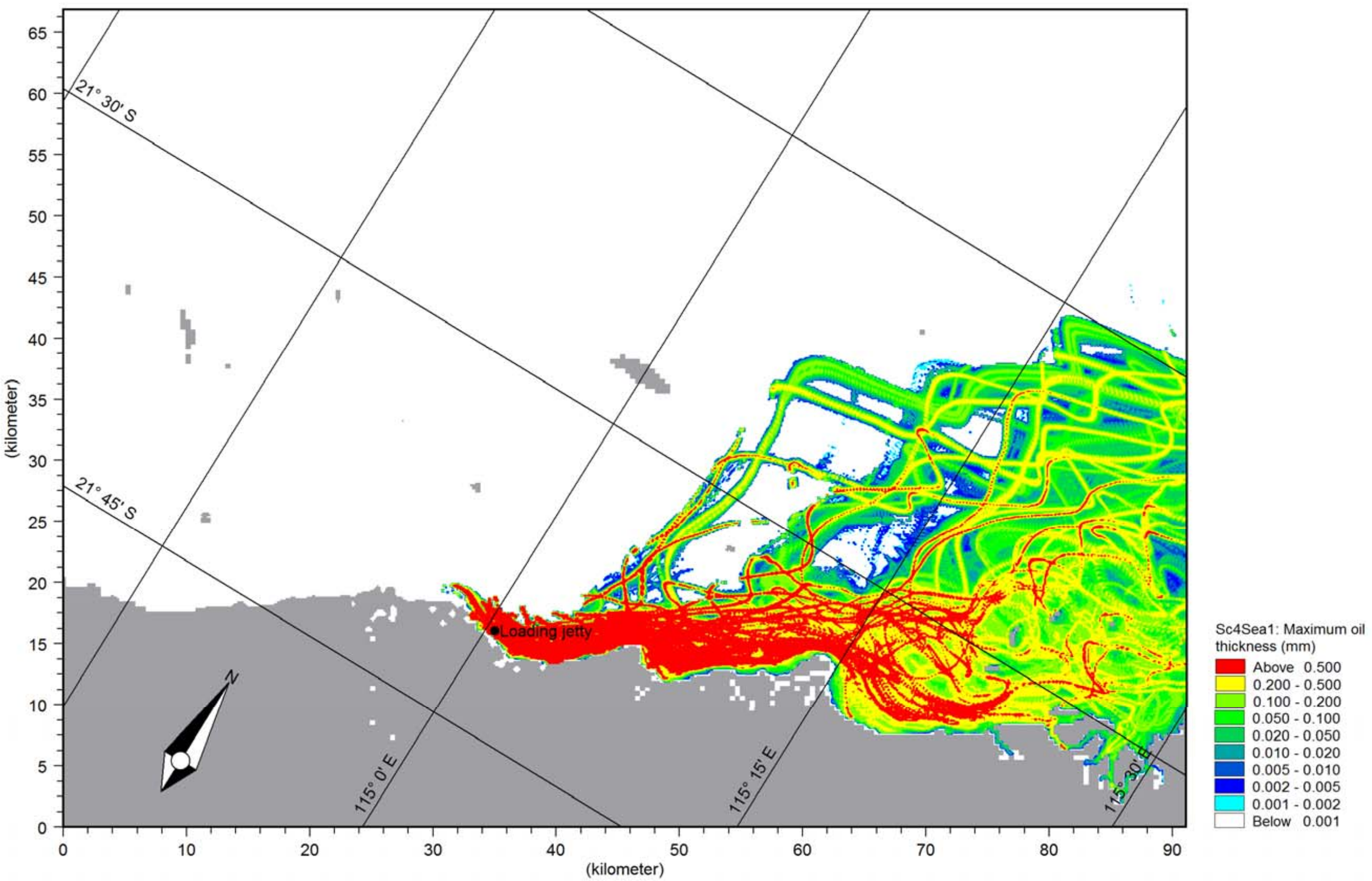

Figure E.1 Condensate Spill at PLF, summer, maximum oil thickness

DHI Water & Environment

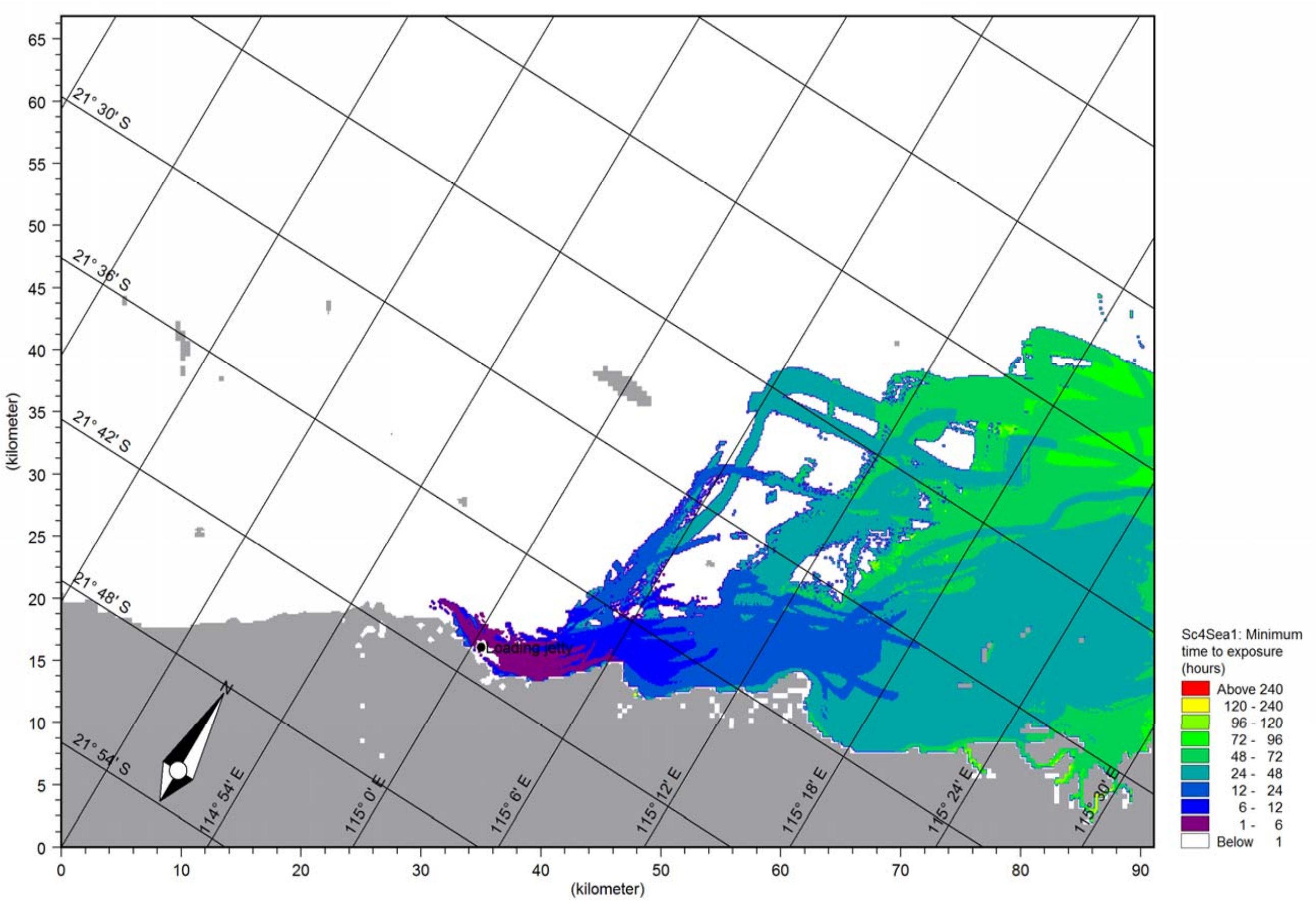

Figure E.2 Condensate Spill at PLF, summer, minimum time to exposure

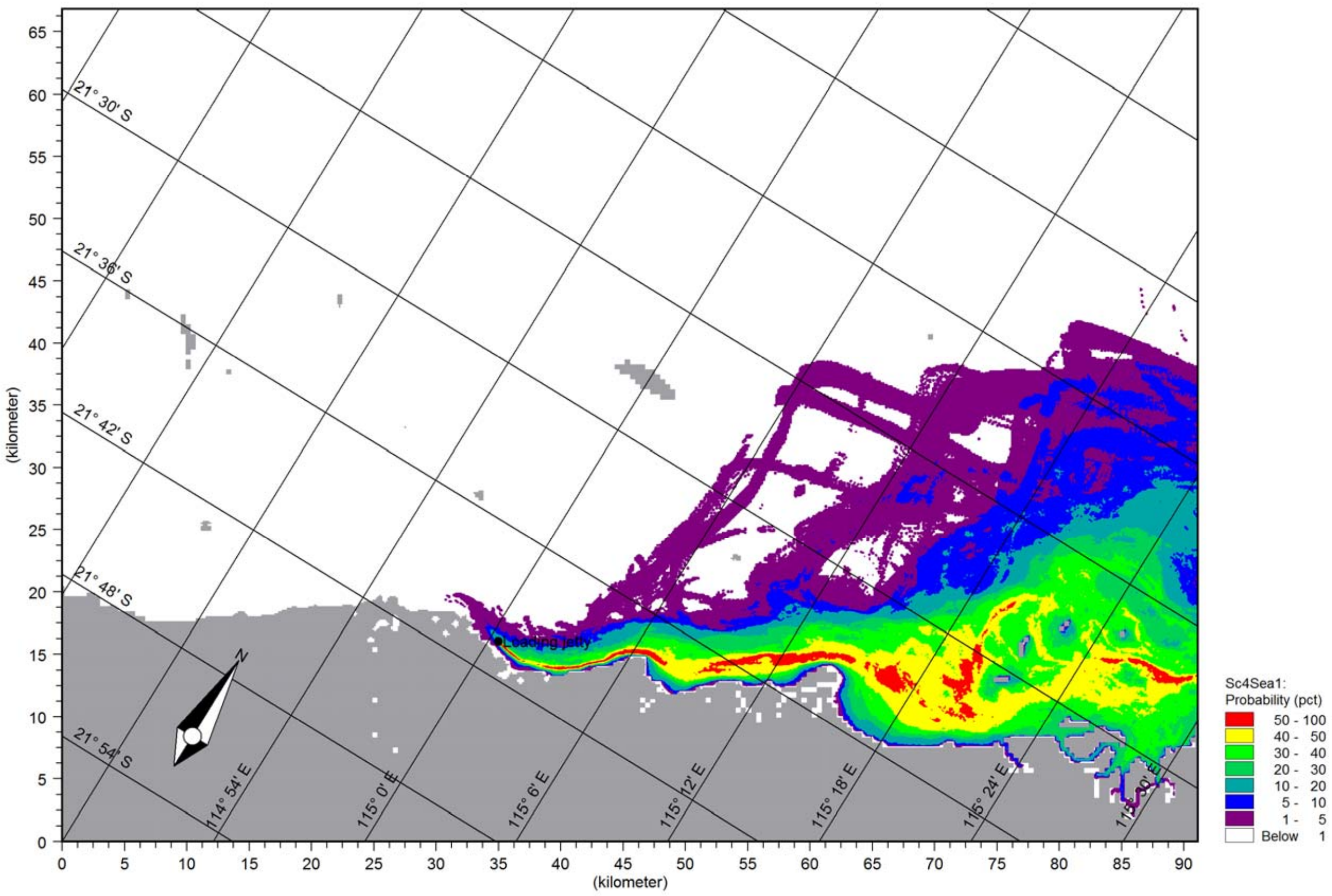

Figure E.3 Condensate Spill at PLF, summer, probability of exposure

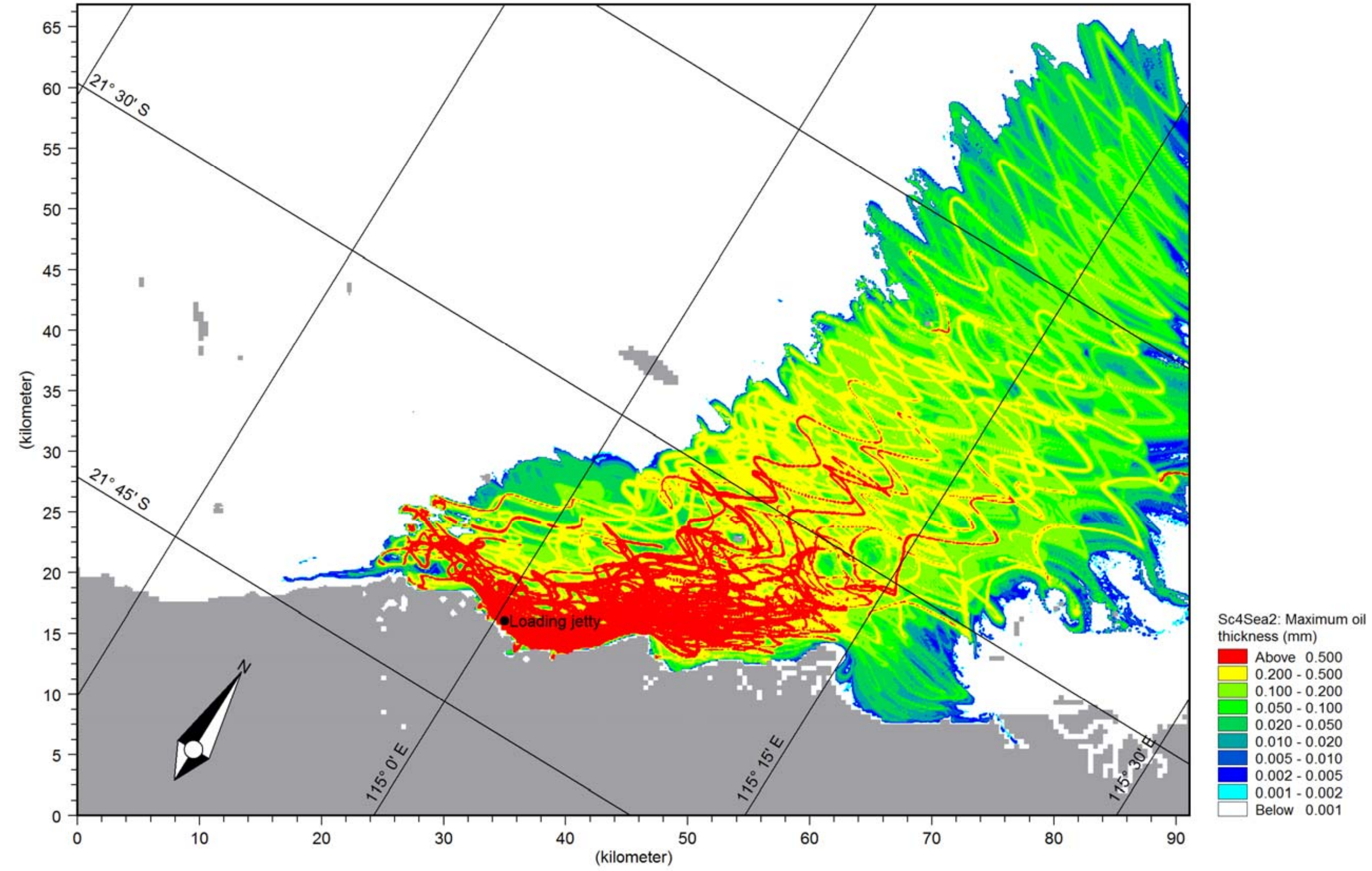

Figure E.4 Condensate Spill at PLF, transitional periods, maximum oil thickness

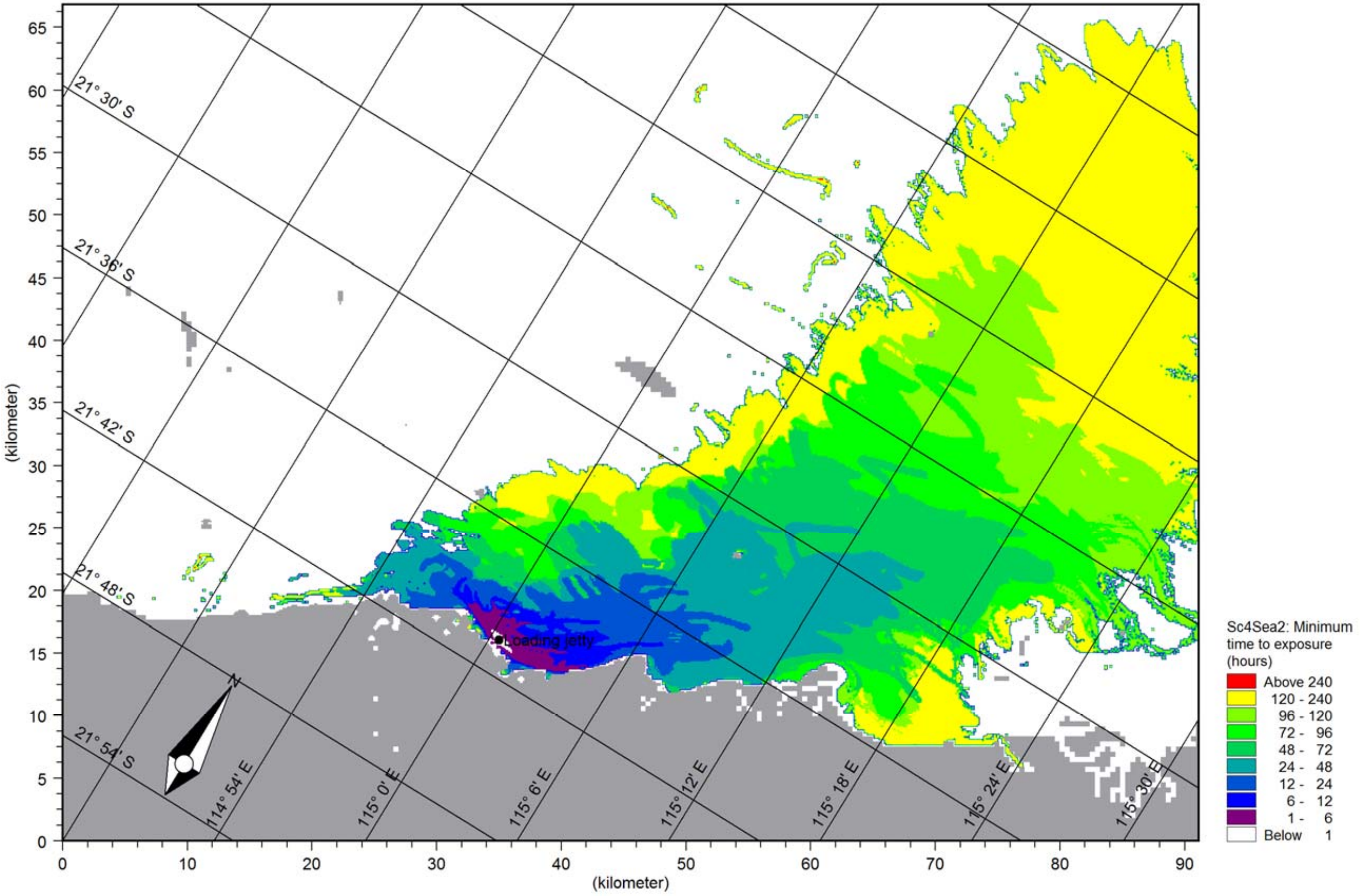

Figure E.5 Condensate Spill at PLF, transitional periods, minimum time to exposure

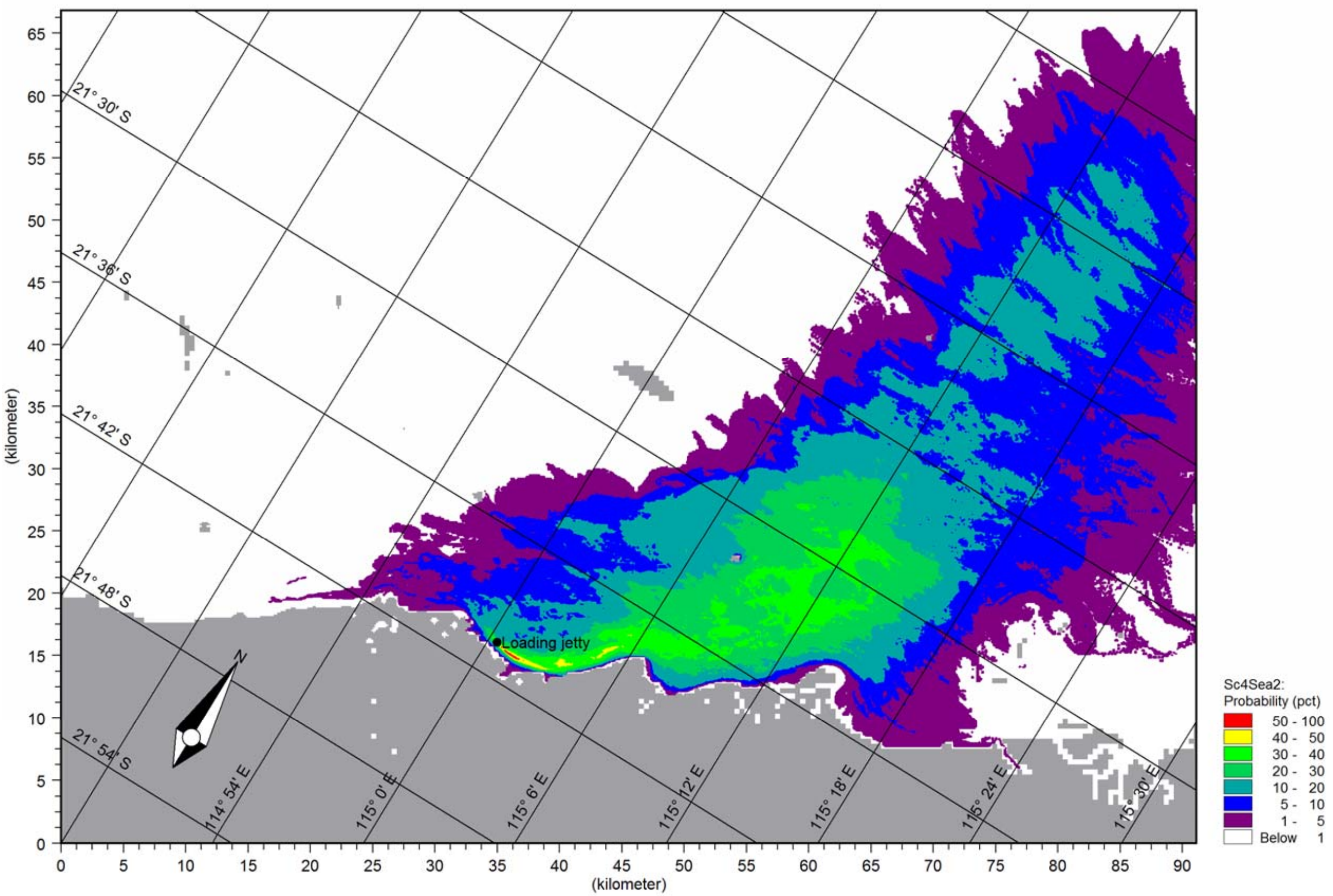

Figure E.6 Condensate Spill at PLF, transitional periods, probability of exposure

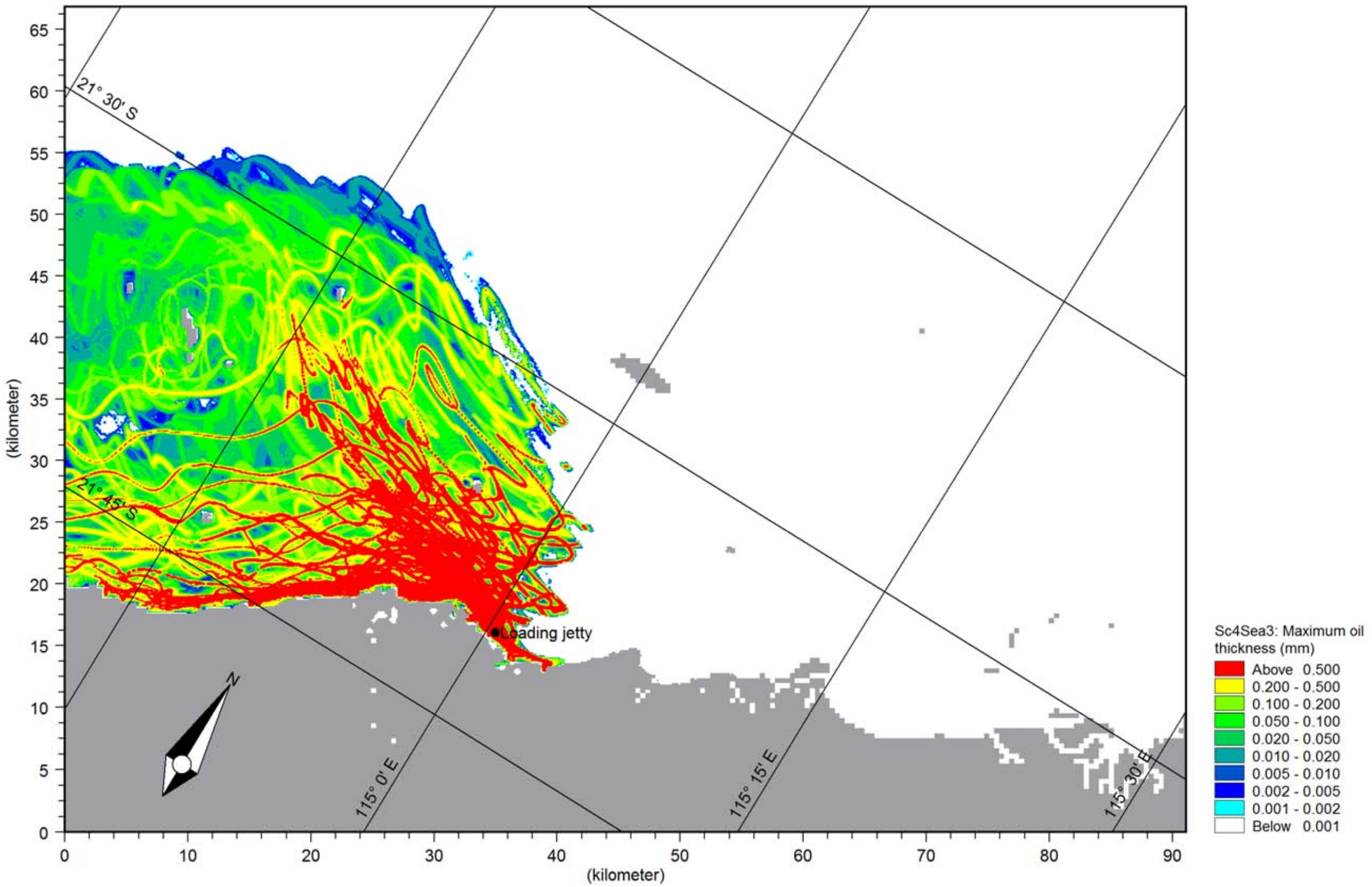

Figure E.7 Condensate Spill at PLF, winter, maximum oil thickness

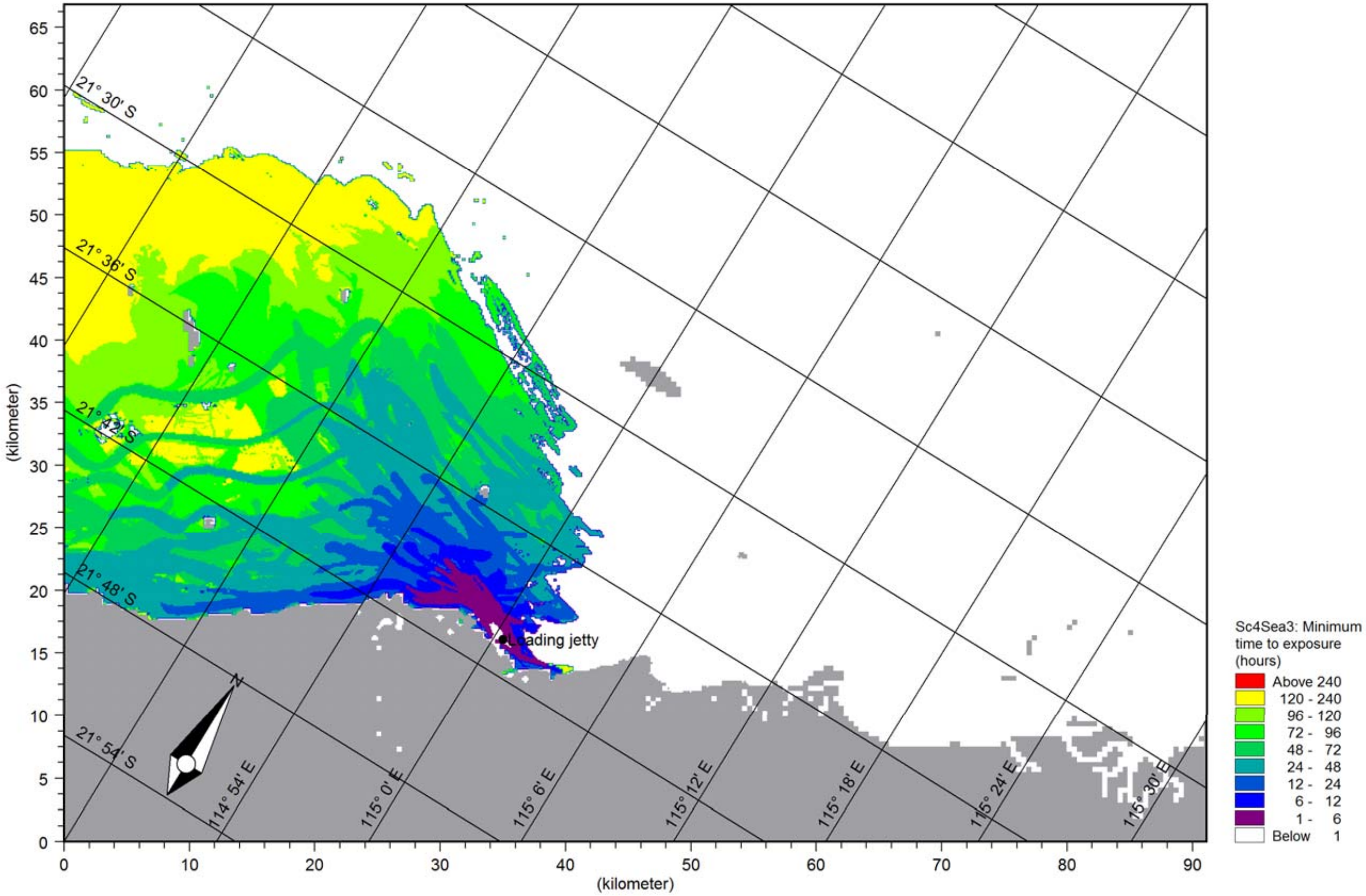

Figure E.8 Condensate Spill at PLF, winter, minimum time to exposure

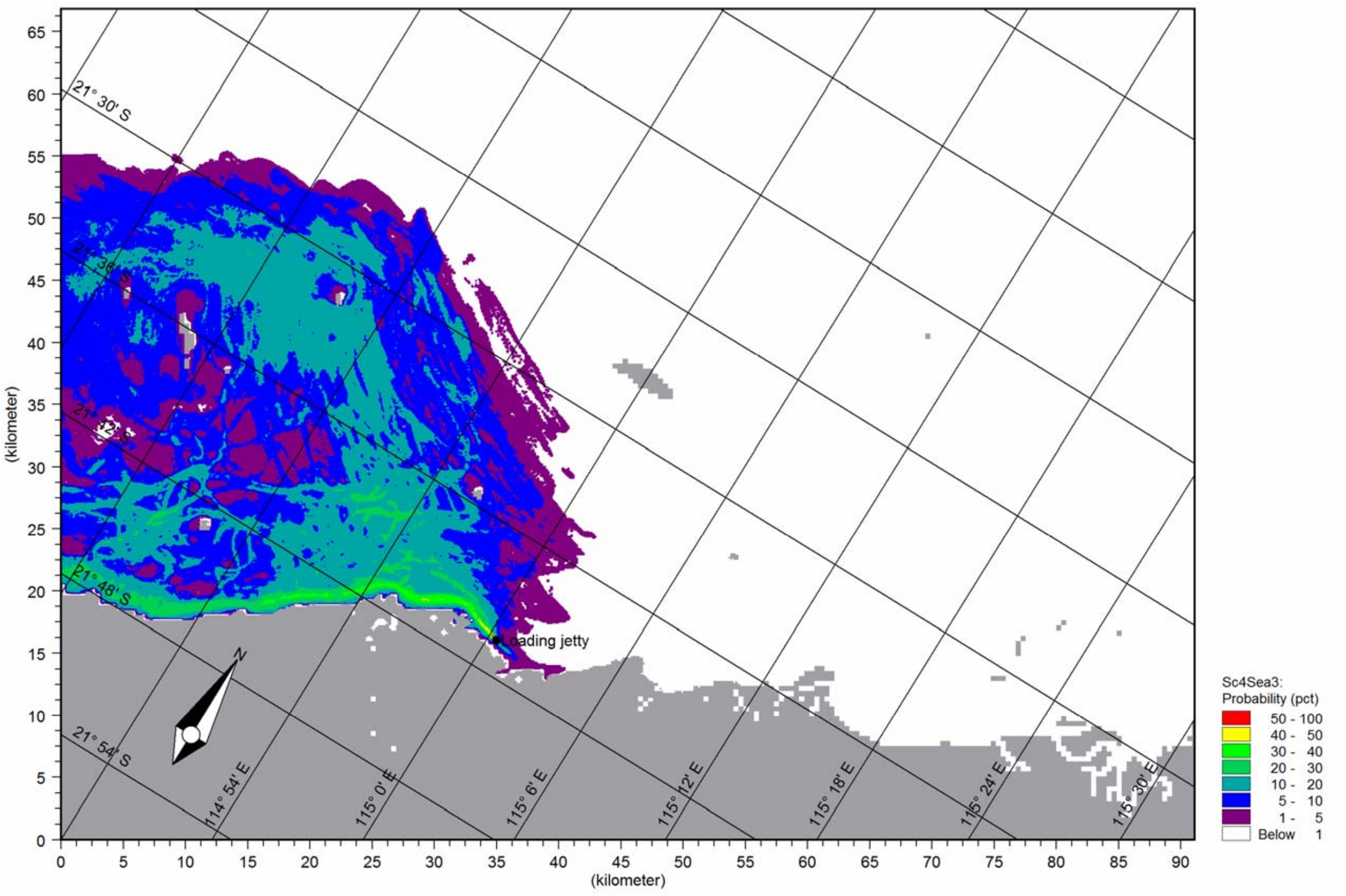

Figure E.9 Condensate Spill at PLF, winter, probability of exposure

APPENDIX F

Scenario 5 – Diesel Spill at MOF

Key Results

DHI Water & Environment

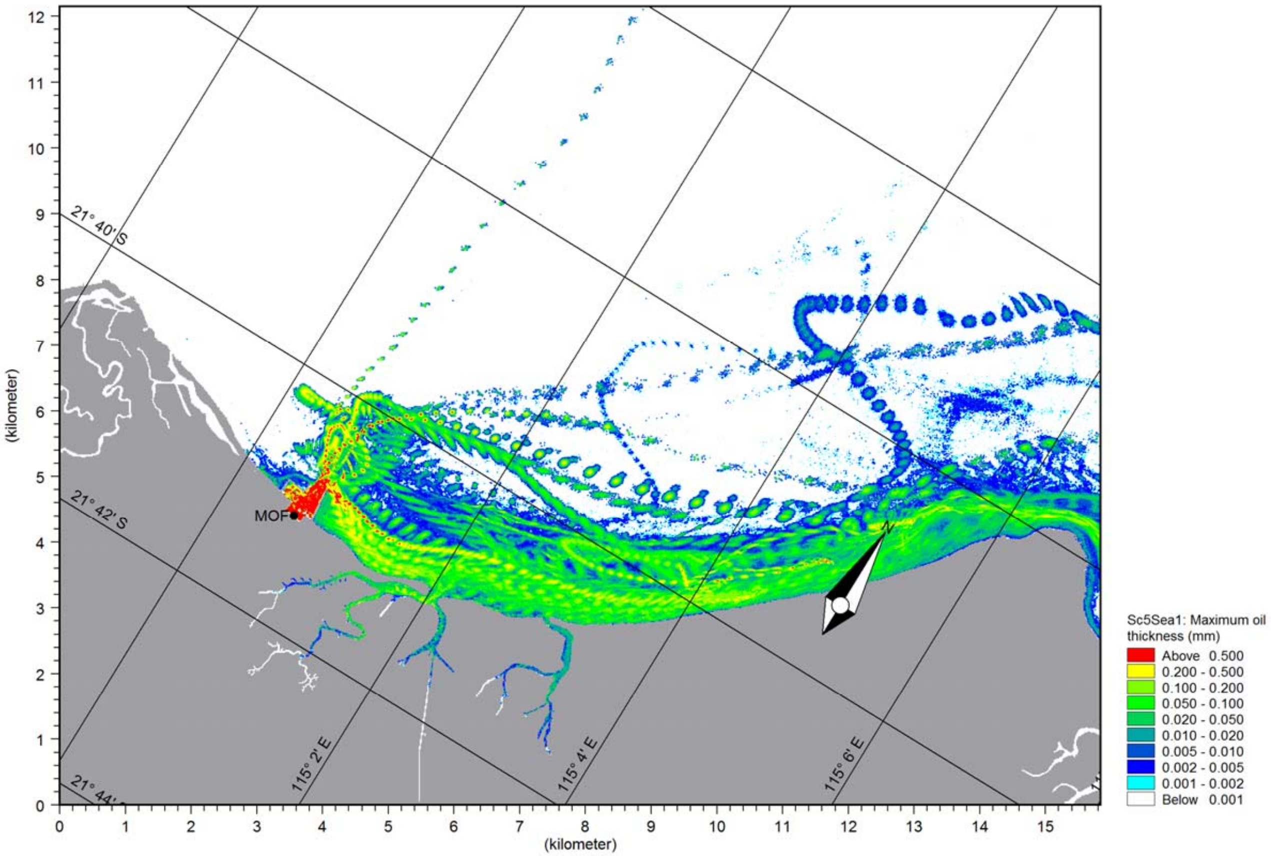

Figure F.1 Diesel Spill at MOF, summer, maximum oil thickness

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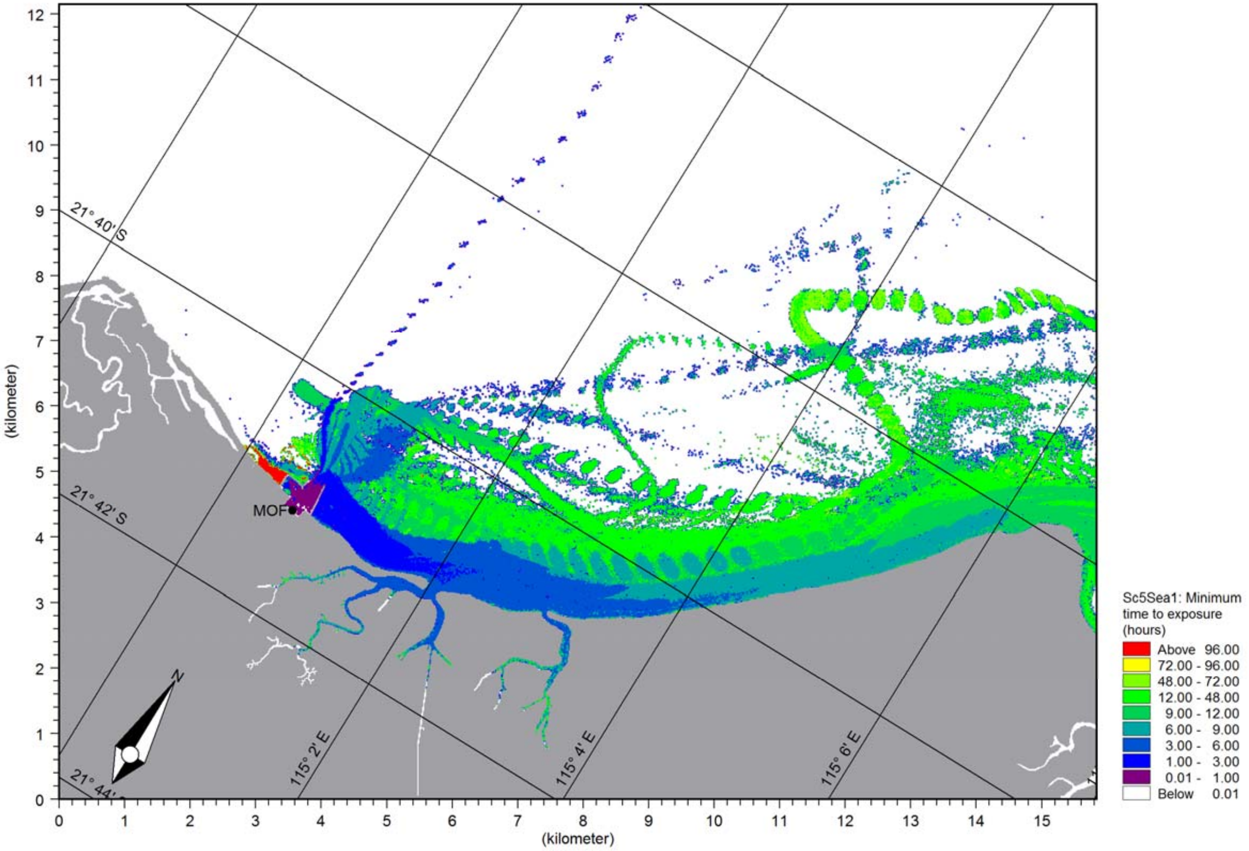

Figure F.2 Diesel Spill at MOF, summer, minimum time to exposure

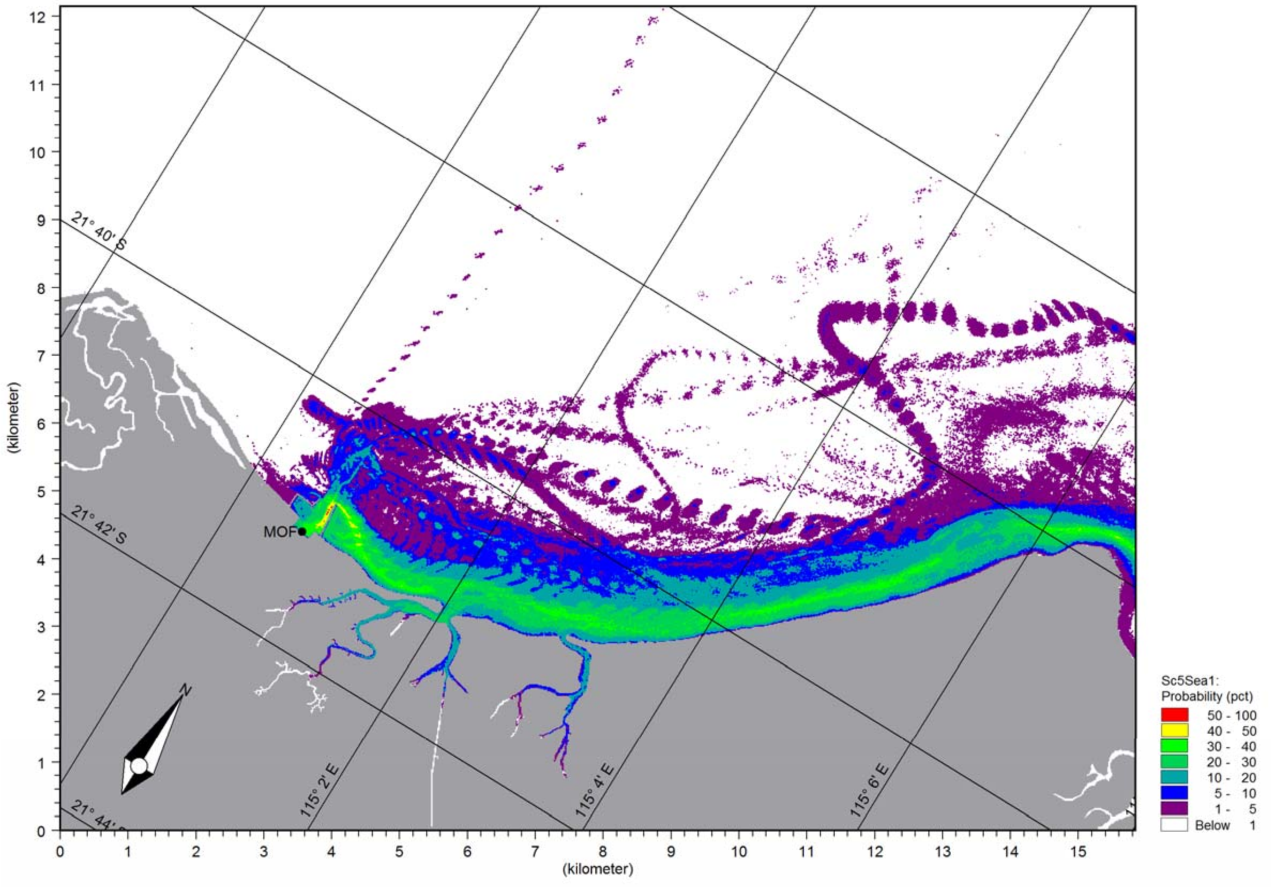

Figure F.3 Diesel Spill at MOF, summer, probability of exposure

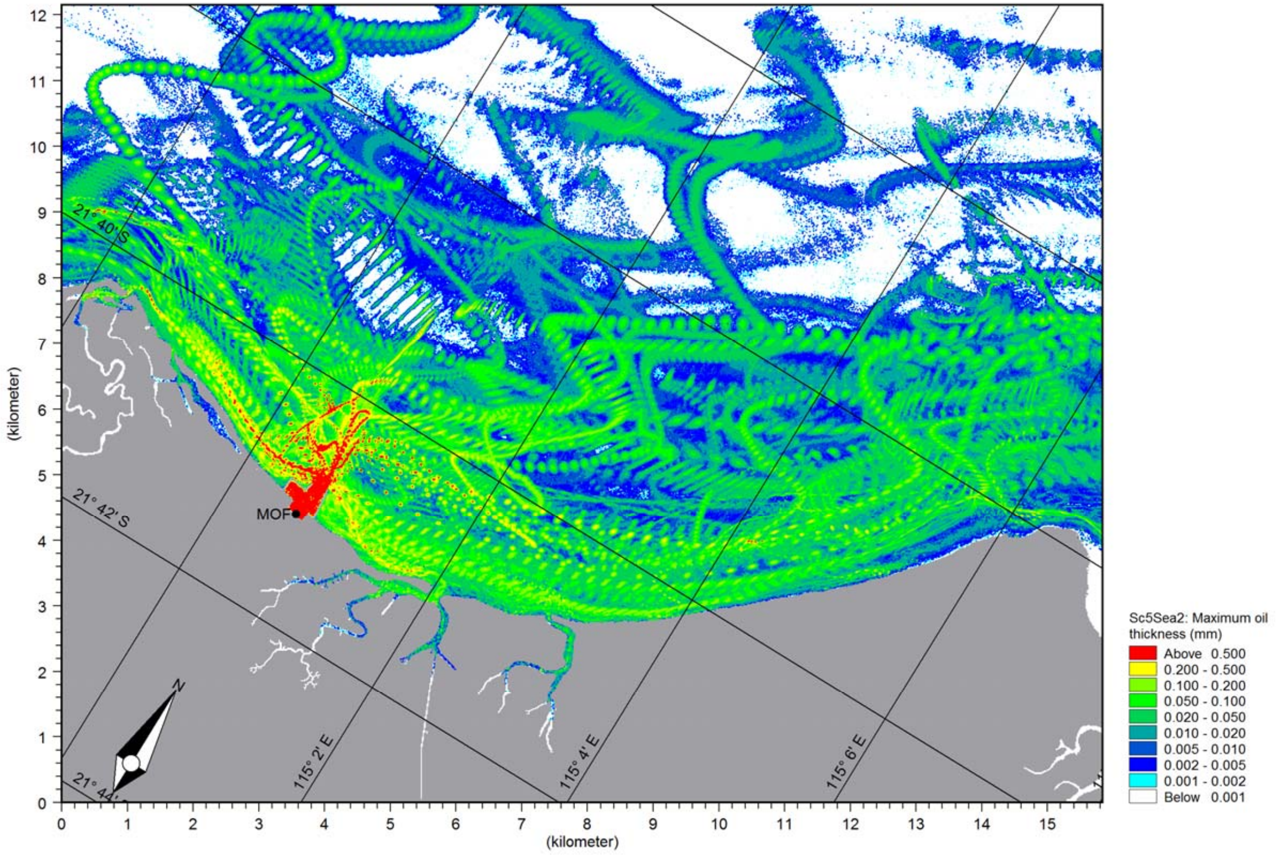

Figure F.4 Diesel Spill at MOF, transitional periods, maximum oil thickness

DHI Water & Environment

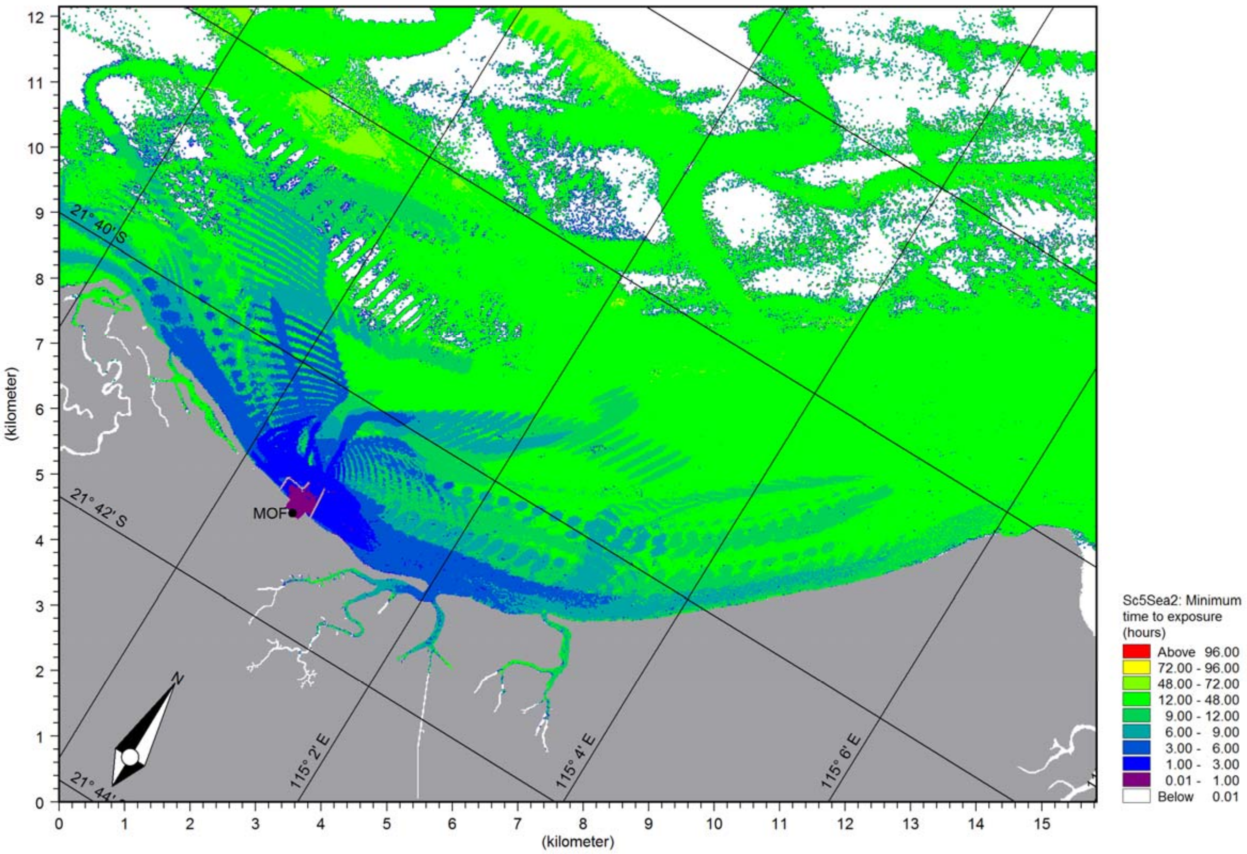

Figure F.5 Diesel Spill at MOF, transitional periods, minimum time to exposure

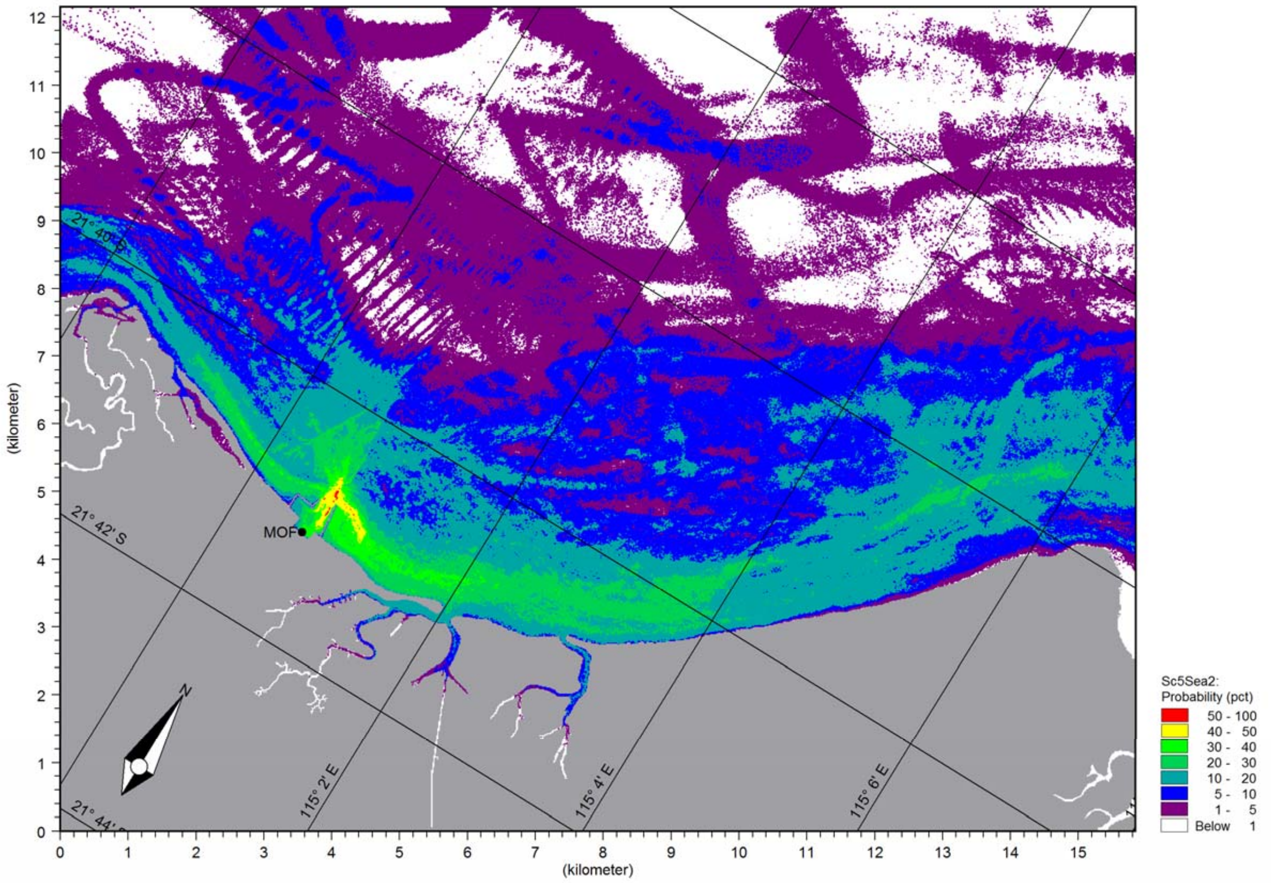

Figure F.6 Diesel Spill at MOF, transitional periods, probability of exposure

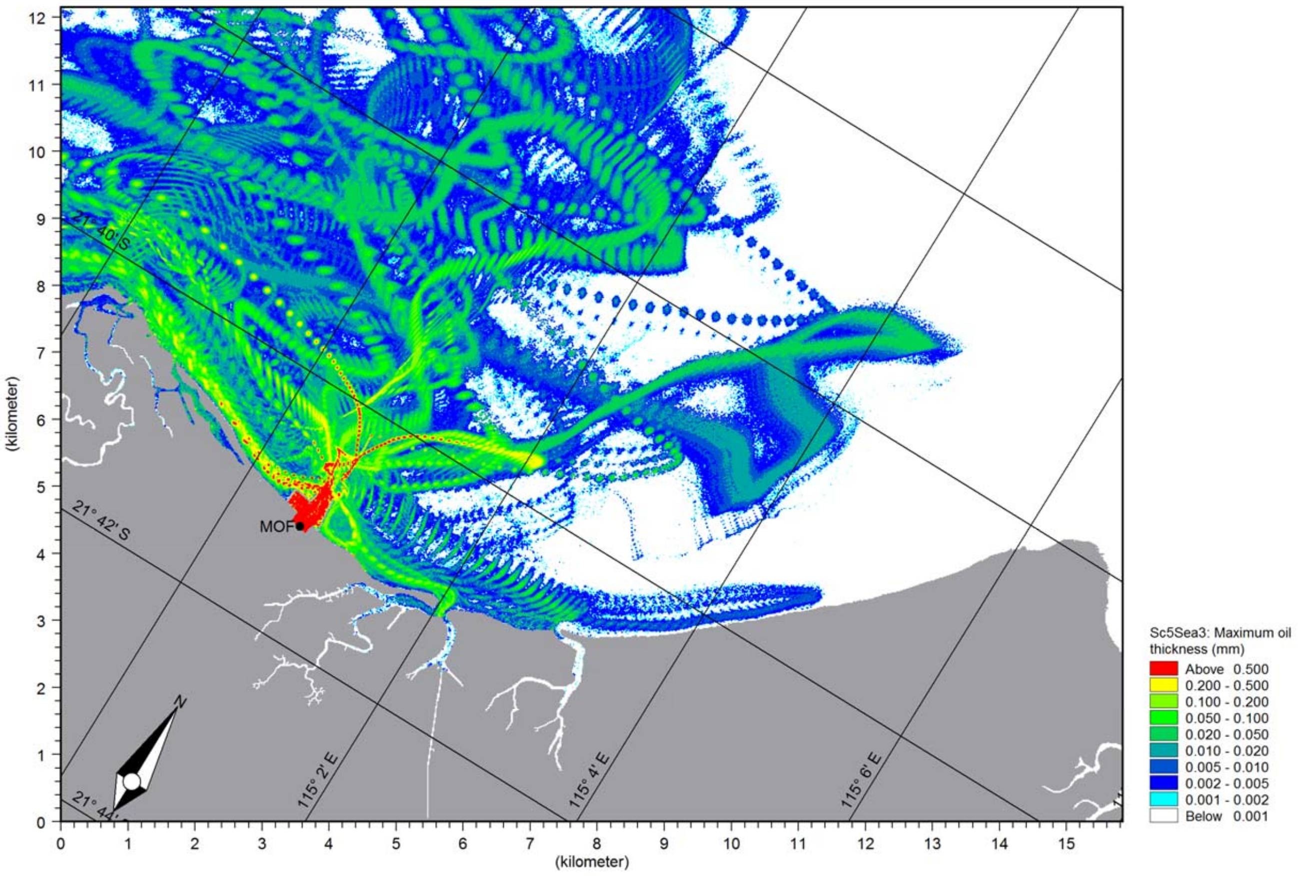

Figure F.7 Diesel Spill at MOF, winter, maximum oil thickness

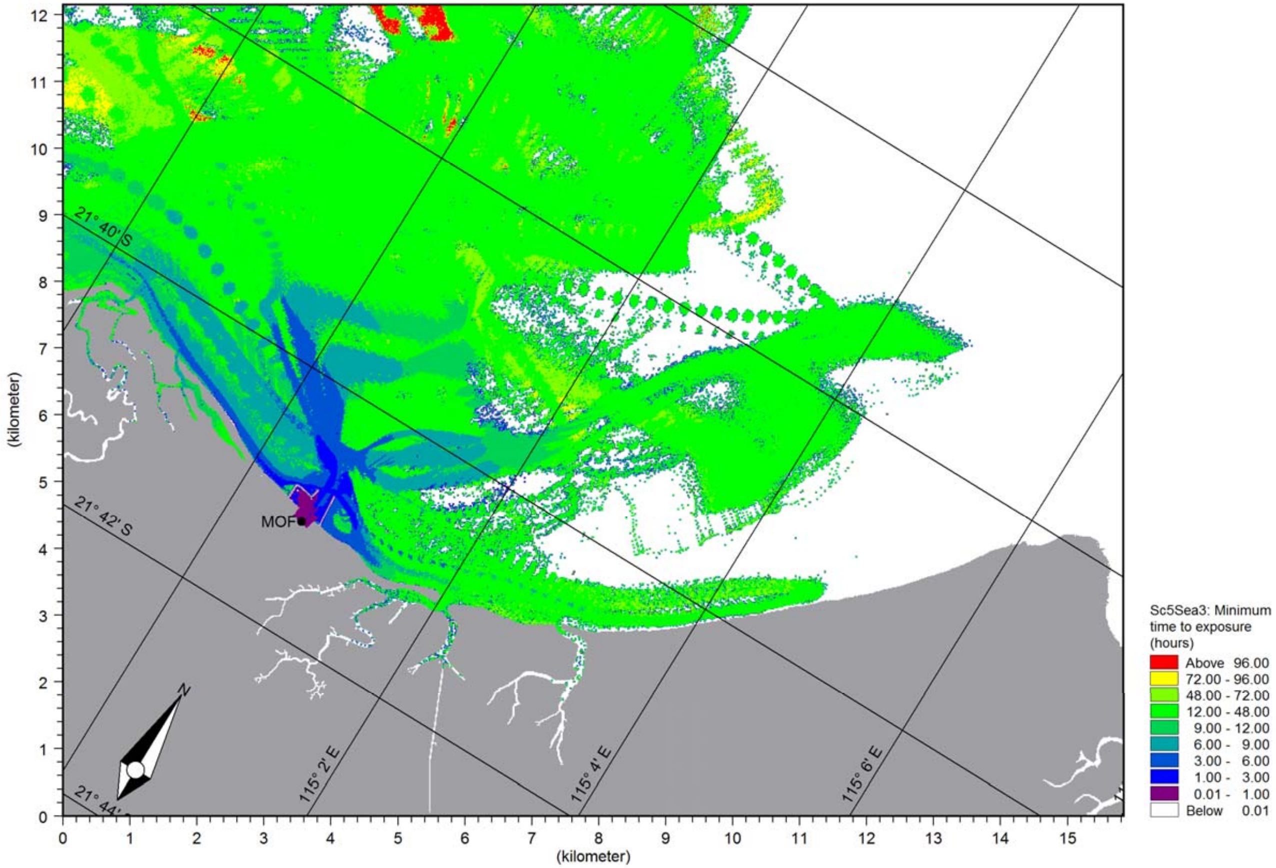

Figure F.8 Diesel Spill at MOF, winter, minimum time to exposure

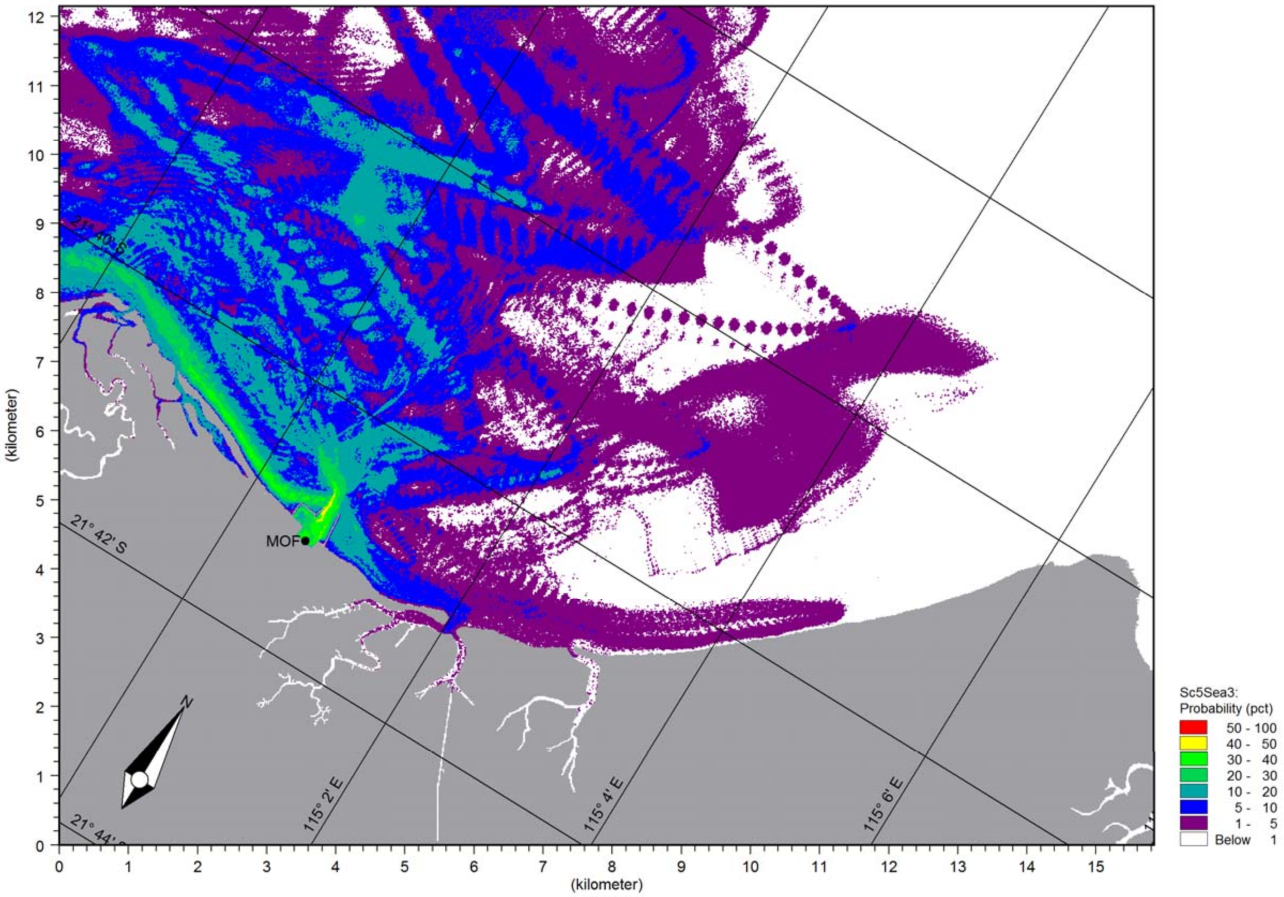

Figure F.9 Diesel Spill at MOF, winter, probability of exposure

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Appendix Q3

Modelling of the Discharges to the Marine Environment

Tables

Figures

Figures (cont'd)

Appendices

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Report

Wheatstone Project - Modelling of the Discharges to the Marine Environment

25 JUNE 2010

Prepared for

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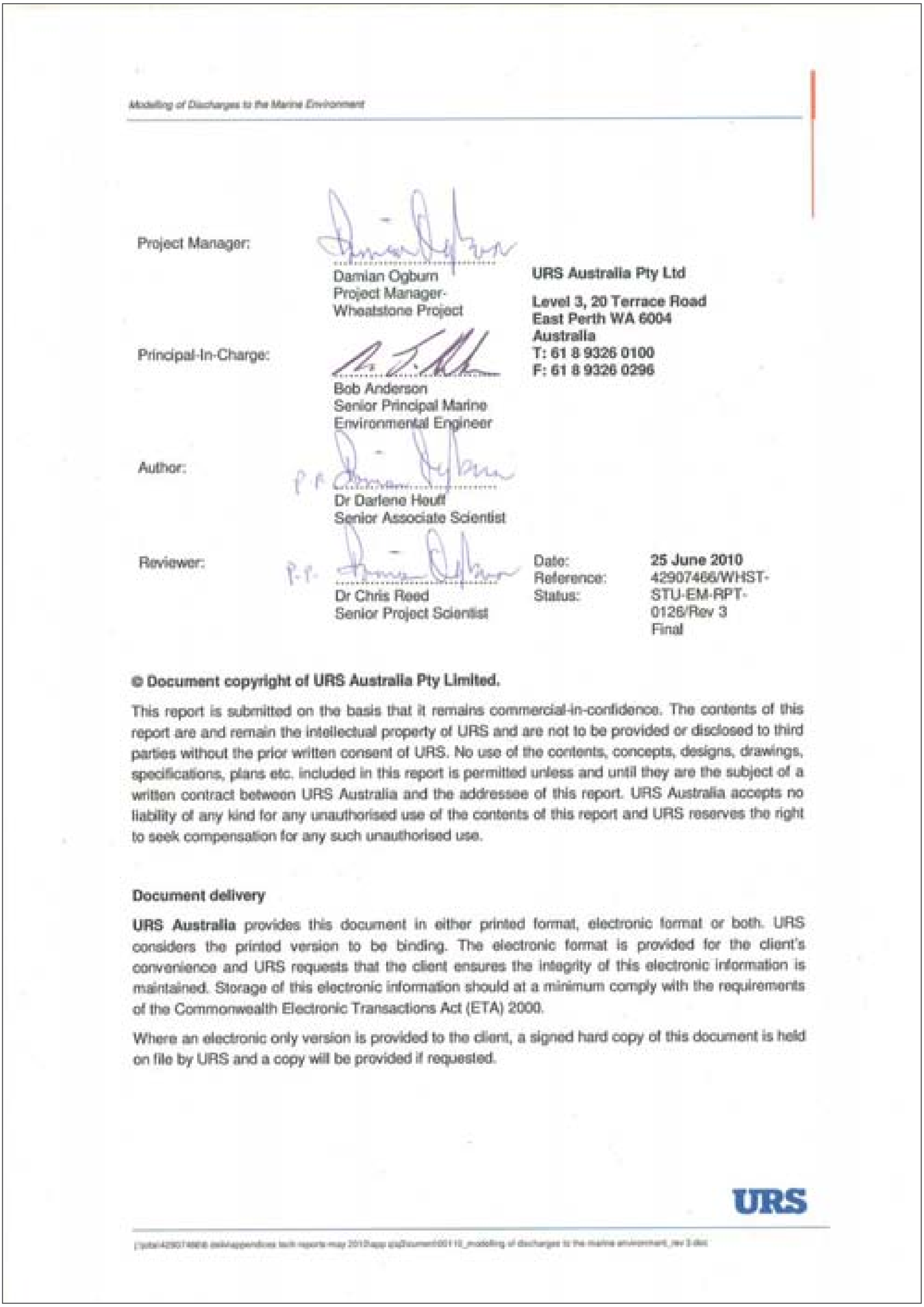

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Status:	Final

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Abbreviations

Abbreviation	**Description**
°C	Degrees Celsius
2D	Two-dimensional
3D	Three-dimensional
ANZECC	Australian and New Zealand Environment Conservation Council
bpd	Barrels per day
cm/s	Centimetres per second
CW	Cooling water
E	Easting
g/kg	Grams per kilogram
g/L	Grams per litre
km	kilometres
kg/m^3	Kilograms per cubic metre
l/s	Litres per second
LNG	Liquefied natural gas
m	Meters
m^3/hr	Cubic meters per hour
MEG	Monoethylene glycol
MEG/PW	Monoethylene glycol and produced water stream
MEG/PW/CW	Monoethylene glycol, produced water and cooling water streams
mm	Millimetres
Mtpa	Million tonnes per annum
N	Northing
ppt	Parts per thousand
PW	Produced water
RO	Reverse osmosis
USEPA	United States Environmental Protection Agency

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Executive Summary

URS has been commissioned by Chevron Australia (Chevron) to conduct modelling of discharges to the marine environment associated with The Wheatstone Project (Project).

A total of three discharge locations have been considered. Two discharge points are located within the nearshore environment and the third is located in the offshore environment at the Wheatstone Platform (WP).

The URS Dilution Model was developed specifically for this project and was used to extend short period 3D far field model simulations of discharge impacts to represent long-term conditions. The URS Dilution Model required less than one minute of computer processing to simulate a two year time period, and could therefore provide long-term 'worst case' conditions for each discharge that were not otherwise feasible using detailed 3D transport models. The URS Dilution Model is an extension of the steady-state CORMIX dilution model that takes into account unsteady currents for year long (or multiple-year) time periods.

For each of the discharge scenarios investigated, dilution curves were developed highlighting the predicted dilution as a function of distance from the discharge point. This information was then used to determine mixing zone concentrations relative to ANZECC guidelines or relative to derived environmental quality criteria and subsequently to assess potential discharge impacts. The interpretation of the results of the dilution modelling based on the project water quality goals is outside the scope of this assessment and has been considered elsewhere (Chevron Australia 2010),

Nearshore Discharges

Discharges in the nearshore emanated from two discharge points: Outlet 1 located along the Product Loading Facility (PLF) in 5 m depth of water, and Outlet 2 approximately 20 km offshore in 20 m depth of water.

Scenario 1 focused on three discharge scenarios from Outlet 1. Two operational flow scenarios were considered: a maximum flow scenario (Scenario 1A) and a typical flow scenario (Scenario 1b). The characteristics of the discharge were such that the discharge plume for Scenario 1A was buoyant, while the plume associated with Scenario 1B was determined to be negatively buoyant. Scenario 1C focused on a scenario during the construction phase of the Project and was also associated with a negatively buoyant plume.

Although Outlet 1 is proposed to be equipped with a diffuser, results of the assessment suggest that the dilution potential of the nearshore environment is limited by a combination of the density differential between the discharge and the ambient environment combined with the limited depth of the water column.

Scenario 2 involved the discharge of produced water (PW) from Outlet 2. At the time of the assessment, information relating to the characterisation of the discharge was limited. The discharge plume is anticipated to be positively buoyant. The effectiveness of the proposed diffuser will depend on the details of the characterisation of the produced water that will be discharged form this location.

Offshore Discharges

Discharges associated with the WP, located approximately 150 km offshore in 73 m of water, involved the release of PW, cooling water (CW) and monoethylene glycol (MEG) into the marine environment.

Executive Summary

Scenario 3 investigated the fate of a continuous discharge of PW from the platform. Scenarios have been considered for the discharge of produced water in isolation (Scenario 3A, 3D, 3E, 3F) as well as in combination with CW (Scenarios 3B and 3C). The combined PW/CW discharge has a significant impact on the characterisation of the discharged stream as the volume of CW discharged (8000 m^3/hr) is significantly greater than the flow rate of produced water (272 m^3/hr). Results suggest that improved dilution outcomes for PW are associated with segregated discharge streams of PW and CW.

Scenario 4 was associated with a total of five different MEG/PW 18 hour batch discharge scenarios including the co-mingled discharge of MEG/PW and CW that is discharged via the same caisson.

Scenario 4A, 4B, 4C, and 4D considered the dilution of the MEG/PW stream in isolation of the CW. Scenario 4C was identified as the worst-case dilution scenario and was investigated in some detail. Results of the dilution modelling suggested that the MEG would disperse within 24 hours of cessation of the MEG from the discharge stream.

Scenario 4E represents the MEG/PW/CW discharge configuration. A preliminary investigation into a variety of mitigation options has been conducted and results suggest that end of pipe engineering may lead to an improved environmental outcome.

1

Introduction

Chevron Australia Pty Ltd proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast. The LNG and Domgas plant will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and other yet-to-be determined gas fields. The project is referred to as the Wheatstone Project and "Ashburton North" is the proposed site for the LNG and Domgas plant. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land. The LNG plant will have a maximum capacity of 25 Million Tonnes Per Annum (MTPA) of LNG. The Wheatstone Project has been referred to the State Environmental Protection Authority (EPA) and the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA). URS has been commissioned by Chevron to undertake dispersion modelling of discharges to the marine environment associated with the Project to support the environmental impact assessment process.

A total of three discharge locations have been considered. Two discharge points are located within the nearshore environment and the third is located in the offshore environment at the Wheatstone Platform.

This report presents the methodology and findings of the discharge modelling including both near and far field modelling of the various discharges to the marine environment. The focus of the assessment is on the development of estimates of worst-case profiles of dilution.

The interpretation of the results of the dilution modelling based on the project water quality goals is outside the scope of this assessment and has been considered elsewhere (Chevron 2010)

1.1 Background

Chevron is proposing to develop the Petroleum Titles for locations WA-17-R, WA-253-P and WA 356-P which are located approximately 145 km offshore in the Carnarvon Basin.

Gas, condensate and associated water will be brought to the surface via a network of sub-sea wells and pipelines to the central Wheatstone Platform for processing. At the platform the water produced with the gas and condensate will be separated from the stream, cleaned and discharged to the marine environment. The gas and condensate will be dehydrated, compressed and sent to the onshore liquefied natural gas (LNG) facility via a 200 km pipeline.

The onshore facility will consist of up to five LNG trains with a total capacity of 25 MTPA. At the onshore facility, the condensate and gas streams will be separated. The condensate will be stabilised in preparation for refining at Australian and overseas destinations. The gas stream will be prepared for use both domestically and for export.

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Discharge Scenarios

2.1 Discharge Locations

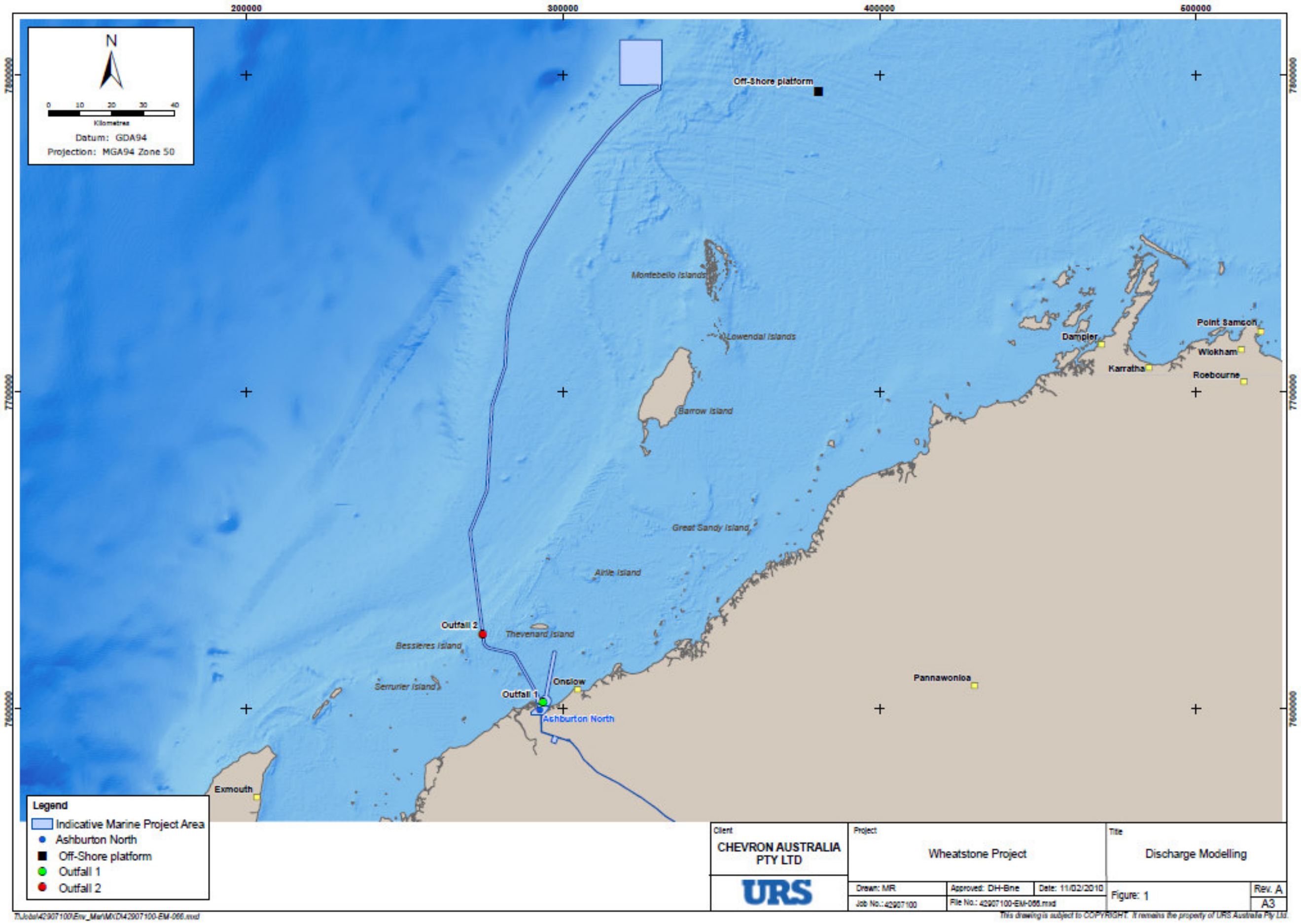
Figure 2-1 and Figure 2-2 show the location of the discharge outlets associated with the onshore LNG facility (Outlet 1 and Outlet 2) and the Wheatstone Platform located approximately 145 km offshore

Within the nearshore environment, Outlet 1 and Outlet 2 are located at approximately -5 m chart datum (CD) and -20 m CD in marine water, respectively. Due to the gradual slope of the seafloor, Outlet 2 is located approximately 20 km offshore. The Wheatstone Platform is located within 73 m of water depth (Table 2-1).

Table 2-1 Discharge Locations

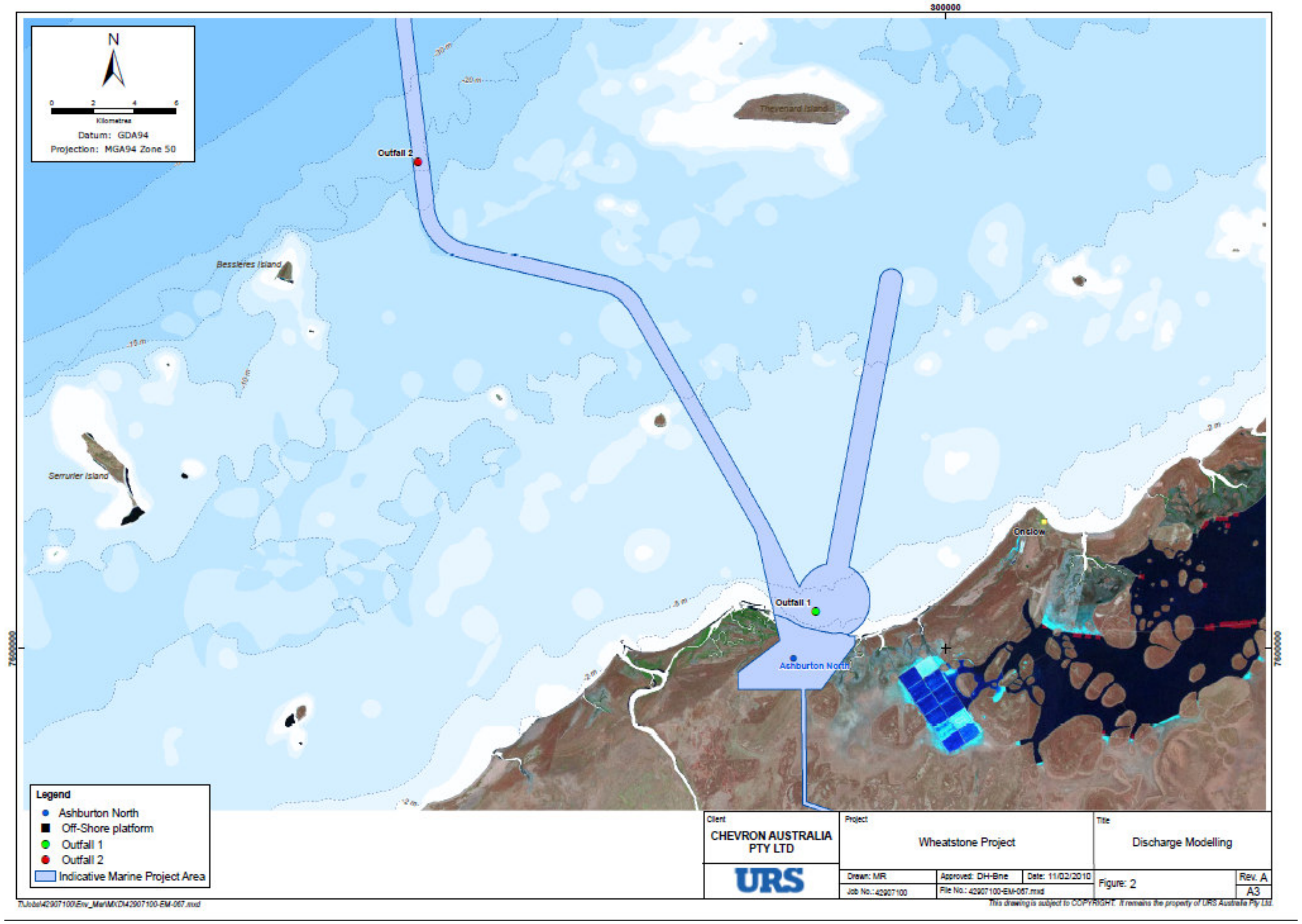
Parameter	Outfall 1	Outfall 2	Offshore platform
Location	293,754 E, 7,601,736 N	274,621 E, 7,623,332 N	380,860 E, 7,795,000 N
Depth of water column	5	20	73

Figure 2-1 Discharge Locations



2 Discharge Scenarios

Figure 2-2 Close up of Discharge Locations



2.2 Nearshore Discharge Scenarios

As noted in Section 2.1, there are two Outlet locations associated with discharges to the marine environment in the nearshore environment.

From Outlet 1 located along the Product Loading Facility (PLF), a number of different waste streams will be continuously co-discharged including treated sanitary wastewater, treated process wastewater, treated contact storm water, desalination filter plant brine, and desalination reverse osmosis plant brine. The characteristics of the co-mingled discharge will vary with the ratio of the input streams.

Treated produced water (PW) will be continuously discharged from Outlet 2. The characteristics of the PW discharge will be more consistent than the discharge from Outlet 1.

This section presents the details of the nearshore discharges and the specifics of the discharge scenarios that have been considered for this assessment.

2.2.1 Scenario 1: Continuous Co-mingled Discharges from Outlet 1

The discharge of sanitary wastewater, process wastewater, contact stormwater, desalination filter plant brine and desalination plant reverse osmosis (RO) plant brine, is proposed to be co-discharged from the nearshore outlet located along the PLF in 5 m of water (Outlet 1,Figure 2-2). A total of three continuous discharge scenarios have been considered; representing peak volumes during the operational phase of the onshore facility (associated with heavy rainfall events and large percentage discharges of stormwater runoff), typical operational volumes of co-mingled discharges, and a discharge scenario associated with the construction phase of the Project.

Details of the discharge scenarios are presented in Table 2-2 and additional information relating to the characterisation of the co-mingled discharges is presented in Appendix A.

Table 2-2 Scenario 1: Co-mingled Discharge from Outlet 1

Parameter	**Units**	**Scenario 1A**	**Scenario 1B**	**Scenario 1C**
Description	-	Operational – maximum	Operational -typical	Construction
Discharge Streams	-	Sanitary wastewater, process wastewater, contact stormwater, desalination filter plant brine, Desalination RO Plant Brine	Sanitary wastewater, process wastewater, contact stormwater, desalination filter plant brine, Desalination RO Plant Brine	Sanitary wastewater, contact stormwater, Desalination RO Plant Brine
Depth	m	5	5	5
Temperature	C	ambient	ambient	ambient
Salinity	ppt	22.4$^{(1)}$	60.16$^{(1)}$	45.69$^{(1)}$
Density	kg/m^3	1013.88$^{(1)}$	1042.51$^{(1)}$	1031.41$^{(1)}$
Flow rate	m^3/hr	776	172	517

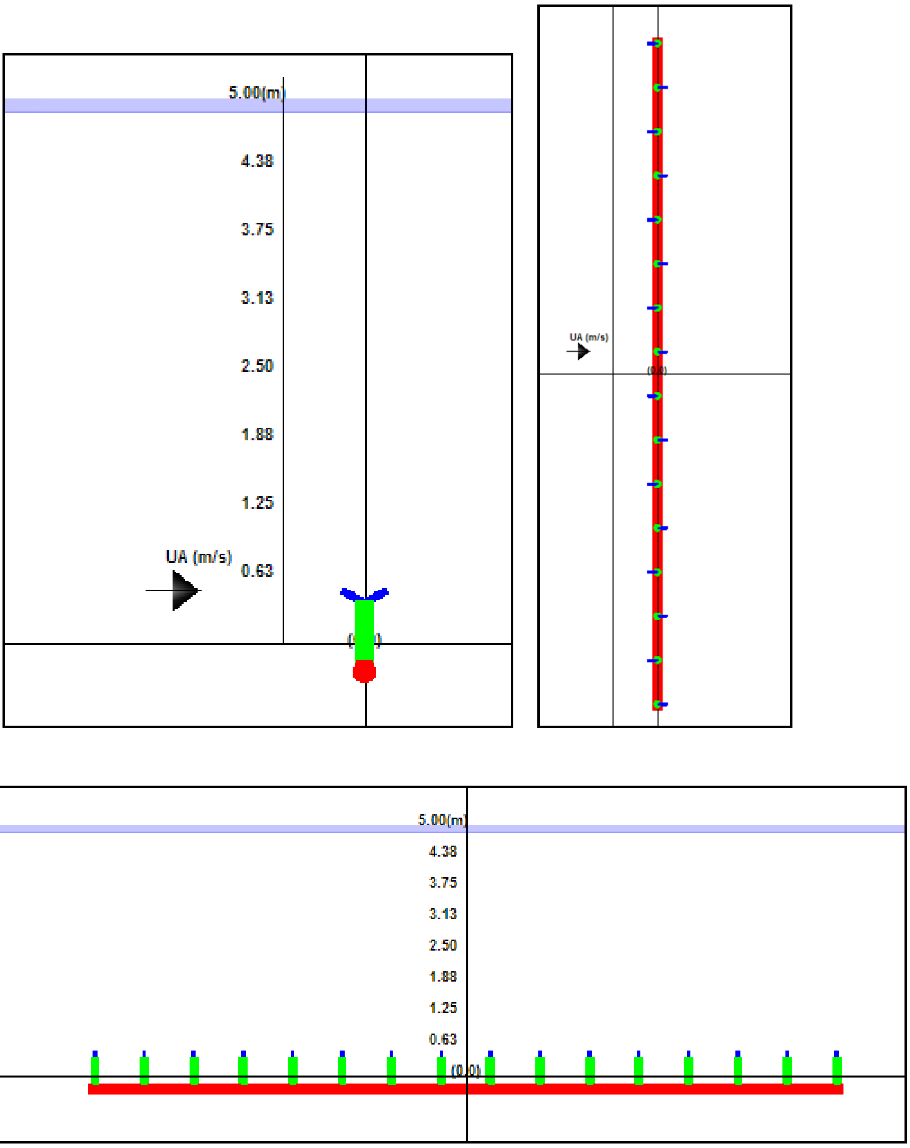
Note (1): Calculated based on an ambient temperature of 25°C

Based on the resultant densities and ambient water characteristics, it is expected that the discharge for Scenario 1A will be positively buoyant, and tend to rise to the water surface. The discharges for Scenario 1B and 1C will be negatively buoyant and initially remain near sea floor.

2 Discharge Scenarios

The discharge outlet is proposed to be fitted with a diffuser designed to optimise the dilution of the discharge within the marine environment. Details of the proposed diffuser are summarised in Table 2-3 and depicted in Figure 2-3.

Figure 2-3 Diffuser Configuration: (A) Top left, side view (B) Top right, top view, (C) Side view with diffuser perpendicular to coastline



2 Discharge Scenarios

Table 2-3 Diffuser Design Characteristics

Parameter	Units	Value
Design volume	m^3/hr	331(1)
Pipeline diameter	mm	254(1)
Port diameter	mm	76.2(1)
Number of ports	-	16(1)
Port arrangement	-	alternating without fanning(1)
Port type	-	Sharp edge(1)
Diffuser length	m	15(1)
Diffuser type	-	Alternating perpendicular(1)
Length of port	m	0.5(2)
Angle of outlets	degrees	30(2)

Note (1) Based on information provided by Bechtel

(2) Assumed for the purposes of this assessment.

2.2.2 Scenario 2: Discharge of Produced Water from Outlet 2

Outlet 2 (Figure 2-2) is associated with the continuous discharge of PW from the onshore facility. At the time of this assessment, source and detailed characterisation of the PW was not available. The discharge scenario is summarised in Table 2-4 and was developed based on characteristics of the PW that will be discharged from the offshore platform (Scenario 3, Section 2.3.1).

A diffuser has been proposed for use at Outlet 2. As details of the diffuser design are yet to be finalised, for this assessment, a diffuser similar that that described in Section 2.2.1 was assumed. In order to satisfy the near field model design criteria (Appendix C), it has been assumed that the diffuser for Outlet 2 is 20 m in length. All other diffuser design characteristics applied to Outlet 2 are as summarised in Table 2-3.

Table 2-4 Scenario 2: Discharge of Produced Water from Outlet 2

Parameter	Units	Scenario 2A
Description	-	Operational phase, continuous discharge
Discharge Streams	-	PW
Depth	m	20
Temperature	C	Ambient + 30
Salinity	ppt	17(1)
Density	kg/m^3	998.19(2)
Flow rate	m^3/hr	552

Note (1): Assumed based on salinity characteristics of Iago (conservative).

(2): Calculated based on an ambient temperature of 25°C Based on the discharge densities and ambient water characteristics, it is expected that the discharge for Scenario 2 will be positively buoyant, and tend to rise to the water surface.

2.3 OffShore Discharge Scenarios

Three discharge types have been assessed: the continuous discharge of PW, the continuous discharge of CW and the batch discharge of monoethylene glycol (MEG). The primary focus of the assessment is on the PW and MEG discharges. The co-mingled discharge of PW or PW/MEG with the CW stream has been investigated as mitigation options for the PW and the PW/MEG discharge streams. The details of the discharge scenarios are presented in the following sections.

2.3.1 Scenario 3: Continuous Discharge of Produced Water from the Wheatstone Platform

The discharge of PW at the Wheatstone Platform is proposed to occur continuously at a rate of approximately 6.36 ML (40,000 barrels) per day. Six PW discharge scenarios have been investigated for worst-case dilutions associated with the discharge of PW in isolation and in combination with the discharge of CW. CW is proposed to be discharged continuously at a rate of approximately 238 GL (1.5 million barrels) per day.

Scenario 3A involves an isolated discharge of PW from a 1.5 m caisson with a discharge depth of 20 m.

Scenario 3B incorporates the continuous discharge of CW within the same caisson as the PW. The discharge will thus consist of co-mingled PW and CW which enters the marine environment at a depth of 20 m below the surface of the water column.

Scenario 3C is identical to Scenario 3B with the exception that the co-mingled PW/CW discharge is proposed to enter the marine environment at a depth of 40 m.

Scenario 3D, Scenario 3E and Scenario 3F incorporate segregated PW and CW discharge streams that are separated by a horizontal distance of 124 m. For these scenarios, the release of the CW and the PW occur at opposite corners of the platform. The dilution of the discharge streams are investigated for a PW release depth of 40 m (all three scenarios) and a release depth of CW of either 20 m (Scenario 3D) or 40 m (Scenario 3E and Scenario 3F). In order to maximise the path length between the two discharges, Scenario 3F incorporates a PW discharge pipe that is oriented at an angle of 45° below horizontal and directed away from the CW outlet.

Details of the discharge scenarios are summarised in Table 2-5. In all cases, the discharges associated with Scenario 3 are positively buoyant.

Table 2-5 Scenario 3: Discharge of Produced Water

Parameter	Units	Scenario 3A	Scenario 3B	Scenario 3C	Scenario 3D	Scenario 3E	Scenario 3F
Description	-	Operational phase, continuous discharge	Operational phase, continuous discharge	Operational phase, continuous discharge	Operational phase, continuous discharge	Operational phase, continuous discharge	Operational phase, continuous discharge
Discharge Streams	-	PW	Co-mingled PW and CW	Co-mingled PW and CW	Separated PW and CW streams	Separated PW and CW streams	Separated PW and CW streams
Pipe Diameter	m	1.5	1.5	1.5	PW 0.305 CW 1.5	PW 0.305 CW 1.5	PW 0.305 at 45°(2) CW 1.5
Depth	m	73	20	40	PW 40 CW 20	PW 40 CW 40	PW 40 CW 40
Temperature	C	75	45.8	45.8	PW 75 CW 45	PW 75 CW 45	PW 75 CW 45
Density	kg/m^3	963(1)	1012	1012	PW 963 @ 75 CW 1013 @ 45	PW 963 @ 75 CW 1013 @ 45	PW 963 @ 75 CW 1013 @ 45
Flow rate	m^3/hr	272	7788	7788	PW 208 CW 7580	PW 208 CW 7580	PW 208 CW 7580
Chlorine concentration	ppm	n/a	0.195	0.195	PW n/a CW 0.2	PW n/a CW 0.2	PW n/a CW 0.2

Note (1): Based on information provided by Chevron
(2) Angled downward from horizontal and away from CW discharge point

2.3.2 Scenario 4: Batch Discharge of MEG from the Wheatstone Platform

The discharge of MEG from the WP is proposed to occur approximately four times per year during start up events. Five discharge scenarios have been considered. Scenario A through Scenario D involve the discharge of a mixture of MEG and PW to the marine environment at 50°C for a period of 18 hours (Appendix B). The volume of MEG discharged each hour remains constant for a given scenario at between 20 m^3/hr and 150 m^3/hr. The volume of PW increases during the 18 hours from a flow rate of 0 m^3/hr to a maximum of between 36.3 m^3/hr and 272 m^3/hr depending on the scenario (Table 2-6). The co-mingled discharge stream of MEG and PW will be abbreviated as MEG/PW.

Due to the characteristics of the combined MEG and PW, this discharge stream (in isolation) is negatively buoyant for the 18 hours that MEG is contained within the discharge stream (Appendix B). Thus the MEG/PW (in isolation) will descend through the water column to the seafloor.

Alternatively, the discharge of MEG/PW may occur within the same caisson as the CW discharge. The combined discharges will be positively buoyant (Appendix B) and will rise to the surface of the water column once entering the marine environment. The co-mingled discharge of MEG/PW and cooling water (MEG/PW/CW) has also been assessed (Scenario E).

Additional information relating to these five discharge scenarios is provided in Appendix B.

2 Discharge Scenarios

Table 2-6 Scenario 4: Batch Discharge of MEG

Parameter	**Units**	**Scenario 4A**	**Scenario 4B**	**Scenario 4C**	**Scenario 4D**	**Scenario 4E**
Description	-	Combined MEG & PW	Combined MEG & PW	Combined MEG & PW	Combined MEG & PW	Combined MEG & PW & CW
Discharge Streams	-	384 & 484	384 & 484	384 & 484	384 & 484	384 & 484 & CW
Depth	m	73	73	73	73	73
Duration	hr	18	18	18	18	18
Temperature	C	50	50	50	50	50
Density	kg/m^3	Variable(1)	Variable(1)	Variable (1)	Variable (1)	Variable (1)
MEG flow rate	m^3/hr	20	50	150	100	100
PW flow rate	m^3/hr	Ramping from 0 to 36.3	Ramping from 0 to 90.7	Ramping from 0 to 272	Ramping from 0 to 272	Ramping from 0 to 272
CW flow rate	m^3/hr	-	-	-	-	8000
Note (1): Varies by hour depending on ratio of PW to MEG in solution. Refer to Appendix B.						

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Characterisation of the Ambient Environment

Detailed analysis of available ambient environmental data including both meteorological and marine data has been presented elsewhere in the EIS including, but not limited to:

- Chevron Australia (2010) Chapter 6
- DHI (2010): "Wheatstone Project. Dredge Spoil Modelling"
- GEMS (2010): Wheatstone Wind, Currents and Wave Verification and Analysis

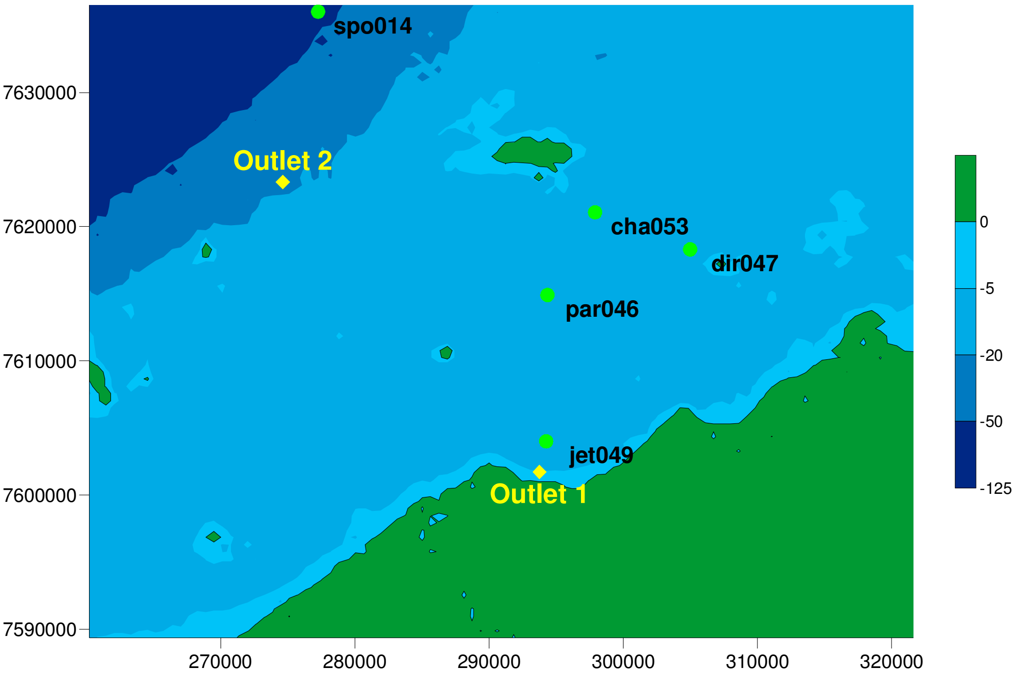
The following sections summarise the data that will be used in the near and/or far field modelling of the discharges to the marine environment.

Details of the analysis of observational data that has been undertaken for use in the development and calibration of the URS Dilution Model (Section 5.2) are provided in Appendix E

3.1 Nearshore Environment

Seawater temperature, salinity and current data from a number of nearshore locations (Figure 3-1) have been reviewed for the purposes of this assessment. Temperature data was available for the 46 day period 26/07/09 through 10/09/2009 at several locations, and the extended through month 11/01/09 and 16/04/09 at two locations (jet049 and spo014).

Figure 3-1 Location of Ambient Environment Sampling Locations



3 Characterisation of the Ambient Environment

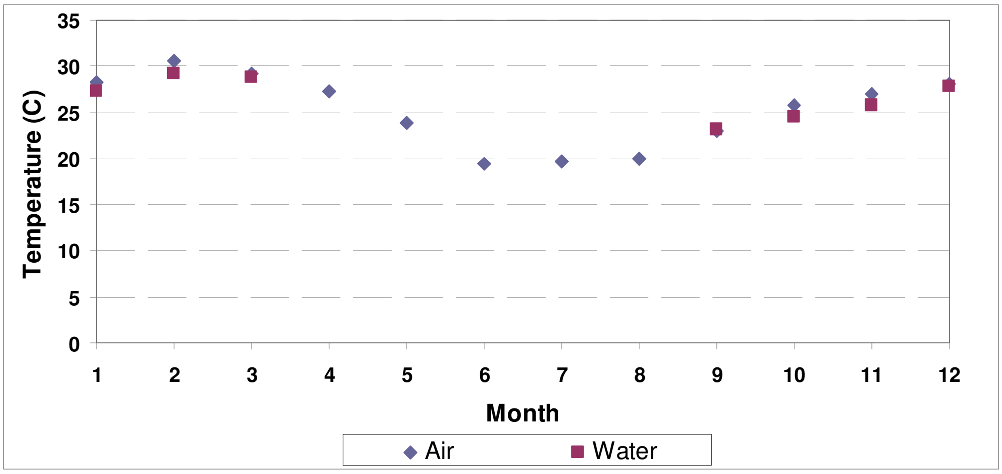
3.1.1 Bathymetry

As noted in Section 2.1, Outlet 1 and Outlet 2 are located within the nearshore environment at water depths of 5 m and 20 m respectively. The seafloor slopes gradually with Outlet 2 (at -20 m CD) located approximately 20 km from the shoreline (Figure 3-1).

3.1.2 Ambient Air and Seawater Temperature

In the absence of a additional seawater temperature data, data from the Onslow Meteorological Station was processed into monthly averaged ambient air temperature and compared with monthly averaged temperature measurements of seawater from jet049 (Figure 3-1). Results show good agreement between the monthly averaged air temperature and seawater temperature at these locations. Thus, when required, gaps in the seawater temperature were supplemented by the monthly averaged air temperature.

Figure 3-2 Comparison of Monthly Averaged Air and Seawater Temperature Data

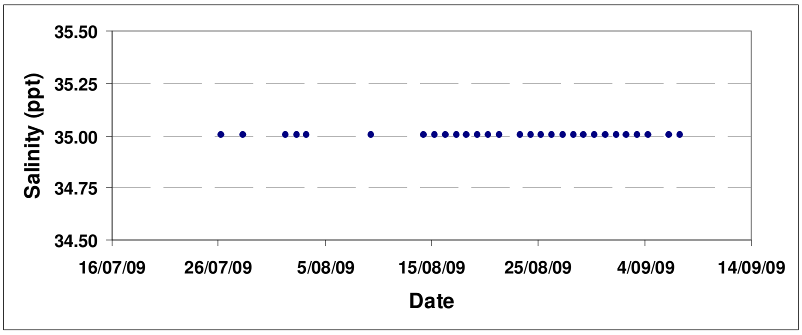


3.1.3 Salinity

In the absence of additional salinity data, salinity data at the jet049 location (Figure 3-1) the 46 day period 26/07/09 through 10/09/09 was used to characterize the salinity in the area. The data is shown in Figure 3-3 from which an ambient salinity of 35 ppt was adopted for this assessment.

3 Characterisation of the Ambient Environment

Figure 3-3 Salinity Data



3.1.4 Currents

The currents used for this assessment were extracted from the DHI developed MIKE21 hydrodynamic model that has been set-up for this area has been described in detail in *DHI Wheatstone Project Dredge Spoil Modelling (DHI 2010)*. A total of 12 months of hourly depth averaged currents (2007) were extracted from the model in the vicinity of Outlet 1 and Outlet 2.

Appendix C provides further details on the MIKE21 model set-up.

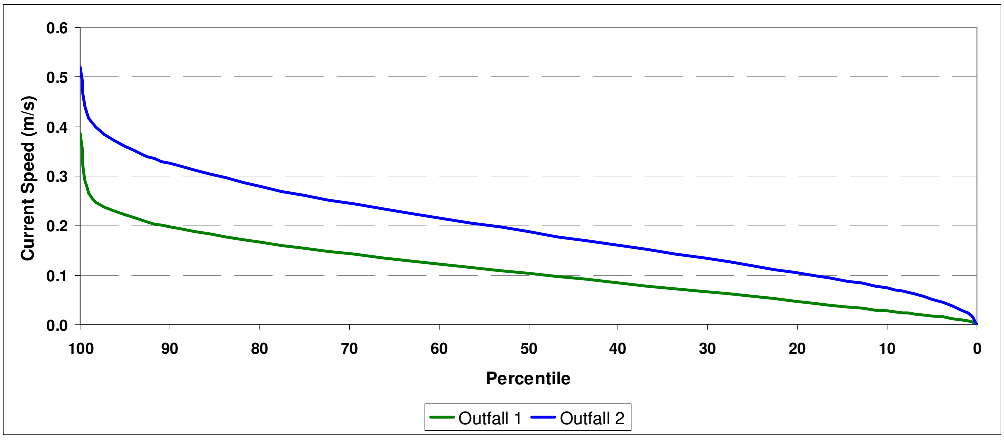
A summary of the depth averaged current speeds is presented in Table 3-1 and depicted in Figure 3-4. In general, the percentiles of current speeds at Outlet 1 are less than those for Outlet 2 with median current speeds of 10 cm/s and 19 cm/s respectively.

Table 3-1 Percentile Distribution of Depth Averaged Current Speeds (m/s) for Year 2007

Percentile	Outlet 1	Outlet 2
100	0.39	0.52
99	0.26	0.42
95	0.22	0.36
75	0.15	0.26
50	0.10	0.19
25	0.06	0.12
10	0.03	0.07
5	0.02	0.05

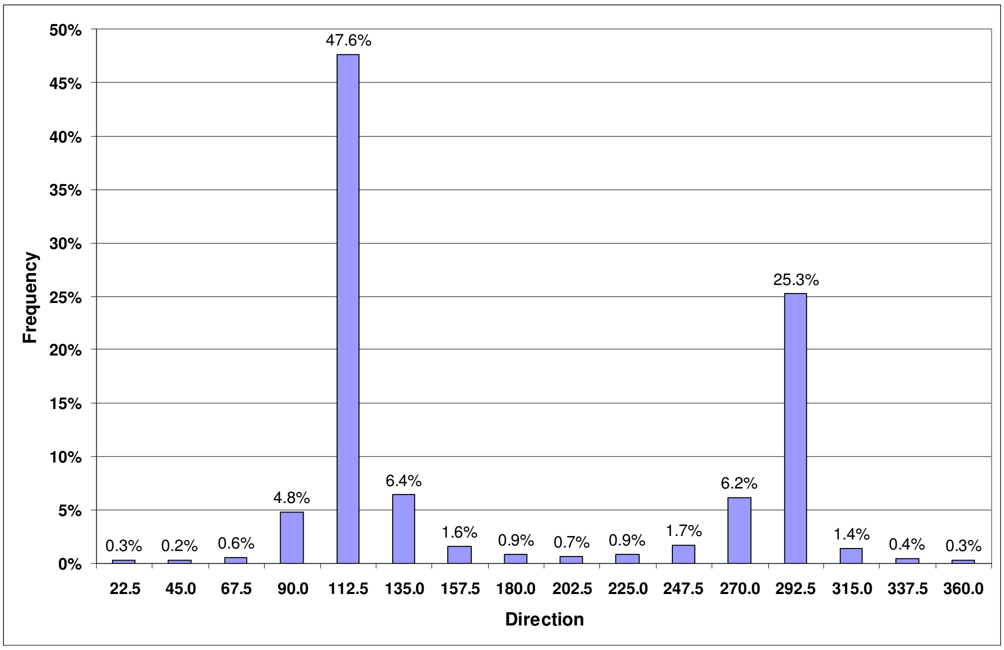
3 Characterisation of the Ambient Environment

Figure 3-4 Ranked Depth Averaged Current Speeds for Outlet 1 and Outlet 2, 2007



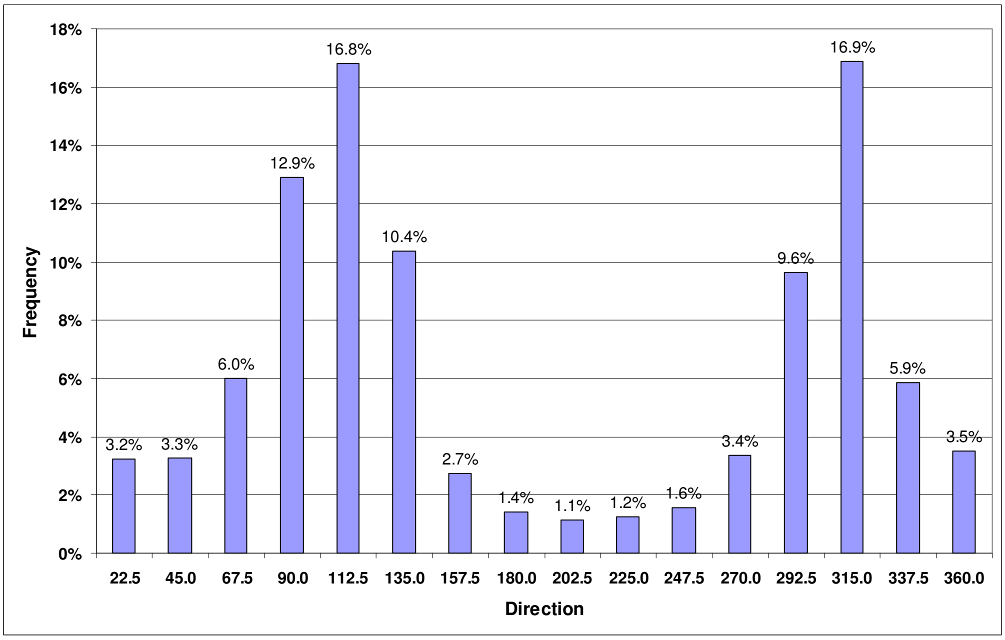
The longshore directionality of the current at Outlet 1 is highlighted in the direction frequency distribution plot of Figure 3-5 with increased variability in current direction associated with Outlet 2 located approximately 20 km offshore (Figure 3-6).

Figure 3-5 Outlet 1 Depth Averaged Current Direction Frequency Plot, 2007



3 Characterisation of the Ambient Environment

Figure 3-6 Outlet 2 Depth Averaged Current Direction Frequency Plot, 2007



3.2 Offshore Environment

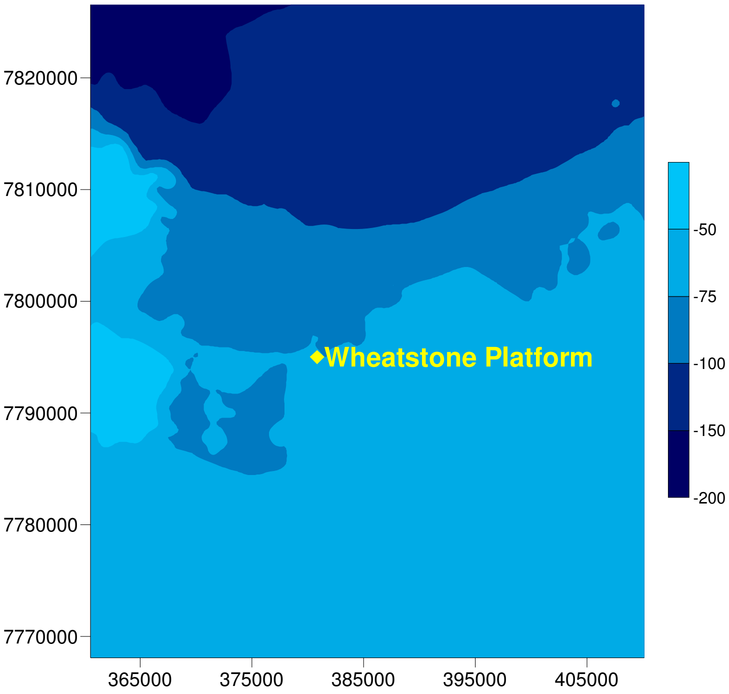
Limited data was available for the characterisation of the ambient environment in the vicinity of the Wheatstone Platform.

3.2.1 Bathymetry

As noted in Section 2.1, the Wheatstone Platform is to be located approximately 150 km off shore in water depth of 73 m (Figure 3-7).

3 Characterisation of the Ambient Environment

Figure 3-7 Bathymetry in the Vicinity of the Wheatstone Platform



3.2.2 Temperature

In the absence of additional information, for the purposes of this assessment, ambient temperatures were assumed to correspond to those of the nearshore environment.

3.2.3 Salinity

In the absence of additional information, for the purposes of this assessment, ambient salinity was assumed to be equal to 35 ppt for all months.

3.2.4 Currents

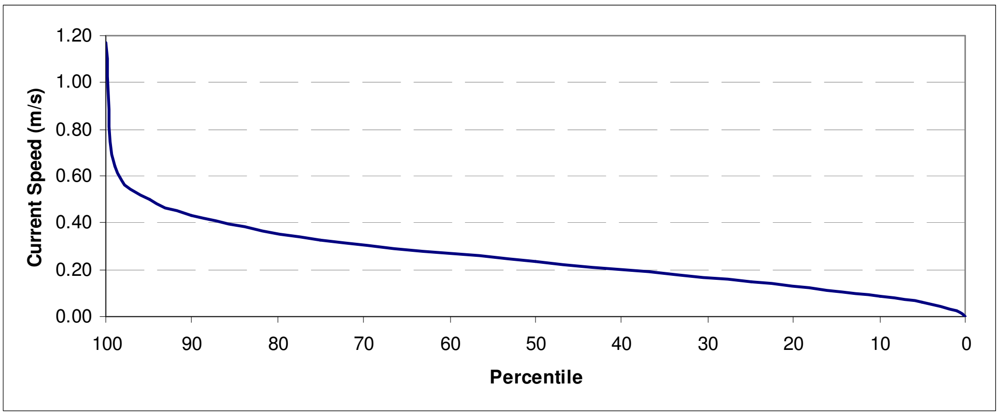
A total of 24 months of hourly depth averaged currents (2006-2007) in the vicinity of the platform were extracted from the 1215 m grid of the DHI two-dimensional hydrodynamic model MIKE21.

3 Characterisation of the Ambient Environment

Table 3-2 Percentile Distribution of Depth Averaged Current Speeds (m/s), 2006-2007

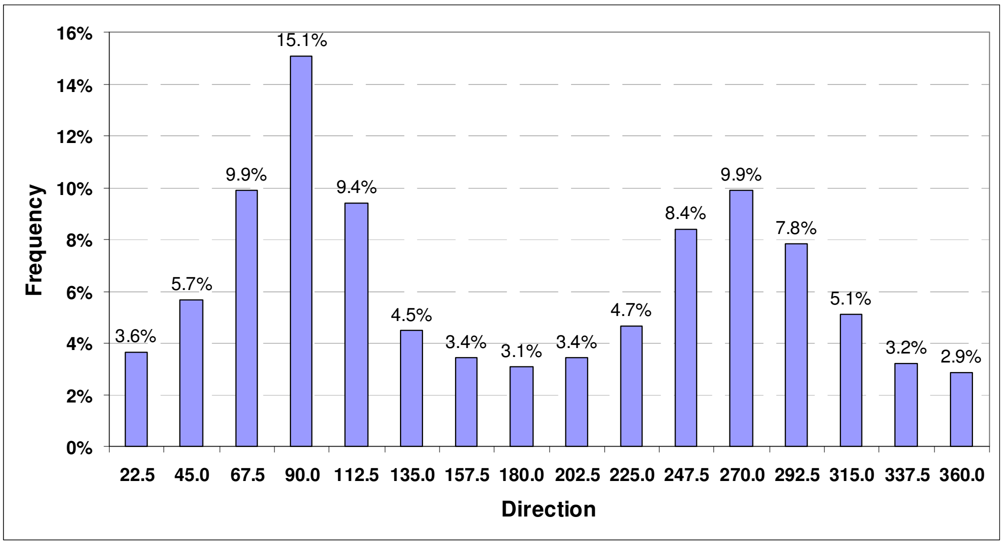
Percentile	Wheatstone Platform
100	1.17
99	0.65
95	0.50
75	0.33
50	0.23
25	0.15
10	0.09
5	0.06

Figure 3-8 Ranked Depth Averaged Current Speeds for Wheatstone Platform, 2006-2007



3 Characterisation of the Ambient Environment

Figure 3-9 Wheatstone Platform Depth Averaged Current Direction Frequency Plot, 2006-2007



Water Quality Criteria

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) established the water quality standard necessary to support the environmental values identified in the State Water Quality Management Strategy No.6 (Department of Environment 2004). These guidelines provide instructions for translating the desired environmental values into water quality management criteria and also provide a framework for assessing the risks of each pollutant in the proposed discharge and how it affects each environmental value.

Summarised in Table 4-1 are the adopted project-related water quality criteria.

The interpretation of the results of this assessment based on the project-goals has been considered elsewhere (Chevron Australia 2010, Appendix Q).

Table 4-1 Project Water Quality Criteria

Region	**Pollutant**	**Units**	**Objective**
Nearshore	Nitrogen(1)	µg/l	100
	Phosphorous(1)	µg/l	15
	PW(2)	-	1300 dilution
	Temperature excess	C	2
	Salinity excess/deficit	ppt	±5%
Off shore	MEG	mg/l	50
	Untreated PW(2)	-	1300 dilution
	Temperature excess	℃	<3
	Salinity excess/deficit	ppt	±5%
	Chlorine	ppb	3

Note(1): ANZECC Table 3.3.4 http://www.mincos.gov.au/__data/assets/pdf_file/0019/316126/wqg-ch3.pdf
(2): Pluto EIA http://www.woodside.com.au/Our+Business/Projects/Pluto/Sustainability/Environmental+Approval.htm

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Discharge Modelling Methodology

For this assessment a combination of models has been utilised including MIKE21, MIKE3D, CORMIX and a URS developed steady state dilution model based on the results of CORMIX.

Further details are presented in:

- Appendix C Dispersion Modelling Software
- Appendix D Development of the URS Dilution Model
- Appendix E Calibration of URS Plume Model Using Results of MIKE3D

5.1 CORMIX

The CORMIX modelling system is a software system for the analysis, prediction and design of pollutant discharges into diverse water bodies. The key focus of the assessment is on the geometry and dilution characteristics of the initial mixing zone, including compliance with regulatory constraints as well as predicting the behaviour of the discharge plume with distance from the diffuser. CORMIX consists of a series of software modules for the prediction of discharges into receiving waters, with emphasis on steady-state values for the geometry and dilution characteristics. The collection of modules consist of regional flow models based upon integral, length scale, and passive diffusion approaches to simulate the hydrodynamics of near field and far field jets and plumes (Doneker and Jirka, 2007). The CORMIX modelling system consists of four integrated hydrodynamic models:

- CORMIX 1 for single port discharges.
- CORMIX 2 for multi-port diffuser discharges.
- CORMIX 3 for buoyant surface discharges.
- DHYDRO for the analysis of dense and/or sediment discharges in coastal environments.

CORMIX predicts the geometry and dilution characteristics of effluent flow resulting from a single or multi-port discharge or arbitrary density, location, and geometry into an ambient receiving water body that may be stagnant or flowing and have ambient density stratification of different types. The plume is assumed to be at steady state, which means that successive elements follow the same trajectory. Predictions include dilution, plume diameter, plume elevation, and other plume properties. Once the effluent plume surfaces, the far field solution calculates dilution due to horizontal turbulent mixing of the plume with ambient water.

Appendix C provides details of the CORMIX model set-up for the different discharge scenarios.

5.2 URS Dilution Model

The URS Dilution Model was developed specifically for this project and intended to be used to extend short period 3D far field model simulations of discharge impacts to represent long-term conditions. The URS Dilution Model requires less than one minute of computer processing to simulate a two year time period, and could therefore provide long-term ‘worst case’ conditions for each discharge that are not feasible within this project deliverable using detailed 3D transport models.

The URS Dilution Model is an extension of the steady-state CORMIX dilution model to account for unsteady currents for year-long time periods.

The adjustments to the CORMIX model predictions are made to account for the effects of unsteady currents on:

- plume duration and direction

- plume dispersion
- build-up of background concentration

Appendix D provides details about the development of the URS Dilution Model and Appendix E details of the calibration of the model using results from MIKE3D.

5.3 Limitations of the Dilution Modelling

General Limitations

Modelling of complex physical systems is based on the use of numerical techniques to solve a set of governing equations. In general, the more complicated the system that is modelled, the more parameterisations (or approximations) that are required in order to solve these equations; particularly in relation to the representation of sub-grid scale processes. Thus, there are inherently a number of 'tuneable' parameters that are required as input into the models. Model developers often suggest default values for these parameters which may be based on observational data, laboratory experiments or professional experience. Depending on the scale of the project, assessing the sensitivity of model results to input data and/or the value of tuneable parameters can be prohibitive, either in terms of computational requirements, timeframes for completion of the assessment, and/or budget constraints.

Model validation is a critical component to both model development and application. Rarely, however, does a suitable data set exist with which to conduct a detailed, statistically meaningful model validation study.

Another challenge facing the dilution modeller is the uncertainty in relation to the preciseness and representativeness of input data combined with limited observational data, which are key factors contributing to the lack of comprehensive model validation studies for the majority of dilution/dispersion assessments.

CORMIX Assumptions and Limitations

Dispersion of the discharges associated with the Wheatstone Project was modelled using CORMIX, which has been widely used elsewhere for near field modelling studies. These models describe the dispersion of pollutants on timescale from minutes to hours after discharge from the diffuser.

However, CORMIX is based upon a number of assumptions that need to be considered when interpreting the data from the model including (but not limited to):

- CORMIX is a simplified simulation of a complex process. It is most robust in simulation of the initial mixing of a plume. The model calculates far field dispersion based on depth specified data at a single port, and as such cannot capture circulation or ambient conditions that change with distance from the diffuser.
- In general, it is recommended that the dilution and path predictions provided by CORMIX should only be treated with confidence within approximately 100 m from the diffuser. While dilutions at greater distances can be obtained using the model, these should be treated as indicative only.
- CORMIX assumes that the area available for dilution is unconstrained by changing bathymetry. This assumption may be a significant simplification of the true environment.
- CORMIX does not cope well with a "bottom hit" of the plume. In reality, a bottom hit will also constrain the entrainment into the plume, and should result in decreased rate of dilution.

- For a diffuser that incorporates alternating outlet designs, CORMIX assumes that the discharge is adequately represented by the average angle which is typically equivalent to a vertically upwards release of effluent to the receiving environment.

URS Dilution Model Limitations

The URS Dispersion Model has been developed to estimate the dilution of a conservative tracer within a homogenous marine environment. It has been calibrated against DHI MIKE3D simulations for scenarios representing a two-week period in each of summer and winter (Appendix E).

The URS Dilution Model is based on the steady state solutions of CORMIX and has been calibrated against output from MIKE21 and MIKE3D. Thus the inherent limitations associated with CORMIX, MIKE21 (Appendix C, DHI (2009)) and MIKE3D (Appendix C) will apply to the URS Dilution Model well.

Project-Specific Limitations

This assessment relies on the completeness, accuracy and/or representativeness of a number of input data sets including:

- Project information including (but not limited to):
    - Representativeness of the discharge scenarios
    - Characterisation of the discharges
    - Diffuser design
- Client supplied data including (but not limited to):
    - Bathymetry
    - Current
    - Temperature, salinity
    - Wind fields
- Non site-specific default parameters used in the modelling including (but not limited to):
    - Manning number
    - Background accumulation
    - 2D dispersion coefficients
    - 3D eddy viscosity coefficients

Other limitations of the assessment include (but may not be limited to):

- The accuracy of the characterisation of the ambient environment; and
- The sensitivity of the dilution modelling results to tuneable model input parameters.

5.4 Interpretation of Results

When reviewing contour plots from the URS Dilution Model or dispersion results from MIKE21 and MIKE3D it is important to interpret the results presented in the context of the limitations outlined in the previous section. In particular, those associated with validating the relevance and applicability of both the model input data sets and model output which may have a significant impact on the accuracy of the results presented.

5 Discharge Modelling Methodology

It is noted that the presentation of CORMIX results within the tables are reported to include several significant figures. However, this suggests a level of accuracy of model predictions which is not realisable, nor verifiable. Quantifying the uncertainty in the results presented is in general, not undertaken for the reasons discussed in Section 5.3.

It should be noted that software graphics packages such as SURFER, which has been used in this assessment to develop the dilution contour plots, involve the interpolation of results onto the contour grid and will therefore be associated with some degree of spatial uncertainty. Results presented in tabular form are extracted directly from model output and are thus a better representation of predicted dilutions.

Finally, it is important to note that the results presented in the form of a contour plot for the maximum dilution (concentration, etc), represents a composite of the maximum dilution for the period under consideration at each location on the grid (regardless of when it occurred) and does not represent a ‘snapshot’ in time.

Nearshore Discharges – Co-mingled and Produced Water

This section presents the findings of the dispersion modelling of the nearshore discharges using CORMIX and/or the URS Dilution Model described in Section 5 and presented in detail in Appendix C and Appendix D.

6.1 Discharge Scenario 1A: Co-mingled Discharge (Operational Phase)

Table 2-2 showed that scenario 1A represents the co-mingled discharge of a number of streams (sanitary waste water, process wastewater, contact stormwater, and brine) and is associated with maximum flow volume conditions (776 m^3/hr) during the operational phase of the project at a depth of -5 m CD. The discharge stream will be released into the marine environment at ambient temperature but is buoyant relative to the marine environment due to the high volume of stormwater runoff. The outlet is proposed to be fitted with a diffuser with characteristics as outlined in Section 2.2.1

Table 3-1 showed that the depth averaged current speeds for 2007 at the location of outlet 1 ranged from 3 cm/s (10th percentile) to 22 cm/s (95th percentile) with a top speed of 39 cm/s (Table 6-1).

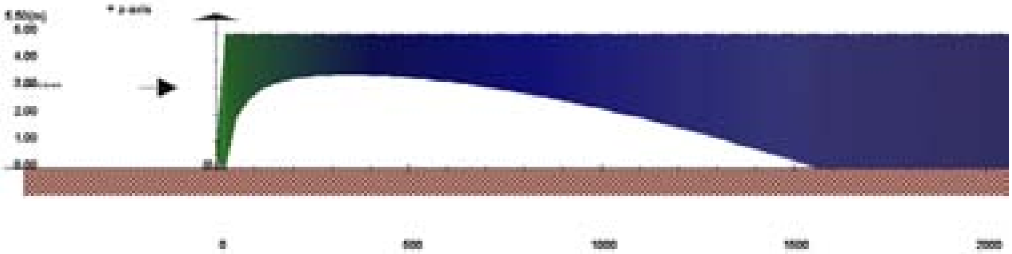
Table 6-1 Outlet 1 Depth Averaged Current Speeds, MIKE21 2007

Percentile	Speed (m/s)
100	0.39
95	0.22
75	0.15
50	0.10
25	0.06
10	0.03
5	0.02

Figure 6-1 shows an example of plume development downstream of the diffuser, based on results of CORMIX for a uniform current speed of 20 cm/s. Results for Scenario 1A (for all current speeds) suggests that initial mixing of the discharge over the 5 m water column occurs rapidly. However, the density of the combined discharge with the ambient environment results in a marine mixture that is less dense than the far field ambient environment and the plume is predicted to begin to rise to the surface at a distance of approximately 25 m downstream of the diffuser, Continued mixing as the plume propagates downstream leads eventually to a uniformly mixed 5 m layer, with the downstream distance to return to a state that is uniformly mixed over the water column dependent on the ambient current speed.

6 Nearshore Discharges – Co-mingled and Produced Water

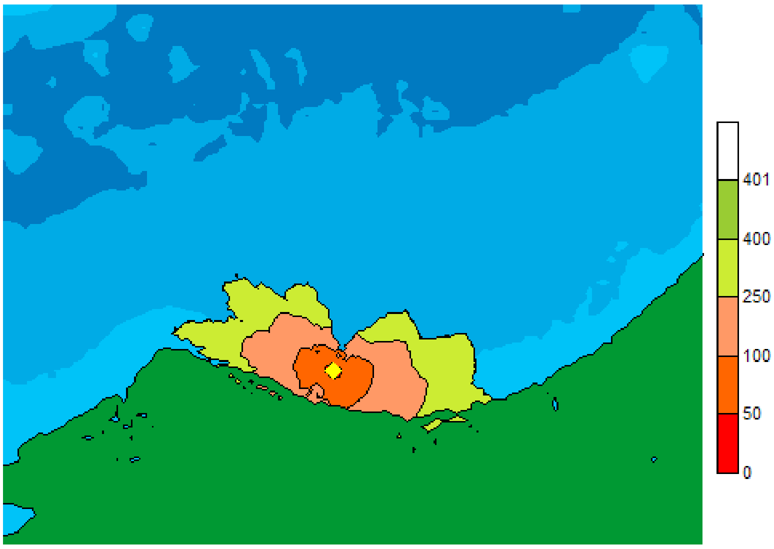
Figure 6-1 Scenario 1A: Side view of plume development downstream (m) of the diffuser (current speed of 20 cm/s)



A contour plot of the results from the URS Dilution Model is presented in Figure 6-2 for 2007.

The worst-case dilution as a function of distance from the diffuser is depicted in Figure 6-3 and for the near field in Figure 6-4. Results suggest that the dilution of the plume occurs gradually with dilutions of less than 600 occurring at distances of over 5 km downstream. Results of the modelling (Appendix E) do not suggest significant build up of pollutants in this area, however, the continuous discharge of materials combined with the limited water depth inhibit rapid dilution of the plume.

Figure 6-2 Scenario 1A: Results from the Dilution Model, 2007[1]



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[1] Note that the results presented in the figure represent a composite of the maximum dilution at each location on the grid (regardless of when it occurred) for the one year period and are not representative of a snap shot in time.

6 Nearshore Discharges – Co-mingled and Produced Water

Figure 6-3 Scenario 1A: Worst Case Dilution with Distance from the Outlet, 2007

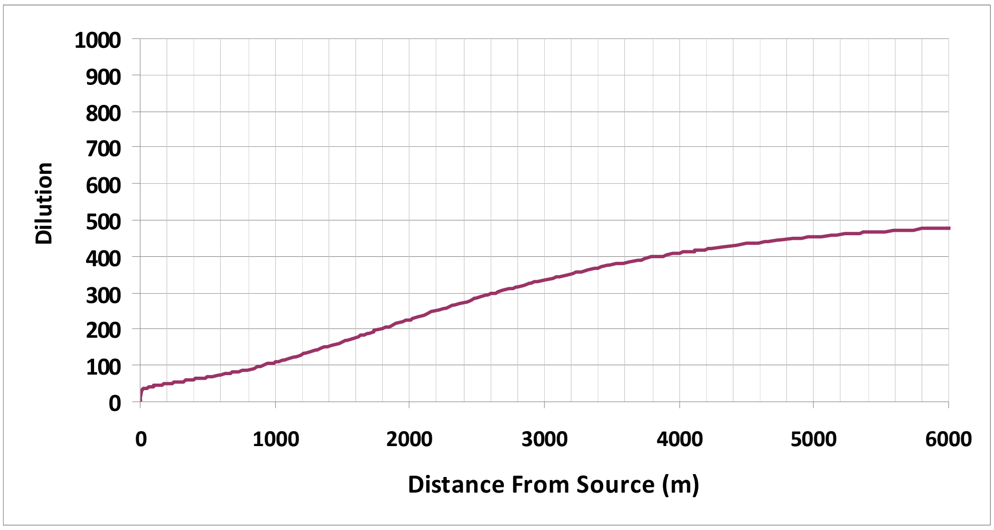
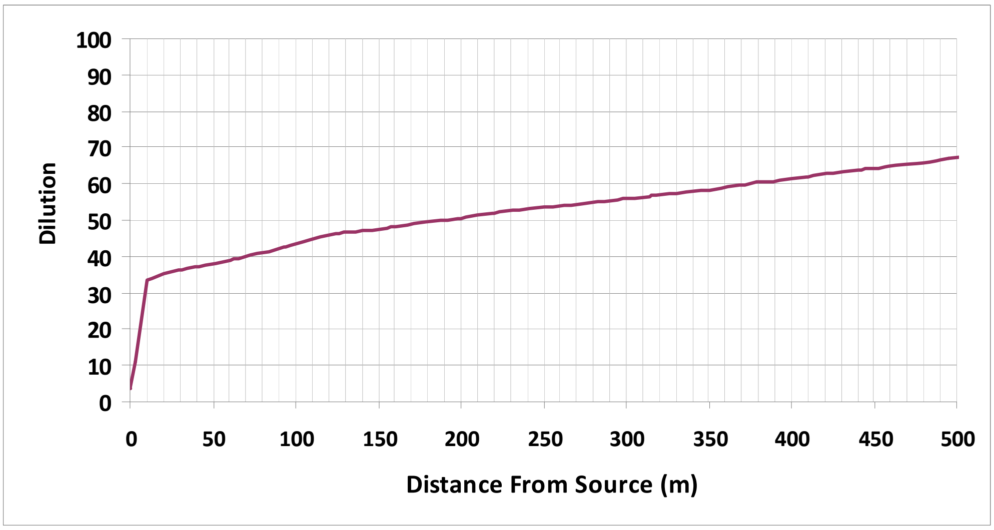


Figure 6-4 Scenario 1A: Near Field Worst Case Dilution with Distance from the Outlet, 2007



6.2 Discharge Scenario 1B: Co-mingled Discharge (Operational Phase)

Scenario 1B is associated with a co-mingled discharge of sanitary waste water, process wastewater, contact stormwater, and brine which is discharged into the marine environment at a rate of 172 m^3/hr and a depth of -5 m CD. In contrast to the Scenario 1 discharge, Scenario 2 is associated with a negatively buoyant discharge plume whose tendency is to descend within the water column to the seafloor.

Momentum associated with the diffuser leads initially to a well mixed water column in the vicinity of the diffuser. However, as was the case for Scenario 1, the combined marine mixture of the initial discharge and the ambient environment is predicted by CORMIX to lead to a plume which is still negatively buoyant when compared with the far field marine environment and will descend within the water column as depicted in Figure 6-5. The extent of the descent and the distance downstream for which uniform mixing over the entire water column occurs depends on the ambient current velocity.

Figure 6-5 Scenario 1B: Side view of plume development downstream (m) of the diffuser (current speed of 20 cm/s

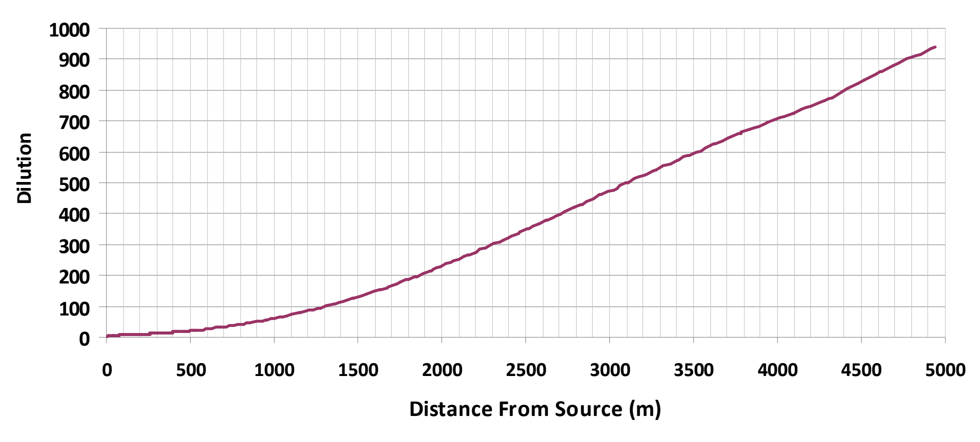
A contour plot of the results from the URS Dilution Model is presented in Figure 6-6 for 2007.

The worst-case dilution as a function of distance from the diffuser is depicted in Figure 6-7 and for the near field in Figure 6-8. Results suggest that the dilution of the plume occurs more rapidly than was found for Scenario 1. Dilution is still predicted to occur gradually, however, with limited water depth playing a significant role in inhibiting dilution in this area.

6 Nearshore Discharges – Co-mingled and Produced Water

Figure 6-6 Scenario 1B: Results from the Dilution Model, 2007[2]

Figure 6-7 Scenario 1B: Worst Case Dilution with Distance from the Outlet, 2007



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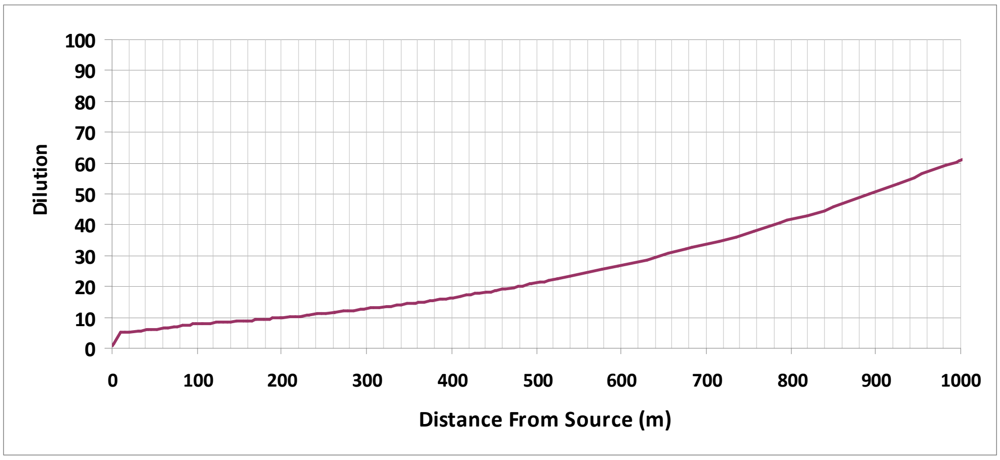
[2] Note that the results presented in the figure represent a composite of the maximum dilution at each location on the grid (regardless of when it occurred) for the one year period and are not representative of a snap shot in time.

6 Nearshore Discharges – Co-mingled and Produced Water

Figure 6-8 Scenario 1B: Near Field Worst Case Dilution with Distance from the Outlet, 2007



6.3 Discharge Scenario 1C: Co-mingled Discharge (Construction Phase)

Scenario 1C focuses on the impact of co-mingled discharges (sanitary waste water, contact stormwater, brine) from Outlet 1 associated with the Construction phase of the project. The discharges will enter the marine environment at a rate of 517 m^3/hr and a depth of -5 m CD. Based on the properties of the co-mingled discharge (Appendix A), the plume is less buoyant than the surrounding marine environment. The diffuser will ensure that the discharge is mixed over the vertical extent of the water column within a short distance of the discharge outlets. However, as was found in the previous scenarios, the resultant mixture will still be denser than the far field ambient environment. Results from CORMIX suggest that a situation similar to that depicted in Figure 6-5 is likely to occur in which the plume becomes isolated within the lower portion of the water column, before being entrained to form a well-mixed layer further downstream.

Presented in Figure 6-9 is a contour plot of dilution based on the results of the URS Dilution Model for 2007. Presented in Figure 6-10 is the worst-case dilution for 2007 with a close up of the near field region presented in Figure 6-11. Results are similar to that found for Scenario 1A and Scenario 1B with dilution occurring gradually with distance from the discharge point.

6 Nearshore Discharges – Co-mingled and Produced Water

Figure 6-9 Scenario 1C: Results from the Dilution Model, 2007[3]

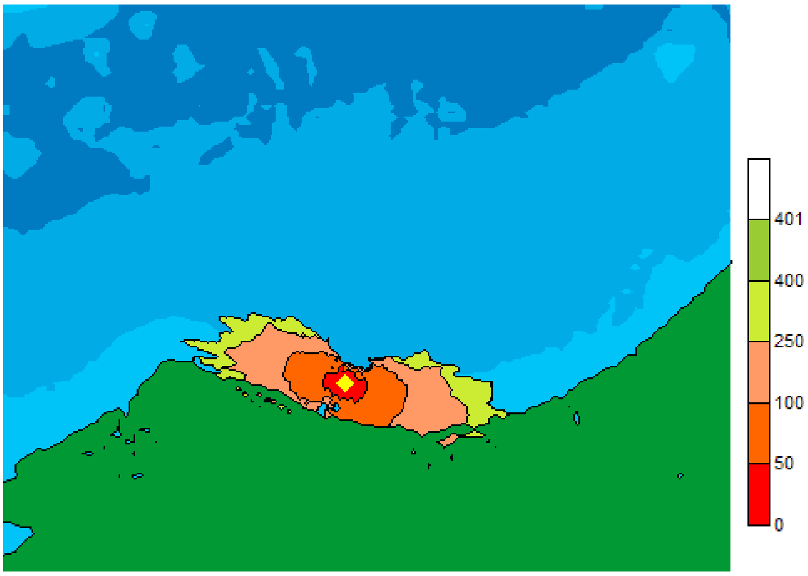
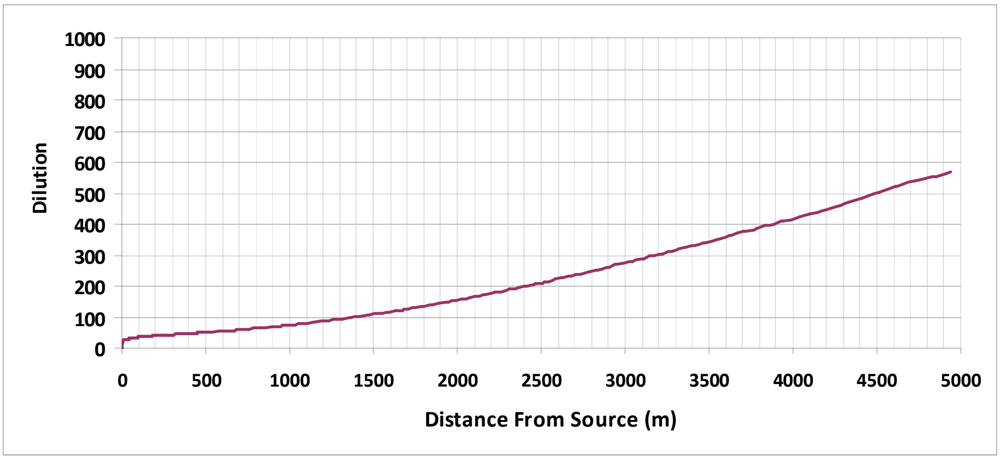


Figure 6-10 Scenario 1C: Worst Case Dilution with Distance from the Outlet, 2007



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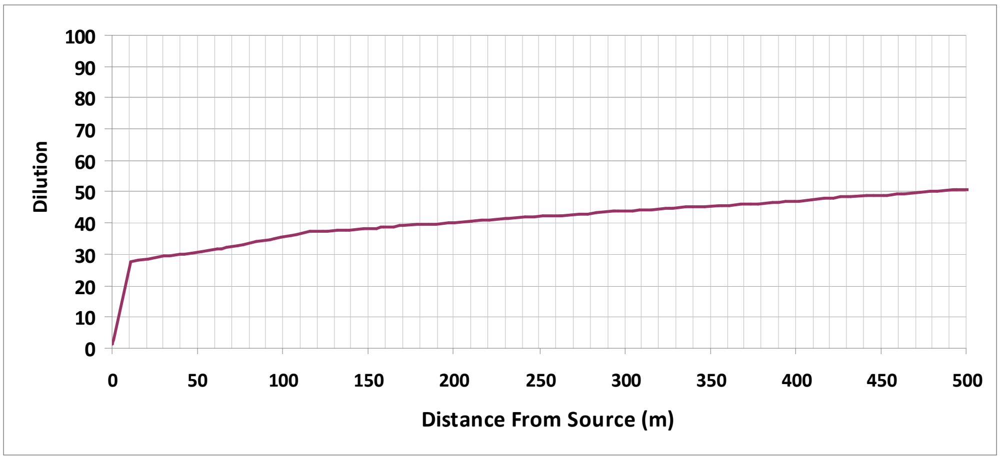
[3] Note that the results presented in the figure represent a composite of the maximum dilution at each location on the grid (regardless of when it occurred) for the one year period and are not representative of a snap shot in time.

6 Nearshore Discharges – Co-mingled and Produced Water

Figure 6-11 Scenario 1C: Near Field Worst Case Dilution with Distance from the Outlet, 2007



6.4 Discharge Scenario 2: Produced Water

Scenario 2 involves the discharge of PW at a rate of 552 m^3/hr from Outlet 2 located approximately 20 km off shore in –20 m CD of water and equipped with a diffuser to accelerate the dispersion of the plume in the near field.

Table 6-2 Percentile Distribution of Depth Averaged Current Speeds (m/s), MIKE21 2007

Percentile	Speed
100	0.52
95	0.36
75	0.26
50	0.19
25	0.12
10	0.07
5	0.05

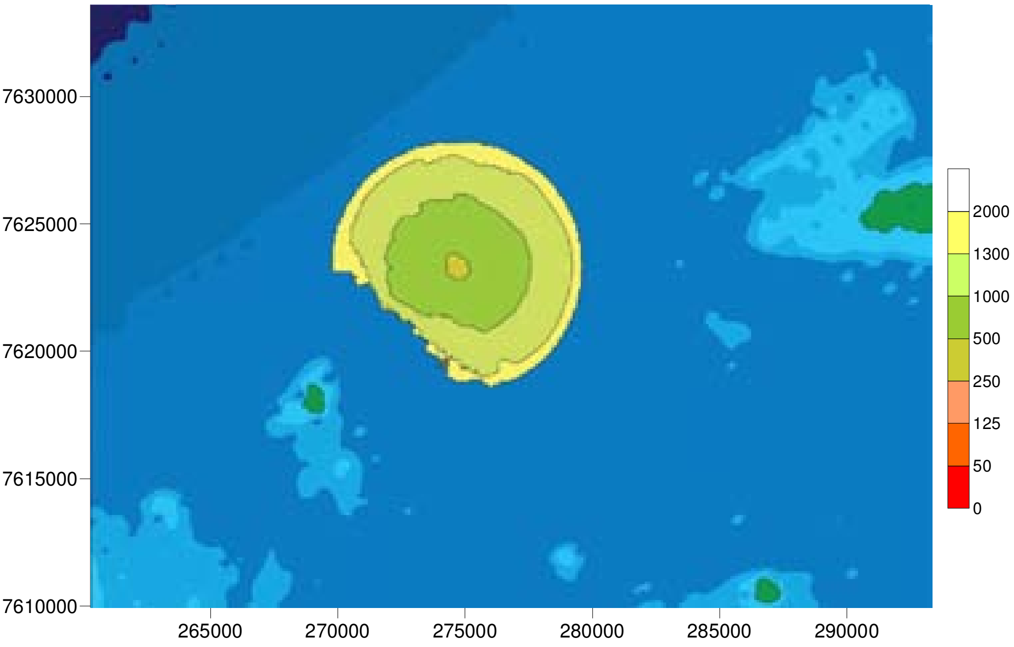
The plume of PW is buoyant relative to the marine environment and although initially mixed to the depth of the water column, similar to Scenario 1, the plume is predicted by CORMIX to be distinguishable from the ambient marine environment and rise to the surface of the water column (Figure 6-12). For the case of an ambient current velocity of 20 cm/s, the plume is predicted to be well mixed through the depth of the water column at a distance greater than 4 km from the outlet.

6 Nearshore Discharges – Co-mingled and Produced Water

Figure 6-12 Scenario 2: Side view of plume development downstream (m) of the diffuser (current speed of 30 cm/s

Presented in Figure 6-13 is a contour plot of the dilution for 2007 based on results from the URS Dilution Model. Figure 6-14 presents the worst-case dilution transect, with results depicted in Figure 6-15 for the near field region. Dilutions of approximately 400 are predicted within 120 meters from the discharge. Dilutions of 1300 are predicted to occur at distances of over 4 km from the discharge outlet.

Figure 6-13 Scenario 2: Results from the Dilution Model, 2007[4]



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[4] Note that the results presented in the figure represent a composite of the maximum dilution at each location on the grid (regardless of when it occurred) for the one year period and are not representative of a snap shot in time.

6 Nearshore Discharges – Co-mingled and Produced Water

Figure 6-14 Scenario 2: Worst Case Dilution with Distance from the Outlet, 2007

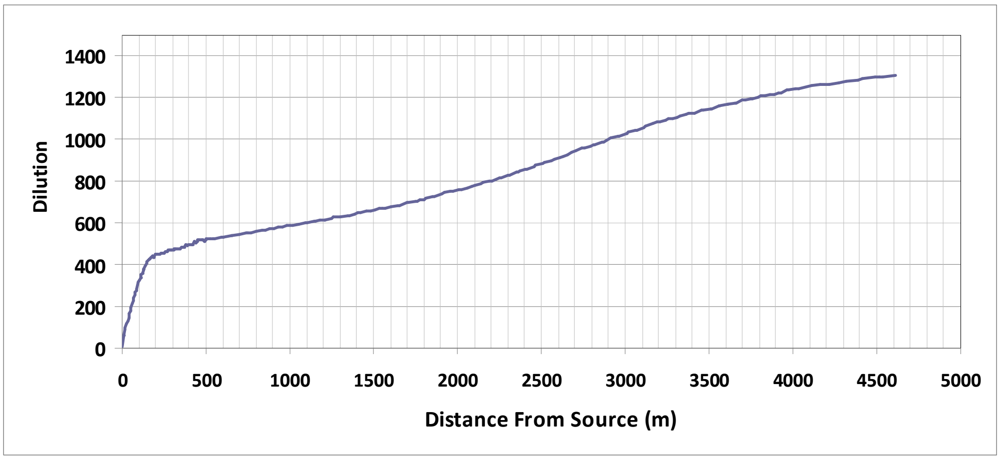
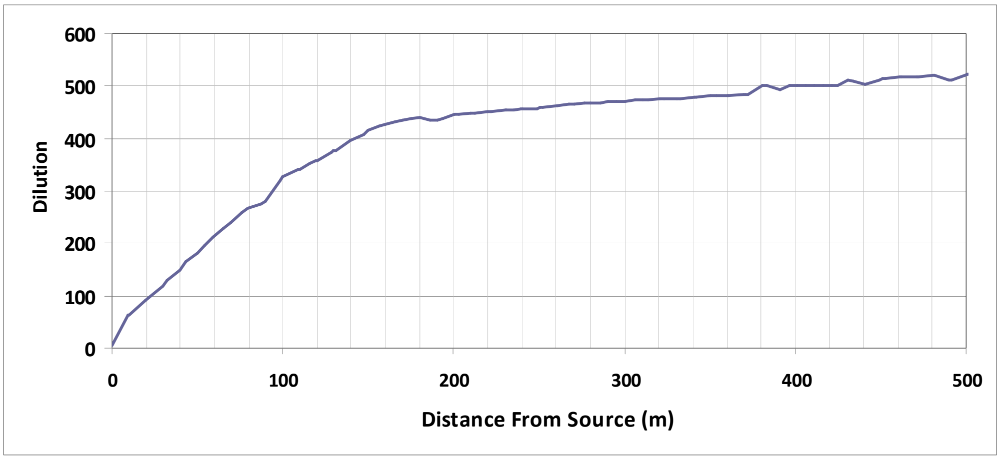


Figure 6-15 Scenario 2: Near Field Worst Case Dilution with Distance from the Outlet, 2007



Offshore Discharges – Produced Water and MEG

This section presents the findings of the dispersion modelling of the offshore discharges using CORMIX and/or the URS Dilution Model described in Section 5 and presented in detail in Appendix C and Appendix D.

Table 7-1 shows the current velocity percentiles based on 2 years of MIKE21 simulations (2006-2007). The depth average currents for 2006-2007 will be used to assess the dispersion of the offshore plumes for Scenario 3 and Scenario 4.

Table 7-1 Current percentile velocities, 2006 -2007 (MIKE21)

Percentile	Velocity (cm/s)
99	64.5
95	50.1
90	43.1
75	32.9
50	23.3
25	14.9
10	8.9
5	6.2
1	2.8

7.1 Discharge Scenario 3: Produced Water

Scenario 3 focuses on the discharge of PW from the Wheatstone Platform. Results for six scenarios are presented which investigate worst-case dilution associated with the discharge of PW in isolation and in combination with the discharge of CW.

Table 7-2 summarises the dilutions required to achieve the water quality criteria presented in Table 4-1 for each of the six scenarios.

Table 7-2 Dilutions Required to meet Water Quality Criteria

Parameter	Scenario 3A	Scenario 3B	Scenario 3C	Scenario 3D	Scenario 3E	Scenario 3F
Oil	1300	1270(2)	1270(2)	PW 1300, CW n/a	PW 1300, CW n/a	PW 1300, CW n/a
Temperature(1)	18.3	8.6	8.6	PW 18.3, CW 8.3	PW 18.3, CW 8.3	PW 18.3, CW 8.3
Chlorine	-	65.0	65.0	PW n/a CW 66.7	PW n/a CW 66.7	PW n/a CW 66.7

Note (1): Based on an ambient temperature of 20°C.

(2): An initial dilution of 30 is achieved as a result of the commingling of PW with CW prior to release.

(3): n/a Not applicable

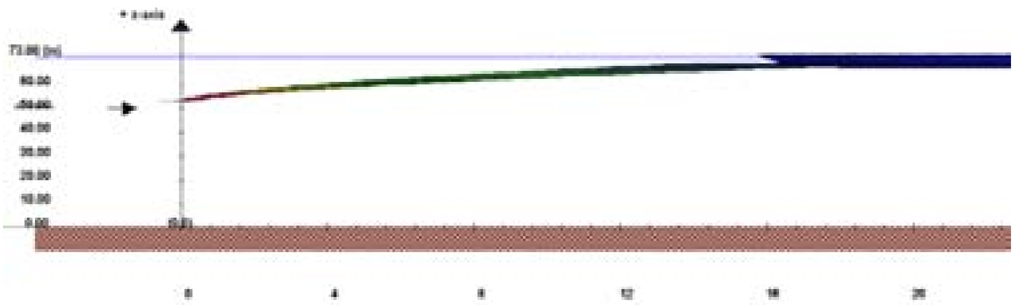
7 Offshore Discharges – Produced Water and MEG

7.1.1 Scenario 3A

Scenario 3A represents the discharge of PW from the Wheatstone Platform in isolation from other discharge streams. The PW willl be discharged at a rate of 272 m^3/hr and a depth of 20 m. Due to its low density (963 kg/m^3) the discharge plume will be very buoyant when compared with the ambient environment into which it is discharged.

The development of the discharge plume with distance from the caisson, based on the near field modelling using CORMIX is depicted in Figure 7-1 for an ambient current speed of 20 cm/s. The highly buoyant plume is predicted to rise rapidly to the surface and remain as a thin layer at the surface for some distance downstream.

Figure 7-1 Scenario 3: Side view of Plume Development with Distance Downstream (m) from the Caisson, (Depth Averaged Current Speed of 20 cm/s)



A contour plot of the results of the URS Dilution Model is presented in Figure 7-2. The worst case dilution transect is presented in Figure 7-3 with Figure 7-4 focusing on the near field region. The dilution profile is similar to that for Scenario 3 (discharge of PW from Outlet 2), with dilution contours of 1300 extending beyond 4 km from the point of discharge.

7 Offshore Discharges – Produced Water and MEG

Figure 7-2 Scenario 3: Results of the Dilution Model, 2006-2007[5]

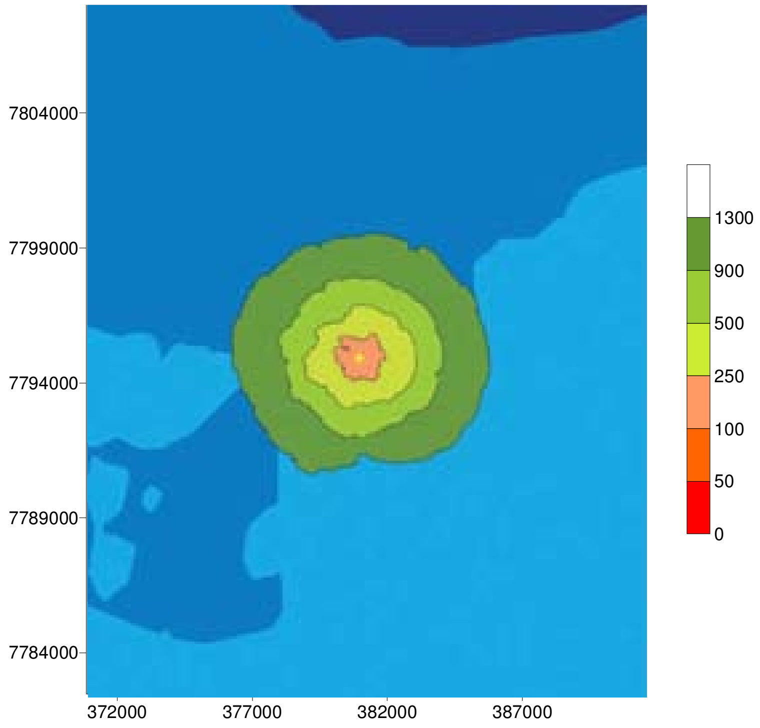
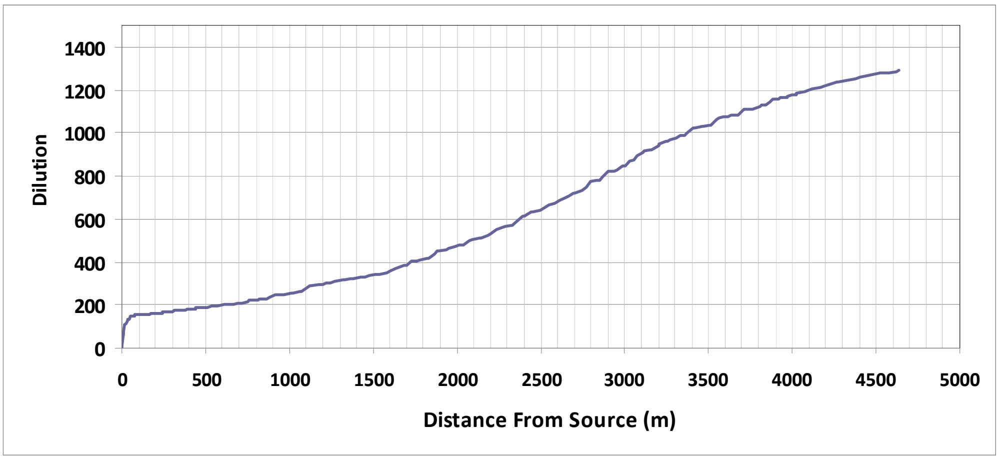


Figure 7-3 Scenario 3: Worst Case Dilution with Distance from the Caisson, 2006-2007



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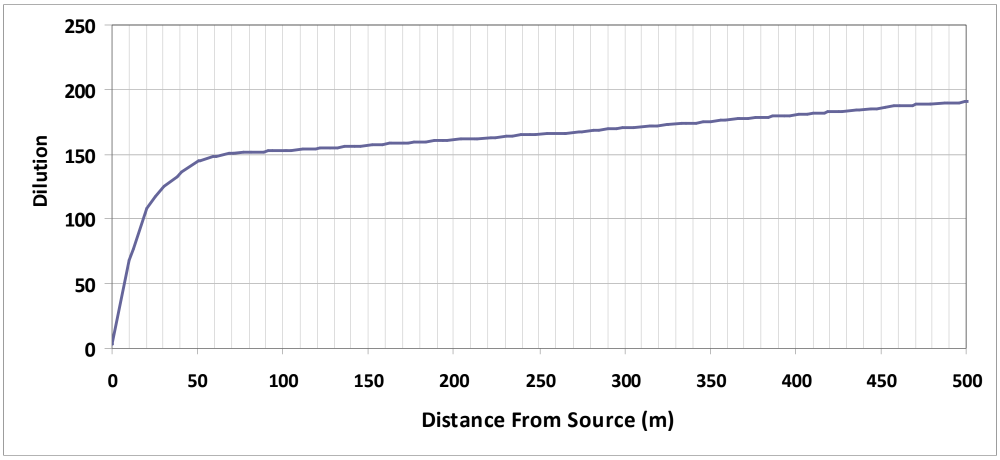
[5] Note that the results presented in the figure represent a composite of the maximum dilution at each location on the grid (regardless of when it occurred) for the two year period and are not representative of a snap shot in time.

7 Offshore Discharges – Produced Water and MEG

Figure 7-4 Scenario 3: Worst Case Near Field Dilution with Distance from the Caisson, 2006-2007



7.1.2 Scenarios 3B, 3C, 3D and 3E

Results from CORMIX

Presented in Table 7-3 is a summary of CORMIX results. For each of the scenarios, the downstream distance to achieve the required dilution for temperature is highlighted in the table in red, chlorine in green and PW dilution in blue.

Results suggest that the dilution of PW in isolation is more effective than when combined with the CW. The initial improved dilution of 30 associated with the co-mingled discharged is lost as the co-mingled discharge plume is large as well as very buoyant relative to the ambient environment and reaches the surface within 16 m (Scenario 3B) when released at 20 m depth. Releasing the co-mingled discharge at 40 m depth does not lead to significant improvements in dilution with the plume predicted to reach the surface at a downstream distance of 33 m (Scenario 3C) in a 20 cm/s current.

Results highlight the benefit of segregated PW and CW discharge outlets. PW released in isolation of CW at a depth of 20 m is estimated to exceed the dilution criteria of 1300 at distances of 1,700 m downstream of the discharge outlet (Scenario 3A). As is the case for the release of CW (Scenario 3D and 3E), increasing the discharge depth of PW to 40 m leads to a significant improvement in the dilution with criteria attainable within a downstream distance of 65 m from the discharge outlet.

Results do not highlight any issues relating to temperature with the <3°C above ambient criteria met within 15 m of the point of discharge outlet.

With respect to chlorine, results suggest that the water quality objective of 3 ppb will be achieved within 50 m to 150 m for discharges released from 40 m depth (Scenario 3C, Scenario 3E, Scenario 3F). Results for Scenario 3B and Scenario 3D which involve the release of CW at a depth of 20 m

7 Offshore Discharges – Produced Water and MEG

suggest that distances in the order of 2000 m will be required in order to achieve the 3 ppb water quality objective for chlorine.

Table 7-3 CORMIX Results for the Worst-Case Distance (m) to Required Dilution (Ambient Current Speed, 20 cm/s)

Dilution	**Scenario 3A PW @ 20 m**	**Scenario 3B PW/CW @ 20 m**	**Scenario 3C PW/CW @ 40 m**	**Scenario 3D**		**Scenario 3E**		**Scenario 3F**	
				PW @40	**CW @20**	**PW @40**	**CW @40**	**PW @40**	**CW @40**
10	2	**12(1)**	**12(1)**	2	**13**	2	**13**	0.5	**13**
20	**4(1)**	22	21	**3.5**	22	**3.5**	22	**2**	22
65	9	**2,200(2)**	**120(2)**	8	**2,000**	8	**48**	7	**48**
100	12	3,500	850	12	3,200	12	840	10	840
500	422	9,200	8,450	36	8,600	36	8,030	34	8,030
1000	1,300	12,600	12,400	59	12,000	59	12,000	57	12,000
1270	1,650	**14,000(3)**	**14,000(3)**	65	13,300	65	13,200	64	13,200
1300	**1,700(3)**	14,200	14,200	**65**	13,400	**65**	13,500	**64**	13,500
1500	1,950	15,000	15,000	66	14,300	66	14,500	66	14,500

Note (1): Distance to required dilution based on temperature criteria (< 3°C above ambient)
(2): Distance to required dilution based on criteria relevant to chlorine (3 ppb)
(3): Distance to required dilution based on criteria for PW (dilution of 1300)

To complement the information presented in Table 7-3, the CORMIX results are presented graphically in Figure 7-5 through Figure 7-8. The dilution as a function of downstream distance from the discharge point is presented along with the required dilutions to achieve ambient water quality criteria.

7 Offshore Discharges – Produced Water and MEG

Figure 7-5 Scenario 3B and Scenario 3C: Near Field Worst-case Dilution with Distance Downstream of the Platform (Ambient Current Velocity 20 cm/s)

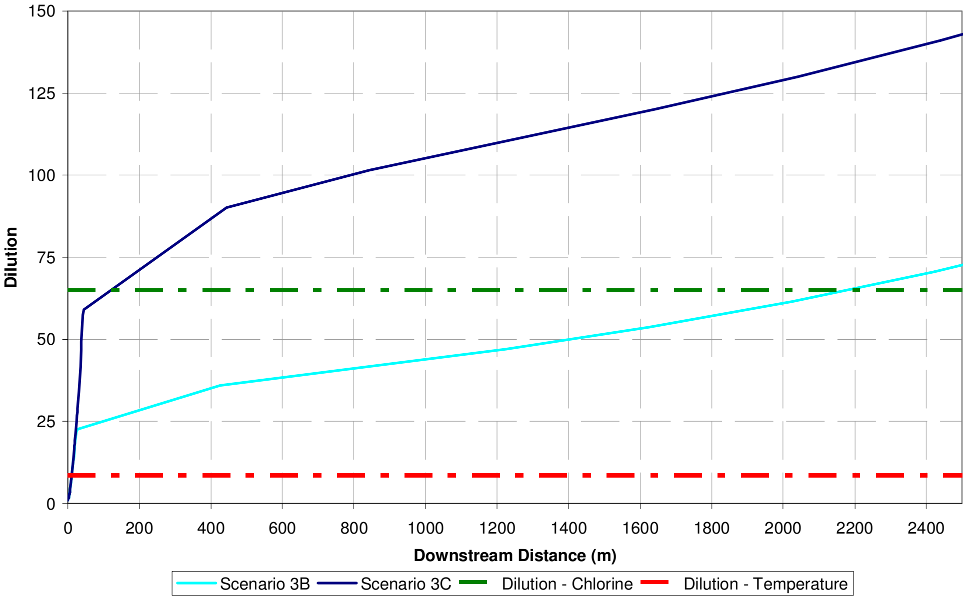
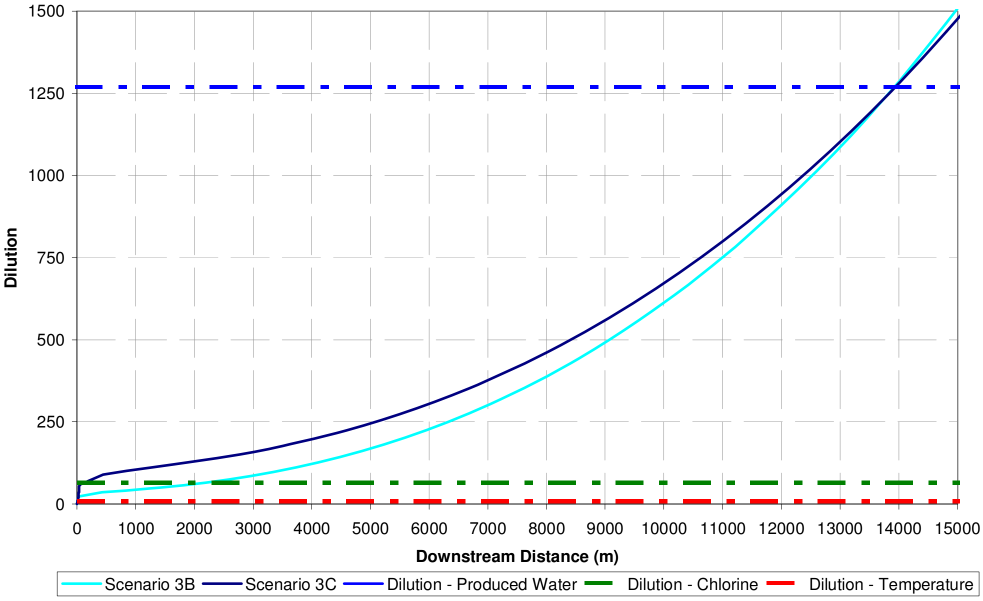


Figure 7-6 Scenario 3B and Scenario 3C: Far Field Worst-case Dilution with Distance Downstream of the Platform (Ambient Current Velocity 20 cm/s)



7 Offshore Discharges – Produced Water and MEG

Figure 7-7 Cooling Water Discharge: Near Field Worst-case Dilution with Distance Downstream of the Platform (Ambient Current Velocity 20 cm/s)

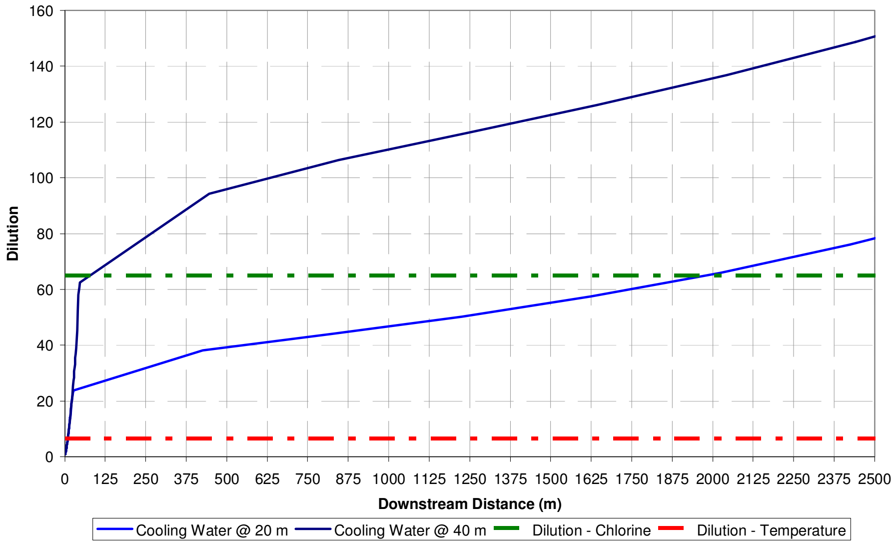
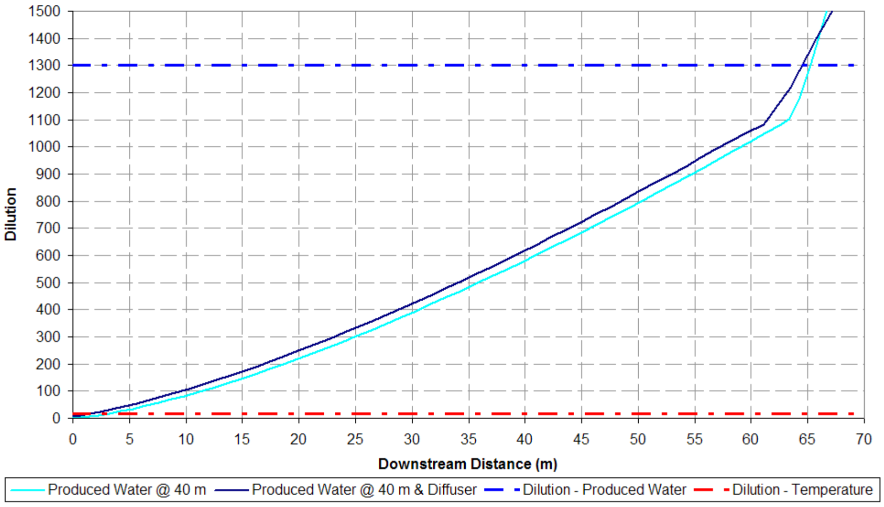


Figure 7-8 Produced Water Discharge: Near Field Worst-case Dilution with Distance Downstream of the Platform (Ambient Current Velocity 20 cm/s)



7.1.3 Summary Scenario 3

CORMIX results for Scenario 3 suggest that:

- Meeting the water quality objective of <3°C above ambient will be achievable within 15 m of the discharge outlet for all scenarios.
- Results for a segregated PW discharge at 20 m depth (Scenario 3A) suggest that the water quality criteria for PW dilution are exceeded at distances in excess of 1700 m.
- Results for co-mingled CW/PW discharge at both 20 m and 40 m depth (Scenario 3B and Scenario 3C) suggest that the water quality criteria for PW dilution are exceeded at distances in excess of 14,000 m.
- Results for CW discharges at 20 m depth (Scenario 3D) suggest that water quality criteria for chlorine are exceeded at distances in excess of 2000 m.
- The segregation of the PW and CW discharges and release at a horizontal separation distance of 124 m will lead to improved dilution outcomes when compared with co-mingled or adjacent discharges.

Results for segregated CW and PW discharges at 40 m depth (Scenario 3E and Scenario 3F) suggest that water quality criteria for chlorine and PW dilution are achievable within 65 m of the platform.

7.2 Discharge Scenario 4: MEG

As noted in Section 2.3.2, consideration has been given to the discharge of the MEG/PW in isolation (Scenarios 4A, 4B, 4C and 4D) and in combination with CW (Scenario 4E) that is discharged from the same caisson.

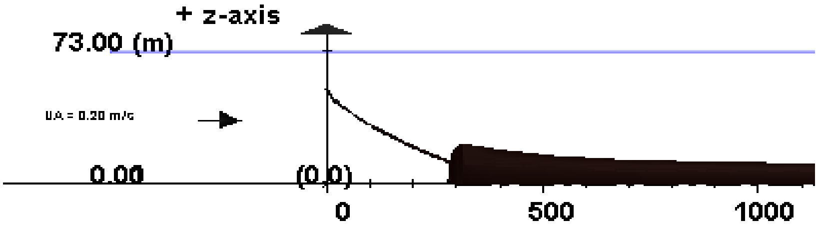
For Scenario 4A through Scenario 4D the assessment of the dilution of the MEG/PW discharge has focused on worst-case discharge conditions. As the ratio of PW to MEG increases, the density differential between the discharge and the ambient marine environment (during summer ambient conditions) reduces from a maximum effluent density access of 61.3 kg/m^3 (Hour 0, Appendix B) to 4.9 kg/m^3 (Hour 17, Appendix B). Consequently, the discharge flow rate increases with increasing volumes of PW.

For Scenario 4A through Scenario 4D, as a result of the negative buoyancy of the MEG/PW with respect to the marine environment into which it is discharged, results of the CORMIX modelling suggests that for all 14 hours of the batch discharge, the effluent will descend through the water column to the seafloor.

The plume profile depicted in Figure 7-9 is typical of the CORMIX results and highlights the characteristics of the MEG/PW layer once it impacts the seafloor. The layer thickness is predicted to range from approximately 3 m to greater than 10 m. Under certain conditions (higher flow rates and light ambient current conditions), the plume may also spread upstream of the impact point along the seafloor.

7 Offshore Discharges – Produced Water and MEG

Figure 7-9 Scenario 4A: Side view of plume development downstream (m) of the caisson (current speed of 20 cm/s



Based on water quality criteria for MEG concentration of less than 50 mg/l, the required dilutions per hour for each of the five MEG discharge scenarios is presented in Table 7-4.

Table 7-4 Scenario 4: Dilutions to Meet Water Quality Criteria of 50 mg/l

Hour	Scenario 4A	Scenario 4B	Scenario 4C	Scenario 4D	Scenario 4E
0	19840	19840	19840	18973	269
1	18175	18175	18175	16771	269
2	16768	16768	16768	15028	268
3	15563	15563	15563	13612	268
4	14520	14520	14520	12441	267
5	13607	13607	13607	11455	267
6	12803	12803	12803	10613	266
7	12089	12089	12089	9887	266
8	11450	11450	11450	9254	265
9	10875	10875	10875	8697	265
10	10355	10355	10355	8204	264
11	9882	9882	9882	7763	264
12	9451	9451	9451	7367	263
13	9056	9056	9056	7010	263
14	8693	8693	8693	6686	262
15	8357	8357	8357	6390	262
16	8047	8047	8047	6120	261
17	7758	7758	7758	5871	261

As CORMIX is a steady state dilution model, and since the discharge of MEG/PW is a batch discharge for which the MEG concentration decreases as the flow rate increases with increasing time, results from CORMIX are likely to be highly conservative. Thus in order to assess more realistically the timescale of the dilution of MEG within the ambient environment over the period of hours to days after the cessation of the batch discharge, 3D modelling using MIKE3D was undertaken for Scenario 4C (Appendix B) corresponding to the highest discharge rate of MEG per hour.

Detail results for Scenario 4C from both the CORMIX and MIKE3D modelling studies are presented in detail in the following sections.

7.2.1 Discharge Scenario 4C

Results from CORMIX

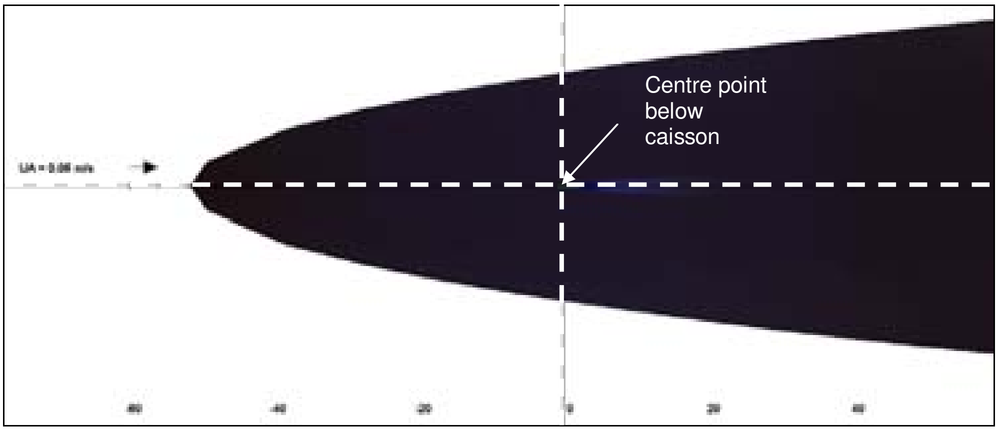
For the purposes of assessing the worst case impact of the release of MEG from the Wheatstone Platform, consideration has been given to the results of the CORMIX modelling for Hour 0 (Appendix B) with ambient and discharge conditions as summarised in Table 7-5.

Table 7-5 Scenario 4: Ambient and Discharge Characteristics

Flow	Parameter	Unit	Value
Ambient	Temperature	C	30
	Salinity	ppt	35
	Velocity	m/s	Variable
	Density		1021.38
Discharge	Density		1082.7
	Flow rate	m3/hr	165.11
	End of pipe	-	None

Presented in Figure 7-10 is a depiction of steady state plume development based on CORMIX results for an ambient current speed of 6.2 cm/s (5th percentile). Under these conditions the plume is predicted to extend along the sea floor upstream of the caisson by approximately 50 m.

Figure 7-10 Scenario 4C: Top view of plume development (m) both upstream and downstream of the caisson (current speed of 6.2 cm/3)



7 Offshore Discharges – Produced Water and MEG

Table 7-6 Scenario 4C: Side view of plume development (m) (current speed of 23.3 cm/s)

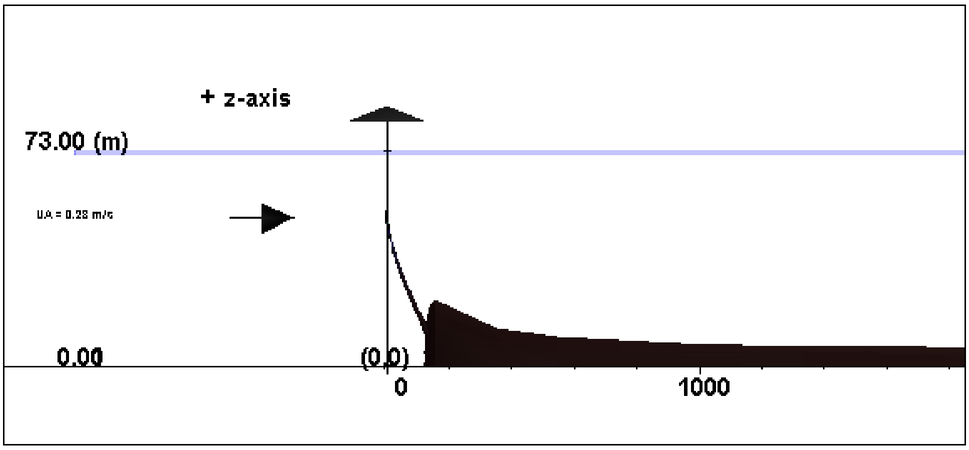
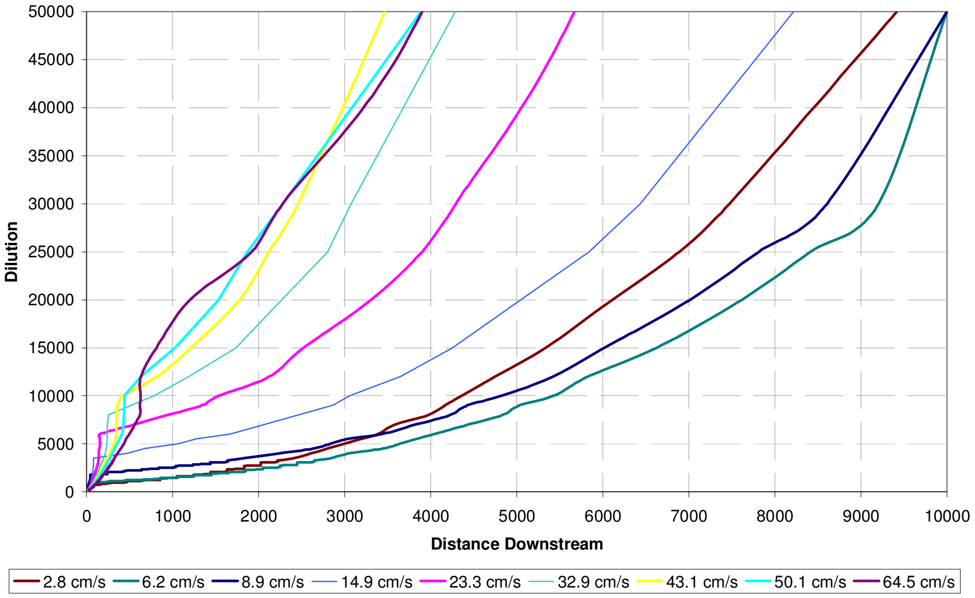


Figure 7-11 Scenario 4C: Dilution Contours for Various Ambient Current Speeds for Hour 0, CORMIX



Presented in Table 7-7 are the worst-case distances to different dilutions based on the steady-state results of CORMIX for hour 0, hour 5, hour 11, and hour 17. With the exception of the dilution of 1000, the maximum distances to the different dilutions were associated with the 5th percentile current velocity of 6.2 cm/s. Highlighted in blue font is the approximate distance to the required dilutions for each of the hours presented (refer to Table 7-4).

7 Offshore Discharges – Produced Water and MEG

Table 7-7 Scenario 4C: Worst Case Distance to Required Dilution (m), CORMIX (5th percentile)

Dilution	Hour 0	Hour 5	Hour 11	Hour 17
1000	60	851	1444	1445
2000	1651	2243	2837	2639
3000	2446	3238	3633	3435
4000	3042	3834	4230	4031
5000	3639	4232	4827	4628
6000	4036	4829	5225	5026
7000	4434	5227	5623	5424
8000	4831	5624	6021	5822
9000	5030	5823	6419	6220
10000	5428	6221	6617	6419
11000	5627	6420	7015	6817
12000	5825	6818	7214	7016
13000	6223	7017	7612	7215
14000	6422	7216	7811	7613
15000	6621	7613	8010	7812
20000	7615	8608	9204	8806
25000	8410	9602	10000	9801
30000	9205	10000	10000	10000

Results from MIKE3D

The results presented in the previous section were limited by the steady-state assumptions of CORMIX. As the MEG component of the MEG/PW discharge occurs for an 18 hour period only, CORMIX is not able to provide critical information on the timescale of dilution of the MEG within the marine environment once the MEG stream has been terminated.

Therefore, in order to better understand the timeframe of dilution post hour 18, three-dimensional, two-week simulations for a summer and winter scenario were undertaken by DHI using the MIKE3D software (Appendix E).

A summary of results for the winter scenario (11/06/07-25/06/07) which is the more conservative case is presented here. The reader is directed to Appendix E for more details.

Presented in Figure 7-12 is the foot print of the maximum tracer concentration for the duration of the two week simulation. The (0.004578) contour is equivalent to the water quality objective for the concentration of MEG of 50 mg/l.

Presented in Figure 7-13 is a snapshot of the footprint of the area that exceeds the 50 mg/l water quality objective at Hour 27:30. (Note that there has been a change in colour scale between these two figures.)

Results from MIKE3D suggest that the MEG will dilute to the required concentration of 50 mg/l rapidly (i.e. within an estimated 24 hours) after the cessation of the discharge of MEG to the marine environment under these conditions. Additional simulations would be required to determine the maximum dilution time required for a range of environmental conditions.

7 Offshore Discharges – Produced Water and MEG

Figure 7-12 Maximum Tracer Concentrations from MIKE3D for the Winter Scenario, 11/06/07 – 25/06/07[6]

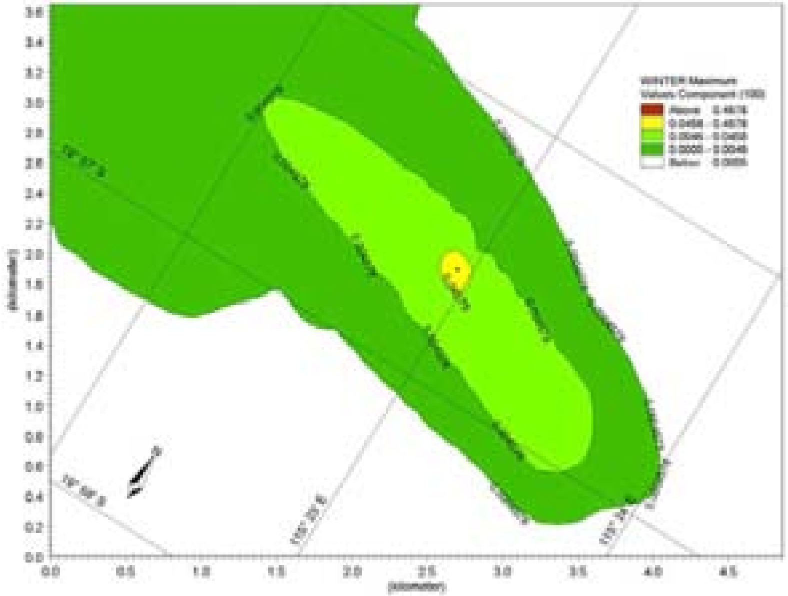
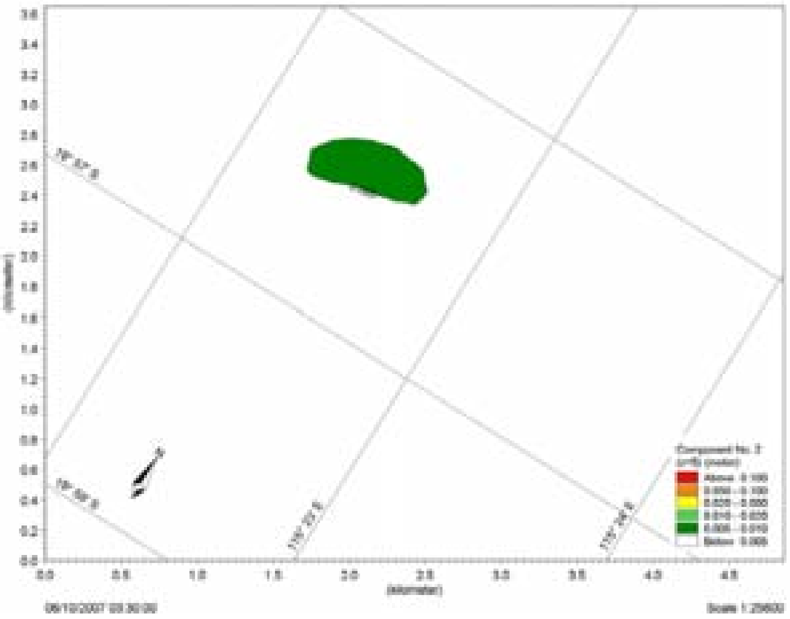


Figure 7-13 Footprint of Tracer Concentration from MIKE3D for the Winter Scenario, Hour 27:30



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[6] Note that the results presented in the figure represent a composite of the maximum dilution at each location on the grid (regardless of when it occurred) for the two week period and are not representative of a snap shot in time.

7 Offshore Discharges – Produced Water and MEG

7.2.2 Implication for Discharge Scenarios 4A, 4B, 4D

Table 7-8 is a summary of the downstream distance from the caisson to the required dilution based on results from CORMIX for hour 0 for Scenario A, Scenario B and Scenario D. Included in the table are the results from Scenario C (Table 7-7) for comparison.

Of the four MEG discharge scenarios proposed in Table 2-6, results presented in Table 7-8 highlight that Scenario 4C represents the worst-case conditions (as assessed using CORMIX) and is likely to be associated with the maximum dispersal time. Additional three-dimensional modelling would be required in order to confirm the relative dispersal rate of these four scenarios.

As Scenario 4C represents the worst-case condition and has been assessed in detail in Section 7.2.1, Scenarios 4A, 4B and 4 D have not been considered further.

Table 7-8 Scenario 4C: Hour 0, Distance to Required Dilution (m), CORMIX (5th percentile)

Dilution	4A	4B	4D	4C
1000	16	21	29	60
2000	26	33	649	1651
3000	35	43	1643	2446
4000	43	242	2240	3042
5000	49	638	2638	3639
6000	52	1035	3036	4036
7000	59	1332	3235	4434
8000	62	1630	3633	4831
9000	62	1927	3832	5030
10000	160	2125	4031	5428
11000	358	2323	4230	5627
12000	457	2423	4429	5825
13000	654	2621	4827	6223
14000	753	2720	4827	6422
15000	951	2918	5026	6621
20000	1444	3513	5822	7615
25000	1839	4009	6618	8410
30000	2136	4405	7214	9205

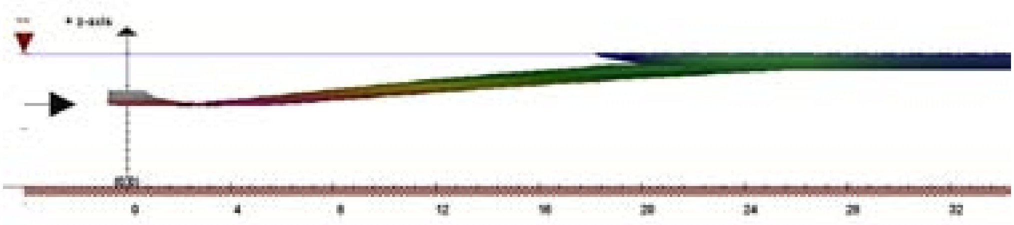
7.3 Discharge Scenario 4E

Scenario 4E investigates the fate of the discharge of MEG/PW within the same caisson as the CW. The combination of 50°C MEG/PW (maximum flow rate of 422 m^3/hr) and 8000 m^3/hr of 45°C CW will result in an effluent that is buoyant when compared to the marine environment into which it is discharged.

An investigation into the dilution of the combined MEG/PW/CW discharge has been undertaken using CORMIX and the URS Dilution Model.

Figure 7-14 presents a side view of the development of the discharge plume downstream of the caisson as predicted by CORMIX for an ambient current speed of 20 cm/s. Discharged at a depth of 20 m, results suggest that the plume will reach the surface of the water column approximately 25 metres downstream of the discharge point. A dilution of 18 is predicted at this point on the surface. Once reaching the surface of the water column, the potential for dilution will be reduced when compared with the dilution over the first 20 metres.

Figure 7-14 Scenario 4E: Side view of plume development downstream of the caisson (current speed of 20 cm/s



Presented in Figure 7-15 is a contour plot of the results from the URS Dilution Model for 2006-2007. The worst-case dilution transect is presented in Figure 7-16 and a close-up of the near field dilution is presented in Figure 7-17.

Table 7-4 showed that a dilution of 269 is required if the MEG concentration is to meet the water quality objective of 50 mg/l. Results of the dilution modelling suggest that a distance of over 5.6 km from the discharge caisson will be required to meet this dilution objective.

Note that these results are comparable with those of Scenario 3 (nearshore discharge of PW) with discrepancies attributed to slight differences in the discharge temperature, discharge density, and flow rate.

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Figure 7-15 Scenario 4E: Results from the Dilution Model, 2006-2007[7]

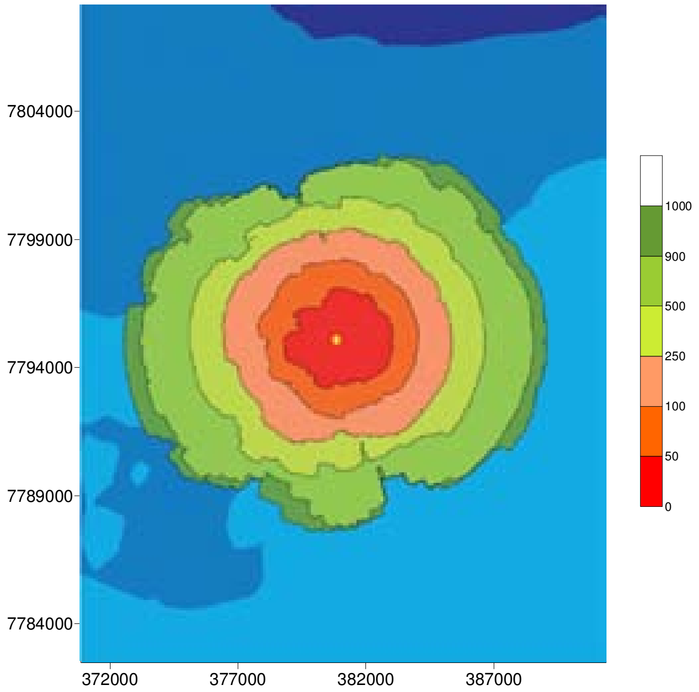
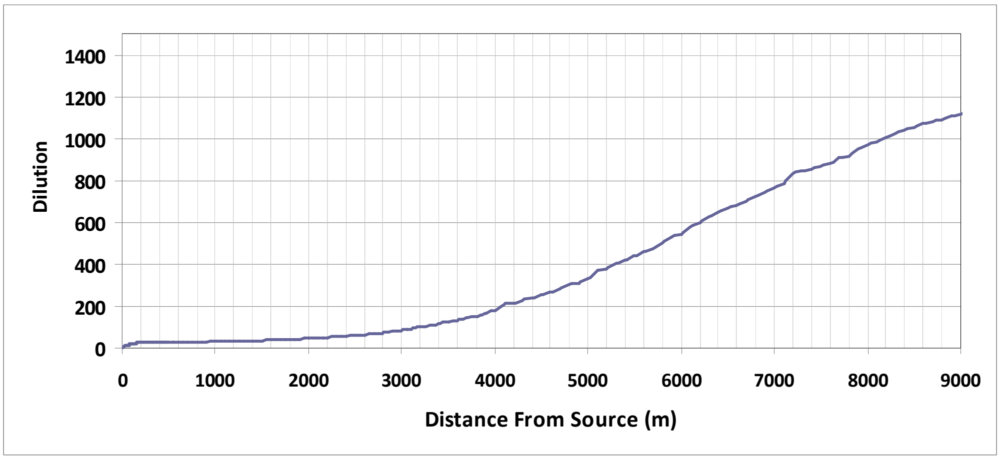


Figure 7-16 Scenario 4E: Worst Case Dilution with Distance from the Caisson, 2006-2007



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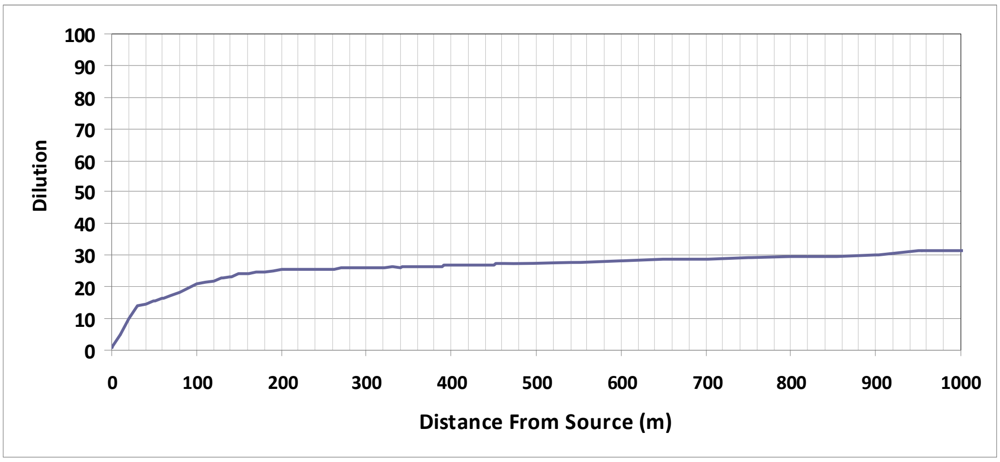
[7] Note that the results presented in the figure represent a composite of the maximum dilution at each location on the grid (regardless of when it occurred) for the two year period and are not representative of a snap shot in time.

7 Offshore Discharges – Produced Water and MEG

Figure 7-17 Scenario 4E: Worst Case Near Field Dilution with Distance from the Caisson, 2006-2007



7.3.1 Scenario 4E: Mitigation Options

Ideally, water quality criteria are achievable prior to the plume reaching the top (or bottom) of the water column as the rate of dilution may be significantly reduced once reaching the boundaries.

An investigation into various mitigation options has been conducted in order to assess the increase in dilution when the plume first impacts on the top of the water column including:

a) Extending the depth of the discharge to 40 m:
b) End of pipe discharge diameter of 1 m; and
c) End of pipe diffuser consisting of two downward pointing (-45°) outlets of 0.5m diameter.

All other discharge characteristics for each of the mitigation scenarios are the same as those in Table 2-6 for Scenario 4C.

Results of the CORMIX runs for an ambient current speed of 20 cm/s for each of the three mitigation options are summarised in Table 7-9.

Table 7-9 Scenario 4E Comparison of Mitigation Options (current speed of 20 cm/s)

Parameter	**Scenario 4E**	**Mitigation Option**		
		(a)	**(b)**	**(c)**
Dilution when plume reaches surface	18	43	40	98
Distance downstream (m) when plume reaches surfaces	25	46	47	94
Approximate distance (m) to 269 dilution	5600	4500	4450	900

7 Offshore Discharges – Produced Water and MEG

Results suggest that none of the mitigation options considered will, in isolation, achieve the required dilution of MEG prior to the discharge plume reaching the surface of the water column. Scenario 4E(c) does suggest that two downward pointing outlets of 0.5 m diameter would significantly reduce the distance downstream of the caisson at which the required dilution of 269 is achieved from 5600 m to 900 m.

It is important to recall that CORMIX is a steady state model that assumes the discharge is continuous. CORMIX modelling alone will not be able to provide insight into the rate of dilution once the MEG within the discharge stream ceases.

Results do suggest, however, that mitigation measures such as options for end of pipe engineering may lead to improved dilution outcomes.

Summary

URS has conducted dilution modelling of discharges to the marine environment associated with the Chevron Wheatstone Project.

The URS Dilution Model was developed specifically for this project and was used to extend short period 3D far field model simulations of discharge impacts to represent long-term conditions. The URS Dilution Model required less than one minute of computer processing to simulate a two year time period, and could therefore provide long-term 'worst case' conditions for each discharge. This was not feasible within this project deliverable using a detailed 3D transport models. The URS Dilution Model is an extension of the steady-state CORMIX dilution model that takes into account unsteady currents for year long (or multiple-year) time periods.

Note that the assessment of the impact of the results of the dilution modelling as it relates to the water quality objectives of Section 4 has been addressed separately from this assessment (Chevron Australia 2010).

8.1 Nearshore Discharges

Discharges in the nearshore emanated from two discharge points:

Outlet 1 located on the PLF at -5 m CD, and

Outlet 2 located approximately 20 km offshore at -20 m CD.

Scenario 1 with three discharge scenarios from Outlet 1:

- Two discharge flow scenarios were considered for the Operational Phase: a maximum flow scenario (Scenario 1A) and a typical flow scenario (Scenario 1B). The characteristics of the discharge were such that the discharge plume for Scenario 1A was buoyant, while the plume associated with Scenario 1B was determined to be negatively buoyant.
- Scenario 1C focused on a Construction discharge scenario and was also associated with a negatively buoyant plume.

Although Outlet 1 is proposed to be equipped with a diffuser, results of the assessment suggest that the dilution potential of the nearshore environment is limited by a combination of the density differential between the discharge and the ambient environment combined with the limited depth of the water column.

Scenario 2 concerns the discharge of PW from Outlet 2. At the time of the assessment, information relating to the characterisation of the discharge was limited. The discharge plume is anticipated to be positively buoyant. The effectiveness of the proposed diffuser will depend on the details of the characterisation of the PW that will be discharged form this location.

8.2 Offshore Discharges

Discharges associated with the Wheatstone Platform located approximately 150 km offshore in 73 m of water, included the release of PW and MEG from a 1.5 m diameter caisson into the marine environment.

Scenario 3 investigated the fate of a continuous discharge of PW from the platform both in isolation and co-mingled with CW. This combined PW/CW flow will have a significant impact on the characterisation of the discharged stream as the volume of CW discharged (8000 m^3/hr) is significantly greater than the flow rate of PW (272 m^3/hr). A total of six scenarios were considered. Results suggested that segregated CW and PW discharges would lead to improved dilution outcomes for PW.

Scenario 4 was associated with a total of five different MEG/PW 18 hour batch discharge scenarios including the co-mingled discharge of MEG/PW and CW that is discharged via the same caisson.

Scenario 4A, 4B, 4C, and 4D considered the dilution of the MEG/PW stream in isolation of the CW. Scenario 4C was identified as the worst-case dilution scenario and was investigated in some detail. Results of the dilution modelling suggested that the MEG would disperse within 24 hours of cessation of the MEG from the discharge stream.

Scenario 4E represents the MEG/PW discharge configuration that will be realised in practice. A preliminary investigation into a variety of mitigation options was conducted and results suggest that end of pipe engineering may lead to an improved environmental outcome.

8.3 Recommendations

Consideration should be given to some or all of the following:

- Refinement of the characterisations of the discharges
- Refinement of the discharge scenarios
- Refinement of the CORMIX, URS Dilution Model, and/or MIKE3D modelling to include heat flux at the surface of the water column. This would reduce the level of conservatism in the results predicted by the models.
- Extension of the time period covered by the 3D simulations

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Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron Australia Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 20/01/2010.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 27/01/2010 and 17/02/2010 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Appendix A Characterisation of Discharges

A.1 Scenario 1: Nearshore Discharge Outlet 1

Table A-1 Scenario 1 A: Characterisation of Co-mingled Discharge during Operation – Maximum Flow Rate

Outfall 1	**Volume**	**BOD5**	**TN**	**TP**	**TDS**	**TSS**	**pH**	**oil/grease**
Units	(kl/d)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	-	(mg/l)
Sanitary outfall	435	10	30	5	750	10	7.5	10
CPI outfall	12600	70.2	0.8	0.004	111.9	18.6	5.9	6.7
RO plant outfall	5100	10	0	0	55000	0	7.9	0
Desal filter plant brine	500	-	-	-	35000	360	-	0
Total	**18635**	**50**	**1**	**0.12**	**16085**	**22**	**6**	**5**

Table A-2 Scenario 1 B: Characterisation of Co-mingled Discharge during Operation – Normal Flow Rate

Outfall 1	**Volume**	**BOD5**	**TN**	**TP**	**TDS**	**TSS**	**pH**	**oil/grease**
Units	(kl/d)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	-	(mg/l)
Sanitary outfall	120	10	30	5	750	10	7.5	10
CPI outfall	360	295.0	1.0	0.015	150.0	30.0	6.8	12.0
RO plant outfall	3456	10	0	0	55000	0	7.9	0
Desal filter plant brine	192	-	-	-	35000	360	-	0
Total	**4128**	**34**	**1**	**0.15**	**47709**	**20**	**7**	**1**

Table A-3 Scenario 1C: Characterisation of Co-mingled Discharge during Construction

Outfall 1	**Volume**	**BOD5**	**TN**	**TP**	**TDS**	**TSS**	**pH**	**oil/grease**
Units	(kl/d)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	-	(mg/l)
Sanitary outfall	2315	10	30	5	750	10	7.5	10
CPI outfall	1396	129.1	0.9	0.007	121.9	21.6	6.1	9.4
RO plant outfall	7450	10	0	0	50100	80	7.9	0
Total	**11161**	**25**	**6.33**	**1.04**	**33613**	**58**	**8**	**3**

Appendix A

A.1.1 Conversion of TDS to Salinity

In order to estimate the density of the discharge, the TDS value (mg/L) was added to the density of pure water at ambient temperature. To determine the equivalent salinity of the discharge, the density and temperature values were used to back calculate the required salinity. This methodology is demonstrated with an example (Table A-4).

Table A-4 Example - Converting TDS to Salinity (ppt)

Step #1 – Convert TDS to Density in units of kg/m^3			
TDS	=	16,085	mg/l
	=	16.1	g/l
	=	16.1	kg/m3
Step #2 Calculate(1) the density of pure water @ 25 ℃ (ambient temperature)			
D_{fresh}	=	997	kg/m^3
Step #3 Calculate(1) the Density of the Discharge			
$D_{Discharge}$	=	D_{fresh} + TDS	kg/m3
	=	997+16.1	kg/m^3
	=	1013.1	kg/m^3
Step #4 Calculate(1) the salinity (ppt) that corresponds to the required density at 25 ℃			
$S_{Discharge}$	=	21.4	ppt

Note (1): Calculated using the CORMIX Density Calculator (minimum salinity of 1 ppt required)

A.2 Scenario 2: Nearshore Discharge Outlet 2

Characterisation of the nearshore PW was not available at the time of this assessment. Thus for the purposes of assessing the potential impact of the discharge of PW into the marine environment, a number of assumptions have been applied as summarised in Table A-5.

Table A-5 Scenario 2: Characterisation of Produced Water Discharge

Parameter	Units	Value	Source
Temperature	C	Ambient + 30	Based on PW discharge temperature of 50 C at Wheatstone Platform (Scenario 3). Conservative.
Salinity	ppt	17	Based on the salinity content of Iago PW. Conservative.

A.3 Scenario 3: Off Shore Discharge of Produced Water from the Wheatstone Platform

Table A-6 Scenario 3: Characterisation of PW Discharge

Parameter	Units	Value
Temperature	C	75
Salinity	ppt	17(1)

Note (1) Based on formation water estimated salt content for Iago,. Conservative

Table A-7 Formation Water Estimated Salt Content

Parameter	Salt	Value
Wheatstone	NaCl	19.293
	KCl	1.236
Iago	NaCl	17.097
	KCl	0

A.4 Scenario 4: Off Shore Discharge of MEG from the Wheatstone Platform

Table A-8 Scenario 4: Characterisation of MEG Discharge

Discharge Stream	Parameter	Units	Value
MEG	Temperature	C	50
	Density	Kg/m^3	1092
PW	Temperature	C	50
	Density(1)	Kg/m^3	990
CW	Temperature	C	45
	Salinity	ppt	35
	Density	Kg/m^3	1015.86

Note (1) Based on pure water at 50°C, Chevron

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Appendix B MEG Discharge Scenarios

Table B-9 Scenario 4A Condensed Water Only: Mid Field-Life (5,400 bbl/d)

Time	**PW**	**MEG (@100% Concentration)**	**PW, MEG Total**	**%Meg in solution**	**Density of solution**
hr	m3/hr	m3/hr	m3/hr	-	kg/m3
0	2.0	20	22.0	91%	1082.7
1	4.0	20	24.0	83%	1074.9
2	6.1	20	26.1	77%	1068.3
3	8.1	20	28.1	71%	1062.7
4	10.1	20	30.1	66%	1057.8
5	12.1	20	32.1	62%	1053.6
6	14.1	20	34.1	59%	1049.8
7	16.1	20	36.1	55%	1046.5
8	18.2	20	38.2	52%	1043.5
9	20.2	20	40.2	50%	1040.8
10	22.2	20	42.2	47%	1038.4
11	24.2	20	44.2	45%	1036.2
12	26.2	20	46.2	43%	1034.1
13	28.2	20	48.2	41%	1032.3
14	30.3	20	50.3	40%	1030.6
15	32.3	20	52.3	38%	1029.0
16	34.3	20	54.3	37%	1027.6
17	36.3	20	56.3	36%	1026.2
18	36.3	0	36.3	0%	990.0
19	36.3	0	36.3	0%	990.0
20	36.3	0	36.3	0%	990.0
21	36.3	0	36.3	0%	990.0
22	36.3	0	36.3	0%	990.0
23	36.3	0	36.3	0%	990.0

Appendix B

Table B-10 Scenario 4B Mid Water Production (13,500 bbl/day)

Time	**PW**	**MEG (@100% Concentration)**	**PW, MEG Total**	**%Meg in solution**	**Density of solution**
hr	m3/hr	m3/hr	m3/hr	-	kg/m3
0	5.0	50	55.0	91%	1082.7
1	10.1	50	60.1	83%	1074.9
2	15.1	50	65.1	77%	1068.3
3	20.2	50	70.2	71%	1062.7
4	25.2	50	75.2	66%	1057.8
5	30.2	50	80.2	62%	1053.6
6	35.3	50	85.3	59%	1049.8
7	40.3	50	90.3	55%	1046.5
8	45.4	50	95.4	52%	1043.5
9	50.4	50	100.4	50%	1040.8
10	55.4	50	105.4	47%	1038.4
11	60.5	50	110.5	45%	1036.2
12	65.5	50	115.5	43%	1034.1
13	70.5	50	120.5	41%	1032.3
14	75.6	50	125.6	40%	1030.6
15	80.6	50	130.6	38%	1029.0
16	85.7	50	135.7	37%	1027.6
17	90.7	50	140.7	36%	1026.2
18	90.7	0	90.7	0%	990.0
19	90.7	0	90.7	0%	990.0
20	90.7	0	90.7	0%	990.0
21	90.7	0	90.7	0%	990.0
22	90.7	0	90.7	0%	990.0
23	90.7	0	90.7	0%	990.0

Table B-11 Scenario 4C Peak Water Production (40,000 bbl/day)

Time	PW	MEG (@100% Concentration)	PW, MEG Total	%Meg in solution	Density of solution
hr	m3/hr	m3/hr	m3/hr	-	kg/m3
0	15.1	150	165.1	91%	1082.7
1	30.2	150	180.2	83%	1074.9
2	45.3	150	195.3	77%	1068.3
3	60.4	150	210.4	71%	1062.7
4	75.6	150	225.6	66%	1057.8
5	90.7	150	240.7	62%	1053.6
6	105.8	150	255.8	59%	1049.8
7	120.9	150	270.9	55%	1046.5
8	136.0	150	286.0	52%	1043.5
9	151.1	150	301.1	50%	1040.8
10	166.2	150	316.2	47%	1038.4
11	181.3	150	331.3	45%	1036.2
12	196.4	150	346.4	43%	1034.1
13	211.6	150	361.6	41%	1032.3
14	226.7	150	376.7	40%	1030.6
15	241.8	150	391.8	38%	1029.0
16	256.9	150	406.9	37%	1027.6
17	272.0	150	422.0	36%	1026.2
18	272.0	0	272.0	0%	990.0
19	272.0	0	272.0	0%	990.0
20	272.0	0	272.0	0%	990.0
21	272.0	0	272.0	0%	990.0
22	272.0	0	272.0	0%	990.0
23	272.0	0	272.0	0%	990.0

Appendix B

Table B-12 Scenario 4D Peak Water Production (40,000 bbl/day)

Time	PW	MEG (@100% Concentration)	PW, MEG Total	%Meg in solution	Density of solution
hr	m3/hr	m3/hr	m3/hr	-	kg/m3
0	15.1	100	115.1	87%	1078.6
1	30.2	100	130.2	77%	1068.3
2	45.3	100	145.3	69%	1060.2
3	60.4	100	160.4	62%	1053.6
4	75.6	100	175.6	57%	1048.1
5	90.7	100	190.7	52%	1043.5
6	105.8	100	205.8	49%	1039.6
7	120.9	100	220.9	45%	1036.2
8	136.0	100	236.0	42%	1033.2
9	151.1	100	251.1	40%	1030.6
10	166.2	100	266.2	38%	1028.3
11	181.3	100	281.3	36%	1026.3
12	196.4	100	296.4	34%	1024.4
13	211.6	100	311.6	32%	1022.7
14	226.7	100	326.7	31%	1021.2
15	241.8	100	341.8	29%	1019.8
16	256.9	100	356.9	28%	1018.6
17	272.0	100	372.0	27%	1017.4
18	272.0	0	272.0	0%	990.0
19	272.0	0	272.0	0%	990.0
20	272.0	0	272.0	0%	990.0
21	272.0	0	272.0	0%	990.0
22	272.0	0	272.0	0%	990.0
23	272.0	0	272.0	0%	990.0

Table B-13 Scenario 4E Peak Water Production (40,000 bbl/day) Co-mingled with Cooling Water Discharge

Time	**PW**	**MEG (@100% Concentration)**	**CW**	**Total**	**%Meg in solution**	**Density of solution**
hr	m3/hr	m3/hr	m3/hr	m3/hr	-	kg/m3
0	15.1	100	8000	8115.1	1.2%	1016.8
1	30.2	100	8000	8130.2	1.2%	1016.7
2	45.3	100	8000	8145.3	1.2%	1016.7
3	60.4	100	8000	8160.4	1.2%	1016.6
4	75.6	100	8000	8175.6	1.2%	1016.6
5	90.7	100	8000	8190.7	1.2%	1016.5
6	105.8	100	8000	8205.8	1.2%	1016.5
7	120.9	100	8000	8220.9	1.2%	1016.4
8	136.0	100	8000	8236.0	1.2%	1016.4
9	151.1	100	8000	8251.1	1.2%	1016.3
10	166.2	100	8000	8266.2	1.2%	1016.3
11	181.3	100	8000	8281.3	1.2%	1016.2
12	196.4	100	8000	8296.4	1.2%	1016.2
13	211.6	100	8000	8311.6	1.2%	1016.1
14	226.7	100	8000	8326.7	1.2%	1016.1
15	241.8	100	8000	8341.8	1.2%	1016.0
16	256.9	100	8000	8356.9	1.2%	1016.0
17	272.0	100	8000	8372.0	1.2%	1015.9
18	272.0	0	8000	8272.0	0.0%	1015.0
19	272.0	0	8000	8272.0	0.0%	1015.0
20	272.0	0	8000	8272.0	0.0%	1015.0
21	272.0	0	8000	8272.0	0.0%	1015.0
22	272.0	0	8000	8272.0	0.0%	1015.0
23	272.0	0	8000	8272.0	0.0%	1015.0

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Appendix C Dispersion Modelling Software

C.1 MIKE 21

Details of the MIKE21 model developed for this region are outlined in DHI (2009). The reader is directed to this report for details of the model set-up and calibration.

C.2 MIKE 3HD

C.2.1 Background

DHI's MIKE 3 has been setup to simulate the sediment plume dispersion and stratification in the vicinity of the proposed dredged channels and disposal site. MIKE 3 is an engineering software tool for three-dimensional free-surface flows. It is applicable to simulations of hydraulics, water quality and sediment transport in rivers, lakes, estuaries, bays, coastal areas, seas and other water bodies. MIKE 3 simulates unsteady flow taking into account density variations, bathymetry and external forcing such as meteorology, tidal elevations, currents and other hydrographic conditions.

The equations on which Mike 3 is based are discretised in an implicit finite difference scheme on a staggered grid, solved non-iteratively by the use of the alternating directions implicit finite difference technique. A phase and amplification analysis neglecting the effects of viscosity, corrective terms, rotation and density variations renders the finite difference scheme unconditionally stable.

The mathematical foundation for the system is the Reynolds-averaged Navier-Stokes equations in three dimensions together with the mass conservation equation:

$$\frac{\partial u_i}{\partial t}+\frac{\partial\left(u_i u_j\right)}{\partial x_j}+2\Omega_{ij}u_j=-\frac{1}{\rho}\frac{\partial P}{\partial x_i}+g_i+\frac{\partial}{\partial x_j}\left[\upsilon^T\left\{\frac{\partial u_i}{\partial x_j}+\frac{\partial u_i}{\partial x_i}\right\}-\frac{2}{3}\delta_{ij}K\right]$$

$$\frac{\partial\rho}{\partial t}+\frac{\partial}{\partial x_j}\left(\rho u_j\right)=0$$

where ρ is the local density of the fluid, υ^T is the turbulent eddy viscosity, u_i is the velocity in the x_i direction, δ is the Kronecker delta function, Ω_{ij} is the Coriolis tensor, K is the turbulent kinetic energy, P is the fluid pressure, t is time, and g_i is the gravitational vector.

$$\frac{\partial(\rho S)}{\partial t}+\frac{\partial}{\partial x_j}\left(\rho S u_j\right)=\frac{\partial}{\partial x_j}\left(\rho D_s\right)\frac{\partial s}{\partial x_j}$$

$$\frac{\partial(\partial T)}{\partial t}+\frac{\partial}{\partial x_j}\left(\rho T u_j\right)=\frac{\partial}{\partial x_j}\left(\rho D_t\frac{\partial T}{\partial x_j}\right)$$

where S is the salinity and T the temperature. D_S and D_T are the dispersion coefficients for salinity and temperature respectively.

The closure problem is solved in the turbulence module through the Boussinesq eddy viscosity concept relating the Reynold stresses to the mean velocity field. To handle density variations, the equations for conservation of salinity and temperature are included and solved in the transport equation module. An equation of state (the UNESCO formulation) constitutes the relation between the density and the variations in salinity and temperature. Thus, the turbulence module and the transport equation module are integrated components of the hydrodynamic module, and the suite of those three constitutes the HD module.

The turbulent fluctuations (Reynolds stresses) are modelled employing the Boussinesq eddy viscosity concept. In MIKE 3 a total of five different turbulent closures can be employed. These are:

- constant eddy viscosity
- Smagorinsky subgrid scale model
- k-model
- k-ε model
- mixed Smagorinsky/ k-ε model

The latter turbulence formulation is a combination of the Smagorinsky model in the two horizontal directions and the k-ε model in the vertical direction. This formulation utilises the advantages from both models and is the turbulent closure model adopted for the present study.

C.2.2 MIKE3HD Model Set-up

For each discharge scenario modelled using MIKE3HD, both a two week summer (13/01/07-30/01/07) and a two week winter (8/06/07-25/06/07) were simulated. The time periods modelled were consistent with those selected by DHI based on previous work conducted by DHI in this locale (DHI, 2009).

Table C-14 Parameters used in the Set-up of MIKE3HD

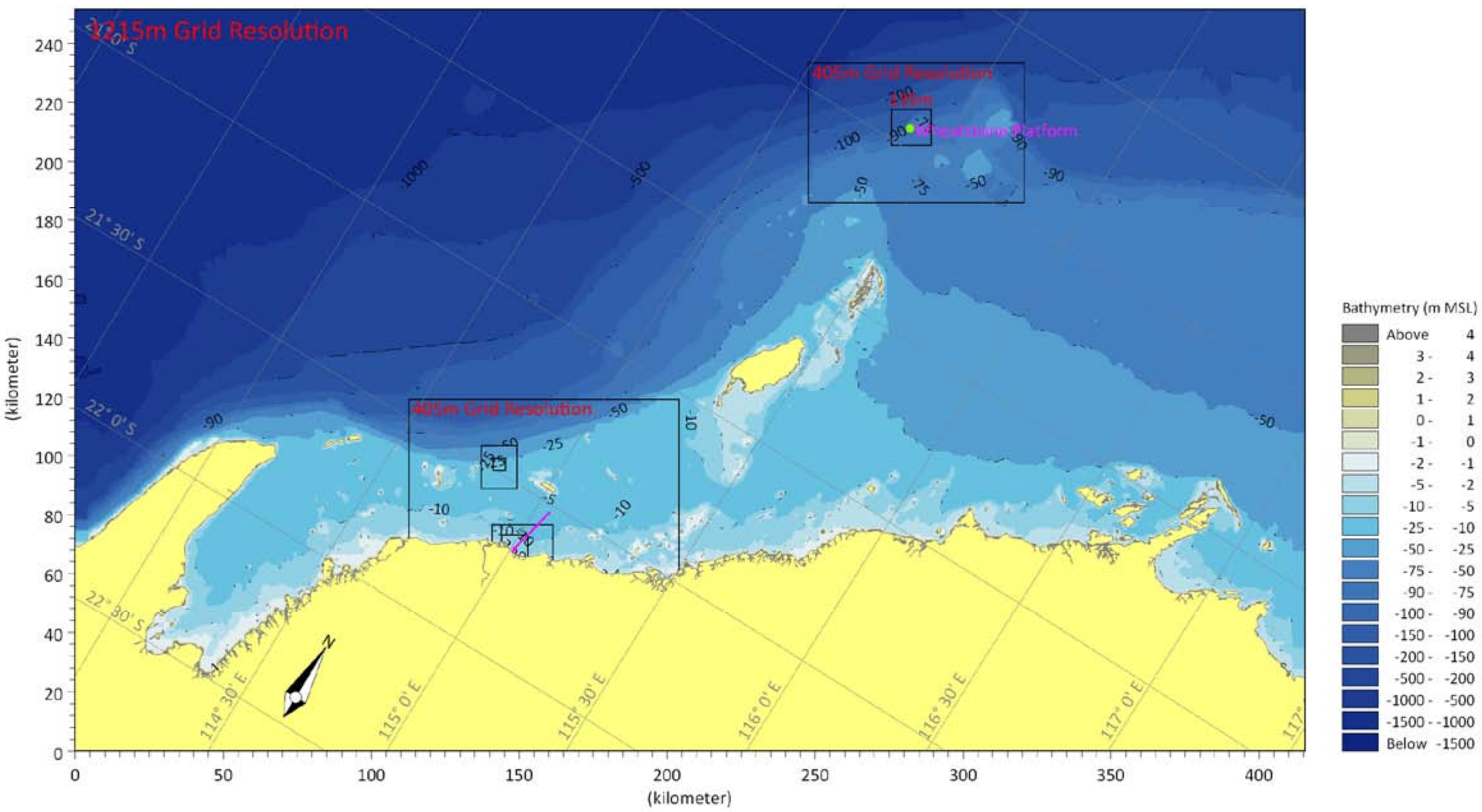
Parameter	Value	Outlet 1	Outlet 2	Wheatstone Platform
Grid resolution (m)	1215	√	√	√
	405	√	√	√
	135	√	√	√
	45	√	√	-
	15	√	-	-
Vertical resolution	Number of layers	7	7	18
	Layer thickness (m)	1	1	5
Wind forcing	-	Onslow Met Station	Onslow Met Station	MesoLaps (6-hourly)

Other model parameters include (but may not be limited to):

- Turbulence Model (Smagorinsky formulation):
  - Smagorinsky coefficients: Horizontal: 0.5 Vertical: 0.176
- Dispersion:
  - Proportional Eddy viscosity: with dispersion factor: Horizontal: 0.1 Vertical: 0.1

Appendix C

Figure C-1 Nested 1215 m, 405 m, 135 m, 45 m and 15 m Grids used for the MIKE3D Simulations



Appendix C

Figure C-2 Close Up of Grid Coverage for Outlet 1 and Outlet 2

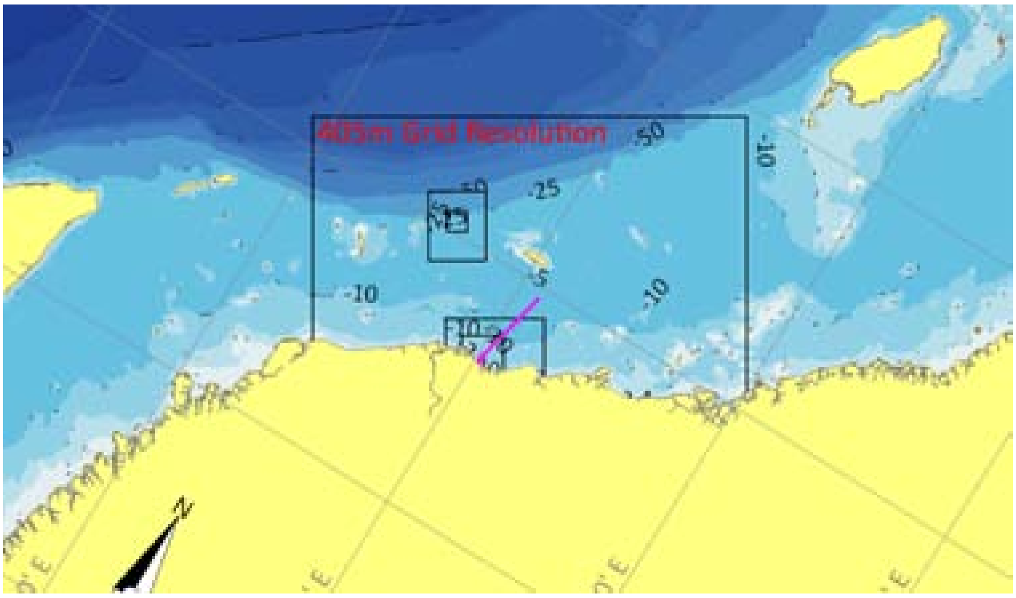
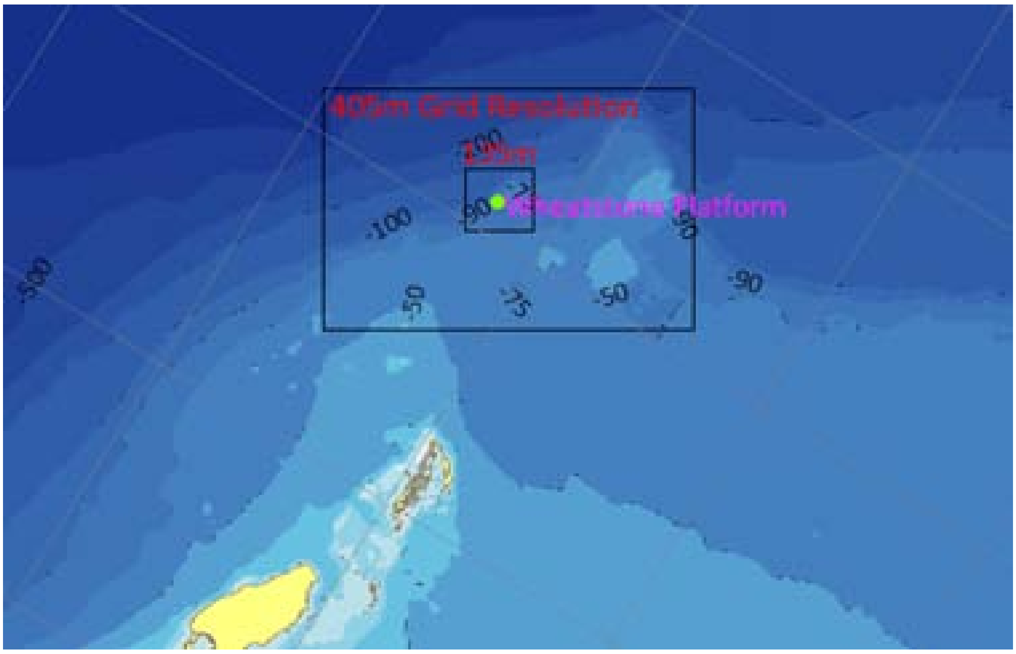


Figure C-3 Close Up of Grid Coverage for Wheatstone Platform



C.3 CORMIX

The CORMIX modelling system is a software system for the analysis, prediction and design of pollutant discharges into diverse water bodies. The key focus of the assessment is on the geometry and dilution characteristics of the initial mixing zone, including compliance with regulatory constraints as well as predicting the behaviour of the discharge plume with distance from the diffuser. The CORMIX modelling system consists of four integrated hydrodynamic models:

- CORMIX 1 for single port discharges.
- CORMIX 2 for multi-port diffuser discharges.
- CORMIX 3 for buoyant surface discharges.
- DHYDRO for the analysis of dense and/or sediment discharges in coastal environments.

CORMIX predicts the geometry and dilution characteristics of effluent flow resulting from a single or multi-port discharge or arbitrary density, location, and geometry into an ambient receiving water body that may be stagnant or flowing and have ambient density stratification of different types. The plume is assumed to be at steady state, which means that successive elements follow the same trajectory. Predictions include dilution, plume diameter, plume elevation, and other plume properties. Once the effluent plume surfaces, the far field solution calculates dilution due to horizontal turbulent mixing of the plume with ambient water.

C.3.1 Near Field Model Set-up

For the purposes of this assessment, the following apply:

- Wind speed of 3 m/s
- Uniform water column properties of temperature and salinity
- Typically, a range of current speeds have been investigated
- Scenario 4A, 4B, 4C, 4D comparison:
  - ambient current velocity of 20 cm/s
- Scenario 4E mitigation options:
  - ambient current velocity of 20 cm/s
- Manning number of 0.025 (a measure of seabed roughness).

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Appendix D Development of the Dilution model

The URS Dilution Model was developed specifically for this project and intended to be used to extend short period 3D far field model simulations of discharge impacts to represent long-term conditions. The URS Dilution Model required less than one minute of CPU to simulate a two year time period, and could therefore provide long-term 'worst case' conditions for each discharge that were not feasible within this project deliverable using a detailed 3D transport model.

The URS Dilution Model is an extension of the steady-state CORMIX dilution model to account for unsteady currents for year long time periods. CORMIX consists of a series of software modules for the prediction of discharges into receiving waters, with emphasis on steady-state values for the geometry and dilution characteristics. The collection of modules consist of regional flow models based upon integral, length scale, and passive diffusion approaches to simulate the hydrodynamics of near field and far field jets and plumes (Doneker and Jirka, 2007)

The adjustments to the CORMIX model predictions are made to account for the effects of unsteady currents on:

- plume duration and direction
- plume dispersion
- build-up of background concentration

The model approach consists of analysing a current time series for sequences of flow direction, duration and speed. Each sequence identified is referred to as a "current scenario" and defined by the current speed, duration and direction. For each current scenario, the discharge plume is estimated using a CORMIX model simulation using input parameters that reflect the current scenario, speed, duration and direction of the flow, the ambient water conditions and the discharge density, flow rate and diffuser configuration.

The output from each CORMIX simulation consists of the plume dilution and width as a function of distance away from discharge location. As a steady-flow model, CORMIX can predict dilutions to large distances from the discharge location. For unsteady flows, such as those that occur in coastal regions, the plume extent is typically limited due to flow reversals associated with changing tides and winds, Therefore, the duration of each current scenario is used to limit the downstream extent of the plume predicted by CORMIX.

As the current time series is analysed over the entire time period (typically 30 minute data over a one year period) current scenario and associated CORMIX predicted plume is mapped onto a discrete grid centred on the discharge location so that the plume dilution pattern is recorded. The square grid extends from the discharge location a 10 kilometres in the east, west and north and south directions, with 10 m grid spacing for the first kilometre, 50 meters spacing from 1 km to 4 km, and 100 meter spacing from 4 km to 10 km. This arrangement was developed to produce manageable files sizes and provide sufficient resolution in the vicinity of the discharge while covering the full range of plume extent

Very often multiple plumes will record dilutions in a particular cell. Since the 'worst case' conditions are required for this project, only the minimum dilution is at each cell is retained. Dilution values from plumes that are higher than the minimum recorded at a cell are discarded.

A number of methods were developed and tested for efficiently identifying current scenarios. After some testing it was found that the simple approach of using a 6 hour sliding time average of currents yielded very good results. Thus for a current time series with a 30 minute interval, each consecutive 12 currents was vector averaged to determine the total excursion length, as well as the average speed

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and direction. These values were then used to set-up the CORMIX simulations, the results of which were mapped onto the grid. The 6 hour scale was chosen initially because it represented one-half of a tidal period.

Two additional parameters have been introduced to adjust the CORMIX outputs to account for dispersion due to unsteady currents, and background build-up. The CORMIX predicted dilution D(s), where s is the downstream distance was modified according to

$$D'(s) = D(s)*f,$$

where f is the scale factor. The background build-up, as a percentage of the discharge concentration, is introduced by another modification to the CORMIX predicted dilution according to:

$$D''(s) = 1 \ / \ (1/D'(s) - g),$$

where g is the background build-up.

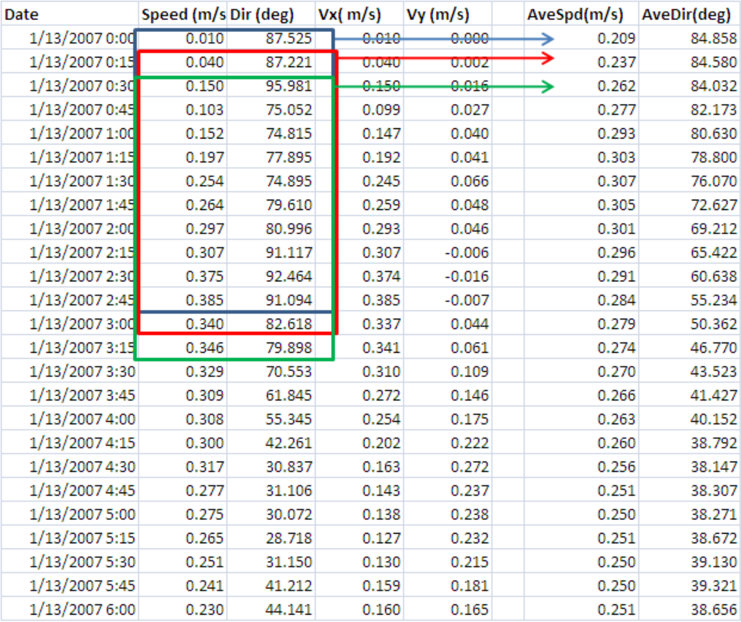
In order to facilitate the assembly of CORMIX simulations, a discrete set of simulations were made for a range of likely speeds. The final speeds selected are 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.0 and 1.1 m/s. The speeds were selected to span the range of possible currents speeds and provide good coverage of the changes in plume behaviour as the current speed changes.

The final set of URS Dilution Model inputs are:

- A time series of current speed and direction (or u and v components) at the discharge location for the desired period of time (typically 30 minute intervals for a year).
- A set of CORMIX simulation outputs for each of the discrete speeds identified above.
- For the CORMIX simulations the following data are required:
  - Discharge characteristics (flow rate, concentration, density)
  - Ambient water conditions (density, current speed, water depth, bottom slope)
  - Discharge configuration (number of ports, orientation, depth in the water column)

An example application of the URS Dilution is provided below. Figure D-4, the time series of flow speed and direction is shown, along with the vector components and the associated speed, length and direction for the first three current scenarios.

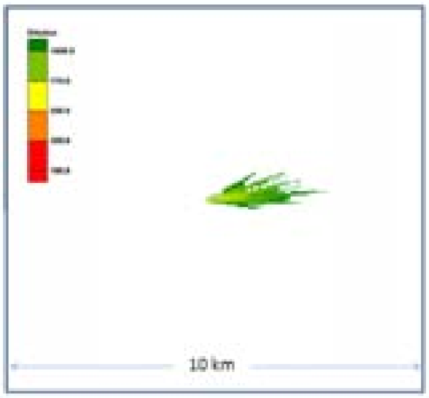
Figure D-4 Example showing the vector averaging of the current time series data for use in the URS Dilution Model



Date	Speed (m/s	Dir (deg)	Vx(m/s)	Vy (m/s)		AveSpd(m/s)	AveDir(deg)
1/13/2007 0:00	0.010	87.525	0.010	0.000		0.209	84.858
1/13/2007 0:15	0.040	87.221	0.040	0.002		0.237	84.580
1/13/2007 0:30	0.150	95.981	0.150	0.016		0.262	84.032
1/13/2007 0:45	0.103	75.052	0.099	0.027		0.277	82.173
1/13/2007 1:00	0.152	74.815	0.147	0.040		0.293	80.630
1/13/2007 1:15	0.197	77.895	0.192	0.041		0.303	78.800
1/13/2007 1:30	0.254	74.895	0.245	0.066		0.307	76.070
1/13/2007 1:45	0.264	79.610	0.259	0.048		0.305	72.627
1/13/2007 2:00	0.297	80.996	0.293	0.046		0.301	69.212
1/13/2007 2:15	0.307	91.117	0.307	-0.006		0.296	65.422
1/13/2007 2:30	0.375	92.464	0.374	-0.016		0.291	60.638
1/13/2007 2:45	0.385	91.094	0.385	-0.007		0.284	55.234
1/13/2007 3:00	0.340	82.618	0.337	0.044		0.279	50.362
1/13/2007 3:15	0.346	79.898	0.341	0.061		0.274	46.770
1/13/2007 3:30	0.329	70.553	0.310	0.109		0.270	43.523
1/13/2007 3:45	0.309	61.845	0.272	0.146		0.266	41.427
1/13/2007 4:00	0.308	55.345	0.254	0.175		0.263	40.152
1/13/2007 4:15	0.300	42.261	0.202	0.222		0.260	38.792
1/13/2007 4:30	0.317	30.837	0.163	0.272		0.256	38.147
1/13/2007 4:45	0.277	31.106	0.143	0.237		0.251	38.307
1/13/2007 5:00	0.275	30.072	0.138	0.238		0.250	38.271
1/13/2007 5:15	0.265	28.718	0.127	0.232		0.251	38.672
1/13/2007 5:30	0.251	31.150	0.130	0.215		0.250	39.130
1/13/2007 5:45	0.241	41.212	0.159	0.181		0.250	39.321
1/13/2007 6:00	0.230	44.141	0.160	0.165		0.251	38.656

The CORMIX plume that is mapped onto the grid for the first three current scenarios shown is shown in Figure D-5. Note that for any grid cells that were overlain by two or more plumes, the minimum dilution was recorded.

Figure D-5 Example showing the modified CORMIX plumes for the first three records in Figure D-4 mapped onto the grid



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There are actual six plumes visible in Figure D-5. After some initial testing and calibration it was found that using two time scales provided better results. The URS Dilution Model was modified to sample the current time series twice, once for each time scale. For the example above the time scales were 3 hours and 6 hours, For some applications where longer plumes occurred, the time scales were set to 6 hours and 12 hours. The longer time scale assured that some current scenarios with large excursions were simulated in the analysis.

Results for one week of simulation are shown in Figure D-6 and results for the entire year‘s record of currents times series is shown in Figure D-7.

Figure D-6 Example showing the modified CORMIX plumes for the first week of current time series records

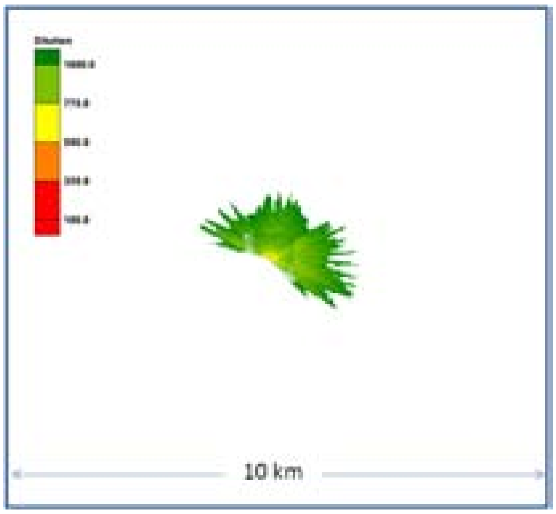
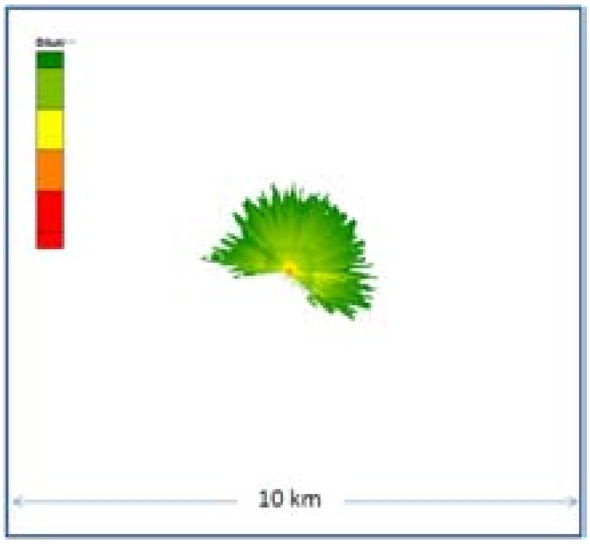


Figure D-7 Example showing the modified CORMIX plumes for the entire year of current time series records



The increased area for the dilution contours with increasing current time series length is evident in these results.

The URS Dilution Model provides a means to extend short-term detailed discharge model of far field conditions. Since the model is based on extensions of CORMIX, the URS Dilution Model also includes near filed dilutions results, thus providing both near field and far field dilution contours.

The URS Dilution Model should not be applied without first calibrating to short period results, and should not be applied for current conditions and dilution levels that differ significantly from the calibrated range. However, since the CORMIX model does account for variations in discharge flow rates and density differences, the URS Dilution Model can be applied for different discharge conditions than those explicitly used for calibration.

D.1 References

Doneker, R.L. and G.H. Jirka, "CORMIX User Manual: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters", EPA-823-K-07-001, Dec. 2007.

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Appendix E Calibration of Dilution model against Results from MIKE3D

The URS Dispersion Model was developed specifically for this project and intended to be used to extend short period 3D far field model results to represent long-term conditions. The URS Dilution Model required less than one minute of CPU to simulate a two year time period, and could therefore provide long-term 'worst case' conditions for each discharge that were not feasible using a detailed 3D transport model. To calibrate the URS Dilution Model, six 3D discharge simulations using the MIKE3D modelling package were executed for two 14 day periods, one representing summer hydrodynamic conditions and one representing winter hydrodynamic conditions. The six scenarios are listed in Table E-15.

Table E-15 Modelling scenarios for Constraining the URS Dilution Model

Parameter	Property	Units	Outlet 1 Positively Buoyant Discharge		Outlet 1 Negatively Buoyant Discharge	
			Scenario E1 Summer	Scenario E2 Winter	Scenario E3 Summer	Scenario E4 Winter
Ambient	Temperature	C	30	20	30	20
	Salinity	ppt	35	35	35	35
	Density	Kg/m3	1021.73	1024.76	1021.73	1024.76
Discharge	Temperature	C	30	20	30	20
	Salinity	ppt	15.9	15.9	44.7	44.7
	Release	-	surface	surface	bottom	bottom
	Flow rate	m3/hr	776	776	172	172
	Density	Kg/m3	1007.48	1010.26	1029.02	1032.18

These scenarios were intended to represent the range of environmental and discharge conditions that might be realized at each discharge location. The time period for the summer simulation period is 16/01/07 - 30/01/07 and for the winter period, 11/06/07 - 25/06/07.

The model calibration was conducted in two phases to accommodate the differences in applying 3D currents and 2D currents in the analysis. The short-term two-week summer and winter MIKE3D model simulation provided 3D currents for use in the model calibration. However, for the application of the URS Dilution Model to extend conditions over a full year, only depth-averaged (2D) data was available from previous MIKE21 hydrodynamic models (DHI, 2009). Therefore the URS Dilution Model was first calibrated using the 3D current data for each two week period. These calibrations demonstrated the capabilities of the URS Dilution Model when exact flow conditions are known. The URS Dilution Model was then calibrated using the 2D current data corresponding to the same two week period. This calibration demonstrates any potential limitation associated with using the 2D current data. For the calibration using the 3D current data, surface layer currents were used when calibrating for positively buoyant discharges and bottom layer currents were used when calibrating to negatively buoyant discharges.

The basis of the calibrations is a comparison of minimum dilution with distance from the discharge location. For each calibration the URS Dilution Model parameters for dilution scale, the background build-up, and time scales were varied to obtain the calibration. The time scale was initially set to 6 hours, which is one-half the tidal period, and representative of the normal tidal excursions. These values worked well for the Outfall 2 location. However, prevailing winds during the summer and winter can prevent tidal current reversals and create longer excursions lengths for the Outfall 1 location. It was found during some initial URS Dilution Model simulations that a time scale twice the half-tidal-period scale was required to properly simulate the impact of the discharges farther from the discharge location, in the 5K to 10K range. For those simulations, the two time scales used were 6 hours, and 12 hours.

For each calibration scenario, a series of CORMIX simulations were conducted and the output processed for use in the URS Dilution Model. The CORMIX simulations were executed for the range of speed (0.5, 0.10, 0.15, 0.25, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90 and 1.0 m/s using the discharge flow rate and density conditions specific to each scenario (Table E-15).

E.1 Positively Buoyant Discharge from Outlet 1

The MIKE3D simulation results for the summer and winter two-week periods are shown in Figure E-8 and Figure E-9. The MIKE3D plots are show contours of salinity. The dilutions associated with the salinity contours are listed in Table E-16. The farthest distance at which each dilution occurs is also recorded in Table E-16, and was determined by measuring the distance of each contour in Figure E-8 and Figure E-9

Table E-16 MIKE3D model Temperature and Related Dilutions

Temperature (°C)	Dilution	Maximum Distance (m) (summer)	Maximum Distance (m) (winter)
34.618	50	200	200
34.809	100	700	700
34.924	250	2200	2800
34.962	500	5400	6000
34.981	1000	7800	8500
34.985	1300	9500	9600

The maximum distances for each dilution level for the larger dilutions are slightly higher for the winter conditions than for the summer conditions. This is likely due to the coastline geometry. During the summer the predominant current direction is to the east, where the coastline curvature is concave. During the winter, the predominant current direction is to the west, where the coastline curvature is convex. The convex curvature is likely to enhance dispersion since the flows will tend to diverge.

For the lower dilution levels (100 and 250 m), the maximum distance to the dilution level is the same for both the summer and winter. This is the expected results since the near field conditions are less sensitive to the coastline curvature.

Figure E-8 **MIKE 3D results for Outfall 1 Positively Buoyant Summer (Scenario E1) Conditions showing the maximum distance to each dilution (refer to Table E-16 for temperature – dilution correspondence)**

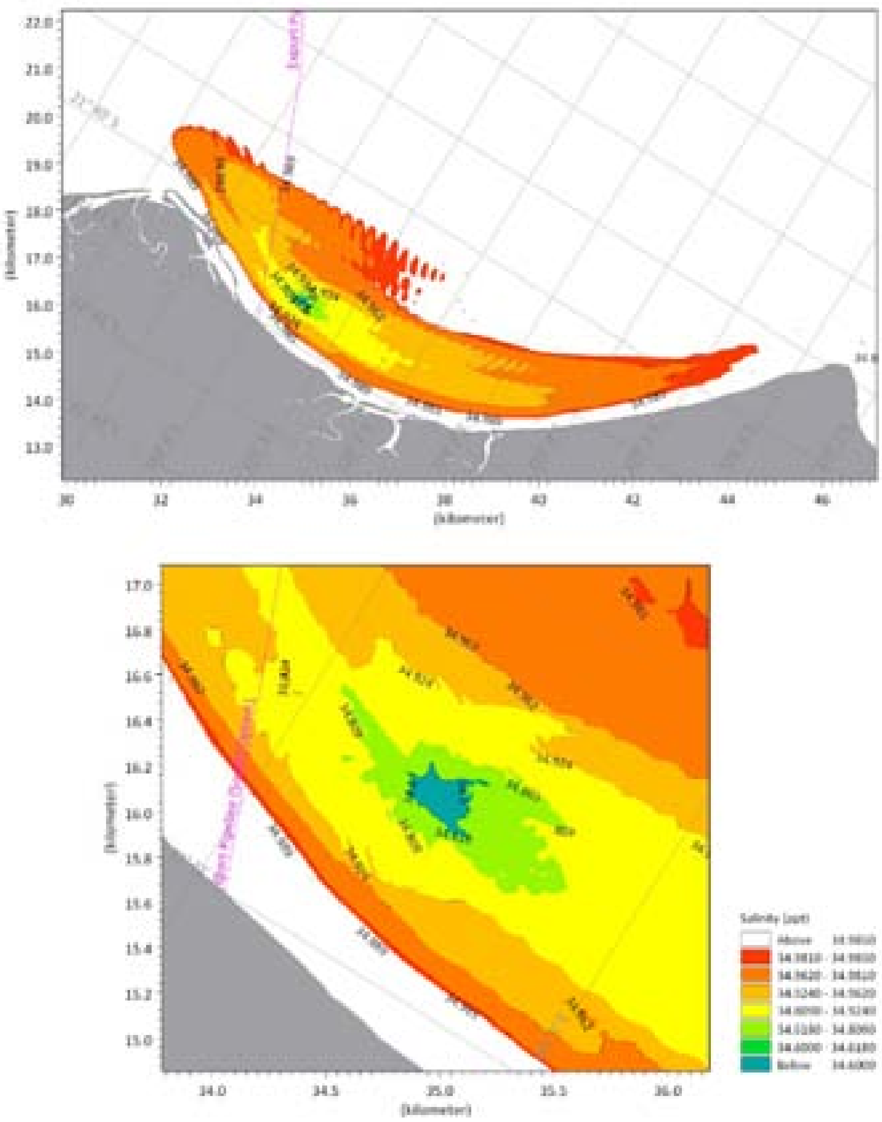

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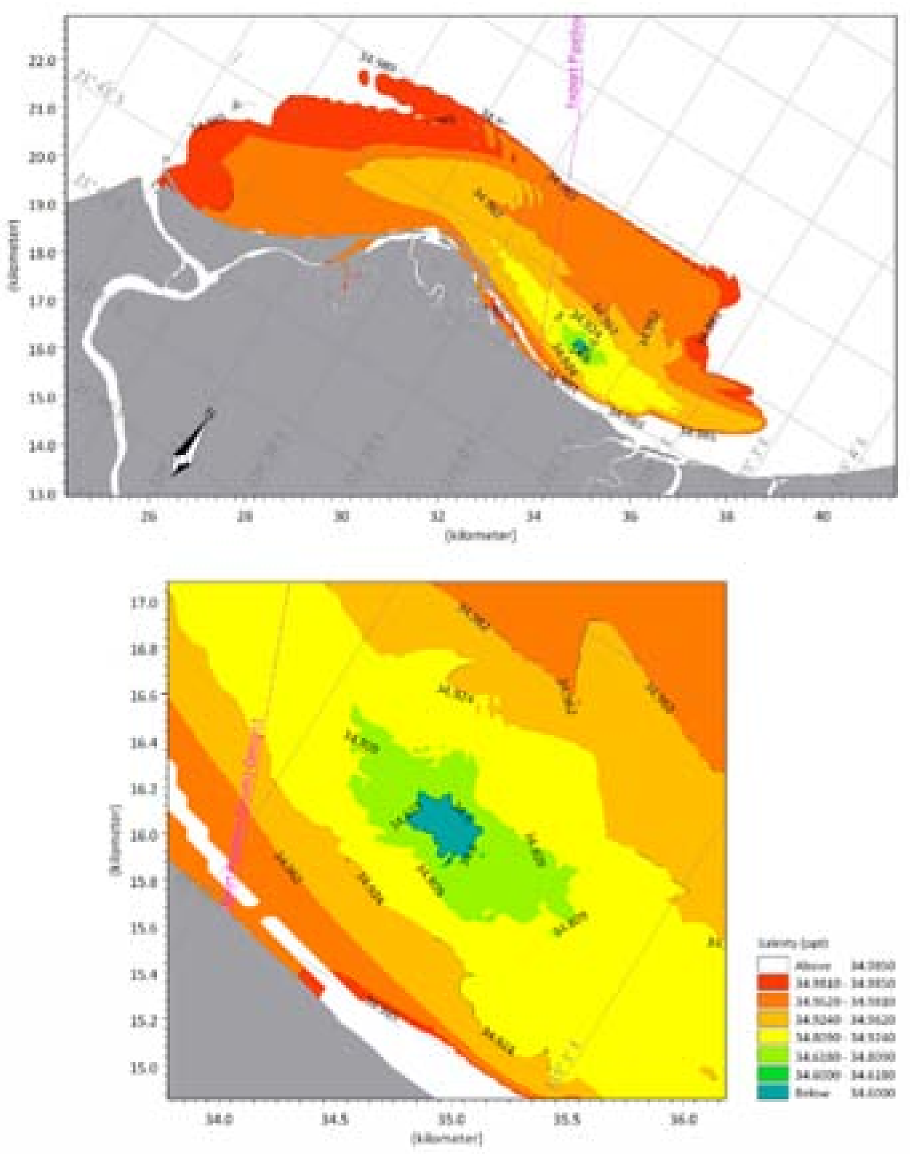
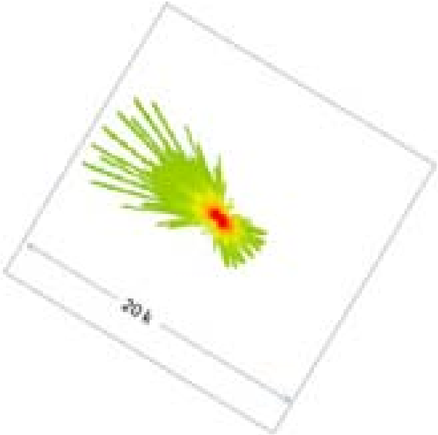
Figure E-9 MIKE 3D results for Outfall 1 Positively Buoyant Winter (Scenario E2) Conditions showing the maximum distance to each dilution (refer to Table E-16 for temperature – dilution correspondence)



The corresponding results for the URS Dilution Model for the Phase 1 calibration using the 3D surface currents) are shown in Figure E-10 and Figure E-11.

Figure E-10 URS Dilution Model results for Outfall 1 Positively Buoyant Summer (Scenario E1) Conditions showing the maximum distance to each dilution using 3D currents

Figure E-11 URS Dilution Model results for Outfall 1 Positively Buoyant Winter (Scenario E2) Conditions showing the maximum distance to each dilution using 3D currents



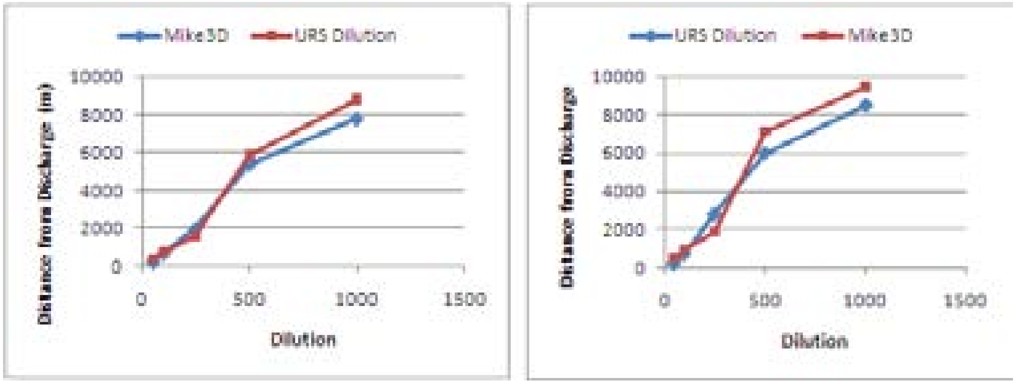
In general the alignment of the minimum dilution contours and the general maximum distances to each dilution level are consistent with those of the MIKE3D simulations. The most notable difference in the MIKE3D results and the URS Dilution Model are (1) the larger spread in the dilution contours and (2) the contours do not follow the general curvature of the coastline.

The larger spread is a direct consequence of the URS Dilution Model only using the current speeds at the discharge location. When the model calculates the excursion from the discharge point for any point in the current time series, it may happen that the direction is not exactly parallel to the coastline. In actuality, as the plume moves away from the discharge point, the current direction will change and become more parallel to the coastline, but this process is not captured in the URS Dilution Model. Thus the plume is simulated to follow the initial path and yields a larger spread.

The lack of curvature is also a direct effect of the URS Dilution Model only using the currents at the discharge location. The CORMIX plumes are aligned with the current direction at the discharge location, which does not reflect the changes in coastline direction and associated change in current direction both upstream and downstream from the discharge location.

The larger spread and lack of curvature are not critical, however, since the primary results are the maximum distance to each dilution level is similar. Figure E-12 shows a comparison of the maximum distance to each dilution level for the MIKE3D and the URS Dilution Model simulations.

Figure E-12 Comparison of MIKE 3D and URS Dilution Model predicted maximum distance to dilution levels for both the Outfall 1 Buoyant Summer and Winter simulations (Scenarios E1 and E2)



(a) Summer (b) Winter

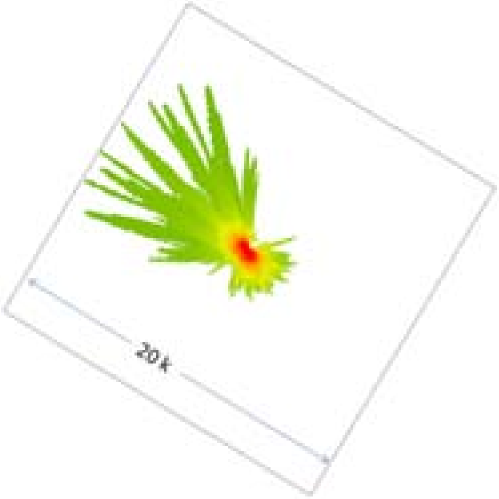
There is generally very good agreement between the two models. The URS Dilution Model calibration was obtained using a dilution scale factor of 1.5 for the summer conditions, 1.2 for the winter conditions and a background build-up of 0.035 °C for both scenarios.

The dilution scale factor of 1.5 and 1.1 indicate that the MIKE21 results represent a higher dispersion than those predicted by the CORMIX model. This is likely due to the CORMIX model being steady-state and not including the effects of unsteady flow, large scale eddies and possible wind shear related dispersion. Also, CORMIX is known to be highly conservative and therefore under-represent dispersion. The build-up value of 0.035 °C is low, and consistent with the highly dispersive conditions characteristics of offshore regions (as opposed to confined tidal regions such as bays and estuaries.

The Phase 2 calibration was conducted next for scenarios E1 and E2, which differed only by the application of the depth-averaged currents for each of the two-week simulation periods. The results for the URS Dilution Model for scenarios E1 and E2 are shown in Figure E-13 and Figure E-14.

Figure E-13 URS Dilution Model results for Outfall 1 Positively Buoyant Summer (Scenario E1) Conditions showing the maximum distance to each dilution using 2D currents

Figure E-14 URS Dilution Model results for Outfall 1 Positively Buoyant Winter (Scenario E2) Conditions showing the maximum distance to each dilution using 2D currents



In general the alignment of the minimum dilution contours and the general maximum distances to each dilution level are consistent with those of the MIKE3D simulations and Phase 1 URS Dilution Model simulations. There appears to be a larger spread in the contours, in comparison to the previous Phase 1 URS Dilution Model results and is larger due to differences in the 3D and 2D current patterns obtained form the 2D and 3D MIKE21 and MIKE3D models.

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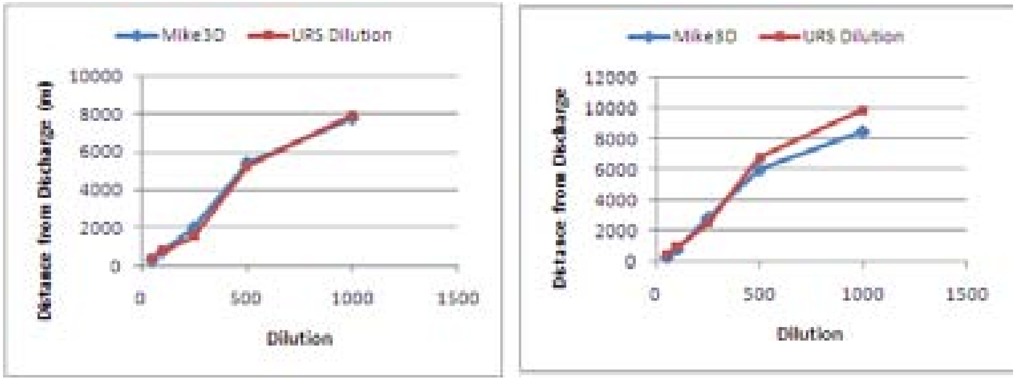
Figure E-15 shows a comparison of the maximum distance to each dilution level for the MIKE3D and the Phase 2 URS Dilution Model simulations.

Figure E-15 Comparison of MIKE 3D and URS Dilution Model predicted maximum distance to dilution levels for both the Outfall 1 Positively Buoyant Summer and Winter simulations (Scenarios E1 and E2)



(a) Summer (b) Winter

There is generally very good agreement between the two models. The URS Dilution Model calibration was obtained using a dilution scale factor of 1.4 for the summer conditions, 1.2 for the winter conditions and a background build-up of 0.035 °C for both scenarios.

The results plotted in Figure E-15 highlight the ability of the URS Dilution Model to simulate the maximum distance to the dilution levels relative to the MIKE3D model. Thus the plots represent accuracy limitations. Subsequent applications of the model should not be used to delineate distances for dilutions much larger than 1000, as this is the upper range for which the model was calibrated.

E.2 Negatively Buoyant Discharge from Outlet 1

The MIKE3D simulation results for the summer and winter two-week periods are shown in Figure E-16 and Figure E-17. The MIKE3D plots are show contours of salinity. The dilutions associated with the salinity contours are listed in Table E-17. The farthest distance at which each dilution occurs is also recorded in Table E-3, and was determined by measuring the distance of each contour in Figure E-16 and Figure E-17.

Table E-17 MIKE3D model Temperature and Related Dilutions

Temperature (°C)	Dilution	Maximum Distance (m) (summer)	Maximum Distance (m) (winter)
35.194	50	200	200
35.097	100	500	500
35.039	250	900	1100
35.019	500	1500	1700
35.010	1000	2000	2800
35.007	1300	2250	3100

The results for negatively buoyant discharge are similar to those for the positively buoyant discharge with similar maximum distances for the lower dilution levels for summer and winter periods, and a larger maximum distance to the larger dilutions levels in the winter than in the summer. The primary difference in the results is that the maximum distances are lower for the negatively buoyant discharges. The smaller extent of the plume is due to lower bottom currents and a lower discharge rate for these scenarios.

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Figure E-16 MIKE 3D results for Outfall 1 Negatively Buoyant Summer (Scenario E3) Conditions showing the maximum distance to each dilution (refer to Table E-2 for temperature – dilution correspondence)

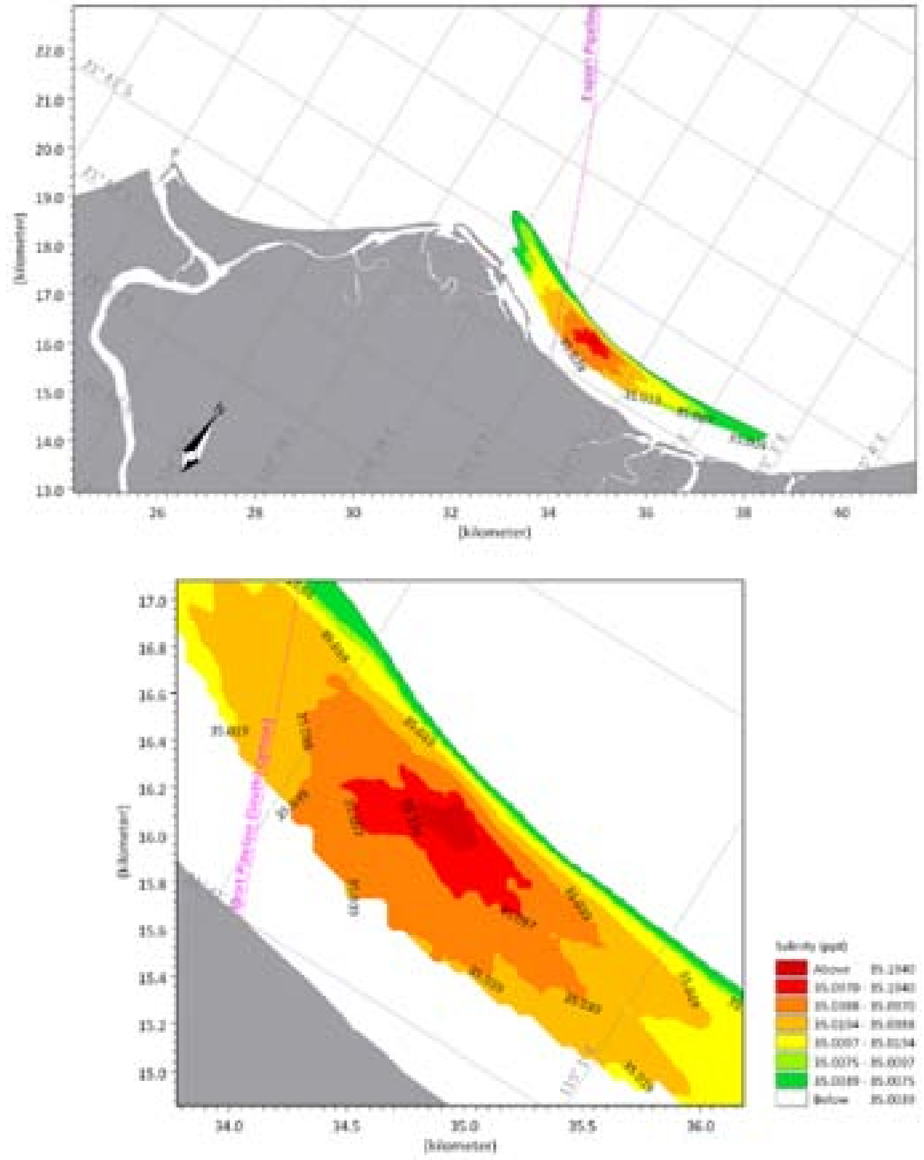
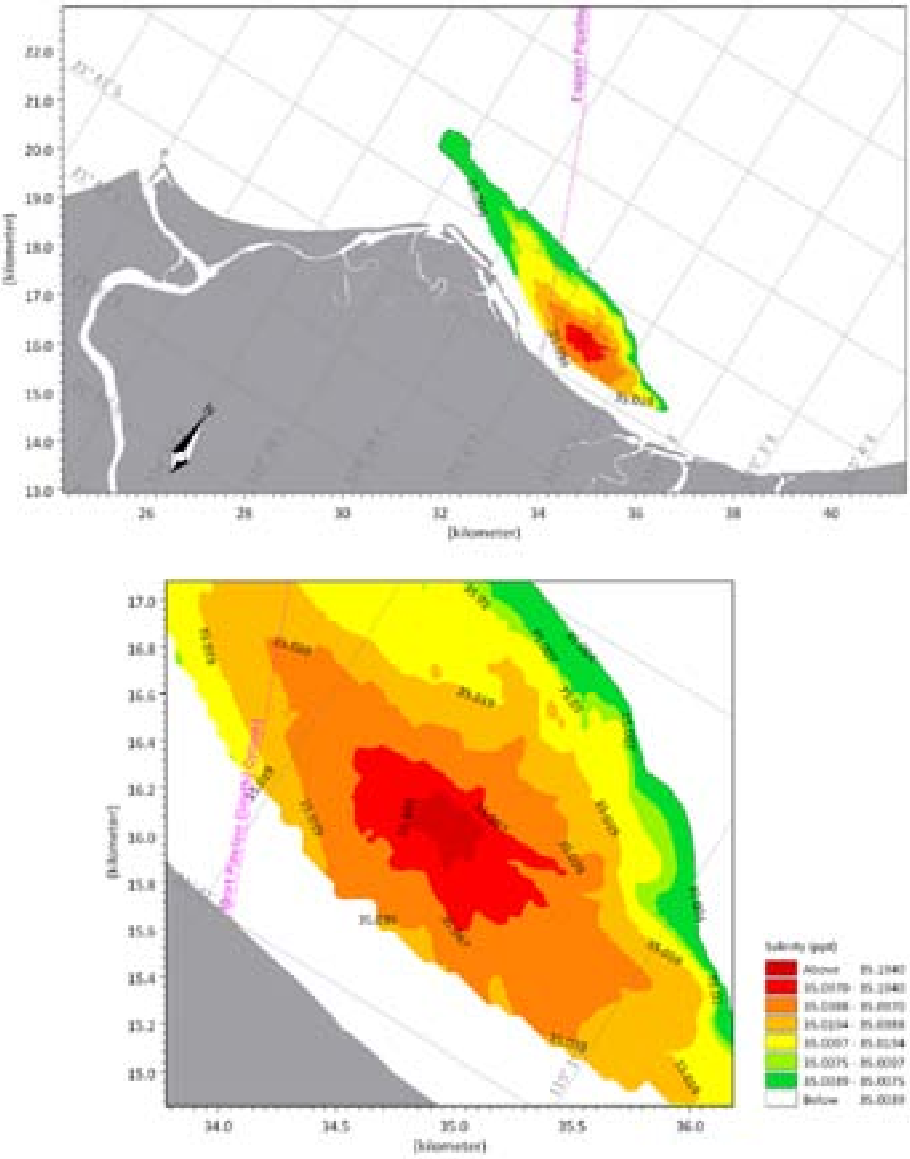


Figure E-17 MIKE 3D results for Outfall 1 Negatively Buoyant Winter (Scenario E4) Conditions showing the maximum distance to each dilution (refer to Table E-2 for temperature – dilution correspondence)



The corresponding results for the URS Dilution Model for the Phase 1 calibration using the 3D surface currents) are shown in Figure E-18 and Figure E-19.

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Figure E-18 MIKE 3D results for Outfall 1 Negatively Buoyant Summer (Scenario E3) Conditions showing the maximum distance to each dilution using 3D currents

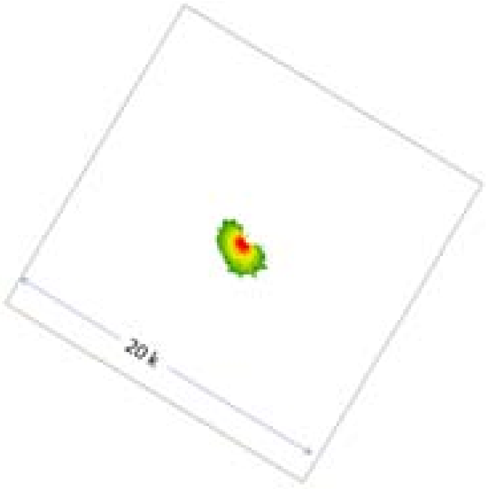
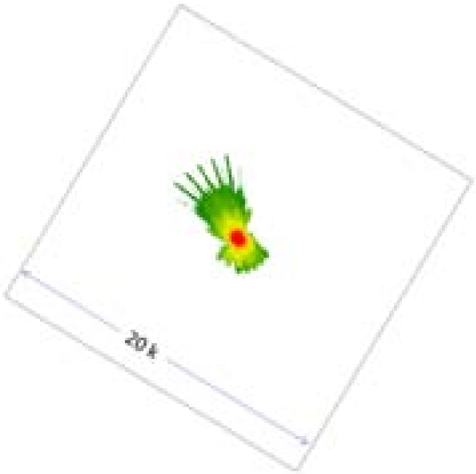


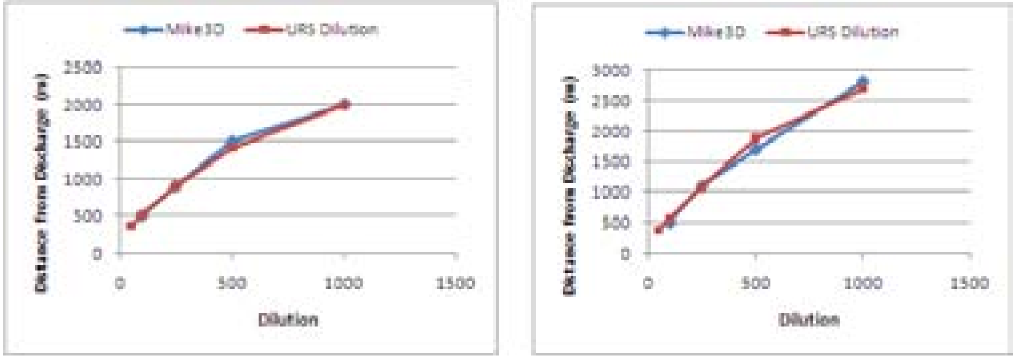
Figure E-19 MIKE 3D results for Outfall 1 Negatively Buoyant Winter (Scenario E4) Conditions showing the maximum distance to each dilution using 3D currents



In general the alignment of the minimum dilution contours and the general maximum distances to each dilution level are consistent with those of the MIKE3D simulations. The most notable difference in the MIKE3D results and the URS Dilution Model are (1) the larger spread in the dilution contours and (2) the contours do not follow the general curvature of the coastline. The explanation for these differences are the same here as for the positively buoyant plume and are related to the use of a single current time series to represent a spatially variable flow field. (Section E.2)

The larger spread and lack of curvature are not critical, however, since the primary results are the maximum distance to each dilution level is similar. Figure E-20 shows a comparison of the maximum distance to each dilution level for the MIKE3D and the URS Dilution Model simulations.

Figure E-20 Comparison of MIKE 3D and URS Dilution Model predicted maximum distance to dilution levels for both the Outfall 1 Buoyant Summer and Winter simulations (Scenarios E1 and E2)



(a) Summer (b) Winter

There is generally very good agreement between the two models. The URS Dilution Model calibration was obtained using a dilution scale factor of 0.85 for the summer conditions, 0.8 for the winter conditions and a background build-up of 0.005 °C for both scenarios.

The dilution scale factor of 0.85 and 0.8 indicate that the MIKE21 results represent a lower dispersion than those predicted by the CORMIX model. However, the negatively buoyant module of the CORMIX model is relatively new, and therefore it's testing and validation is still evolving. Thus it is likely that the required reduction of the CORMIX predicted dilutions, relative to those of MIKE21, are due to uncertainties associated with the recently developed CORMIX module. The build-up value of 0.005 °C is low, and consistent with the highly dispersion conditions characteristics of offshore regions (as opposed to confined tidal regions such as bays and estuaries.

The Phase 2 calibration was conducted next for scenarios E1 and E2, which differed only by the application of the depth-averaged currents for each of the two-week simulation periods. The results for the URS Dilution Model for scenarios E1 and E2 are shown in Figure E-21 and Figure E-22.

Appendix E

Figure E-21 MIKE 3D results for Outfall 1 Positively Buoyant Summer (Scenario E1) Conditions showing the maximum distance to each dilution using 2D currents

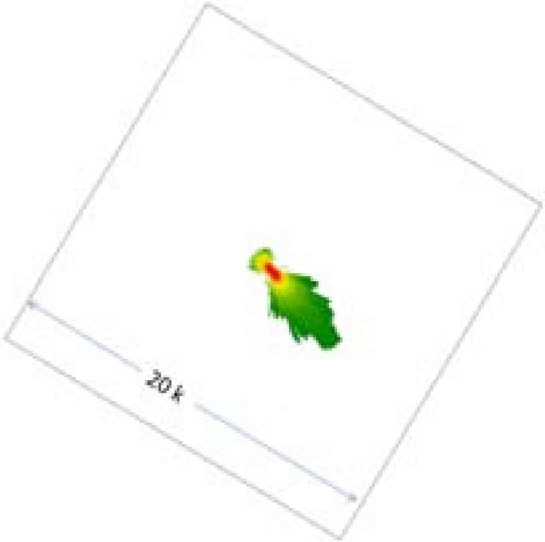
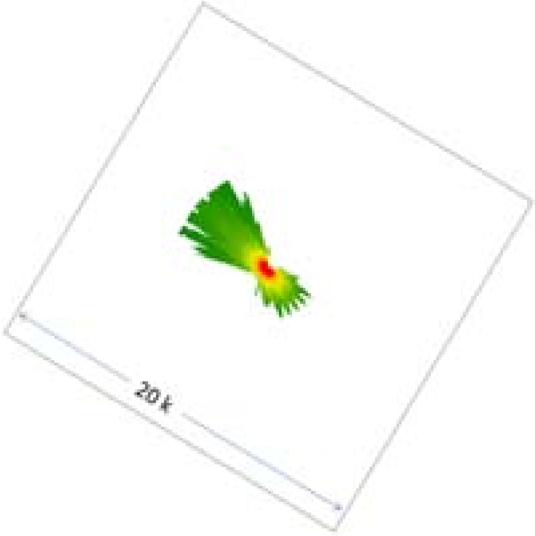


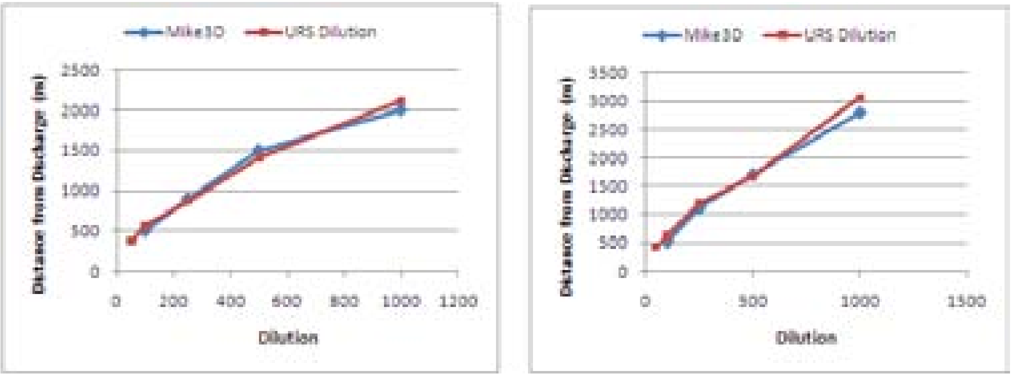
Figure E-22 MIKE 3D results for Outfall 1 Positively Buoyant Winter (Scenario E2) Conditions showing the maximum distance to each dilution using 2D currents



In general the alignment of the minimum dilution contours and the general maximum distances to each dilution level are consistent with those of the MIKE3D simulations and Phase 1 URS Dilution Model simulations. There appears to be a larger spread in the contours, in comparison to the previous Phase 1 URS Dilution Model results and is larger due to differences in the 3D and2D current patterns obtained form the 2D and 3D MIKE21 and MIKE 3D models.

Figure E-23 shows a comparison of the maximum distance to each dilution level for the MIKE3D and the Phase 2 URS Dilution Model simulations.

Figure E-23 Comparison of MIKE 3D and URS Dilution Model predicted maximum distance to dilution levels for both the Outfall 1 Positively Buoyant Summer and Winter simulations (Scenarios E1 and E2)



(a) Summer (b) Winter

There is generally very good agreement between the two models. The URS Dilution Model calibration was obtained using a dilution scale factor of 0.75 for the summer conditions, 0.7 for the winter conditions and a background build-up of 0.005 °C for both scenarios.

The results plotted in Figure E-16 represent the ability of the URS Dilution Model to simulate the maximum distance to the dilution levels relative to the MIKE3D model. Thus the plots represent accuracy limitations. Subsequent applications of the model should not be used to delineate distances for dilutions much larger than 1000, as this is the upper range for which the model was calibrated.

Appendix E

E.3 Produced Water Discharge from Outlet 2

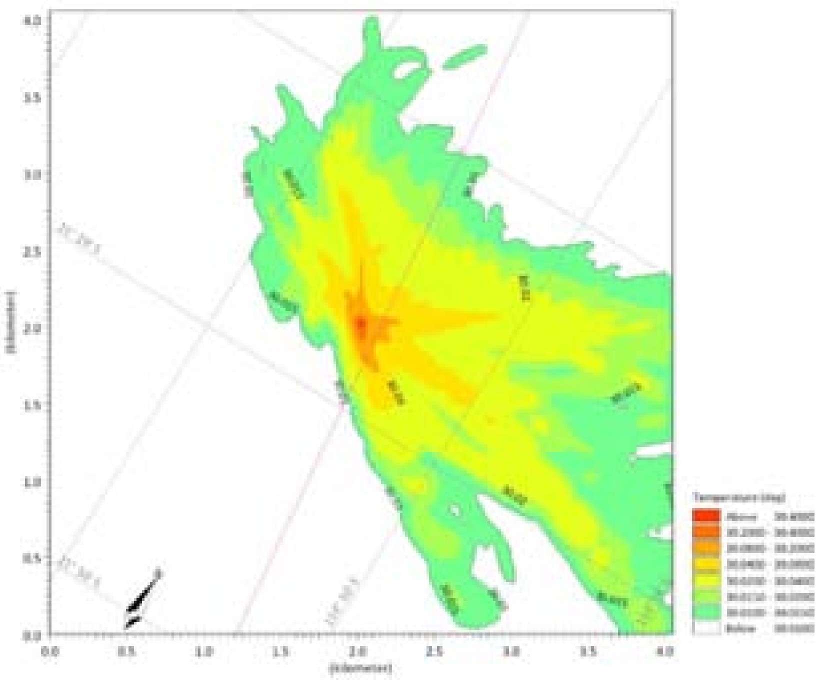
The MIKE3D simulation results for the summer and winter two-week periods are shown in Figure E-24 and Figure E-25. The MIKE3D plots are show contours of temperature. The dilutions associated with the temperature contours are listed in Table E-18. The farthest distance at which each dilution occurs is also recorded in Table E-18, and was determined by measuring the distance of each contour in Figure E-24 and Figure E-25.

Table E-18 MIKE3D model Temperature and Related Dilutions

Scenario E5 (Summer)			**Scenario E6 (Winter)**		
Temperature (℃)	Dilution	Maximum Distance m) (summer)	Temperature (℃)	Dilution	Maximum Distance m) (winter)
30.4	50	-	20.6	50	-
30.2	100	-	20.3	100	50
30.08	250	250	20.12	250	600
30.04	500	900	20.06	500	2000
30.02	1000	2200	20.03	1000	2500
30.015	1300	2800	20.023	1300	3100

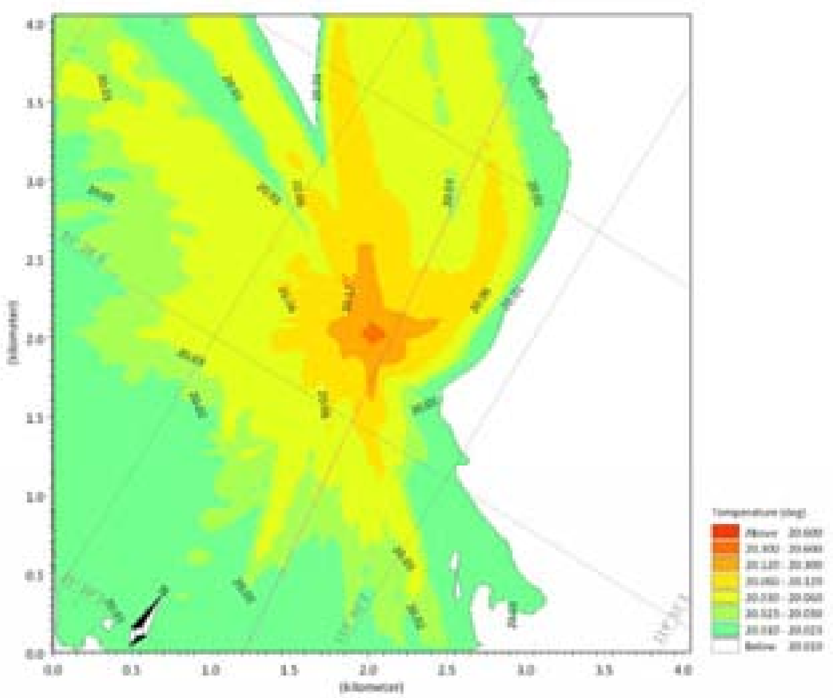
The maximum distances for each dilution level for the larger dilutions are slightly higher for the winter conditions than for the summer conditions.

Figure E-24 MIKE 3D results for Outfall 2 Positively Buoyant Summer (Scenario E5) Conditions showing the maximum distance to each dilution (refer to Table E-3 for temperature – dilution correspondence)



Appendix E

Figure E-25 MIKE 3D results for Outfall 2 Positively Buoyant Winter (Scenario E6) Conditions showing the maximum distance to each dilution (refer to Table E-3 for temperature – dilution correspondence)



The corresponding results for the URS Dilution Model for the Phase 1 calibration using the 3D surface currents) are shown in Figure E-26 and Figure E-27.

Figure E-26 URS Dilution Model results for Outfall 2 Positively Buoyant Summer (Scenario E5) Conditions showing the maximum distance to each dilution using 3D currents

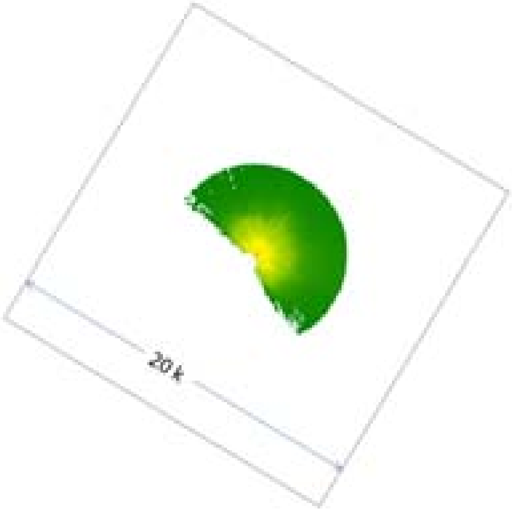
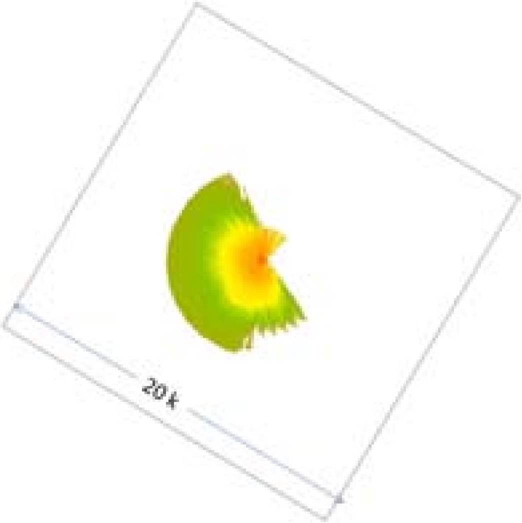


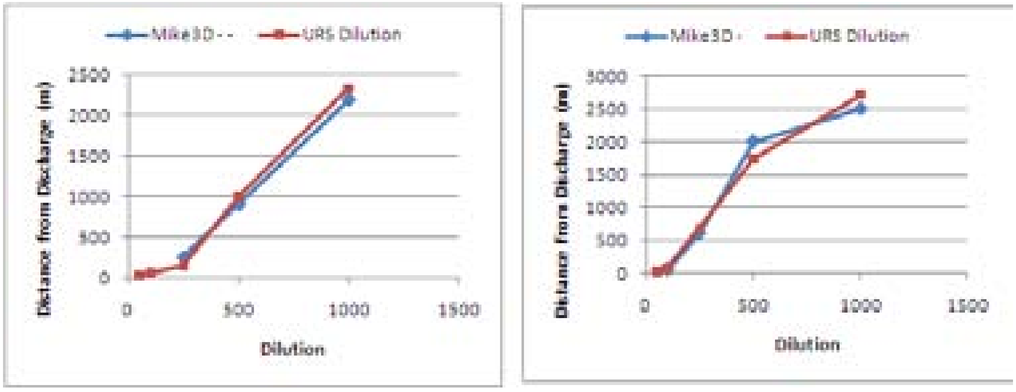
Figure E-27 URS Dilution Model results for Outfall 2 Positively Buoyant Winter (Scenario E6) Conditions showing the maximum distance to each dilution using 3D currents



In general the area of impact is well represented by the URS Dilution Model. The detailed patterns seen in the MIKE3D results are not as distinct in the results of the URS Dilution Model, and are due to limitations of the URS Dilution Model in representing patterns associated with the unsteady currents.

These differences are not critical, however, since the primary results are the maximum distance to each dilution level is similar, which are well represented. Figure E-28 shows a comparison of the maximum distance to each dilution level for the MIKE3D and the URS Dilution Model simulations.

Figure E-28 Comparison of MIKE 3D and URS Dilution Model predicted maximum distance to dilution levels for both the Outfall 1 Buoyant Summer and Winter simulations (Scenarios E1 and E2)



(a) Summer

(b) Winter

There is generally very good agreement between the two models. The URS Dilution Model calibration was obtained using a dilution scale factor of 1.7 for the summer conditions, 1.8 for the winter conditions and a background build-up of 0.015 ℃ and 0.02 ℃ for summer and winter conditions.

The dilution scale factor of 1.7 and 1.8 indicate that the MIKE21 results represent a higher dispersion than those predicted by the CORMIX model. This is likely due to the CORMIX model being steady-state and not including the effects of unsteady flow, large scale eddies and possible wind shear related dispersion. Also, CORMIX is known to be highly conservative and therefore under-represent dispersion. The scale factor values are also higher for the Outfall 2 location relative to the Outfall 1 location. This is consistent with expectations, since the Outfall 2 location is further away from the coastline; the currents are expect to be more variable and therefore the dispersion higher. The build-up value of 0.015 ℃ and 0.02 ℃ are low, and consistent with the highly dispersion conditions characteristics of offshore regions (as opposed to confined tidal regions such as bays and estuaries).

The Phase 2 calibration was conducted next for scenarios E5 and E6, which differed only by the application of the depth-averaged currents for each of the two-week simulation periods. The results for the URS Dilution Model for scenarios E5 and E6 are shown in Figure E-29 and Figure E-30.

Figure E-29 URS Dilution Model results for Outfall 2 Positively Buoyant Summer (Scenario E5) Conditions showing the maximum distance to each dilution using 2D currents

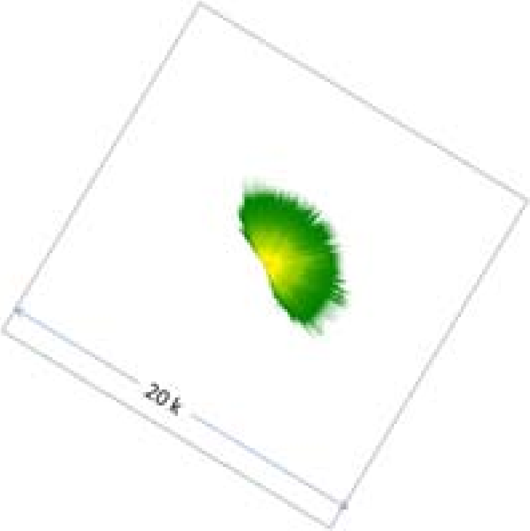
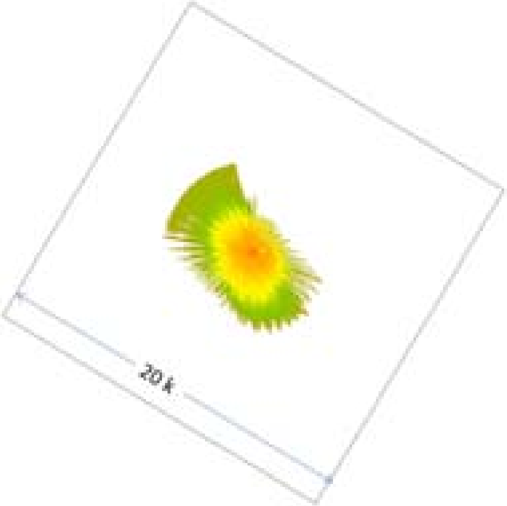


Figure E-30 URS Dilution Model results for Outfall 2 Positively Buoyant Winter (Scenario E6) Conditions showing the maximum distance to each dilution using 2D currents

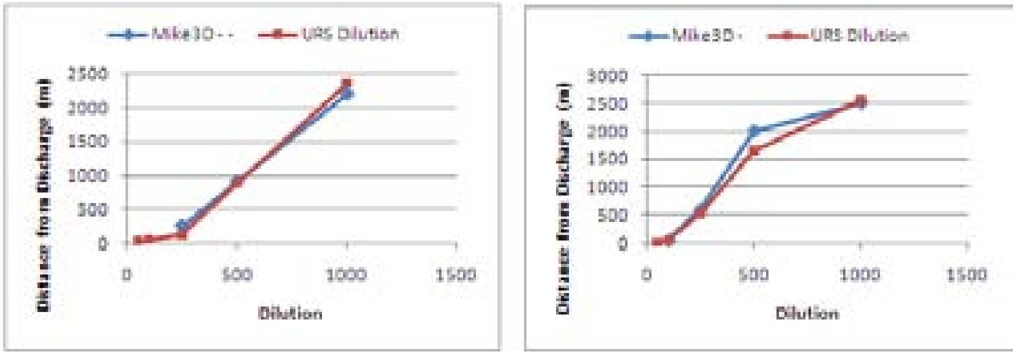


The Phase 2 calibration patterns for summer conditions are very similar to those of the Phase 1 calibration, but less so for the winter conditions. The differences can be attributed to differences in the 3D and2D current patterns obtained from the 2D MIKE21 and 3D MIKE3D models.

Appendix E

Figure E-31 shows a comparison of the maximum distance to each dilution level for the MIKE3D and the Phase 2 URS Dilution Model simulations.

Figure E-31 Comparison of MIKE 3D and URS Dilution Model predicted maximum distance to dilution levels for both the Outfall 2 Positively Buoyant Summer and Winter simulations (Scenarios E1 and E2)



(a) Summer (b) Winter

There is generally very good agreement between the two models. The URS Dilution Model calibration was obtained using a dilution scale factor of 1.6 for the Summer conditions, 1.8 for the winter conditions and a background build-up of 0.015 °C and 0.02 °C for the summer and winter scenarios.

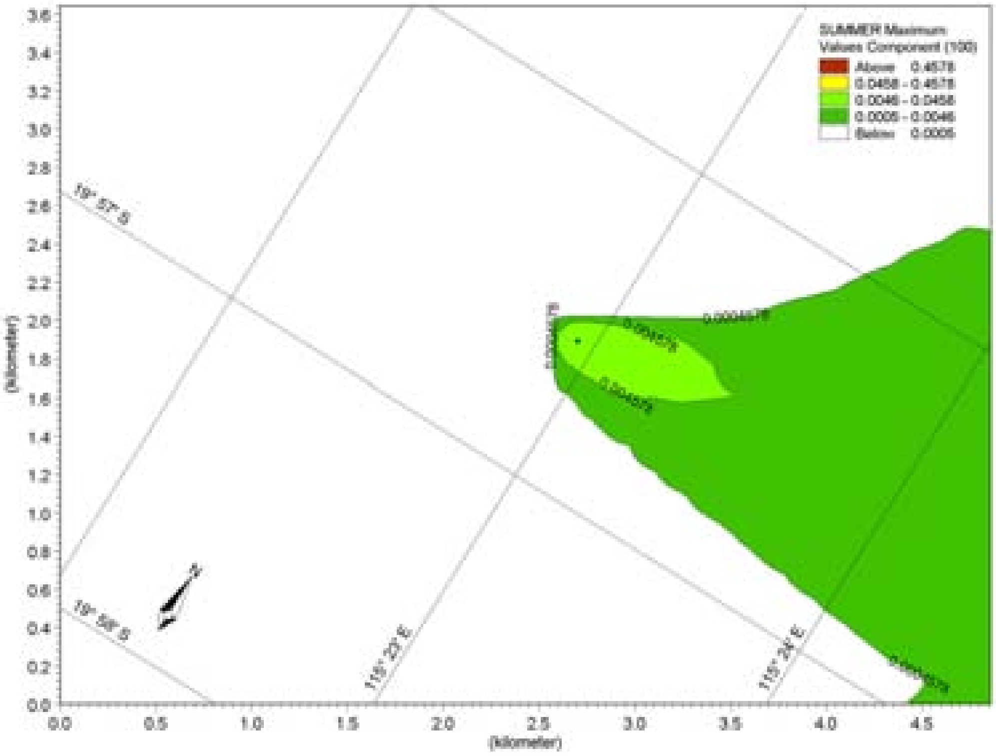
The results plotted in Figure E-31 represent the ability of the URS Dilution Model to simulate the maximum distance to the dilution levels relative to the MIKE3D model. Thus the plots represent accuracy limitations. Subsequent applications of the model should not be used to delineate distances for dilutions much larger than 1000, as this is the upper range for which the model was calibrated.

Appendix F Results of MIKE3D for MEG Scenario 4C

F.1 Summer

Results for the summer scenario suggest that under these conditions, the plume disperses quickly downstream of the discharge point.

Figure F-32 Maximum Tracer Concentrations from MIKE3D for the Summer Scenario, 16/01/07 – 30/01/07



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Appendix Q4

Nearshore Acid Sulfate Soils Investigation (Turning Basin and Dredge Channel)

Tables

Figures

Appendices

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Report

Wheatstone Project

Nearshore Acid Sulfate Soils Investigation (Turning Basin & Dredge Channel)

9 JULY 2010

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Chevron Australia Pty Ltd

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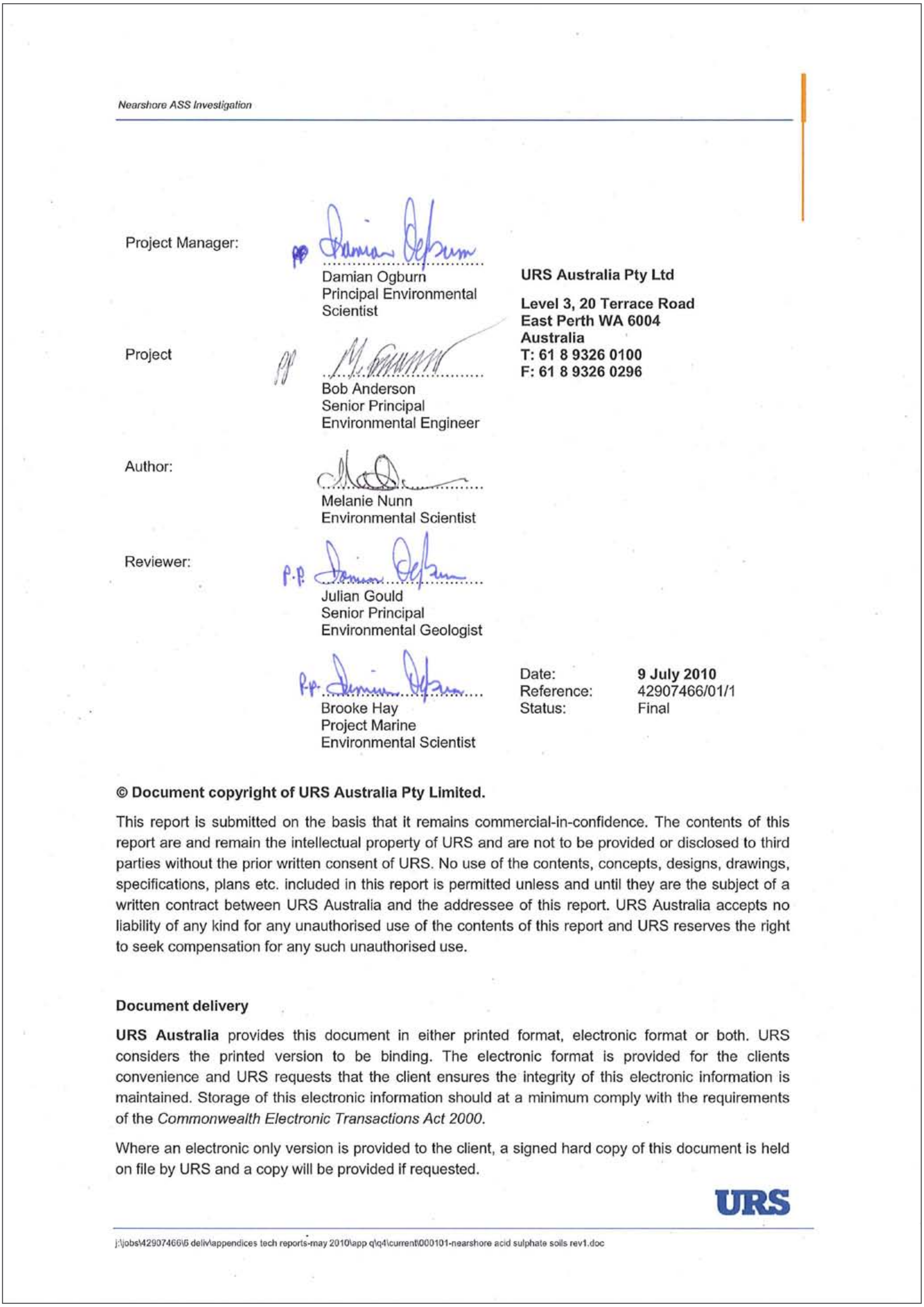
42907466



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Executive Summary

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara coast. The LNG and Domgas plant will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and other yet-to-be determined gas fields. The Wheatstone Project is referred to as the Project and the Ashburton North Strategic Industrial Area (Ashburton North SIA) is the proposed site for the LNG and Domgas plant. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land. The LNG plant will have a maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Project has been referred to the State Environmental Protection Authority (EPA) and the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

Commissioning of the Project will require installation of onshore and nearshore infrastructure, adjacent to the Ashburton River delta and nearby to the Hooley Creek tidal system. Infrastructure installation will require dredging of marine sediments (approximately 45 000 000 m^3) to construct a navigation channel and turning basin, with the sediments being placed at one of five proposed offshore dredge material placement sites.

For dredging, and subsequent placement to occur, a geochemical assessment of the sediment is required to determine whether the potential for acid sulphate soils (ASS) to develop exists. ASS is naturally occurring in soils, sediments and peats that contain iron sulfide minerals (commonly in the form of pyrite (FeS_2)). They are typically encountered in low lying, water logged, high organic areas as these environments provide key elements for the formation of sulfuric acid (e.g. bacteria, oxygen). In an undisturbed anoxic state these materials remain benign, do not pose a significant risk to the environment, and are referred to as potential acid sulphate soils (PASS). Development of ASS may cause biological changes in the surrounding environs, including disturbance or displacement of benthic primary producer habitat (BPPH) and marine fauna due to the placement of potentially contaminated sediment into the marine environment.

The objective of this investigation was to determine whether the sediments and profiles that may be disturbed during the dredging process will pose any adverse environmental impacts to the marine environment. This was achieved by compiling and interpreting lithological core log data and interpreting analytical laboratory data.

The nearshore sampling programme was undertaken between 26 June 2009 and 12 July 2009, with a total of 72 samples being taken from 15 deep core borehole locations (MC001-MC015) at varying depths, along the length of the proposed navigation channel and turning basin. An assessment of potential acid sulphate soils (PASS) and the carbonate buffering capacity of shallow and deep sediments was made from these samples.

The collection of samples was made in accordance with the following guidelines:

- *Development of Sampling and Analysis Programs*
- *DRAFT Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes*
- *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes*
- *Contaminated Sites Management Series: Assessment levels for Soil, Sediment and Water*; and
- *National Assessment Guidelines for Dredging.*

Executive Summary

The assessment criteria adopted for PASS in Western Australia is the Texture Based PASS Action Criteria, developed by Ahern *et al*. (1998).

Analytical methods used to determine the presence of PASS included the Acid Sulfate Soils Screening test (based on pH_f and pH_{fox} values and a reaction rating), the Chromium Suite (Scr) for Acid Sulfate Soils test (based on levels of chromium reducible sulfur (Scr), pH_{KCl}, total titratable acid (TAA), and acid neutralising capacity (ANC)) and Carbonate Buffering.

It is anticipated that the likelihood of encountering PASS or AASS material during the construction of the proposed navigation channel and turning basin is low. This is indicated by the negligible acid generating capacity of the sediment encountered during the field sampling programme. Where PASS was encountered, typically in the superficial sediment profile close to the coastline, based on laboratory results it is considered that the sediments have sufficient available carbonate buffering capacity to negate any potential acidity for material that may be placed onshore. However, given the requirements outlined in the DEC (2009b) guidelines, it is likely that management options, in the form of an acid sulfate soils management plan (ASSMP) would be required if onshore placement of material is undertaken of the dredge material.

1

Introduction

1.1 Project Description

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara coast. The LNG and Domgas plant will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and other yet-to-be determined gas fields. The Wheatstone Project is referred to as the Project and the Ashburton North Strategic Industrial Area (Ashburton North SIA) is the proposed site for the LNG and Domgas plant. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land. The LNG plant will have a maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Project has been referred to the State Environmental Protection Authority (EPA) and the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

1.2 Project Dredging Requirements

Onshore and nearshore infrastructure will be located adjacent to the Ashburton River delta and nearby to the Hooley Creek tidal system. The construction of onshore and nearshore infrastructure will require the dredging of a navigation channel and turning basin (Figure 1-1). Dredging of marine sediments will be required to enable the construction of the aforementioned marine facilities, with the resultant dredged material requiring placement at one of five potential sites (Sites A – E; Figure 1-1). It is understood that up to 10 Mm^3 of dredge material may require placement onshore.

Capital dredging of sediments as part of construction at the Ashburton North SIA requires a geochemical assessment of sediments, which is the principal focus of this report. The indicative in-situ gross volume of sediment expected to be dredged during construction is anticipated as being 45 000 000 m^3 (Table 1-1) over an area of approximately 11 500 000 m^2).

Table 1-1 Project dredge material volumes.

Dredge Area	Total for Area
Temporary access channel	935 000
Materials offloading facility (MOF)	1 580 000
Product loading facility (PLF)	16 445 000
PLF Approach	20 160 000
Total Capital Dredge volume	39 120 000
Design uncertainties	5 880 000
Estimated total Capital Dredge volume	45 000 000

1 Introduction

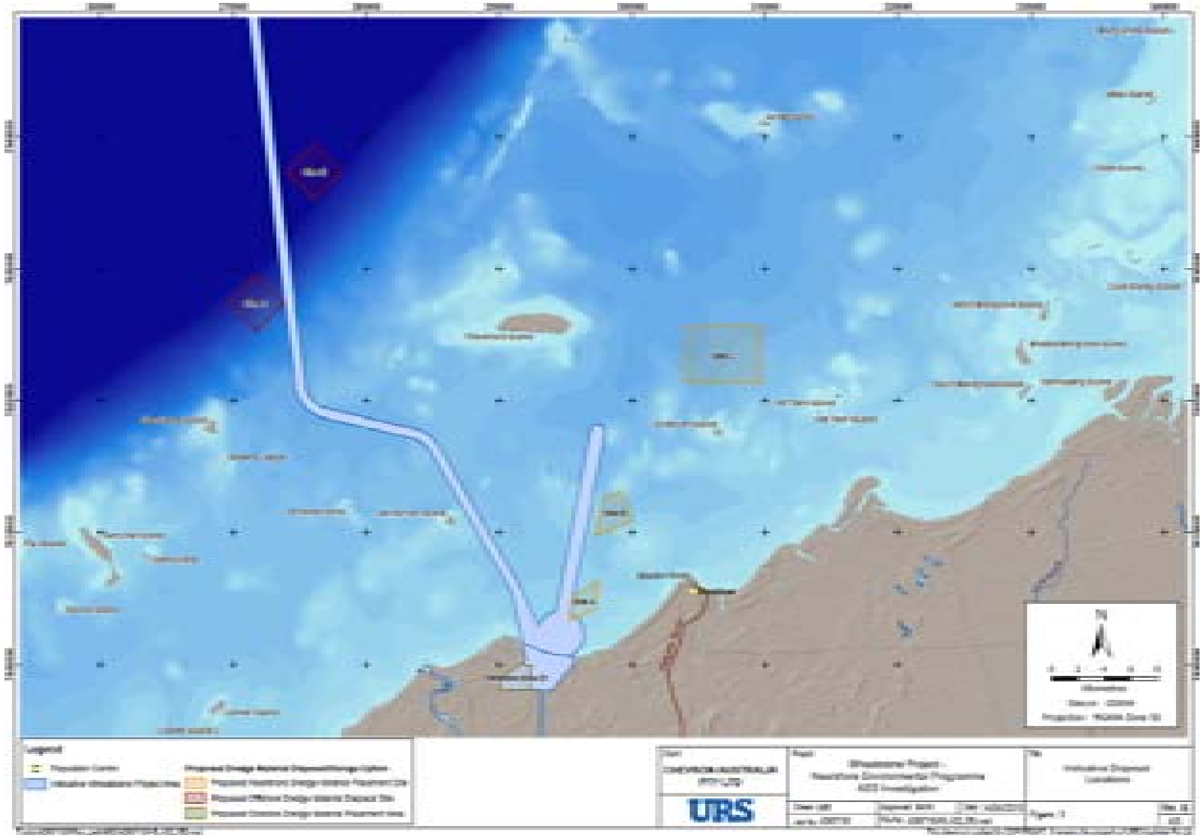

Figure 1-1 Location of proposed dredged navigation channel and turning basin, and proposed dredge material placement sites (A-E).

1.3 Deep Core Sampling Programme

Potential environmental issues arising from the proposed dredging activities may include physical changes arising from sediment dispersion, oxidation and subsequent acid generation in marine sediments. Biological changes may also occur ad include disturbance or displacement of benthic primary producer habitat (BPPH) and marine fauna due to the placement of potential acid sulfate soil (PASS) dredged material into the marine environment.

Chevron commissioned URS Australia Pty Ltd (URS) to complete the reporting component of the nearshore deep core sampling field programme, undertaken by Coffey Geosciences (Coffey; 2009), in conjunction with the nearshore geotechnical investigation. The nearshore sampling programme was undertaken between 26 June 2009 and 12 July 2009 at 15 deep core locations (MC001-MC015) from along the length of the proposed navigation channel and turning basin (Figure 1-2).

The sampling programme completed during this investigation included an assessment of PASS and an assessment of the carbonate buffering capacity of shallow and deep core sediments along the route of the turning basin and navigation channel. The programme was undertaken in accordance with the following guidelines:

- *Development of Sampling and Analysis Programs* (Department of Environment and Conservation (DEC) 2001);
- *DRAFT Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes* (DEC 2009a);
- *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DEC 2009b);
- *Contaminated Sites Management Series: Assessment levels for Soil, Sediment and Water* (DEC 2010); and
- *National Assessment Guidelines for Dredging* (DEWHA 2009).

This report is for the interpretation and reporting of PASS of the proposed turning basin and navigation channel *only*. The interpretation and reporting of metals in sediments was completed in a separate study (URS 2010).

1.4 Objective & Aims

The objective of this investigation is to determine whether the sediments and strata that will be disturbed during the dredging process will pose any adverse environmental impacts to the marine environment.

Specific aims of the investigation are to:

- Obtain a broad understand of the acid-generating potential of sediments at depth along the proposed turning basin and navigation channel.
- Establish whether dredged material type will negatively impact the surrounding environment based on the proposed placement options.

1.5 Scope of Work

To meet the objectives and aims outlined above, the following works were required:

- interpretation of lithological core log data, provided by Coffey (2009), to identify PASS and to produce generalised lithological core profiles;

1 Introduction

- interpretation of analytical data provided by Coffey (2009);
- preparation of a report comprising methodology, field results and analytic data; and
- discussion of implications for BPPH and marine fauna with regard to dredging of sediments, and offshore placement of dredged material.

1 Introduction

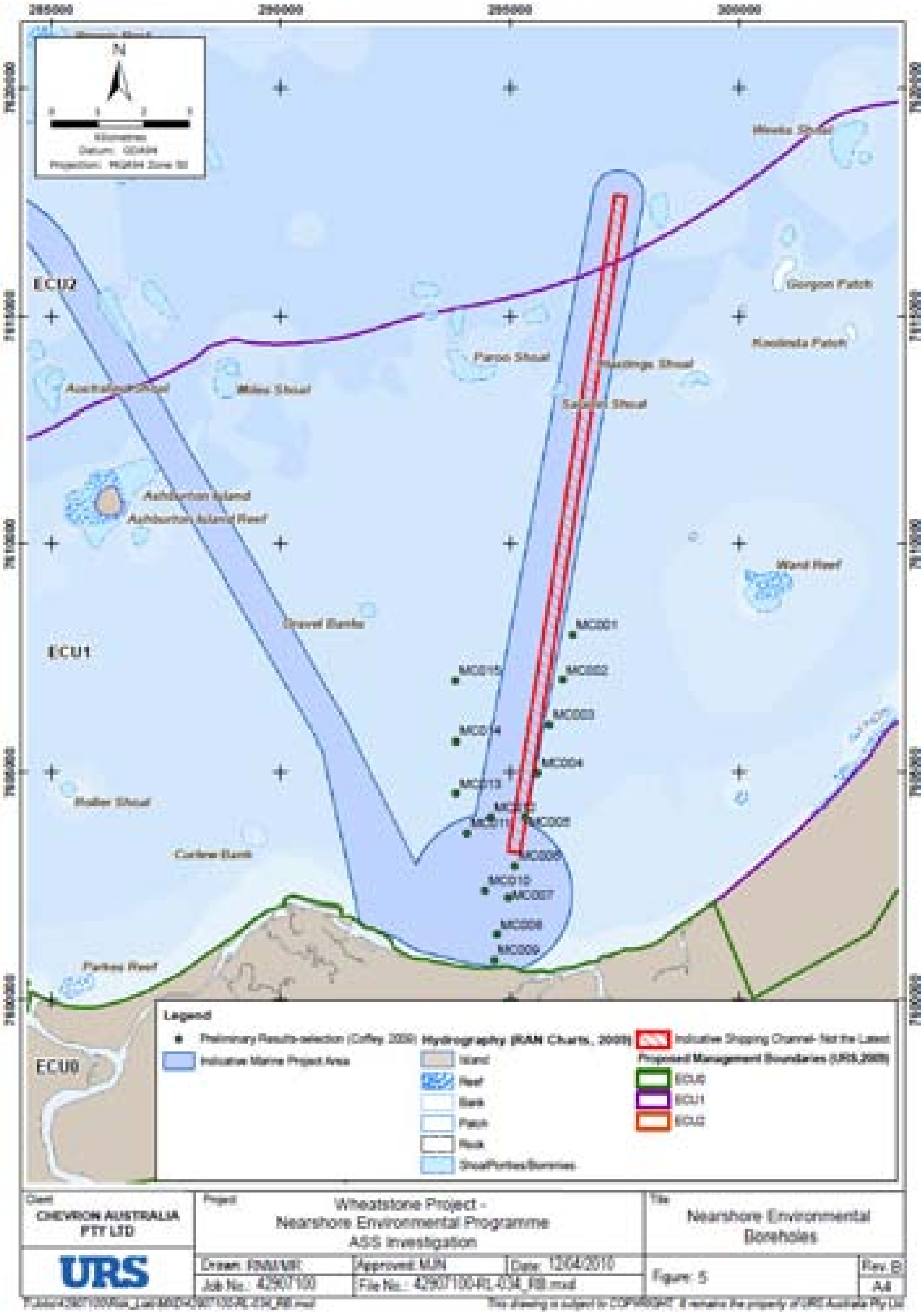

Figure 1-2 **Location of deep core sample sites from within the propose navigation channel and turning basin (MC001-MC015).**

1.6 Environmental Setting

1.6.1 Regional Geology

The Palaeozoic-Recent Northern Carnarvon Basin is a large, mainly offshore basin located on the northwest shelf of Western Australia. It developed during four successive periods of extension and thermal subsidence. The nearshore Project infrastructure sits within the Peedamullah Shelf in the southeast of the Northern Carnarvon Basin. The main deposition centres of the Northern Carnarvon Basin host up to 12 km of sedimentary infill. Triassic to Early-Cretaceous deposition is dominantly siliclastic deltaic to marine, whereas slope and shelfal marls and carbonates dominate the Mid-Cretaceous to Cainozoic section. The carbonate rich sediments were deposited as a series of northwest propagating wedges as the region continued to cool and subside resulting in the deep burial of the underlying Mesozoic sequence.

Partially lithified and unconsolidated alluvial sediments, mainly red sands, dominate the terrestrial landscape of the Project. In the nearshore environment these are overlain, in places, by sediments of marine origin including mainly shelly sands and reworked alluvial sands (Semeniuk 1993, Semeniuk 1996). Some of the sands are of recent Holocene origin. Mixed with reworked alluvial material, these recent sands abut and overlie older Pleistocene sedimentary structures, particularly along the beach and in the nearshore waters.

1.6.2 Project Geology

A generalised sub-seabed profile was completed by Coffey (2009). The profile comprises a thin veneer of sand, overlying sedimentary deposits of red/brown carbonate silty sandy clayey mud, becoming variably cemented claystone, siliceous calcarenite, sandstone and conglomeratic calcirudite with increasing depth. Cementing agents consist of predominantly calcium carbonate ($CaCO_3$) and limonite (an iron oxide). These overlie $CaCO_3$-cemented off-white/yellow siliceous detrital limestone.

The shallow geological sequence was further characterised by geophysical survey which was used to acquire *in situ* seismic velocity data (to approximately 6 m BSBL) and structural data (to the limit of acoustic penetration) for the shallow sediments (Coffey 2009). During the survey, seabed topography and sediment type was mapped. Seabed surface geology along the proposed navigation channel and turning basin is illustrated below (Figure 1-3). Survey methodology is reported in Coffey 2009. Results of the geophysical survey indicate that shallow seabed sediments along the navigation channel and turning basin generally comprise sandy clay and fine to medium grained sands. Partly cemented sediments of flat-lying outcrops were interspersed throughout the survey area.

1 Introduction

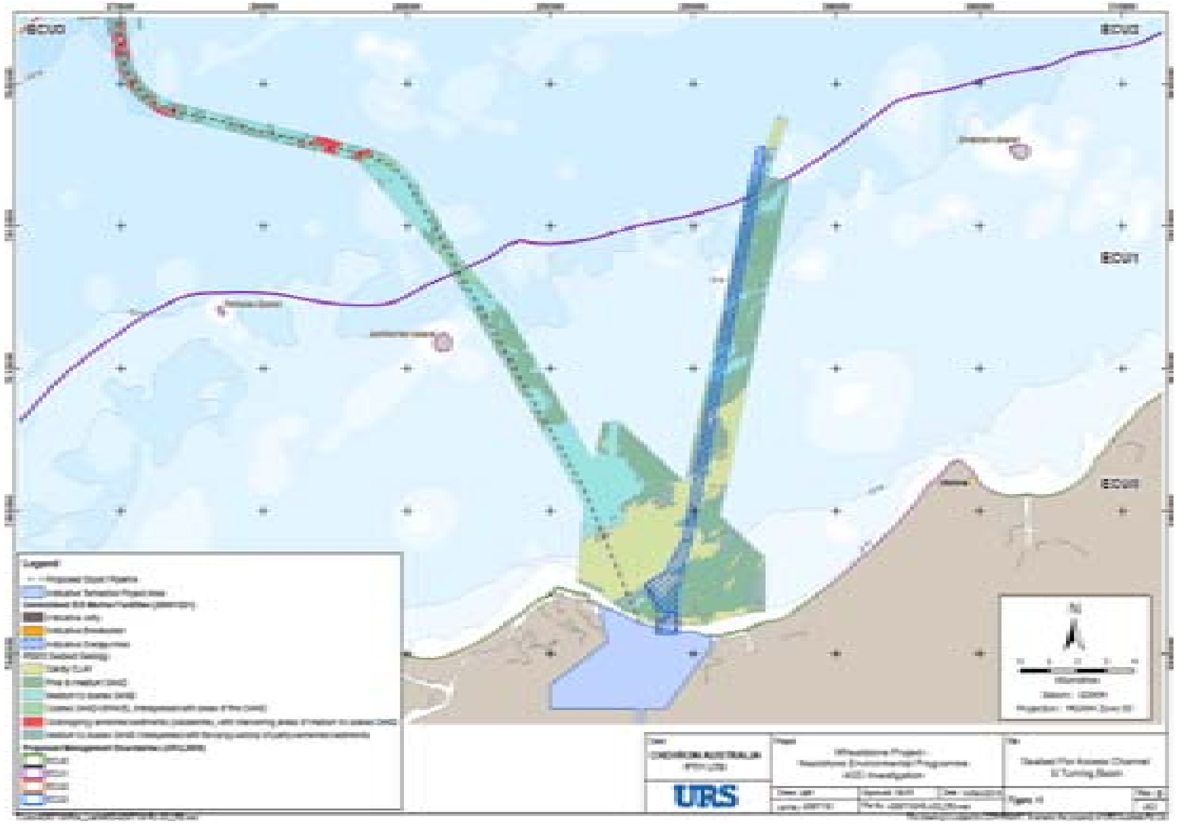

Figure 1-3 Seabed surface geology mapping.

1 Introduction

Acid Sulfate Soils

Acid sulfate soils (ASS) are naturally occurring soils, sediments and peats that contain iron sulfide minerals (commonly in the form of pyrite (FeS_2)). ASS are generally of Holocene origin, and are typically encountered in low lying, water logged, high organic areas as these environments provide key elements for the formation of sulfuric acid (e.g. bacteria, oxygen). In an undisturbed anoxic state these materials remain benign, do not pose a significant risk to the environment, and are referred to as PASS. However, the disturbance of PASS, and its exposure to oxygen, leads to sulfide oxidation which supplies a significant source of iron and acid in solution. Acidic conditions may lead to dissolution of aluminosilicate and oxide minerals which may release elements such as aluminium, silicon, manganese and chromium. The release of acid and metals, which may result from the oxidation of sulfides in ASS, has the potential to cause significant environmental and economic impacts including:

- fish kills and loss of biodiversity in waterbodies;
- contamination of groundwater through leaching of arsenic and heavy metals, and acidification; and
- corrosion of concrete and steel infrastructure.

Inappropriate disposal of PASS, including dredged materials, can also provide appropriate conditions for the formation of secondary sulfide minerals. As the sediments age, they increase in pyrite content due to sulfate reduction while the carbonate buffering capacity is depleted over time. Older dredged material may have little to no buffering capacity and, if these sediments are disturbed or exposed on a large scale, sulfide oxidation rapidly depletes the limited bicarbonate buffering capacity. This can cause offsite impact due to the discharge of large amounts of acidic and potentially metal-rich waters.

Although the DEC, in association with LandGate, has produced ASS risk maps for terrestrial landscapes (LandGate 2009), similar maps have not been produced for the nearshore environment. Therefore it has been assumed, based on the proximity of the proposed dredged areas to BPPH of the Ashburton River delta and Hooley Creek tidal system, that a risk of encountering ASS exists. It is expected, however, that the risk of intercepting ASS material will reduce with increasing distance from shore. The risk is anticipated to be moderate for sediments of the intertidal to nearshore zone at depths of less than 3 mBSBL. The risk is anticipated to be low to nonexistent for sediments further from the shore in deeper water.

Sampling & Analysis Protocol

2.1 Programme Rationale

The sampling programme undertaken by Coffey (2009), in conjunction with the geotechnical investigation, was completed in accordance with the Sampling and Analysis Plan (SAP) presented in Appendix A. however, where deviations from the SAP were anticipated or were inevitable, Chevron were notified, therefore the SAP is to be referred to as a guide only and should not be used to determine compliance. Additionally, the SAP was designed based on plans produced by Bechtel (2009a; 2009b), which have subsequently been amended since the sampling programme was implemented. The sampling programme is still valid, however, as sediment samples were taken from the current proposed navigation channel and turning basin.

2.2 Assessment Guideline

The assessment criteria adopted for PASS in Western Australia is the *Texture Based PASS Action Criteria* developed by Ahern *et al.* (1998). The criteria act as a guide to determine whether sediments will generally require treatment and/or management, based on net acidity (net acidity = S_{cr} + titratable actual acidity (TAA)) as sulfur (% S) or equivalent acidity (mole H^+/tonne). As clay content tends to influence a sediments natural buffering capacity, the action criteria are grouped into three broad texture categories (i.e. sands to loamy sands, sandy loams to light clays, medium to heavy clays and silty clays). Texture categories are based on McDonald *et al.* (1990).

2.3 Survey Details

The fieldwork component of the nearshore geotechnical investigation involved collecting samples from a total of 15 boreholes, with sample depth ranging from 2.0 m to 45.5 m below sea bed level (BSBL). Final borehole locations and termination depths were based on data provided by Chevron.

Sampling data for each of the boreholes surveyed as part of the sampling programme is presented below (Table 2-1). The location of each borehole is presented above (Figure 1-2).

Table 2-1 Nearshore borehole sampling details.

Borehole	**Location**	**Easting (m)**	**Northing (m)**	**Water Depth (LAT)**	**Drilling Depth mBSBL**	**Completion Date**
MC001	Navigation Channel	296373.5	7608001.7	-11.17	7.0	03/07/2009
MC002	Navigation Channel	296146.4	7607006.9	-10.02	8.0	04/07/2009
MC003	Navigation Channel	295865.0	7606006.0	-9.27	9.0	05/07/2009
MC004	Navigation Channel	295609.4	7604977.9	-7.95	10.0	06/07/2009
MC005	Navigation Channel	295330.2	7604003.1	-7.28	10.5	07/07/2009
MC006	Turning Basin	295109.2	7602919.8	-6.85	12.0	09/07/2009
MC007	Navigation Channel	294963.6	7602227.9	-3.71	12.0	27/06/2009
MC008	Navigation Channel	294721.8	7601435.8	-2.45	13.5	26/06/2009
MC009	Turning Basin	294655.3	7600873.7	-1.69	14.0	12/07/2009
MC010	Navigation Channel	294454.0	7602375.9	-6.20	12.0	11/07/2009
MC011	Navigation Channel	294059.9	7603651.7	-5.76	10.5	28/06/2009
MC012	Navigation Channel	294588.0	7603999.5	-7.79	11.0	08/07/2009
MC013	Navigation Channel	293818.8	7604525.0	-6.69	9.5	30/06/2009
MC014	Navigation Channel	293822.4	7605658.3	-7.68	8.5	01/07/2009
MC015	Navigation Channel	293815.5	7606981.1	-7.53	8.0	02/07/2009

NB: LAT – lowest astronomical tide.

2.4 Sampling Methodology & Analysis

2.4.1 Coring Decontamination

All cores, spilt tubes, drill bits and rods were degreased and cleaned using Decon 90, a non-hazardous laboratory grade cleaning fluid, prior to environmental core sampling. In addition, non-hazardous and non-toxic drilling grease was used on all drill and core parts for corrosion protection and lubrication while drilling.

2.4.2 Sample Collection

Samples were collected in accordance with the SAP (Appendix A), and as per Coffeys Standard Operating Procedures for field sampling. Procedural information followed to develop the geotechnical borehole logs and engineering logs are available in Coffey (2009). Colour core photographs are presented in Appendix E.

The sampling programme was designed to be representative of strata encountered across the dredge area. Sampling generally targeted shallow, unconsolidated sediments (up to 1 m BSBL), with additional samples collected below this depth at intervals of approximately 2-3 m BSBL based on strata encountered.

In total, 72 primary samples were collected from 15 boreholes. The total number of samples selected reflects the analytical regime of taking between four and five samples per environmental borehole. Depths at which each sample was taken in provided below (Table 2-2).

2 Sampling & Analysis Protocol

Table 2-2 Sample depths.

Borehole Location	**Sample Depths (m BSBL)**					
MC001	0.45-0.55	0.90-1.00	1.00-2.00*	3.40-3.50	6.4-6.5	-
MC002	1.00-1.10	1.90-2.00	2.90-3.00	6.40-6.50	-	-
MC003	0.45-0.55	0.90-1.00	1.00-2.00*	3.40-3.50	6.9-7.0	-
MC004	0.50-1.00	1.00-2.00*	3.90-4.00	8.00-8.10	-	-
MC005	0.45-0.55	0.90-1.00	1.00-2.00*	3.00-3.10	6.9-7.0	-
MC006	0.45-0.55	0.90-1.00	3.26-3.36	9.90-10.00	1.0-2.0	-
MC007	0.45-0.55	0.80-0.90	1.00-2.00*	-	-	-
MC008	0.45-0.55	0.80-0.90	2.00-3.00*	3.80-3.90	7.0-7.1	-
MC009	1.00-1.10	2.00-3.00	3.90-4.00	8.90-9.00	13.4-13.5	-
MC010	0.45-0.55	0.90-1.00	1.00-2.00	3.45-3.55	7.9-8.0	10.9-11.0
MC011	0.00-0.40	1.00-1.10	2.00-3.00*	3.50-3.60	7.45-7.55	-
MC012	9.40-9.50	0.45-0.55	0.90-1.00	1.00-2.00*	4.0-4.1	-
MC013	0.45-0.55	0.80-0.90	1.00-2.00*	3.40-3.50	7.9-8.0	-
MC014	0.45-0.55	0.80-0.90	1.00-2.00*	3.40-3.50	6.9-7.0	-
MC015	0.45-0.55	0.90-1.00	1.00-2.00*	3.40-3.50	6.4-6.5	-

*NB: * indicates a composite sample.*

Sample Transport

All PASS samples were frozen in bags immediately after sampling to prevent oxidation of the sample material. To ensure the integrity of the sample was not jeopardised, samples remained frozen during transportation from Onslow to Perth in sealed eskies. Coffey managed the transportation of the samples to the analytical laboratory with appropriate chain of custody documentation.

2.4.3 Sample Analysis

PASS screening tests are typically completed in the field however, due to the large number of samples collected during the sampling programme and the length of time required for the completion of the field tests, PASS screening tests were completed in the laboratory.

Primary samples were submitted to Australian Laboratory Services (ALS) Perth, a National Association of Testing Authorities (NATA) accredited laboratory, for the completion of PASS screening tests. Of the 72 samples taken, 55 were submitted on the 9th of July 2009 and the remaining 17 samples were submitted on the 15th of July 2009. The summarised laboratory schedule is presented below (Table 2-3) and the complete laboratory schedule is presented in Appendix B.

2 Sampling & Analysis Protocol

Table 2-3 Summarised laboratory schedule for PASS analytical methods.

Borehole	**Date Sampled**	**# samples/ borehole**	**Analytical Schedule (tests completed)**		
			PASS Field Screening	**Chromium Suite**	**Carbonate Buffering**
MC001	03/07/2009	5	5	5	0
MC002	03/07/2009	4	4	4	0
MC003	04/07/2009	5	5	5	0
MC004	05/07/2009	4	4	4	1
MC005	06/07/2009	5	5	5	1
MC006	15/07/2009	5	5	5	0
MC007	26/06/2009	3	3	3	0
MC008	26/06/2009	5	5	5	1
MC009	11/07/2009-12/07/2009	5	5	5	0
MC010	09/07/2009-11/07/2009	6	6	6	0
MC011	27/07/2009-28/07/2009	5	5	5	0
MC012	07/07/2009	5	5	5	1
MC013	29/06/2009	5	5	5	1
MC014	30/06/2009	5	5	5	1
MC015	02/07/2009	5	5	5	0
Total Primary Tests Completed			**72**	**72**	**6**

Overview of PASS Screening Methods

The analytical methods selected for the analysis of PASS was undertaken in accordance with laboratory methodologies outlined in Ahern *et a*l. (2004) and is the preferred analytical method adopted by the DEC (2009a; 2009b).

A brief description of the three selected NATA accredited laboratory analytical methods is as follows:

- **EA037: Acid Sulfate Soils Screening Test** – This method is used to aid the selection of samples for analytical testing. The method used is described in Ahern *et al*. (2004). As samples are received, they are tested for pH_f and pH_{fox} and are given a reaction rating.
- **EA033: Chromium Suite (Scr) for Acid Sulfate Soils** – This method determines levels of chromium reducible sulfur (SCR); pH_{KCl}; TAA; acid neutralising capacity (ANC) by back titration; liming rate; and net acid soluble sulfur, which incorporates peroxide sulfur. It applies to sediments derived from coastal regions.
- **Carbonate Buffering** – ANC was determined by oven-drying moist sediments (at 800°C for 24 hrs), and then crushing them in a jaw-crusher with clearance set to 2 mm. Equilibration time between titrant additions was 15 minutes with 1.00 g of crushed sample initially dispersed in 150 mL of deionised water. Titrations were performed using a Metrohm ® 736 Titrino auto-titrator and 0.05 M-H_2SO_4.

2 Sampling & Analysis Protocol

Description of PASS Screening Tests

PASS screening tests are a measure of pH_f and pH_{fox} (including an assessment of reaction rating). The pH_f test measures the existing acidity and is therefore a useful indicator as to whether ASS are present. The pH_{fox} test (or rapid oxidation) is used to indicate the presence of iron sulfides or PASS.

The test involves adding 30 per cent hydrogen peroxide (H_2O_2) to a sample of sediment (to mimic the natural addition of air to the sediment). If sulfides are present, a reaction with the hydrogen peroxide will occur. The reaction can be influenced by the amount of sulfides in the sample and the presence of organic matter. A more vigorous reaction usually indicates a higher potential for acidity. The value of pH_{fox} and its relationship to pH_f is also used to identify PASS. A lower final pH_{fox} value and a greater difference between pH_{fox} in comparison $pH_{f,}$ is indicative of the presence of PASS.

Detailed PASS screening test methodology is presented in Appendix C (DEC 2001; Ahern *et al*. 2004) and is further described in the Acid Sulfate Soils Laboratory Methods Guidelines (Ahern *et al*. 2004).

Chromium Suite Testing

Laboratory analytical tests quantitatively assess the amount of existing, and potential, acidity present in sediments. This provides a general measure of the likelihood of acidic conditions forming if these sediments are disturbed, and may assist with determining whether sediments require treatment and/or management based on net acidity produced by the sediment. The chromium suite (Scr) method provides an analytical determination of inorganic sulfur (e.g. iron sulfides) in sediments, and is not subject to interferences from sulfur, either in organic matter or as sulfate minerals.

A total of 72 primary samples were assessed for their ANC and for the presence of PASS using the Scr method.

Carbonate Buffering

Based on the analytical results of the Scr analytical tests, a total of six samples were selected for carbonate buffering using the acidimetric auto-titration method and where submitted to Graeme Campbell and Associates (GCA) for testing. The auto-titration methodology assesses the acid consuming properties of marine sediment samples and is conducted in accordance with procedures detailed by Sobek *et al*. (1978).

2.4.4 Data Validation

Analytical data was thoroughly checked by ALS Perth prior to release. URS subsequently checked the analytical data against the data quality objectives of the project by comparing detection limits against action criteria trigger values, calculating Relative Percent Differences (RPDs) for field duplicates and by comparing RPDs with guideline recommendations. The RPD calculation is used to normalise each pair of results to allow for better QA/QC data interpretation. In general, an RPD value of below 50% for data correlation is considered acceptable. However, there are exceptions based on limit of reporting. The permitted ranges for the RPD of duplicates are dependent on the magnitude of results, in comparison to the level of reporting (i.e. Result = < 10 times the LoR: no Limit; Result = 10-20 times the LoR: 0%-50%; Result = > 20 times the LoR: 0%-20%). The 50% data correlation value is an internationally accepted guideline and is used through Australia.

Comparison of duplicates using RPDs may identify analytical results that appear to be outliers, prompting reanalysis of the samples by the laboratory as a further check of precision. Results may also be categorised as ‘estimates only’. High RPD values may also be an indication of high heterogeneity of sediment contaminant levels at the sample locations, or might result from widely varying characteristics of the sediments, such as particle size distribution and/or organic content.

The following quality control/quality assurance (QA/QC) procedures were undertaken during the collection of samples in the field:

- compilation of field records;
- completion of chain-of-custody (CoC) documentation; and
- adherence to Coffey Standard Operating Procedures for geochemical sample collection and storage.

The following QA/QC procedures were undertaken by ALS Perth:

- testing of primary and duplicate samples (split sample analysis; Table 2-4);
- testing of rinsate blank samples (two rinsate samples were analysed for inorganic analytes only; Table 2-5);
- testing of laboratory duplicates;
- testing of method blanks;
- testing of laboratory control samples;
- testing for matrix spikes;
- provision of certificates of analysis; and
- provision of data validation reports.

Results of field and laboratory QA/QC analyses are presented in Appendix G.

2 Sampling & Analysis Protocol

Table 2-4 Analytical data for split sample analyses.

Analyte	Units	LoR	Sample ID					
			MC009	**MC009**	**MC012**	**MC012**	**MC015**	**MC015**
Depth	mBSBL	n/a	3.9-4.0	3.9-4.0	0.9-1.0	0.9-1.0	0.45-0.55	0.45-0.55
Sample Type	QA/QC or Analytical	n/a	QA/QC	Analytical	QA/QC	analytical	QA/QC	analytical
PASS Field Screening Analysis								
pH (F)	pH Unit	0.1	7.5	7.6	8.3	8.4	8.9	8.6
pH (Fox)	pH Unit	0.1	6.1	6.5	6.3	6.4	6.6	6.6
Reaction Rate	n/a	n/a	Slight	Moderate	Slight	Slight	Slight	Slight
Scr Method Analysis								
Actual Acidity								
pH_{KCl}	pH Unit	0.1	8.6	9	9.2	9	9.6	9.5
TAA	mole H+ / t	2	<2	<2	<2	<2	<2	<2
Sulfidic - TAA	% pyrite S	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Potential Acidity								
Chromium Reducible Sulfur	% S	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Acidity - Chromium Reducible Sulfur	mole H+ / t	10	<10	<10	<10	<10	<10	<10
ANC								
ANC	% CaCO3	0.01	1.06	4.69	5.26	5.41	48.5	32.8
Acidity - ANC	mole H+ / t	10	212	937	1,050	1,080	9,690	6,560
Sulfidic - ANC	% pyrite S	0.01	0.34	1.5	1.68	1.73	15.5	10.5
Acid Base Accounting								
ANC Fineness Factor	-	0.5	1.5	1.5	1.5	1.5	1.5	1.5

2 Sampling & Analysis Protocol

Analyte	**Units**	**LoR**	**Sample ID**					
			MC009	**MC009**	**MC012**	**MC012**	**MC015**	**MC015**
Net Acidity (sulfur units)	% S	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10	<10	<10	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1	<1	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	<10	<10	<10	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1	<1	<1	<1	<1	<1	<1

2 Sampling & Analysis Protocol

Table 2-5 Total metals data for rinsate sample analysis.

Analyte	LOR	Units	Sample ID	
			QA/QC	**QA/QC**
Date Sampled	n/a	n/a	3/07/2009	9/07/2009
Antimony	0.001	mg/L	0.002	<0.005
Arsenic	0.001	mg/L	<0.001	<0.005
Barium	0.001	mg/L	0.006	0.065
Beryllium	0.001	mg/L	<0.001	<0.005
Chromium	0.001	mg/L	<0.001	<0.005
Cobalt	0.001	mg/L	<0.001	<0.005
Copper	0.001	mg/L	0.006	0.026
Iron	0.05	mg/L	0.27	2.41
Lead	0.001	mg/L	<0.001	<0.005
Manganese	0.001	mg/L	0.005	0.018
Mercury	0.0001	mg/L	<0.0001	<0.0001
Molybdenum	0.001	mg/L	0.012	0.013
Nickel	0.001	mg/L	0.005	0.009
Selenium	0.01	mg/L	<0.01	<0.05
Silver	0.001	mg/L	<0.001	-
Tin	0.001	mg/L	<0.001	0.008
Vanadium	0.01	mg/L	<0.01	<0.05
Zinc	0.005	mg/L	0.01	0.027
Cadmium	0.0001	mg/L	<0.0001	<0.0005

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Results

3.1 Assessment Guideline

Classification of the sediments encountered during the field survey ranged from medium to fine grained. Based on this generalised classification, and assuming a disturbance of greater than 1 000 t of sediment, the selected action criteria for net acidity is 0.03 % S or 18.7 mole H$^+$/tonne (Table 3-1).

Table 3-1 Texture based action criteria for PASS (Ahern *et al.* 1998, McDonald *et al.* 1990).

Material Type		**Net Acidity Action Criteria**			
		1-1000 tonnes		**>1000 tonnes**	
Texture range	**Clay Content (%)**	**%S**	**mole H+/tonne**	**%S**	**mole H+/tonne**
Coarse Texture (sands to loamy sands)	<5%	0.03	18.7	0.03	18.7
Medium Texture (sandy loams to light clays)	5-40%	0.06	37.4	0.03*	18.7*
Fine Texture (medium to heavy clays and silty clays)	>40%	0.1	64.8	0.03*	18.7*

*NB: an * indicates that the values has exceeded the action criteria.*

3.2 Lithological Profile

The generalised lithological profile identified along the proposed navigation channel and turning basin consists of variable amounts of silty sand, clay, and gravel at depths of up to 10 m BSBL. The profile is typically thicker and sandier closer to the shore line. Underlying the unconsolidated and consolidated sediment layer is extremely low strength claystone and conglomerate rock, with extremely low strength carbonate rock generally detected closer to the shoreline.

Typical lithological units identified *in-situ* along the length of the turning basin and navigation channel are presented below (Table 3-2). Deep core borehole logs and descriptions of the vertical profile of each borehole have been included in Appendix D. Core photos are included in Appendix E. Appendix F present geological cross section data (Coffey 2009). These cross sections illustrate the generalised subsurface profiles of each borehole at depth along the length of the proposed navigation channel and turning basin.

3 Results

Table 3-2 Generalised lithological profile along the navigation channel and turning basin.

Unit Name	Material Type	Profile	Profile Depth Range (mBSBL)	Profile Thickness (mBSBL)	Description	Borehole
Dune sand and sandplain, marine sediments and recent alluvial soils, Ashburton red bed	Marine sediment	Sandy clay clayey sand clayey sandy gravel gravelly clay clay sand	Between 0.0 and 10.0	0.9 to 10.0 Profile is typically thicker and sandier closer to shore	Variable amounts of silts, clays, sands (quartz) and carbonate material in profiles. Some shell fragments. Generally brown to red brown.	All boreholes
Ashburton Red Bed	Rock	Claystone	Between 0.9 and 9.40	0.55 to 4.75	Generally underlies the unconsolidated/consolidated sediment. Typically not encountered close to shore. Red brown, fine to medium, variably cemented, rock mass extremely low to very low strength rock.	All boreholes except MC008, MC010
		Conglomerate	Between 5.0 and 11.6	0.75 to 3.75	Generally fine to coarse grained, red brown, clasts are sub-angular to angular, of well cemented claystone in a matrix of clay/siltstone, variably cemented, extremely low strength rock	MC001, MC003, MC004, MC005, MC006, MC009, MC012, MC015
		Clayey sandstone/ Clayey sand Sandstone	Between 2.5 and 8.2	0.8 to 3.45	Generally underlies claystone and/or conglomerate layers. Fine to medium, red brown, variably cemented soil unit becoming extremely slow strength clayey sandstone to sandstone dense to very dense.	MC001, MC002, MC003, MC004, MC006, MC007, MC010, MC011, MC012, MC013, MC015.

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Unit Name	**Material Type**	**Profile**	**Profile Depth Range (mBSBL)**	**Profile Thickness (mBSBL)**	**Description**	**Borehole**
Carbonate Rock	Carbonate rock	Calcareous conglomerate	Between 8.45 and 12.1	0.4 to 3.55	Fine to coarse grained, clasts are fine to cobble sized, sub rounded to angular , of well cemented claystone, quartzite, chert and or sandstone in a matrix of, claystone, clay, sand silt.	MC006, MC007, MC008, MC009, MC010, MC011, MC013.
		Calcareous sandstone. siliceous calcarenite	12	1	Fine to medium grained, pale yellow brown, sand is mainly quartz, well cemented.	MC008.
		Calcareous siltstone	13	1	Fine to medium grained, red brown, with some well cemented nodules of sandstone	MC008.

3.3 pH_f & pH_{fox} Screening Tests

As mentioned above, PASS field screening tests for pH_f and pH_{fox} are normally undertaken in the field to provide a rapid qualitative assessment of the likelihood of PASS occurring by providing an indication of the existing and potential acidity levels in sediments. The tests, however, cannot give a quantitative measure of the amount of PASS that has been in the sediment, or how much may be produced through oxidation.

Interpretation of PASS field screening tests was undertaken in accordance with Ahern *et al* (1998) (Appendix C) which considers a combination of three factors in arriving at a positive identification of sulfides or PASS (i.e. hydrogen peroxide reaction, pH_{fox} value, change in pH_{fox} and pH_f values).

Data mean and range values, and reaction type for pH_f and pH_{fox}, by sediment type, is presented below (Table 3-3). Complete analytical test results are presented in Appendix G. Laboratory certificates are presented in Appendix H.

The sediment sampling during the field survey ranged in mean pH_f from 7.2 pH for silty clayey sands, to 8.5 pH for clayey sandy gravel. Subsequent pH_{fox} values ranged from 6.4 pH for clayey gravel to 7.4 pH for clayey gravelly sand, indicating that the likelihood of encountering PASS material is low. Mean changes in pH ranged between 0.9 pH for clay, calcareous conglomerate, and sandstone, and 1.65 pH for clayey sandy gravel.

Reaction types ranged from slight to strong throughout the sediment profile, with the strongest reaction observed in claystone and the least reaction observed in sandy clay. However, end pH values suggest that reactions may have been buffered, with a large amount of carbonate material being observed throughout the profile.

3 Results

Table 3-3 Data summary for pH_f and pH_{fox} with reaction type, by sediment type.

Sediment Type	Borehole Location	pH(f)		pH(fox)		pH (difference)		Reaction Type
		mean	range	mean	range	mean	range	
Calcareous conglomerate	MC009, MC010	7.6	7.4-7.8	6.7	6.7	0.9	0.7-1.1	slight
Clay	MC003, MC006, MC009, MC010	7.74	7.3-8.5	6.84	6.4-7.2	0.9	0.3-2.1	slight to strong
Clayey gravel	MC009	8.4	n/a	6.4	n/a	2	n/a	slight
Clayey gravelly sand	MC014	7.8	n/a	7.4	n/a	0.4	n/a	strong
Clayey sand	MC002, MC003, MC005, MC007, MC008, MC012, MC014, MC015	8.29	7.6-8.6	6.64	6.1-7.1	1.65	0.9-2.6	slight to strong
Clayey sandstone	MC001, MC006	7.85	6.9-8.8	6.45	6.0-6.9	1.4	0.9-1.9	slight and strong
Clayey sandy gravel	MC004	8.5	n/a	6.8	n/a	1.7	n/a	moderate
Claystone	MC001, MC005, MC006, MC010, MC015	7.96	7.4-8.6	6.81	6.4-8.7	1.14	-0.7-2.1	slight to strong
Conglomerate	MC001, MC003, MC012	7.57	7.0-8.4	6.33	6.1-6.5	1.23	0.8-2.0	slight and strong
Gravelly clay	MC009, MC11	8.15	8.0-8.3	6.65	6.4-6.9	1.5	1.4-1.6	slight and strong
Sand	MC008	7.7	n/a	6.5	n/a	1.2	n/a	slight
Sandstone	MC11	8.1	n/a	7.2	n/a	0.9	n/a	strong
Sandy clay	All boreholes except MC009	8.4	7.9-8.8	6.6	6.0-7.7	1.8	0.7-2.1	slight to strong
Silty clayey sand	MC10	7.2	n/a	6.5	n/a	0.7	n/a	strong
Silty sand	MC002	8.4	n/a	6.7	n/a	1.7	n/a	moderate

3.4 Chromium Suite

As mentioned above, Scr analytical results were compared against the ‘action criteria’ of 0.03 % S as an indication of whether PASS material is present within the proposed navigation channel and turning basin.

A data summary of the Scr results is presented below (Table 3-4). Complete analytical test results are presented in Appendix G. Laboratory certificates are presented in Appendix H[1].

Alkaline sediments were identified along the length of the navigation channel and turning basin, with results showing a mean pH_{KCl} of 9.1 pH and a range of 8.6 pH to 9.5 pH. All TAA concentrations were below the LoR (<0.02 % S) for existing acidity (sulfer). Calculated net acidity concentrations in exceedance of the action criteria of 0.03 % S ranged between 0.03 % S and 0.04 % S at boreholes MC005, MC0010, MC011 and MC012. Sample depths at each borehole ranged between 0.0 mBSBL and 0.55 mBSBL. Sediment types with elevated S % concentrations included clayey sand, gravelly clay and sandy clay.

The ANC of sediments ranged between 0.65 % kg $CaCO_3$/t and 52 % kg $CaCO_3$/t, indicating a potential for significant buffering of low pH sediments. The ANC was highly variable both along the length of the proposed navigation channel and turning basin, and within the sediment type (Table 3-4).

Four sampling locations within shallow unconsolidated surface sediments showed elevated acid levels, slightly above or at the action criteria trigger value (Table 3-4).

Overall, it is considered that there would be negligible risk to the environment (with regard to acid sulfate soils issues) of the subaqueous disposal of the dredged material at the proposed offshore placement sites (A to E), given that sediments will remain underwater or are kept saturated during transport and following disposal, acid production is considered low.

With regards to onshore placement of dredge spoil, although some oxidation of PASS material may occur during the drying process associated with onshore placement, acid generation is considered to be low given the relatively small volume of PASS material encountered, the comparably low %S concentrations reported, and the calculated ANC of the dredge spoil. It should be noted, however, that given the requirements outlined in the DEC (2009b) guidelines, ANC (Carbonate availability is discussed further in Section 3.5.) is typically excluded when assigning requirements for an ASSMP.

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[1] It should be noted, that the environmental sampling program (ASS investigation) was undertaken in conjunction with the geotechnical program undertaken by Coffey. A number of samples (MV series) submitted and analysed for Scr suite by Coffey were done so erroneously as they are not within the scope of work proposed by URS (i.e. they are considered to be outside the dredging footprint investigation area). These results have not been used for interpretation purposes. The results, however, are presented in Appendix H as part of the laboratory documentation.

3 Results

Table 3-4 Data summary for Scr, by sediment type.

Sediment Type	**Borehole Location**	**# samples Exceeding -0.03%**	**pH_{KCl}**		**Chromium Reducible sulfur (%S)**		**Net acidity (excluding ANC) (%S)**		**ANC (%$CaCO^3$)**	
			mean	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**
Calcareous conglomerate	MC009, MC010	0	9.35	9.3-9.4	ND	NA	ND	NA	51.55	51.1-52
Clay	MC003, MC006, MC009, MC010	0	9	8.6-9.1	ND	NA	ND	NA	5.65	1.17-11.9
Clayey gravel	MC009	0	9.2	NA	ND	NA	ND	NA	1.03	NA
Clayey gravelly sand	MC014	0	8.9	NA	ND	NA	ND	NA	0.65	NA
Clayey sand	MC002, MC003, MC005, MC007, MC008, MC012, MC014, MC015	2	9.3	9.1-9.5	0.035	<0.02-0.04	0.035	<0.02-0.04	17.7	0.74-35
Clayey sandstone	MC001, MC006	0	9	8.8-9.2	ND	NA	ND	NA	18.4	0.88-35.9
Clayey sandy gravel	MC004	0	9.3	NA	ND	NA	ND	NA	26.1	NA
Claystone	MC001, MC005, MC006, MC010, MC015	0	9	8.8-9.2	ND	NA	ND	NA	6.7	1.01-17.2
Conglomerate	MC001, MC003, MC012	0	9.1	9.0-9.2	ND	NA	ND	NA	8.3	5.3-13
Gravelly clay	MC009, MC11	1	9.25	9.1-9.4	0.03	<0.02-0.03	0.03	<0.02-0.03	17.6	0.74-32.8
Sand	MC008	0	9.4	NA	0.02	NA	0.02	NA	6.61	NA
Sandstone	MC11	0	9.2	NA	ND	NA	ND	NA	31.3	NA
Sandy clay	All boreholes except MC009	1	9.1	8.8-9.4	0.03	<0.02-0.03	0.03	<0.02-0.03	8.35	0.8-31.7
Silty clayey sand	MC10	0	9.3	NA	ND	NA	ND	NA	13.4	NA
Silty sand	MC002	0	9.3	NA	ND	NA	ND	NA	23	NA

3.5 Carbonate Buffering Potential

A data summary of the carbonate buffering capacity of the sediments sampled is presented below (Table 3-5). Complete analytical test results are presented in Appendix G. Laboratory certificates are presented in Appendix H.

The ANC values reported for carbonate buffering potential ranged from 26 kg H_2SO_4/tonne at borehole MC005 (1.6-1.65 mBSBL) to 350 kg H_2SO_4/tonne at borehole MC004 (5-0.56 mBSBL). Samples reacted vigorously upon addition of dilute HCl, indicating the presence of reactive variants of carbonate minerals (e.g. calcite). Sediment samples with the highest ANC where those comprising fine to coarse grained sandy gravel, while samples with the lowest ANC where those comprising brown, low plasticity sandy clay, variably cemented with chert and sandstone.

The pH buffering curves for the samples typically showed inflection points of between 6 pH and 7 pH, which is usually consistent with the occurrence of reactive carbonates. This was less evident for the low ANC samples (e.g. MC005 (1.6 -1.65 mBSBL)), which were only slightly calcareous.

Overall, it is considered that the carbonate buffering potential of the subsurface profile indicates that in the event of PASS oxidation, there is sufficient available carbonate buffering capacity of the surrounding environment to negate any potential acidity generation, particularly where onshore placement of dredge spoil is proposed. As discussed in **Section 3.4**, however, the DEC (2009b) will require an ASSMP regardless of the ANC and carbonate buffering capacity of PASS where any exceedances of the adopted trigger value for %S (0.03 %S) is reported.

Table 3-5 Data summary for carbonate buffering potential of selected sediment samples.

Borehole	ANC (kgH_2S0_4/tonne)	ANC (%$CaCO_3$)
MC004	350	35
MC005	26	2.6
MC008	99	9.8
MC012	140	14
MC013	310	31
MC014	59	5.9

3.6 Data Validation

A review of pH values reported for the PASS field screening test and Scr suite method was undertaken to ensure that results were reproducible and that no oxidation of the samples had occurred between field screening tests and Scr testing. It was identified that pH_{KCl} values were more alkaline than the initial pH_f values reported during the PASS field screening tests. This was most likely due to a difference in methodology used when assessing pH. Specifically, the PASS field screening test was undertaken on ‘wet’ samples, while the Scr test was undertaken on dried and pulverised sediments, hence pH may be overestimated and therefore ANC may also be overestimated. However, it is unlikely that this difference in methodology will impact the outcome of the investigation as field screening tests for pH_f also reported alkaline pH values.

3 Results

Calculated RPD values for PASS field screening tests and Scr tests from field duplicates were generally below the guideline of ±50% (Table 3-6). The only exception was for the duplicate ANC value for borehole MC009. It was identified that the reported ANC values for sediments sampled during the field programme were highly variable and that the RPD non-compliance reflects this variability.

Rinsate samples reported slightly elevated concentrations of antinomy, barium, copper, iron, manganese, molybdenum, nickel, tin and zinc. As the concentrations were generally near the LoR it was deemed unlikely that contamination had occurred between sample sites.

ALS Perths laboratory interpretive quality control report (Appendix H) indicated that no outliers existed in any of the data sets for any of the data batches submitted (Batch Report #s EP0903738, EP0903741, EP0903858 and EP0904291).

3 Results

Table 3-6 Field duplicate RPD values for PASS field screening and Scr tests.

	Sample ID	**MC009**	**MC009**	**RPD (%)**	**MC012**	**MC012**	**RPD (%)**	**MC015**	**MC015**	**RPD (%)**
Analyte	**Units**									
Depth	mBSBL	3.9-4.0	3.9-4.0		0.9-1.0	0.9-1.0		0.45-0.55	0.45-0.55	
Sample Type	-	QA/QC	QA/QC		QA/QC	QA/QC		QA/QC	QA/QC	
PASS Field Screening Analysis										
pH_f	pH	7.5	7.6	1.32	8.3	8.4	1.2	8.9	8.6	3.43
pH_{fox}	pH	6.1	6.5	6.35	6.3	6.4	1.57	6.6	6.6	0
Reaction Rate	-	Slight	Moderate	-	Slight	Slight	-	Slight	Slight	-
Actual Acidity										
pH_{KCl}	pH	8.6	9	4.55	9.2	9	2.2	9.6	9.5	1.05
TAA	mole H+/tonne	<2	<2	-	<2	<2	-	<2	<2	-
sulfidic - TAA	% S	<0.02	<0.02	-	<0.02	<0.02	-	<0.02	<0.02	-
Potential Acidity										
Chromium Reducible Sulfur	% S	<0.02	<0.02	-	<0.02	<0.02	-	<0.02	<0.02	-
acidity - Chromium Reducible Sulfur	mole H+/tonne	<10	<10	-	<10	<10	-	<10	<10	-
ANC										
ANC	% $CaCO_3$	1.06	4.69	126.26	5.26	5.41	2.81	48.5	32.8	38.62
acidity - ANC	mole H+/tonne	212	937	126.2	1050	1080	2.82	9690	6560	38.52
sulfidic - ANC	% S	0.34	1.5	126.09	1.68	1.73	2.93	15.5	10.5	38.46

4

Conclusion

It is anticipated that the likelihood of encountering PASS or AASS material during the construction of the proposed navigation channel and turning basin is low. This is indicated by the negligible acid generating capacity of the sediment encountered during the field sampling programme. Where PASS was encountered, typically in the superficial sediment profile close to the coastline, based on laboratory results it is considered that the sediments have sufficient available carbonate buffering capacity to negate any potential acidity for material that may be placed onshore. However, given the requirements outlined in the DEC (2009b) guidelines, it is likely that management options, in the form of an acid sulfate soils management plan (ASSMP) would be required if onshore placement is undertaken of the dredge material.

Results of the pH_f & pH_{fox} screening tests confirm this conclusion and, based on the results presented above, it is anticipated that it would be unlikely that PASS material exists along the length of the proposed navigation channel and turning basin. This is further supported by the results of the Scr testing which also indicated, overall, that the sediment profiles along the survey area where not likely to be acid generating. The ANC values of all sediment samples corresponded to alkalinity forms (chiefly reactive carbonates) which suggest a circum-neutral buffering capacity of the sediments that is not chemically non-limiting.

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Limitations

URS Australia Pty Ltd has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron Australia Pty Ltd and only those third parties who have been authorised in writing by URS Australia Pty Ltd to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in CTR 1.14.

The methodology adopted and sources of information used by URS Australia Pty Ltd are outlined in this report. URS Australia Pty Ltd has made no independent verification of this information beyond the agreed scope of works and URS Australia Pty Ltd assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS Australia Pty Ltd was false.

This report was prepared between 1 November and 11 May 2010 and is based on the conditions encountered and information reviewed at the time of preparation. URS Australia Pty Ltd disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Appendix A Sampling & Analysis Plan

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URS

6 May 2009

Project No. 42907103

Chevron Wheatstone LNG
250 St. George's Terrace
Perth
WA 6000

Attention: Karl Bauer

Dear Karl,

Subject: Wheatstone LNG Settlement Characteristics and Acid Generating Properties of Material to be Dredged Scope of Work and Methodologies

1 Summary of Changes

The following amended scope of work and methodologies is in response to a number of logistical issues presented to URS Australia Pty Ltd (URS) by Coffey Geotechnics of Perth (Coffey) on 19 March 2009 with respect to the completion of environmental sampling in conjunction with geotechnical requirements for the nearshore Wheatstone Project.

Further, the scope of works and methodologies has been amended to account for the most current survey as presented in Drawing No. WS1-0000-GEO-SUR-BEC-000-00010-00 Rev0, WS1-0000-GEO-SUR-BEC-000-00006-00 Rev0 and preliminary coordinates provided for the export pipeline (EP-41 to EP-58).

Lastly, the SAP was further finalised on 6 May 2009 based on specific sampling requirements outlined in the 2009 National Assessment Guidelines for Dredging and changes to the upstream nearshore investigation. The changes to the SAP are outlined in **Section 6.3.1** and are highlighted in **Table 1.**

The sampling and analysis plan (SAP) has been provided and was largely developed assuming a certain level of homogeny of the consolidated material at depth along the proposed areas of disturbance and hence is based on a minimum requirement to satisfy regulatory guidelines. It is anticipated that this will be satisfactory for the completion of the geotechnical component with disturbing the integrity of the cores.

The total number of analytical tests has been reduced to reflect the new number of geotechnical locations. Total organic carbon has been eliminated from the laboratory schedule due to issues with holding times. This is not considered critical to the outcome of the investigation. The SPOCAS suite has been replaced with Scr Suite for ASS material which is now the preferred analytical suite for the Department of Environment and Conservation. Based on analytical results provided from the pilot

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sediment study completed by URS-Marine, it is not anticipated that ecotoxicology or elutriate analysis is required.

2 Introduction and Background

URS has been commissioned by Chevron Australia Pty Ltd (Chevron) to undertake an assessment of the settlement characteristics and the potential acid generating capacity of materials to be dredged offshore at the proposed Wheatstone LNG facility (the site). The site is located at the proposed Ashburton North site situated 10km to the south-west of the town of Onslow in Western Australia.

As part of the environmental impact assessment works, impacts to the marine environment from the proposed dredging activities is to be assessed through the development and running of an Ocean Model. The model, which is currently being developed by DHI, requires calibration using quantitative data of the settlement characteristics of the actual material that will be dredged.

Further, in the event that dredge spoil will be returned onshore, an investigation into the potential acid generating capacity (and hence potential metal contamination) of the dredge spoil and assessment of the risk to the receiving environment and human health will be assessed. Based on the outcomes of the investigation, management of such material may need to be addressed prior to the commencement of dredging.

The most effective way of obtaining this data is through the selective testing and analysis of samples obtained from cores obtained through the proposed geotechnical investigation of the areas of interest.

Based on the most current drawings, it is understood that a total of 17 locations (M101, M103, M105, M107, M109, M111, M113, M115, M117, M120, M122, M123, M125, M218, M220, M222, M224) will be investigated along the shipping channel, turning basin and breakwater with depths of bores ranging between 2m and 32.5 m, and a further 18 (EP-41 to EP-58) locations along the export pipeline with depths of bores ranging between 2.80 m and 18.05m.

This letter report outlines the amended proposed scope of work and associated methodologies associated with the identification and assessment of the settlement characteristics and potential acid generating capacity of the material to be dredged, to enable Coffey to cost and schedule the required works.

3 Objectives

The principal objectives of the proposed works are to:

1. Provide sufficient quantitative data on the particle size distribution and settlement characteristics of the material to be dredged for input into the dredging component of the Ocean Model being developed by DHI. Ultimately all the information obtained from the various investigation component including the modelling, will be used to develop a comprehensive Dredge Management Plan;

2. Determine whether strata that will be disturbed during dredging operations will pose any environmental risks to the marine environment, or to the terrestrial environment if bought onshore; and
3. Identify specific issues including potential acid generation and potential metal contamination. Further, the carbonate availability dredge spoil material for the buffering of potentially acid generating material will be investigated

The works are to be completed in accordance with State and National Regulations and Guidelines, where relevant, and to internal Chevron Guidelines.

4 Proposed Scope of Works

In order to meet the objectives outlined above, a comprehensive scope of works has been identified. At this time it is envisaged that the works will be undertaken in one phase (one mobilisation) as the data needs to be obtained in a timely manner to allow sufficient time for inclusion in the dredging component of the Ocean Model.

This scope of work needs to be coordinated with the geotechnical investigation. Coordination between these study components is considered crucial to allow sufficient material to be obtained for all of the study requirements and to reduce the requirement for multiple mobilisations.

The following tasks address the general scope of works, with more detailed methodologies presented in **Section 6.**

Task 1: Investigation of Geotechnical Characteristics of Dredge Material–This component of the investigation will be completed by Coffey, however to meet the objectives of the investigation and for the completion of **Task 2** and **Task 3,** the completion of field tests specific for the identification of acid potential generating material and a specific sampling programme, will need to be completed as part of the geotechnical investigation. These requirements (and assumptions) are outlined in greater detail in **Section 5 and Section 6.**

Further, this work should include a suitable number of geological cross-sections within the subject areas presenting the different stratigraphic units present.

Task 2: Investigation of Settlement Characteristics of Dredge Material – This includes the Particle Size Distribution (PSD) testing and Laser Diffraction or equivalent testing on selected representative samples.

Task 3: Environmental Investigation--This includes field testing of cores, sampling (including the appropriate storage of samples) and the completion of analytical tests for the determination of the acid generating potential , metal contamination and the carbonate buffering potential. The selected analytical methods proposed include the Chromium reducible method (S_{cr}) method, a suite of total metals of commonly detected metals in the Pilbara region, and the completion of acidimetric auto-titrations on a select number of samples.

The above works are in accordance with the Department of Environment and Conservation (DEC) Guidelines for Acid Sulphate Soils (2003).

Task 3: Reporting – two separate reports will be provided**.**

The first report will be based on works completed as part of **Task 1** and **Task 2** and will include an actual report and presentation of data in a format suitable for submittal to DHI.

The second report (environmental report) will be based on works completed as part of **Task 1** and **Task 3** and will include the preparation of a factual report that covers the methodology, observations and results of the field work and laboratory results. The report will also provide technical input into the discussion of implications for dredging impacts of onshore disposal.

5 Roles and Responsibilities

The following roles and responsibilities have been identified for the duration of the nearshore geotechnical and environmental investigation.

Coffey are responsible for the provision of personnel for the completion of environmental investigation which includes the extraction of environmental samples, ensuring decontamination between locations, completion of field tests, sampling (including quality control samples), appropriate sample storage, transfer of samples to appropriate laboratory, provision of field test results and preliminary log data to URS with COC (so sample selection can be completed), scheduling of analytical testing (once URS have selected appropriate samples for analysis), and all analytical results and accompanying laboratory certificates.

URS also understands that Coffey will provide analytical results required for the Ocean Modelling component of the investigation in a timely manner as received from CSIRO. It is also understood that Coffey will be transporting samples on a weekly basis, pending the momentum of the drilling programme.

URS' key responsibilities will be to liase with Coffey to provide guidance with the proposed environmental programme, to complete sample selection prior to submission of samples to CSIRO (based on field tests and preliminary field logs as provided by Coffey) and completion of the environmental interpretative report in a timely manner.

6 Detailed Methodologies

The following sections provide information on the methodologies that will be employed for the various tasks identified.

6.1 Task 1 - Investigation of Geotechnical Characteristics of Dredge Material

It is assumed that for the completion of **Task 2** and **Task 3** the following will be completed:

- Boreholes will be advanced using geotechnical drill rigs mounted on jack-up barges.
- Standard penetration testing (SPT) will be carried out on granular materials in accordance with AS1289.6.3.1 to determine the SPT "N" value.
- Continuous PQ3 wire-line coring will be carried out in the consolidated sediment, variably cemented materials and sound rock to obtain core for laboratory examination, testing and for future inspection/reference.

- Field strength testing of the core will be completed which will comprise Point Load Strength Index testing, performed at approximate 1m intervals in accordance with AS4133.4.1.
- Borehole logs will be compiled in the field with descriptions of soils and rocks encountered in accordance with the Soil and Rock Classification System from AS1726-1993. The field logs will be augmented by the laboratory test results and the final logs updated to include this information as deemed relevant.
- Laboratory testing will include, in addition to analytical testing required for the completion of **Task 2** and **Task 3**, the following:
  - Calcium carbonate tests.
  - Rock Porosity and Dry Density.
  - Rock Strength Tests.

Using the information obtained in the field and from the laboratory testing, the site conditions in the areas of interest will be identified. This will include the identification of the stratum encountered in the investigation areas, usually divided into Units. A profile of the dredging area will be presented which is to include geological cross-sections along the borehole transects where sufficient relevant information is available for cross-sections to be developed.

6.2 Task 2 – Investigation of the Settlement Characteristics of Dredge Material

In addition to the general geotechnical assessment, comprehensive PSD testing and analysis is required on the material to be dredged to identify the settlement characteristic of the material. To make this meaningful in relation to the dredging, this requires the complete crushing of the consolidated and sound rock found in the profile to assume the worst case scenario (use of a Cutter Suction Dredger).

The principal objective of the **Task 2** works is to provide information and advice on the total fines content of the dredged material particularly the PSD of the fraction below 30 microns. It is assumed that all the proposed geotechnical boreholes will be utilised for the **Task 2** study.

It is understood that the laboratory testing for the PSD using Laser Diffraction or equivalent testing will be carried out by a combination of Coffey and CSIRO Minerals of Perth. The PSD analysis identifies the size distribution of fines within a given sample of material, while the specialist Laser Diffraction (or equivalent) testing provides additional information on the settling characteristics of the fines.

PSD testing will be carried out on selected samples. At this stage it is envisaged that samples will be obtained from each strata encountered in each of the boreholes to the depth of the borehole (assumed proposed dredge depth plus an allowance of 1.5m over-dredge depth). As a conservative measure, an allowance for up to 4 samples per borehole should be allowed for. PSD testing is to be carried out in accordance with AS1289.3.6.1 and where the sample contains 10% or more fines, the test method is to revert to AS1289.3.6.2 (includes a hydrometer analysis of the fine fraction of the sample).

Diffraction testing is to be undertaken on selected samples. Samples will be sent to CSIRO by Coffey, who will select suitable sub-samples for testing. The testing includes the removal of coarse grain sized material (>500um) by wet sieving followed by laser diffraction which calculates the PSD based on laser light scattering.

The results of the PSD using Laser Diffraction (or equivalent) testing will be divided into the geological strata from which the sample originated and the results used to identify an average PSD for each stratum. PSD distributions and graphs are to be prepared for each same analysed (percentage fines and settling curves).

Note: To meet proposed settlement modelling timelines, it is critical that samples are received by the laboratory as soon as reasonably possible*. It is important that samples are transported to Perth in batches on a weekly basis*, to allow for the commencement of analysis. This also allows the laboratory to schedule and complete the works in a timely manner.

6.3 Task 3- Environmental Investigation

In addition to the field works outlined in **Task 1**, the following will be required to achieve the objectives of the investigation:

Field Tests: The pH of an unaltered sample (pH_{field}) and an oxidised sample (addition of hydrogen peroxide) (pH_{fox}) will be determined to semi-quantitatively assess potential acidity. This information is used to guide sample selection for laboratory analysis. Field test procedures are attached to the letter proposal as **Attachment 1**. Field test depths are outlined in the sampling and analysis plan detailed in **Section 6.3.1.**

Note: It is critical that samples are not contaminated with hydrogen chloride, hydrogen peroxide, sodium hydroxide or any other chemical used in field testing as this will interfere with laboratory test results.

Sampling Requirements: Sampling requirements are outlined in detail in **Section 6.3.1.** The sampling and analysis plan has largely been developed assuming a certain homogeny of the consolidated material at depth along the proposed areas of disturbance and hence are based on a minimum requirement to satisfy regulatory guidelines.

It is assumed that the less consolidated material intercepted at the sediment interface will be extracted using the most reliable method, such as SPT, to provide reasonable core recovery.

All samples should be labelled with the project name, project number, field engineer's initials, the date, bore location and depth of sample prior to the appropriate storage

Coring Decontamination Requirements for Environmental Cores: Prior to environmental core sampling all cores, spilt tubes, drill bits and rods will be degreased and cleaned using non-hazardous environmental fluid such as Liquid-Pol and a non-hazardous and non-toxic grease, such as Liquid Lanolin, will be used on all drill and core parts for corrosion protection and lubrication while drilling.

Cold Storage Requirements: All ASS samples (bags) are required to be frozen immediately after sampling to prevent oxidation of samples. To ensure the integrity of the sample is not jeopardised, samples must remain frozen during transportation. There are a number of cold transport companies that courier from Karratha to Perth. Samples should be sent in sealed eskies with appropriate COC documentation.

Samples for metals analysis (glass jars) do not require to be frozen, although must be kept in a cool area with a continuous temperature of approximately 4^0C

Laboratory Assessment: It is anticipated that on arrival of samples to Perth, a URS personnel experienced in acid sulphate soils, will select samples for laboratory analysis. Sample selection will be based on field logs and field tests for $pH_{(field)}$ and $pH_{(fox)}$. URS assume that draft field logs will be provided to aid in sample selection.

Based on the proposed 13 geotechnical cores completed as part of the nearshore investigation (dredge main access channel and turning basin and breakwater), it is anticipated that a total of 56 primary samples and 3 field duplicates (and other required QA/QC requirements) will be submitted to a NATA accredited laboratory, ALS Environmental (ALS) (Perth) for Scr suite (which includes Scr, pH_{KCL}, TAA, ANC and S_{NAS})). The total sampling regime equates to approximately 4 samples per location (although will ultimately depend on materials encountered). If any significant metals or acid producing material is detected from analysis additional testing may be required on stored samples.

It is currently anticipated that the assessment of geotechnical cores along the export pipeline will be based on analytical results of the nearshore investigation.

A further 10 primary samples will be submitted for acidimetric auto-titrations (carbonate buffering) to Graeme Campbell and Associates (GCA).

A brief description of the laboratory methods is provided:

1. **Scr Suite:**. Chromium Reducible Sulfur - A commonly used method of determining reducible inorganic sulfur compounds. It does not suffer from interferences from organic sulfur compounds or sulfates. Often used where results are close to trigger values, and where significant organics are present although does not quantify the actual acidity resulting from AASS
2. **Metals:** Samples will be analysed for a range of heavy metals known from the Pilbara and compared against ANZECC (2000) sediment quality guidelines. These guideline values also apply to sea dumping. It is anticipated that the metals suite will include Sb, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Ag, Se, Sn, Zn by ICP-MS
3. **Carbonate Buffering:** Each sample will be oven-dried (80^0C for *c.* 24 hrs), and crushed in a jaw-crusher with clearance set to 2-3mm (final clearance to be discussed with analytical laboratory). Equal-weight-based composites will be prepared from respective individual samples. The Acid-Neutralisation-Capacity (ANC) values will be based on laboratory results provided by CSIRO, while the acidimetric auto-titrations will be performed in the Graeme Campbell and Associates (GCA) Testing-Laboratory in Bridgetown.

Please note, that testing for carbonate material is a subsample of the ASS sample and collection of a separate sample is not required. ALS will need to provide GCA with the prepared sample once they have completed the required ASS analysis (inclusive of ANC).

6.3.1 Sampling and Analysis Plan

The following sampling and analysis plan (SAP) has been proposed based on known bore locations and depths of geotechnical bores along the shipping channel and turning basin and on preliminary bore locations for the export pipeline.

Approximate sample depths for the export pipeline will be determined once analytical results have been received for the dredged main access channel and turning basin. Based on these results the sampling intensity may be reduced and/or specific lithologies identified as ‘high risk’ will be targeted.

Please note that that the following SAP was amended on 17 April 2009 to comply with the new 2009 National Assessment Guidelines for Dredging in addition to the DEC Guidelines for ASS (2003) and the Contaminated Sites Guidelines (2001).

To comply with ALL guidelines the following has been amended:

- Approximate Sample Depths: In core sampling, the top 50 cm of the core (or to the depth of dredging if less than 50 cm) is to be used as a single sample for analysis. A second sample is to be taken from the 50 – 100 cm interval. A composited single sample is required of material below 1 m. Additional sample depths are notated and highlighted in **Table 1.**
- QA/QC Sampling Frequency and Sample Control Requirements:
    1. 1 in 20 (locations) a composite sample representative of the core should be thoroughly mixed then split into three containers to assess laboratory variation, with one of the three samples sent to a second (reference) laboratory for analysis,
    2. Rinsate Sample (of selected field equipment) at a frequency of one per week
    3. 1 sample that has been analysed in a previous batch (if more than one batch is sent) to determine the analytical variation between batches.

These changes have been highlighted in the following table.

Table 1: Amended Sampling and Analysis Plan for Environmental Investigation

Area	Bore Location	Approximate Boring Penetration (m)	Total Samples required per borehole	Approximate Sample Depths (m)	Field Tests[1]	Acid sulphate soils[2]	Metals[3]	Carbonate Buffering[4]	QA/QC Sample[5]
Dredged Main	MD101	2	3	Top 0.5 m Between 0.5-1.0 m Composite below 1m	x	All but composite	x	Composite below 1m	QC_01 (at M101_0.0)

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[1] Field test methodology attached to document as **Attachment 1.**
[2] ASS samples require 200g in a laboratory supplied sealable plastic bag and frozen
[3] Metals samples require 250 g in a laboratory supplied Teflon lid glass jar
[4] Carbonate sample is a subsample of the ASS sample and does not need a separate sample bag. Please note on COC which sample will require carbonate buffering as outlined in **Table 1.**
[5] Field duplicate for both ASS and metals analysis must be completed and labeled QC_xx

Area	Bore Location	Approximate Boring Penetration (m)	Total Samples required per borehole	Approximate Sample Depths (m)	Field Tests[1]	Acid sulphate soils[2]	Metals[3]	Carbonate Buffering[4]	QA/QC Sample[5]
	MD103	3.5	3	Top 0.5 m Between 0.5-1.0 m Composite below 1m	x	All but composite	x		
	MD105	4.5	3	Top 0.5 m Between 0.5-1.0 m Composite below 1m	x	All but composite	x		
	MD107	6	4	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 1.5	x	All but composite	x	0.5	
	MD109	6	4	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 3.5	x	All but composite	x		
	MD111	6.5	4	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 3.0	x	All but composite	x		
	MD113	9.5	5	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 6.0 and 8.0	x	All but composite	x	6.0	
	MD115	9.5	5	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 5.0 and 8.0	x	All but composite	x		QC_02 (at M115_2.0)
	MD117	10.5	6	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 4.0, 7.0, 10.0	x	All but composite	x	7.0	
	MD120	11.5	6	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 4.5, 7.0, 11.0	x	All but composite	x		
	MD122	11.5	6	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 5.0, 9.0, 11.5	x	All but composite	x	11.5	
	MD123	7	4	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 5.0	x	All but composite	x		QC03 (at M123_5.0)
	MD125	8	5	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 2.0 and 5.5	x	All but composite	x		
Breakwater	MD218	32.5	6	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 3,7,14,	x	All but composite	x		
	MD220	28	7	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 3.0, 5.0, 10, 14,	x	All but composite	x	10.0	

Area	Bore Location	Approximate Boring Penetration (m)	Total Samples required per borehole	Approximate Sample Depths (m)	Field Tests[1]	Acid sulphate soils[2]	Metals[3]	Carbonate Buffering[4]	QA/QC Sample[5]
	MD222	32.5	6	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 5.0, 9, 14	x	All but composite	x	14	Composite Triplicate Sample
	MD224	28	6	Top 0.5 m Between 0.5-1.0 m Composite below 1m Sample at 2.0 , 8.0, 14	x	All but composite	x		QC04(at M224_5.0)
Export Pipeline	MU001	3	3	-	x	x	x		
	MU003	3	3		x	x	x		
	MU005	5	3	-	x	x	x		
	MU007	3	3		x	x	x		
	MU009	3	3	-	x	x	x		
	MU011	3	3		x	x	x		
	MU013	3	3	-	x	x	x		
	MU015	3	3		x	x	x		
	MU017	3	3	-	x	x	x	x	
	MU019	5	3		x	x	x		
	MU021	3	3	-	x	x	x		
	MU023	3	3		x	x	x		
	MU025	3	3	-	x	x	x		

6.4 Reporting

URS will provide two separate reports for the works completed as part of **Task 2** and **Task 3** of the investigation.

The comprehensive interpretative reports will include copies of all field data, including field logs, as well as the finalised logs. Plans showing the locations of boreholes advanced (including the borehole identification number and samples obtained from each borehole) are to be produced including the geological cross-sections where possible. All laboratory reports are to be included as appendices.

Additionally, the environmental report will compare analytical results with current DEC guidelines for metals and ASS material, with respect to known background levels of the Pilbara Region. Further, the report will also provide technical input into the discussion of implications for dredging impacts of onshore disposal inclusive of an assessment of risk to the receiving environment and human health.

It is hoped that the above provides sufficient information on the proposed/required scope of work and associated methodologies. If you have any queries in relation to the above or require further detail please do not hesitate to contact the undersigned.

Yours sincerely
URS Australia Pty Ltd

Julian Gould
Senior Principal

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Appendix B Laboratory Schedule

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Nearshore Environmental Programme

PASS Laboratory Schedule

Wheatstone Project, Onslow WA

SampleCode	Sampled_Date/Time	Lab Login-ASS Screening	Lab_Login_Date_Other	LocCode	Sample_Depth	ASS Screening	Scr Suite	carbonate buffering
EP0904291047	3-Jul-09	9-Jul-09	4-Aug-09	MC001	0.45-0.55	1	1	
EP0904291048	3-Jul-09	9-Jul-09	4-Aug-09	MC001	0.9-1.0	1	1	
EP0904291049	3-Jul-09	9-Jul-09	4-Aug-09	MC001	(comp)1.0-2.0	1	1	
EP0904291050	3-Jul-09	9-Jul-09	4-Aug-09	MC001	3.4-3.5	1	1	
EP0904291051	3-Jul-09	9-Jul-09	4-Aug-09	MC001	6.4-6.5	1	1	
EP0904291043	3-Jul-09	9-Jul-09	4-Aug-09	MC002	1.0-1.1	1	1	
EP0904291044	3-Jul-09	9-Jul-09	4-Aug-09	MC002	1.9-2.0	1	1	
EP0904291045	3-Jul-09	9-Jul-09	4-Aug-09	MC002	2.9-3.0	1	1	
EP0904291046	4-Jul-09	9-Jul-09	4-Aug-09	MC002	6.4-6.5	1	1	
EP0904291038	4-Jul-09	9-Jul-09	4-Aug-09	MC003	0.45-0.55	1	1	
EP0904291039	4-Jul-09	9-Jul-09	4-Aug-09	MC003	0.9-1.0	1	1	
EP0904291040	4-Jul-09	9-Jul-09	4-Aug-09	MC003	(comp)1-2	1	1	
EP0904291041	4-Jul-09	9-Jul-09	4-Aug-09	MC003	3.4-3.5	1	1	
EP0904291042	5-Jul-09	9-Jul-09	4-Aug-09	MC003	6.9-7.0	1	1	
EP0904291034	5-Jul-09	9-Jul-09	4-Aug-09	MC004	0.5-1.0	1	1	1
EP0904291035	5-Jul-09	9-Jul-09	4-Aug-09	MC004	(comp)1.0-2.0	1	1	
EP0904291036	5-Jul-09	9-Jul-09	4-Aug-09	MC004	3.9-4.0	1	1	
EP0904291037	6-Jun-09	9-Jul-09	4-Aug-09	MC004	8.0-8.1	1	1	
EP0904291029	6-Jul-09	9-Jul-09	4-Aug-09	MC005	0.45-0.55	1	1	1
EP0904291030	6-Jul-09	9-Jul-09	4-Aug-09	MC005	0.9-1.0	1	1	
EP0904291031	6-Jul-09	9-Jul-09	4-Aug-09	MC005	(comp)1.0-2.0	1	1	
EP0904291032	6-Jul-09	9-Jul-09	4-Aug-09	MC005	3.0-3.1	1	1	
EP0904291033	6-Jul-09	9-Jul-09	4-Aug-09	MC005	6.9-7.0	1	1	
EP0904291071	8-Jul-09	15-Jul-09	4-Aug-09	MC006	0.45-0.55	1	1	
EP0904291072	8-Jul-09	15-Jul-09	4-Aug-09	MC006	0.9-1.0	1	1	
EP0903858029	15-Jul-09	15-Jul-09	4-Aug-09	MC006	1.0-2.0	1	1	
EP0904291073	8-Jul-09	15-Jul-09	4-Aug-09	MC006	3.26-3.36	1	1	
EP0904291074	9-Jul-09	15-Jul-09	4-Aug-09	MC006	9.9-10.0	1	1	
EP0904291001	26-Jun-09	9-Jul-09	4-Aug-09	MC007	0.45-0.55	1	1	
EP0904291002	26-Jun-09	9-Jul-09	4-Aug-09	MC007	0.8-0.9	1	1	
EP0904291003	26-Jun-09	9-Jul-09	4-Aug-09	MC007	(comp)1.0-2.0	1	1	
EP0904291004	25-Jun-09	9-Jul-09	4-Aug-09	MC008	0.45-0.55	1	1	
EP0904291005	25-Jun-09	9-Jul-09	4-Aug-09	MC008	0.8-0.9	1	1	
EP0904291006	25-Jun-09	9-Jul-09	4-Aug-09	MC008	(comp)2.0-3.0	1	1	
EP0904291007	25-Jun-09	9-Jul-09	4-Aug-09	MC008	3.8-3.9	1	1	
EP0904291008	25-Jun-09	9-Jul-09	4-Aug-09	MC008	7.0-7.1	1	1	1
EP0904291058	11-Jul-09	15-Jul-09	4-Aug-09	MC009	1.0-1.1	1	1	
EP0904291062	12-Jul-09	15-Jul-09	4-Aug-09	MC009	13.4-13.5	1	1	
EP0904291059	11-Jul-09	15-Jul-09	4-Aug-09	MC009	2.0-3.0	1	1	
EP0904291060	11-Jul-09	15-Jul-09	4-Aug-09	MC009	3.9-4.0	1	1	
EP0904291061	12-Jul-09	15-Jul-09	4-Aug-09	MC009	8.9-9.0	1	1	
EP0904291064	9-Jul-09	15-Jul-09	4-Aug-09	MC010	0.45-0.55	1	1	
EP0904291065	9-Jul-09	15-Jul-09	4-Aug-09	MC010	0.9-1.0	1	1	
EP0904291066	9-Jul-09	15-Jul-09	4-Aug-09	MC010	1.0-2.0	1	1	
EP0904291069	11-Jul-09	15-Jul-09	4-Aug-09	MC010	10.9-11.0	1	1	
EP0904291067	9-Jul-09	15-Jul-09	4-Aug-09	MC010	3.45-3.55	1	1	
EP0904291068	9-Jul-09	15-Jul-09	4-Aug-09	MC010	7.9-8.0	1	1	
EP0904291009	27-Jun-09	9-Jul-09	4-Aug-09	MC11	0.0-0.4	1	1	
EP0904291010	27-Jun-09	9-Jul-09	4-Aug-09	MC11	1.0-1.1	1	1	
EP0904291011	28-Jun-09	9-Jul-09	4-Aug-09	MC11	(comp)2.0-3.0	1	1	
EP0904291012	28-Jun-09	9-Jul-09	4-Aug-09	MC11	3.5-3.6	1	1	
EP0904291013	28-Jun-09	9-Jul-09	4-Aug-09	MC11	7.45-7.55	1	1	
EP0904291024	7-Jul-09	9-Jul-09	4-Aug-09	MC012	0.45-0.55	1	1	1
EP0904291025	7-Jul-09	9-Jul-09	4-Aug-09	MC012	0.9-1.0	1	1	
EP0904291026	7-Jul-09	9-Jul-09	4-Aug-09	MC012	(comp)1.0-2.0	1	1	
EP0904291027	7-Jul-09	9-Jul-09	4-Aug-09	MC012	4.0-4.1	1	1	
EP0904291070	8-Jul-09	15-Jul-09	4-Aug-09	MC012	9.4-9.5	1	1	
EP0904291014	29-Jun-09	9-Jul-09	4-Aug-09	MC013	0.45-0.55	1	1	
EP0904291015	29-Jun-09	9-Jul-09	4-Aug-09	MC013	0.8-0.9	1	1	1
EP0904291016	29-Jun-09	9-Jul-09	4-Aug-09	MC013	(comp)1.0-2.0	1	1	
EP0904291017	29-Jun-09	9-Jul-09	4-Aug-09	MC013	3.4-3.5	1	1	
EP0904291018	29-Jun-09	9-Jul-09	4-Aug-09	MC013	7.9-8.0	1	1	
EP0904291019	30-Jun-09	9-Jul-09	4-Aug-09	MC014	0.45-0.55	1	1	1
EP0904291020	30-Jun-09	9-Jul-09	4-Aug-09	MC014	0.8-0.9	1	1	
EP0904291021	30-Jun-09	9-Jul-09	4-Aug-09	MC014	(comp)1.0-2.0	1	1	
EP0904291022	30-Jun-09	9-Jul-09	4-Aug-09	MC014	3.4-3.5	1	1	
EP0904291023	30-Jun-09	9-Jul-09	4-Aug-09	MC014	6.9-7.0	1	1	
EP0904291052	2-Jul-09	**9-Jul-09**	4-Aug-09	MC015	0.45-0.55	1	1	
EP0904291053	2-Jul-09	9-Jul-09	4-Aug-09	MC015	0.9-1.0	1	1	
EP0904291054	2-Jul-09	9-Jul-09	4-Aug-09	MC015	(comp)1.0-2.0	1	1	
EP0904291055	2-Jul-09	9-Jul-09	4-Aug-09	MC015	3.4-3.5	1	1	
EP0904291056	2-Jul-09	9-Jul-09	4-Aug-09	MC015	6.4-6.5	1	1	
TOTAL PRIMARY SAMPLES						**72**	**72**	**6**

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Lab Schedule.xls

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Appendix C Field Test Procedures and Guidelines

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APPENDIX 1. Performing and interpreting soil field pH tests

It is important to note that whilst a useful exploratory tool, soil field pH tests are indicative only, are definitely not quantitative and cannot be used as a substitute for laboratory analysis to determine the presence or absence of ASS. Laboratory analysis is needed to quantify the amount of **existing, plus potential, acidity**. This Appendix provides information on how to perform field pH tests and interpret the results from them. For further information on how to conduct and interpret these tests, consult the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998 (*Ahern *et al.,* 1998*)*.

Field pH tests should be conducted using a field pH meter calibrated according to the manufacturer's instructions. All results (pH_F and pH_{FOX} values, peroxide reaction) should be tabulated and reported.

A1 Suggested equipment for field tests

It is important that prior to conducting the field tests, the appropriate testing equipment is obtained. For a basic set up the following items would be required:

1. pH meter and electrode – charged and calibrated
2. at least 2 buffer solutions – e.g. pH 4.0 and pH 7.0
3. test tubes or beakers – wide, unbreakable, heat resistant, and clear e.g. Falcon 50ml polypropylene (pH_F test tubes are ideally shallow to facilitate cleaning e.g. cut the top off a 50ml tube at about 10ml)
4. test tube rack or jar rack marked with depths – use a separate rack for pH_F tests and pH_{FOX} tests in case they bubble over
5. skewers or stirrers – wooden, for test tubes
6. 30% hydrogen peroxide (H_2O_2) pH adjusted to 4.5–5.5
7. storage bottle for H_2O_2
8. sodium hydroxide (NaOH) – to raise pH of peroxide to 4.5–5.5 (pH 5.5 ideal)
9. deionised (DI) water
10. squirt bottle for DI water
11. tissues
12. gloves and safety glasses
13. protective clothing
14. bucket – to tip used soil and hydrogen peroxide into
15. bucket and brush – to rinse tubes out in ready for next site
16. recording sheets
17. excess water for rinsing
18. first aid kit – especially eye wash solutions
19. 1M hydrochloric (HCl) acid – to test for shell presence

A2 Conducting field tests – Some considerations

When the analytical results are reported, the field test results (when accompanied by good soil profile descriptions) will help increase the understanding of profile processes with respect to acidity.

When performing field tests, the soil samples must not be left in the open air in the test tubes or beakers for an extended period of time before conducting the tests. If sulfides are present, there is a risk that they will oxidise, and this will substantially affect the end pH result by lowering the pH_F. This will give a misleading result that the soil profile is more acid than it really is. It would be preferable (and more efficient) to prepare the field pH test tubes with the soil:water pastes and the soil:peroxide mixtures and commence the soil profile descriptions while the reactions are occurring. This way, the soils are given time to react and there is no time wasted waiting for pH_{FOX} samples to cool. It is important though, to keep an eye on the reactions as some may be vigorous and overflow, and result in contamination of nearby soil samples.

When conducting the pH_{FOX} test, it is important to allow enough time for the reaction to occur, especially if low strength (i.e. <30%) hydrogen peroxide is used.

The field pH_F and pH_{FOX} tests can be made more consistent if a fixed volume of soil (using a small scoop) is used, a consistent volume of peroxide is added and left to react for at least an hour (at a secure location, the pH_{FOX} can be left overnight). The sample can then be moistened with deionised water before reading the pH_F and pH_{FOX}.

Field tests should preferably be performed on-site, however there are many areas (e.g. wetlands) where performing field tests can prove difficult (e.g. too wet, mosquito problems). In this situation, samples must be placed on dry ice and taken to a suitable location for conducting field tests. These tests should be performed ideally within 24 hours. As some samples may contain large amounts of organic matter (especially in wetland situations) and may also contain monosulfides, any delay in performing field tests could result in misleading pH_F results.

A3 On–site Chemical and Material Safety Precautions

A3.1 Hydrogen peroxide

Care needs to be taken when using hydrogen peroxide (H_2O_2) in the field. H_2O_2 (30%) is used as the primary reagent in the pH_{FOX} test. The concentration is 10 times stronger than the peroxide commonly found in household medicine cabinets. The reaction of peroxide with soil containing iron sulfides may produce sulfurous gases, as well as giving off heat in excess of 90°C.

Caution: 30% Hydrogen Peroxide is a strong oxidising agent and should be handled carefully with appropriate eye and skin protection. **This test is suitable for experienced operators only.** Even the less concentrated 6% peroxide (which some operators are using) should be used with caution.

The peroxide when first received may have a pH of 3.5 or lower. Chemical companies commonly put stabilisers in the peroxide to prevent it from decomposing and releasing oxygen by keeping the pH low. The pH required for the field pH peroxide test is pH 4.5–5.5. This may be obtained by adding sodium hydroxide (pH 14) to the peroxide. Since both of these chemicals are highly corrosive, and many of the long-term side effects are not fully known, it is recommended that the following precautions are taken when performing field tests.

Always:
1. use gloves, safety glasses, lab coat or protective clothes;
2. conduct pH peroxide test in a well ventilated area;
3. use test tubes capable of withstanding rapid heat changes and high temperatures;
4. avoid skin and eye contact with peroxide; and
5. label all peroxide bottles with safety data information.

A3.2 Other chemicals

Several other chemicals are used in the field when sampling for ASS. Buffering solutions and potassium chloride (KCl) solutions are used to calibrate and maintain pH meters and care should be exercised when using these substances. Follow safety directions on Material Safety Data Sheets (MSDS).

Hydrochloric acid (HCl) is used when performing tests to assess the presence of carbonates in soil material. HCl is strongly acidic and is very corrosive to skin therefore caution is required when using it. Again, follow directions on MSDS. Store HCl separate from buffer solutions as HCl gas may slowly diffuse through the plastic bottles and alter the buffer solutions.

A4 Field pH test (pH_F)

The pH_F test measures the existing acidity of a soil:water paste, and is therefore used to help identify if ASS are present. If the measured pH of the soil paste is $pH_F < 4$, oxidation of sulfides has probably occurred in the past, indicating the presence of AASS. Highly organic soils or heavily fertilised soils may also return a pH_F close to 4. A pH_F >4 but $\leq$5 indicates an acid soil, but the cause of the acidity will need to be further investigated by laboratory analysis. The pH_F test does not detect any unoxidised sulfides (i.e. PASS). For this reason, this test must be used in conjunction with the pH_{FOX} test.

A4.1 Soil: water mixtures and soil pastes

Standard field soil pH tests have been conducted using a 1:5 soil:water mixture. This is quite successful where sands are concerned (as they breakdown readily), however in a field situation it is often difficult to get all soil into solution by shaking only for a brief period of time. In particular, where wet clays are present, it becomes very difficult in the field to shake the mixture to suspend all the clay particles in solution. It is more likely that the clay will stay in a ball and while some fine particles previously attached to the edge of the clay bolus are suspended, the remainder sticks to the bottom of the test tube. This means that the soil:liquid ratio is widened substantially and the pH of the mixture will have a higher reading, so that it will not give a true and accurate measurement of the pH of the soil. In the laboratory, this sample would be dried, ground, mixed, and shaken mechanically for hours allowing substantial time for the clay to be broken down—in the field, this option is not practical. Further, it is not practical to weigh out soils in the field to obtain a perfect 1:5 soil:water mixture, and so any solutions made up are usually done on a volumetric basis assisted by graduated test tubes, flasks, or beakers.

Making a soil:water paste is more practical for field situations and is recommended for ASS field pH (pH_F) tests. This is detailed in the procedure below. It is recommended that short test tubes are used for pH_F tests as they are easy to clean. Further, the paste must be stirred using a stirring implement (e.g. skewer or strong toothpicks). Stirring the paste well will enhance the accuracy of the pH result as the electrode will get good contact with the soil.

A4.2 Field pH test procedure

Procedural outline – field pH_F test

1. Calibrate battery powered field pH meter.
2. Prepare the test tubes in the test tube rack. Make sure the rack is marked with the depths so there is no confusion about the top and bottom of the profile. Use of separate racks for the pH_F and pH_{FOX} tests is recommended as contamination may occur when the pH_{FOX} reactions are violent.
3. Conduct tests at intervals on the soil profile of 0.25m or at least one test per horizon whichever is lesser.
4. Remove approximately 1 teaspoon of soil from the profile. Place approximately ½ teaspoon of the soil into the pH_F test tube and place ½ teaspoon of the soil into the pH_{FOX} test tube for the corresponding depth test. It is important that these 2 sub-samples come from the same depth and that they are similar in characteristics. For example, DO NOT take ½ teaspoon of soil from the 0–0.25m depth that is grey mud, while selecting ½ teaspoon from the same depth that is a yellow mottled sample. These will obviously give different results independent of the type of test conducted.
5. Place enough deionised water (pH 5.5) in the pH_F test tube to make a paste similar to ‘grout mix’ or ‘white sauce’, stirring with a skewer or similar to ensure all soil ‘lumps’ are removed. Do not leave the soil samples in the test tubes without water for more than 10 minutes.

6. This will reduce the risk of sulfide oxidation—the pH_F is designed to measure existing acidity, any oxidation subsequent to the soil's removal from the ground will not reflect the true situation. In some instances, in less than 5 minutes, monosulfidic material may start to oxidise and substantially affect the pH_F results.
7. Immediately place the spear point electrode (preferred method) into the test tube, ensuring that the spear point is totally submerged in the soil: water paste. Never stir the paste with the electrode. This will damage the semi-permeable glass membrane.
8. Measure the pH_F using a pH meter with spear point electrode.
9. Wait for the reading to stabilise and record the pH measurement. All measurements and pH calibration should be recorded on a data sheet.

TABLE A1: Results – field pH test

pH value	Result	Comments
$pH_F \leq 4$	Actual acid sulfate soils (AASS) indicating oxidation of sulfides	This is generally <u>not</u> conclusive because highly organic soils such as peats and occasionally heavily fertilised soils may also give $pH_F \leq 4$.
$pH_F \leq 3.7$	Expected if jarosite exists in the sample	This is also an AASS. Jarosite needs a pH of 3.7 or lower to form. Horizons containing some jarosite and some other mottling (iron, grey) may have a pH >3.7 if the sample contains a mixture of jarosite and higher pH soil. This depends on the level of oxidation and the ability of the soil to 'hold' the acid.
$pH_F > 7$	Expected in waterlogged, unoxidised, or poorly drained soils	Marine muds commonly have a pH >7 and this reflects seawater (pH 8.2) influence. May be a PASS after oxidation with H_2O_2 .
$4 < pH_F \leq 5.5$	An acid soil	Investigate further for possible ASS link, e.g. AASS with shell presence.

A5 Field pH peroxide test (pH_{FOX})

The pH_{FOX} test is used to indicate the presence of iron sulfides or PASS. This test involves adding 30% hydrogen peroxide (pH adjusted to 4.5–5.5) to a sample of soil. If sulfides are present a reaction will occur. The reaction can be influenced by the amount of sulfides present in the sample, the presence of organic matter, or the presence of manganese. Once the reaction has occurred, the pH is measured.

Adding hydrogen peroxide, a strong oxidising agent, 'mimics' what would naturally occur if the soil was exposed to air. In a natural environment, if left exposed, soils may take from two hours for sands, possibly through to many decades for heavy marine clays, for some or all of the oxidation reactions to take place. Obviously it is not practical to wait for this long for a reaction to occur.

It should be noted that although the iron sulfides are oxidised and acid is produced over a shorter amount of time than would occur naturally, the total amount of acid produced is the same. It is important to assess first the likely presence (through field tests) and secondly the level of iron sulfides present (through laboratory analyses) so that management can prevent any undesirable impacts.

The pH_{FOX} test is purely qualitative. No calculations can be performed to give an accurate account of the levels of sulfides present in the sample. Rather, the test gives an indication of whether sulfides may occur (or whether there is another form of compound contributing to acidity).

This means that a pH_{FOX} test CANNOT give an accurate measurement of how much lime should be added to the soil.

The sample of soil must be taken from the same depth increment (sub-sample) for which the pH_F was measured. It is important that the pH_{FOX} is performed on a separate sub-sample, and NOT on the soil:water paste that was prepared for the pH_F test. This will ensure that the minimal degree of dilution occurs during the oxidation phase, and that the resulting pH_{FOX} measurement is as accurate as possible an indication of the potential for oxidation of that particular sub-sample of soil.

A combination of three factors is considered in arriving at a ‘positive field sulfide identification’:

- a reaction with hydrogen peroxide - the strength of the reaction with peroxide is a useful indicator but cannot be used alone. Organic matter, coffee rock and other soil constituents such as manganese oxides can also cause a reaction. Care should be exercised in interpreting a reaction on surface soils and high organic matter soils such as peats and coffee rock and some mangrove/estuarine muds and marine clays. This reaction should be rated, e.g. L = Low reaction, M = Medium reaction, H = High reaction, X = Extreme reaction, V = volcanic reaction.

- The actual value of pH_{FOX}. - If pH_{FOX} <3, and a significant reaction occurred, then it strongly indicates a PASS. The more the pH_{FOX} drops below 3, the more positive the presence of inorganic sulfides.

- A much lower pH_{FOX} than field pH_F - The lower the final pH_{FOX} value and the greater the difference between the pH_{FOX} compared to the pH_F, the more indicative of the presence of PASS. This difference may not be as great if starting with an already very acid pH_F (close to 4), but if the starting pH is neutral or alkaline then a larger change in pH should be expected. Where fine shell, coral or carbonate is present the change in pH may not be as large due to buffering. The ‘fizz test’ (effervescence with 1 M HCl) should be used to test for carbonates and shell.

Of these three factors, the final pH_{FOX} value is the most conclusive indicator, and the lower the final pH_{FOX}, the more confident one can be that PASS may be present.

A5.1 Strength and pH of peroxide

The pH and strength of peroxide used is important. The pH of the peroxide should be pH 4.5–5.5 (ideally pH 5.5). This ensures that the result measured is a reflection of the oxidation of the soil (if any) and not of the existing pH of the peroxide. When peroxide is purchased often the stabilisers added by the chemical companies will result in a pH of approximately 3.5. This pH can be raised by adding small amounts of sodium hydroxide (NaOH)—failure to adjust the pH can lead to false field results.

Analytical grade peroxide (30%) is most suitable for field pH_{FOX} tests as an oxidation agent that is highly effective and ‘quick’ to react with any iron sulfides in a soil sample. This strength of peroxide is highly corrosive, slightly unstable, highly reactive and can cause severe skin irritation. As such, a high level of safety precautions is required. However, there is no reason why a well-trained officer cannot safely and responsibly conduct field tests with 30% hydrogen peroxide.

A5.2 Field pH peroxide test procedure

Procedural outline – Field pH peroxide test

1. Adjust the pH of the hydrogen peroxide to 5.0 -5.5 before going into the field. This can be done by adding a few drops of NaOH at a time, checking the pH with the electrode regularly. NaOH is highly caustic so safety precautions must be exercised. Also, NaOH will raise the pH quickly so the pH needs to be monitored. Do NOT buffer a large quantity of hydrogen peroxide at one time. Only buffer the amount to be used in the field. Hydrogen peroxide

should be well labelled and only small quantities should be taken into the field at any one time. This will ensure the longevity of the peroxide. Further, over time, the pH of the peroxide that has already been buffered may change. It is important to check the pH of the peroxide in the morning before departing to the field. Having a small quantity of NaOH in the field kit is recommended so the pH of the peroxide can be adjusted if required.

2. Calibrate battery powered field pH meter.
3. Prepare the test tubes in the test tube rack as for pH_F test. Make sure the rack is marked with the depths so there is not confusion about the top and bottom of the profile. Use of separate racks for the pH_F and pH_{FOX} tests is recommended as contamination may occur when the pH_{FOX} reactions are violent.
4. Conduct pH_F tests at intervals of 0.25m down the soil profile or at least one per horizon whichever is lesser.
5. Remove approximately one teaspoon of soil from the profile. Place approximately ½ teaspoon of that soil into the pH_F test tube and place ½ teaspoon of soil into the pH_{FOX} test tube for the corresponding depth test. It is important that these two sub-samples come from the same depth and that they are similar in characteristics. For example, DO NOT take ½ teaspoon of soil from the 0-0.25m depth that is grey mud, while selecting ½ teaspoon from the same depth that is a yellow mottled sample. These will obviously give different results independent of the type of test conducted.
6. Add a few drops of 30% H_2O_2 adjusted to pH 4.5–5.5 to the soil in a heat-resistant test tube and stir the mixture. DO NOT add the peroxide to the test tube in which the pH_F test was conducted. The pH_{FOX} test tube <u>should not</u> have any deionised water in it. Beakers can be used however when multiple tests are being conducted it is difficult to handle the large beaker size efficiently. DO NOT add more than a few drops of H_2O_2 at a time. This will prevent overflow and wastage of peroxide. A day's supply of peroxide should be allowed to reach room temperature prior to use (cold peroxide from the fridge may be too slow to react).
7. Ideally, allow approximately 20 minutes for any reactions to occur. If substantial sulfides are present, the reaction will be vigorous and may occur almost instantly. In this case, it may not be necessary to stir the mixture. Careful watch will be needed in the early stages to ensure that there is no cross contamination of samples in the test tube rack. If the reaction is violent and the soil/peroxide mix is escaping from the test tube, a small amount of deionised water can be added to cool and calm the reaction. Usually this controls overflow. Do NOT add too much deionised water as this may dilute the mixture and affect the pH value. It is important to only use a small amount of soil otherwise violent reactions will overflow and the sample will be lost.
8. Steps 6 and 7 may be repeated until the soil/peroxide mixture reaction has slowed. This will ensure that most of the sulfides have reacted. In the lab this procedure would be repeated until no further reaction occurs, however in the field, best judgement is recommended.
9. If there is no initial reaction, individual test tubes containing the soil/peroxide mixture can be placed into a cup of hot water (especially in cooler weather) or in direct sunlight. This will encourage the initial reaction to occur. When the sample starts to 'bubble', remove the test tube immediately from the cup and replace into test tube rack.
10. Wait for the soil/peroxide mixture to cool (may take up to 10 minutes). The reactions often exceed 90^{o}C. Placing an electrode into these high temperature situations may result in physical damage and inaccurate readings as most pH meters are set to record a result for an ambient temperature of approximately 25^{o}C.
11. Use an electronic pH meter (preferred method) to measure the pH_{FOX}. Place a spear point electrode into the test tube, ensuring that the spear point is totally submerged in the soil/peroxide mixture. Ensure that the plastic soil sleeve that exposes the spear point totally is used on the end of the electrode in preference to the protective pronged sleeve that almost totally conceals the spear point. This will ensure good contact with the soil. Never stir the mixture with the electrode. This will damage the semi-permeable glass membrane.
12. Rate the reaction using a LMHXV scale (Section A5).
13. Wait for the reading to stabilise and record the pH_{FOX} measurement.

14. All measurements and pH calibration measurements should be recorded on a data sheet.

TABLE A2: Results – field pH$_{\mathrm{FOX}}$ test.

pH value and reaction	Result	Comments
A strong reaction of soil with peroxide – X or V	A useful indicator but cannot be used alone.	Organic matter, coffee rock, and other soil constituents such as manganese oxides can also cause a reaction. Care must be exercised in interpreting a reaction on surface soils and high organic matter soils such as peats and coffee rocks, and some mangrove/estuarine muds and marine clays.
pH$_{\mathrm{FOX}}$ value at least one unit below field pH$_{\mathrm{F}}$ and reaction to peroxide	May indicate PASS but depends on the initial and resultant pH	The greater the difference between the two measurements (ΔpH), the more indicative the value is of a PASS. The lower the final pH$_{\mathrm{FOX}}$, the better the indication of a positive result (e.g. a 1 unit change from pH 8 to 7 would not indicate PASS, however a 1 unit change from pH 3.5 to 2.5 would be indicative).
pH$_{\mathrm{FOX}}$ <3, strong reaction with peroxide, and large ΔpH	Strongly indicates PASS – potential for the soil to produce sulfidic acid upon oxidation	The lower the pH$_{\mathrm{FOX}}$ below 3, the more positive the likely presence of sulfides. A combination of all three parameters (reaction strength, unit pH change, and final pH$_{\mathrm{FOX}}$ result) is most confirmatory.
A pH$_{\mathrm{FOX}}$ 3–4 and reaction to peroxide	The test is less positive and is a borderline result	Sulfides may be present however organic matter may also be responsible for the decrease in pH. Laboratory analyses are required to confirm if sulfides are present.
pH$_{\mathrm{FOX}}$ 4–5	The test is neither positive nor negative	Sulfides may be present either in small quantities and be poorly reactive under quick test field conditions, or the sample may contain shell/carbonate, which neutralises some or all acid produced by oxidation. Equally the pH$_{\mathrm{FOX}}$ value may be due to the production of organic acids and there may be no sulfides present in this situation. In such cases, the chromium reducible sulfur method would be best to check for the presence of iron sulfides.
pH$_{\mathrm{FOX}}$ >5 and little or no drop in pH from pH$_{\mathrm{F}}$ but reaction to peroxide	Little net acidifying ability is indicated	On soils with neutral to alkaline field pH and shell or white concretions present, the fizz test with 1M HCl should be used to test for carbonates. The SPOCAS method should be used to check for any oxidisable sulfides and the presence of self-neutralising ability.

A6 Field test results interpretation

Field test results are dependant on many factors including accuracy of pH meters, strength of reagents, and operator skill. The reactions and results obtained from the field pH peroxide test can be further influenced by additional factors such as soil type, moisture content, ambient air temperature, presence of organic matter, or bicarbonate as shell or seawater in the soil sample. Some of these reactions are listed in Table A3 together with explanatory comments.

TABLE A3: Some common field test results.

pH_F	**pH_{FOX} (at completion of reaction)**	**Δ pH**	**Reaction rate**	**Result (e.g. **PASS or ***AASS)**	**Comments / Possible explanation**
3.5	3.3	0.2	L	AASS present	Oxidation has occurred and sulfuric acid has formed in the past. This soil may not have much more potential to oxidise further as the pH_F and pH_{FOX} are similar.
3.7	1.4	2.3	X or V	AASS present; PASS – strong indication	Oxidation has occurred in the past. This soil has the potential to oxidise further indicated by the strong reaction, appreciable pH unit difference (pH_{FOX} is significantly lower than the pH_F) and the very low final pH_{FOX}.
6.5	2.1 (1.9)*	4.4	X or V	No AASS; PASS – strong indication	This soil is not yet oxidised but has the ability to produce sulfuric acid if exposed. Little buffering capacity in the soil. Laboratory analysis using SPOCAS could confirm this.
8.5	3.0 (3.2)*	5.5	H	No AASS; PASS – likely	The initial pH may be reflecting a strong seawater influence (pH 8.2) or some form of dissolved carbonates. The large ΔpH indicates a strong likelihood of PASS even though the pH_{FOX} is borderline. Here, the ΔpH and the reaction gives strength to the argument. Laboratory analysis using SPOCAS and reacted calcium (Ca_A) could confirm this (see Ahern & McElnea (1999)).
8.0	2.0 (6.0)*	?	H	No AASS; PASS – strong indication; Considerable buffering capacity	The initial alkaline pH_F indicates a seawater influence. The initial large decrease in pH indicates the soil is likely to contain sulfides. The pH measured after 20 minutes may indicate a large % of shell dissolving into solution as the acid contacts it (a small amount of HCl added to a sample of soil could confirm its presence). Laboratory analysis using SPOCAS and Ca_A could confirm this (see Ahern & McElnea (1999)).
5.5	5.4 (5.3)*	0.2	X or V	No AASS; PASS – unlikely	The strong reaction is probably due to the presence of manganese in the soil sample.
5.5	3.8 (3.5)*	2.0	H (slow froth)	No AASS; PASS – possible	The strength of the reaction indicates possible organic matter. There may be some sulfides present also. Laboratory analysis using the S_{CR} could confirm this.

* pH_{FOX} after 20 minutes (or overnight)
** PASS – Potential Acid Sulfate Soils
*** AASS – Actual Acid Sulfate Soils

SECTION H: FIELD TESTS

1. ACID SULFATE SOIL FIELD pH TESTS

KM Watling, CR Ahern and KM Hey

1.1 INTRODUCTION

The field pH (pH_F) and field pH peroxide (pH_{FOX}) tests have been developed for a rapid assessment in the field of the likelihood of acid sulfate soils. These tests are easy to conduct, quick, and have a minimum set-up cost. The field tests have been developed to give reasonable prediction for many soils (provided the tests are performed properly) whilst at the same time being relatively easy to perform with a minimal amount of equipment. Soil field pH tests provide a useful indication of the existing and potential acidity levels in the soil. Although these field tests may provide an indication of ASS presence, they are purely qualitative and do not give any quantitative measure of the amount of acid that has been or could be produced through the oxidation process.

Field pH tests should be part of any ASS investigation. The field pH tests (both pH_F and pH_{FOX}) should be conducted at 0.25 m intervals on the soil profile, ensuring at least one test per horizon. It is recommended that field tests be conducted on-site, in the field. If the tests can't be performed in the field on-site, tests should be conducted within 24 hours of soil sample collection, ensuring appropriate sample handling procedures (see Section B). Samples suspected of containing monosulfides should undergo field pH testing immediately in the field.

1.2 FIELD pH TEST (pH_F)

The procedure for the field pH test (pH_F) is outlined below:

- ☐ **Calibrate battery powered field pH meter** according to manufacturer's instructions.
- ☐ **Prepare the test tubes in the test tube rack**. Make sure the rack is marked with the depths so there is no confusion about the top and bottom of the profile. Use of separate racks for the pH_F and pH_{FOX} tests is recommended as contamination may occur when the pH_{FOX} reactions are violent. As the soil:water paste is inclined to stick to the walls of tubes, it is best to use shallow, broad test tubes as this makes cleaning easier.
- ☐ **Conduct tests at intervals on the soil profile of 0.25 m or at least one test per horizon** whichever is lesser.
- ☐ **Remove approximately 1 teaspoon of soil from the profile. Place approximately ½ teaspoon of that soil into the pH_F test tube and place ½ teaspoon of the soil into the pH_{FOX} test tube** for the corresponding depth test. It is important that these two sub-samples come from the same depth and that they are similar in characteristics. For example, DO NOT take ½ teaspoon of soil from the 0–0.25m depth that is grey mud, while selecting ½ teaspoon from the same depth that is a yellow mottled sample. These will obviously give different results independent of the type of test conducted.
- ☐ **Place enough deionised water** (or demineralised water if deionised water is not available; never use tap water) **in the pH_F test tube** to make a paste similar to 'grout mix' or 'white sauce', **stirring the soil:water paste** with a skewer, strong tooth pick or similar to ensure all soil 'lumps' are removed. Do not leave the soil samples in the test tubes without water for more than 10 minutes. This will reduce the risk of sulfide oxidation—the pH_F is designed to indicate the existing pH of a soil in the field; any oxidation subsequent to the soil's removal

from the ground will not reflect the true field pH. In some instances, in less than 5 minutes, monosulfidic material may start to oxidise and substantially affect the pH_F results.

- ☐ **Immediately place the spear point electrode (preferred method) into the test tube**, ensuring that the spear point is totally submerged in the soil:water paste. Never stir the paste with the electrode. This will damage the semi-permeable glass membrane.
- ☐ **Measure the pH_F** using a pH meter with spear point electrode.
- ☐ **Wait for the reading to stabilise and record the pH measurement.**
- ☐ **All measurements should be recorded on a data sheet**.

1.3 FIELD pH PEROXIDE TEST (pH_{FOX})

It is recommended that 30% hydrogen peroxide (H_2O_2) be used in the pH_{FOX} test. 30% H_2O_2 is highly corrosive and care should be taken when handling and using the peroxide. Safety glasses and gloves should be worn when handling and using peroxide. All chemical bottles should be clearly labelled and Material Safety Data Sheets (MSDS) should be kept with the chemicals at all times. Appropriate health and safety precautions should be adhered to. Peroxide should be kept in the fridge when not in use.

The procedure for the field pH peroxide test (pH_{FOX}) is outlined below:

- ☐ **Adjust the pH of the hydrogen peroxide to pH 4.5–5.5 before going into the field**. This can be done by adding a few drops of dilute NaOH stirring and checking the pH with the electrode regularly until the correct range is reached. NaOH is highly caustic so safety precautions must be exercised. NaOH can raise the pH quickly or slowly, so the pH needs to be monitored. Recheck the pH after allowing the peroxide to stand for 15 minutes. Do NOT buffer a large quantity of hydrogen peroxide at one time. Only buffer the amount to be used in the field for about a month. This must be kept in a fridge, well labelled with only small quantities to be taken into the field at one time. This will ensure the longevity of the peroxide. Further, over time, the pH of the peroxide that has already been buffered may change. It is important to check the pH of the peroxide in the morning before departing to the field. Having a small quantity of NaOH in the field kit is recommended so the peroxide can be buffered if required.
- ☐ **Calibrate battery powered field pH meter** according to manufacturer's instructions.
- ☐ **Prepare the test tubes in the test tube rack as for pH_F test**. Make sure the rack is marked with the depths so there is not confusion about the top and bottom of the profile. Use of separate racks for the pH_F and pH_{FOX} tests is recommended as contamination may occur when the pH_{FOX} reactions are violent. It is important to use **heat-resistant test tubes** for the pH_{FOX} test as the reaction can generate considerable heat (up to 90°C). It is recommended that a tall, wide tube be used for this test as considerable bubbling may occur, particularly on highly sulfidic or organic samples.
- ☐ **Conduct pH_{FOX} tests at intervals on the soil profile of 0.25 m or at least one per horizon** whichever is lesser.
- ☐ **From the teaspoon of soil previously collected for the pH_F test, place approximately ½ teaspoon of the soil into the pH_{FOX} test tube** for the corresponding depth test. It is important that these two sub-samples come from the same depth and that they are similar in characteristics. For example, DO NOT take ½ teaspoon of soil from the 0–0.25m depth that is grey mud, while selecting ½ teaspoon from the same depth that is a yellow mottled sample. These will obviously give different results independent of the type of test conducted.
- ☐ **Add a few millilitres of 30% H_2O_2** (adjusted to pH 4.5–5.5) **to the soil** (sufficient to cover the soil with peroxide) **and stir the mixture**. Do NOT add the peroxide to the test tube in which the pH_F test was conducted, that is, the pH_{FOX} test tube should not have any deionised water in it. Beakers can be used, however glass is usually easily broken when conducting field work, and when multiple tests are being conducted it is difficult to handle large beaker

sizes efficiently. Do NOT add more than a few millilitres at a time. This will prevent overflow and wastage of peroxide. A day's supply of peroxide should be allowed to reach room temperature prior to use (cold peroxide from the fridge may be too slow to react).

- ☐ **Rate the reaction of soil and peroxide using a XXXX scale** (see below and Table H1.1).
- ☐ **Ideally, allow approximately 15 minutes for any reactions to occur**. If substantial sulfides occur, the reaction will be vigorous and may occur almost instantly. In this case, it may not be necessary to stir the mixture. Careful watch will be needed in the early stages to ensure that there is no cross contamination of samples in the test tube rack. If the reaction is violent and the soil:peroxide mix is escaping from the test tube, a small amount of deionised water (or demineralised water; not tap water) can be added (using a wash bottle) to cool and calm the reaction. Usually this controls overflow. Do NOT add too much deionised water as this may dilute the mixture and affect the pH value. It is important to only use a small amount of soil otherwise violent reactions will overflow and the sample will be lost.
- ☐ **Steps 6 to 8 may be repeated** until the soil:peroxide mixture reaction has slowed. This will ensure that most of the sulfides have reacted. In the lab this procedure would be repeated until no further reaction occurs, however in the field, best judgement is recommended. Usually one or two extra additions of a few millilitres of peroxide are sufficient.
- ☐ If there is no initial reaction, individual test tubes containing the soil:peroxide mixture can be placed into a container of hot water (especially in cooler weather) or in direct sunlight. This will encourage the initial reaction to occur. When the sample starts to 'bubble', remove the test tube immediately from the hot water and replace into test tube rack.
- ☐ **Wait for the soil:peroxide mixture to cool** (may take up to 10 minutes). The reactions often exceed 90°C. Placing an electrode into these high temperature situations may result in physical damage and inaccurate readings. Check the temperature range of the pH meter and probe to see what temperature is suitable. Note that a more exact pH is achieved if a temperature probe is also used, however this may be impractical in some field situations.
- ☐ U**se an electronic pH meter (preferred method) to measure the pH$_{FOX}$**. Place a spear point electrode into the test tube, ensuring that the spear point is totally submerged in the soil:peroxide mixture. Never stir the mixture with the electrode. This will damage the semi-permeable glass membrane.
- ☐ **Wait for the reading to stabilise and record the pH$_{FOX}$ measurement**.
- ☐ **All measurements should be recorded on a data sheet**.

a) Rating soil reactions of the pH$_{FOX}$ test using the XXXX scale

The rate of the reaction generally indicates the level of sulfides present, but depends also on texture and other soil constituents. A soil containing very little sulfides may only rate an 'X' however a soil containing high levels of sulfides (remember the exact level of sulfides cannot be determined using the pH$_{FOX}$ test) is more likely to rate a 'XXXX' although there are exceptions. This rating scale alone should not be used to identify ASS. It is not a very reliable feature in isolation as there are other factors including manganese and organic acids which may trigger reactions. Reactions with organic matter tend to be more 'frothing' and don't tend to generate as much heat as sulfidic reactions. Manganese reactions will be quite extreme, but don't tend to lower the pH$_{FOX}$. Table H1.1 indicates the reaction scale for pH$_{FOX}$ tests.

Table H1.1. Soil reaction rating scale for the pH$_{FOX}$ test.

Reaction scale	Rate of reaction
X	Slight reaction
XX	Moderate reaction
XXX	High reaction
XXXX	Very vigorous reaction, gas evolution and heat generation commonly >80°C

1.4 INTERPRETATION OF FIELD pH TESTS

For information on interpreting field pH test results, please consult the following documents and publications:

Ahern CR, Ahern MR, Powell B (1998). ‘Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998’. pp. 28–30 (Queensland Department of Natural Resources: Brisbane)

Ahern CR, Stone Y, Blunden B (1998). Acid Sulfate Soils Assessment Guidelines. In ‘Acid Sulfate Soils Manual 1998’. pp. 56–58 (Acid Sulfate Soil Management Advisory Committee: Wollongbar, NSW)

Hey KM, Ahern CR, Watling KM (2000) Using Chemical Field Tests to Identify Acid Sulfate Soils Likelihood. In ‘Acid Sulfate Soils: Environmental Issues, Assessment and Management, Technical Papers.’ (Eds CR Ahern, KM Hey, KM Watling, VJ Eldershaw) pp. 16/9–16/12 (Queensland Department of Natural Resources: Brisbane)

Hey KM (Ed) (2002). ‘Field Testing, Sampling and Safety for Acid Sulfate Soils’. pp. 12–16 (Queensland Department of Natural Resources and Mines: Brisbane)

Appendix D Bore Logs (Draft) Coffey

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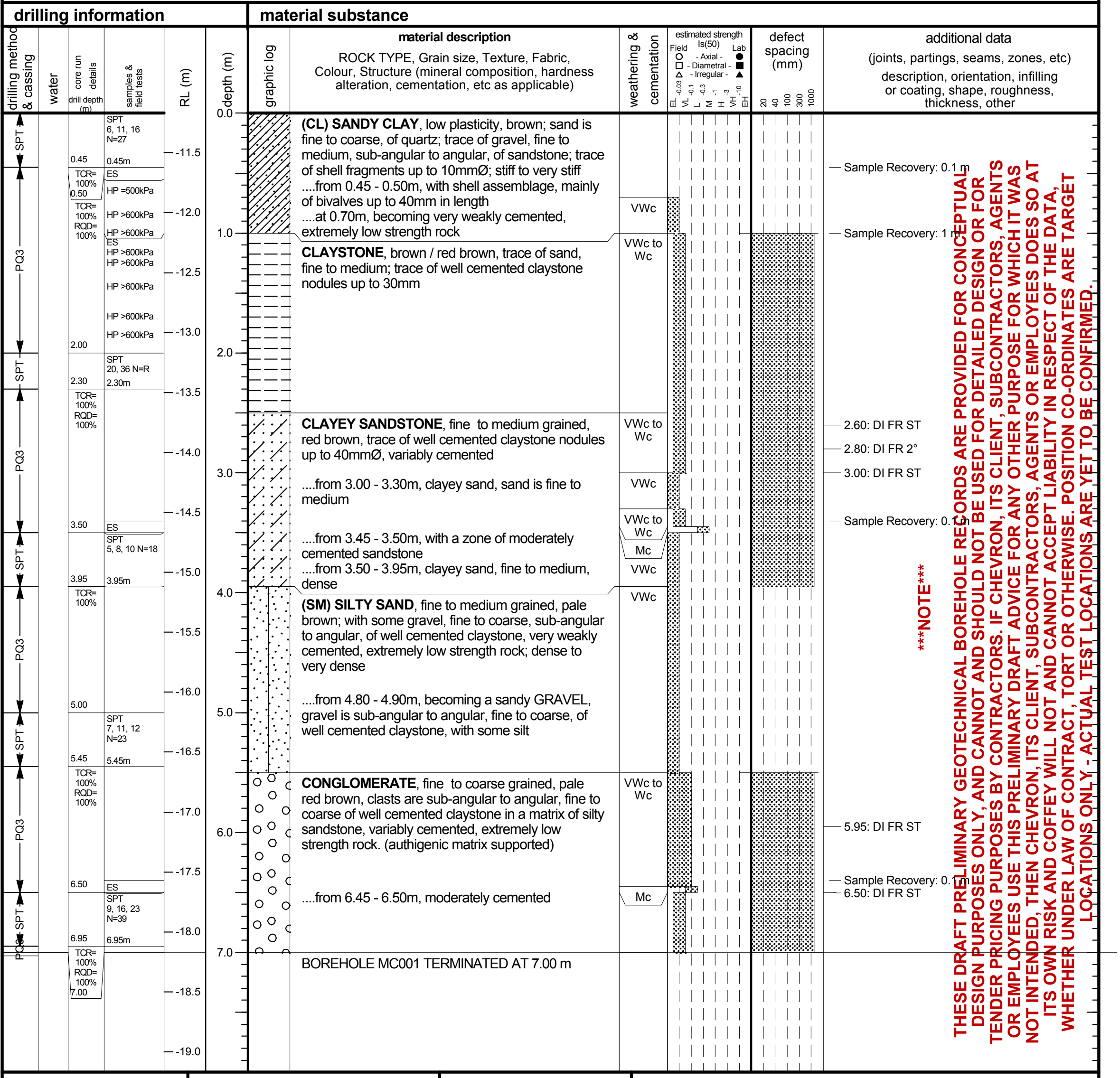
coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC001***
Sheet No.	1 of 1
Project No.	***GEOTHERD08668AA***
Client	***Chevron Australia Pty Ltd***
Principal	
Project	***Wheatstone Development Project***
Location	***Ashburton North***
Date started	***3/7/09***
Date completed	***3/7/09***
Logged by	***MG***
Checked by	

Position : E: 296373.46, N: 7608001.68 (50 MGA94)
Surface Elevation : -11.17m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm



drilling information

drilling method & casing	water	core run details drill depth (m)	samples & field tests
SPT (0.00–0.45)		0.45	SPT 6, 11, 16 N=27 0.45m
PQ3 (0.45–2.00)		TCR= 100% 0.50 TCR= 100% RQD= 100% 2.00	ES HP =500kPa HP >600kPa HP >600kPa ES HP >600kPa HP >600kPa HP >600kPa HP >600kPa HP >600kPa
SPT (2.00–2.30)		2.30	SPT 20, 36 N=R 2.30m
PQ3 (2.30–3.50)		TCR= 100% RQD= 100% 3.50	ES
SPT (3.50–3.95)		3.95	SPT 5, 8, 10 N=18 3.95m
PQ3 (3.95–5.00)		TCR= 100% 5.00	
SPT (5.00–5.45)		5.45	SPT 7, 11, 12 N=23 5.45m
PQ3 (5.45–6.50)		TCR= 100% RQD= 100% 6.50	ES
SPT (6.50–6.95)		6.95	SPT 9, 16, 23 N=39 6.95m
PQ3 (6.95–7.00)		TCR= 100% RQD= 100% 7.00	

material substance

depth (m)	material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation
0.0–1.0	**(CL) SANDY CLAY**, low plasticity, brown; sand is fine to coarse, of quartz; trace of gravel, fine to medium, sub-angular to angular, of sandstone; trace of shell fragments up to 10mmØ; stiff to very stiff ....from 0.45 - 0.50m, with shell assemblage, mainly of bivalves up to 40mm in length ....at 0.70m, becoming very weakly cemented, extremely low strength rock	VWc
1.0–2.5	**CLAYSTONE**, brown / red brown, trace of sand, fine to medium; trace of well cemented claystone nodules up to 30mm	VWc to Wc
2.5–4.0	**CLAYEY SANDSTONE**, fine to medium grained, red brown, trace of well cemented claystone nodules up to 40mmØ, variably cemented	VWc to Wc
	....from 3.00 - 3.30m, clayey sand, sand is fine to medium	VWc
	....from 3.45 - 3.50m, with a zone of moderately cemented sandstone	VWc to Wc Mc
	....from 3.50 - 3.95m, clayey sand, fine to medium, dense	VWc
4.0–5.5	**(SM) SILTY SAND**, fine to medium grained, pale brown; with some gravel, fine to coarse, sub-angular to angular, of well cemented claystone, very weakly cemented, extremely low strength rock; dense to very dense ....from 4.80 - 4.90m, becoming a sandy GRAVEL, gravel is sub-angular to angular, fine to coarse, of well cemented claystone, with some silt	VWc
5.5–7.0	**CONGLOMERATE**, fine to coarse grained, pale red brown, clasts are sub-angular to angular, fine to coarse of well cemented claystone in a matrix of silty sandstone, variably cemented, extremely low strength rock. (authigenic matrix supported)	VWc to Wc
	....from 6.45 - 6.50m, moderately cemented	Mc
7.0	BOREHOLE MC001 TERMINATED AT 7.00 m	

additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other

- Sample Recovery: 0.1 m
- Sample Recovery: 1 m
- 2.60: DI FR ST
- 2.80: DI FR 2°
- 3.00: DI FR ST
- Sample Recovery: 0.1 m
- 5.95: DI FR ST
- Sample Recovery: 0.1 m
- 6.50: DI FR ST

NOTE

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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:26

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

☰	core recovered - graphic symbols indicate material
☒	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
►	water inflow
◄	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation		weathering		strength	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		planarity		roughness		coating	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture,JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

Engineering Log - Cored Borehole

Hole No. **MC002**
Sheet No. 1 of 2
Project No. **GEOTHERD08668AA**

Client : **Chevron Australia Pty Ltd**
Principal :
Project : **Wheatstone Development Project**
Location : **Ashburton North**

Date started : **3/7/09**
Date completed : **3/7/09**
Logged by : **MG**
Checked by :

Position : E: 296146.44, N: 7607006.88 (50 MGA94)
Rig type : UDR100
Surface Elevation : -10.02m (AHD)
Mounting : Jack up Barge
Angle from horizontal : 90°
Hole Diameter : 123 mm

GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:27

drilling method & casing	water	core run details drill depth (m)	samples & field tests	RL (m)	depth (m)	material description: ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
SPT			SPT 2, 3, 4 N=7		0.0	**(CL) SANDY CLAY**, low plasticity, brown; sand is fine to coarse, mainly of quartz; trace of gravel, fine to coarse, sub-rounded to angular, trace of shell fragments up to 30mmØ; stiff to very stiff		
		0.45	0.45m					
PQ3		TCR= 100% 0.50 TCR= 73%		-10.5		CORE LOSS 0.40m (0.45-0.85)		
			ES	-11.0	1.0	**(SM) SILTY SAND**, fine to coarse grained, brown; with some gravel, fine to coarse, sub-rounded to angular, of chert and quartzite; dense		Sample Recovery: 0.1m
				-11.5		....from 1.38 - 1.40m, gravel band		
						(SC) CLAYEY SAND, fine to medium grained, brown; with some gravel; gravel is fine to coarse, sub-rounded to angular, with some chert and quartzite; dense to very dense		
		2.00	ES	-12.0	2.0			Sample Recovery: 0.1m
SPT			SPT 5, 7, 13 N=20			....from 2.20m, becoming a sandy clay, low plasticity; with trace gravel, sub-angular to angular, fine to medium		
		2.45	2.45m					
PQ3		TCR= 100%	HP =300kPa	-12.5		**(CI) SANDY CLAY**, medium plasticity, red brown; sand is fine to medium; trace of well cemented claystone nodules up to 15mmØ; very stiff		
			HP =460kPa					
			ES	-13.0	3.0			Sample Recovery: 0.1m
		3.50		-13.5				
SPT			SPT 10, 19, 29 N=48			....from 3.50m, becoming a clay, low plasticity; with some sand		
		3.95	3.95m					
PQ3		TCR= 100% RQD= 100%	HP =550kPa HP =490kPa HP =510kPa	-14.0	4.0	**CLAYSTONE**, red brown, low plasticity, with some sand, fine to medium; trace of well cemented claystone nodules up to 35mmØ; variably cemented extremely low to very low strength rock	VWc	3.95-4.00: Recovered as drill induced sandy gravel, sub-angular to angular, fine to coarse, of claystone
			HP >600kPa	-14.5				
			HP >600kPa			**(SC) CLAYEY SAND**, fine to medium grained, red brown; trace of well cemented claystone nodules up to 30mmØ; variably cemented soil to clayey sandstone extremely low strength rock	VWc	
		5.00		-15.0	5.0			
SPT			SPT 11, 14, 17 N=31			....from 5.30 - 5.40m, sandy CLAY / SILT, pale brown, sand is fine to medium		
		5.45	5.45m					
PQ3		TCR= 100% RQD= 100%		-15.5				
				-16.0	6.0			
		6.50	ES	-16.5				Sample Recovery: 0.1m
SPT			SPT 8, 12, 14 N=26			**(SC) CLAYEY SAND**, fine to medium grained, red brown; trace of gravel, sub-angular to angular, fine to coarse of well cemented claystone nodules up to 15mmØ; dense to very dense		
		6.95	6.95m					
PQ3		TCR= 100% 7.30 TCR= 100%		-17.0	7.0			
				-17.5		....from 7.30 - 7.60m, SAND, fine to medium; trace of clay and silt		
		8.00						

estimated strength Is(50): Field ○ - Axial - ● Lab; □ - Diametral - ■; △ - Irregular - ▲; EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20 40 100 300 1000

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm
HQ	wireline core (63.5mm
PQ	wireline core (85.0mm
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

core recovered - graphic symbols indicate material
no core recovered

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC002***
Sheet No.	2 of 2
Project No.	***GEOTHERD08668AA***
Client :	***Chevron Australia Pty Ltd***
Date started :	***3/7/09***
Principal :	
Date completed :	***3/7/09***
Project :	***Wheatstone Development Project***
Logged by :	***MG***
Location :	***Ashburton North***
Checked by :	

Position : E: 296146.44, N: 7607006.88 (50 MGA94) Surface Elevation : -10.02m (AHD) Angle from horizontal : 90°
Rig type : UDR100 Mounting : Jack up Barge Hole Diameter : 123 mm

drilling information						material substance					
drilling method & casing	water	core run details drill depth (m)	samples & field tests	RL (m)	depth (m)	graphic log	**material description** ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	estimated strength Is(50) Field ○ □ △ - Axial - ● - Diametral - ■ - Irregular - ▲ Lab EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH	defect spacing (mm) 20 40 100 300 1000	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
					8.0		....from 7.90 - 8.00m, recovered as sandy CLAY, low plasticity; with some gravel, sub-angular to angular fine to coarse of cemented claystone nodules				
				-18.5			BOREHOLE MC002 TERMINATED AT 8.00 m				
				-19.0	9.0						
				-19.5							
				-20.0	10.0						
				-20.5							
				-21.0	11.0						
				-21.5							
				-22.0	12.0						
				-22.5							
				-23.0	13.0						
				-23.5							
				-24.0	14.0						
				-24.5							
				-25.0	15.0						
				-25.5							

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm
HQ	wireline core (63.5mm
PQ	wireline core (85.0mm
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

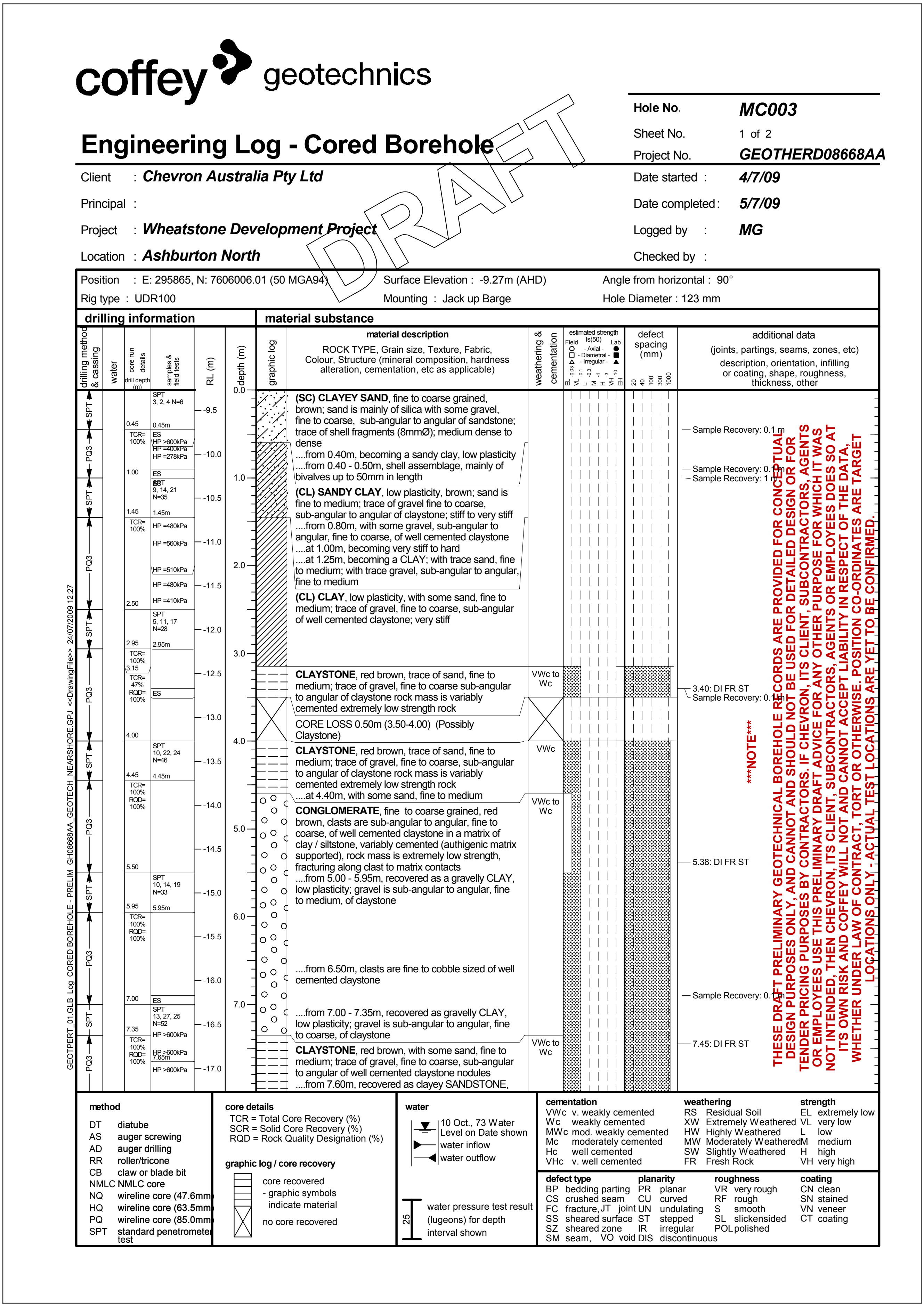
▤ core recovered - graphic symbols indicate material
☒ no core recovered

water

▼ 10 Oct., 73 Water Level on Date shown
▶ water inflow
◀ water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM seam, VO void		DIS	discontinuous				



coffey geotechnics

Engineering Log - Cored Borehole

DRAFT

Hole No.	***MC003***
Sheet No.	1 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***4/7/09***
Date completed :	***5/7/09***
Logged by :	***MG***
Checked by :	

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Position : E: 295865, N: 7606006.01 (50 MGA94)
Surface Elevation : -9.27m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information

drilling method & casing	water	core run details / drill depth (m)		samples & field tests
SPT		0.45		SPT 3, 2, 4 N=6 0.45m
PQ3		1.00	TCR= 100%	ES HP >600kPa HP =400kPa HP =278kPa ES
SPT		1.45		ES SPT 9, 14, 21 N=35 1.45m
PQ3		2.50	TCR= 100%	HP =480kPa HP =560kPa HP =510kPa HP =480kPa HP =410kPa
SPT		2.95		SPT 5, 11, 17 N=28 2.95m
PQ3		3.15 4.00	TCR= 100% TCR= 47% RQD= 100%	ES
SPT		4.45		SPT 10, 22, 24 N=46 4.45m
PQ3		5.50	TCR= 100% RQD= 100%	
SPT		5.95		SPT 10, 14, 19 N=33 5.95m
PQ3		7.00	TCR= 100% RQD= 100%	ES
SPT		7.35		SPT 13, 27, 25 N=52
PQ3			TCR= 100% RQD= 100%	HP >600kPa HP >600kPa 7.65m HP >600kPa

RL (m): -9.5, -10.0, -10.5, -11.0, -11.5, -12.0, -12.5, -13.0, -13.5, -14.0, -14.5, -15.0, -15.5, -16.0, -16.5, -17.0

depth (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0

material substance

material description
ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)

(SC) CLAYEY SAND, fine to coarse grained, brown; sand is mainly of silica with some gravel, fine to coarse, sub-angular to angular of sandstone; trace of shell fragments (8mmØ); medium dense to dense
....from 0.40m, becoming a sandy clay, low plasticity
....from 0.40 - 0.50m, shell assemblage, mainly of bivalves up to 50mm in length

(CL) SANDY CLAY, low plasticity, brown; sand is fine to medium; trace of gravel fine to coarse, sub-angular to angular of claystone; stiff to very stiff
....from 0.80m, with some gravel, sub-angular to angular, fine to coarse, of well cemented claystone
....at 1.00m, becoming very stiff to hard
....at 1.25m, becoming a CLAY; with trace sand, fine to medium; with trace gravel, sub-angular to angular, fine to medium

(CL) CLAY, low plasticity, with some sand, fine to medium; trace of gravel, fine to coarse, sub-angular of well cemented claystone; very stiff

CLAYSTONE, red brown, trace of sand, fine to medium; trace of gravel, fine to coarse sub-angular to angular of claystone rock mass is variably cemented extremely low strength rock — VWc to Wc

CORE LOSS 0.50m (3.50-4.00) (Possibly Claystone)

CLAYSTONE, red brown, trace of sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular of claystone rock mass is variably cemented extremely low strength rock — VWc
....at 4.40m, with some sand, fine to medium

CONGLOMERATE, fine to coarse grained, red brown, clasts are sub-angular to angular, fine to coarse, of well cemented claystone in a matrix of clay / siltstone, variably cemented (authigenic matrix supported), rock mass is extremely low strength, fracturing along clast to matrix contacts — VWc to Wc
....from 5.00 - 5.95m, recovered as a gravelly CLAY, low plasticity; gravel is sub-angular to angular, fine to medium, of claystone
....from 6.50m, clasts are fine to cobble sized of well cemented claystone
....from 7.00 - 7.35m, recovered as gravelly CLAY, low plasticity; gravel is sub-angular to angular, fine to coarse, of claystone

CLAYSTONE, red brown, with some sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules — VWc to Wc
....from 7.60m, recovered as clayey SANDSTONE,

weathering & cementation

estimated strength Is(50): Field ○ - Axial - ● Lab; □ - Diametral - ■; △ - Irregular - ▲
EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20 40 100 300 1000

additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other

- Sample Recovery: 0.1 m
- Sample Recovery: 0.1 m
- Sample Recovery: 1 m
- 3.40: DI FR ST
- Sample Recovery: 0.1 m
- 5.38: DI FR ST
- Sample Recovery: 0.1 m
- 7.45: DI FR ST

NOTE

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method

DT	diatube
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SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery
▤ core recovered - graphic symbols indicate material
☒ no core recovered

water
▼ 10 Oct., 73 Water Level on Date shown
► water inflow
◄ water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
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VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	*MC003*
Sheet No.	2 of 2
Project No.	*GEOTHERD08668AA*
Date started :	*4/7/09*
Date completed :	*5/7/09*
Logged by :	*MG*
Checked by :	

Client : *Chevron Australia Pty Ltd*
Principal :
Project : *Wheatstone Development Project*
Location : *Ashburton North*

Position : E: 295865, N: 7606006.01 (50 MGA94)
Surface Elevation : -9.27m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information						material substance					
drilling method & casing	water	core run details drill depth (m)	samples & field tests	RL (m)	depth (m)	graphic log	**material description** ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	estimated strength Is(50) Field ○ - Axial - ● Lab □ - Diametral - ■ △ - Irregular - ▲ EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH	defect spacing (mm) 20 40 100 300 1000	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
PQ3		TCR= 100% RQD= 100% 8.50			8.0		fine to medium grained				8.00: DI FR ST 8.12: DI FR ST 8.19: DI FR ST 8.25: DI FR ST 8.45: DI FR ST
				-17.5			**CLAYEY SANDSTONE**, fine to medium grained, red brown, sand is fine to medium; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone ....from 8.30m, trace of grey coloration along weathered partings, possibly palygorskite				
		TCR= 100% RQD= 100% 9.00		-18.0							
					9.0		BOREHOLE MC003 TERMINATED AT 9.00 m				
				-18.5							
				-19.0							
					10.0						
				-19.5							
				-20.0							
					11.0						
				-20.5							
				-21.0							
					12.0						
				-21.5							
				-22.0							
					13.0						
				-22.5							
				-23.0							
					14.0						
				-23.5							
				-24.0							
					15.0						
				-24.5							
				-25.0							

NOTE

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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:27

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

☰	core recovered - graphic symbols indicate material
☒	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
▶—	water inflow
—◀	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC004***
Sheet No.	1 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***5/7/09***
Date completed :	***5/7/09***
Logged by :	***MG***
Checked by :	

Client : ***Chevron Australia Pty Ltd***

Principal :

Project : ***Wheatstone Development Project***

Location : ***Ashburton North***

Position : E: 295609.4, N: 7604977.86 (50 MGA94)
Surface Elevation : -7.95m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:27

drilling information

drilling method & casing	water	core run details drill depth (m)		samples & field tests
SPT		0.45		SPT 5, 5, 7 N=12 0.45m
PQ3		1.00	TCR= 100%	HP =600kPa HP =500kPa ES
SPT		1.45		SPT 6, 8, 9 N=17 1.45m
PQ3		2.50	TCR= 100% RQD= 100%	HP =550kPa HP >600kPa HP >600kPa HP =420kPa HP >600kPa
SPT		2.95		SPT 11, 13, 18 N=31 2.95m
PQ3		4.00	TCR= 100%	HP =300kPa HP =270kPa HP =170kPa HP =220kPa ES
SPT		4.45		SPT 6, 10, 10 N=20 4.45m
PQ3		5.50	TCR= 100%	
SPT		5.95		SPT 10, 19, 23 N=42 5.95m
PQ3		7.00	TCR= 100% RQD= 100%	HP =550kPa HP =600kPa HP =490kPa
SPT		7.45		SPT 8, 13, 18 N=31 7.45m
PQ3			TCR= 100%	

RL (m): -8.0, -8.5, -9.0, -9.5, -10.0, -10.5, -11.0, -11.5, -12.0, -12.5, -13.0, -13.5, -14.0, -14.5, -15.0, -15.5

depth (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0

material substance

material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
(GW) CLAYEY SANDY GRAVEL, fine to coarse grained, sub-angular to angular, brown; gravel is sandstone; sand is fine to coarse, mainly of silica; trace of shell fragments up to 10mmØ; dense		
(GW) SANDY GRAVEL, fine to coarse grained, sub-rounded to angular; brown, gravel is of chert and quartzite; sand is fine to coarse, mainly of silica; trace of fines; dense		Sample Recovery: 0.1m Sample Recovery: 1 m
(CL) SANDY CLAY, low plasticity, brown; sand is fine to coarse, mainly of silica; trace of gravel fine to coarse, sub-angular to angular of sandstone and chert; stiff to very stiff	VWc to Wc	
CLAYSTONE, red brown, with some sand, fine to medium; trace of gravel fine to coarse, sub-angular to angular of well cemented claystone nodules, rock mass is variably cemented, extremely low strength rock		2.00: DI FR ST
(CL) SANDY CLAY, low plasticity, pale red brown; sand is fine to medium; with some gravel, fine to coarse, sub-angular to angular of well cemented claystone; stiff to very stiff ....from 4.20 - 4.45m, recovered as silty gravelly SAND, fine to medium, pale red brown; gravel is sub-angular to angular, fine to coarse, of well cemented claystone		Sample Recovery: 0.1m
(SW) SAND, fine to coarse grained, pale red brown; sand is mainly of quartzite, trace of gravel, sub-angular to angular, fine to cobble sized of well cemented claystone; some fines content; dense to very dense ....at 5.50m, becoming very dense, cemented ....from 5.70 - 5.95m, recovered as clayey GRAVEL, sub-angular to angular, fine to coarse, pale brown; with some sand, fine to medium	VWc	
SANDY CLAYSTONE, red brown, low plasticity, sand is fine to medium; with some gravel fine to coarse, sub-angular to angular of well cemented claystone, variably cemented soil to claystone extremely low strength rock ....from 6.60 - 6.80m, recovered as a clayey SAND, fine to medium grained ....from 7.30 - 7.45m, recovered as a clayey SAND, fine to medium grained	VWc to Wc	
(SC) CLAYEY SAND, fine to medium grained, red brown; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone; dense to very		

estimated strength Is(50): Field ○ - Axial - ● Lab; □ - Diametral - ■; △ - Irregular - ▲; EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20, 40, 100, 300, 1000

NOTE
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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details
TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery
core recovered - graphic symbols indicate material
no core recovered

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow
water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

Hole No. **MC004**
Sheet No. 2 of 2
Project No. **GEOTHERD08668AA**

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Date started : ***5/7/09***
Date completed : ***5/7/09***
Logged by : ***MG***
Checked by :

Position : E: 295609.4, N: 7604977.86 (50 MGA94)
Surface Elevation : -7.95m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information					material substance					
drilling method & casing	water	core run details drill depth (m)	samples & field tests	RL (m)	depth (m)	graphic log	material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	estimated strength Is(50) Field ○ - Axial - ● Lab □ - Diametral - ■ △ - Irregular - ▲ EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH	defect spacing (mm) 20 40 100 300 1000	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
PQ3		TCR= 100%	HP =520kPa ES	-16.0	8.0		dense	VWc			Sample Recovery: 0.1 m
			HP =390kPa				**(CL) SANDY CLAY**, low plasticity, red brown; sand is fine to medium; trace of gravel fine to coarse, sub-angular to angular of well cemented claystone; very stiff to hard				
		8.50	HP >600kPa								
SPT		8.77	SPT 20, 12/120mm N=R 8.77m	-16.5				VWc to Wc			
PQ3		TCR= 100% RQD= 100%					....at 8.5m, becoming weakly cemented extremely low strength rock	VWc to Wc			
				-17.0	9.0		**CONGLOMERATE**, fine to coarse grained, red brown, clasts are sub-angular to angular of well cemented claystone in a matrix of claystone, trace of calcite veins up to 2mm in width (orthogenic matrix supported)				
			HP >600kPa HP >600kPa HP =580kPa	-17.5			....at 9.40m, becoming a claystone with some gravel	VWc to Wc			
		10.00		-18.0	10.0		**CLAYSTONE**, red brown, with trace sand, fine to medium; trace of gravel fine to coarse, sub-angular to angular of well cemented claystone, trace grey colouration possibly palygorskite				
				-18.5			BOREHOLE MC004 TERMINATED AT 10.00 m				
				-19.0	11.0						
				-19.5							
				-20.0	12.0						
				-20.5							
				-21.0	13.0						
				-21.5							
				-22.0	14.0						
				-22.5							
				-23.0	15.0						
				-23.5							

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

☰	core recovered - graphic symbols indicate material
⊠	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
▶	water inflow
◀	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

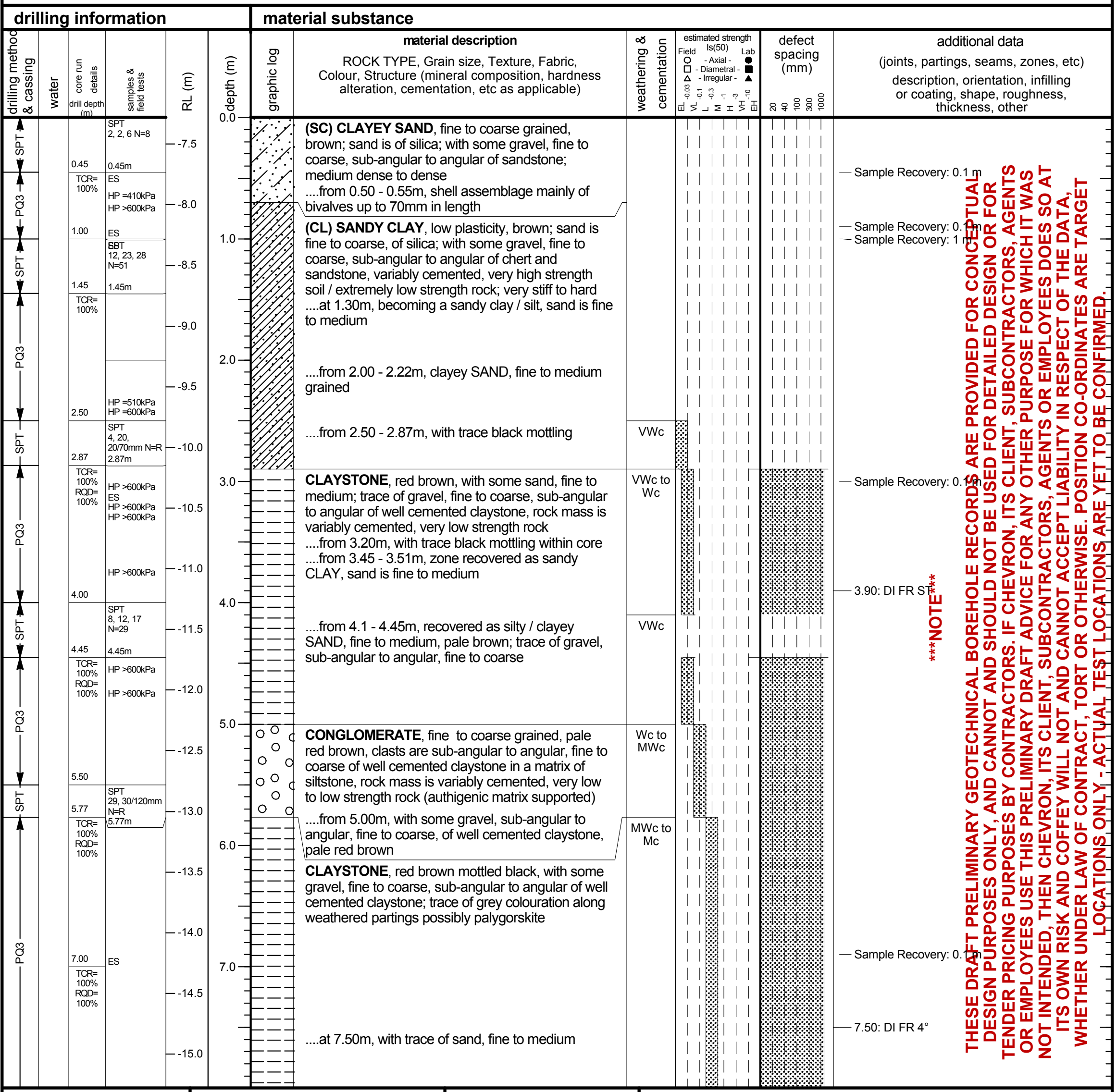
Engineering Log - Cored Borehole

Hole No. **MC005**
Sheet No. 1 of 2
Project No. **GEOTHERD08668AA**

Client : **Chevron Australia Pty Ltd**
Principal :
Project : **Wheatstone Development Project**
Location : **Ashburton North**

Date started : **6/7/09**
Date completed : **6/7/09**
Logged by : **MG**
Checked by :

Position : E: 295330.22, N: 7604003.11 (50 MGA94)
Surface Elevation : -7.28m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm



drilling information

drilling method & casing	water	core run details drill depth (m)	core run details	samples & field tests
SPT		0.45		SPT 2, 2, 6 N=8 0.45m
PQ3		1.00	TCR= 100%	ES HP =410kPa HP >600kPa ES
SPT		1.45		SPT 12, 23, 28 N=51 1.45m
PQ3		2.50	TCR= 100%	HP =510kPa HP =600kPa
SPT		2.87		SPT 4, 20, 20/70mm N=R 2.87m
PQ3		4.00	TCR= 100% RQD= 100%	HP >600kPa ES HP >600kPa HP >600kPa HP >600kPa
SPT		4.45		SPT 8, 12, 17 N=29 4.45m
PQ3		5.50	TCR= 100% RQD= 100%	HP >600kPa HP >600kPa
SPT		5.77		SPT 29, 30/120mm N=R 5.77m
PQ3		7.00	TCR= 100% RQD= 100%	ES
PQ3			TCR= 100% RQD= 100%	

RL (m): -7.5, -8.0, -8.5, -9.0, -9.5, -10.0, -10.5, -11.0, -11.5, -12.0, -12.5, -13.0, -13.5, -14.0, -14.5, -15.0

material substance

depth (m)	material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
0.0	**(SC) CLAYEY SAND**, fine to coarse grained, brown; sand is of silica; with some gravel, fine to coarse, sub-angular to angular of sandstone; medium dense to dense ....from 0.50 - 0.55m, shell assemblage mainly of bivalves up to 70mm in length		Sample Recovery: 0.1 m
	(CL) SANDY CLAY, low plasticity, brown; sand is fine to coarse, of silica; with some gravel, fine to coarse, sub-angular to angular of chert and sandstone, variably cemented, very high strength soil / extremely low strength rock; very stiff to hard ....at 1.30m, becoming a sandy clay / silt, sand is fine to medium		Sample Recovery: 0.1 m Sample Recovery: 1 m
2.0	....from 2.00 - 2.22m, clayey SAND, fine to medium grained		
	....from 2.50 - 2.87m, with trace black mottling	VWc	
3.0	**CLAYSTONE**, red brown, with some sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone, rock mass is variably cemented, very low strength rock ....from 3.20m, with trace black mottling within core ....from 3.45 - 3.51m, zone recovered as sandy CLAY, sand is fine to medium	VWc to Wc	Sample Recovery: 0.1 m 3.90: DI FR ST
4.0	....from 4.1 - 4.45m, recovered as silty / clayey SAND, fine to medium, pale brown; trace of gravel, sub-angular to angular, fine to coarse	VWc	
5.0	**CONGLOMERATE**, fine to coarse grained, pale red brown, clasts are sub-angular to angular, fine to coarse of well cemented claystone in a matrix of siltstone, rock mass is variably cemented, very low to low strength rock (authigenic matrix supported) ....from 5.00m, with some gravel, sub-angular to angular, fine to coarse, of well cemented claystone, pale red brown	Wc to MWc	
6.0	**CLAYSTONE**, red brown mottled black, with some gravel, fine to coarse, sub-angular to angular of well cemented claystone; trace of grey colouration along weathered partings possibly palygorskite	MWc to Mc	Sample Recovery: 0.1 m
7.0	....at 7.50m, with trace of sand, fine to medium		7.50: DI FR 4°

estimated strength Is(50): Field ○ □ △ - Axial - - Diametral - - Irregular - Lab ● ■ ▲; EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20, 40, 100, 300, 1000

NOTE

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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:28

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

☐ core recovered - graphic symbols indicate material
☒ no core recovered

water

▼ 10 Oct., 73 Water Level on Date shown
► water inflow
◄ water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
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Hc	well cemented
VHc	v. well cemented

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XW	Extremely Weathered
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VL	very low
L	low
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VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

Hole No. **MC005**
Sheet No. 2 of 2
Project No. **GEOTHERD08668AA**

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Date started : ***6/7/09***
Date completed : ***6/7/09***
Logged by : ***MG***
Checked by :

Position : E: 295330.22, N: 7604003.11 (50 MGA94)
Surface Elevation : -7.28m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information						material substance					
drilling method & casing	water	core run details drill depth (m)	samples & field tests	RL (m)	depth (m)	graphic log	material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	estimated strength Is(50) Field ○ - Axial - ● Lab □ - Diametral - ■ △ - Irregular - ▲ EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH	defect spacing (mm) 20 40 100 300 1000	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
PQ3		TCR= 100% RQD= 100% 8.50		-15.5	8.0		**CLAYSTONE**, red brown mottled black, with some gravel, fine to coarse, sub-angular to angular of well cemented claystone; trace of grey colouration along weathered partings possibly palygorskite *(continued)*	MWc to Mc			8.00: DI FR ST 8.40: DI FR ST 8.50: DI FR ST
		TCR= 100% RQD= 100% 10.00		-16.0 -16.5 -17.0	9.0		....from 9.00m, with some grey coloration along weathered partings, possibly palygorskite				
		TCR= 100% RQD= 100% 10.50		-17.5	10.0		....from 10.00 - 10.50m, increase in black mottling within core				10.00: DI FR ST
				-18.0 -18.5 -19.0 -19.5 -20.0 -20.5 -21.0 -21.5 -22.0 -22.5 -23.0	11.0 12.0 13.0 14.0 15.0		BOREHOLE MC005 TERMINATED AT 10.50 m				

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method

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AD	auger drilling
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RQD = Rock Quality Designation (%)

graphic log / core recovery

core recovered - graphic symbols indicate material

no core recovered

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

25 water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	*MC006*
Sheet No.	1 of 2
Project No.	*GEOTHERD08668AA*
Client :	*Chevron Australia Pty Ltd*
Principal :	
Project :	*Wheatstone Development Project*
Location :	*Ashburton North*
Date started :	*8/7/09*
Date completed :	*9/7/09*
Logged by :	*MG*
Checked by :	

Position : E: 295109.2, N: 7602919.79 (50 MGA94)
Surface Elevation : -6.85m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information / material substance

drilling method & casing	core run details drill depth (m)	samples & field tests	RL (m)	depth (m)	material description: ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
SPT	0.45	SPT 2, 5, 11 N=16 0.45m	-7.0	0.0	**(CL) SANDY CLAY**, low plasticity, red brown / brown; sand is fine to coarse, mainly of silica; trace of gravel, sub-angular to angular, fine to coarse, of sandstone and claystone; trace of shell fragments <10mm; stiff		
PQ3	TCR= 100% 1.50	ES HP =490kPa HP >600kPa HP >600kPa ES HP =580kPa HP >600kPa	-7.5 -8.0	1.0	....at 0.50m, gravel is of claystone only, fine to coarse, sub-angular to angular **CLAY**, low plasticity, red brown; with some sand; trace of gravel, fine to coarse, sub-angular to angular, of well cemented claystone, variably cemented, becoming a extremely low strength claystone with depth, very stiff to hard	VWc VWc to Wc	Sample Recovery: 0.1 m Sample Recovery: 1 m
SPT	1.89	SPT 11, 21, 19/90mm N=R 1.89m	-8.5		....at 1.30 - 1.45m, becoming very weakly cemented to weakly cemented		
PQ3	TCR= 100% RQD= 100% 3.00		-9.0 -9.5	2.0	**CLAYSTONE**, red brown mottled black, trace of sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular, of well cemented claystone, variably cemented extremely low strength to very low strength rock	VWc to Wc	
SPT	3.26	SPT 15, 26/110mm N=R 3.26m	-10.0	3.0			Sample Recovery: 0.1 m
PQ3	TCR= 100% RQD= 100% 4.50	ES HP >600kPa HP >600kPa	-10.5 -11.0	4.0	....at 3.26m, with some sand, becoming very weakly cemented, extremely low strength rock ....at 4.00m, with some gravel, fine to coarse, sub-angular to angular, of well cemented claystone	VWc	3.45: DI FR ST 3.76: DI FR ST 4.00: DI FR ST 4.36: DI FR ST
SPT	4.95	SPT 13, 21, 24 N=45 4.95m	-11.5				
PQ3	TCR= 100% RQD= 100% 6.00		-12.0 -12.5	5.0	**CONGLOMERATE**, fine to coarse grained, red brown, clasts are fine to coarse, sub-angular to angular, of well cemented claystone clasts in a claystone matrix (authigenic matrix supported)	VWc to Wc	5.43: DI FR ST 5.76: DI FR 4° 6.00: DI FR ST
	TCR= 100% RQD= 100% 7.50		-13.0 -13.5 -14.0	6.0 7.0	**CLAYSTONE**, red brown, trace of sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular, of well cemented claystone	VWc to Wc	6.30: DI FR 4° 6.50: DI FR ST 7.00: DI FR 2° 7.10: DI FR ST
	TCR= 100% RQD= 100%		-14.5		....from 7.50m, with trace grey coloration along weathered partings, possibly palygorskite		7.40-7.50: Recovered as drilling induced clayey gravel, fine to coarse, sub-angular to angular, of claystone 7.50: DI FR ST

estimated strength Is(50): Field ○ □ △ Lab ● ■ ▲ - Axial - / - Diametral - / - Irregular -; EL VL L M H VH EH (0.03, 0.1, 0.3, 1, 3, 10)

defect spacing (mm): 20 40 100 300 1000

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

core recovered - graphic symbols indicate material
☒ no core recovered

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

25 water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

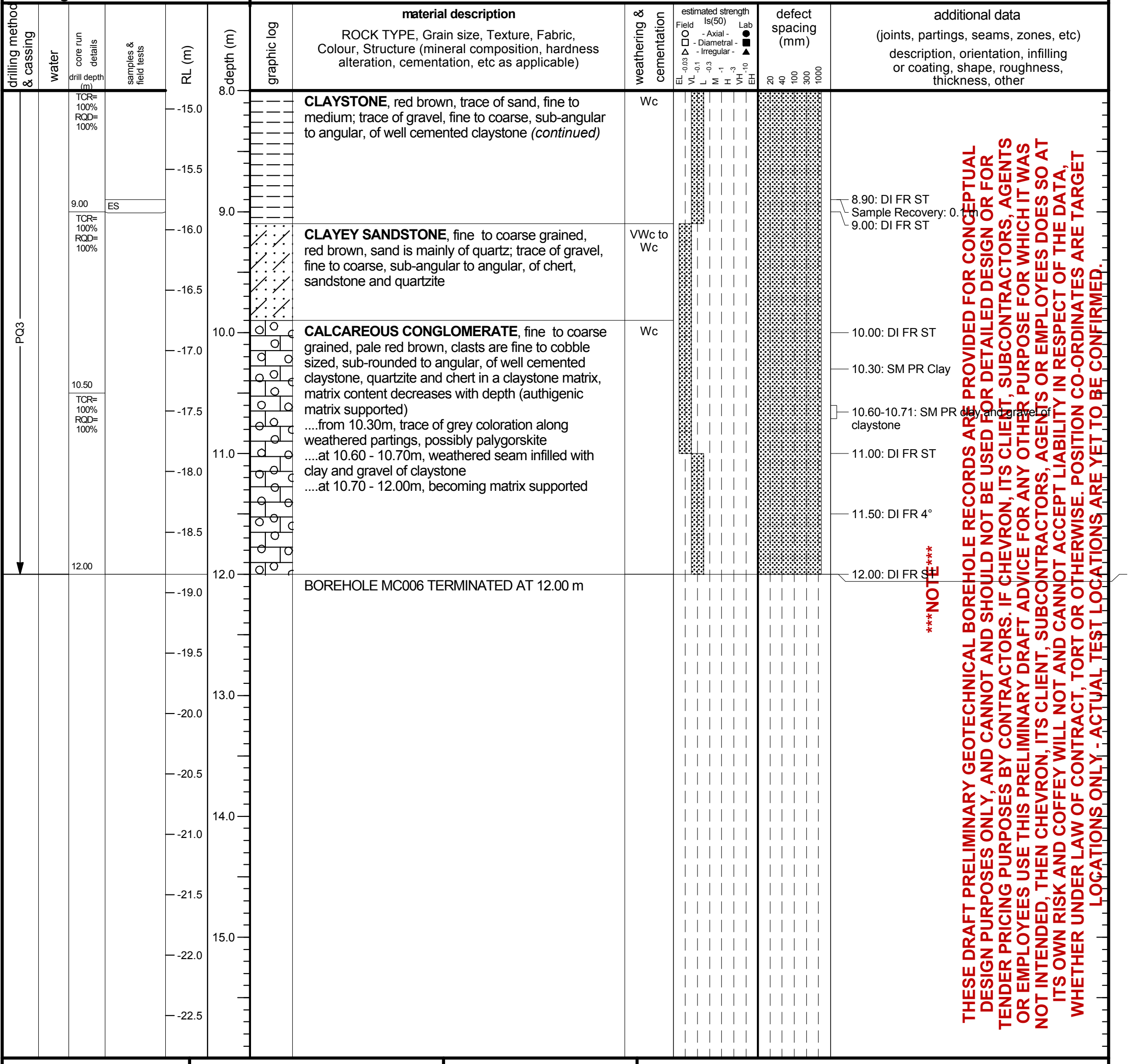
Hole No. **MC006**
Sheet No. 2 of 2
Project No. **GEOTHERD08668AA**

Client : **Chevron Australia Pty Ltd**
Principal :
Project : **Wheatstone Development Project**
Location : **Ashburton North**

Date started : **8/7/09**
Date completed : **9/7/09**
Logged by : **MG**
Checked by :

Position : E: 295109.2, N: 7602919.79 (50 MGA94)
Surface Elevation : -6.85m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information / material substance



drilling method & casing	core run details (drill depth (m))	samples & field tests	material description (ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
PQ3	TCR= 100% RQD= 100% 9.00	ES	**CLAYSTONE**, red brown, trace of sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular, of well cemented claystone *(continued)*	Wc	8.90: DI FR ST Sample Recovery: 0.1m 9.00: DI FR ST
	TCR= 100% RQD= 100% 10.50		**CLAYEY SANDSTONE**, fine to coarse grained, red brown, sand is mainly of quartz; trace of gravel, fine to coarse, sub-angular to angular, of chert, sandstone and quartzite	VWc to Wc	
	TCR= 100% RQD= 100% 12.00		**CALCAREOUS CONGLOMERATE**, fine to coarse grained, pale red brown, clasts are fine to cobble sized, sub-rounded to angular, of well cemented claystone, quartzite and chert in a claystone matrix, matrix content decreases with depth (authigenic matrix supported) ....from 10.30m, trace of grey coloration along weathered partings, possibly palygorskite ....at 10.60 - 10.70m, weathered seam infilled with clay and gravel of claystone ....at 10.70 - 12.00m, becoming matrix supported	Wc	10.00: DI FR ST 10.30: SM PR Clay 10.60-10.71: SM PR clay and gravel of claystone 11.00: DI FR ST 11.50: DI FR 4° 12.00: DI FR ST
			BOREHOLE MC006 TERMINATED AT 12.00 m		

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

▤ core recovered - graphic symbols indicate material
☒ no core recovered

water

▼ 10 Oct., 73 Water Level on Date shown
► water inflow
◄ water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC007***
Sheet No.	1 of 2
Project No.	***GEOTHERD08668AA***

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Date started : ***26/6/09***
Date completed : ***27/6/09***
Logged by : ***MG***
Checked by :

Position : E: 294963.61, N: 7602227.93 (50 MGA94)
Surface Elevation : -3.71m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information / material substance

drilling method & casing	water	core run details – drill depth (m)	samples & field tests	depth (m)	material description – ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
SPT		0.45	SPT 3, 4, 6 N=10 0.45m	0.0	**(CI) SANDY CLAY**, medium plasticity, brown; sand is fine to medium; trace of gravel, fine to medium, sub-angular to angular, trace of shell fragments up to 20mmØ		Sample Recovery: 0.1 m
PQ		TCR= 100% 2.00	ES ES ES	0.90	....at 0.90m, becoming clayey sand		Sample Recovery: 0.1 m Sample Recovery: 1 m
				1.0	**(SC) CLAYEY SAND**, fine to medium grained, red brown; trace of gravel, fine to medium, sub-rounded to angular of chert and quartzite,soil is variably cemented, increasing with depth; dense to very dense ....from 1.30 - 1.45m, recovered as SAND, fine to medium of quartz with some fines content	VWc to Wc	
SPT		2.45	SPT 7, 9, 12 N=21 2.45m	2.0			
PQ		TCR= 100% 3.50		2.70	....from 2.70 - 2.80m, with some gravel, sub-rounded to angular, fine to coarse of quartzite		
SPT		3.95	SPT 5, 8, 11 N=19 3.95m	3.50			
PQ		TCR= 100% 5.00		4.00	....from 4.00 - 4.60m, becoming a SAND with some clay, very weakly cemented	VWc	
SPT		5.45	SPT 12, 21, 23 N=44 5.45m	5.0	....at 5.0m, becoming very dense, very weakly cemented		
PQ		TCR= 100% 6.50		5.50	....from 5.50 - 5.95m, with some gravel, sub-rounded to angular, fine to medium of chert, very weakly cemented		
				6.30	....from 6.30 - 6.50m, becoming extremely low to very low strength SANDSTONE	Wc	
SPT		6.76	SPT 22, 12/110mm N=R 6.76m	6.50			
PQ		TCR= 100% RQD= 100% 8.00		6.76	**SANDSTONE**, fine to medium grained, red brown, with some fines content, with some gravel fine to coarse, sub-angular to angular of well cemented sandstone nodules and chert, trace of grey colouration along weathered partings possibly palygorskite ....from 7.00 - 8.50m, increasing number of well cemented sandstone nodules, becoming clast supported conglomerate	Wc to MWc	7.00: DI FR ST 7.52: DI FR 5°

RL (m): -4.0, -4.5, -5.0, -5.5, -6.0, -6.5, -7.0, -7.5, -8.0, -8.5, -9.0, -9.5, -10.0, -10.5, -11.0, -11.5

depth (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0

graphic log

estimated strength Is(50): Field ○ - Axial - ● Lab; □ - Diametral - ■; △ - Irregular - ▲; EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20 40 100 300 1000

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details
TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery
▤ core recovered - graphic symbols indicate material
☒ no core recovered

water
▼ 10 Oct., 73 Water Level on Date shown
▶— water inflow
—◀ water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	**MC007**
Sheet No.	2 of 2
Project No.	**GEOTHERD08668AA**
Date started :	**26/6/09**
Date completed :	**27/6/09**
Logged by :	**MG**
Checked by :	

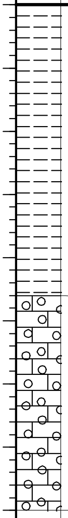
Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

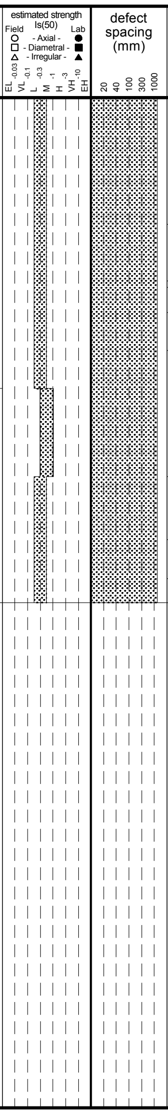
Position : E: 294963.61, N: 7602227.93 (50 MGA94)
Surface Elevation : -3.71m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information / material substance

drilling method & casing	water	core run details / drill depth (m)	samples & field tests	RL (m)	depth (m)	material description: ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
PQ		TCR= 100% RQD= 100%		-11.71 to -13.21	8.0–9.50	**CLAYSTONE**, red brown, with some sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules, trace veins of calcite up to 2mm width	Wc to MWc	8.00: DI FR ST 9.00: DI FR ST 9.45-9.50: Recovered as drilling induced clayey gravel, sub-rounded to angular, fine to medium of claystone
		9.50 TCR= 100% RQD= 100%			9.50–10.35	....at 10.00m, with an increasing number of well cemented claystone and becoming a conglomerate		9.70: DI FR ST 10.00: DI FR ST
					10.35–11.00	**CALCAREOUS CONGLOMERATE**, fine to coarse grained, pale red brown, clasts are sub-angular to angular, fine to cobble sized of well cemented claystone and sandstone, in a clay / siltstone matrix (authigenicmatrix supported) ....at 10.40m, with some shell fragments (up to 20mm long)	Mc	
		11.00 TCR= 100% RQD= 100%			11.00–12.00	....at 11.00m, with a decreasing number of clasts ....at 11.40m, with trace of grey coloration possibly palygorskite		11.00: DI FR ST 11.50: DI FR 12° 11.81: DI FR ST
		12.00		-15.71	12.0	BOREHOLE MC007 TERMINATED AT 12.00 m		

RL (m) scale: -12.0, -12.5, -13.0, -13.5, -14.0, -14.5, -15.0, -15.5, -16.0, -16.5, -17.0, -17.5, -18.0, -18.5, -19.0, -19.5
depth (m) scale: 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0





NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

☰	core recovered - graphic symbols indicate material
☒	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
▶	water inflow
◀	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:28

coffey geotechnics

Engineering Log - Cored Borehole

Hole No. **MC008**
Sheet No. 1 of 2
Project No. **GEOTHERD08668AA**

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

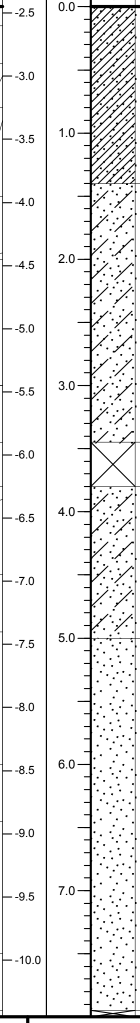
Date started : ***25/6/09***
Date completed : ***26/6/09***
Logged by : ***MG***
Checked by :

Position : E: 294721.79, N: 7601435.75 (50 MGA94)
Rig type : UDR100
Surface Elevation : -2.45m (AHD)
Mounting : Jack up Barge
Angle from horizontal : 90°
Hole Diameter : 123 mm

GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:28

drilling information

drilling method & casing	water	core run details / drill depth (m)	samples & field tests
SPT		0.45	SPT 5, 8, 10 N=18 ES 0.45m
PQ		TCR= 100% 1.50	HP =340kPa HP =390kPa ES HP =310kPa HP =345kPa HP =270kPa
SPT		1.95	SPT 3, 5, 7 N=12 1.95m
PQ		TCR= 100% 3.00	ES
SPT		3.45	SPT 4, 6, 9 N=15 3.45m
PQ		TCR= 67% 4.50	ES
SPT		4.95	SPT 7, 10, 22 N=32 4.95m
PQ		TCR= 100% 5.65 TCR= 100% 6.00	
SPT		6.45	SPT 15, 22, 22 N=44 6.45m
PQ		7.50	ES
SPT		7.95	SPT 6, 20, 17 N=37 7.95m



material substance

material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	estimated strength Is(50) Field / Lab: ○ ● - Axial -; □ ■ - Diametral -; △ ▲ - Irregular -; EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH	defect spacing (mm) 20 40 100 300 1000	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
(CL) SANDY CLAY, low plasticity, brown; sand is fine to coarse of quartz; trace of sun-angular to angular gravel; trace of shell fragments up to 15mmØ	VWc			Sample Recovery: 0.4 m Sample Recovery: 0.1 m
(SC) CLAYEY SAND, fine to medium grained, red brown; with trace gravel, fine to medium, sub-rounded to angular of quartzite and chert; dense				Sample Recovery: 1 m
CORE LOSS 0.35m (3.45-3.80) (Possibly Clayey Sand)				
(SC) CLAYEY SAND, fine to medium grained, brown; with trace gravel, fine to medium, sub-rounded to angular of quartzite and chert. ....from 4.30 - 4.40m, sandy CLAY, low plasticity	VWc			Sample Recovery: 0.1 m
SAND, fine to medium grained, brown; with some fines; trace of gravel, fine to medium, sub-rounded to angular; dense to very dense	VWc			
....at 5.70m, with some sub-rounded to angular, fine to coarse gravel of moderately cemented sandstone ....below 6.00m, becoming very dense, moderately weakly cemented	Wc to MWc			
	VWc			

NOTE
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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details
TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery
core recovered - graphic symbols indicate material
no core recovered

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation		weathering		strength	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		planarity		roughness		coating	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture,JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

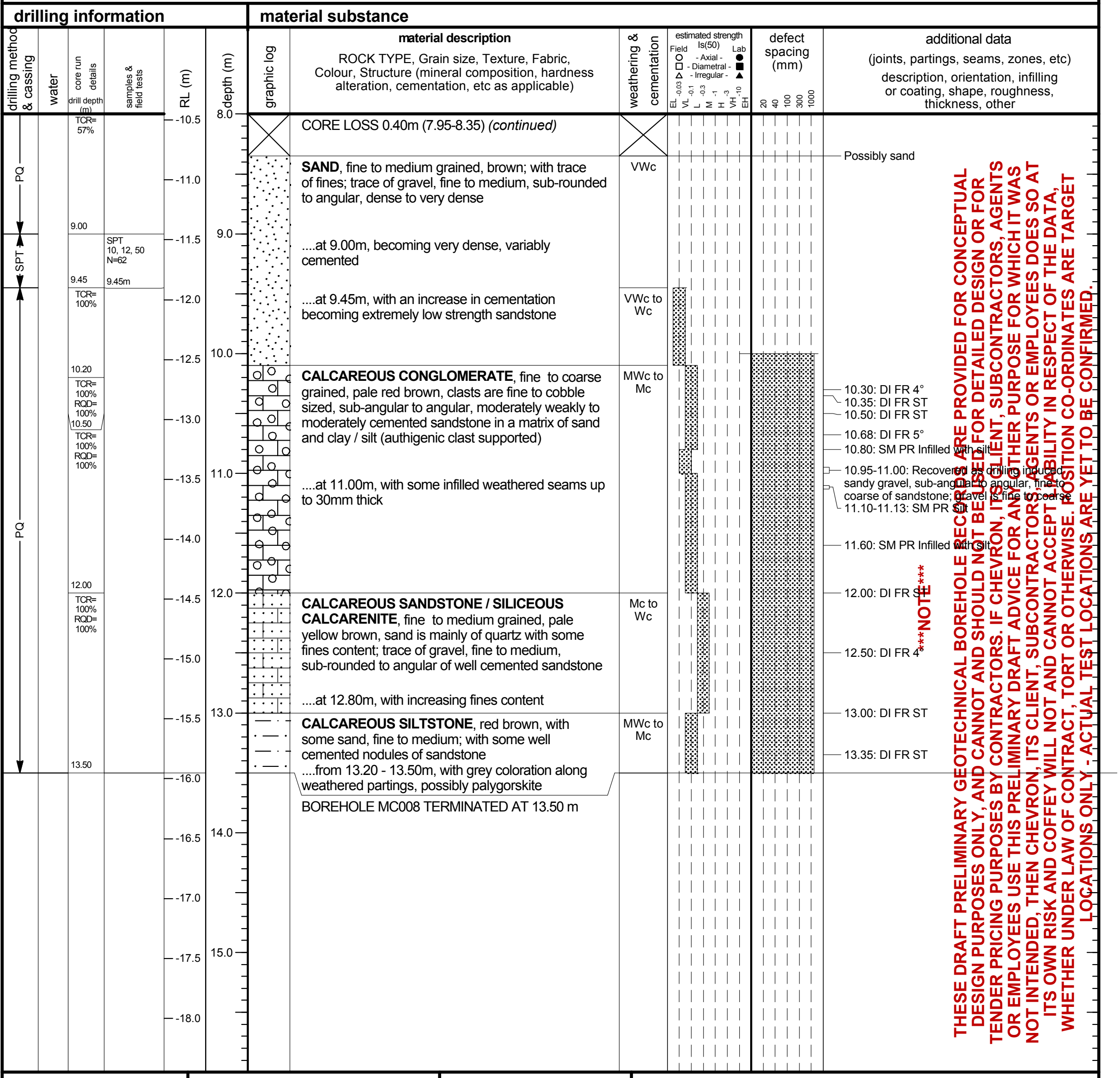
coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC008***
Sheet No.	2 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***25/6/09***
Date completed :	***26/6/09***
Logged by :	***MG***
Checked by :	

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Position : E: 294721.79, N: 7601435.75 (50 MGA94)
Surface Elevation : -2.45m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm



drilling information

drilling method & casing	core run details / drill depth (m)	samples & field tests	RL (m)	depth (m)
PQ	TCR= 57%		-10.5	8.0
			-11.0	
	9.00		-11.5	9.0
SPT	9.45	SPT 10, 12, 50 N=62 9.45m		
PQ	TCR= 100%		-12.0	
	10.20		-12.5	10.0
	TCR= 100% RQD= 100%			
	10.50		-13.0	
	TCR= 100% RQD= 100%		-13.5	11.0
			-14.0	
	12.00		-14.5	12.0
	TCR= 100% RQD= 100%		-15.0	
			-15.5	13.0
	13.50		-16.0	
			-16.5	14.0
			-17.0	
			-17.5	15.0
			-18.0	

material substance

material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
CORE LOSS 0.40m (7.95-8.35) *(continued)*		
SAND, fine to medium grained, brown; with trace of fines; trace of gravel, fine to medium, sub-rounded to angular, dense to very dense	VWc	Possibly sand
....at 9.00m, becoming very dense, variably cemented		
....at 9.45m, with an increase in cementation becoming extremely low strength sandstone	VWc to Wc	
CALCAREOUS CONGLOMERATE, fine to coarse grained, pale red brown, clasts are fine to cobble sized, sub-angular to angular, moderately weakly to moderately cemented sandstone in a matrix of sand and clay / silt (authigenic clast supported)	MWc to Mc	10.30: DI FR 4° 10.35: DI FR ST 10.50: DI FR ST 10.68: DI FR 5° 10.80: SM PR Infilled with silt 10.95-11.00: Recovered as drilling induced sandy gravel, sub-angular to angular, fine to coarse of sandstone; gravel is fine to coarse 11.10-11.13: SM PR Silt
....at 11.00m, with some infilled weathered seams up to 30mm thick		11.60: SM PR Infilled with silt
CALCAREOUS SANDSTONE / SILICEOUS CALCARENITE, fine to medium grained, pale yellow brown, sand is mainly of quartz with some fines content; trace of gravel, fine to medium, sub-rounded to angular of well cemented sandstone	Mc to Wc	12.00: DI FR ST 12.50: DI FR 4°
....at 12.80m, with increasing fines content		
CALCAREOUS SILTSTONE, red brown, with some sand, fine to medium; with some well cemented nodules of sandstone	MWc to Mc	13.00: DI FR ST
....from 13.20 - 13.50m, with grey coloration along weathered partings, possibly palygorskite		13.35: DI FR ST
BOREHOLE MC008 TERMINATED AT 13.50 m		

NOTE

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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:28

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details
TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery
▤ core recovered - graphic symbols indicate material
☒ no core recovered

water
▼ 10 Oct., 73 Water Level on Date shown
▶ water inflow
◀ water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

Engineering Log - Cored Borehole

Hole No. **MC009**
Sheet No. 1 of 2
Project No. **GEOTHERD08668AA**

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Date started : ***11/7/09***
Date completed : ***12/7/09***
Logged by : ***CT***
Checked by :

Position :
Rig type : UDR100
Surface Elevation : -1.69m (AHD)
Mounting : Jack up Barge
Angle from horizontal : 90°
Hole Diameter : 123 mm

drilling information / **material substance**

drilling method & casing	water	core run details drill depth (m)	samples & field tests	RL (m)	depth (m)	graphic log	material description (ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	estimated strength Is(50)	defect spacing (mm)	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
SPT		0.45	SPT 3, 4, 6 N=10 0.45m	-2.0	0.0		**(SC) CLAYEY SAND**, fine to medium grained of silica, red brown; clay is low plasticity; trace shell fragments; dense				
PQ3		TCR= 48% 1.50	ES	-2.5 -3.0	1.0	☒	CORE LOSS 0.55m (0.45-1.00) **(GC) CLAYEY GRAVEL**, fine to coarse grained, sub-rounded to sub-angular, red brown; gravel is of well cemented sandstone and claystone; with some sand, fine to coarse, trace of shell fragments; dense to very dense	☒			Sample Recovery: 0.1m
SPT		1.95	SPT 7, 7, 9 N=16 1.95m	-3.5							
PQ3		TCR= 100% 3.00	ES HP =520kPa HP >600kPa HP >600kPa	-4.0 -4.5	2.0		**(CL) GRAVELLY CLAY**, low plasticity, dark red brown; gravel is fine to coarse, angular to sub-rounded, of well cemented sandstone and claystone; some sand, fine to coarse, of silica; very stiff to hard				Sample Recovery: 1 m
SPT		3.45	SPT 8, 15, 20 N=35 3.45m	-5.0	3.0		**(CI) CLAY**, medium plasticity, red brown; trace of gravel, fine to coarse, sub-angular to angular of well cemented sandstone and claystone; trace of sand, fine to medium, of silica; very stiff to hard				
PQ3		TCR= 100% 4.50	HP >600kPa HP >600kPa HP >600kPa ES HP =450kPa HP =350kPa	-5.5 -6.0	4.0						Sample Recovery: 0.1m
SPT		4.95	SPT 3, 8, 11 N=19 4.95m	-6.5							
PQ3		TCR= 100% 6.00	HP =300kPa HP =350kPa HP =450kPa HP =450kPa HP =450kPa	-7.0 -7.5	5.0		....from 5.00 - 5.35m, layer of high plasticity CLAY, very stiff				
SPT		6.45	SPT 6, 11, 19 N=30 6.45m	-8.0	6.0		....at 6.00m, with some black mottling				
PQ3		TCR= 100% 7.50	HP =420kPa HP =600kPa HP =500kPa HP =480kPa HP >600kPa	-8.5 -9.0	7.0						
SPT		7.95	SPT 8, 13, 21 N=34 7.95m	-9.5							

estimated strength Is(50): Field ○ □ △ - Axial - Diametral - Irregular - ● ■ ▲ Lab; EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20 40 100 300 1000

*****NOTE*****

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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:29

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details
TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

▤	core recovered - graphic symbols indicate material
☒	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
▶	water inflow
◀	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

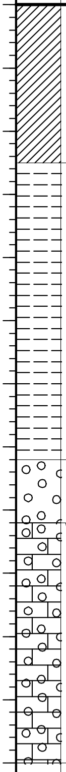
Hole No.	***MC009***
Sheet No.	2 of 2
Project No.	***GEOTHERD08668AA***
Client	***Chevron Australia Pty Ltd***
Principal	
Project	***Wheatstone Development Project***
Location	***Ashburton North***
Date started	***11/7/09***
Date completed	***12/7/09***
Logged by	***CT***
Checked by	

Position :
Surface Elevation : -1.69m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

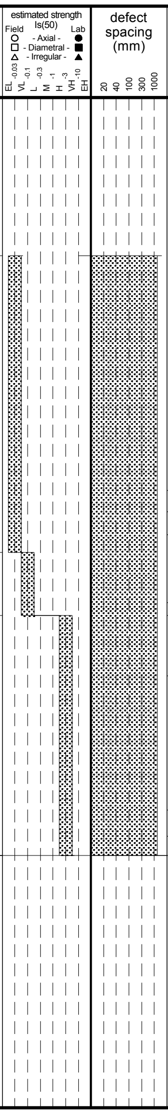
drilling information

drilling method & casing	core run details / drill depth (m)	samples & field tests	RL (m)
PQ3 (8.00–9.00)	TCR= 100%	HP =450kPa HP >600kPa HP =300kPa HP >600kPa	-10.0, -10.5
	9.00	ES	
SPT (9.00–9.45)		SPT 5, 16, 22 N=38	-11.0
	9.45	9.45m	
PQ3 (9.45–10.50)	TCR= 100% RQD= 100%	HP >600kPa HP >600kPa HP >600kPa HP >600kPa	-11.5, -12.0
	10.50		
SPT (10.50–10.80)		SPT 18, 33 N=R 10.80m	-12.5
	10.80		
PQ3 (10.80–14.00)	TCR= 100% RQD= 100%		-13.0, -13.5
	12.00		
	TCR= 100% RQD= 100%		-14.0, -14.5, -15.0
	13.50	ES	
	TCR= 100% RQD= 100%		-15.5
	14.00		-16.0, -16.5, -17.0, -17.5

material substance



depth (m)	material description (ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable))	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
8.0–9.25	**(CI) CLAY**, medium plasticity, red brown; trace of gravel, fine to coarse, sub-angular to angular of well cemented sandstone and claystone; trace of sand, fine to medium, of silica; very stiff to hard *(continued)*		Sample Recovery: 0.1m
9.25–11.6	**CLAYSTONE**, red brown, with some sand, fine to medium, of silica, trace of gravel, fine to medium, sub-angular to sub-rounded of well cemented claystone nodules	Wc	11.11: Drilling Induced Fracture 11.28: Drilling Induced Fracture 11.46: Drilling Induced Fracture
11.6–12.1	**CONGLOMERATE**, fine to coarse grained, red brown, clasts are fine to coarse, sub-angular to sub-rounded, of well cemented claystone and sandstone, matrix is fine grained clay and sand, moderately cemented, very low to low strength (orthogenic matrix supported)	Mc	12.00-12.10: Recovered as gravel, drilling induced
12.1–14.0	**CALCAREOUS CONGLOMERATE**, fine to coarse grained, pale red brown, clasts are fine to coarse up to 700mmØ of sandstone/ quartzite and claystone, matrix is sand, fine to medium grained and clay; some shell fragments and carbonate replacement along seams (authigenic clast supported), trace grey colouration of clay, possibly palygorskite, rock mass fails along clast / matrix contacts	Wc	12.58: Drilling Induced Fracture Sample Recovery: 0.1m 13.64: Drilling Induced Fracture 13.85: Drilling Induced Fracture
14.0	BOREHOLE MC009 TERMINATED AT 14.00 m		



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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:29

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

☰	core recovered - graphic symbols indicate material
☒	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
▶	water inflow
◀	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture,JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

DRAFT

Hole No.	***MC010***
Sheet No.	1 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***9/7/09***
Date completed :	***11/7/09***
Logged by :	***MG***
Checked by :	

Client : ***Chevron Australia Pty Ltd***

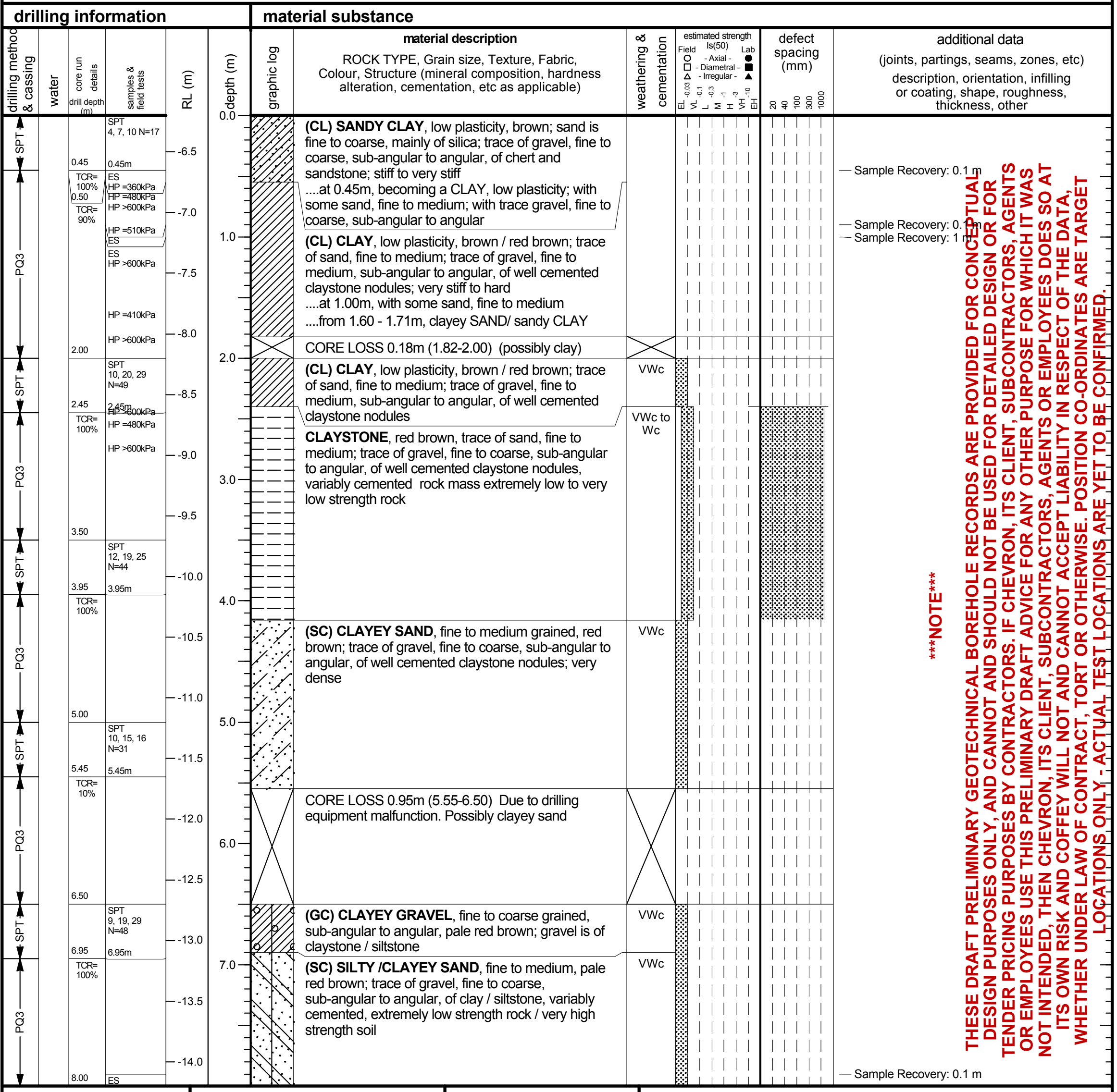
Principal :

Project : ***Wheatstone Development Project***

Location : ***Ashburton North***

Position : E: 294454.02, N: 7602375.87 (50 MGA94) | Surface Elevation : -6.2m (AHD) | Angle from horizontal : 90°

Rig type : UDR100 | Mounting : Jack up Barge | Hole Diameter : 123 mm



drilling information

drilling method & casing	water	core run details / drill depth (m)	samples & field tests
SPT		0.45	SPT 4, 7, 10 N=17 0.45m
PQ3		TCR= 100% 0.50 TCR= 90% 2.00	ES HP =360kPa HP =480kPa HP >600kPa HP =510kPa ES ES HP >600kPa HP =410kPa HP >600kPa
SPT		2.45	SPT 10, 20, 29 N=49 2.45m
PQ3		TCR= 100% 3.50	HP >600kPa HP =480kPa HP >600kPa
SPT		3.95	SPT 12, 19, 25 N=44 3.95m
PQ3		TCR= 100% 5.00	
SPT		5.45	SPT 10, 15, 16 N=31 5.45m
PQ3		TCR= 10% 6.50	
SPT		6.95	SPT 9, 19, 29 N=48 6.95m
PQ3		TCR= 100% 8.00	ES

material substance

material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
(CL) SANDY CLAY, low plasticity, brown; sand is fine to coarse, mainly of silica; trace of gravel, fine to coarse, sub-angular to angular, of chert and sandstone; stiff to very stiff ....at 0.45m, becoming a CLAY, low plasticity; with some sand, fine to medium; with trace gravel, fine to coarse, sub-angular to angular		Sample Recovery: 0.1 m
(CL) CLAY, low plasticity, brown / red brown; trace of sand, fine to medium; trace of gravel, fine to medium, sub-angular to angular, of well cemented claystone nodules; very stiff to hard ....at 1.00m, with some sand, fine to medium ....from 1.60 - 1.71m, clayey SAND/ sandy CLAY		Sample Recovery: 0.1 m Sample Recovery: 1 m
CORE LOSS 0.18m (1.82-2.00) (possibly clay)		
(CL) CLAY, low plasticity, brown / red brown; trace of sand, fine to medium; trace of gravel, fine to medium, sub-angular to angular, of well cemented claystone nodules	VWc	
CLAYSTONE, red brown, trace of sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular, of well cemented claystone nodules, variably cemented rock mass extremely low to very low strength rock	VWc to Wc	
(SC) CLAYEY SAND, fine to medium grained, red brown; trace of gravel, fine to coarse, sub-angular to angular, of well cemented claystone nodules; very dense	VWc	
CORE LOSS 0.95m (5.55-6.50) Due to drilling equipment malfunction. Possibly clayey sand		
(GC) CLAYEY GRAVEL, fine to coarse grained, sub-angular to angular, pale red brown; gravel is of claystone / siltstone	VWc	
(SC) SILTY /CLAYEY SAND, fine to medium, pale red brown; trace of gravel, fine to coarse, sub-angular to angular, of clay / siltstone, variably cemented, extremely low strength rock / very high strength soil	VWc	Sample Recovery: 0.1 m

NOTE

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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:29

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

core recovered - graphic symbols indicate material

no core recovered

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

25 water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

Engineering Log - Cored Borehole

Hole No. **MC010**
Sheet No. 2 of 2
Project No. **GEOTHERD08668AA**

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

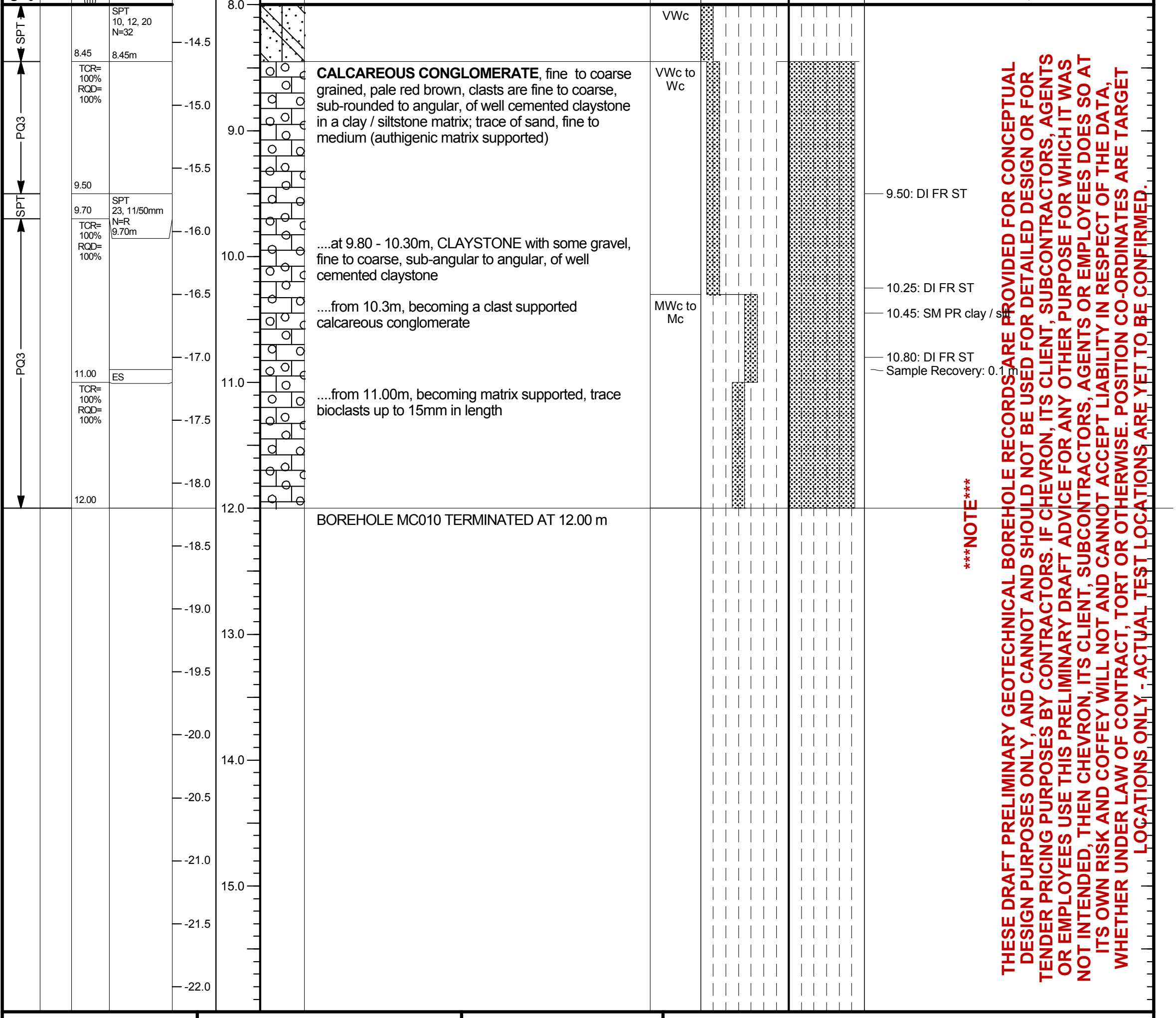
Date started : ***9/7/09***
Date completed : ***11/7/09***
Logged by : ***MG***
Checked by :

Position : E: 294454.02, N: 7602375.87 (50 MGA94)
Surface Elevation : -6.2m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information

material substance

drilling method & casing	water	core run details / drill depth (m)	samples & field tests	RL (m)	depth (m)	graphic log	material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	estimated strength Is(50) Field ○ - Axial - ● Lab □ - Diametral - ■ △ - Irregular - ▲ EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH	defect spacing (mm) 20 40 100 300 1000	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other



drilling method & casing	drill depth (m)	samples & field tests
SPT	8.45	SPT 10, 12, 20 N=32 8.45m
PQ3	TCR= 100% RQD= 100% 9.50	
SPT	9.70	SPT 23, 11/50mm N=R 9.70m
PQ3	TCR= 100% RQD= 100% 11.00	ES
	TCR= 100% RQD= 100% 12.00	

weathering & cementation	material description
VWc	
VWc to Wc	**CALCAREOUS CONGLOMERATE**, fine to coarse grained, pale red brown, clasts are fine to coarse, sub-rounded to angular, of well cemented claystone in a clay / siltstone matrix; trace of sand, fine to medium (authigenic matrix supported) ....at 9.80 - 10.30m, CLAYSTONE with some gravel, fine to coarse, sub-angular to angular, of well cemented claystone
MWc to Mc	....from 10.3m, becoming a clast supported calcareous conglomerate ....from 11.00m, becoming matrix supported, trace bioclasts up to 15mm in length
	BOREHOLE MC010 TERMINATED AT 12.00 m

additional data:
- 9.50: DI FR ST
- 10.25: DI FR ST
- 10.45: SM PR clay / silt
- 10.80: DI FR ST
- Sample Recovery: 0.1 m

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

⊟	core recovered - graphic symbols indicate material
☒	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
▶—	water inflow
—◀	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC011***
Sheet No.	1 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***26/6/09***
Date completed :	***26/6/09***
Logged by :	***MG***
Checked by :	

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Position : E: 294059.91, N: 7603651.67 (50 MGA94)
Surface Elevation : -5.76m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information

drilling method & casing	water	core run details / drill depth (m)	samples & field tests	RL (m)	depth (m)
SPT		0.45	SPT ES 4, 4, 5 N=9 HP =210kPa 0.45m	-6.0	0.0
PQ		TCR= 100% 1.00		-6.5	
PQ		TCR= 100% 1.50	ES HP =450kPa HP >600kPa HP >600kPa	-7.0	1.0
SPT		1.95	SPT 9, 10, 10 N=20 1.95m	-7.5	
PQ		TCR= 100% 3.00	HP >600kPa ES HP >600kPa HP >600kPa	-8.0 -8.5	2.0
SPT		3.40	SPT 12, 26 N=R HP >600kPa 3.40m	-9.0	3.0
PQ		TCR= 100% RQD= 100% 4.50	ES HP >600kPa HP >600kPa HP >600kPa	-9.5 -10.0	4.0
SPT		4.90	SPT 10, 26 N=R 4.90m	-10.5	
PQ		TCR= 100% RQD= 100% 6.00		-11.0 -11.5	5.0
PQ		TCR= 100% RQD= 100% 7.50	ES	-12.0 -12.5 -13.0	6.0 7.0
PQ		TCR= 100% RQD= 100%		-13.5	

material substance

depth (m)	material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
0.0	**(CI) GRAVELLY CLAY**, medium plasticity, red brown, gravel is fine to coarse, sub-angular to angular of quartzite; with some sand fine to coarse of silica, with some shell fragments up to 70mmØ; stiff to very stiff ....from 0.70 - 0.80m, shell assemblage of bivalves		Sample Recovery: 0.4 m
1.0	**(CI) SANDY CLAY**, medium plasticity, red brown; sand is fine to medium; trace of gravel, fine to medium, sub-angular, becoming well cemented in zones; very stiff ....from 1.80 - 1.90m, becoming a clayey SAND	VWc	Sample Recovery: 0.1 m Sample Recovery: 1 m
	(SC) CLAYEY SAND, fine to medium grained, brown; sand is of silica; trace of gravel, fine to medium, sub-angular to angular, trace shell fragments up to 10mmØ, variably cemented; dense to very dense ....at 3.00m, becoming very dense ....at 3.20m, becoming sandy clay		Sample Recovery: 0.1 m
	(CL) SANDY CLAY, low plasticity, red brown; sand is fine to medium; trace of gravel, fine to medium, sub-rounded to angular	MWc	3.60: DI FR ST 3.80: DI FR ST
4.0	**CLAYSTONE**, red brown, trace of sand, fine to medium; trace of grey colouration along weathered partings, possibly palygorskite ....at 5.00m, with some clasts of well cemented claystone up to 15mmØ		4.10: DI FR ST 4.30: DI FR ST 4.47: DI FR ST
6.0	....at 6.00m, with some calcite / carbonate cementation and veins up to 70mm thick	MWc to Mc	
	SANDSTONE, fine to medium grained, red brown, with some fines; with some gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules up to 30mmØ; trace of grey colouration along weathered partings, possibly palygorskite	Mc	
		Mc	7.65: DI FR ST

estimated strength Is(50): Field ○ - Axial - ●; □ - Diametral - ■; △ - Irregular - ▲ Lab; EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20 40 100 300 1000

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details
TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery
- core recovered - graphic symbols indicate material
- ☒ no core recovered

water
- ▼ 10 Oct., 73 Water Level on Date shown
- ▶ water inflow
- ◀ water outflow
- 25 water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture,JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

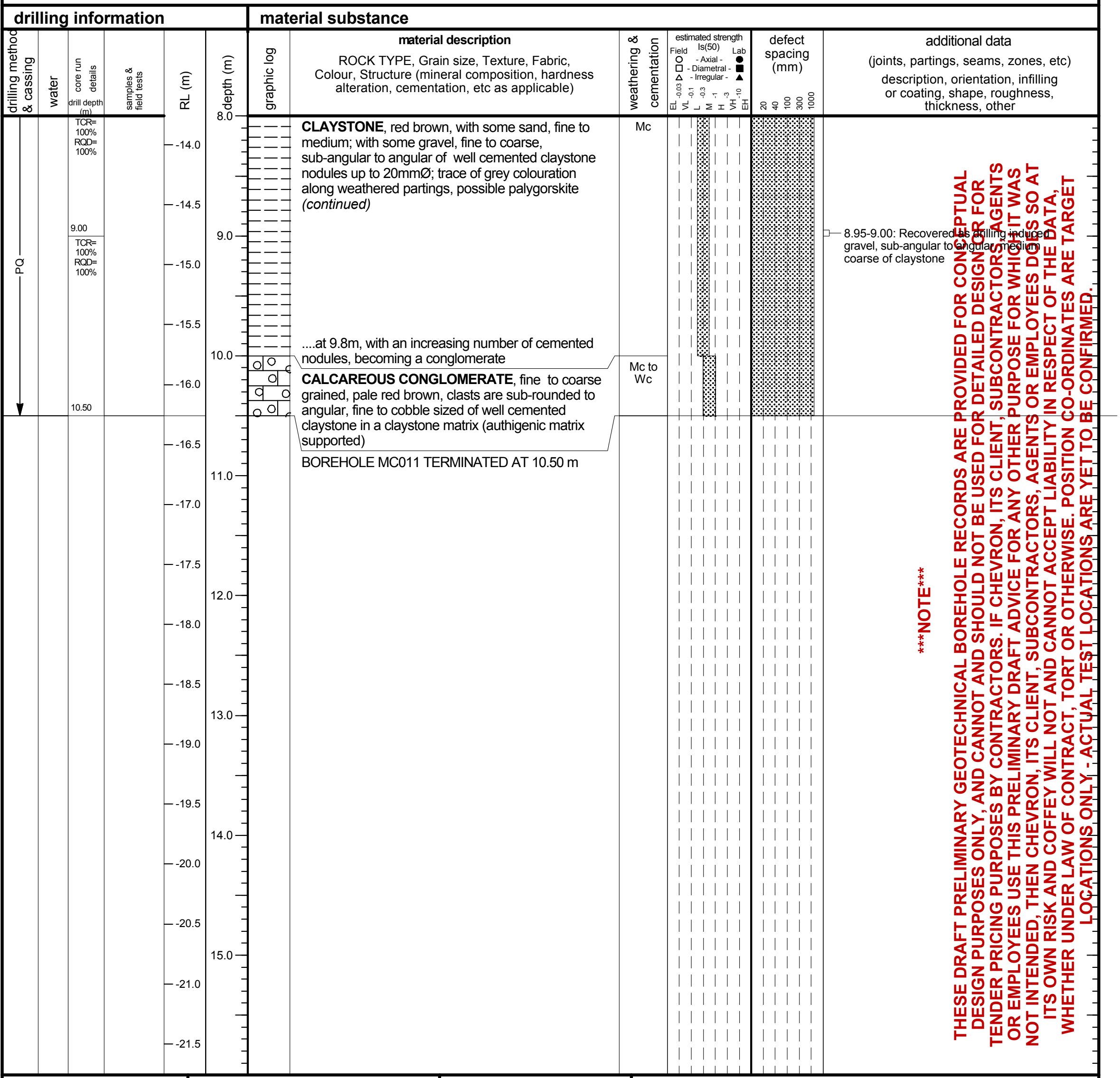
coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC011***
Sheet No.	2 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***26/6/09***
Date completed :	***26/6/09***
Logged by :	***MG***
Checked by :	

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Position : E: 294059.91, N: 7603651.67 (50 MGA94)
Surface Elevation : -5.76m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm



material description
ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)

additional data
(joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other

CLAYSTONE, red brown, with some sand, fine to medium; with some gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules up to 20mmØ; trace of grey colouration along weathered partings, possible palygorskite *(continued)*

8.95-9.00: Recovered as drilling induced gravel, sub-angular to angular, medium coarse of claystone

....at 9.8m, with an increasing number of cemented nodules, becoming a conglomerate

CALCAREOUS CONGLOMERATE, fine to coarse grained, pale red brown, clasts are sub-rounded to angular, fine to cobble sized of well cemented claystone in a claystone matrix (authigenic matrix supported)

BOREHOLE MC011 TERMINATED AT 10.50 m

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details
TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery
▤ core recovered - graphic symbols indicate material
☒ no core recovered

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture,JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

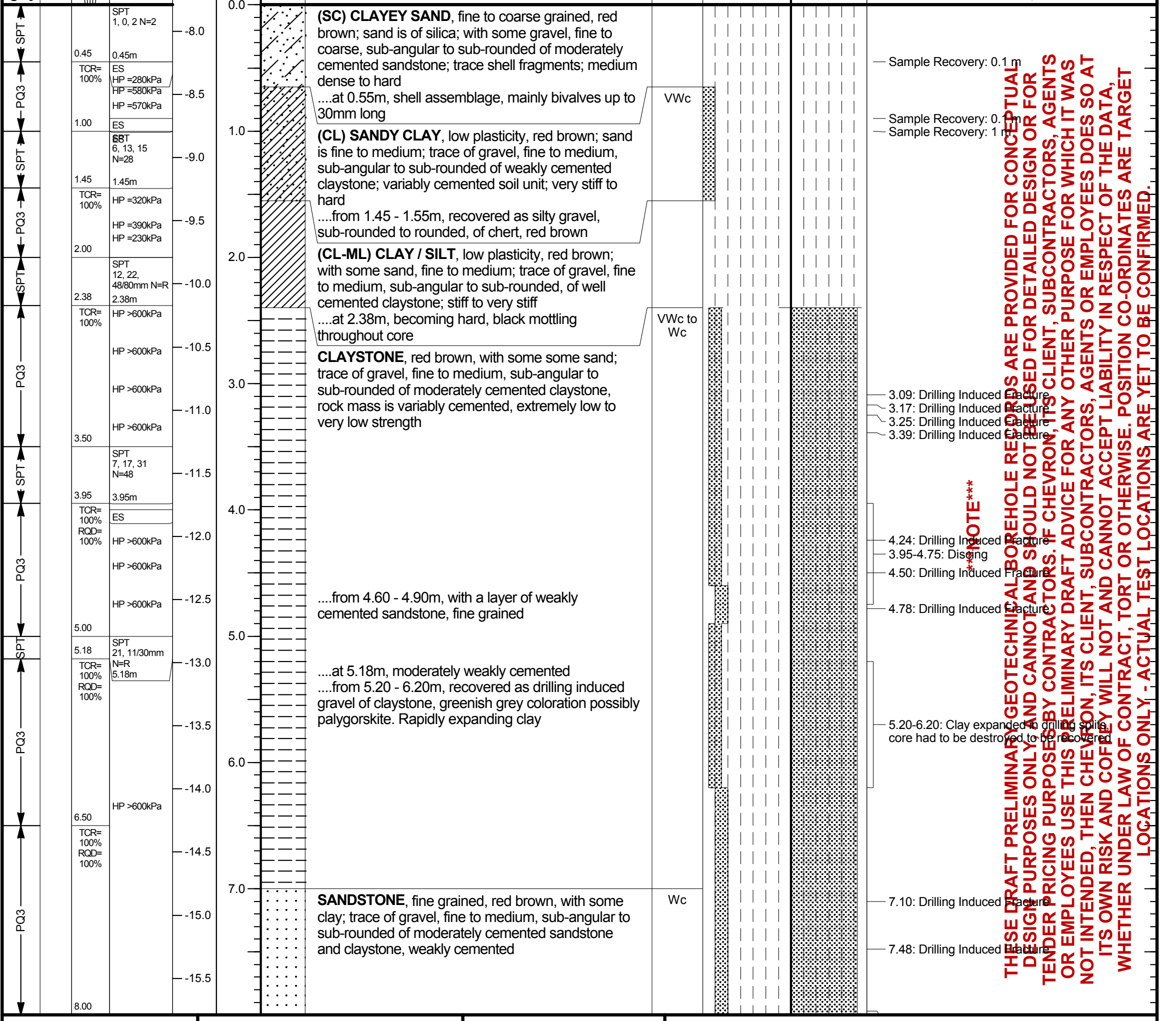
Hole No.	***MC012***
Sheet No.	1 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***7/7/09***
Date completed :	***8/7/09***
Logged by :	***CT***
Checked by :	

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Position : E: 294588, N: 7603999.49 (50 MGA94)
Rig type : UDR100
Surface Elevation : -7.79m (AHD)
Mounting : Jack up Barge
Angle from horizontal : 90°
Hole Diameter : 123 mm

drilling information

material substance



drilling method & casing	core run details	drill depth (m)	samples & field tests
SPT		0.45	SPT 1, 0, 2 N=2 0.45m
PQ3	TCR= 100%	1.00	ES HP =280kPa HP =580kPa HP =570kPa ES
SPT		1.45	SPT ES 6, 13, 15 N=28 1.45m
PQ3	TCR= 100%	2.00	HP =320kPa HP =390kPa HP =230kPa
SPT		2.38	SPT 12, 22, 48/80mm N=R 2.38m
PQ3	TCR= 100%	3.50	HP >600kPa HP >600kPa HP >600kPa HP >600kPa
SPT		3.95	SPT 7, 17, 31 N=48 3.95m
PQ3	TCR= 100% RQD= 100%	5.00	ES HP >600kPa HP >600kPa HP >600kPa
SPT		5.18	SPT 21, 11/30mm N=R 5.18m
PQ3	TCR= 100% RQD= 100%	6.50	HP >600kPa
PQ3	TCR= 100% RQD= 100%	8.00	

material description
ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)

(SC) CLAYEY SAND, fine to coarse grained, red brown; sand is of silica; with some gravel, fine to coarse, sub-angular to sub-rounded of moderately cemented sandstone; trace shell fragments; medium dense to hard

....at 0.55m, shell assemblage, mainly bivalves up to 30mm long — VWc

(CL) SANDY CLAY, low plasticity, red brown; sand is fine to medium; trace of gravel, fine to medium, sub-angular to sub-rounded of weakly cemented claystone; variably cemented soil unit; very stiff to hard

....from 1.45 - 1.55m, recovered as silty gravel, sub-rounded to rounded, of chert, red brown

(CL-ML) CLAY / SILT, low plasticity, red brown; with some sand, fine to medium; trace of gravel, fine to medium, sub-angular to sub-rounded, of well cemented claystone; stiff to very stiff

....at 2.38m, becoming hard, black mottling throughout core — VWc to Wc

CLAYSTONE, red brown, with some some sand; trace of gravel, fine to medium, sub-angular to sub-rounded of moderately cemented claystone, rock mass is variably cemented, extremely low to very low strength

....from 4.60 - 4.90m, with a layer of weakly cemented sandstone, fine grained

....at 5.18m, moderately weakly cemented

....from 5.20 - 6.20m, recovered as drilling induced gravel of claystone, greenish grey coloration possibly palygorskite. Rapidly expanding clay

SANDSTONE, fine grained, red brown, with some clay; trace of gravel, fine to medium, sub-angular to sub-rounded of moderately cemented sandstone and claystone, weakly cemented — Wc

additional data
(joints, partings, seams, zones, etc)
description, orientation, infilling or coating, shape, roughness, thickness, other

- Sample Recovery: 0.1 m
- Sample Recovery: 0.1 m
- Sample Recovery: 1 m
- 3.09: Drilling Induced Fracture
- 3.17: Drilling Induced Fracture
- 3.25: Drilling Induced Fracture
- 3.39: Drilling Induced Fracture
- 4.24: Drilling Induced Fracture
- 3.95-4.75: Discing
- 4.50: Drilling Induced Fracture
- 4.78: Drilling Induced Fracture
- 5.20-6.20: Clay expanded in drilling splits, core had to be destroyed to be recovered
- 7.10: Drilling Induced Fracture
- 7.48: Drilling Induced Fracture

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details
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SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

☰	core recovered - graphic symbols indicate material
☒	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
▶	water inflow
◀	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

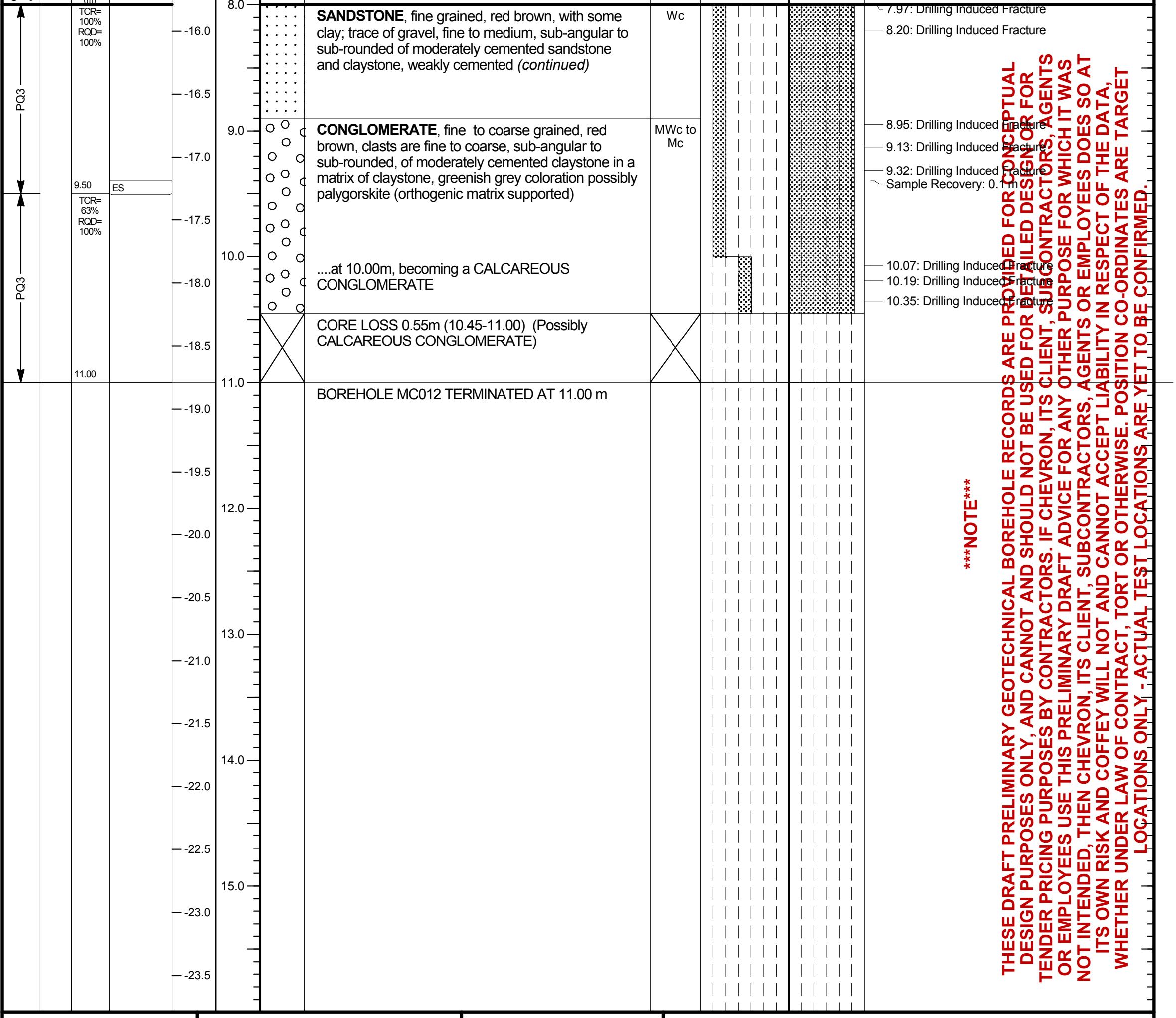
coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC012***
Sheet No.	2 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***7/7/09***
Date completed:	***8/7/09***
Logged by :	***CT***
Checked by :	

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Position : E: 294588, N: 7603999.49 (50 MGA94)
Surface Elevation : -7.79m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm



drilling information

drilling method & casing	water	core run details / drill depth (m)	samples & field tests	RL (m)	depth (m)
PQ3		TCR= 100% RQD= 100%		-16.0	8.0
				-16.5	
				-17.0	9.0
		9.50	ES		
PQ3		TCR= 63% RQD= 100%		-17.5	
				-18.0	10.0
		11.00		-18.5	11.0
				-19.0	
				-19.5	12.0
				-20.0	
				-20.5	13.0
				-21.0	
				-21.5	14.0
				-22.0	
				-22.5	15.0
				-23.0	
				-23.5	

material substance

material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
SANDSTONE, fine grained, red brown, with some clay; trace of gravel, fine to medium, sub-angular to sub-rounded of moderately cemented sandstone and claystone, weakly cemented *(continued)*	Wc	7.97: Drilling Induced Fracture 8.20: Drilling Induced Fracture
CONGLOMERATE, fine to coarse grained, red brown, clasts are fine to coarse, sub-angular to sub-rounded, of moderately cemented claystone in a matrix of claystone, greenish grey coloration possibly palygorskite (orthogenic matrix supported) ....at 10.00m, becoming a CALCAREOUS CONGLOMERATE	MWc to Mc	8.95: Drilling Induced Fracture 9.13: Drilling Induced Fracture 9.32: Drilling Induced Fracture Sample Recovery: 0.1 m 10.07: Drilling Induced Fracture 10.19: Drilling Induced Fracture 10.35: Drilling Induced Fracture
CORE LOSS 0.55m (10.45-11.00) (Possibly CALCAREOUS CONGLOMERATE)		
BOREHOLE MC012 TERMINATED AT 11.00 m		

NOTE

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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:30

method
DT diatube
AS auger screwing
AD auger drilling
RR roller/tricone
CB claw or blade bit
NMLC NMLC core
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetrometer test

core details
TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery
core recovered - graphic symbols indicate material
no core recovered

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation
VWc v. weakly cemented
Wc weakly cemented
MWc mod. weakly cemented
Mc moderately cemented
Hc well cemented
VHc v. well cemented

weathering
RS Residual Soil
XW Extremely Weathered
HW Highly Weathered
MW Moderately Weathered
SW Slightly Weathered
FR Fresh Rock

strength
EL extremely low
VL very low
L low
M medium
H high
VH very high

defect type
BP bedding parting
CS crushed seam
FC fracture,JT joint
SS sheared surface
SZ sheared zone
SM seam, VO void

planarity
PR planar
CU curved
UN undulating
ST stepped
IR irregular
DIS discontinuous

roughness
VR very rough
RF rough
S smooth
SL slickensided
POL polished

coating
CN clean
SN stained
VN veneer
CT coating

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC013***
Sheet No.	1 of 2
Project No.	***GEOTHERD08668AA***
Date started :	***28/6/09***
Date completed :	***30/6/09***
Logged by :	***CT***
Checked by :	

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Position : E: 293818.79, N: 7604524.99 (50 MGA94) Surface Elevation : -6.69m (AHD) Angle from horizontal : 90°
Rig type : UDR100 Mounting : Jack up Barge Hole Diameter : 123 mm

drilling information

drilling method & casing	water	core run details drill depth (m)	samples & field tests
SPT		0.45	SPT 4, 8, 14 N=22 0.45m
PQ		TCR= 100% 2.00	ES ES ES HP >600kPa HP >600kPa
SPT		2.45	SPT 9, 15, 22 N=37 2.45m
PQ		TCR= 100% 3.50	HP >600kPa
SPT		3.95	SPT 5, 15, 28 N=43 3.95m
PQ		TCR= 100% 5.00	
SPT		5.45	SPT 8, 10, 14 N=24 5.45m
PQ		TCR= 100% 6.50	
SPT		6.95	SPT 17, 12, 15 N=27 6.95m
PQ		TCR= 100% RQD= 100% 8.00	ES HP =500kPa HP >600kPa HP >600kPa

RL (m): -7.0, -7.5, -8.0, -8.5, -9.0, -9.5, -10.0, -10.5, -11.0, -11.5, -12.0, -12.5, -13.0, -13.5, -14.0, -14.5

material substance

depth (m)	material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
0.0	**(CL) SANDY CLAY**, medium plasticity, red brown; sand is fine to medium; trace of shell fragments up to 25mm; trace of gravel, fine to medium, sub-angular to sub-rounded of moderately cemented claystone; high percentage of bivalve shells within upper 10cm; stiff to very stiff ....from 0.65 - 0.75m, with shell assemblage of bivalves up to 40mm		Sample Recovery: 0.1 m Sample Recovery: 0.1 m
1.0	**CLAYSTONE**, red brown, with some fine to medium, rock mass is variably cemented extremely low to very low rock strength ....at 2.15m, with trace fine gravel, sub-angular to sub-rounded, of moderately cemented claystone	VWc to Wc	Sample Recovery: 1 m
4.0	**(SC) CLAYEY SAND**, fine to medium grained, red brown; trace of gravel, fine to medium, sub-angular to sub-rounded of well cemented sandstone, dense to very dense, variably cemented	VWc	
7.0	**CLAYSTONE**, red brown, with some fine to medium sand; trace of gravel, fine to medium, sub-angular to sub-rounded of well cemented claystone; some grey colouration along weathered partings, possibly palygorskite	VWc to Wc	Sample Recovery: 0.05 m

estimated strength Is(50): Field ○ - Axial - ● Lab; □ - Diametral - ■; △ - Irregular - ▲
EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20 40 100 300 1000

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

core recovered - graphic symbols indicate material
no core recovered

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:30

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	*MC013*
Sheet No.	2 of 2
Project No.	*GEOTHERD08668AA*
Date started :	*28/6/09*
Date completed :	*30/6/09*
Logged by :	*CT*
Checked by :	

Client : *Chevron Australia Pty Ltd*
Principal :
Project : *Wheatstone Development Project*
Location : *Ashburton North*

Position : E: 293818.79, N: 7604524.99 (50 MGA94)
Surface Elevation : -6.69m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

drilling information / material substance

drilling method & casing	water	core run details / drill depth (m)	samples & field tests	RL (m)	depth (m)	material description: ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
SPT		8.45	SPT 10, 24, 26/100mm N=R 8.40m		8.0	**CLAYSTONE**, red brown, with some fine to medium sand; trace of gravel, fine to medium, sub-angular to sub-rounded of well cemented claystone; some grey colouration along weathered partings, possibly palygorskite *(continued)* ....at 8.00m, sand content decreasing to trace of sand	VWc to Wc	
PQ		TCR= 100% RQD= 100% 9.50		-15.0 -15.5	9.0			
				-16.0		**CALCAREOUS CONGLOMERATE**, fine to coarse grained, red brown, clasts are fine to coarse, sub-angular to sub-rounded of sandstone and shell fragments in a matrix of clay, trace of sand, fine to medium (authigenic clast supported)	VWc to Wc Mc VWc to Wc	9.22: SM PR RF Infilled with clayey gravel
				-16.5		BOREHOLE MC013 TERMINATED AT 9.50 m		
				-17.0 -17.5	10.0			
				-18.0 -18.5	11.0			
				-19.0 -19.5	12.0			
				-20.0 -20.5	13.0			
				-21.0 -21.5	14.0			
				-22.0 -22.5	15.0			

estimated strength Is(50): Field ○ - Axial - ● Lab; □ - Diametral - ■; △ - Irregular - ▲; EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm): 20 40 100 300 1000

NOTE

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GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:30

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

core recovered - graphic symbols indicate material
no core recovered

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

25 water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

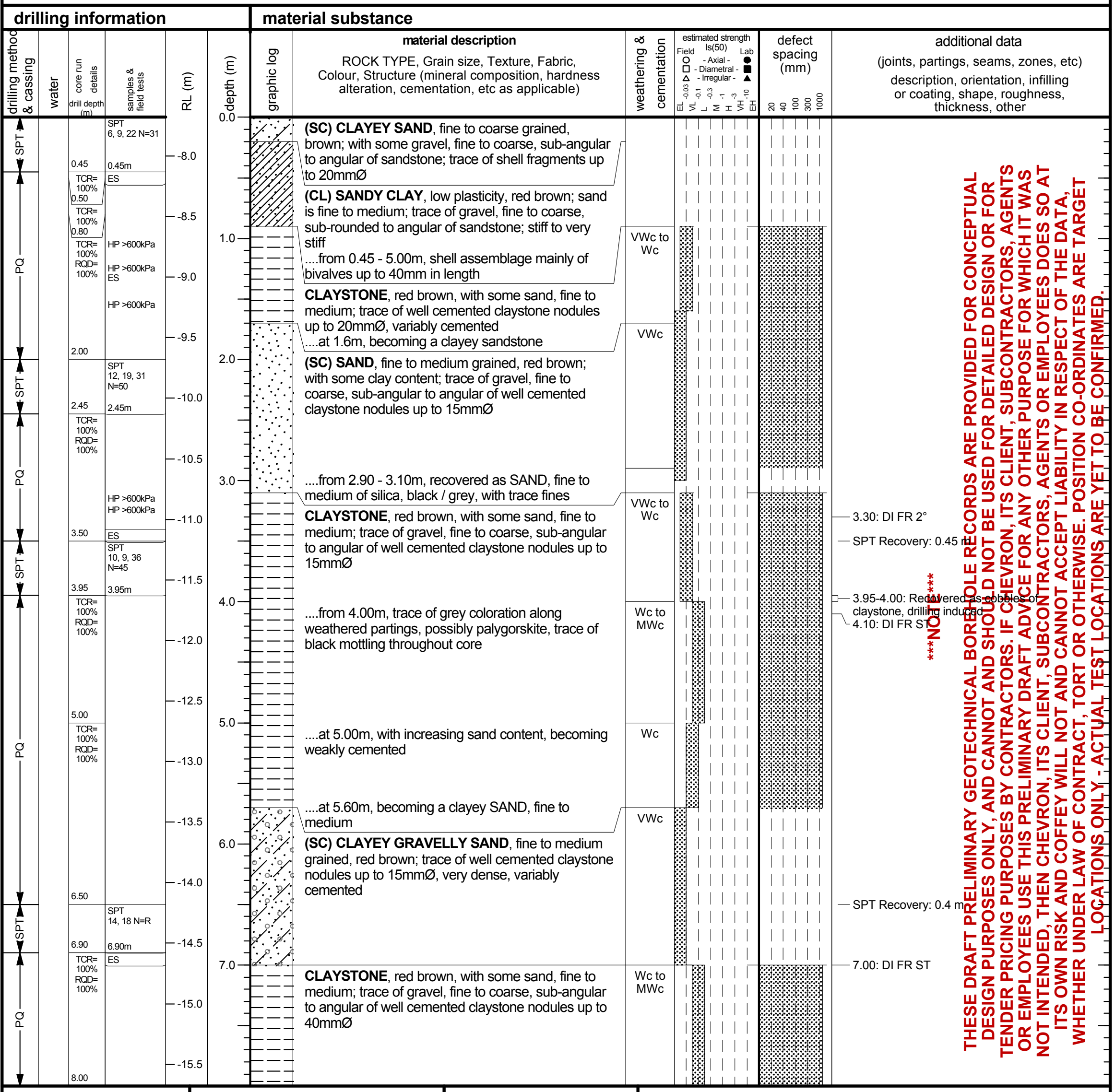
Engineering Log - Cored Borehole

Hole No.	**MC014**
Sheet No.	1 of 2
Project No.	GEOTHERD08668AA
Date started :	30/6/09
Date completed :	30/6/09
Logged by :	MG
Checked by :	

Client : *Chevron Australia Pty Ltd*
Principal :
Project : *Wheatstone Development Project*
Location : *Ashburton North*

Position : E: 293822.4, N: 7605658.31 (50 MGA94)
Surface Elevation : -7.68m (AHD)
Angle from horizontal : 90°
Rig type : UDR100
Mounting : Jack up Barge
Hole Diameter : 123 mm

GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:30



drilling information

drilling method & casing	core run details drill depth (m)	samples & field tests
SPT	0.45	SPT 6, 9, 22 N=31 0.45m
PQ	TCR= 100% 0.50 TCR= 100% 0.80 TCR= 100% RQD= 100% 2.00	ES HP >600kPa HP >600kPa ES HP >600kPa
SPT	2.45	SPT 12, 19, 31 N=50 2.45m
PQ	TCR= 100% RQD= 100% 3.50	HP >600kPa HP >600kPa ES
SPT	3.95	SPT 10, 9, 36 N=45 3.95m
PQ	TCR= 100% RQD= 100% 5.00	
PQ	TCR= 100% RQD= 100% 6.50	
SPT	6.90	SPT 14, 18 N=R 6.90m
PQ	TCR= 100% RQD= 100% 8.00	ES

material substance

material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
(SC) CLAYEY SAND, fine to coarse grained, brown; with some gravel, fine to coarse, sub-angular to angular of sandstone; trace of shell fragments up to 20mmØ		
(CL) SANDY CLAY, low plasticity, red brown; sand is fine to medium; trace of gravel, fine to coarse, sub-rounded to angular of sandstone; stiff to very stiff ....from 0.45 - 5.00m, shell assemblage mainly of bivalves up to 40mm in length		
CLAYSTONE, red brown, with some sand, fine to medium; trace of well cemented claystone nodules up to 20mmØ, variably cemented ....at 1.6m, becoming a clayey sandstone	VWc to Wc	
(SC) SAND, fine to medium grained, red brown; with some clay content; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules up to 15mmØ ....from 2.90 - 3.10m, recovered as SAND, fine to medium of silica, black / grey, with trace fines	VWc	
CLAYSTONE, red brown, with some sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules up to 15mmØ	VWc to Wc	3.30: DI FR 2° SPT Recovery: 0.45 m 3.95-4.00: Recovered as cobbles of claystone, drilling induced
....from 4.00m, trace of grey coloration along weathered partings, possibly palygorskite, trace of black mottling throughout core	Wc to MWc	4.10: DI FR ST
....at 5.00m, with increasing sand content, becoming weakly cemented	Wc	
....at 5.60m, becoming a clayey SAND, fine to medium **(SC) CLAYEY GRAVELLY SAND**, fine to medium grained, red brown; trace of well cemented claystone nodules up to 15mmØ, very dense, variably cemented	VWc	SPT Recovery: 0.4 m
CLAYSTONE, red brown, with some sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules up to 40mmØ	Wc to MWc	7.00: DI FR ST

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm
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PQ	wireline core (85.0mm
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

▤ core recovered - graphic symbols indicate material
☒ no core recovered

water

▼ 10 Oct., 73 Water Level on Date shown
▶ water inflow
◀ water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
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weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

coffey geotechnics

Engineering Log - Cored Borehole

Hole No.	***MC014***
Sheet No.	2 of 2
Project No.	***GEOTHERD08668AA***

Client	: ***Chevron Australia Pty Ltd***	Date started :	***30/6/09***
Principal	:	Date completed :	***30/6/09***
Project	: ***Wheatstone Development Project***	Logged by :	***MG***
Location	: ***Ashburton North***	Checked by :	

Position : E: 293822.4, N: 7605658.31 (50 MGA94)	Surface Elevation : -7.68m (AHD)	Angle from horizontal : 90°
Rig type : UDR100	Mounting : Jack up Barge	Hole Diameter : 123 mm

drilling information						material substance					
drilling method & casing	water	core run details drill depth (m)	samples & field tests	RL (m)	depth (m)	graphic log	**material description** ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation	estimated strength Is(50) Field ○ ☐ △ - Axial - ● - Diametral - ■ - Irregular - ▲ Lab EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH	defect spacing (mm) 20 40 100 300 1000	additional data (joints, partings, seams, zones, etc) description, orientation, infilling or coating, shape, roughness, thickness, other
PQ		TCR= 100% RQD= 100% 8.50		-16.0	8.0		....from 8.00 - 8.30m, trace of grey coloration along weathered partings possibly palygorskite	Wc to MWc			8.00: DI FR ST 8.13: DI FR ST 8.24: DI FR ST
				-16.5			BOREHOLE MC014 TERMINATED AT 8.50 m				
					9.0						
				-17.0							
				-17.5							
					10.0						
				-18.0							
				-18.5							
					11.0						
				-19.0							
				-19.5							
					12.0						
				-20.0							
				-20.5							
					13.0						
				-21.0							
				-21.5							
					14.0						
				-22.0							
				-22.5							
					15.0						
				-23.0							
				-23.5							

NOTE

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method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ	wireline core (47.6mm)
HQ	wireline core (63.5mm)
PQ	wireline core (85.0mm)
SPT	standard penetrometer test

core details

TCR = Total Core Recovery (%)
SCR = Solid Core Recovery (%)
RQD = Rock Quality Designation (%)

graphic log / core recovery

▤	core recovered - graphic symbols indicate material
☒	no core recovered

water

▼	10 Oct., 73 Water Level on Date shown
▶—	water inflow
—◀	water outflow
25	water pressure test result (lugeons) for depth interval shown

cementation		**weathering**		**strength**	
VWc	v. weakly cemented	RS	Residual Soil	EL	extremely low
Wc	weakly cemented	XW	Extremely Weathered	VL	very low
MWc	mod. weakly cemented	HW	Highly Weathered	L	low
Mc	moderately cemented	MW	Moderately Weathered	M	medium
Hc	well cemented	SW	Slightly Weathered	H	high
VHc	v. well cemented	FR	Fresh Rock	VH	very high

defect type		**planarity**		**roughness**		**coating**	
BP	bedding parting	PR	planar	VR	very rough	CN	clean
CS	crushed seam	CU	curved	RF	rough	SN	stained
FC	fracture, JT joint	UN	undulating	S	smooth	VN	veneer
SS	sheared surface	ST	stepped	SL	slickensided	CT	coating
SZ	sheared zone	IR	irregular	POL	polished		
SM	seam, VO void	DIS	discontinuous				

GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:30

coffey geotechnics

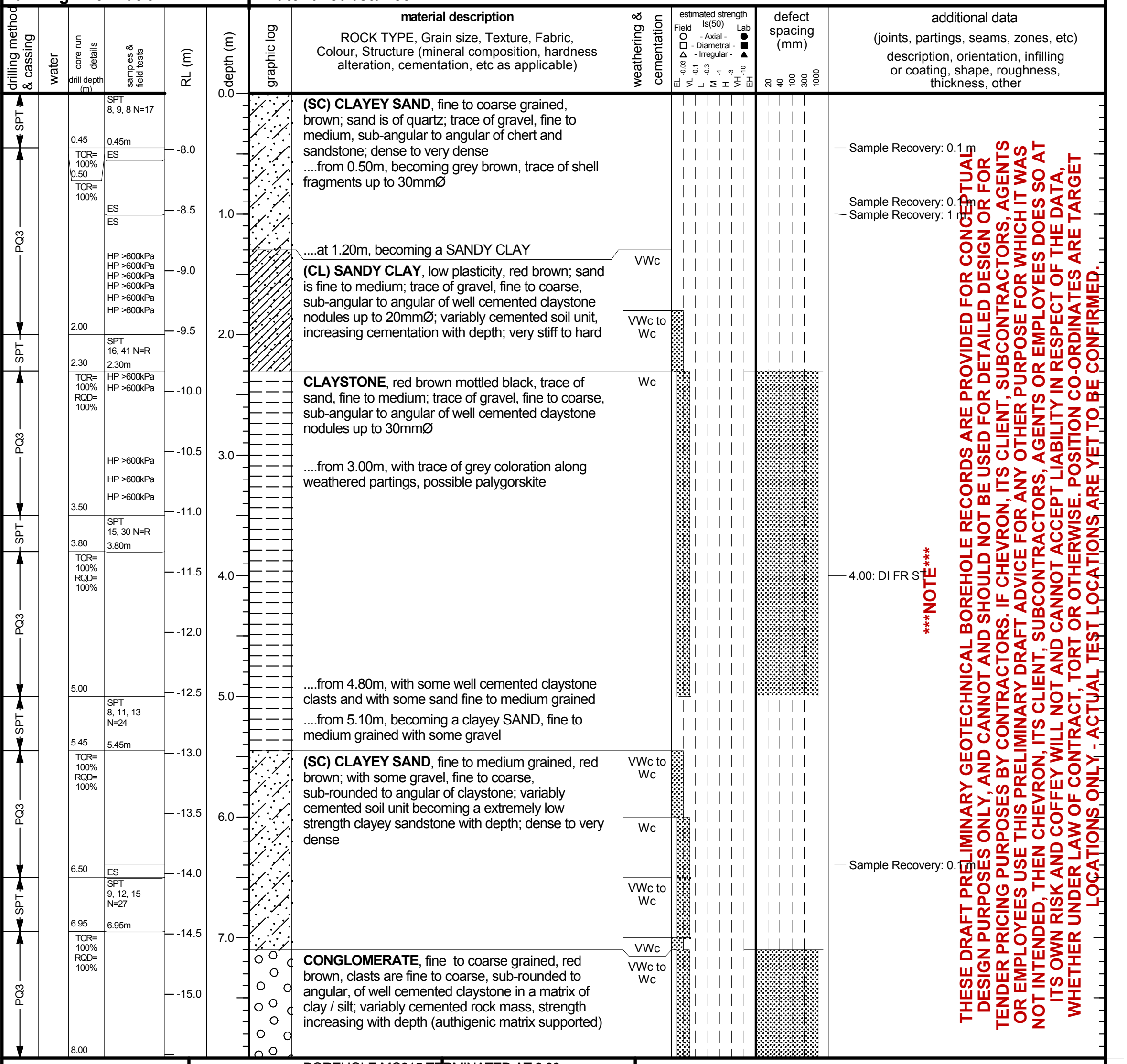
Engineering Log - Cored Borehole

Hole No. **MC015**
Sheet No. 1 of 1
Project No. **GEOTHERD08668AA**

Client : ***Chevron Australia Pty Ltd***
Principal :
Project : ***Wheatstone Development Project***
Location : ***Ashburton North***

Date started : ***1/7/09***
Date completed : ***2/7/09***
Logged by : ***MG***
Checked by :

Position : E: 293815.59, N: 7606981.11 (50 MGA94)
Rig type : UDR100
Surface Elevation : -7.53m (AHD)
Mounting : Jack up Barge
Angle from horizontal : 90°
Hole Diameter : 123 mm



drilling information

drilling method & casing	core run details drill depth (m)	samples & field tests
SPT	0.45	SPT 8, 9, 8 N=17 0.45m
PQ3	TCR= 100% 0.50 TCR= 100% 2.00	ES ES ES HP >600kPa HP >600kPa HP >600kPa HP >600kPa HP >600kPa HP >600kPa
SPT	2.30	SPT 16, 41 N=R 2.30m
PQ3	TCR= 100% RQD= 100% 3.50	HP >600kPa HP >600kPa HP >600kPa HP >600kPa HP >600kPa
SPT	3.80	SPT 15, 30 N=R 3.80m
PQ3	TCR= 100% RQD= 100% 5.00	
SPT	5.45	SPT 8, 11, 13 N=24 5.45m
PQ3	TCR= 100% RQD= 100% 6.50	ES
SPT	6.95	SPT 9, 12, 15 N=27 6.95m
PQ3	TCR= 100% RQD= 100% 8.00	

water

RL (m): -8.0, -8.5, -9.0, -9.5, -10.0, -10.5, -11.0, -11.5, -12.0, -12.5, -13.0, -13.5, -14.0, -14.5, -15.0

depth (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0

material substance

graphic log	material description ROCK TYPE, Grain size, Texture, Fabric, Colour, Structure (mineral composition, hardness alteration, cementation, etc as applicable)	weathering & cementation
	(SC) CLAYEY SAND, fine to coarse grained, brown; sand is of quartz; trace of gravel, fine to medium, sub-angular to angular of chert and sandstone; dense to very dense ....from 0.50m, becoming grey brown, trace of shell fragments up to 30mmØ ....at 1.20m, becoming a SANDY CLAY	
	(CL) SANDY CLAY, low plasticity, red brown; sand is fine to medium; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules up to 20mmØ; variably cemented soil unit, increasing cementation with depth; very stiff to hard	VWc VWc to Wc
	CLAYSTONE, red brown mottled black, trace of sand, fine to medium; trace of gravel, fine to coarse, sub-angular to angular of well cemented claystone nodules up to 30mmØ ....from 3.00m, with trace of grey coloration along weathered partings, possible palygorskite ....from 4.80m, with some well cemented claystone clasts and with some sand fine to medium grained ....from 5.10m, becoming a clayey SAND, fine to medium grained with some gravel	Wc
	(SC) CLAYEY SAND, fine to medium grained, red brown; with some gravel, fine to coarse, sub-rounded to angular of claystone; variably cemented soil unit becoming a extremely low strength clayey sandstone with depth; dense to very dense	VWc to Wc Wc VWc to Wc
	CONGLOMERATE, fine to coarse grained, red brown, clasts are fine to coarse, sub-rounded to angular, of well cemented claystone in a matrix of clay / silt; variably cemented rock mass, strength increasing with depth (authigenic matrix supported)	VWc VWc to Wc

BOREHOLE MC015 TERMINATED AT 8.00 m

estimated strength Is(50)
Field ○ - Axial - ● Lab
□ - Diametral - ■
△ - Irregular - ▲
EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH

defect spacing (mm)
20 40 100 300 1000

additional data
(joints, partings, seams, zones, etc)
description, orientation, infilling or coating, shape, roughness, thickness, other

Sample Recovery: 0.1 m
Sample Recovery: 0.1m
Sample Recovery: 1 m
4.00: DI FR ST
Sample Recovery: 0.1m

NOTE
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graphic log / core recovery
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10 Oct., 73 Water Level on Date shown
water inflow
water outflow
25 water pressure test result (lugeons) for depth interval shown

cementation

VWc	v. weakly cemented
Wc	weakly cemented
MWc	mod. weakly cemented
Mc	moderately cemented
Hc	well cemented
VHc	v. well cemented

weathering

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
FR	Fresh Rock

strength

EL	extremely low
VL	very low
L	low
M	medium
H	high
VH	very high

defect type

BP	bedding parting
CS	crushed seam
FC	fracture, JT joint
SS	sheared surface
SZ	sheared zone
SM	seam, VO void

planarity

PR	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular
DIS	discontinuous

roughness

VR	very rough
RF	rough
S	smooth
SL	slickensided
POL	polished

coating

CN	clean
SN	stained
VN	veneer
CT	coating

GEOTPERT_01.GLB Log CORED BOREHOLE - PRELIM GH08668AA_GEOTECH_NEARSHORE.GPJ <<DrawingFile>> 24/07/2009 12:30

Appendix E Core Photos (Coffey)

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GEOTHERD08668AA WHEATSTONE PROJECT CHEVRON MC001 0.0-3.0m 3/7/09 MG TRAY 1
SPT 0.0-0.45m N=27 REC:450mm
0.45m ENV. SAMPLE 0.55m
0.9m ENV SAMPLE 1.0m
2m
SPT 2.0-2.3m N=R REC=300mm 2.3m
0.0m
1.0m
2.0m
3.0m


GEOTHERD08668AA WHEATSTONE PROJECT CHEVRON MC001 3.0-6.0m 3/7/09 MG TRAY 2
SPT 3.5-3.95m N*=18 REC=450mm
ENV. SAMPLE
3.5m
5m
5.45m
SPT 5.0-5.45m N*=23 REC=450mm
5.0m
4.0m
5.0m
6.0m
3.0m
4.0m
5.0m


7m EOH
6.95m
SPT 6.5-6.95m N*=39 Rec=450mm
6.5m
ENV. SAMPLE
6.4m
6m


GEOTHERD003668AA WHEATSTONE PROJECT CHEVRON MC002 3.0-6.0m 3/7/09 MG TRAY 2
CORE LOSS 3.1-3.5m (0.4m)
SPT 3.5-3.95m N*=48 REC=450mm
SPT 5.0-5.45m N*=31 REC=450mm
3.0m
4.0m
5.0m
6.0m
3.1m
3.5m
3.95m
5m
5.45m


SPT 6.5-6.95m N*=26 REC:450mm
6.95m
6.5
ENV. SAMPLE
8m EOH
7.3m
6.0-8.0m EOH
MC002
CHEVRON
WHEATSTONE PROJECT
TRAY 3
7.0m
8.0m EOH
6.0m
7.0m


GEOTHERDOBGGAA WHEATSTONE PROJECT CHEVRON MC002 0.0-3.0m 3/1/09 MG TRAY 1
SPT 0.0-0.45m N*=7 REC=450mm
CORELOSS 0.45-0.85m (0.4m)
ENV. SAMPLE 1.0
ENV. SAMPLE 2.0m
SPT 2.0-2.45m N*=20 REC=450MM
ENV. SAMPLE 3.0
0.0m
1.0m
2.0m
3.0m


GEOTHERDOBOSSAN WHEATSTONE PROJECT CHEVRON MC003 0.0-3.0m 4/7/09 MC TRM 1
0.0m
1.0m
2.0m
3.0m
SPT 0.0-0.45m N*=6 REC=450mm
0.45m
ENV. SAMPLE
0.55m
0.9m ENV. SAMPLE
1.0m
SPT 1.0-1.45m N*=35 REC=450mm
1.45m
2.5m
SPT 2.5-2.95m N*=28 REC=450mm
2.95m


WHEATSTONE PROJECT CHEVRON MC003 3.0-6.0m 4/7/10 M6 TRAY 2
3.0m
3.15m
3.4m
ENV. SAMPLE
3.5m
CORELOSS 3.5-4.0m (500mm)
4.0m
4.0m
SPT 4.0-4.45m N*= 46 REC=450mm
4.45m
5.0m
5.0m
5.5m
SPT 5.5-5.95m N*=32 REC=450mm
5.95m
6.0m


7.0m
8.0m
9.0m EoH
7.0m
6.9m ENV. SAMPLE
9.0m EoH
GEOTHERDO08668AH WHEATSTONE PROJECT CHEVRON MC003 6.0-9.0m EoH 5/1/09 MG TRM 3
8.5m
7.35m
SPT 7.0-7.35m N*=R REC=350mm
7.0m
6.0m
7.0m
8.0m


4.0m
5.0m
6.0m
4.0m
ENV. SAMPLE
3.9m
4.45
SPT 4.0-4.45m N:20 REC:450mm
4.0m
5.95m
SPT 5.5-5.95m N:42 REC:450mm
5.5m
WHEATSTONE PROJECT
CHEVRON
MC004
3.0-6.0m
5/7/09
MG
TRAY 2
3.0m
4.0m
5.0m


7.0m
8.0m
9.0m
7m
WHEATSTONE PROJECT CHEVRON MC004 6.0-9.0m 5/07/08 MG TRAY 3
7.45m
SPT 7.0-7.45m N* = 31 REC: 450mm
8.37m
SPT 8.5-8.77m N*R REC: 270mm
8.5m
8.1m
ENV. SAMPLE
8.0m
6.0m
7.0m
8.0m


10.0m EOH
10.0m EOH
9.0m


GEOTHERD08668AA WHEATSTONE PROJECT CHEVRON MC004 0.0 - 6.0m 5/7/09 MG TRAY 1
SPT 0.0-0.45m N*=12 REC=450mm
0.45m
0.9 ENV. SAMPLE 1.0
SPT 1.0-1.45m N*=17 REC=450mm
1.45m
2.5m
SPT 2.5-2.95m N*=31 REC=450mm
2.95m
0.0m
1.0m
2.0m
3.0m


WHEATSTONE PROJECT CHEVRON MC005 3.0-6.0m 6/2/09 MG TRAY 2
3.0m
ENV. SAMPLE 3.1m
4.0m
SPT 4.0-4.45m N=29 REC:450mm
4.45m
5.0m
5.5m
SPT 5.5-5.77m N=R REC:270mm
5.77m
6.0m


7.0m
8.0m
9.0m
6.9m ENV SAMPLE 7.0m
8.5
GH0866 9221 WHEATSTONE PROJECT CHEVRON MC005 6.0-9.0m 6/7/09 M6 TRAY 3
6.0m
7.0m
8.0m


10.0m
10.5m EOH
10m
10.5m EOH
WHEATSTONE PROJECT
CHEVRON
MC005
9.0-10.5m EOH
6/7/08
MG
TRAY 4
9.0m
10.0m


1.0m
2.0m
3.0m
ENV. SAMPLE
0.9m
1.0m
2.87m
SPT 2.5-2.87m N*=R REC:370mm
0.55m
0.45m
ENV. SAMPLE
SPT 0.0-0.45m N*=8 REC:450mm
1.45m
SPT 1.0-1.45m N*=51 REC:450mm
1.0m
2.5m
GH08608PA WHEATSTONE PROJECT CHEVRON MC005 0.0-3.0m 6/7/08 MG TRAY 1
0.0m
0.0m
1.0m
2.0m


7.0m
8.0m
9.0m
9.0m
WHEATSTONE PROJECT CHEVRON NC006 6.0-9.0m 8/7/09 MG TRAY 3
7.5m
6.0m
7.0m
8.0m


10.0m
11.0m
12.0m EOH
10.0m
9.9m ENV. SAMPLE
12.0m EOH
TRAY 4
MG
9/7/09
9.0-12.0m EOH
MC006
CHEVRON
WHEATSTONE PROJECT
GH08608A
10.5m
9.0m
10.0m
11.0m


0.0m
1.0m
2.0m
3.0m
CHEVRON WHEATSTONE PROJECT CHEVRON MC006 0.0-3.0m 8/3/08 MG TRAY 1
SPT 0.0-0.45M N:16 REC:150mm
0.45 ENV. SAMPLE 0.55
0.9 ENV. SAMPLE 1.0m
SPT 1.5-1.89m N:R REC:390MM
1.5
1.89m


G1006-AA WHEATSTONE PROJECT CHEVRON MC006 3.0-6.0m 8/7/09 MG TRAY 2
SPT 3.0-3.26m N°: R
REC: 260mm
ENV. SAMPLE
SPT 4.5-4.95m N°: 45 REC: 450mm
3.0m
4.0m
5.0m
6.0m

W8
SPT 6.5-6.76m N=7
REC=260mm
6.76m
6.5m
CH0BGR AA WHEATSTONE PROJECT CHEVRON MC007 6.0-9.0m 27/6/09 MG TRAY 3


10m
11m
12m EOH
11m
12.0m EOH
9.5m
GHO6688A WHEATSTONE PROJECT CHEVRON MC007 9.0 - 12.0m EOH 27/6/09 MG TRAY 4
9m
10m
11m


4m
5m
6m
3.95m
SPT 3.5-3.95m N*:19 REC:450mm
TRAY 2
MG
26/6/08
3.0-6.0m
MC002
CHEVRON
WHEATSTONE PROJECT
3.5m
5m
4.85m
5.45m
SPT 5.0-5.45m N*:43 REC:450mm
5m
4m
5m


0m
1m
2m
3m
GH0860844 WHEATSTONE PROJECT CHEVRON MC007 0.0-3.0m MG TRAY 1 26-6-09
0.9m
ENV SAMPLE
0.8m
0.55m
ENV SAMPLE
0.45m
SPT 0.0-0.45m N*:10 Rec:450mm
2.45m
SPT 2.0-2.45m N*:21 Rec:450mm


TRAY 1
MG
0.0-3.0m
MC008
CHEVRON
WHEATSTONE PROJECT
SPT 0.0-0.45m N:18 REC:450mm
0.45m
ENV. SAMPLE
0.55m
0.8m
ENV SAMPLE
0.9m
1.5m
SPT 1.5-1.95m N:12 REC:450mm
1.95m
3m
0m
1m
2m


4m
5m
6m
GHOTGAFFA WHEATSTONE PROJECT CHEVRON MEC008 3-6.0m 25/6/10A MG TRAY 2
SPT 3.0-3.45m N=15 Rec: 450mm
3.45
CORE LOSS 3.45-3.80m
ENV SAMPLE 3.8-3.9m
4.5m
SPT 4.5-4.95m N=32 Rec: 450mm
4.95m
6.0m
5.65m
3m
3m
4m
5m

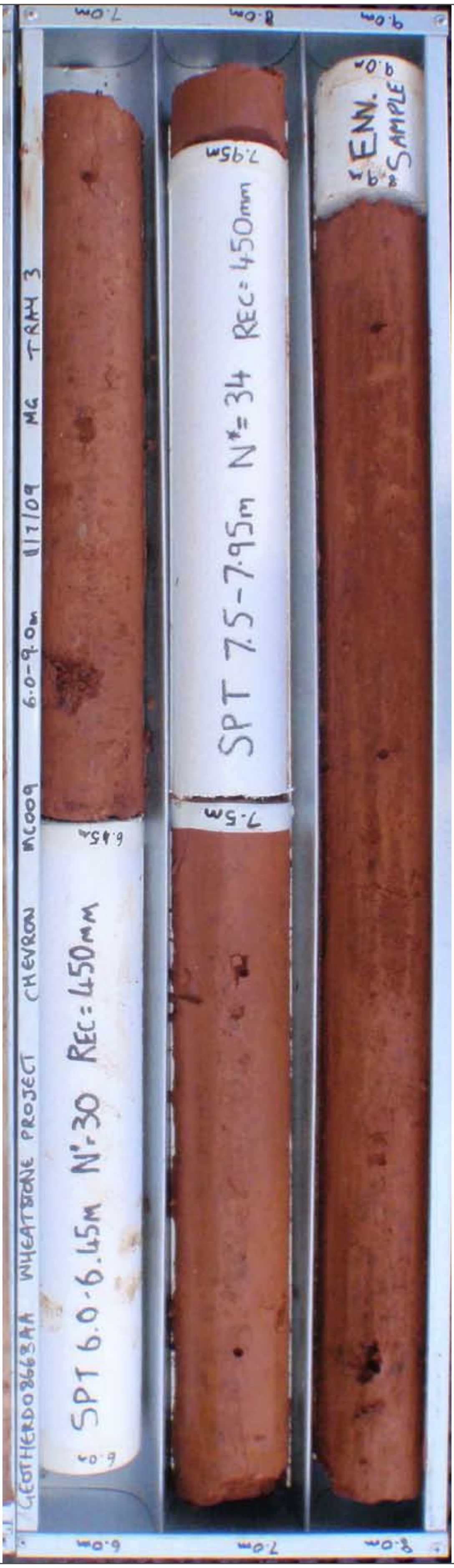

GH0868AA WHEATSTONE PROJECT CHEVRON MC008 6–9.0m 25/6/09 MG TRAY 3
SPT 6.0-6.45m N*=44 REC:450mm.
SPT: 7.5-7.95m N*=37 REC:450mm
7.95m
7.5m
ENV. SAMPLE 7m
CORELOSS 7.95-8.35m (0.45m)
8.35m
9m
7m
8m
9m
6m
7m
8m


GH036088A WHEATSTONE PROJECT CHEVRON MC008 9.0-12.0m 25/6/09 MG TRAY 4
SPT: 9-9.45m N*=62 REC=450mm
9.0m
9.46m
10.2
10.5m
12m
9m
10m
11m
10m
11m
12m


13m
13.5m EOH
WHEATSTONE PROJECT CHEVRON MC008 12.0 - 13.5m EOH 26/6/09 MG TRAY 5
13.5m EOH
12m
13m


1.0m
2.0m
3.0m
SPT 0.0-0.45m N*=10 REC=450mm
CORELOSS 0.45-1.0m (0.55m)
SPT 1.5-1.95m N*=16 REC=450mm
ENV SAMPLE
WHEATSTONE PROJECT CHEVRON
0.0-3.0m
MG
TRAY 1
0.0m
1.0m
2.0m


SPT 3.0-3.45m N*=35 REC=450mm
3.0m
3.45m
ENV. SAMPLE
4.0m
SPT 4.5-4.95m N*:19 REC:450MM
4.5m
4.95m
6m
WHEATSTONE PROJECT
CHEVRON
MC009
3.0-6.0m
TRAY 2
3.0m
4.0m
5.0m
4.0m
5.0m
6.0m


7.0m
8.0m
9.0m
GEOTHERD0863AA WHEATSTONE PROJECT CHEVRON MC009 6.0-9.0m 1/7/09 MG TRAY 3
6.45m
SPT 6.0-6.45M N*=30 REC: 450MM
6.0m
7.95m
SPT 7.5-7.95m N*=34 REC: 450mm
7.5m
9.0m
ENV. SAMPLE
8.9
6.0m
7.0m
8.0m


10.0m
11.0m
12.0m
12m
10.8m
SPT 10.5-10.8m N*= R REC= 300mm
10.5m
9.45m
SPT 9.0-9.45m N*= 38 REC= 450
9.0m
GH09668AA WHEATSTONE PROJECT CHEVRON MC009 9.0-12.0m 12/1/09 MG TRAY 4
9.0m
10.0m
11.0m


13.0m
14.0m EOH
14m EOH
GEOTHERD08668AA WHEATSTONE PROJECT CHEVRON MC009 12.0 - 14.0m EOH 12/7/09 MG TRAY 5
13.5m
13.5 ENV. SAMPLE
12.0m
13.0m


WHEATSTONE PROJECT
CHEVRON
MC010
6.0-9.0m
9/7/09
MG
TRAY 3
6.0m
7.0m
8.0m
9.0m
CORELOSS 5.55-6.5m Cont.
6.5m
SPT 6.5-6.95 N*=48 REC=450mm
6.95m
7.9m
ENV. SAMPLE
8.0m
SPT 8.0-8.45m N*=34 REC=450mm
8.45m


GEOTHERD08668AA WHEATSTONE PROJECT CHEVRON MC010 9.0-12.0m 4/11/09 MG TRAY 4
SPT 9.5-9.7m
N*=R REC=200mm
9.7m
9.5m
11.0m
ENV SAMPLE
10.0m
11.0m
9.0m


0.0m
1.0m
2.0m
1.0m
2.0m
3.0m
GEOTHERD0868AA WHEATSTONE PROJECT CHEVRON MC010 0.0-3.0m 9/7/09 NIG TRAY 1
0.0m
SPT 0.0-0.45m N=17 REC=450mm
0.45m
ENV. SAMPLE
0.55m
0.9
ENV. SAMPLE
1.0m
1.82
CORELOSS (0.18m)
2.0
2.0m
SPT 2.0-2.45m N=49 REC=450mm
2.45m

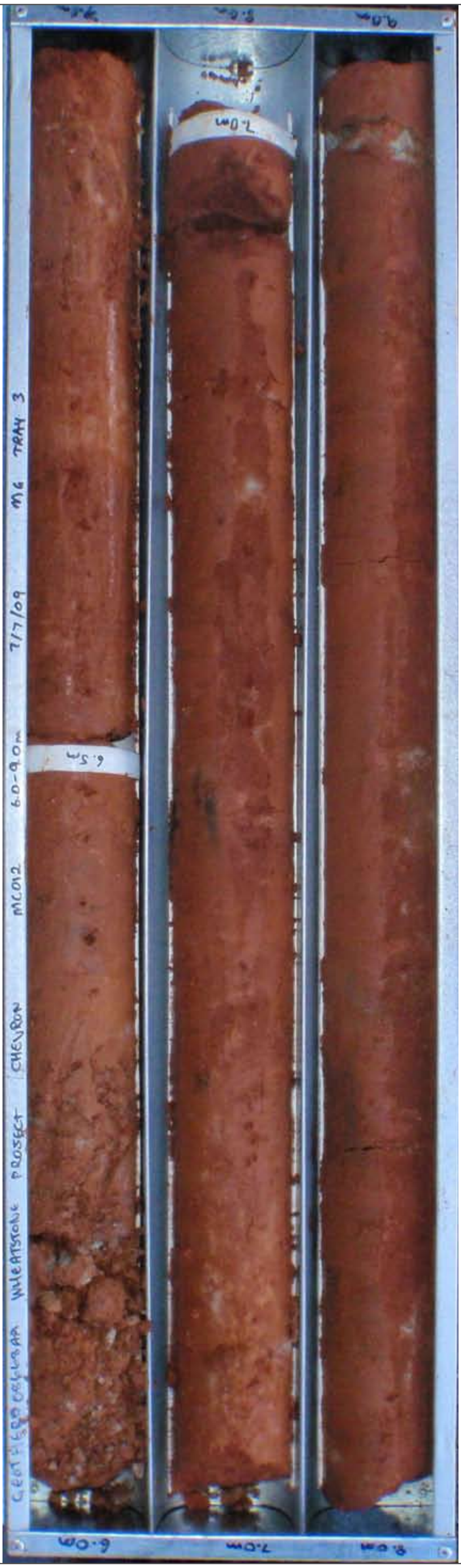

GEOTHERDO866BAA WHEATSTONE PROJECT CHEVRON MC010 3.0-6.0m 9/7/09 MG TRAY 2
SPT 3.5-3.95m N°=44 REC=450mm
3.95m
ENV. SAMPLE 3.4 3.5
5.0m
SPT 5.0-5.45m N*=31 REC=450mm
5.45m
CORE LOSS 5.55-6.5m (0.95m)
3.0m
4.0m
5.0m

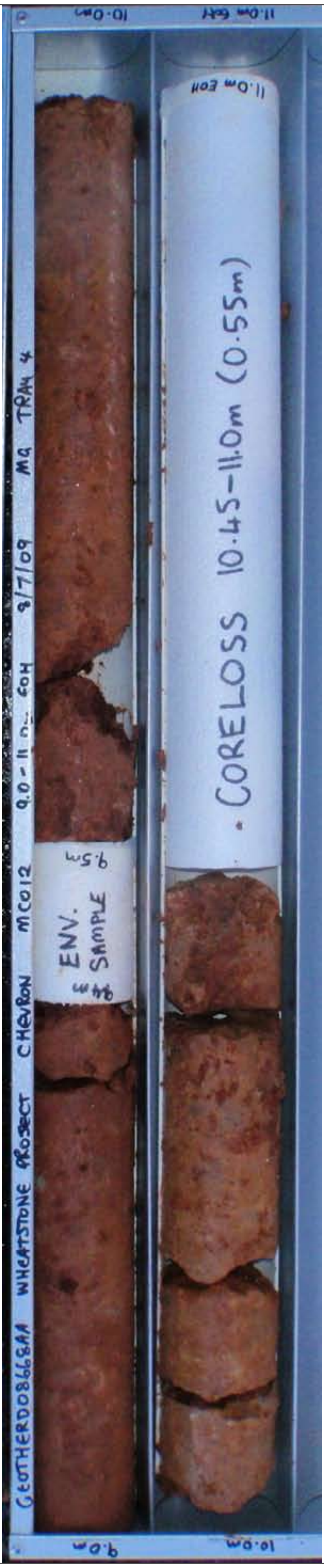

7.0m
8.0m
9.0m
9m
GHDGLOBAL WHEATSTONE PROJECT CHEVRON MC011 6.0-9.0m 28/6/09 MG TRAY 3
7.55
BULK SAMPLE
6.0m
7.0m
8.0m


10m
10.5m EOH
GEOTHERD0868AA WHEATSTONE PROJECT CHEVRON MCOLL 9.0-10.5m 28/6/09 MG TRAY 4
10.5m EOH
9.0m
10.0m


GEOTHERD08668AA WHEATSTONE CHEVRON MC011 0.0 - 3.0m TRAY 1 MG 27/6/09
SPT 0.0-0.45m N*=9 REC: 450mm
SPT 1.5-1.95m N*=19 REC: 450mm
ENV. SAMPLE
0.0m
0.45m
1.0m
1.5m
1.95m
2.0m
3.0m


SPT 3.0-3.4m N:R REC:400mm
ENV. SAMPLE
SPT 4.5-4.9m N:R REC:400mm
4.5m
4.9m
6.0m
3.0-6.0m
TRAY 2
CHEVRON
4m
5m
6m


8.0m
9.0m
7.0m
6.5m
GEOTHERO COLLBAR WHEATSTONE PROJECT CHEVRON MC012 6.0-9.0m 7/7/09 MG TRAY 3
6.0m
7.0m
8.0m


GEOTHERD0866AA WHEATSTONE PROJECT CHEVRON MC012 9.0-11.0m EOH 8/7/09 MQ TRAY 4
CORELOSS 10.45-11.0m (0.55m)
ENV. SAMPLE
9.4m
9.5m
10.0m
11.0m EOH
9.0m
10.0m
11.0m EOH


GEOTHERD0866BAA WHEATSTONE PROJECT CHEVRON MC012 0.0-3.0m 7/7/09 MG TRAY 1
1.0m
2.0m
3.0m
0.9m ENV. SAMPLE
1.0m
0.55m
ENV. SAMPLE
0.45m
SPT 0.0-0.45m N=2 Rec=450mm
0.0m
2.0m
1.45m
SPT 1.0m-1.45m N=28 Rec=450mm
1.0m
2.38m
SPT 2.0-2.38 N=R Rec=380mm
2.0m
0.0m
1.0m
2.0m


4.0m
5.0m
6.0m
3.15m
5.0m
SPT 3.5-3.95m N*=48 REC=450mm
WHEATSTONE PROJECT CHEVRON MC012 3.0-6.0m 7/7/09 MG TRAY 2
3.5m
ENV. SAMPLE 4.0m
SPT 5.0-5.18m N*=R REC=180mm
3.0m
4.0m
5.0m


4.0m
5.0m
6.0m
GEOTHERDOR668A1 WHEATSTONE PROJECT CHEVRON MC013 3.0-6.0m 29/6/09 TRAM 2 MG
SPT 3.5-3.95m N:43 REC: 450mm
3.5
3.95
ENV SAMPLE
5.0m
5.45
SPT 5.0-5.45m N*=24 Rec=450mm
5.0m
3.0m
4.0m
5.0m


GEOTHERDOBLEBAA WHEATSTONE PROJECT CHEVRON MC013 6.0 - 9.0m 29/6/09 MG TRAY 3
SPT 6.5 - 6.95m N* = 27 REC = 450mm
6.95 → 7.0m ENV SAMPLE
SPT 8.0 - 8.4m N* = R REC = 400mm
6.0m
7.0m
8.0m
9.0m


GEOTHERDO0868AA, WHEATSTONE PROJECT, CHEVRON, MC013, 9.0→9.5m EOH, 30/6/09, MG, TRAY 4
9.5m EOH
9.0m


GEOTHERD0866BAA WHEATSTONE PROJECT CHEVRON MC013 0.0-3.0m 28/8/09 TRAY 1 MG
SPT 0.0-0.45m N*=22 REC=450MM
0.45m ENV. SAMPLE 0.55m
0.8 ENV. SAMPLE
2m
SPT 2.0-2.45m N*=37 Rec=450mm
0.0m
1.0m
2.0m


3m
4m
5m
4m
5m
6m
GHOBGEBRA
WHEATSTONE PROJECT
CHEVRON
MC014
3.0-6.0m
30/6/09
MF
TRAY 2
ENV SAMPLE 3.4-3.5m
3.4m
3.5m
SPT 3.5-3.95m N*=R
REC=450mm
3.95m
5.0m


7m
8m
8.5m EOH
ENV SAMPLE 6.9-7.0m
6.9m
SPT 6.5-6.9m N: R REC: 400mm
6.5m
GHORLEBAR WHEATSTONE PROJECT CHEVRON MK014 6.0-8.5m EOH 30/6/08 MG TRAY 3
8.5m EOH
6m
7m
8m


GEOTHERD 8668A1 WHEATSTONE PROJECT CHEVRON MC04 0.0-3.0m 30/6/09 TRAY 1 MG
SPT 0.0-0.45m N*:31 REC:450mm
0.45m ENV. SAMPLE 0.55m
0.8m ENV. SAMPLE
2m
SPT 2.0-2.45m N*:50 REC:450mm
2.45m
0.0m
1.0m
2.0m
3.0m


GEOTHERDOS668AR WHEATSTONE PROJECT CHEVRON MC015 3.0-6.0m 2/7/09 MG TRAY 2
SPT 3.5-3.8m N:R REC:
3.8
3.5m
ENV SAMPE 3.4-3.5m
3.4
5.0m
SPT 5.0-5.45m N:24 REC:450mm
5.45
4.0m
5.0m
6.0m
3.0m
4.0m
5.0m


GEOTHERD08663AA WHEATSTONE PROJECT CHEVRON MC015 6.0 - 8.0m EOH TRAY 3 2/7/09 MC
ENV SAMPLE
6.5m
SPT 6.5-6.95m N:27 Rec:450mm
6.95
7.0m
8.0m EOH
6.0m
7.0m


1.0m
2.0m
3.0m
GEOTHERDO8668AA WHEATSTONE PROJECT CHEVRON MC015 0.0-3.0m 2/7/09 MC TRAY 1
ENV. SAMPLE
ENV. SAMPLE
SPT 0.0-0.45m N=17 R=450mm
SPT 2.0-2.30m N=R Rec: 300mm
0.0m
1.0m
2.0m

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Appendix F Coffey Geological Cross-Section

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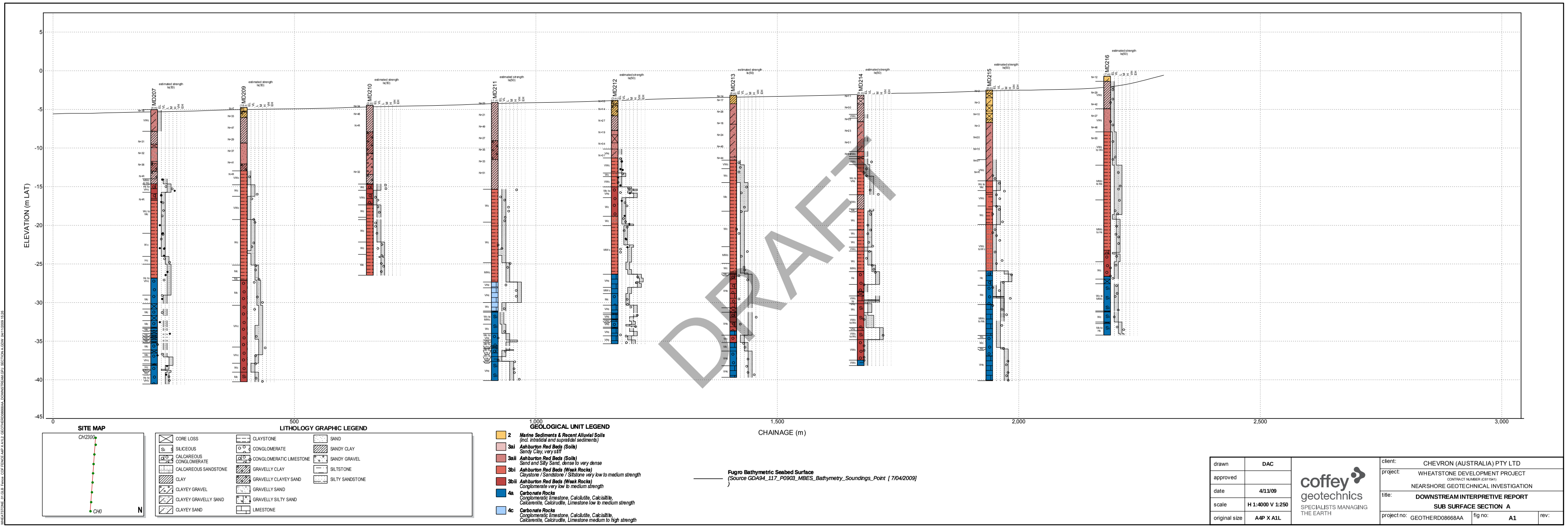

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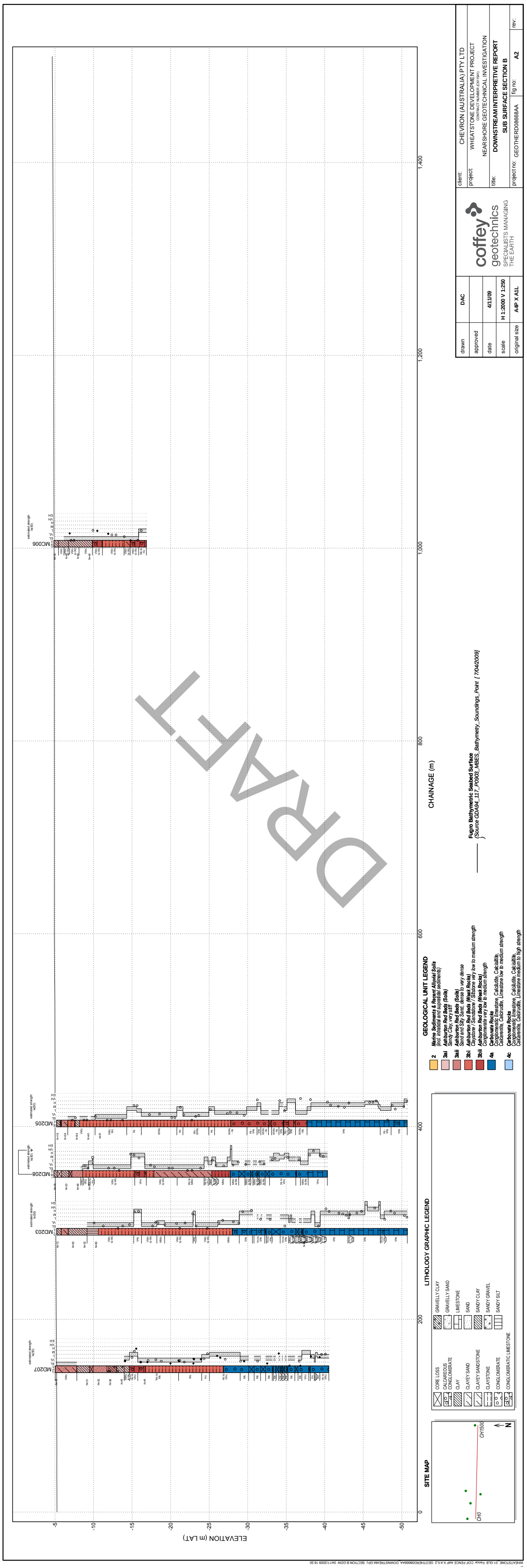
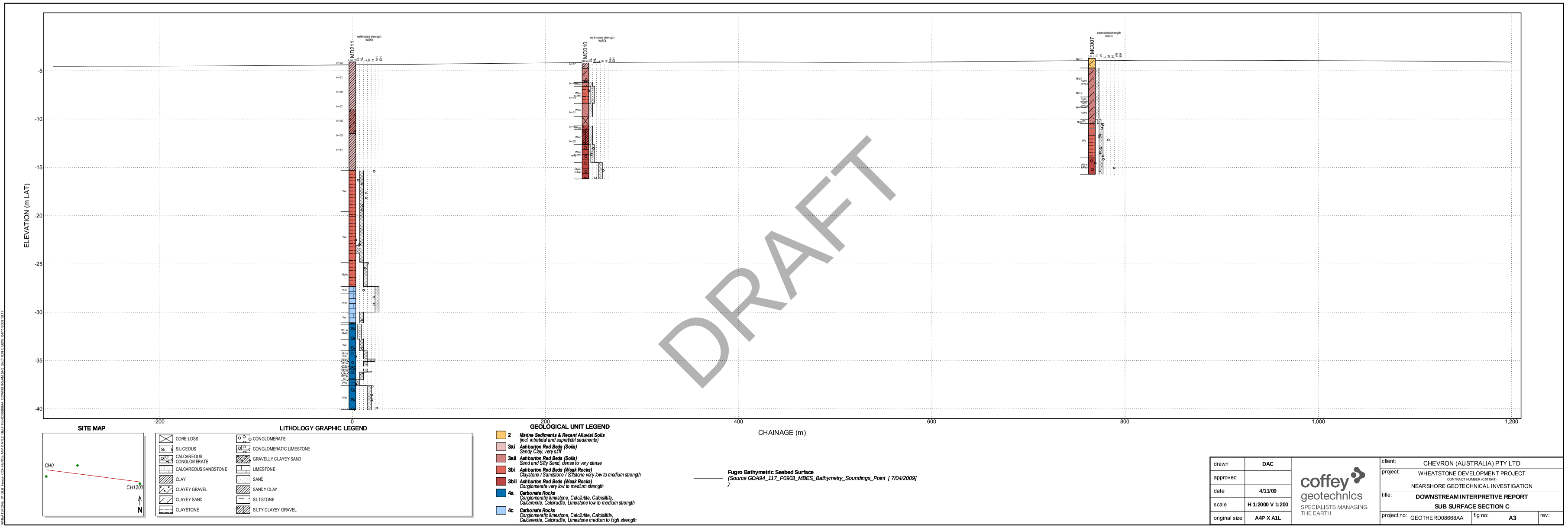
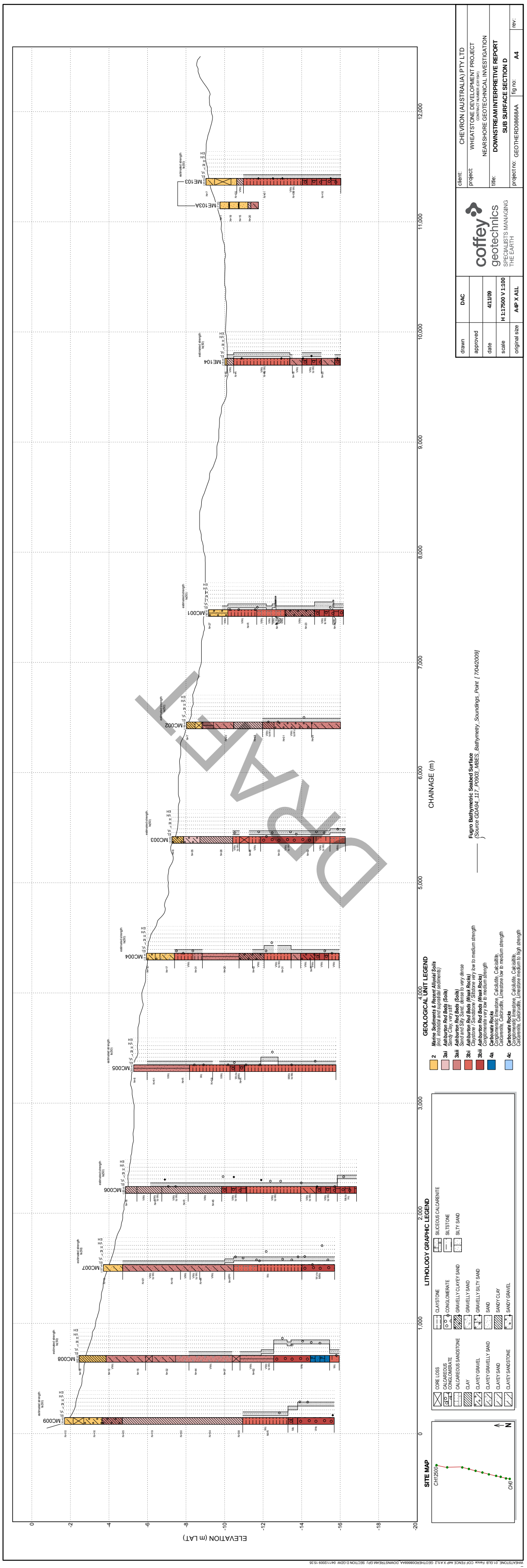
approved		project:	WHEATSTONE DEVELOPMENT PROJECT CONTRACT NUMBER (C611541) NEARSHORE GEOTECHNICAL INVESTIGATION
date	4/11/09	title:	DOWNSTREAM INTERPRETIVE REPORT SUB SURFACE SECTION A
scale	H 1:4000 V 1:250	project no:	GEOTHERD08668AA
original size	A4P X A1L	fig no:	A1
		rev:	


ELEVATION (m LAT)
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
CHAINAGE (m)
0
200
400
600
800
1,000
1,200
1,400
MD207
MD203
MD208
MD205
MD006
DRAFT
SITE MAP
CH0
CH1500
N
LITHOLOGY GRAPHIC LEGEND
CORE LOSS
CALCAREOUS CONGLOMERATE
CLAY
CLAYEY SAND
CLAYEY SANDSTONE
CLAYSTONE
CONGLOMERATE
CONGLOMERATIC LIMESTONE
GRAVELLY CLAY
GRAVELLY SAND
LIMESTONE
SAND
SANDY CLAY
SANDY GRAVEL
SANDY SILT
GEOLOGICAL UNIT LEGEND
2 Marine Sediments & Recent Alluvial Soils (incl. intratidal and supratidal sediments)
3ai Ashburton Red Beds (Soils) Sandy Clay, very stiff
3aii Ashburton Red Beds (Soils) Sand and Silty Sand, dense to very dense
3bi Ashburton Red Beds (Weak Rocks) Claystone / Sandstone / Siltstone very low to medium strength
3bii Ashburton Red Beds (Weak Rocks) Conglomerate very low to medium strength
4a Carbonate Rocks Conglomeratic limestone, Calcilutite, Calcisiltite, Calcarenite, Calcirudite, Limestone low to medium strength
4c Carbonate Rocks Conglomeratic limestone, Calcilutite, Calcisiltite, Calcarenite, Calcirudite, Limestone medium to high strength
Fugro Bathymetric Seabed Surface
(Source GDA94_117_P0903_MBES_Bathymetry_Soundings_Point [7/04/2009])
drawn DAC
approved
date 4/11/09
scale H 1:2000 V 1:250
original size A4P X A1L
coffey geotechnics
SPECIALISTS MANAGING THE EARTH
client: CHEVRON (AUSTRALIA) PTY LTD
project: WHEATSTONE DEVELOPMENT PROJECT
CONTRACT NUMBER (C611541)
NEARSHORE GEOTECHNICAL INVESTIGATION
title: DOWNSTREAM INTERPRETIVE REPORT
SUB SURFACE SECTION B
project no: GEOTHERD08668AA
fig no: A2
rev:



drawn	DAC	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	CHEVRON (AUSTRALIA) PTY LTD
approved			project:	WHEATSTONE DEVELOPMENT PROJECT CONTRACT NUMBER (C611541) NEARSHORE GEOTECHNICAL INVESTIGATION
date	4/11/09		title:	DOWNSTREAM INTERPRETIVE REPORT SUB SURFACE SECTION C
scale	H 1:2000 V 1:200		project no: GEOTHERD08668AA	fig no: A3 rev:
original size	A4P X A1L			


MC009
MC008
MC007
MC006
MC005
MC004
MC003
MC002
MC001
ME104
ME103A
ME103
DRAFT
ELEVATION (m LAT)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
CHAINAGE (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
SITE MAP
CH12500
CH0
N
LITHOLOGY GRAPHIC LEGEND
CORE LOSS
CALCAREOUS CONGLOMERATE
CALCAREOUS SANDSTONE
CLAY
CLAYEY GRAVEL
CLAYEY GRAVELLY SAND
CLAYEY SAND
CLAYEY SANDSTONE
CLAYSTONE
CONGLOMERATE
GRAVELLY CLAYEY SAND
GRAVELLY SAND
GRAVELLY SILTY SAND
SAND
SANDY CLAY
SANDY GRAVEL
SILICEOUS CALCARENITE
SILTSTONE
SILTY SAND
GEOLOGICAL UNIT LEGEND
2 Marine Sediments & Recent Alluvial Soils (incl. intratidal and supratidal sediments)
3ai Ashburton Red Beds (Soils) Sandy Clay, very stiff
3aii Ashburton Red Beds (Soils) Sand and Silty Sand, dense to very dense
3bi Ashburton Red Beds (Weak Rocks) Claystone / Sandstone / Siltstone very low to medium strength
3bii Ashburton Red Beds (Weak Rocks) Conglomerate very low to medium strength
4a Carbonate Rocks Conglomeratic limestone, Calcilutite, Calcisiltite, Calcarenite, Calcirudite, Limestone low to medium strength
4c Carbonate Rocks Conglomeratic limestone, Calcilutite, Calcisiltite, Calcarenite, Calcirudite, Limestone medium to high strength
Fugro Bathymetric Seabed Surface
(Source GDA94_117_P0903_MBES_Bathymetry_Soundings_Point [7/04/2009])
drawn DAC
approved
date 4/11/09
scale H 1:17500 V 1:100
original size A4P X A1L
coffey geotechnics
SPECIALISTS MANAGING THE EARTH
client: CHEVRON (AUSTRALIA) PTY LTD
project: WHEATSTONE DEVELOPMENT PROJECT
CONTRACT NUMBER (C611541)
NEARSHORE GEOTECHNICAL INVESTIGATION
title: DOWNSTREAM INTERPRETIVE REPORT
SUB SURFACE SECTION D
project no: GEOTHERD08668AA
fig no: A4
rev:

Appendix G Analytical Test Results

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APPENDIX G
ASS Field Screening Test Results

Bore Location	Sample Depth		pH (F)	pH (Fox)	pH(change)	Reaction Rate
		Soil Type	pH Unit	pH Unit	pH Unit	slight/moderate/ high/vigorous
		Field Classification	0.1	0.1	0.1	
MC001	0.45-0.55	Sandy CLAY	8.8	6.5	2.3	Moderate
MC001	0.9-1.0	CLAYSTONE	8.6	6.5	2.1	Slight
MC001	(comp)1.0-2.0	CLAYSTONE	8.2	6.4	1.8	Slight
MC001	3.4-3.5	Clayey SANDSTONE	8.8	6.9	1.9	Strong
MC001	6.4-6.5	CONGLOMERATE	8.4	6.4	2	Slight
MC002	1.0-1.1	Silty SAND	8.4	6.7	1.7	Moderate
MC002	1.9-2.0	Clayey SAND	9	6.4	2.6	Slight
MC002	2.9-3.0	Sandy CLAY	7.9	6.4	1.5	Moderate
MC002	6.4-6.5	Clayey SAND	7.9	7	0.9	Strong
MC003	0.45-0.55	Clayey SAND	8.6	6.6	2	Slight
MC003	0.9-1.0	Sandy CLAY	8.5	6.7	1.8	Slight
MC003	(comp)1-2	Sandy CLAY	8.7	6.5	2.2	Slight
MC003	3.4-3.5	CLAY	7.5	6.9	0.6	Strong
MC003	6.9-7.0	CONGLOMERATE	7	6.1	0.9	Slight
MC004	0.5-1.0	Clayey Sandy GRAVEL	8.5	6.8	1.7	Moderate
MC004	(comp)1.0-2.0	Sandy CLAY	8.8	6.7	2.1	Slight
MC004	3.9-4.0	Sandy CLAY	8.4	6.9	1.5	Moderate
MC004	8.0-8.1	Sandy CLAY	8.3	6.4	1.9	Slight
MC005	0.45-0.55	Clayey SAND	8.5	6.6	1.9	Slight
MC005	0.9-1.0	Sandy CLAY	8.6	6.7	1.9	Slight
MC005	(comp)1.0-2.0	Sandy CLAY	8.2	6	2.2	Slight
MC005	3.0-3.1	CLAYSTONE	7.8	6.8	1	Strong
MC005	6.9-7.0	CLAYSTONE	7.4	6.2	1.2	Slight
MC006	0.45-0.55	Sandy CLAY	8.1	7.4	0.7	Strong
MC006	0.9-1.0	CLAY	7.9	7.2	0.7	Strong
MC006	3.26-3.36	CLAYSTONE	7.1	7.1	0	Strong
MC006	9.9-10.0	Clayey SANDSTONE	6.9	6	0.9	Slight
MC006	1.0-2.0	CLAY	7.4	6.4	1	Strong
MC007	0.45-0.55	Sandy CLAY	8	6.5	1.5	Slight
MC007	0.8-0.9	Sandy CLAY	8.5	6.5	2	Slight
MC007	(comp)1.0-2.0	Clayey SAND	8.3	6.6	1.7	Moderate
MC008	0.45-0.55	Sandy CLAY	8.4	6.4	2	Slight
MC008	0.8-0.9	Sandy CLAY	8.5	6.5	2	Slight
MC008	(comp)2.0-3.0	Clayey SAND	7.6	6.1	1.5	Slight
MC008	3.8-3.9	Clayey SAND	7.6	6.6	1	Slight
MC008	7.0-7.1	SAND	7.7	6.5	1.2	Slight
MC009	1.0-1.1	Clayey GRAVEL	8.4	6.4	2	Slight
MC009	2.0-3.0	Gravelly CLAY	8	6.4	1.6	Slight
MC009	3.9-4.0	CLAY	7.6	6.5	1.1	Moderate
MC009	8.9-9.0	CLAY	7.3	6.8	0.5	Moderate
MC009	13.4-13.5	Calcareous CONGLOMERATE	7.8	6.7	1.1	Slight
MC010	0.45-0.55	Sandy CLAY	8.5	6.4	2.1	Slight
MC010	0.9-1.0	CLAY	8.5	6.4	2.1	Slight
MC010	1.0-2.0	CLAY	8	7.7	0.3	Strong
MC010	3.45-3.55	CLAYSTONE	7.9	6	1.9	Moderate
MC010	7.9-8.0	Silty Clayey SAND	7.2	6.5	0.7	Strong
MC010	10.9-11.0	Calcaerous CONGLOMERATE	7.4	6.7	0.7	Slight
MC11	0.0-0.4	Gravelly CLAY	8.3	6.9	1.4	Strong
MC11	1.0-1.1	Sandy CLAY	7.9	6.6	1.3	Slight
MC11	(comp)2.0-3.0	Sandy CLAY	8.1	6.2	1.9	Slight
MC11	3.5-3.6	CLAYSTONE	8	8.7	-0.7	Strong
MC11	7.45-7.55	SANDSTONE	8.1	7.2	0.9	Strong
MC012	0.45-0.55	Clayey SAND	8.4	6.6	1.8	Moderate
MC012	0.9-1.0	Sandy CLAY	8.4	6.4	2	Slight
MC012	9.4-9.5	CONGLOMERATE	7.3	6.5	0.8	Strong
MC012	(comp)1.0-2.0	Sandy CLAY	8.1	6.6	1.5	Slight
MC012	4.0-4.1	CLAYSTONE	7.4	6.2	1.2	Slight
MC013	0.45-0.55	Sandy CLAY	8.7	7.7	1	Moderate
MC013	0.8-0.9	Sandy CLAY	8.8	6.5	2.3	Moderate
MC013	(comp)1.0-2.0	CLAYSTONE	8.6	6.7	1.9	Strong
MC013	3.4-3.5	CLAYSTONE	8.3	7.1	1.2	Strong
MC013	7.9-8.0	CLAYSTONE	8.2	7.6	0.6	Strong
MC014	0.45-0.55	Clayey SAND	8.3	7.1	1.2	Moderate
MC014	0.8-0.9	Sandy CLAY	8.3	6.8	1.5	Slight
MC014	(comp)1.0-2.0	CLAYSTONE	8.4	6.4	2	Slight
MC014	3.4-3.5	CLAYSTONE	7.7	7.6	0.1	Strong
MC014	6.9-7.0	Clayey Gravelley SAND	7.8	7.4	0.4	Strong
MC015	0.45-0.55	Clayey SAND	8.6	6.6	2	Slight
MC015	(comp)1.0-2.0	Sandy CLAY	8.6	6.4	2.2	Slight
MC015	3.4-3.5	CLAYSTONE	7.8	6.1	1.7	Slight
MC015	6.4-6.5	Clayey SAND	8.4	6.8	1.6	Strong

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APPENDIX G

			Sample Type:	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
			ALS Sample number:	EP0904291047	EP0904291048	EP0904291049	EP0904291050	EP0904291051	EP0904291043
			Sample date:	03/07/2009	03/07/2009	03/07/2009	03/07/2009	03/07/2009	03/07/2009
			Client sample ID (1st):	MC001	MC001	MC001	MC001	MC001	MC002
			Client sample ID (2nd):	0.45-0.55	0.9-1.0	(comp)1.0-2.0	3.4-3.5	6.4-6.5	1.0-1.1
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**Sandy CLAY**	**CLAYSTONE**	**CLAYSTONE**	**Clayey SANDSTONE**	**CONGLOMERATE**	**Silty SAND**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**8.8**	**8.6**	**8.2**	**8.8**	**8.4**	**8.4**
pH (Fox)	pH Unit	0.1		**6.5**	**6.5**	**6.4**	**6.9**	**6.4**	**6.7**
Reaction Rate	-	1		**Moderate**	**Slight**	**Slight**	**Strong**	**Slight**	**Moderate**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9.2**	**9.1**	**9**	**9.2**	**9.2**	**9.3**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	<10	<10	<10	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**9.27**	**7.58**	**11.5**	**35.9**	**5.33**	**23**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**1850**	**1510**	**2300**	**7180**	**1060**	**4610**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**2.97**	**2.43**	**3.68**	**11.5**	**1.71**	**7.38**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	<10	<10	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2S0_4/tonne	-							
ANC	% CaCO3	-							

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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APPENDIX G

			Sample Type:	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
			ALS Sample number:	EP0904291044	EP0904291045	EP0904291046	EP0904291038	EP0904291039	EP0904291040
			Sample date:	03/07/2009	03/07/2009	04/07/2009	04/07/2009	04/07/2009	04/07/2009
			Client sample ID (1st):	MC002	MC002	MC002	MC003	MC003	MC003
			Client sample ID (2nd):	1.9-2.0	2.9-3.0	6.4-6.5	0.45-0.55	0.9-1.0	(comp)1-2
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**Clayey SAND**	**Sandy CLAY**	**Clayey SAND**	**Clayey SAND**	**Sandy CLAY**	**Sandy CLAY**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**9**	**7.9**	**7.9**	**8.6**	**8.5**	**8.7**
pH (Fox)	pH Unit	0.1		**6.4**	**6.4**	**7**	**6.6**	**6.7**	**6.5**
Reaction Rate	-	1		**Slight**	**Moderate**	**Strong**	**Slight**	**Slight**	**Slight**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9.1**	**8.8**	**9.3**	**9.3**	**9.2**	**9.2**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	<10	<10	<10	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**0.74**	**2.21**	**12.5**	**20.3**	**13.3**	**10.2**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**148**	**441**	**2500**	**4050**	**2650**	**2040**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**0.24**	**0.71**	**4.01**	**6.49**	**4.26**	**3.27**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	<10	<10	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2S0_4/tonne	-							
ANC	% CaCO3	-							

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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			Sample Type:	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
			ALS Sample number:	EP0904291041	EP0904291042	EP0904291034	GCA8529	EP0904291035	EP0904291036
			Sample date:	04/07/2009	05/07/2009	05/07/2009	05/07/2009	05/07/2009	05/07/2009
			Client sample ID (1st):	MC003	MC003	MC004	MC004	MC004	MC004
			Client sample ID (2nd):	3.4-3.5	6.9-7.0	0.5-1.0	0.5-0.56	(comp)1.0-2.0	3.9-4.0
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**CLAY**	**CONGLOMERATE**	**Clayey Sandy GRAVEL**	**-**	**Sandy CLAY**	**Sandy CLAY**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**7.5**	**7**	**8.5**	-	**8.8**	**8.4**
pH (Fox)	pH Unit	0.1		**6.9**	**6.1**	**6.8**	-	**6.7**	**6.9**
Reaction Rate	-	1		**Strong**	**Slight**	**Moderate**	-	**Slight**	**Moderate**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**8.6**	**9.1**	**9.3**	-	**9.3**	**9.4**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	<2	-	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	<0.02	-	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	<0.02	<0.02	-	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	<10	<10	-	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**3.68**	**6.64**	**26.1**	-	**18.6**	**31.7**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**734**	**1330**	**5210**	-	**3720**	**6340**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**1.18**	**2.13**	**8.35**	-	**5.96**	**10.2**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**1.5**	-	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	<0.02	-	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	<10	-	<10	<10
Liming Rate	kg CaCO3/t	1		<1	<1	<1	-	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	<0.02	<0.02	-	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	<10	<10	-	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	<1	<1	-	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2S0_4/tonne	-					**350**		
ANC	% CaCO3	-					**35**		

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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			Sample Type:	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
			ALS Sample number:	EP0904291037	EP0904291029	EP0904291030	EP0904291031	GCA8526	EP0904291032
			Sample date:	06/06/2009	06/07/2009	06/07/2009	06/07/2009	06/07/2009	06/07/2009
			Client sample ID (1st):	MC004	MC005	MC005	MC005	MC005	MC005
			Client sample ID (2nd):	8.0-8.1	0.45-0.55	0.9-1.0	(comp)1.0-2.0	1.6-1.65	3.0-3.1
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**Sandy CLAY**	**Clayey SAND**	**Sandy CLAY**	**Sandy CLAY**		**CLAYSTONE**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**8.3**	**8.5**	**8.6**	**8.2**	-	**7.8**
pH (Fox)	pH Unit	0.1		**6.4**	**6.6**	**6.7**	**6**	-	**6.8**
Reaction Rate	-	1		**Slight**	**Slight**	**Slight**	**Slight**	-	**Strong**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9.1**	**9.5**	**9.2**	**9.1**	-	**8.9**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	<2	<2	-	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	<0.02	<0.02	-	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	**0.04**	<0.02	<0.02	-	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	**23**	<10	<10	-	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**6.13**	**32.4**	**13.2**	**3.73**	-	**1.01**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**1220**	**6470**	**2650**	**746**	-	**202**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**1.96**	**10.4**	**4.25**	**1.2**	-	**0.32**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**1.5**	**1.5**	-	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	<0.02	<0.02	-	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	<10	<10	-	<10
Liming Rate	kg CaCO3/t	1		<1	<1	<1	<1	-	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	**0.04**	<0.02	<0.02	-	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	**23**	<10	<10	-	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	**2**	<1	<1	-	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-						**26**	
ANC	% CaCO3	-						**2.6**	

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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			Sample Type:	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
			ALS Sample number:	EP0904291033	EP0904291071	EP0904291072	EP0904291073	EP0904291074	EP0904291086
			Sample date:	06/07/2009	08/07/2009	08/07/2009	08/07/2009	09/07/2009	15/07/2009
			Client sample ID (1st):	MC005	MC006	MC006	MC006	MC006	MC006
			Client sample ID (2nd):	6.9-7.0	0.45-0.55	0.9-1.0	3.26-3.36	9.9-10.0	1.0-2.0
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**CLAYSTONE**	**Sandy CLAY**	**CLAY**	**CLAYSTONE**	**Clayey SANDSTONE**	**CLAY**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**7.4**	**8.1**	**7.9**	**7.1**	**6.9**	**7.4**
pH (Fox)	pH Unit	0.1		**6.2**	**7.4**	**7.2**	**7.1**	**6**	**6.4**
Reaction Rate	-	1		**Slight**	**Strong**	**Strong**	**Strong**	**Slight**	**Strong**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9**	**9.1**	**9**	**9**	**8.8**	**9**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	<10	**12**	<10	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**17.2**	**11.7**	**11.9**	**1.93**	**0.88**	**3.88**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**3440**	**2330**	**2380**	**386**	**177**	**775**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**5.52**	**3.74**	**3.81**	**0.62**	**0.28**	**1.24**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	<10	**12**	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-							
ANC	% CaCO3	-							

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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			Sample Type:	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
			ALS Sample number:	EP0904291001	EP0904291002	EP0904291003	EP0904291004	EP0904291005	EP0904291006
			Sample date:	26/06/2009	26/06/2009	26/06/2009	25/06/2009	25/06/2009	25/06/2009
			Client sample ID (1st):	MC007	MC007	MC007	MC008	MC008	MC008
			Client sample ID (2nd):	0.45-0.55	0.8-0.9	(comp)1.0-2.0	0.45-0.55	0.8-0.9	(comp)2.0-3.0
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**Sandy CLAY**	**Sandy CLAY**	**Clayey SAND**	**Sandy CLAY**	**Sandy CLAY**	**Clayey SAND**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**8**	**8.5**	**8.3**	**8.4**	**8.5**	**7.6**
pH (Fox)	pH Unit	0.1		**6.5**	**6.5**	**6.6**	**6.4**	**6.5**	**6.1**
Reaction Rate	-	1		**Slight**	**Slight**	**Moderate**	**Slight**	**Slight**	**Slight**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9**	**9**	**9.1**	**8.9**	**8.9**	**9.2**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	<10	<10	<10	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**1.97**	**2**	**5.01**	**1.63**	**1.28**	**4.26**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**394**	**399**	**1000**	**326**	**255**	**851**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**0.63**	**0.64**	**1.6**	**0.52**	**0.41**	**1.36**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	<10	<10	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-							
ANC	% CaCO3	-							

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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Analyte grouping/Analyte	Units	LOR	Action Criteria for >1000 tonnes disturbed	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Sample Type:				Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
ALS Sample number:				EP0904291007	EP0904291008	GCA8522	EP0904291058	EP0904291059	EP0904291060
Sample date:				25/06/2009	25/06/2009	25/06/2009	11/07/2009	11/07/2009	11/07/2009
Client sample ID (1st):				MC008	MC008	MC008	MC009	MC009	MC009
Client sample ID (2nd):				3.8-3.9	7.0-7.1	7.16-7.22	1.0-1.1	2.0-3.0	3.9-4.0
Soil Type (Field Classification)				**Clayey SAND**	**SAND**	**-**	**Clayey GRAVEL**	**Gravelly CLAY**	**CLAY**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**7.6**	**7.7**	-	**8.4**	**8**	**7.6**
pH (Fox)	pH Unit	0.1		**6.6**	**6.5**	-	**6.4**	**6.4**	**6.5**
Reaction Rate	-	1		**Slight**	**Slight**	-	**Slight**	**Slight**	**Moderate**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9.1**	**9.4**		**9.2**	**9.1**	**9**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2		<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	-	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	**0.02**	**-**	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	**15**	**-**	<10	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**1.59**	**6.61**	**-**	**1.03**	**7.99**	**4.69**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**318**	**1320**	**-**	**205**	**1600**	**937**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**0.51**	**2.12**	**-**	**0.33**	**2.56**	**1.5**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**-**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	**-**	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	**-**	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	<1	**-**	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	**0.02**	**-**	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	**15**	**-**	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	**1**	**-**	<1	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-				**99**			
ANC	% CaCO3	-				**9.8**			

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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Analyte grouping/Analyte	Units	LOR	Action Criteria for >1000 tonnes disturbed	Duplicate Sample	RPD %*	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Sample Type:				Duplicate Sample	RPD %*	Primary Sample	Primary Sample	Primary Sample	Primary Sample
ALS Sample number:				EP0904291063		EP0904291061	EP0904291062	EP0904291064	EP0904291065
Sample date:				11/07/2009		12/07/2009	12/07/2009	09/07/2009	09/07/2009
Client sample ID (1st):				MC009		MC009	MC009	MC010	MC010
Client sample ID (2nd):				QA/QC		8.9-9.0	13.4-13.5	0.45-0.55	0.9-1.0
Soil Type (Field Classification)				CLAY		CLAY	Calcareous CONGLOMERATE	Sandy CLAY	CLAY
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		7.5	1.32	7.3	7.8	8.5	8.5
pH (Fox)	pH Unit	0.1		6.1	6.35	6.8	6.7	6.4	6.4
Reaction Rate	-	1		Slight	-	Moderate	Slight	Slight	Slight
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		8.6	4.55	9.1	9.4	9.1	9.1
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	-	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	-	<0.02	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	-	<0.02	<0.02	0.03	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	-	<10	<10	16	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		1.06	126.26	9.62	52	2.96	4.65
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		212	126.20	1920	10400	591	930
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		0.34	126.09	3.08	16.7	0.95	1.49
Acid Base Accounting									
ANC Fineness Factor	-	0.5		1.5	0	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	% S	0.02		<0.02	-	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	-	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	-	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	0.03	<0.02	-	<0.02	<0.02	0.03	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	18	<10	-	<10	<10	16	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	-	<1	<1	1	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-							
ANC	% CaCO3	-							

Legend:

🟨 Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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Sample Type:				**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
ALS Sample number:				EP0904291066	EP0904291067	EP0904291068	EP0904291069	EP0904291009	EP0904291010
Sample date:				09/07/2009	09/07/2009	09/07/2009	11/07/2009	27/06/2009	27/06/2009
Client sample ID (1st):				MC010	MC010	MC010	MC010	MC11	MC11
Client sample ID (2nd):				1.0-2.0	3.45-3.55	7.9-8.0	10.9-11.0	0.0-0.4	1.0-1.1
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**CLAY**	**CLAYSTONE**	**Silty Clayey SAND**	**Calcaerous CONGLOMERATE**	**Gravelly CLAY**	**Sandy CLAY**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**8**	**7.9**	**7.2**	**7.4**	**8.3**	**7.9**
pH (Fox)	pH Unit	0.1		**7.7**	**6**	**6.5**	**6.7**	**6.9**	**6.6**
Reaction Rate	-	1		**Strong**	**Moderate**	**Strong**	**Slight**	**Strong**	**Slight**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9.1**	**8.9**	**9.3**	**9.3**	**9.4**	**9.2**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	<0.02	<0.02	<0.02	**0.03**	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	<10	<10	<10	**22**	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**1.17**	**4.2**	**13.4**	**51.1**	**27.2**	**14.5**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**233**	**838**	**2670**	**10200**	**5450**	**2890**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**0.37**	**1.34**	**4.28**	**16.4**	**8.73**	**4.64**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	<0.02	<0.02	<0.02	**0.03**	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	<10	<10	<10	**22**	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	<1	<1	<1	**2**	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-							
ANC	% CaCO3	-							

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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Sample Type:				**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
ALS Sample number:				EP0904291011	EP0904291012	EP0904291013	EP0904291024	GCA8524	EP0904291025
Sample date:				28/06/2009	28/06/2009	28/06/2009	07/07/2009	07/07/2009	07/07/2009
Client sample ID (1st):				MC11	MC11	MC11	MC012	MC012	MC012
Client sample ID (2nd):				(comp)2.0-3.0	3.5-3.6	7.45-7.55	0.45-0.55	0.66-0.71	0.9-1.0
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**Sandy CLAY**	**CLAYSTONE**	**SANDSTONE**	**Clayey SAND**	**-**	**Sandy CLAY**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**8.1**	**8**	**8.1**	**8.4**	-	**8.4**
pH (Fox)	pH Unit	0.1		**6.2**	**8.7**	**7.2**	**6.6**	-	**6.4**
Reaction Rate	-	1		**Slight**	**Strong**	**Strong**	**Moderate**	-	**Slight**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9.1**	**9.2**	**9.2**	**9.4**	-	**9**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	<2	<2	-	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	<0.02	<0.02	-	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	<0.02	<0.02	**0.03**	-	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	**12**	<10	**19**	-	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**0.8**	**1.49**	**31.3**	**30.5**	-	**5.41**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**160**	**298**	**6260**	**6100**	-	**1080**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**0.26**	**0.48**	**10**	**9.77**	-	**1.73**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**1.5**	**1.5**	**1.5**	-	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	<0.02	<0.02	-	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	<10	<10	-	<10
Liming Rate	kg CaCO3/t	1		<1	<1	<1	<1	-	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	<0.02	<0.02	**0.03**	-	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	**12**	<10	**19**	-	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	<1	<1	**1**	-	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-						**140**	
ANC	% CaCO3	-						**14**	

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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Sample Type:				**Duplicate Sample**	**RPD %***	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
ALS Sample number:				EP0904291028		EP0904291070	EP0904291026	EP0904291027	EP0904291014
Sample date:				07/07/2009		08/07/2009	07/07/2009	07/07/2009	29/06/2009
Client sample ID (1st):				MC012		MC012	MC012	MC012	MC013
Client sample ID (2nd):				QA/QC		9.4-9.5	(comp)1.0-2.0	4.0-4.1	0.45-0.55
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**Sandy CLAY**		**CONGLOMERATE**	**Sandy CLAY**	**CLAYSTONE**	**Sandy CLAY**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**8.3**	**1.20**	**7.3**	**8.1**	**7.4**	**8.7**
pH (Fox)	pH Unit	0.1		**6.3**	**1.57**	**6.5**	**6.6**	**6.2**	**7.7**
Reaction Rate	-	1		**Slight**	**-**	**Strong**	**Slight**	**Slight**	**Moderate**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9.2**	**2.20**	**9**	**9.1**	**8.9**	**9.1**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	-	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	-	<0.02	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	-	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	-	<10	<10	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**5.26**	**2.81**	**13**	**5.54**	**3.06**	**1.33**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**1050**	**2.82**	**2600**	**1110**	**612**	**266**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**1.68**	**2.93**	**4.18**	**1.77**	**0.98**	**0.43**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**0.00**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	-	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	-	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	-	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	-	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	-	<10	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	-	<1	<1	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-							
ANC	% CaCO3	-							

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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			Sample Type:	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**	**Primary Sample**
			ALS Sample number:	EP0904291015	GCA8525	EP0904291016	EP0904291017	EP0904291018	EP0904291019
			Sample date:	29/06/2009	29/06/2010	29/06/2009	29/06/2009	30/07/2009	30/07/2009
			Client sample ID (1st):	MC013	MC013	MC013	MC013	MC013	MC014
			Client sample ID (2nd):	0.8-0.9	0.9-1.0	(comp)1.0-2.0	3.4-3.5	7.9-8.0	0.45-0.55
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**						
Soil Type (Field Classification)				**Sandy CLAY**	**-**	**CLAYSTONE**	**CLAYSTONE**	**CLAYSTONE**	**Clayey SAND**
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		**8.8**	**-**	**8.6**	**8.3**	**8.2**	**8.3**
pH (Fox)	pH Unit	0.1		**6.5**	**-**	**6.7**	**7.1**	**7.6**	**7.1**
Reaction Rate	-	1		**Moderate**	**-**	**Strong**	**Strong**	**Strong**	**Moderate**
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		**9.3**	**-**	**9.1**	**8.8**	**9.2**	**9.3**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	-	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	-	<0.02	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	-	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	-	**11**	<10	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**26.2**	**-**	**15.2**	**11.9**	**4.48**	**27.4**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**5240**	**-**	**3040**	**2380**	**895**	**5470**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**8.4**	**-**	**4.87**	**3.81**	**1.43**	**8.78**
Acid Base Accounting									
ANC Fineness Factor	-	0.5		**1.5**	**-**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	-	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	-	<10	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	-	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	-	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	-	**11**	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	-	<1	<1	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-			**310**				
ANC	% CaCO3	-			**31**				

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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Analyte grouping/Analyte	Units	LOR	Action Criteria for >1000 tonnes disturbed						
Sample Type:				Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
ALS Sample number:				EP0904291020	EP0904291021	GCA8527	EP0904291022	EP0904291023	EP0904291052
Sample date:				30/07/2009	30/07/2009	30/07/2009	30/07/2009	30/07/2009	02/07/2009
Client sample ID (1st):				MC014	MC014	MC014	MC014	MC014	MC015
Client sample ID (2nd):				0.8-0.9	(comp)1.0-2.0	1.49-1.56	3.4-3.5	6.9-7.0	0.45-0.55
Soil Type (Field Classification)				Sandy CLAY	CLAYSTONE	-	CLAYSTONE	Clayey Gravelley SAND	Clayey SAND
ASS Field Screening Analysis									
pH (F)	pH Unit	0.1		8.3	8.4	-	7.7	7.8	8.6
pH (Fox)	pH Unit	0.1		6.8	6.4	-	7.6	7.4	6.6
Reaction Rate	-	1		Slight	Slight	-	Strong	Strong	Slight
Actual Acidity									
pH KCl (23A)	pH Unit	0.1		9	9	-	8.9	8.9	9.5
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	<2	-	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	<0.02	-	<0.02	<0.02	<0.02
Potential Acidity									
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	<0.02	-	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	<10	-	<10	<10	<10
Acid Neutralising Capacity									
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		1.51	5.7	-	5.7	0.65	32.8
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		302	1140	-	1140	131	6560
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		0.48	1.82	-	1.83	0.21	10.5
Acid Base Accounting									
ANC Fineness Factor	-	0.5		1.5	1.5	-	1.5	1.5	1.5
Net Acidity (sulfur units)	% S	0.02		<0.02	<0.02	-	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	<10	-	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	<1	-	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	0.03	<0.02	<0.02	-	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	18	<10	<10	-	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	<1	-	<1	<1	<1
Carbonate Buffering Potential									
ANC	kg H_2SO_4/tonne	-				59			
ANC	% CaCO3	-				5.9			

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

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			Sample Type:	**Duplicate Sample**	**RPD %***	**Primary Sample**	**Primary Sample**	**Primary Sample**
			ALS Sample number:	EP0904291057		EP0904291054	EP0904291055	EP0904291056
			Sample date:	02/07/2009		02/07/2009	02/07/2009	02/07/2009
			Client sample ID (1st):	MC015		MC015	MC015	MC015
			Client sample ID (2nd):	QA/QC		(comp)1.0-2.0	3.4-3.5	6.4-6.5
Analyte grouping/Analyte	**Units**	**LOR**	**Action Criteria for >1000 tonnes disturbed**					
Soil Type (Field Classification)				**Clayey SAND**		**Sandy CLAY**	**CLAYSTONE**	**Clayey SAND**
ASS Field Screening Analysis								
pH (F)	pH Unit	0.1		**8.9**	**3.43**	**8.6**	**7.8**	**8.4**
pH (Fox)	pH Unit	0.1		**6.6**	**0.00**	**6.4**	**6.1**	**6.8**
Reaction Rate	-	1		**Slight**	**-**	**Slight**	**Slight**	**Strong**
Actual Acidity								
pH KCl (23A)	pH Unit	0.1		**9.6**	**1.05**	**9**	**8.9**	**9.4**
Titratable Actual Acidity (23F)	mole H+ / t	2		<2	-	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02		<0.02	-	<0.02	<0.02	<0.02
Potential Acidity								
Chromium Reducible Sulfur (22B)	% S	0.02		<0.02	-	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10		<10	-	<10	<10	<10
Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	% CaCO3	0.01		**48.5**	**38.62**	**6.87**	**2.3**	**26.8**
acidity - Acid Neutralising Capacity (a-19A2)	mole H+ / t	10		**9690**	**38.52**	**1370**	**460**	**5350**
sulfidic - Acid Neutralising Capacity (s-19A2)	% pyrite S	0.01		**15.5**	**38.46**	**2.2**	**0.74**	**8.57**
Acid Base Accounting								
ANC Fineness Factor	-	0.5		**1.5**	**0.00**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	% S	0.02		<0.02	-	<0.02	<0.02	<0.02
Net Acidity (acidity units)	mole H+ / t	10		<10	-	<10	<10	<10
Liming Rate	kg CaCO3/t	1		<1	-	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	% S	0.02	**0.03**	<0.02	-	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	**18**	<10	-	<10	<10	<10
Liming Rate excluding ANC	kg CaCO3/t	1		<1	-	<1	<1	<1
Carbonate Buffering Potential								
ANC	kg H_2SO_4/tonne	-						
ANC	% CaCO3	-						

Legend:

Exceeds the Action Criteria of 0.03 %S for >1000 tonnes disturbed

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

* RPD Acceptable Limits: 4-10 x LOR (50%), >10 x LOR (30%)

J:\Jobs\42907100\6 Deliv\E0000 Environmental Marine\E0700 Marine Sediment Dredging Study\ASS Nearshore Investigation\Final Report_Rev B\Appendix G\
PASS Tables.xls

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Appendix H Laboratory Certificates

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ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EP0903741**

Client : **COFFEY GEOTECHNICS**
Contact : MS CASSANDRA TURVEY
Address : PO BOX 1810
WEST PERTH WA, AUSTRALIA 6872

E-mail : cassandra_turvey@coffey.com
Telephone : +61 08 9347 0321
Facsimile : ----

Project : GEOTHERD08668AA
Order number : ----
C-O-C number : ----
Sampler : CASSIE TURVEY
Site : WHEATSTONE NEARSHORE

Quote number : ----

Page : 1 of 9

Laboratory : Environmental Division Perth
Contact : Michael Sharp
Address : 10 Hod Way Malaga WA Australia 6090

E-mail : michael.sharp@alsenviro.com
Telephone : +61-8-9209 7655
Facsimile : +61-8-9209 7600

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 08-JUL-2009
Issue Date : 10-JUL-2009

No. of samples received : 34
No. of samples analysed : 34

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

Environmental Division Perth
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10 Hod Way Malaga WA Australia 6090
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A Campbell Brothers Limited Company

Page : 2 of 9
Work Order : EP0903741
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS Field Screening: NATA accreditation does not cover performance of this service.**

Page : 3 of 9
Work Order : EP0903741
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**MC012 0.45-0.55**	**MC012 0.9-1.0**	**MC012 (comp)1.0-2.0**	**MC012 4.0-4.1**	**MC012 QA/QC**
			Client sampling date / time	07-JUL-2009 15:00	07-JUL-2009 15:00	07-JUL-2009 15:00	07-JUL-2009 15:00	07-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903741-001**	**EP0903741-002**	**EP0903741-003**	**EP0903741-004**	**EP0903741-005**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.4**	**8.4**	**8.1**	**7.4**	**8.3**
pH (Fox)	----	0.1	pH Unit	**6.6**	**6.4**	**6.6**	**6.2**	**6.3**
Reaction Rate	----	1	-	**Moderate**	**Slight**	**Slight**	**Slight**	**Slight**

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Page : 4 of 9
Work Order : EP0903741
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC005 0.45-0.55**	**MC005 0.9-1.0**	**MC005 (comp)1.0-2.0**	**MC005 3.0-3.1**	**MC005 6.9-7.0**
			Client sampling date / time	06-JUL-2009 15:00	06-JUL-2009 15:00	06-JUL-2009 15:00	06-JUL-2009 15:00	06-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	**EP0903741-006**	**EP0903741-007**	**EP0903741-008**	**EP0903741-009**	**EP0903741-010**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.5**	**8.6**	**8.2**	**7.8**	**7.4**
pH (Fox)	----	0.1	pH Unit	**6.6**	**6.7**	**6.0**	**6.8**	**6.2**
Reaction Rate	----	1	-	**Slight**	**Slight**	**Slight**	**Strong**	**Slight**

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Analytical Results

Sub-Matrix: **SOIL**

Client sample ID				**MC004** **0.5-1.0**	**MC004** **(comp)1.0-2.0**	**MC004** **3.9-4.0**	**MC004** **8.0-8.1**	**MC003** **0.45-0.55**
Client sampling date / time				05-JUL-2009 15:00	05-JUL-2009 15:00	05-JUL-2009 15:00	06-JUN-2009 15:00	04-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903741-011**	**EP0903741-012**	**EP0903741-013**	**EP0903741-014**	**EP0903741-015**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.5**	**8.8**	**8.4**	**8.3**	**8.6**
pH (Fox)	----	0.1	pH Unit	**6.8**	**6.7**	**6.9**	**6.4**	**6.6**
Reaction Rate	----	1	-	**Moderate**	**Slight**	**Moderate**	**Slight**	**Slight**

Page : 6 of 9
Work Order : EP0903741
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

				MC003 **0.9-1.0**	**MC003** **(comp)1-2**	**MC003** **3.4-3.5**	**MC003** **6.9-7.0**	**MC002** **1.0-1.1**
			Client sample ID					
			Client sampling date / time	04-JUL-2009 15:00	04-JUL-2009 15:00	04-JUL-2009 15:00	05-JUL-2009 15:00	03-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903741-016**	**EP0903741-017**	**EP0903741-018**	**EP0903741-019**	**EP0903741-020**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.5**	**8.7**	**7.5**	**7.0**	**8.4**
pH (Fox)	----	0.1	pH Unit	**6.7**	**6.5**	**6.9**	**6.1**	**6.7**
Reaction Rate	----	1	-	**Slight**	**Slight**	**Strong**	**Slight**	**Moderate**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC002 1.9-2.0**	**MC002 2.9-3.0**	**MC002 6.4-6.5**	**MC001 0.45-0.55**	**MC001 0.9-1.0**
			Client sampling date / time	03-JUL-2009 15:00	03-JUL-2009 15:00	04-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903741-021**	**EP0903741-022**	**EP0903741-023**	**EP0903741-024**	**EP0903741-025**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**9.0**	**7.9**	**7.9**	**8.8**	**8.6**
pH (Fox)	----	0.1	pH Unit	**6.4**	**6.4**	**7.0**	**6.5**	**6.5**
Reaction Rate	----	1	-	**Slight**	**Moderate**	**Strong**	**Moderate**	**Slight**

Page : 8 of 9
Work Order : EP0903741
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC001 (comp)1.0-2.0**	**MC001 3.4-3.5**	**MC001 6.4-6.5**	**MC015 0.45-0.55**	**MC015 0.9-1.0**
			Client sampling date / time	03-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	**EP0903741-026**	**EP0903741-027**	**EP0903741-028**	**EP0903741-029**	**EP0903741-030**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.2**	**8.8**	**8.4**	**8.6**	**8.8**
pH (Fox)	----	0.1	pH Unit	**6.4**	**6.9**	**6.4**	**6.6**	**6.7**
Reaction Rate	----	1	-	**Slight**	**Strong**	**Slight**	**Slight**	**Slight**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC015 (comp)1.0-2.0**	**MC015 3.4-3.5**	**MC015 6.4-6.5**	**MC015 QA/QC**	----
			Client sampling date / time	02-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903741-031**	**EP0903741-032**	**EP0903741-033**	**EP0903741-034**	**----**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.6**	**7.8**	**8.4**	**8.9**	----
pH (Fox)	----	0.1	pH Unit	**6.4**	**6.1**	**6.8**	**6.6**	----
Reaction Rate	----	1	-	**Slight**	**Slight**	**Strong**	**Slight**	----

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0903858**	Page	: 1 of 8
Client	: **COFFEY GEOTECHNICS**	Laboratory	: Environmental Division Perth
Contact	: MR ERIK BROUWER	Contact	: Michael Sharp
Address	: PO BOX 1810 WEST PERTH WA, AUSTRALIA 6872	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: erik_brouwer@coffey.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: ----	Telephone	: +61-8-9209 7655
Facsimile	: ----	Facsimile	: +61-8-9209 7600
Project	: GEOTHERD08668AA	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 14-JUL-2009
Sampler	: CASSIE TURVEY	Issue Date	: 16-JUL-2009
Site	: WHEATSTONE NEARSHORE		
		No. of samples received	: 29
Quote number	: ----	No. of samples analysed	: 29

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

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A Campbell Brothers Limited Company

Page : 2 of 8
Work Order : EP0903858
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS Field Screening: NATA accreditation does not cover performance of this service.**

Page : 3 of 8
Work Order : EP0903858
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC009 1.0-1.1	MC009 2.0-3.0	MC009 3.9-4.0	MC009 8.9-9.0	MC009 13.4-13.5
			Client sampling date / time	11-JUL-2009 15:00	11-JUL-2009 15:00	11-JUL-2009 15:00	12-JUL-2009 15:00	12-JUL-2009 15:00
				EP0903858-001	**EP0903858-002**	**EP0903858-003**	**EP0903858-004**	**EP0903858-005**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.4**	**8.0**	**7.6**	**7.3**	**7.8**
pH (Fox)	----	0.1	pH Unit	**6.4**	**6.4**	**6.5**	**6.8**	**6.7**
Reaction Rate	----	1	-	**Slight**	**Slight**	**Moderate**	**Moderate**	**Slight**

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Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**MC009** **QA/QC**	**MC010** **0.45-0.55**	**MC010** **0.9-1.0**	**MC010** **1.0-2.0**	**MC010** **3.45-3.55**
			Client sampling date / time	11-JUL-2009 15:00	09-JUL-2009 15:00	09-JUL-2009 15:00	09-JUL-2009 15:00	09-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903858-006**	**EP0903858-007**	**EP0903858-008**	**EP0903858-009**	**EP0903858-010**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.5**	**8.5**	**8.0**	**7.9**	**7.2**
pH (Fox)	----	0.1	pH Unit	**6.1**	**6.4**	**7.7**	**6.0**	**6.5**
Reaction Rate	----	1	-	**Slight**	**Slight**	**Strong**	**Moderate**	**Strong**

Page : 5 of 8
Work Order : EP0903858
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**MC010 7.9-8.0**	**MC010 10.9-11.0**	**MC012 9.4-9.5**	**MC006 0.45-0.55**	**MC006 0.9-1.0**
			Client sampling date / time	09-JUL-2009 15:00	11-JUL-2009 15:00	08-JUL-2009 15:00	08-JUL-2009 15:00	08-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903858-011**	**EP0903858-012**	**EP0903858-013**	**EP0903858-014**	**EP0903858-015**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.4**	**7.4**	**7.3**	**8.1**	**7.9**
pH (Fox)	----	0.1	pH Unit	**6.7**	**7.0**	**6.5**	**7.4**	**7.2**
Reaction Rate	----	1	-	**Slight**	**Slight**	**Strong**	**Strong**	**Strong**

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**MC006 3.26-3.36**	**MC006 9.9-10.0**	**MV021 0.45-0.55**	**MV021 09-1.0**	**MV021 1.0-2.0**
			Client sampling date / time	08-JUL-2009 15:00	09-JUL-2009 15:00	13-JUL-2009 15:00	13-JUL-2009 15:00	13-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903858-016**	**EP0903858-017**	**EP0903858-018**	**EP0903858-019**	**EP0903858-020**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**7.1**	**6.9**	**8.2**	**8.6**	**8.0**
pH (Fox)	----	0.1	pH Unit	**7.1**	**6.0**	**6.8**	**6.8**	**6.7**
Reaction Rate	----	1	-	**Strong**	**Slight**	**Moderate**	**Moderate**	**Slight**

Page : 7 of 8
Work Order : EP0903858
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MV025 0.45-0.55	MV025 0.9-1.0	MV025 1.0-2.0	MV025 3.4-3.5	MV023 0.45-0.55
Client sampling date / time				12-JUL-2009 15:00	12-JUL-2009 15:00	12-JUL-2009 15:00	12-JUL-2009 15:00	13-JUL-2009 15:00
				EP0903858-021	EP0903858-022	EP0903858-023	EP0903858-024	EP0903858-025
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	8.5	8.4	8.3	7.9	8.4
pH (Fox)	----	0.1	pH Unit	7.4	6.6	6.6	6.2	7.0
Reaction Rate	----	1	-	Extreme	Slight	Slight	Slight	Moderate

A Campbell Brothers Limited Company

Page	: 8 of 8
Work Order	: EP0903858
Client	: COFFEY GEOTECHNICS
Project	: GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MV023** **0.9-1.0**	**MV023** **1.0-2.0**	**MV023** **3.5-3.6**	**MC006** **1.0-2.0**	----
			Client sampling date / time	13-JUL-2009 15:00	13-JUL-2009 15:00	13-JUL-2009 15:00	[15-JUL-2009]	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903858-026**	**EP0903858-027**	**EP0903858-028**	**EP0903858-029**	**----**
EA037: Ass Field Screening Analysis								
pH (F)	----	0.1	pH Unit	**8.9**	**8.0**	**8.0**	**7.4**	----
pH (Fox)	----	0.1	pH Unit	**7.2**	**7.3**	**6.9**	**6.4**	----
Reaction Rate	----	1	-	**Strong**	**Slight**	**Strong**	**Strong**	----

A Campbell Brothers Limited Company

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EP0904291**

Client : **COFFEY GEOTECHNICS**
Contact : MS CASSANDRA TURVEY
Address : PO BOX 1810
WEST PERTH WA, AUSTRALIA 6872

E-mail : cassandra_turvey@coffey.com
Telephone : +61 08 9347 0321
Facsimile : ----

Project : Ex-EP0903726 3741 3738 3858 3984
Order number : ----
C-O-C number : ----
Sampler : CASSIE TURVEY
Site : WHEATSTONE NEARSHORE

Quote number : ----

Page : 1 of 21

Laboratory : Environmental Division Perth
Contact : Michael Sharp
Address : 10 Hod Way Malaga WA Australia 6090

E-mail : michael.sharp@alsenviro.com
Telephone : +61-8-9209 7655
Facsimile : +61-8-9209 7600

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 03-AUG-2009
Issue Date : 10-AUG-2009

No. of samples received : 92
No. of samples analysed : 92

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

Environmental Division Perth
Part of the **ALS Laboratory Group**
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A Campbell Brothers Limited Company

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Work Order : EP0904291
Client : COFFEY GEOTECHNICS
Project : Ex-EP0903726 3741 3738 3858 3984

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.**
- **Retained Acidity not required because pH KCl greater than or equal to 4.5**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC007 0.45-0.55**	**MC007 0.8-0.9**	**MC007 (comp)1.0-2.0**	**MC008 0.45-0.55**	**MC008 0.8-0.9**
			Client sampling date / time	26-JUN-2009 15:00	26-JUN-2009 15:00	26-JUN-2009 15:00	25-JUN-2009 15:00	25-JUN-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-001**	**EP0904291-002**	**EP0904291-003**	**EP0904291-004**	**EP0904291-005**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.0**	**9.0**	**9.1**	**8.9**	**8.9**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**1.97**	**2.00**	**5.01**	**1.63**	**1.28**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**394**	**399**	**1000**	**326**	**255**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.63**	**0.64**	**1.60**	**0.52**	**0.41**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC008 (comp)2.0-3.0	MC008 3.8-3.9	MC008 7.0-7.1	MC11 0.0-0.4	MC11 1.0-1.1
Client sampling date / time				25-JUN-2009 15:00	25-JUN-2009 15:00	25-JUN-2009 15:00	27-JUN-2009 15:00	27-JUN-2009 15:00
				EP0904291-006	**EP0904291-007**	**EP0904291-008**	**EP0904291-009**	**EP0904291-010**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.2**	**9.1**	**9.4**	**9.4**	**9.2**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	**0.02**	**0.03**	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	**15**	**22**	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**4.26**	**1.59**	**6.61**	**27.2**	**14.5**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**851**	**318**	**1320**	**5450**	**2890**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.36**	**0.51**	**2.12**	**8.73**	**4.64**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	**0.02**	**0.03**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	**15**	**22**	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	**1**	**2**	<1

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC11 (comp)2.0-3.0**	**MC11 3.5-3.6**	**MC11 7.45-7.55**	**MC013 0.45-0.55**	**MC013 0.8-0.9**
			Client sampling date / time	28-JUN-2009 15:00	28-JUN-2009 15:00	28-JUN-2009 15:00	29-JUN-2009 15:00	29-JUN-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-011**	**EP0904291-012**	**EP0904291-013**	**EP0904291-014**	**EP0904291-015**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.1**	**9.2**	**9.2**	**9.1**	**9.3**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**12**	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**0.80**	**1.49**	**31.3**	**1.33**	**26.2**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**160**	**298**	**6260**	**266**	**5240**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.26**	**0.48**	**10.0**	**0.43**	**8.40**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	**12**	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC013 (comp)1.0-2.0	MC013 3.4-3.5	MC013 7.9-8.0	MC014 0.45-0.55	MC014 0.8-0.9
			Client sampling date / time	29-JUN-2009 15:00	29-JUN-2009 15:00	30-JUL-2009 15:00	30-JUL-2009 15:00	30-JUL-2009 15:00
				EP0904291-016	**EP0904291-017**	**EP0904291-018**	**EP0904291-019**	**EP0904291-020**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.1**	**8.8**	**9.2**	**9.3**	**9.0**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**11**	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**15.2**	**11.9**	**4.48**	**27.4**	**1.51**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**3040**	**2380**	**895**	**5470**	**302**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**4.87**	**3.81**	**1.43**	**8.78**	**0.48**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**11**	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	MC014 (comp)1.0-2.0	MC014 3.4-3.5	MC014 6.9-7.0	MC012 0.45-0.55	MC012 0.9-1.0
			Client sampling date / time	30-JUL-2009 15:00	30-JUL-2009 15:00	30-JUL-2009 15:00	07-JUL-2009 15:00	07-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-021**	**EP0904291-022**	**EP0904291-023**	**EP0904291-024**	**EP0904291-025**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.0**	**8.9**	**8.9**	**9.4**	**9.0**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	**0.03**	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	**19**	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**5.70**	**5.70**	**0.65**	**30.5**	**5.41**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**1140**	**1140**	**131**	**6100**	**1080**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.82**	**1.83**	**0.21**	**9.77**	**1.73**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	**0.03**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	**19**	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	**1**	<1

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC012 (comp)1.0-2.0**	**MC012 4.0-4.1**	**MC012 QA/QC**	**MC005 0.45-0.55**	**MC005 0.9-1.0**
			Client sampling date / time	07-JUL-2009 15:00	07-JUL-2009 15:00	07-JUL-2009 15:00	06-JUL-2009 15:00	06-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-026**	**EP0904291-027**	**EP0904291-028**	**EP0904291-029**	**EP0904291-030**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.1**	**8.9**	**9.2**	**9.5**	**9.2**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	**0.04**	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	**23**	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**5.54**	**3.06**	**5.26**	**32.4**	**13.2**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**1110**	**612**	**1050**	**6470**	**2650**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.77**	**0.98**	**1.68**	**10.4**	**4.25**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	**0.04**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	**23**	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	**2**	<1

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Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC005 (comp)1.0-2.0	MC005 3.0-3.1	MC005 6.9-7.0	MC004 0.5-1.0	MC004 (comp)1.0-2.0
Client sampling date / time				06-JUL-2009 15:00	06-JUL-2009 15:00	06-JUL-2009 15:00	05-JUL-2009 15:00	05-JUL-2009 15:00
				EP0904291-031	**EP0904291-032**	**EP0904291-033**	**EP0904291-034**	**EP0904291-035**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.1**	**8.9**	**9.0**	**9.3**	**9.3**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**3.73**	**1.01**	**17.2**	**26.1**	**18.6**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**746**	**202**	**3440**	**5210**	**3720**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.20**	**0.32**	**5.52**	**8.35**	**5.96**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

Client sample ID				**MC004** **3.9-4.0**	**MC004** **8.0-8.1**	**MC003** **0.45-0.55**	**MC003** **0.9-1.0**	**MC003** **(comp)1-2**
Client sampling date / time				05-JUL-2009 15:00	06-JUN-2009 15:00	04-JUL-2009 15:00	04-JUL-2009 15:00	04-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-036**	**EP0904291-037**	**EP0904291-038**	**EP0904291-039**	**EP0904291-040**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.4**	**9.1**	**9.3**	**9.2**	**9.2**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**31.7**	**6.13**	**20.3**	**13.3**	**10.2**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**6340**	**1220**	**4050**	**2650**	**2040**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**10.2**	**1.96**	**6.49**	**4.26**	**3.27**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC003 3.4-3.5**	**MC003 6.9-7.0**	**MC002 1.0-1.1**	**MC002 1.9-2.0**	**MC002 2.9-3.0**
			Client sampling date / time	04-JUL-2009 15:00	05-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-041**	**EP0904291-042**	**EP0904291-043**	**EP0904291-044**	**EP0904291-045**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**8.6**	**9.1**	**9.3**	**9.1**	**8.8**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**3.68**	**6.64**	**23.0**	**0.74**	**2.21**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**734**	**1330**	**4610**	**148**	**441**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.18**	**2.13**	**7.38**	**0.24**	**0.71**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC002 6.4-6.5	MC001 0.45-0.55	MC001 0.9-1.0	MC001 (comp)1.0-2.0	MC001 3.4-3.5
			Client sampling date / time	04-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00
				EP0904291-046	**EP0904291-047**	**EP0904291-048**	**EP0904291-049**	**EP0904291-050**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.3**	**9.2**	**9.1**	**9.0**	**9.2**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**12.5**	**9.27**	**7.58**	**11.5**	**35.9**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**2500**	**1850**	**1510**	**2300**	**7180**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**4.01**	**2.97**	**2.43**	**3.68**	**11.5**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC001 6.4-6.5**	**MC015 0.45-0.55**	**MC015 0.9-1.0**	**MC015 (comp)1.0-2.0**	**MC015 3.4-3.5**
			Client sampling date / time	03-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-051**	**EP0904291-052**	**EP0904291-053**	**EP0904291-054**	**EP0904291-055**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.2**	**9.5**	**9.2**	**9.0**	**8.9**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**5.33**	**32.8**	**16.2**	**6.87**	**2.30**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**1060**	**6560**	**3240**	**1370**	**460**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.71**	**10.5**	**5.20**	**2.20**	**0.74**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

Client sample ID				**MC015 6.4-6.5**	**MC015 QA/QC**	**MC009 1.0-1.1**	**MC009 2.0-3.0**	**MC009 3.9-4.0**
Client sampling date / time				02-JUL-2009 15:00	02-JUL-2009 15:00	11-JUL-2009 15:00	11-JUL-2009 15:00	11-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-056**	**EP0904291-057**	**EP0904291-058**	**EP0904291-059**	**EP0904291-060**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.4**	**9.6**	**9.2**	**9.1**	**9.0**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**26.8**	**48.5**	**1.03**	**7.99**	**4.69**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**5350**	**9690**	**205**	**1600**	**937**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**8.57**	**15.5**	**0.33**	**2.56**	**1.50**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC009 8.9-9.0 12-JUL-2009 15:00 EP0904291-061	MC009 13.4-13.5 12-JUL-2009 15:00 EP0904291-062	MC009 QA/QC 11-JUL-2009 15:00 EP0904291-063	MC010 0.45-0.55 09-JUL-2009 15:00 EP0904291-064	MC010 0.9-1.0 09-JUL-2009 15:00 EP0904291-065
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.1**	**9.4**	**8.6**	**9.1**	**9.1**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	**0.03**	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	**16**	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**9.62**	**52.0**	**1.06**	**2.96**	**4.65**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**1920**	**10400**	**212**	**591**	**930**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**3.08**	**16.7**	**0.34**	**0.95**	**1.49**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	**0.03**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	**16**	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	**1**	<1

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC010 1.0-2.0	MC010 3.45-3.55	MC010 7.9-8.0	MC010 10.9-11.0	MC012 9.4-9.5
			Client sampling date / time	09-JUL-2009 15:00	09-JUL-2009 15:00	09-JUL-2009 15:00	11-JUL-2009 15:00	08-JUL-2009 15:00
				EP0904291-066	**EP0904291-067**	**EP0904291-068**	**EP0904291-069**	**EP0904291-070**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.1**	**8.9**	**9.3**	**9.3**	**9.0**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**1.17**	**4.20**	**13.4**	**51.1**	**13.0**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**233**	**838**	**2670**	**10200**	**2600**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.37**	**1.34**	**4.28**	**16.4**	**4.18**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

Client sample ID				**MC006 0.45-0.55**	**MC006 0.9-1.0**	**MC006 3.26-3.36**	**MC006 9.9-10.0**	**MV021 0.45-0.55**
Client sampling date / time				08-JUL-2009 15:00	08-JUL-2009 15:00	08-JUL-2009 15:00	09-JUL-2009 15:00	13-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-071**	**EP0904291-072**	**EP0904291-073**	**EP0904291-074**	**EP0904291-075**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.1**	**9.0**	**9.0**	**8.8**	**9.5**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**12**	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**11.7**	**11.9**	**1.93**	**0.88**	**31.8**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**2330**	**2380**	**386**	**177**	**6350**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**3.74**	**3.81**	**0.62**	**0.28**	**10.2**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	**12**	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MV021** **09-1.0**	**MV021** **1.0-2.0**	**MV025** **0.45-0.55**	**MV025** **0.9-1.0**	**MV025** **1.0-2.0**
			Client sampling date / time	13-JUL-2009 15:00	13-JUL-2009 15:00	12-JUL-2009 15:00	12-JUL-2009 15:00	12-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-076**	**EP0904291-077**	**EP0904291-078**	**EP0904291-079**	**EP0904291-080**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.3**	**9.2**	**9.2**	**8.9**	**8.9**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	**0.06**	<0.02	**0.07**	**0.06**	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**36**	<10	**42**	**41**	**12**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**33.8**	**19.0**	**10.1**	**2.61**	**2.10**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**6750**	**3800**	**2020**	**522**	**420**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**10.8**	**6.10**	**3.24**	**0.84**	**0.67**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.06**	<0.02	**0.07**	**0.06**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**36**	<10	**42**	**41**	**12**
Liming Rate excluding ANC	----	1	kg CaCO3/t	**3**	<1	**3**	**3**	<1

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Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MV025 3.4-3.5	MV023 0.45-0.55	MV023 0.9-1.0	MV023 1.0-2.0	MV023 3.5-3.6
Client sampling date / time				12-JUL-2009 15:00	13-JUL-2009 15:00	13-JUL-2009 15:00	13-JUL-2009 15:00	13-JUL-2009 15:00
				EP0904291-081	**EP0904291-082**	**EP0904291-083**	**EP0904291-084**	**EP0904291-085**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.2**	**9.1**	**8.9**	**9.0**	**9.4**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	**10**	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**5.94**	**17.4**	**9.28**	**15.9**	**29.7**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**1190**	**3480**	**1860**	**3180**	**5930**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.90**	**5.58**	**2.97**	**5.10**	**9.50**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	**10**	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC006 1.0-2.0	MV013 1.45-2.5	MV013 3.9-4.0	MV013 0.5-0.95	MV013 1.0-1.45
			Client sampling date / time	15-JUL-2009 15:00	16-JUL-2009 15:00	16-JUL-2009 15:00	16-JUL-2009 15:00	16-JUL-2009 15:00
				EP0904291-086	**EP0904291-087**	**EP0904291-088**	**EP0904291-089**	**EP0904291-090**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.0**	**9.7**	**9.7**	**9.7**	**9.8**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	**12**	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**3.88**	**51.6**	**50.4**	**55.5**	**56.8**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**775**	**10300**	**10100**	**11100**	**11400**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.24**	**16.5**	**16.1**	**17.8**	**18.2**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	**12**	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	<1

Page	: 21 of 21
Work Order	: EP0904291
Client	: COFFEY GEOTECHNICS
Project	: Ex-EP0903726 3741 3738 3858 3984

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MV021 4.9-5.0**	**QA/QC**	----	----	----
			Client sampling date / time	15-JUL-2009 15:00	15-JUL-2009 15:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904291-091**	**EP0904291-092**	**----**	**----**	**----**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.3**	**9.2**	----	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	----	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	----	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	----	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	----	----	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**16.2**	**15.1**	----	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**3230**	**3030**	----	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**5.18**	**4.85**	----	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	----	----	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	----	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	----	----	----
Liming Rate	----	1	kg CaCO3/t	<1	<1	----	----	----
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	----	----	----
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	----	----	----
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	----	----	----

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1002

COMPANY: URS Australia Pty Ltd

ATTENTION: Melanie Nunns

FROM: Graeme Campbell

SUBJECT: Wheatstone Project: pH-Buffering Properties of Seabed-Sediment Samples

NO. PAGES (including this page): 18 DATE: 24th March 2010

Melanie,

The testwork results for the seabed-sediment samples are presented in Table 1, and shown on Figures 1 and 2. Copies of the laboratory-reports are also attached.

The as-submitted samples were crushed to nominal -2 mm for testing (i.e. the samples were not pulverised to powders [e.g. -75 µm, nominal] for testing).

The Acid-Neutralisation-Capacity (ANC) values were within the range 17-620 kg H_2SO_4/tonne (i.e. *c.* 1.7-62.0 %, as $CaCO_3$-equivalents) [Table 1]. The samples typically "fizzed" vigorously upon the addition of dilute HCl ('in-the-cold') in the ANC testwork indicating the occurrence of reactive variants of carbonate-minerals (e.g. calcites, aragonites, etc.).

The pH-buffering curves for the samples typically showed "inflection-points" near pH=6-7, consistent with the occurrence of reactive-carbonates (Figures 1 and 2). Such behaviour was less evident for the Low-ANC samples GCA8526 and GCA8528 (viz. ANC values 17-26 kg H_2SO_4/tonne) which were only slightly calcareous.

In brief, the ANC values of all samples correspond to alkalinity forms (chiefly reactive-carbonates) whose rates of availability for circum-neutral buffering are "chemically-non-limiting".

Regards,

Dr GD Campbell
Director

Table 1: Acid-Neutralisation-Capacity Values of Seabed-Sediment Samples

GCA-SAMPLE NO.	SAMPLE DETAILS	ANC (kg H_2SO_4/tonne)
GCA8522	MC008, 7.16-7.22 m	99 (97)
GCA8523	MV017, 0.50-0.95 m	620
GCA8524	MC012, 0.66-0.71 m	140
GCA8525	MC013, 0.90-1.00 m	310
GCA8526	MC005, 1.60-1.65 m	26
GCA8527	MC014, 1.49-1.56 m	59
GCA8528	MV025, 0.84-0.90 m	17
GCA8529	MC004, 0.50-0.56 m	350
GCA8530	MV015, 0.50-0.95 m	480

Notes:
ANC = Acid-Neutralisation Capacity.
Values in parentheses represent duplicates.

Figure 1

pH-Buffering Curves for Seabed-Sediment Samples
(ANC values less than 100 kg H2SO4/tonne)

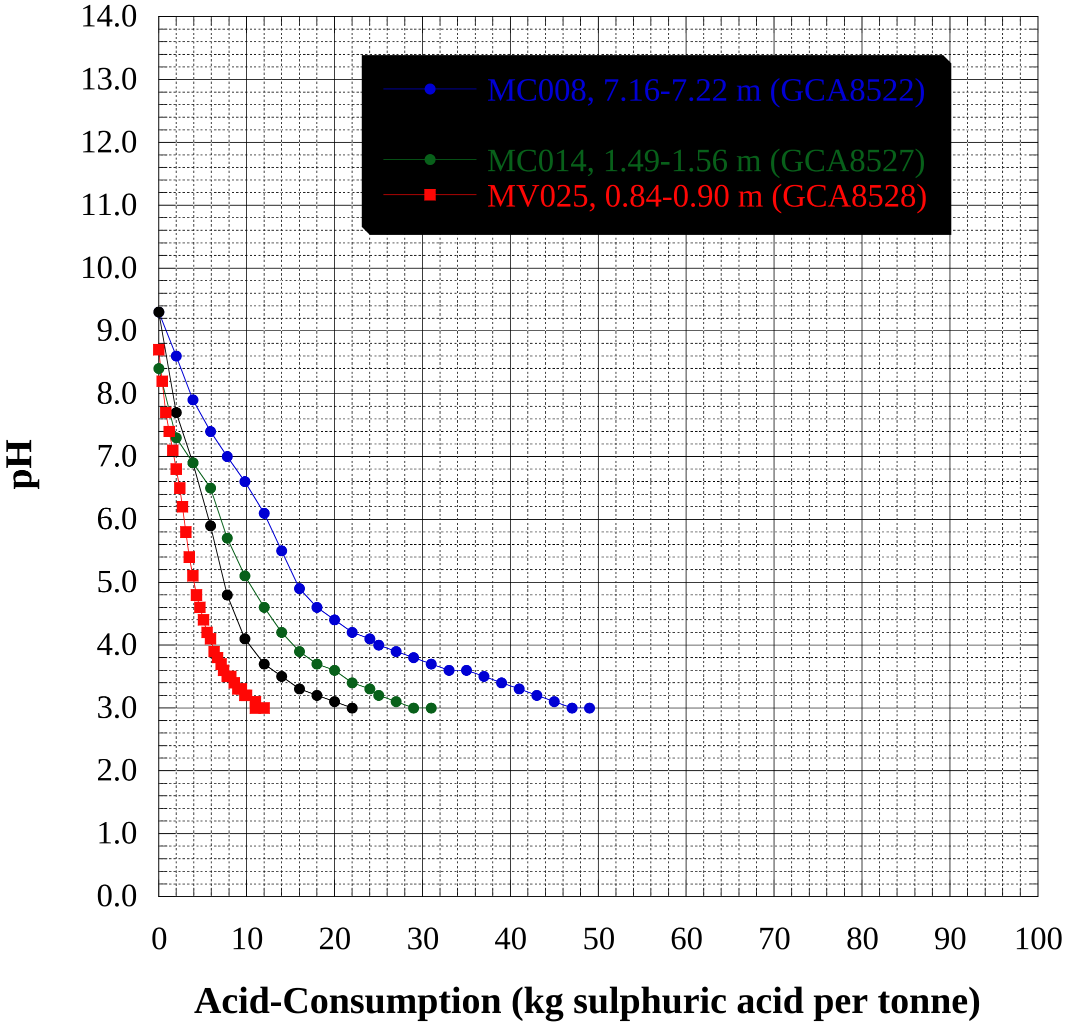
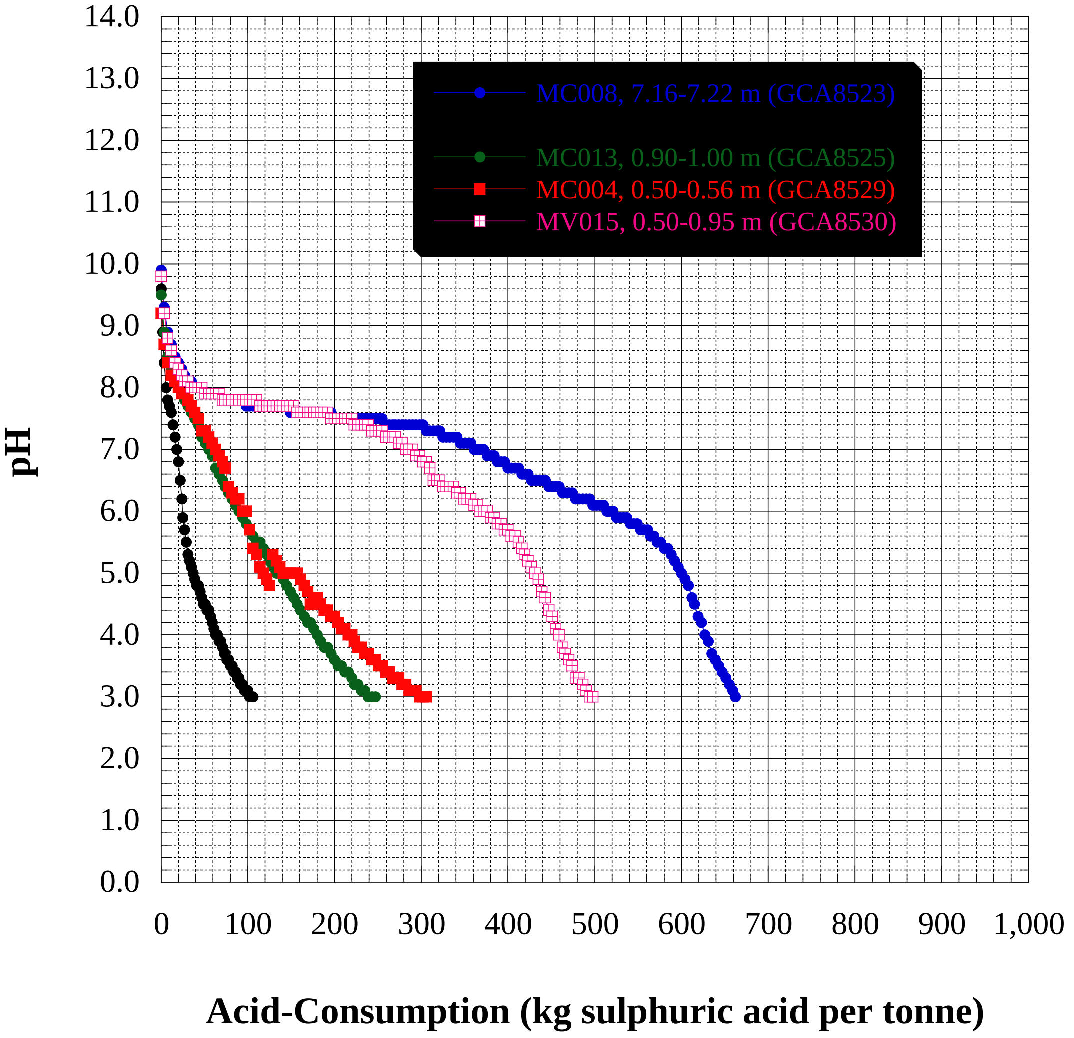
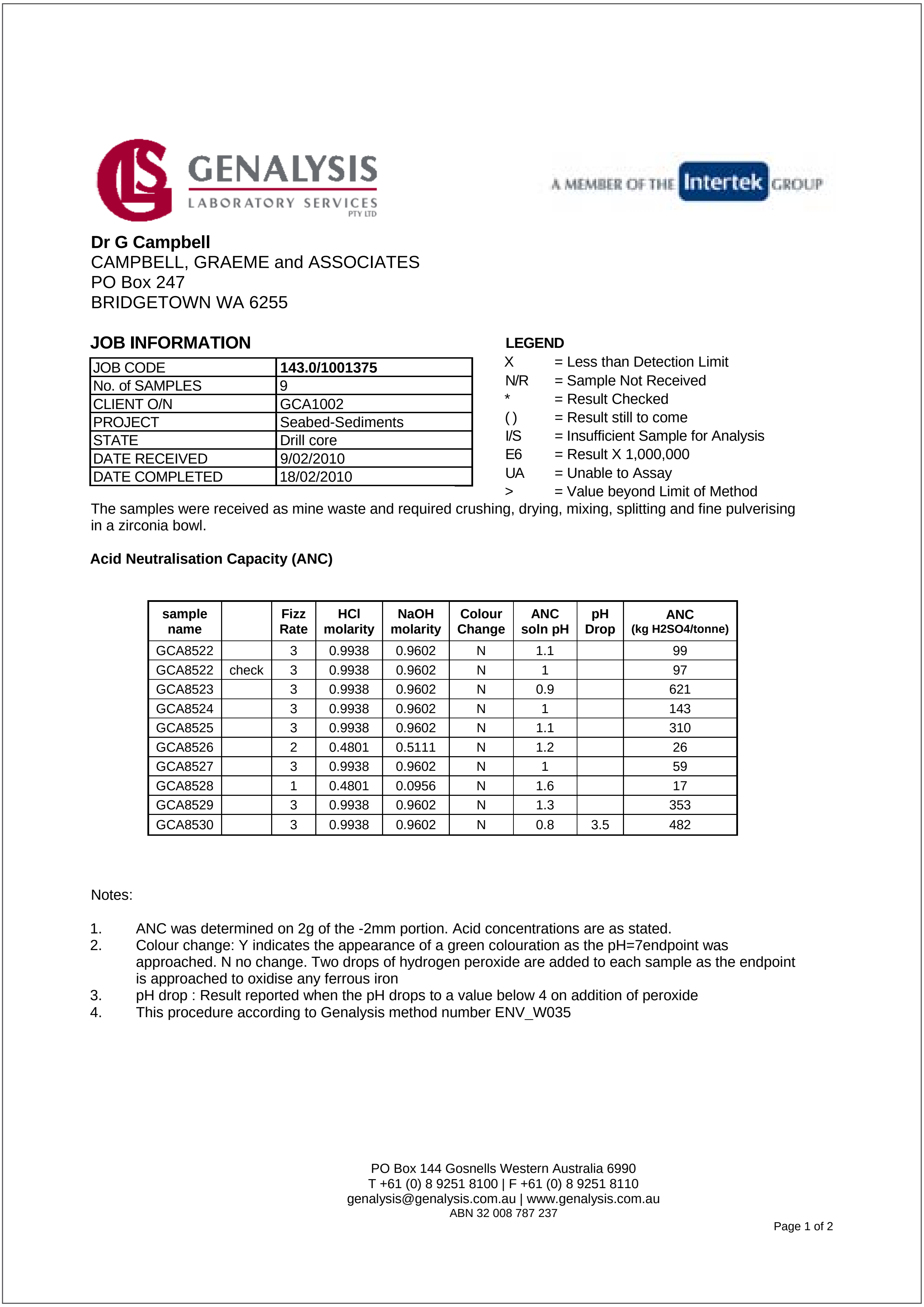


Figure 2

pH-Buffering Curves for Seabed-Sediment Samples (ANC values greater than 100 kg H2SO4/tonne)





GENALYSIS LABORATORY SERVICES PTY LTD

A MEMBER OF THE Intertek GROUP

Dr G Campbell
CAMPBELL, GRAEME and ASSOCIATES
PO Box 247
BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	**143.0/1001375**
No. of SAMPLES	9
CLIENT O/N	GCA1002
PROJECT	Seabed-Sediments
STATE	Drill core
DATE RECEIVED	9/02/2010
DATE COMPLETED	18/02/2010

LEGEND

X = Less than Detection Limit
N/R = Sample Not Received
* = Result Checked
( ) = Result still to come
I/S = Insufficient Sample for Analysis
E6 = Result X 1,000,000
UA = Unable to Assay
> = Value beyond Limit of Method

The samples were received as mine waste and required crushing, drying, mixing, splitting and fine pulverising in a zirconia bowl.

Acid Neutralisation Capacity (ANC)

sample name		Fizz Rate	HCl molarity	NaOH molarity	Colour Change	ANC soln pH	pH Drop	ANC (kg H2SO4/tonne)
GCA8522		3	0.9938	0.9602	N	1.1		99
GCA8522	check	3	0.9938	0.9602	N	1		97
GCA8523		3	0.9938	0.9602	N	0.9		621
GCA8524		3	0.9938	0.9602	N	1		143
GCA8525		3	0.9938	0.9602	N	1.1		310
GCA8526		2	0.4801	0.5111	N	1.2		26
GCA8527		3	0.9938	0.9602	N	1		59
GCA8528		1	0.4801	0.0956	N	1.6		17
GCA8529		3	0.9938	0.9602	N	1.3		353
GCA8530		3	0.9938	0.9602	N	0.8	3.5	482

Notes:

1. ANC was determined on 2g of the -2mm portion. Acid concentrations are as stated.
2. Colour change: Y indicates the appearance of a green colouration as the pH=7endpoint was approached. N no change. Two drops of hydrogen peroxide are added to each sample as the endpoint is approached to oxidise any ferrous iron
3. pH drop : Result reported when the pH drops to a value below 4 on addition of peroxide
4. This procedure according to Genalysis method number ENV_W035

GLS Job Code 143.0/1001375 Client ON GCA1002

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NATA Signatory: Ann Evers

Date: 18th February 2010

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Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA8522)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	9.3
0.40	2.0	8.6
0.80	3.9	7.9
1.20	5.9	7.4
1.60	7.8	7.0
2.00	9.8	6.6
2.40	12	6.1
2.80	14	5.5
3.20	16	4.9
3.60	18	4.6
4.00	20	4.4
4.40	22	4.2
4.80	24	4.1
5.20	25	4.0
5.60	27	3.9
6.00	29	3.8
6.40	31	3.7
6.80	33	3.6
7.20	35	3.6
7.60	37	3.5
8.00	39	3.4
8.40	41	3.3
8.80	43	3.2
9.20	45	3.1
9.60	47	3.0
10.00	49	3.0

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 1.00 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.
Calibration of pH-Glass Electrode:
Immediately prior to titration: asymmetry potential = -7 mV (pH=7.00); slope-point = 175 mV (pH=4.00); 94.9 % of Nernstian response for 25 °C.
Immediately following titration: pH=7.00 buffer read pH=7.03 and pH=4.00 buffer read pH=4.02. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
1st March 2010

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA8523)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	9.9	16.80	165	7.6
0.40	3.9	9.3	17.20	169	7.6
0.80	7.8	8.9	17.60	172	7.6
1.20	12	8.7	18.00	176	7.6
1.60	16	8.5	18.40	180	7.6
2.00	20	8.4	18.80	184	7.6
2.40	24	8.3	19.20	188	7.6
2.80	27	8.2	19.60	192	7.6
3.20	31	8.1	20.00	196	7.6
3.60	35	8.1	20.40	200	7.5
4.00	39	8.0	20.80	204	7.5
4.40	43	8.0	21.20	208	7.5
4.80	47	8.0	21.60	212	7.5
5.20	51	7.9	22.00	216	7.5
5.60	55	7.9	22.40	220	7.5
6.00	59	7.9	22.80	223	7.5
6.40	63	7.9	23.20	227	7.5
6.80	67	7.9	23.60	231	7.5
7.20	71	7.8	24.00	235	7.5
7.60	74	7.8	24.40	239	7.5
8.00	78	7.8	24.80	243	7.5
8.40	82	7.8	25.20	247	7.5
8.80	86	7.8	25.60	251	7.5
9.20	90	7.8	26.00	255	7.5
9.60	94	7.8	26.40	259	7.4
10.00	98	7.7	26.80	263	7.4
10.40	102	7.7	27.20	267	7.4
10.80	106	7.7	27.60	270	7.4
11.20	110	7.7	28.00	274	7.4
11.60	114	7.7	28.40	278	7.4
12.00	118	7.7	28.80	282	7.4
12.40	122	7.7	29.20	286	7.4
12.80	125	7.7	29.60	290	7.4
13.20	129	7.7	30.00	294	7.4
13.60	133	7.7	30.40	298	7.4
14.00	137	7.7	30.80	302	7.4
14.40	141	7.7	31.20	306	7.3
14.80	145	7.7	31.60	310	7.3
15.20	149	7.6	32.00	314	7.3
15.60	153	7.6	32.40	318	7.3
16.00	157	7.6	32.80	321	7.3
16.40	161	7.6	33.20	325	7.2

Cumulative Volume of Acid Added (mL)	**Cumulative Acid Consumption (kg H_2SO_4/tonne)**	**pH**	**Cumulative Volume of Acid Added (mL)**	**Cumulative Acid Consumption (kg H_2SO_4/tonne)**	**pH**
33.60	329	7.2	44.00	431	6.5
34.00	333	7.2	44.40	435	6.5
34.40	337	7.2	44.80	439	6.5
34.80	341	7.2	45.20	443	6.5
35.20	345	7.1	45.60	447	6.4
35.60	349	7.1	46.00	451	6.4
36.00	353	7.1	46.40	455	6.4
36.40	357	7.1	46.80	459	6.4
36.80	361	7.0	47.20	463	6.3
37.20	365	7.0	47.60	466	6.3
37.60	368	7.0	48.00	470	6.3
38.00	372	7.0	48.40	474	6.3
38.40	376	6.9	48.80	478	6.2
38.80	380	6.9	49.20	482	6.2
39.20	384	6.9	49.60	486	6.2
39.60	388	6.8	50.00	490	6.2
40.00	392	6.8	50.40	494	6.2
40.40	396	6.8	50.80	498	6.1
40.80	400	6.7	51.20	502	6.1
41.20	404	6.7	51.60	506	6.1
41.60	408	6.7	52.00	510	6.1
42.00	412	6.7	52.40	514	6.0
42.40	416	6.6	52.80	517	6.0
42.80	419	6.6	53.20	521	6.0
43.20	423	6.6	53.60	525	5.9
43.60	427	6.5	54.00	529	5.9

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
54.40	533	5.9	64.80	635	3.7
54.80	537	5.9	65.20	639	3.6
55.20	541	5.8	65.60	643	3.5
55.60	545	5.8	66.00	647	3.4
56.00	549	5.8	66.40	651	3.3
56.40	553	5.7	66.80	655	3.2
56.80	557	5.7	67.20	659	3.1
57.20	561	5.7	67.60	662	3.0
57.60	564	5.6			
58.00	568	5.6			
58.40	572	5.5			
58.80	576	5.5			
59.20	580	5.4			
59.60	584	5.4			
60.00	588	5.3			
60.40	592	5.2			
60.80	596	5.1			
61.20	600	5.0			
61.60	604	4.9			
62.00	608	4.8			
62.40	612	4.6			
62.80	615	4.5			
63.20	619	4.3			
63.60	623	4.2			
64.00	627	4.0			
64.40	631	3.9			

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 0.50 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -7 mV (pH=7.00); slope-point = 176 mV (pH=4.00); 95.3 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.04 and pH=4.00 buffer read pH=4.03. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
1st March 2010

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA8524)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	9.6	16.80	82	3.5
0.40	2.0	8.9	17.20	84	3.4
0.80	3.9	8.4	17.60	86	3.4
1.20	5.9	8.0	18.00	88	3.3
1.60	7.8	7.8	18.40	90	3.3
2.00	9.8	7.7	18.80	92	3.2
2.40	12	7.6	19.20	94	3.2
2.80	14	7.4	19.60	96	3.1
3.20	16	7.2	20.00	98	3.1
3.60	18	7.0	20.40	100	3.1
4.00	20	6.8	20.80	102	3.0
4.40	22	6.5	21.20	104	3.0
4.80	24	6.2	21.60	106	3.0
5.20	25	5.9			
5.60	27	5.7			
6.00	29	5.5			
6.40	31	5.3			
6.80	33	5.2			
7.20	35	5.1			
7.60	37	5.0			
8.00	39	4.9			
8.40	41	4.8			
8.80	43	4.8			
9.20	45	4.7			
9.60	47	4.6			
10.00	49	4.5			
10.40	51	4.5			
10.80	53	4.4			
11.20	55	4.4			
11.60	57	4.3			
12.00	59	4.2			
12.40	61	4.1			
12.80	63	4.0			
13.20	65	4.0			
13.60	67	3.9			
14.00	69	3.9			
14.40	71	3.8			
14.80	73	3.7			
15.20	74	3.7			
15.60	76	3.6			
16.00	78	3.6			
16.40	80	3.5			

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 1.00 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -8 mV (pH=7.00); slope-point = 176 mV (pH=4.00); 95.0 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.02 and pH=4.00 buffer read pH=4.01. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
2nd March 2010

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA8525)

Cumulative Acid Consumption (kg H_2SO_4/tonne)	**pH**	**Cumulative Volume of Acid Added (mL)**	**Cumulative Acid Consumption (kg H_2SO_4/tonne)**	**pH**
0.0	9.5	16.80	165	4.3
3.9	8.9	17.20	169	4.2
7.8	8.5	17.60	172	4.2
12	8.3	18.00	176	4.1
16	8.2	18.40	180	4.0
20	8.0	18.80	184	3.9
24	7.9	19.20	188	3.8
27	7.8	19.60	192	3.8
31	7.7	20.00	196	3.7
35	7.6	20.40	200	3.6
39	7.5	20.80	204	3.5
43	7.4	21.20	208	3.5
47	7.2	21.60	212	3.4
51	7.1	22.00	216	3.4
55	7.0	22.40	220	3.3
59	6.9	22.80	223	3.2
63	6.7	23.20	227	3.2
67	6.6	23.60	231	3.1
71	6.5	24.00	235	3.1
74	6.4	24.40	239	3.0
78	6.3	24.80	243	3.0
82	6.2	25.20	247	3.0
86	6.1			
90	6.0			
94	5.9			
98	5.8			
102	5.7			
106	5.6			
110	5.5			
114	5.5			
118	5.4			
122	5.3			
125	5.2			
129	5.1			
133	5.0			
137	5.0			
141	4.9			
145	4.8			
149	4.7			
153	4.6			
157	4.5			
161	4.4			

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 0.50 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -9 mV (pH=7.00); slope-point = 178 mV (pH=4.00); 95.2 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.02 and pH=4.00 buffer read pH=4.01. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
2nd March 2010

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Laboratory Report

pH-BUFFERING TESTWORK (GCA8526)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	9.3
0.40	2.0	7.7
0.80	3.9	6.9
1.20	5.9	5.9
1.60	7.8	4.8
2.00	9.8	4.1
2.40	12	3.7
2.80	14	3.5
3.20	16	3.3
3.60	18	3.2
4.00	20	3.1
4.40	22	3.0

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 1.00 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.
Calibration of pH-Glass Electrode:
Immediately prior to titration: asymmetry potential = -7 mV (pH=7.00); slope-point = 176 mV (pH=4.00); 95.1 % of Nernstian response for 25 °C.
Immediately following titration: pH=7.00 buffer read pH=7.03 and pH=4.00 buffer read pH=4.02. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
3rd March 2010

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Laboratory Report

pH-BUFFERING TESTWORK (GCA8527)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	8.4
0.40	2.0	7.3
0.80	3.9	6.9
1.20	5.9	6.5
1.60	7.8	5.7
2.00	9.8	5.1
2.40	12	4.6
2.80	14	4.2
3.20	16	3.9
3.60	18	3.7
4.00	20	3.6
4.40	22	3.4
4.80	24	3.3
5.20	25	3.2
5.60	27	3.1
6.00	29	3.0
6.40	31	3.0

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 1.00 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.
Calibration of pH-Glass Electrode:
Immediately prior to titration: asymmetry potential = -10 mV (pH=7.00); slope-point = 177 mV (pH=4.00); 94.5 % of Nernstian response for 25 °C.
Immediately following titration: pH=7.00 buffer read pH=7.04 and pH=4.00 buffer read pH=4.05. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
3rd March 2010

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Laboratory Report

pH-BUFFERING TESTWORK (GCA8528)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	8.7
0.40	0.4	8.2
0.80	0.8	7.7
1.20	1.2	7.4
1.60	1.6	7.1
2.00	2.0	6.8
2.40	2.4	6.5
2.80	2.7	6.2
3.20	3.1	5.8
3.60	3.5	5.4
4.00	3.9	5.1
4.40	4.3	4.8
4.80	4.7	4.6
5.20	5.1	4.4
5.60	5.5	4.2
6.00	5.9	4.1
6.40	6.3	3.9
6.80	6.7	3.8
7.20	7.1	3.7
7.60	7.4	3.6
8.00	7.8	3.5
8.40	8.2	3.5
8.80	8.6	3.4
9.20	9.0	3.3
9.60	9.4	3.3
10.00	9.8	3.2
10.40	10	3.2
10.80	11	3.1
11.20	11	3.1
11.60	11	3.0
12.00	12	3.0

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 5.00 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:
Immediately prior to titration: asymmetry potential = -8 mV (pH=7.00); slope-point = 177 mV (pH=4.00); 95.2 % of Nernstian response for 25 °C.
Immediately following titration: pH=7.00 buffer read pH=7.03 and pH=4.00 buffer read pH=4.04. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
3rd March 2010

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Laboratory Report

pH-BUFFERING TESTWORK (GCA8529)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	9.2	16.80	165	4.8
0.40	3.9	8.7	17.20	169	4.7
0.80	7.8	8.4	17.60	172	4.5
1.20	12	8.2	18.00	176	4.6
1.60	16	8.1	18.40	180	4.6
2.00	20	8.0	18.80	184	4.5
2.40	24	7.9	19.20	188	4.4
2.80	27	7.9	19.60	192	4.4
3.20	31	7.8	20.00	196	4.3
3.60	35	7.7	20.40	200	4.3
4.00	39	7.6	20.80	204	4.2
4.40	43	7.5	21.20	208	4.1
4.80	47	7.3	21.60	212	4.1
5.20	51	7.3	22.00	216	4.0
5.60	55	7.2	22.40	220	4.0
6.00	59	7.1	22.80	223	3.9
6.40	63	7.0	23.20	227	3.8
6.80	67	6.9	23.60	231	3.8
7.20	71	6.8	24.00	235	3.7
7.60	74	6.7	24.40	239	3.7
8.00	78	6.4	24.80	243	3.6
8.40	82	6.3	25.20	247	3.6
8.80	86	6.2	25.60	251	3.5
9.20	90	6.2	26.00	255	3.5
9.60	94	6.0	26.40	259	3.4
10.00	98	6.0	26.80	263	3.4
10.40	102	5.7	27.20	267	3.3
10.80	106	5.4	27.60	270	3.3
11.20	110	5.3	28.00	274	3.3
11.60	114	5.1	28.40	278	3.2
12.00	118	5.0	28.80	282	3.2
12.40	122	4.9	29.20	286	3.1
12.80	125	4.8	29.60	290	3.1
13.20	129	5.3	30.00	294	3.1
13.60	133	5.2	30.40	298	3.0
14.00	137	5.1	30.80	302	3.0
14.40	141	5.0	31.20	306	3.0
14.80	145	5.0			
15.20	149	5.0			
15.60	153	5.0			
16.00	157	5.0			
16.40	161	4.9			

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 0.50 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -9 mV (pH=7.00); slope-point = 177 mV (pH=4.00); 94.7 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.04 and pH=4.00 buffer read pH=4.05. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
4th March 2010

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA8530)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	9.8	16.80	165	7.6
0.40	3.9	9.2	17.20	169	7.6
0.80	7.8	8.8	17.60	172	7.6
1.20	12	8.6	18.00	176	7.6
1.60	16	8.4	18.40	180	7.6
2.00	20	8.3	18.80	184	7.6
2.40	24	8.2	19.20	188	7.6
2.80	27	8.1	19.60	192	7.6
3.20	31	8.1	20.00	196	7.5
3.60	35	8.0	20.40	200	7.5
4.00	39	8.0	20.80	204	7.5
4.40	43	8.0	21.20	208	7.5
4.80	47	8.0	21.60	212	7.5
5.20	51	7.9	22.00	216	7.5
5.60	55	7.9	22.40	220	7.5
6.00	59	7.9	22.80	223	7.4
6.40	63	7.9	23.20	227	7.4
6.80	67	7.9	23.60	231	7.4
7.20	71	7.8	24.00	235	7.4
7.60	74	7.8	24.40	239	7.4
8.00	78	7.8	24.80	243	7.3
8.40	82	7.8	25.20	247	7.3
8.80	86	7.8	25.60	251	7.3
9.20	90	7.8	26.00	255	7.3
9.60	94	7.8	26.40	259	7.2
10.00	98	7.8	26.80	263	7.2
10.40	102	7.8	27.20	267	7.2
10.80	106	7.8	27.60	270	7.2
11.20	110	7.8	28.00	274	7.1
11.60	114	7.7	28.40	278	7.1
12.00	118	7.7	28.80	282	7.0
12.40	122	7.7	29.20	286	7.0
12.80	125	7.7	29.60	290	7.0
13.20	129	7.7	30.00	294	6.9
13.60	133	7.7	30.40	298	6.9
14.00	137	7.7	30.80	302	6.8
14.40	141	7.7	31.20	306	6.8
14.80	145	7.7	31.60	310	6.7
15.20	149	7.7	32.00	314	6.5
15.60	153	7.7	32.40	318	6.5
16.00	157	7.6	32.80	321	6.5
16.40	161	7.6	33.20	325	6.4

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H2SO$_4$/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
33.60	329	6.4	44.00	431	5.0
34.00	333	6.4	44.40	435	4.9
34.40	337	6.4	44.80	439	4.7
34.80	341	6.3	45.20	443	4.6
35.20	345	6.3	45.60	447	4.4
35.60	349	6.2	46.00	451	4.3
36.00	353	6.2	46.40	455	4.1
36.40	357	6.2	46.80	459	4.0
36.80	361	6.1	47.20	463	3.8
37.20	365	6.1	47.60	466	3.7
37.60	368	6.0	48.00	470	3.6
38.00	372	6.0	48.40	474	3.5
38.40	376	6.0	48.80	478	3.3
38.80	380	5.9	49.20	482	3.3
39.20	384	5.9	49.60	486	3.2
39.60	388	5.8	50.00	490	3.1
40.00	392	5.8	50.40	494	3.0
40.40	396	5.7	50.80	498	3.0
40.80	400	5.7			
41.20	404	5.6			
41.60	408	5.6			
42.00	412	5.5			
42.40	416	5.4			
42.80	419	5.3			
43.20	423	5.2			
43.60	427	5.1			

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 0.50 g of crushed sample (nominal -2mm) initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -8 mV (pH=7.00); slope-point = 176 mV (pH=4.00); 95.1 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.03 and pH=4.00 buffer read pH=4.04. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell
4th March 2010

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Appendix Q5

Sediment Quality Assessment – Wheatstone Dredging Program

Tables

Figures

Appendices

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Appendix F	Particle Size Distribution Analysis
Appendix G	Radionuclide Analysis
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Report

Sediment Quality Assessment
Wheatstone Dredging Program

09 JULY 2010

Prepared for
Chevron Australia Pty Ltd

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Executive Summary

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train liquefied natural gas (LNG) and domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast. The LNG and Domgas plant will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and other yet-to-be determined gas fields. The Wheatstone Project is referred to as the Project and the Ashburton North Strategic Industrial Area (Ashburton North SIA) is the proposed site for the LNG and Domgas plant. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land. The LNG plant will have a maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Project has been referred to the State Environmental Protection Authority (EPA) and the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

Onshore infrastructure will be located adjacent to the Ashburton River delta and nearby to the Hooley Creek tidal system and requires construction of breakwaters across a sandy coastline for the placement of a materials offloading facility (MOF) and navigation channel, a product loading facility (PLF), and the installation of the gas trunkline (Trunkline Route). As part of this proposal, dredging of approximately 45 700 000 m^3 (45 000 000 m^3 for the navigation channel, MOF and PLF; 3 million m^3 for the Trunkline Route) of marine sediments will be required to enable the construction of the aforementioned marine facilities. A range of statutory approvals are required under State and Commonwealth legislation, prior to the proposed development taking place.

Geochemical testing, as well as physical characterisation, of sediments in the Dredge Area and the proposed dredge material placement sites was completed to assess the distribution, variability and concentrations of contaminants of potential concern (COPCs) within dredged sediments, in comparison to sediments within the proposed dredge material placement sites. Preliminary Pilot Survey data (URS Australia Pty Ltd (URS) 2009a) was also incorporated to provide support for the proposed excavation of the Trunkline Route. The sediment quality assessment was carried out in alignment with the Sampling and Analysis Plan (SAP) and the National Assessment Guidelines for Dredging (NAGD) (Commonwealth of Australia, 2009). The primary use of the sediment quality data was to characterise the contaminant status of sediment and confirm its acceptability for offshore placement options.

A total of 72 short core, 15 deep core and 64 grab sediment samples were taken from within and adjacent to the Dredge Area and from within the proposed dredge material placement sites. These samples were analysed for

- total metals and metalloids (short cores: aluminium (Al), antimony (Sb), arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), zinc(Zn); deep cores: as above plus beryllium (Be), cobalt (Co), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silver (Ag), tin (Sn), vanadium (V));
- tributyltin (TBT) (excluding deep cores);
- total organic carbon (TOC) (excluding deep cores);
- moisture content (MC);
- particle size distribution (PSD) (selected short cores and grab samples); and
- carbonate ($CaCO_3$) content (selected short cores and grab samples).

The objectives of the sediment quality assessment included;

Executive Summary

- to complete a field and analytical program of sediment proposed for dredging in accordance with guidance provided in the NAGD;
- to characterise sediment PSD and contaminant concentrations at the proposed dredge material placement sites;
- to assess the physical property of surficial sediment;
- to determine whether the quality and quantity of data gathered are sufficient to adequately characterise the contamination status of the sediments to assess placement options; and
- to classify the sediment as acceptable, or otherwise, for unconfined placement at proposed dredge material placement sites.

The assessment of the physical properties of surficial sediment was also carried out so the resultant information could be used in predictive models of sediment behaviour in dredge and placement plumes.

Concentrations of the COPCs As, Cr and Ni exceeded the NAGD Screening Levels for marine sediments however this only occurred at a limited number of sites and it could be demonstrated that they existed in naturally occurring concentrations. It was determined that dredged sediments from within the Dredge Area would be acceptable for unconfined, offshore placement at the proposed dredge material placement sites. It was also extrapolated that sediments from within the Trunkline Route would not contain significantly high levels of COPCs and thus could also be disposed of within the proposed dredge material placement sites.

1

Introduction

1.1 Background

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train liquefied natural gas (LNG) and domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast. The LNG and Domgas plant will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and other yet-to-be determined gas fields. The Wheatstone Project is referred to as the Project and the Ashburton North Strategic Industrial Area (Ashburton North SIA) is the proposed site for the LNG and Domgas plant. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land. The LNG plant will have a maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Project has been referred to the State Environmental Protection Authority (EPA) and the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

Onshore infrastructure will be located adjacent to the Ashburton River delta and nearby to the Hooley Creek tidal system and requires construction of breakwaters across a sandy coastline for the placement of a materials offloading facility (MOF) and navigation channel, a product loading facility (PLF), and the installation of the gas trunkline (Trunkline Route). As part of this proposal, dredging of approximately 45 700 000 m^3 (45 000 000 m^3 for the navigation channel, MOF and PLF; 3 million m^3 for the Trunkline Route) of marine sediments will be required to enable the construction of the aforementioned marine facilities. A range of statutory approvals are required under State and Commonwealth legislation, prior to the proposed development taking place.

The Dredge Area (Figure 1-1) and the proposed volume to be dredged (Table 1-1) are described in Section 2.1 of the SAP (Appendix A). Capital dredging of sediments as part of construction at the Ashburton North SIA requires a geochemical assessment of these sediments, which is the principal focus of this Sediment Quality Assessment report. Area and volume estimates for capital dredging are based on previously surveyed seabed bathymetry.

The current bathymetry was compared against initial dredging estimates and design depths in order to determine the location, volume and depth of sediment to be dredged in the Dredge Area (including the navigation channels, PLF and MOF). The design depths (including a siltation allowance of 0.45 m, a dredge tolerance of 0.75 m and a survey accuracy of 0.1 m) for the main navigation channel, the MOF and navigation channel and the PLF are no more than 15 m, 15 m and 9 m below LAT, respectively.

The indicative in situ gross volume of sediment expected to be dredged in the MOF and the PLF is approximately 45 000 000 m^3 over an area of 11 500 000 m^2 (Table 1-1). It is proposed that dredged sediments will be disposed of at one of the five proposed dredge material placement sites (Figure 1-2).

The establishment of a Trunkline Route will also be necessary for the placement of the 225 km gas trunkline, running from the Wheatstone Platform (WP) to the onshore facility. This Trunkline Route will cross the shallow, nearshore shelf between Thevenard and Bessiers islands and skirt Ashburton Island before coming ashore at the plant site. The Trunkline Route slopes down from the WP in approximately 70 m of water to 120 m for about 25 km before following the 110 m water-depth contour for most of its length until 60 km from shore. From there it will gradually slope up to the shelf for about 30 km and will level off in about 10 m of water, before rising to the onshore plant in the last few

1 Introduction

kilometres. The gas trunkline will be up to approximately 1.2 m in diameter and be no more than 1 m in height from the sea floor.

The indicative gross volume of sediment to be mechanically trenched from a nearshore section of the Trunkline Route is approximately 3 million m^3. The excavated area will be approximately 5 m wide, while there will be a disturbance corridor of approximately 20 m in width. The excavated material will be placed at the proposed Nearshore Dredge Material Placement Site C.

The dredge material volumes presented below relate to dredging required for the key marine infrastructure, and which have been used in this version of the impact assessment. These volumes do not include excavation material volumes that may be generated from the installation of the Trunkline Route. Ongoing work is being undertaken to finalise these volumes and identify implications for the results of the sediment quality assessment presented to date.

Table 1-1 Dredge Area volumes.

Dredge Area	Total for Area (M^3)
Temporary navigation channel	935 000
MOF areas	1 580 000
PLF areas	16 445 000
PLF Approach	20 160 000
Total Capital Dredge volume	39 120 000
Design uncertainties	5 880 000
Estimated total Capital Dredge volume	45 000 000

1 Introduction

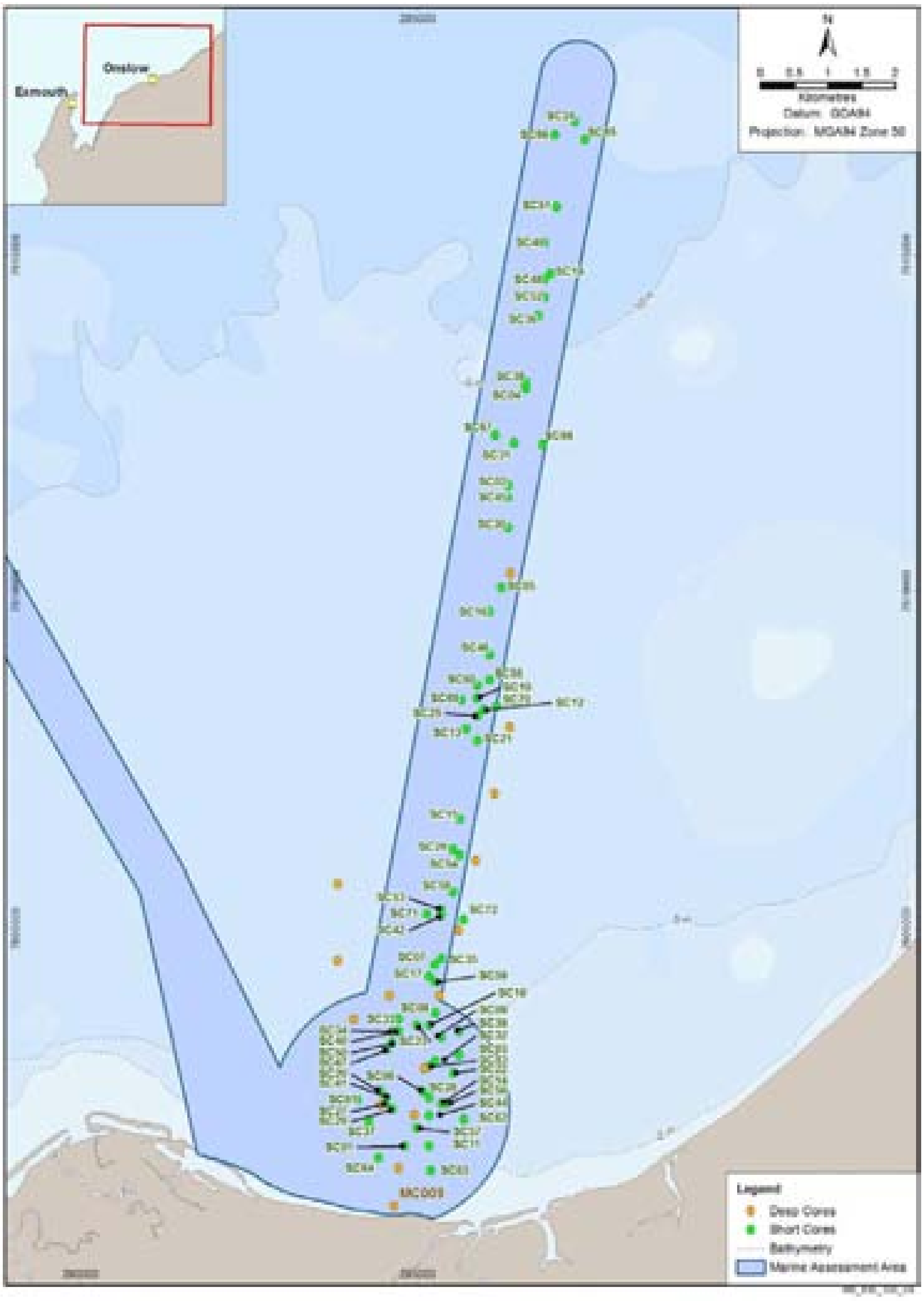

Figure 1-1 Location of the proposed Dredge Area and relevant sampling sites.

1 Introduction

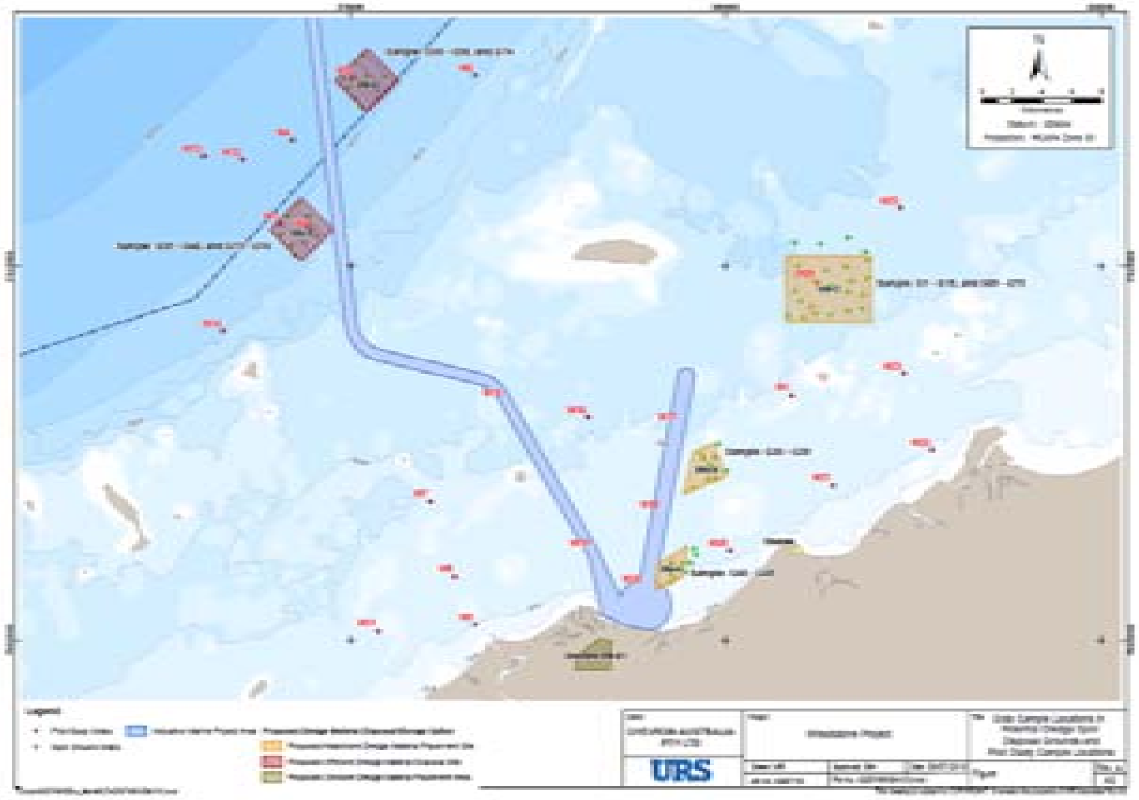

Figure 1-2 Location of potential dredge material placement sites (Site A – E).

1 Introduction

Geochemical testing of sediments in the Dredge Area and the proposed dredge material placement sites was completed to assess the distribution and variability of contaminants within sediments and to compare the concentrations of COPCs to Screening Levels in the NAGD.

Preliminary sediment and geotechnical investigations have indicated that marine sediments in this remote region are unlikely to be contaminated by anthropogenic sources and are likely to be suitable for unconfined placement at sea (URS 2009a). The Pilot Survey involved the collection of 24 sediment grab samples obtained over a large regional area and found that a majority of analytes present in the sediments did not exceeded the NAGD Screening Levels. Ni and As, however, did exceed the NAGD Screening Levels.

This report was prepared with reference to the NAGD to assess the proposed dredging program and any available historical data on the physical and chemical characteristics of sediments in the vicinity of the Dredge Area (Phase I assessment). In addition, this report details sampling and analysis of sediments in the Dredge Area for COPC listed on the Contaminants List of the SAP (Appendix A) and a comparison to NAGD Screening Levels (Phase II assessment). Sampling was undertaken in alignment with the initial SAP.

The primary use of the sediment data is to characterise the contaminant status of sediment and assist in the selection of placement options. The new data, together with limited historic data (where current and appropriate), will be used to classify the sediments in a single dredge management unit.

This report presents the methodologies that were employed during the investigation and covers the following aspects:

- Objectives;
- Brief description of proposed dredging program; and
- Environmental setting.

Historic data and existing information from previous studies is compiled in the SAP (Appendix A) and includes:

- Identification of potential contaminant sources, COPCs and potential data gaps;
- Rationale for the proposed sampling design; and
- Scope of work including assessment methodology.

Field Methods and Procedures and the laboratory analytical program employed during the investigation are also outlined in the SAP (Appendix A).

1.2 Hydrodynamics and Coastal Processes

A summary of hydrodynamics and coastal processes in and near the Dredge Area is provided in the SAP (Appendix A).

1.3 Regional Physical Sediment Characteristics

Surficial sediment may be remobilised by natural processes including current and wind resuspension and large rainfall events, but is not expected to be frequently resuspended by vessels operating in the proposed navigation channel.

As stated in Section 2.3.7 of the SAP (Appendix A), much of the nearshore region adjacent to the Ashburton River mouth is covered by silt and sand sheets of varying thickness that overlie Pleistocene limestone. Sediments located in the vicinity of Ashburton River discharge areas comprise silts and clays with a high silica content. Sediments become increasingly coarse grained and increase in $CaCO_3$ content with distance offshore, due to decreasing input of terrigenous silts and clays from river runoff and coastal erosion. Sediment re-suspension is frequent immediately seaward of the intertidal zone and leads to considerable turbidity (Forde, 1985). Resuspension is mainly due to wind-driven waves, whereas further offshore the sediment movement is a result of internal or subsurface waves (Heywood *et al*., 2000). Coarse and medium-grained calcareous sandy sediments predominate to the 100 m depth contour, with a transition to continental slope muds around 100-150 m depth (Black *et al*., 1994).

1.4 Potential Contaminant Sources of the North-West Shelf

There is a paucity of published literature directly relevant to the NWS as outlined by Heywood *et al*. (2006). A search of the bibliography by Jernakoff *et al*. (2006) reveals that of the 1,725 records, only 26 relate to chemistry, and of those, only 15 are in published literature. Due to the largely undeveloped nature of the Ashburton River catchment area and the Dredge Area, there are very few known sources of anthropogenic contaminants. In addition, potential point sources of contamination to the Dredge Area are likely to result in a low level of contamination of surficial sediments, due to the highly dispersive nature of the NWS marine environment. In particular cyclone activity effectively resuspends and transports sediments to water depths exceeding the depths of the Dredge Area (URS 2009b).

On a broader regional scale, it is difficult to determine the total loading of pollutants to the marine environment from industrial and domestic point sources on the NWS (Heywood *et al*., 2006). Coastal issues related to domestic waste, such as sewage disposal, have been perceived as less significant in this region than elsewhere because of its low population density. However, recurring pollutants from diffuse sources in the region include metals from antifoulants on shipping, harbour works, shore-based plants and cross-shelf trunklines. Several studies using local invertebrates, such as oysters and intertidal gastropods, have detected elevated levels of some metals (Heywood *et al*. 2006).

Potential contaminants from marine based activities on the NWS include organic and inorganic contaminants from the oil and gas industry (i.e. drilling activities and production), shipping activities, commercial and recreational fishing activities aquaculture and tourism (D.A. Lord and Associates, 2002).

Sediment quality has been assessed in the vicinity of the Dredge Area on two previous occasions. In June 2005, marine sediments were sampled by the Department of Environment and Conservation (DEC) at four locations offshore of the mouth of the Ashburton River and at four locations offshore from Onslow to estimate the background concentrations for selected contaminants (DEC, 2006). A primary assumption for this study was that no anthropogenic contamination had occurred in these areas, with sediments analysed for organotins, polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene and xylene compounds (also referred to as BTEX), organochlorine (OC) pesticides and polychlorinated biphenyls (PCBs), as well as total metals and metalloids (Al, As, Cd, Cr, Co, Cu, Fe, Pb, Hg, Ni, Se, Ag, Va and Zn) (DEC, 2006). The results of this study confirmed no discernible anthropogenic enrichment of contaminants in sediments offshore of the Ashburton River mouth or the town of Onslow. All concentrations of organotins, PAHs, TPH, BTEX compounds, OC pesticides and PCBs were reported as below the laboratory limit of reporting (LOR), although the LOR in that investigation exceeded the Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia

1 Introduction

and New Zealand (ANZECC/ARMCANZ) (2000) guideline values for some organic compounds. The DEC (2006) also estimated natural background concentrations of metals in marine sediments, noting that natural background concentrations of As were above the ANZECC/ARMCANZ (2000) guideline value. All other mean metal concentrations in sediments around the Ashburton River mouth and Onslow were below their relevant ANZECC/ARMCANZ (2000) guideline values (DEC, 2006).

In February 2009, URS collected surface sediment samples for the Project at 17 nearshore sites in the vicinity of the Dredge Area and at eight sites within a proposed dredge material placement site. Sediments were analysed for a suite of total metals (Al, As, Cd, Cr, Cu, Fe, Mn, Hg, Ni, Pb, Va and Zn), TPH, BTEX compounds and TBT (URS 2009a). The results of this study supported those of the DEC study, with concentrations of TPH, BTEX compounds, TBT and metals being below the laboratory LOR, or below the relevant NAGD Screening Levels (URS 2009a). The NAGD Screening Levels for As were exceeded in eight of the 25 surficial sediment samples, as previously found in the DEC (2006) investigation. In addition, the concentrations of Ni exceeded NAGD Screening Levels in two of the 25 surficial sediment samples obtained during the Pilot Survey (URS 2009a).

The concentrations of metals in whole sediments sampled in the Pilot Survey (URS 2009a) correlate strongly with the concentrations of Al, which is a proxy analyte for grainsize (i.e. clay mineral content) (Loring and Rantala, 1992). Grainsize is therefore likely to be the principal factor which determines the concentrations of metals in whole sediment, while anthropogenic contributions in these sediments were not discernible in previous investigations. An exception is As, which does not correlate strongly with Al. As may be more strongly associated with the sediment sand fraction (>0.063 mm fraction) and the carboniferous and Fe-oxide sediment components (Davies, 1979). Studies of the geochemistry and mobility of As from sediments under different environmental conditions confirmed that large amounts of As may be bound to sediments due to Fe/As co-precipitation and the formation of insoluble precipitates at the water-sediment interface (Nikolaidis *et al*., 2004). Similarly, Devesa-Rey *et al*. (2008) found As in sediments to be mainly associated with the least mobile fractions and bound to Fe-Al oxides and the residual mineral phase.

Once contaminants are introduced to the marine environment of the NWS they are subject to a range of physical, chemical and biological processes that influence their fate. A review of contaminant sources, impacts, pathways and effects on the NWS by Fandry *et al*. (2006) identified several COPC in the region, including:

- metals (Ba, Cd, Cr, Cu, Pb, Hg and Zn), associated with shipment of minerals and runoff from onshore mining activities;
- TBT, an antifouling constituent on ships;
- nitrogen, a nutrient;
- produced water (PW); and
- hydrocarbons, associated with oil spills and chronic releases such as bilge and tank residues from ships.

As well as these identified COPCs, it was also considered conceivable that PAHs and OC pesticides may have contaminated sediments via runoff from the Ashburton River (Department of Environment, Water, Heritage and the Arts (DEWHA) 2009). However, because of the undeveloped nature of the catchment and the sparse nature of farming activities, it was further considered that these sources would be unlikely to make a substantial contribution to contaminant loads in offshore sediments on the NWS, particular with regard to the highly dispersive inner shelf environment (Department of Agriculture, Forestry and Fishing 2008).

Significant dredging activity occurs in the NWS region, particularly in the major ports of Dampier and Port Hedland. During dredging operations, suspended sediment concentrations are very high for sustained periods. Monitoring suggests that the impact on existing adjacent macro-benthos communities is minimal, but there are no data to show the effects of suspended sediment on very small organisms and on new recruits such as juvenile corals. When synthetic olefin- and ester-based drilling muds are adopted for exploration purposes their effects will need to be studied, particularly in more sensitive areas. Little is known about the transport of cuttings on the NWS or about the implications for dispersion and degradation of the fluids (Heywood *et al*., 2006).

The effects of aromatic components of the PW plume on the water column, and the fate of these compounds in the sea surface microlayer given the high possibility of photo-oxidation, are not fully understood to date. The volume of PW released will increase with the number and age of drilling platforms on the NWS. The fate and effects (if any) of the components other than hydrocarbons, including added chemicals such as corrosion inhibitors, are yet to be studied. Research will be required to determine the effects of chronic, low-level pollution loads on the NWS (Heywood *et al*., 2006).

1.4.1 Tributyltin

The need for effective antifoulants, which prevent the settlement and growth of marine organisms on submerged structures, such as buoys, fish cages and ships hulls, is recognised universally (Evans Birchenough and Brancato 2000; Evans, Tsvetnenko and Woodworth 2000; Konstantinou and Albanis, 2004). For many years, TBT compounds were the most widely used active ingredients in paint formulations. However, use of TBT has been regulated internationally since 1990 due to its severe impact on the aquatic ecosystem (Fent, 1996) and the demonstrated effects of TBT on the disruption of the endocrine system by mimicking or inhibiting the action of gonadal steroid hormones, oestradiol and testosterone (Makita and Omura, 2006).

Prolonged release of TBT from ship-bottom coatings has resulted in the imposition of male sexual characteristics upon female gastropods, or imposex, a phenomenon which was first described by Blaber (1970) in the United Kingdom. Imposex in marine gastropods has subsequently been linked to the exposure of these biota to TBT in aquatic systems worldwide (e.g. Smith, 1981a; Smith, 1981b; Smith, 1981c; Santos *et al*., 2004; Foale, 1993). This cause and effect relationship ultimately resulted in a global ban of TBT. The decline in the occurrence of imposex following worldwide bans has been used as a biomarker and biological indicator for environmental monitoring of TBT since the introductions of these bans in countries worldwide (Axiak *et al*., 2003).

The use of TBT as an antifouling agent was regulated from 1989 and is now controlled under Victoria Government Notifiable Chemicals Order (Victorian State Government 2000). TBT is banned from use on small vessels (i.e. less than 25 m in length) and is being phased out on larger and international vessels. However, despite the partial ban on the use of TBT in Australia, a survey of imposex in *Thais orbita* (a predatory gastropod mollusc) along the New South Wales (NSW) coast found imposex was still widespread 10 years after the introduction of the ban, in particular within harbour/bay areas where contamination “hotspots” are still present and where physical remobilization and dispersion processes may be less pronounced compared to high-energy coastal areas (Gibson and Wilson, 2003).

Australia is signatory to the *International Convention on the Control of Harmful Anti-fouling Systems on Ships* (International Maritime Organisation 2001), which prohibits the use of harmful organotins in anti-fouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. Under the terms of the Convention, Parties to the Convention are required to prohibit and/or restrict the use of harmful anti-fouling systems on ships flying their flag, as well as ships not entitled to fly their flag but which operate under their authority and all ships that enter a port, shipyard or offshore terminal of a Party.

Importantly, the presence of TBT is not necessarily linked to silts and muds because TBT occurs in flakes that may be deposited in sandy areas as well. Therefore, TBT may potentially be present in quantities above the required analytical detection limit of 0.5 µg Sn/kg.

1.4.2 Mercury

There are no natural resources of Hg in the Ashburton River catchment and offshore environment adjacent to Onslow. Atmospheric contributions of particulate-bound anthropogenic Hg emissions have been shown to be responsible for elevated levels of CH_3Hg^+ (methyl-mercury) since the 1980s that are present in piscivorous fish from aquatic environments remote from industrial sources, such as the Gippsland Lakes region (Fitzgerald *et al*., 1997). However, no such data are currently available for the NWS region.

1.5 Objectives

This Sediment Quality Assessment has the following objectives:

- to complete a field and analytical program of sediment proposed for dredging in accordance with guidance provided in the NAGD ;
- to characterise sediment grainsize and contaminant concentrations at the proposed dredge material placement sites;
- to assess the physical property of surficial sediment;
- to determine whether the quality and quantity of data gathered are sufficient to adequately characterise the contamination status of the sediments to assess placement options; and
- to classify the sediment as acceptable, or otherwise, for unconfined placement at proposed dredge material placement sites.

The assessment of the physical properties of surficial sediment was carried out so the resultant information could be used in predictive models of sediment behaviour in dredge and placement plumes. Additionally, geochemical characteristics of sediments within the Trunkline Route were extrapolated using the existing data set to provide evidence that no further geochemical sampling of sediments is necessary along the Trunkline Route.

1.6 Sediment Quality Assessment Rationale

The SAP (Appendix A) was developed for the sediment quality assessment program at the Dredge Area on the basis of the rationale outlined in the following sections. In accordance with the SAP, samples were collected from within, and outside of, the proposed Dredge Area as well as at five proposed dredge material placement sites (Figure 1-1; Figure 1-2).

1.6.1 Dredge Area

The limited existing chemical data indicates that sediments from within, and adjacent to, the Dredge Area are generally uncontaminated. The exceptions are As and Ni which have been documented as exceeding the NAGD Screening Levels (URS 2009a). However, unlike the current investigation, the previous regional investigation did not specifically focus on sediment within the proposed Dredge Area.

1.7 Scope of Works

This investigation assessed sediments to be dredged from the proposed navigation channel, the MOF and the PLF, and sediments from the proposed dredge material placement sites. Sediments proposed for dredging in this area have been inadequately characterised to date and represent a total estimated area of about 11,500,000 m^2 with a corresponding volume of assessable sediment of about 11,500,000 m^3 in the upper 1 m of the sediment profile (Appendix A).

The primary use of the sediment quality data was to characterise the contaminant status of sediment and confirm its acceptability for offshore placement options. The scope of works for the Dredge Area contamination investigation is outlined in the following sections.

1.7.1 Contaminants of Potential Concern

Review of the available literature in the SAP (Appendix A) indicates that the Dredge Area is distant from all known, current and historical, contaminant sources. The Contaminants List presented in the SAP (Appendix A) was based on COPCs derived from the current understanding of site history (including urbanization and catchment wide industrial activities) and existing data. Short cores were collected at 60 sample locations and sediment samples from short cores were analysed for all COPCs on the Contaminants List:

- metals (Ba, Cd, Cr, Cu, Hg, Ni, Pb, and Zn);
- metalloids (As, Sb);
- TBT; and
- TOC.

In addition, Al was analysed in all samples and a select number of short core samples were analysed for $CaCO_3$ content and PSD to enable a comparison of surficial sediment texture in the Dredge Area and in the proposed dredge material placement sites.

Sediment samples from five randomly selected locations within the Dredge Area also underwent testing for radionuclide activity (SC5, SC13, SC17, SC33, SC55). Sediment samples from deep cores were analysed for the same COPCs as sediment samples from the short cores (excluding TBT, TOC, PSD and $CaCO_3$ content) to confirm the contaminant status of these sediments. Additional metal analytes were opportunistically included for deep core sediment samples, including Be, Co, Fe, Mn, Mo, Se, Ag, Sn and V, although these analytes are not considered further in the current assessment.

As concentrations of TBT in all samples were below the analytical LOR of 0.5 μgSn/kg, normalisation of TBT concentration was not required. Normalisation is usually required when concentrations exceed this limit.

2

Methodology

2.1 Sediment Sampling

Sampling in the Dredge Area and in the proposed dredge material placement sites commenced on 22 September 2009 and was completed on 28 September 2009. Sampling was conducted from a 17 m long twin hull catamaran (RV Adrenalin Sprint; Operator: Broadsword Marine Pty Ltd). The sampling position at each sample location was recorded using a global positional system (GPS) with an accuracy of +/-4 m. Locations were recorded in Eastings and Northings in the AMG94 (Zone 54) coordinate system. Water depths at each sample location were determined using a depth profiler.

2.1.1 Short Cores and Deep Cores

Near-surface sediments were sampled at 60 sample locations (Figure 1-1) using a manually-driven piston coring device to refusal. Refusal was encountered at every short core sample location at a depth of less than 0.40 m, resulting in only one sample per short core location. Sediment samples from the short cores were analysed for all COPCs on the SAP Contaminants List (Appendix A), excluding radionuclide (the sum of gross alpha and gross beta activity) activity, which was assessed in five randomly selected samples.

An additional 12 sample locations adjacent to the Dredge Area (i.e. within 100-200 m west and east) were sampled by short piston corer, or grab sampler if there was a refusal of the corer at or near the surface. Samples from these additional 12 sample locations (SC61-SC72) were analysed for all COPCs on the SAP Contaminants List.

A randomly selected and distributed sample of 19 short cores from across the Dredge Area were also analysed for $CaCO_3$ content and PSD.

In addition to the short cores, 15 deep cores (Figure 1-1) were sampled to the full depth of dredging and were analysed for all COPCs on the SAP Contaminants List, excluding TBT and radionuclide activity. Subsurface, consolidated sediments and sediments deeper than 1 m below the sea floor were sampled as part of geotechnical investigations to characterise the geological strata within and near the Dredge Area. The 15 deep core samples were all taken from within the southern nearshore section of the proposed navigation channel. These deep cores penetrated to the depth of dredging and were collected to validate the assumption that subsurface sediments were not contaminated.

2.1.2 Selection of Sample Locations

The sampling rationale outlined in Section 3 of the SAP (Appendix A) was developed on the basis of the history of the proposed Dredge Area, its known contaminant status and its generally uncontaminated sediment.

Short core sample locations SC1-SC60 were selected by placing a 90 x 90 m square grid over the entire area to be dredged, numbering each square (total 1,500) and selecting 60 squares using random numbers generated by internet sourced software (Urbaniak and Plous, 2009). Samples were collected as close as practicable to the centre of each of the selected grid squares.

An additional 12 sample locations were included within 100-200 m to the west and east of the navigation channel (SC61-SC72), to enable a geochemical characterization of near surface sediments outside the proposed Dredge Area and to provide additional data, should subsequent adjustments to the location of the navigation channel be required (Figure 1-1).

2.1.3 Shallow and Deep Cores in Dredge Area

Sediment was collected to a maximum depth of 0.40 m at the 72 sample locations using a piston corer. A Van Veen sediment grab sampler was used where a core sample was not obtained due to a lack of penetration of the piston corer at these locations (i.e. armoured, shelly and limestone surface and loss of core). A Van Veen grab sampler was used at 11 of the 72 short core sample locations, six of which are located within the Dredge Area (i.e. SC5, SC13, SC16, SC24, SC25 and SC51).

Piston cores in the Dredge Area and in water depths of <15 m were collected by highly experienced URS personnel from the workboat, which was anchored at each sample location. The corer was used to collect unconsolidated sediment to a maximum depth of penetration. Although a maximum designated depth of penetration of 1.0 m below the seabed was attempted at every location, refusal of the core tube at or near the surface in armoured beds (limestone, shells) or in stiff clays at depths of 0.4 m or less was observed at all sample locations.

A clean, polycarbonate barrel (80 mm inner diameter) was loaded into the corer and lowered to the seabed. The barrel was then remotely driven (using weights) into the sediment with a piston remaining at bed level to create a partial vacuum and draw sediments into the barrel. The corer was able to penetrate and retain the entire profile of soft sediments, but penetration was limited in dense sand, or stiff clay units. Core catchers were successfully used in sandy and gravelly substrates to prevent core loss during retrieval from the seabed.

Following sample retrieval, the core length was measured and the sample described, including colour, composition and sediment texture, as well as other distinguishing characteristics, such as shell content, biota and presence of a hydrous layer.

URS sampling staff determined the acceptability of the core following collection, which was based on the following criteria:

- no obvious loss of surficial sediment or sediment from the bottom of the core;
- vertical penetration of core through the sedimentary profile to the required depth or depth of refusal; and
- continuous and undisturbed sediment stratigraphy.

The cores were each logged and photographed through the clear core barrel prior to or after extraction (Appendix B). Descriptions of short core and grab samples are shown in Appendix C and deep core logs are shown in Appendix D. Sample identifiers included the location and depth interval, for example, SC18_0.0-0.30, indicates that the sediment sample was collected from location SC18 and over the interval from 0.0 m to 0.30 m, using a piston corer (i.e. short core). The sampling date was also recorded on the label. A summary of short core and deep core samples is provided in Table 2-1 and Table 2-2, and locational and descriptive data are shown in Appendices C and D. Analytical and physicochemical data (including PSD) for short core samples are shown in Appendix D and analytical data for the deep cores are shown in Appendix E.

The locations of deep cores were selected for geotechnical purposes and their distribution covers the area in and near the Dredge Area evenly. While all 60 short core sample locations (SC1-SC60) are located within the proposed Dredge Area, 11 of the 15 deep core sample locations (MC001-MC015) are located outside of the proposed Dredge Area. These deep cores were obtained as part of the geotechnical investigation. However, 11 of the deep core sample locations are within 500 m of the Dredge Area and therefore provide an adequate characterization of the subsurface sediments below a depth of 1 m and to the depth of dredging in a regional setting.

2 Methodology

Surfical sediments were assessed by URS using shallow sediment coring, while sediments in deep cores were subsampled in cooperation with Coffey Geotechnics, who undertook the geotechnical sampling to maintain project synergies and avoid duplication of sampling activities. Although it is unlikely that contaminants would occur in the sediment below 1.0 m in depth and, while sampling intervals in the deep cores may usually necessitate a compositing of long subsurface core intervals at depths below 1.0 m, the actual subsampling intervals depended on the requirements of the geotechnical investigation. Although 0.1 m sample intervals were selected at appropriate depths and to the depth of dredging to assess the concentrations of COPCs (excluding TBT), composite samples of the 1.0-2.0 m depth interval were also obtained in each core, or where available, to assess the potential for contamination below the upper 1.0 m of sediments, which was assessed by the shallow coring. A total of between four and six downcore subsamples per deep core were taken and analysed for COPCs (excluding TBT), therefore adequately assessed the contamination status at each deep core location.

2 Methodology

Table 2-1 Short core sample IDs and locations.

Sample ID	Easting	Northing	Sample ID	Easting	Northing
SC1	294811	7601769	SC37	294280	7602127
SC2	296346	7611579	SC38	295623	7603478
SC3	295623	7603117	SC39	296611	7613104
SC4	296611	7613015	SC40	294724	7603477
SC5	296249	7610056	SC41	294546	7602486
SC6	295082	7602579	SC42	295351	7605190
SC7	295260	7604469	SC43	295167	7602947
SC8	295265	7603746	SC44	295172	7602223
SC9	295355	7603386	SC45	296341	7611399
SC10	295888	7608426	SC46	296075	7609054
SC11	295178	7601771	SC47	294551	7603207
SC12	295983	7608250	SC48	296885	7614639
SC13	295726	7607976	SC49	296887	7615181
SC14	295358	7602392	SC50	294634	7603305
SC15	295625	7606630	SC51	297065	7615718
SC16	296068	7609695	SC52	296880	7614370
SC17	295177	7604291	SC53	295354	7605281
SC18	295171	7603565	SC54	295626	7606088
SC19	296976	7614726	SC55	296073	7608697
SC20	294455	7602579	SC56	295442	7602396
SC21	295895	7607801	SC57	294996	7602039
SC22	295535	7602847	SC58	295530	7605550
SC23	294995	7603567	SC59	295268	7604199
SC24	297337	7616981	SC60	295893	7608613
SC25	295897	7608159	SC61	294112	7602449
SC26	295176	7602488	SC62	295694	7602174
SC27	294542	7602401	SC63	295202	7601407
SC28	295530	7606178	SC64	294421	7601591
SC29	294634	7602316	SC65	297483	7616720
SC30	296344	7610946	SC66	297037	7616787
SC31	296435	7612208	SC67	296156	7612320
SC32	295263	7603030	SC68	296858	7612181
SC33	294722	7603660	SC69	295656	7608403
SC34	294638	7603470	SC70	296183	7608312
SC35	295356	7604558	SC71	295138	7605216
SC36	296793	7614095	SC72	295687	7605137

2 Methodology

Table 2-2 Deep core sample IDs and locations.

Sample ID	Easting	Northing
MC001	296373	7608002
MC002	296146	7607007
MC003	295865	7606006
MC004	295609	7604978
MC005	295330	7604003
MC006	295109	7602920
MC007	294964	7602228
MC008	294722	7601436
MC009	TBC	TBC
MC010	294454	7602376
MC011	294060	7603652
MC012	294588	7603999
MC013	293819	7604525
MC014	293822	7605658
MC015	293816	7606981

2.1.4 Grab Sampling in Proposed Dredge Material Placement Sites

Dredged sediments are likely to be disposed of at one or more of five proposed dredge material placement sites, located to the east, northeast and northwest of the Dredge Area (Figure 1-2). Surface grab samples were obtained at the following sample locations to assess the surficial sediments:

- 10 sample locations at the proposed Nearshore Dredge Material Placement Site A;
- 10 sample locations at the proposed Nearshore Dredge Material Placement Site B;
- 24 sample locations at the proposed Nearshore Dredge Material Placement Site C, including 4 sample locations to the north of the site;
- 10 sample locations at the proposed Offshore Dredge Material Placement Site D; and
- 10 sample locations at the proposed Offshore Dredge Material Placement Site E.

One sample location at the proposed Nearshore Dredge Material Placement Site C, one sample location at the proposed Nearshore Dredge Material Placement Site A, and two sample locations at the proposed Nearshore Dredge Material Placement Site B had been previously sampled during the Pilot Survey (URS 2009a). The analytical data for these four samples were not included in subsequent discussions to maintain the integrity of the sampling, analysis and data interpretation of the works undertaken in the current investigation.

Therefore, a total of 64 sample locations were sampled within the five proposed dredge material placement sites. Samples were analysed for all COPCs on the Contaminants List, excluding TBT and TOC.

TBT and TOC were analysed in two samples randomly selected from each proposed dredge material placement site, excluding the proposed Nearshore Dredge Material Placement Site C, in which four samples were analysed. $CaCO_3$ content and PSD were also assessed in five or six samples from each proposed dredge material placement site, excluding PSD at the proposed Nearshore Dredge Material Placement Site C, from which 12 samples were obtained.

2 Methodology

A Van Veen grab sampler with a gape of 0.16 m^2 was used to collect surficial sediments to a depth of up to 0.1 m at 64 sample sites within the five proposed dredge material placement sites (Figure 1-2). The grab sampler was retrieved from the seabed to recover the most recently deposited sediments. The depth of penetration of the grab sampler was dependent on the surficial sediment texture, and penetration below a depth of 5 cm was limited in well-armoured substrates overlying stiff clays. A representative and well-homogenized subsample of the recovered grab sample was collected for analysis of COPCs (i.e. metals). Selected grab samples were also analysed for $CaCO_3$ content, PSD, TBT and TOC. A minimum of 10 randomly selected locations were also sampled within each of the potential dredge material placement sites to characterise surface sediments. A summary of grab samples collected is provided below (Table 2-3), while and locational and descriptive data are shown in Appendices C and D. Analytical and physicochemical data (including PSD) for grab samples are shown in Appendix D.

2 Methodology

Table 2-3 Sample locations within the five proposed dredge material placement sites.

Dredge Material Placement Site	Sample ID	Easting	Northing	Samples Collected	Total Samples	Priority
Dredge Material Placement Site A	G40	297892	7606074	10	10	High
	G41	298032	7605724			
	G42	297303	7604505			
	G43	296365	7604379			
	G44	296379	7605178			
	G45	296617	7604071			
	G46	297205	7605136			
	G47	296645	7604757			
	G48	296253	7603861			
	G49	297639	7605178			
Dredge Material Placement Site B	G30	298354	7612444	10	10	High
	G31	298508	7612080			
	G32	299264	7612178			
	G33	299376	7611408			
	G34	297822	7610204			
	G35	298774	7610764			
	G36	300048	7611338			
	G37	299292	7610792			
	G38	298886	7611730			
	G39	299502	7613074			
Dredge Material Placement Site C	G1	309172	7623120	24	25 (1)	High
	G10	306998	7623695			
	G11	308001	7624956			
	G12	309431	7625395			
	G13	309442	7624201			
	G14	309026	7622163			
	G15	306942	7621758			
	G16	308113	7623267			
	G17	306683	7624697			
	G18	304678	7624280			
	G19	305163	7621532			
	G2	306289	7626476			
	G3	309296	7625924			
	G4	308147	7626870			
	G5	304588	7626589			
	G6	304814	7625046			
	G69	305642	7624221			
	G7	304577	7623346			
	G70	308353	7623985			

Dredge Material Placement Site	Sample ID	Easting	Northing	Samples Collected	Total Samples	Priority
	G71	308124	7622034			
	G72	305969	7621821			
	G73	304933	7622661			
	G8	304127	7621690			
	G9	305726	7622309			
Dredge Material Placement Site D	G59	271467	7629145	10	11 (1)	Medium
	G60	270341	7627073			
	G61	271242	7625711			
	G62	272706	7626994			
	G63	272177	7628301			
	G64	271332	7627343			
	G65	270769	7628368			
	G66	271895	7626589			
	G75	272178	7627681			
	G76	271060	7626382			
Dredge Material Placement Site E	G50	276051	7636961	10	12 (2)	Medium
	G51	275792	7639056			
	G52	276085	7637659			
	G53	277233	7637671			
	G54	276772	7636770			
	G55	275679	7635632			
	G56	274857	7636882			
	G57	275251	7638527			
	G58	274497	7637468			
	G74	275223	7636231			

NB: a number in brackets represents the number of pre-existing sediment grab samples.

2.2 Sample Handling

Samples were taken in a manner that ensured that cross-contamination between samples was minimized. Samples collected from each interval were homogenised and then placed into appropriately cleaned and preserved containers provided by ALS. Sample containers were filled with some headspace to allow for freezing and labelled immediately. Samples were then stored in a large freezer for the duration of the sampling program, as the logistics of sampling in remote areas prevented daily dispatches of samples.

Upon completion of the sampling program, eskies were filled to capacity with jars and sealed with adhesive tape and promptly delivered to ALS for processing and analysis. A chain of custody (CoC) form was included in the eskies. Given that the analytical holding times for sediment, as specified in the NAGD, are 14 days for organics (TBT), 28 days for Hg and six months for other metals, submission of samples within 24 hours of sampling is not critical, provided the samples are chilled and kept in the dark.

2.3 Sediment Subsampling Procedures

Sample management procedures on the sampling barge included the careful collection of the sediment samples from the core tubes or grab sampler, following the recovery of the sediment core or grab from the seafloor. The penetration of short piston cores varied from less than 0.1 m to 0.4 m, depending on the sediment substrate encountered, but core refusal was encountered at every sample location. All sample handling and processing was performed to minimize contamination, as described below:

- nitrile gloves were worn by all sampling personnel and gloves were disposed of immediately after each core sample processing to reduce the potential for cross-contamination between samples;
- the workspace on the sampling vessel was rinsed down regularly with ambient seawater to clean all surfaces and minimize dust contamination of samples (e.g. dust from clothing on sampling personnel, shoes, storage containers, etc.;
- sediment was subsampled using a stainless steel sampling spoon; and
- samples collected from each interval were homogenised in a stainless steel bowl and placed into certified clean new screw-cap 250 ml glass jars with Teflon lid liners (inorganics metals and TBT analyses) and clean plastic zip lock bags (PSD analyses) that were provided by ALS Laboratory Group (ALS) Brisbane.

The chemicals in the Contaminants List are non-volatile substances and the concentrations of these chemicals are unlikely to be significantly affected by the homogenization procedure and the storage procedure. The subsampling and storage procedure is therefore unlikely to have resulted in measurable changes in concentrations of analytes on the Contaminants List.

Sample jars were kept in a freezer for the duration of the sampling trip and submitted to ALS frozen in eskies, using a same day courier delivery. A CoC form was included in the eskies. ALS separated samples for analysis of TBT, TOC and other inorganic analytes and PSD. The samples for PSD analyses were then forwarded by courier from ALS Brisbane to ALS in Newcastle, where sample receipt was again confirmed. Analytical holding times were met for all samples and analytes, in alignment with the required time limits set out in the NAGD. Sample analyses were scheduled as soon as practicable following delivery to the laboratory and extractions and analyses were consistent with the analyte holding times required in the NAGD.

2.4 Sediment Analyses

2.4.1 Whole Sediment Chemical Analyses

ALS is a National Association of Testing Authorities (NATA) accredited laboratory service, and carried out the project specific analyses, excluding analyses for PSD. ALS has also previously been independently audited and approved for use by URS environmental chemists.

Classification testing, comprising quantitative determination of the PSD of the sediment into silt/clay and sand/gravel fractions, was undertaken by ALS in accordance with AS1289.3.6.2/AS1289.3.6.3. PSD analysis data is shown in Appendix F.

Whole sediment samples from the Dredge Area and the proposed dredge material placement sites were submitted to ALS Brisbane (short core and grab samples) (Appendix D) and ALS Perth (deep core samples) (Appendix E). All sediment subsamples from the 15 deep cores up to the maximum depth of 13.5 m and the short cores up to a depth 0.4 m were analysed for all COPCs on the

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Contaminants List, excluding radionuclide activity which was analysed in five core samples from five locations only and TBT in the deep core samples.

Whole sediment samples from short cores were analysed for the following:

- total metals and metalloids (Al, As, Ba, Cd, Cr, Cu, Hg, Ni, Sb, Pb, and Zn);
- TBT;
- TOC;
- PSD (selected samples only); and
- $CaCO_3$ content (selected samples only).

Grab samples obtained in the proposed dredge material placement sites were analysed for the same suite of analytes, and with TBT, TOC, PSD and $CaCO_3$ content being assessed in a selected number of samples only.

An assessment of the detection limits achieved by ALS, against NAGD Screening Levels and the requirements of the SAP (Appendix A) is provided in Table 2-4. Analytical LOR in all short core and grab samples met the practical quantitation limits (PQLs), as stipulated in the NAGD, while the LORs in samples from the deep cores were above the PQLs for all analytes. Analytical holding time, sample containers and preservation requirements of samples are shown in Table 2-5.

Radionuclide activity was measured at five sample locations in the Dredge Area (SC5, SC13, SC17, SC33, SC55). The sample locations for the analysis of radionuclide activity were selected randomly from the total number of short core sampling sites. Radionuclide activity assessment was undertaken by a designated subcontractor of ALS (Appendix G).

$CaCO_3$ content and PSD were determined in 19 short core sediment samples, 25 grab samples ($CaCO_3$) and 38 grab samples (PSD). Samples were selected randomly from locations distributed throughout the Dredge Area and the proposed dredge material placement sites.

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Table 2-4 Analytes, PQLs, LORs and the NAGD Screening and Maximum Levels.

Analyte	Unit	PQL[1]	LOR[2]	LOR[3]	NAGD Screening	NAGD Maximum
Al	mg/kg	200	na	50 (na)	na	na
As	mg/kg	1	1	1 (5)	20	70
Ba	mg/kg	na	0.10	na (10)	na	na
Cd	mg/kg	0.10	0.10	0.1 (1)	1.50	10
Cr	mg/kg	1	1	1 (2)	80	370
Cu	mg/kg	1	1	1 (5)	65	270
Hg	mg/kg	0.01	0.01	0.01 (0.1)	0.15	1
Ni	mg/kg	1	1	1 (2)	21	52
Pb	mg/kg	1	1	1 (5)	50	220
Sb	mg/kg	0.50	0.50	0.5 (5)	2	25
TBT	ugSn/kg	1	0.50	0.5 (na)	9	70
TOC	%	0.10	0.10	0.1 (na)	na	na
Zn	mg/kg	1	1	1 (5)	200	410

[1]PQL from the NAGD; [2]LOR from the SAP (for short core and grab samples, deep core in brackets); [3]LOR from ALS.

NB: “na” indicates that a requirement is not available for that analyte.

Table 2-5 Container type, preservation and holding times for sediment samples.

Analyte	Container	Preservation	Holding Time	Reference
MC	G (T)	frozen	7 days	AS 1289.2.1.1 (1992)
Metals & Metalloids	G (T)	frozen	6 months	US EPA SW846 (1994), National Environment Protection Council (NEPC) (1999)
Hg	G (T)	frozen	28 days	US EPA SW846 (1994), NEPC (1999)
TOC	G (T)	frozen	180 days	ALS
TBT	G (T)	frozen	extract within 14 days, analyse within 40 days	US EPA SW846 (1994)
PSD	Z	frozen	na	AS 1289.3.6.2/AS 1289.3.6.3

NB: G (T) = glass jar with teflon coated lid liner; Z = 250ml plastic ziplock bag.

2.4.2 Quality Assurance and /Quality Control

Field and laboratory Quality Assurance/Quality Control (QA/QC) measures carried out for the sampling program included the analysis of one trip blank sample, field triplicate samples (Table 2-6) and split samples (Table 2-7; Table 2-8). In addition, samples were submitted to a NATA-accredited analytical laboratory and detailed field records, CoC documentation, certificates of analysis and data validation reports were produced and kept. QA/QC reports are available for short cores and grab samples (Appendix D) and deep core samples (Appendix E).

Interbatch samples requiring analysis of one sample from a previous batch were not required, as all short core and grab samples were submitted to the analytical laboratory in a single batch at the conclusion of the sampling program.

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Table 2-6 Analytical data for short core sample field triplicate samples.

QC ID	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn	TBT (mgSn/kg)	TOC (%)	MC (%)
QC126	SC3	3850	16.20	8.40	<0.1	29.50	11.20	<0.01	8.80	5.20	<0.5	18.90	n/a		28.40
QC208	SC3	3940	19.80	9.60	<0.1	32.40	10.50	<0.01	11.10	5.60	<0.5	22.40	n/a		29.20
	SC3_0.0-0.22	4050	18.30	10.20	<0.1	35.30	10.70	<0.01	10.40	6.00	<0.5	21.80	<0.5	0.34	27.40
Mean		3947	18.10	9.40	n/a	32.40	10.80	n/a	10.10	5.60	n/a	21.03	n/a	n/a	28.33
SD		100	1.81	0.92	n/a	2.90	0.36	n/a	1.18	0.40	n/a	1.87	n/a	n/a	0.90
RSD (%)		2.5	10.00	9.80	n/a	9.00	3.30	n/a	11.70	7.10	n/a	8.90	n/a	n/a	3.20
QC124	SC6	4460	7.98	14.90	<0.1	41.30	12.90	<0.01	12.90	6.80	<0.5	19.50	<0.5	0.05	21.20
QC206	SC6	3920	8.38	16.10	<0.1	37.00	12.00	<0.01	11.40	6.00	<0.5	17.90	n/a		21.80
	SC6_0.0-0.2	4310	8.65	20.70	<0.1	41.00	12.50	<0.01	12.70	6.60	<0.5	19.40	<0.5	0.04	22.40
Mean		4230	8.34	17.23	n/a	39.77	12.47	n/a	12.33	6.47	n/a	18.93	n/a	n/a	21.80
SD		279	0.34	3.06	n/a	2.40	0.45	n/a	0.81	0.40	n/a	0.90	n/a	n/a	0.60
RSD (%)		6.6	4.00	17.80	n/a	6.00	3.60	n/a	6.60	6.40	n/a	4.70	n/a	n/a	2.80
QC127	SC38	4040	19.00	8.60	<0.1	31.00	10.70	<0.01	10.10	5.60	<0.5	20.20	n/a	n/a	26.40
QC209	SC38	4170	11.90	9.60	<0.1	31.90	9.00	<0.01	9.80	5.50	<0.5	18.40	n/a	n/a	25.20
	SC38_0.0-0.40	3920	11.70	8.60	<0.1	31.70	9.40	<0.01	9.60	5.50	<0.5	19.40	<0.5	0.11	23.80
Mean		4043	14.20	8.93	n/a	31.53	9.70	n/a	9.83	5.53	n/a	19.33	n/a	n/a	25.13
SD		125	4.16	0.58	n/a	0.47	0.89	n/a	0.25	0.07	n/a	0.90	n/a	n/a	1.30
RSD (%)		3.1	**29.30**	6.50	n/a	1.50	9.20	n/a	2.60	1.00	n/a	4.70	n/a	n/a	5.20
QC125	SC43	5310	9.31	23.60	<0.1	38.80	13.30	<0.01	13.30	7.00	<0.5	24.20	<0.5	0.11	22.60
QC207	SC43	5590	9.36	24.80	<0.1	43.00	15.50	<0.01	15.50	7.60	<0.5	24.80	n/a	n/a	25.10
	SC43_0.0-0.23	5300	10.20	21.80	<0.1	39.20	13.20	<0.01	13.60	6.80	<0.5	24.00	<0.5	0.09	22.50
Mean		5400	9.62	23.40	n/a	40.33	14.00	n/a	14.13	7.13	n/a	24.33	n/a	n/a	23.40
SD		165	0.50	1.51	n/a	2.32	1.30	n/a	1.19	0.42	n/a	0.42	n/a	n/a	1.47
RSD (%)		3.0	5.20	6.50	n/a	5.70	9.30	n/a	8.40	5.80	n/a	1.70	n/a	n/a	6.30

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QC ID	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn	TBT (mgSn/kg)	TOC (%)	MC (%)
QC128	SC53	4310	12.80	9.10	<0.1	33.60	9.60	<0.01	10.40	5.70	<0.5	18.80	n/a	n/a	27.20
QC210	SC53	3930	10.90	8.80	<0.1	30.50	9.00	<0.01	8.70	5.30	<0.5	19.00	n/a	n/a	24.20
	SC53_0.0-0.05	4180	12.80	9.80	<0.1	33.50	9.80	<0.01	10.40	6.00	<0.5	19.70	<0.5	0.10	27.90
Mean		4140	12.17	9.23	n/a	32.53	9.47	n/a	9.83	5.67	n/a	19.17	n/a	n/a	26.43
SD		193	1.10	0.51	n/a	1.76	0.42	n/a	0.98	0.40	n/a	0.47	n/a	n/a	1.97
RSD (%)		4.7	9.00	5.60	n/a	5.40	4.40	n/a	10.00	6.20	n/a	2.50	n/a	n/a	7.40
QC123	SC56	3780	9.00	8.30	<0.1	36.50	10.80	<0.01	11.20	6.00	<0.5	18.80	<0.5	0.09	18.90
QC205	SC56	4060	9.73	9.20	<0.1	37.80	10.70	<0.01	11.70	6.20	<0.5	19.80	n/a	n/a	24.10
	SC56_0.0-0.31	3670	12.00	15.90	<0.1	39.40	10.30	<0.01	11.50	6.80	<0.5	20.40	<0.5	0.06	24.10
Mean		3837	10.24	11.13	n/a	37.90	10.60	n/a	11.47	6.33	n/a	19.67	n/a	n/a	22.37
SD		201	1.56	4.15	n/a	1.45	0.26	n/a	0.25	0.40	n/a	0.81	n/a	n/a	3.00
RSD (%)		5.2	15.30	**37.30**	n/a	3.80	2.50	n/a	2.20	6.60	n/a	4.10	n/a	n/a	13.40

NB: all data in mg/kg unless otherwise indicated; bold data = exceedance of RSD limit by >20%; n/a = not analysed.

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Table 2-7 Analytical data for short core and grab sample split sample analysis.

QC ID	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn
	G13	4060	19.8	12.3	<0.1	25.1	4.7	<0.01	4.7	4.4	<0.5	11.9
QC201	G13	5200	20	11	<2	23	5.1	<0.01	15	3.9	<2	11
	G17	4200	25	12.1	<0.1	30	5.2	<0.01	5.2	4.9	<0.5	12.7
QC200	G17	5000	21	10	<2	24	4.6	<0.01	15	3.9	<2	10
	SC13	6820	20.9	17.5	<0.1	35	11.1	<0.01	11.4	6.2	<0.5	24
QC202	SC13	7800	26	16	<2	33	11	<0.01	21	6.8	<2	22
	SC16	5680	20.5	12.9	<0.1	34.1	8.2	<0.01	9.4	5.6	<0.5	21.3
QC203	SC16	5800	19	12	<2	32	8.2	<0.01	16	5.1	<2	19
	SC17_ 0.0-0.35	5560	22.6	5.4	<0.1	40.4	9.3	0.01	10.9	6.1	<0.5	23
QC204	SC17	6600	22	11	<2	36	9.4	<0.01	16	5.5	<2	21

NB: all data in mg/kg.

Table 2-8 Analytical data for deep core split sample analysis.

QA/QC	Sample ID	As	Ba	Be	Cr	Co	Cu	Fe	Pb	Mn	Ni	V	Zn
	MC015_0.45-0.55	11	n/a	n/a	20	5	6	18200	369	n/a	6	36	12
Yes	MC015_0.45-0.55	10	n/a	n/a	20	4	7	18000	370	n/a	6	36	11
	MC012_0.9-1.0	7	20	n/a	45	8	24	34600	8	186	18	57	23
Yes	MC012_0.9-1.0	<5	10	n/a	45	9	18	40100	8	171	20	62	26
	MC009_3.9-4.0	n/a	60	1	62	17	29	53000	14	389	38	76	56
Yes	MC009_3.9-4.0	n/a	60	<1	57	17	26	50100	14	326	36	73	55

NB: n/a = not assessed; all data is mg/kg.

2.4.3 Laboratory Procedures

Receipt of Samples

On receipt of the sediment samples at ALS, the following checks and procedures were undertaken:

- custody seals and tape on the esky check to ensure they were unbroken and uncut;
- signature on the external custody seal checked to ensure it matched one of the sampler(s) signature(s) on the internal CoC;
- examination was untaken to determine if samples had been maintained at the appropriate temperature during shipment;
- sample containers were checked within the cooler to ensure they were intact;
- identification on the sample containers was checked to ensure it corresponded to the entries on the CoC;
- number of sample containers received was checked to ensure it was equal to the number of samples listed on the CoC;
- the relevant area on the CoC was completed by laboratory staff; and

- a copy of the CoC was delivered electronically to the designated URS Project Manager or contact person within three working days.

Once sample custody was determined to be valid, the samples were logged in by the laboratory as per the standard operating procedure. If CoC discrepancies existed, appropriate notes (signed and dated) were made on the CoC and the URS Project Manager was notified by ALS. In the event that the laboratory Sample Custodian judged the sample custody (or part thereof) to be invalid (e.g. samples arrive damaged or custody seals are broken), the Project Manager was advised immediately and those samples were not analysed until authorised by the Project Manager. Any problem with a sample was noted on the CoC Record and URS was notified in writing as soon as practicable for action or response.

2.5 Laboratory Analytical Quality Assurance/Quality Control (QA/QC)

Specific mechanisms that were used to check the accuracy and precision of the analytical data to ensure the data quality objectives for the project are met are outlined in the following sections:

2.5.1 Laboratory Duplicates

Laboratory duplicates are samples prepared by dividing a field sample into two or more aliquots, then analysed separately. Duplicate samples are considered to be two replicates. Replicate samples were ideally representative of the originating sample, but in many cases this is not practical due to the nature of the sample; hence the analysis of replicate samples provide an indication of the effect of sample matrix variability on precision, in addition to assessing analytical precision

2.5.2 Independent Verification Standards

Independent verification standards are standards prepared from an independent batch of primary reference standard(s) to those used for routine calibration. Certified calibration check standards were used to verify that an analytical instrument was correctly calibrated.

2.5.3 Calibration Check Standards

Calibration check standards are pre-prepared from the same solution and were used to confirm linearity of the initial calibration curve. Acceptance must be within predicted limits.

2.5.4 Surrogate Spikes

Surrogates are organic compounds which are similar to analytes of interest in chemical composition, extraction, and chromatography, but which are not normally found in field samples. These compounds are spiked into all sample aliquots prior to preparation and analysis. Percent recoveries are calculated for each surrogate, providing an indication of analytical accuracy including unusual matrix effects and gross sample processing errors.

2.5.5 Standard Reference Materials

The NAGD states:

> "to ensure analytical procedures are conducted properly and produce reliable results, standard reference materials (SRM) should be analysed with each batch, that is, a sample of certified composition".

The intent of the NAGD is that the analytical techniques undertaken will be able to determine potential bias in the analysis. If analyses were regularly under reporting the measured concentrations of contaminants in samples, this would be detected with the use of control samples or standards (SRM). Control samples or alternatively, SRM are required to determine if there is a bias towards under reporting in the analysis of samples. The purpose of the SRM is to verify that there is minimal bias in the results and the concentrations reported in the samples are as close as practical to the measured concentration present in the sample for analysis. This bias can be assessed by a number of alternate methodologies. These alternate methodologies are run with each batch (10 to 20 samples). The three key methodologies employed by ALS to measure bias were:

- laboratory control samples (LCS);
- matrix spikes; and
- surrogates.

A laboratory control sample (LCS), is a sample of known composition (similar to an SRM). The United States Environmental Protection Agencys (US EPA) *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW846)* Chapter 2 (US EPA 1993) defines a laboratory control sample as follows:

> "A laboratory control sample consists of either a control matrix spiked with analytes representative of the target analytes or a certified reference material".

The ALS laboratory control samples (for non-metal inorganics and organics) and the ALS in-house certified reference material for metals are considered to be samples of certified composition. In commercial laboratories in Australia, SRMs are not commonly used due to the high cost and difficulty in obtaining standards for suitable analyte concentrations. Commercial laboratories in Australia do not routinely run SRM with each batch of analysis (10-20 samples) as suggested in the NAGD. There are numerous problems with obtaining SRMs for regular use including:

- timely delivery of the SRM and storage within holding time;
- provision of an SRM for the correct analytes from different suppliers (different SRMs are required for different analyse);
- obtaining an SRM of a comparable matrix to the subject site; and
- obtaining an SRM with a range of contaminant concentrations that is similar to that of the subject site. Ultra trace techniques have a limited dynamic range.

ALS quality procedures follow those outlined in the NEPC (1999) and are based on US EPA protocols, however these procedures differ from those of the NAGD in that ALS spikes appropriate representative surrogates into all samples for targeted organic compound analysis and they do not routinely use certified reference materials as laboratory control samples for organics, but instead use laboratory control samples.

In summary, URS considers that the use of laboratory and control samples, matrix spikes and surrogates by ALS conforms to the intent of the NAGD with respect to SRM. Although SRM are useful for metal analyses, they are not as prevalent or available for organic contaminants. The approach undertaken by ALS, using a combination of laboratory control samples, matrix spikes and surrogates is appropriate for the analysis of organic contaminants in environmental samples. ALS currently uses an in-house certified sample for metals analysis. The use of an in-house certified sample is appropriate in lieu of a SRM.

2.6 Data Handling

All analytical data generated by the analytical laboratory were appropriately reduced and underwent comprehensive validation prior to reporting. Records and numerical calculations were performed so that reconstruction of the work by a qualified individual other than the originator could be preformed.

The originating analyst validated a given data package to ensure that:

- holding times had been met;
- appropriate standard operating procedures had been followed;
- field sample results were correct and complete (if applicable);
- QA/QC checks ensured that results were correct and complete;
- QA/QC checks ensured that results were within established control limits and data quality objectives; and
- documentation was complete.

If the originating analyst found the validity of data to be in doubt due to non-conformance with the above checklist, then the data was flagged and appropriate corrective procedures are initiated. Once the originating analyst has reduced and validated the data package, it was passed onto the Document Control/Quality Assurance Officer, Laboratory Manager, or other appropriately qualified senior personnel for independent review. A NATA approved signatory then signed and released the work reported.

2.6.1 Data Validation

The primary objective of the data validation process is to ensure the data reported can be used to achieve the project objectives. The validity of all analytical data reported was assessed by URS by review of the QA/QC check results. This was performed in accordance with the US EPA guidelines and the NAGD where appropriate (US EPA, 1993). Accuracy and precision measurements from the appropriate QA/QC checks were compared with the analytical Data Quality Objectives (DQOs) to assess the quality of the analytical data.

2.6.2 Analytical Data Quality Objectives

Analytical DQOs requirements are summarized below (Table 2-9). In cases where the DQOs were not met, the potential reasons for non-compliance were identified and the analytical results was flagged, if warranted. The NAGD data validation requirements were met for blanks (“at or near the detection limit”), field replicates (+/-50% relative percentage deviation (RPD)) and spiked duplicates (+/-35% RPD).

Table 2-9 Analytical Data Quality Objectives.

Parameter	Data Quality Objective
Blank Samples (1 per trip)	at or near the LOR and approximately 10% of primary analytical sample concentrations (excluding Hg)
Sample Condition	samples received intact and cold
Holding Time	samples analysed within the NAGD-specified holding times
Field Duplicate Samples (6 triplicate, 5 split, 6 field duplicate (deep cores))	RPD <35% (duplicates) and RSD <50% (triplicates)
Lad Duplicate Sample (1 in 10)	RPD <35% or as per laboratory requirement
Interbatch Samples	n/a (one batch only for short core and grab samples, none for deep core samples)
Laboratory Control Samples (1 in 10)	RPD <35% or as per laboratory requirement
Surrogate (all samples)	recovery as per laboratory requirement

2.7 Statistical Methodology

Spatial assessment of selected COPCs was undertaken using MapInfo^{TM}, a geographical information system. Analytical data was stored, manipulated and analysed in Microsoft Excel™. Laboratory analytical results were supplied as comma separated files. This reduced the labour required for data entry and minimised potential for errors in data input. Laboratory issued data were imported into EDM™, a proprietary database. Tables were created by exporting data from EDM™ into Excel™. Concentrations of organic contaminants, including TBT, were normalised to 1% TOC content in accordance with the requirements in NAGD in Microsoft Excel™.

The NAGD refer to guidance for undertaking 95% Upper Confidence Limit (UCL) provided by the New South Wales Environmental Protection Authority (NSW EPA) (1995). This guidance recommends two procedures for normal and log-normal distributions. Where the coefficient of variation (CoV) is less than 1.2 (indicating a normal distribution), the recommendation is to undertake Procedure D. In cases where the coefficient is greater than 1.2 (indicating a possible log normal distribution) the recommendation is to undertake Procedure G, if it can be demonstrated that the distribution is log-normal. However with variable datasets of log-normal distribution, Procedure G is prone to producing anomalously large results therefore ‘bootstrapping’ routines are commonly undertaken.

The 95% UCL of mean concentrations were calculated for As, Cr and Ni as they exceeded the NAGD Screening Levels). These 95% UCLs were calculated as follows:

- values less than the analytical LOR were assigned a value equal to half the LOR for the purpose of calculating the 95% UCL;
- the CoV of the dataset was determined;
- if the CoV was less than 1.2, the dataset was assumed to be normally distributed and the 95% UCL is calculated based on arithmetic mean (Procedure D of NSW EPA guidance);

2 Methodology

- if the CoV was greater than 1.2, the dataset was tested for log-normal distribution;
- if the dataset was log normal, the 95% UCL was calculated based on geometric mean (Procedure G);
- if the dataset was not log normal, Procedure D was used to calculate the 95% UCL based on arithmetic mean.
- the 95% UCL of mean contaminant concentration was compared with the NAGD Screening Levels.

The NSW EPA (1995) acknowledges that Procedure D can be applied to many forms of contaminant concentration distributions including those that are not normally distributed.

Results

3.1 Sediment Texture

Sediments from the Dredge Area and the five proposed dredge material placement sites varied substantially in textural characteristics and between areas, but were generally similar locally within a single area. The descriptive statistics (minimum, maximum, mean and standard deviation values, and the number of samples) for PSD in sediments within the Dredge Area and in the five proposed dredge material placement sites in presented below (Table 3-1). Note that cobbles are particles greater than 6 cm in width, gravel is greater than 2 mm, sand is 63 µm – 2mm, silt is 2 µm – 63 µm and clay is less than 2 µm.

Mean sand percentages were around 60% in surficial sediments of the proposed Nearshore Dredge Material Placement Sites A and B, increasing to about 70% sand content in sediments of the proposed Nearshore Dredge Material Placement Site C and Offshore Dredge Material Placement Site E. Sediment from the proposed Offshore Dredge Material Placement Site D comprised approximately 80% sand content (Table 3-1). This compares to a mean sand content of about 52% in near surface sediments in the Dredge Area.

Mean clay content was generally similar at all proposed dredge material placement sites, with mean clay content varying between 13.3% and 16.6%. The exception was the proposed Offshore Dredge Material Placement Site D, where mean clay content was 8.4%. Sediments in the Dredge Area were slightly more clayey, with a mean clay content of 17.8% (Table 3-1). However, this slightly higher clay content may be due to the collection of deeper sediment samples of up to a depth of 0.4 m in the Dredge Area compared to the shallow grab samples (<0.1 m depth) collected within the proposed dredge material placement sites.

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Table 3-1 Descriptive statistics of sediment PSD in the Dredge Area and the proposed dredge material placement sites.

Area	Statistic	Cobbles (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Wheatstone Dredge Area (SC1 - SC60)	Min	0	2	17	6	10
	Max	0	34	71	53	33
	Mean	0	14	53	16	18
	SD	0	10	14	10	6
	n	19	19	19	19	19
Dredge Material Placement Site C	Min	0	0	42	2	9
	Max	0	39	83	14	16
	Mean	0	9	71	7	13
	SD	0	13	15	4	2
	n	12	12	12	12	12
Dredge Material Placement Site B	Min	0	6	56	8	11
	Max	0	25	64	13	19
	Mean	0	13	61	10	17
	SD	0	7	3	2	3
	n	5	5	5	5	5
Dredge Material Placement Site A	Min	0	2	42	6	12
	Max	0	34	68	12	28
	Mean	0	16	58	10	17
	SD	0	12	10	3	7
	n	5	5	5	5	5
Dredge Material Placement Site E	Min	0	2	59	9	9
	Max	0	10	77	17	21
	Mean	0	5	70	12	13
	SD	0	3	7	3	5
	n	5	5	5	5	5
Dredge Material Placement Site D	Min	0	1	72	3	8
	Max	0	9	88	11	9
	Mean	0	3	82	7	8
	SD	0	3	6	3	1
	n	5	5	5	5	5

3.1.1 Dredge Area

Sediments within the Dredge Area are generally dark red to red-brown clayey gravelly sands with abundant $CaCO_3$ shells and shell fragments, with varying mud (silt and clay fraction) contents of between 20-40% and gravel contents ranging from <5% to 34%. Hard, armoured surfaces were sampled at numerous locations, where shell and limestone beds made penetration of the piston corer difficult. Clay content of between 10% and 33% was present within the area and refusal of the piston corer in stiff clay or limestone and shell beds at a depth of less than 0.40m was observed at all sample locations. TOC content was generally less than 0.2%.

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3.1.2 Proposed Dredge Material Placement Sites

Sediment texture between three of the proposed Nearshore Dredge Material Placement Site A (water depth: <7 m), Site B (water depth: 10-12 m) and Site C (water depth: 12-15 m) was similar, with mud content ranging from about 20% to 26.8% and surficial sediments comprising red-brown ferruginous slightly gravelly muddy sands. $CaCO^3$ content increased from 40% in the proposed Nearshore Dredge Material Placement Site A and Site B, to more than 60% in the proposed Nearshore Dredge Material Placement Site C. Sediment colour was progressively more gray-greenish with increasing distance from the shore, reflecting the increasing marine influence to the sediment composition (i.e. $CaCO_3$) and a decreasing lithogenic/terrigenous component (i.e. ferruginized clays and silts). Sediments at the proposed Offshore Dredge Material Placement Site D (water depth 38-48 m) and the proposed Offshore Dredge Material Placement Site E (water depth 63-71 m), which are furthest offshore, were generally olive gray-green muddy sands with some shell fragments (<5% gravel) and up to 70% $CaCO_3$. TOC content was generally less than 0.3%.

3.2 Geochemical Results

3.2.1 Dredge Area

A summary of descriptive statistics of the COPCs from the 72 short core samples taken from within the Dredge Area (SC1-SC54, SC56-SC60) and adjacent to the Dredge Area (SC61-SC72) are presented below (Table 3-2). One field replicate sample (SC55) has also been included. Analytical results for geochemical analyses are also shown in Appendix D.

A summary of descriptive statistics of the COPCs from the 15 deep core samples taken from within the Dredge Area (MC001-MC015) are presented below (Table 3-5). Analytical results for geochemical analyses are also shown in Appendix E.

3.2.2 Proposed Dredge Material Placement Sites

A summary of descriptive statistics of the COPCs from the 64 grab samples taken from within the five proposed dredge material placement sites are presented below (Table 3-6). Analytical results for geochemical analyses are also shown in Appendix D.

3 Results

Table 3-2 Analytical data and descriptive statistics for short core samples from within and adjacent to the Dredge Area.

Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
SC1_0.0-0.27	8490	13.20	28.00	0.05	67.80	18.50	0.01	**21.10**	0.25	9.40	33.70	0.25	0.06		22.50
SC2_0.0-0.22	4070	18.90	12.20	0.05	31.10	5.90	0.01	6.10	0.25	4.80	14.80	0.25	0.09	55.20	25.00
SC3_0.0-0.22	4050	18.30	10.20	0.05	35.30	10.70	0.01	10.40	0.25	6.00	21.80	0.25	0.34		27.40
SC4_0.0-0.25	4270	18.60	10.50	0.05	27.50	5.20	0.01	4.50	0.25	4.40	13.40	0.25	0.13		27.00
SC5	11000	**21.40**	17.70	0.05	50.90	17.30	0.01	20.30	0.25	9.30	38.90	0.25	0.34	39.10	40.60
SC6_0.0-0.2	4310	8.65	20.70	0.05	41.00	12.50	0.01	12.70	0.25	6.60	19.40	0.25	0.04		22.40
SC7_0.00.050	5270	**21.50**	10.60	0.05	38.20	9.40	0.01	10.20	0.25	6.00	23.10	0.25	0.11	38.50	20.10
SC8_0.0-0.30	5730	**21.70**	7.00	0.05	42.10	9.80	0.01	11.20	0.25	6.40	24.50	0.25	0.18		21.40
SC9_0.0-0.20	7780	**22.90**	9.50	0.05	55.00	14.70	0.01	16.30	0.25	8.60	32.10	0.25	0.15		30.10
SC10_0.00.050	6040	18.10	12.60	0.05	36.10	9.20	0.01	9.60	0.25	5.60	21.80	0.25	0.12	46.70	25.70
SC11_0.00.055	13400	13.10	112.00	0.05	**82.10**	39.00	0.01	37.00	0.25	15.10	62.00	0.25	0.06		30.80
SC12_0.00.055	6080	16.30	11.00	0.05	37.10	9.20	0.01	9.80	0.25	5.60	21.70	0.25	0.14	46.50	24.80
SC13	6820	**20.90**	17.50	0.05	35.00	11.10	0.01	11.40	0.25	6.20	24.00	0.25	0.16		30.50
SC14_0.00.051	5990	5.48	53.20	0.05	48.80	15.30	0.01	18.10	0.25	8.50	24.70	0.25	0.04		21.30
SC15	6960	18.50	11.40	0.05	49.40	12.30	0.01	15.00	0.25	7.40	28.20	0.25	0.10	32.70	24.60
SC16	5680	**20.50**	12.90	0.05	34.10	8.20	0.01	9.40	0.25	5.60	21.30	0.25	0.13		29.00
SC17_0.0-0.35	5560	**22.60**	5.40	0.05	40.40	9.30	0.01	10.90	0.25	6.10	23.00	0.25	0.10	38.50	22.30
SC18_0.0-0.30	6060	**23.40**	6.00	0.05	40.80	10.20	0.01	11.20	0.25	6.40	24.30	0.25	0.12	45.70	24.90
SC19_0.00.052	4660	16.20	10.90	0.05	30.30	5.70	0.01	6.20	0.25	4.90	15.00	0.25	0.09		26.20
SC20_0.0-0.20	10600	15.80	27.30	0.05	70.00	24.30	0.01	**24.40**	0.25	10.10	38.60	0.25	0.06		26.00
SC21_0.00.055	8820	14.80	15.90	0.05	55.00	17.40	0.01	18.10	0.25	8.10	31.20	0.25	0.13	37.00	25.50
SC22_0.00.053	4540	6.24	19.10	0.05	36.40	18.90	0.01	13.90	0.25	6.40	19.70	0.25	0.06		22.20
SC23_0.0-0.25	5950	**21.10**	10.30	0.05	42.90	10.80	0.01	11.80	0.25	6.60	25.40	0.25	0.09		23.40

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Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
SC24	4210	19.90	18.10	0.05	22.10	4.50	0.01	3.00	0.25	4.30	12.70	0.25	0.14	77.20	30.70
SC25	3970	19.80	12.20	0.05	23.70	6.10	0.01	5.80	0.25	4.30	15.90	0.25	0.15		24.80
SC26_0.00.051	6100	6.80	15.90	0.05	49.50	16.80	0.01	18.50	0.25	8.80	24.60	0.25	0.05	0.01	19.30
SC27_0.0-0.32	5570	11.70	13.60	0.05	42.10	11.00	0.01	12.20	0.25	5.50	18.70	0.25	0.07		19.40
SC28_0.0-0.25	8110	18.80	11.10	0.05	53.30	16.00	0.01	18.10	0.25	7.90	28.40	0.25	0.10	37.50	24.60
SC29_0.0-0.20	8900	15.30	66.30	0.05	67.00	18.40	0.02	**22.30**	0.25	9.40	33.60	0.25	0.07		23.40
SC30_0.0-0.2	6850	18.80	12.80	0.05	33.70	9.50	0.01	9.70	0.25	6.10	21.90	0.25	0.16	52.40	27.30
SC31_0.0-0.20	3860	**20.30**	10.00	0.05	23.30	4.40	0.01	3.60	0.25	4.00	11.80	0.25	0.10		25.10
SC32_0.00.05	4040	12.70	10.60	0.05	30.70	9.90	0.01	9.40	0.25	5.60	20.10	0.25	0.10		21.70
SC33_0.0-0.33	6850	19.10	8.40	0.05	42.80	9.70	0.01	11.20	0.25	6.50	23.00	0.25	0.15		29.70
SC34_0.0-0.25	8140	**28.50**	9.20	0.05	53.00	14.40	0.01	16.00	0.25	8.50	33.20	0.25	0.14		34.30
SC35_0.00.055	4710	**22.40**	12.60	0.05	34.10	8.40	0.01	8.70	0.25	5.60	20.00	0.25	0.01		24.40
SC36_0.00.050	5660	19.80	13.60	0.05	33.50	7.70	0.01	8.10	0.25	5.40	21.90	0.25	0.17		25.80
SC37_0.00.051	13800	14.30	45.60	0.05	78.10	31.40	0.02	**35.40**	0.25	13.40	57.70	0.25	0.10		28.80
SC38_0.0-0.40	3920	11.70	8.60	0.05	31.70	9.40	0.01	9.60	0.25	5.50	19.40	0.25	0.11		23.80
SC39_0.00.050	4910	**20.00**	10.30	0.05	32.60	6.30	0.01	6.90	0.25	5.00	16.20	0.25	0.14		29.20
SC40_0.0-0.31	7890	**26.60**	7.80	0.05	50.60	14.10	0.02	15.90	0.25	8.10	32.40	0.25	0.17		26.30
SC41_0.0-0.30	7250	19.00	20.10	0.05	59.10	15.40	0.01	17.80	0.25	8.00	29.70	0.25	0.09		22.60
SC42_0.0-0.25	5020	18.80	7.50	0.05	31.80	8.60	0.01	7.80	0.25	5.20	17.60	0.25	0.09		24.10
SC43_0.0-0.23	5300	10.20	21.80	0.05	39.20	13.20	0.01	13.60	0.25	6.80	24.00	0.25	0.09		22.50
SC44_0.00.052	5860	4.69	31.90	0.05	50.70	15.00	0.01	19.00	0.25	8.80	23.10	0.25	0.06		20.50
SC45	4540	17.40	11.20	0.05	30.30	6.00	0.01	5.70	0.25	4.70	15.00	0.25	0.15	50.30	24.70
SC46_0.0-0.25	6640	14.00	13.00	0.05	38.30	11.10	0.01	12.60	0.25	6.10	23.80	0.25	0.08	46.90	23.40
SC47_0.0-0.25	4770	**23.80**	5.40	0.05	39.10	7.30	0.01	8.80	0.25	5.60	20.10	0.25	0.10		22.20
SC48_0.00.050	4360	16.90	11.40	0.05	25.50	5.70	0.01	5.70	0.25	4.70	14.40	0.25	0.11	63.20	26.60

Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
SC49_0.00.050	4610	17.40	12.70	0.05	26.90	6.00	0.01	5.00	0.25	4.70	14.70	0.25	0.11		26.90
SC50_0.0-0.23	7350	**22.20**	7.30	0.05	51.80	13.50	0.01	15.50	0.25	8.00	29.80	0.25	0.13		22.80
SC51	4270	**47.40**	20.90	0.10	24.70	5.50	0.01	2.20	0.25	4.50	11.00	0.25	0.09	72.20	25.60
SC52_0.00.050	4920	18.50	12.10	0.05	36.20	6.40	0.01	7.10	0.25	5.50	16.20	0.25	0.11		30.40
SC53_0.00.055	4180	12.80	9.80	0.05	33.50	9.80	0.01	10.40	0.25	6.00	19.70	0.25	0.10		27.90
SC54_0.0-0.20	8880	**22.00**	14.80	0.05	48.40	16.50	0.01	17.80	0.25	34.00	34.10	0.25	0.16		31.70
SC55_0.0-0.30	8400	16.20	20.90	0.40	46.30	14.20	0.01	14.10	0.25	7.10	25.30	0.25	0.12		26.20
SC55_0.0-0.25	5620	**22.80**	7.00	0.05	43.50	8.90	0.01	11.00	0.25	6.60	22.30	0.25	0.11		24.30
SC56_0.0-0.31	3670	12.00	15.90	0.10	39.40	10.30	0.01	11.50	0.25	6.80	20.40	0.25	0.06		18.80
SC57_0.00.055	10100	17.60	37.00	0.05	77.40	23.50	0.01	**26.70**	0.25	11.80	46.00	0.25	0.07	1.23	25.00
SC58_0.00.055	5820	**24.90**	11.50	0.05	38.80	9.50	0.01	10.60	0.25	6.40	23.40	0.25	0.11	45.00	25.40
SC59_0.0-0.23	5760	**22.00**	6.40	0.05	41.60	9.70	0.01	11.70	0.25	6.20	23.60	0.25	0.11		22.90
SC60_0.0-0.20	6460	16.00	7.30	0.05	47.30	10.70	0.01	13.20	0.25	6.60	23.40	0.25	0.09		26.70
SC61_0.00.058	10200	18.50	24.80	0.05	62.20	22.30	0.02	**23.40**	0.25	9.70	40.60	0.25	0.12		29.00
SC62_0.00.050	9600	13.30	34.50	0.05	71.20	19.20	0.03	**23.90**	0.25	10.50	36.10	0.25	0.07		22.30
SC63	6820	19.70	9.40	0.05	52.90	13.80	0.02	14.90	0.25	8.00	29.20	0.25	0.16		24.00
SC64_0.00.055	7680	12.20	14.20	0.05	61.70	16.60	0.01	18.50	0.25	8.30	26.80	0.25	0.07		23.00
SC65	3470	**21.80**	12.60	0.05	19.10	3.60	0.01	1.50	0.25	3.90	11.10	0.25	0.13		28.70
SC66	4360	**26.10**	13.50	0.05	24.40	4.70	0.01	4.00	0.25	4.70	13.40	0.25	0.14		26.20
SC67_0.00.055	3430	**28.20**	5.40	0.05	24.90	3.90	0.01	3.70	0.25	4.00	10.70	0.25	0.07		24.00
SC68_0.0-0.20	3590	19.50	7.00	0.05	27.40	4.40	0.01	3.50	0.25	4.20	11.60	0.25	0.08		24.30
SC69_0.00.056	8020	15.00	15.20	0.10	51.20	18.70	0.01	17.80	0.25	8.10	31.60	0.25	0.09		26.60
SC70_0.00.050	6510	19.90	10.20	0.05	40.70	9.60	0.01	10.80	0.25	6.30	22.30	0.25	0.11		29.40
SC71	7020	**24.70**	7.60	0.05	49.50	11.30	0.01	13.40	0.25	7.40	27.10	0.25	0.12		28.10
SC72	6020	**23.40**	6.90	0.05	41.40	9.80	0.01	10.50	0.25	6.30	22.70	0.25	0.12		27.00

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Sample ID		Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
SC1-SC72	**Minimum**	3430	4.69	5.40	0.05	19.10	3.60	0.01	1.50	0.25	3.90	10.70	0.25	0.01	0.01	18.80
	Maximum	13800	47.40	112.00	0.40	82.10	39.00	0.03	37.00	0.25	34.00	62.00	0.25	0.34	77.20	40.60
	Mean	6303	18.40	16.52	0.06	42.82	11.88	0.01	12.71	0.25	7.17	24.31	0.25	0.11	43.47	25.56
	SD	2226	6.16	15.62	0.04	14.15	6.29	0.00	6.96	0.00	3.83	9.66	0.00	0.05	19.13	3.63
	n	73	73	73	73	73	73	73	73	73	73	73	73	73	19	73
SC1-SC60	**Minimum**	3670	4.69	5.40	0.05	22.10	4.40	0.01	2.20	0.25	4.00	11.00	0.25	0.01	0.01	18.80
	Maximum	13800	47.40	112.00	0.40	82.10	39.00	0.02	37.00	0.25	34.00	62.00	0.25	0.34	77.20	40.60
	Mean	6285	18.05	17.12	0.06	42.60	11.96	0.01	12.82	0.25	7.25	24.45	0.25	0.11	43.47	25.47
	SD	2226	6.34	16.66	0.05	13.66	6.27	0.00	6.84	0.00	4.08	9.64	0.00	0.06	19.13	3.82
	n	61	61	61	61	61	61	61	61	61	61	61	61	61	19	61

NB: all units are mg/kg unless otherwise indicated; if a concentration was recorded as being below the LOR, half of that LOR is reported; bold text indicates that a concentration exceeds the NAGD Screening Level.

3 Results

Table 3-3 Analytical data and descriptive statistics for deep core samples from within the Dredge Area.

Sample ID	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	MC (%)
MC001_1.0-2.0m	2.50	10.00	0.50	52.00	39.00	0.05	**30.00**	2.50	13.00	38.00	17.80
MC001_0.45-0.55m	2.50	30.00	0.50	46.00	19.00	0.05	20.00	2.50	10.00	24.00	14.80
MC001_0.9-1.0m	5.00	90.00	0.50	61.00	25.00	0.05	**38.00**	2.50	14.00	39.00	18.90
MC001_3.4-3.5m	8.00	20.00	0.50	29.00	14.00	0.05	13.00	2.50	8.00	18.00	19.60
MC001_6.4-6.5m	6.00	0.50	0.50	34.00	16.00	0.05	12.00	2.50	7.00	15.00	15.40
MC002_1.0-1.1m	8.00	20.00	0.50	43.00	17.00	0.05	15.00	2.50	8.00	19.00	20.10
MC002_1.9-2.0m	2.50	140.00	0.50	44.00	17.00	0.05	17.00	2.50	7.00	20.00	12.90
MC002_2.9-3.0m	2.50	40.00	0.50	56.00	34.00	0.05	**29.00**	2.50	13.00	41.00	25.30
MC002_6.4-6.5m	7.00	20.00	0.50	31.00	8.00	0.05	10.00	2.50	6.00	12.00	17.60
MC003_1-2m	2.50	50.00	0.50	56.00	26.00	0.05	**29.00**	2.50	10.00	37.00	17.10
MC003_0.45-0.55m	6.00	30.00	0.50	51.00	20.00	0.05	**21.00**	2.50	8.00	26.00	16.20
MC003_0.9-1.0m	5.00	40.00	0.50	51.00	27.00	0.05	**25.00**	2.50	9.00	31.00	16.10
MC003_3.4-3.5m	2.50	80.00	0.50	65.00	39.00	0.05	**35.00**	2.50	17.00	54.00	18.70
MC003_6.9-7.0m	2.50	20.00	0.50	46.00	17.00	0.05	19.00	2.50	8.00	26.00	20.40
MC004_1-2m	5.00	20.00	0.50	36.00	12.00	0.05	12.00	2.50	6.00	14.00	14.20
MC004_0.9-1.0m	7.00	60.00	0.50	34.00	14.00	0.05	12.00	2.50	6.00	14.00	14.20
MC004_3.9-4.0m	14.00	20.00	0.50	20.00	6.00	0.05	6.00	2.50	2.50	7.00	18.90
MC004_8.0-8.1	2.50	80.00	0.50	38.00	13.00	0.05	15.00	2.50	7.00	16.00	16.30
MC005_1-2m	2.50	20.00	0.50	42.00	15.00	0.05	19.00	2.50	9.00	24.00	22.40
MC005_0.45-0.55m	17.00	0.50	0.50	30.00	8.00	0.05	9.00	2.50	6.00	17.00	21.20
MC005_0.9-1.0m	6.00	230.00	0.50	48.00	27.00	0.05	**23.00**	2.50	10.00	31.00	20.70
MC005_3.0-3.1m	2.50	100.00	0.50	47.00	30.00	0.05	**29.00**	2.50	13.00	35.00	15.00
MC005_6.9-7.0m	2.50	20.00	0.50	43.00	24.00	0.05	**28.00**	2.50	12.00	35.00	16.50
MC006_1-2m	2.50	20.00	0.50	48.00	20.00	0.05	**22.00**	2.50	7.00	27.00	15.80
MC006_0.45-0.55	2.50	20.00	0.50	60.00	34.00	0.05	**30.00**	2.50	10.00	35.00	23.70
MC006_0.9-1.0	2.50	240.00	0.50	54.00	29.00	0.05	**28.00**	2.50	10.00	35.00	16.60
MC006_3.26-3.36	6.00	50.00	0.50	46.00	20.00	0.05	20.00	2.50	6.00	27.00	14.00
MC006_9.9-10.0	14.00	90.00	0.50	52.00	32.00	0.05	**24.00**	2.50	14.00	21.00	18.40
MC007_0.45-0.55	2.50	50.00	0.50	52.00	21.00	0.05	**21.00**	2.50	10.00	31.00	15.60
MC007_0.8-0.9	6.00	50.00	0.50	58.00	27.00	0.05	**24.00**	2.50	12.00	32.00	15.60
MC007_1.0-2.0	2.50	30.00	0.50	48.00	26.00	0.05	**23.00**	2.50	10.00	27.00	15.20
MC008_0.45-0.55	2.50	40.00	0.50	58.00	27.00	0.05	**32.00**	2.50	13.00	43.00	15.30
MC008_0.8-0.9	2.50	110.00	0.50	62.00	28.00	0.05	**32.00**	2.50	14.00	44.00	17.60
MC008_2.0-3.0	2.50	0.50	0.50	46.00	19.00	0.05	16.00	2.50	8.00	18.00	12.60
MC008_3.8-3.9	5.00	30.00	0.50	44.00	23.00	0.05	17.00	2.50	8.00	21.00	17.80
MC008_7.0-7.1	6.00	10.00	0.50	34.00	7.00	0.05	9.00	2.50	2.50	12.00	18.80
MC009_2.0-3.0	2.50	40.00	0.50	51.00	21.00	0.05	**29.00**	2.50	11.00	40.00	15.70
MC009_1.0-1.1	7.00	50.00	0.50	48.00	13.00	0.05	15.00	2.50	6.00	21.00	16.10
MC009_13.4-13.5	16.00	0.50	0.50	17.00	5.00	0.05	6.00	2.50	2.50	7.00	17.20
MC009_3.9-4.0	2.50	60.00	0.50	62.00	29.00	0.05	**38.00**	2.50	14.00	56.00	21.50

3 Results

Sample ID	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	MC (%)
MC009_8.9-9.0	2.50	50.00	0.50	48.00	25.00	0.05	**23.00**	2.50	8.00	25.00	12.20
MC010_1.0-2.0	2.50	20.00	0.50	48.00	25.00	0.05	20.00	2.50	7.00	26.00	15.40
MC010_0.45-0.55	6.00	30.00	0.50	55.00	33.00	0.05	**23.00**	2.50	8.00	30.00	15.60
MC010_0.9-1.0	2.50	20.00	0.50	54.00	24.00	0.05	**22.00**	2.50	8.00	29.00	14.10
MC010_10.9-11.0	13.00	30.00	0.50	42.00	18.00	0.05	15.00	2.50	2.50	16.00	15.40
MC010_3.45-3.55	2.50	90.00	0.50	60.00	34.00	0.05	**30.00**	2.50	10.00	42.00	14.10
MC010_7.9-8.0	7.00	0.50	0.50	37.00	12.00	0.05	14.00	2.50	2.50	15.00	18.00
MC011_0.0-0.4	19.00	0.50	0.50	31.00	12.00	0.05	12.00	2.50	7.00	24.00	30.50
MC011_1.0-1.1	2.50	20.00	0.50	50.00	24.00	0.05	**26.00**	2.50	12.00	32.00	18.80
MC011_2.0-3.0	2.50	20.00	0.50	52.00	21.00	0.05	**24.00**	2.50	8.00	38.00	20.30
MC011_3.5-3.6	5.00	140.00	0.50	52.00	30.00	0.05	**27.00**	2.50	9.00	40.00	16.30
MC011_7.5-7.55	5.00	70.00	0.50	44.00	26.00	0.05	**23.00**	2.50	13.00	30.00	15.30
MC012_1.0-2.0m	5.00	40.00	0.50	51.00	31.00	0.05	**26.00**	2.50	11.00	31.00	17.20
MC012_0.45-0.55m	16.00	0.50	0.50	26.00	10.00	0.05	10.00	2.50	6.00	18.00	21.30
MC012_0.9-1.0m	7.00	20.00	0.50	45.00	24.00	0.05	18.00	2.50	8.00	23.00	15.30
MC012_4.0-4.1m	2.50	140.00	0.50	52.00	40.00	0.05	**36.00**	2.50	13.00	50.00	21.60
MC012_9.4-9.5	7.00	170.00	0.50	47.00	28.00	0.05	**34.00**	2.50	16.00	35.00	21.60
MC013_0.45-0.55	16.00	20.00	0.50	53.00	21.00	0.05	**22.00**	2.50	12.00	31.00	17.30
MC013_0.8-0.9	8.00	10.00	0.50	37.00	16.00	0.05	16.00	2.50	9.00	25.00	17.70
MC013_1.0-2.0	5.00	60.00	0.50	55.00	32.00	0.05	**30.00**	2.50	14.00	41.00	16.50
MC013_3.4-3.5	2.50	200.00	0.50	56.00	38.00	0.05	**38.00**	2.50	14.00	50.00	19.10
MC013_6.9-7.0	6.00	0.50	0.50	41.00	11.00	0.05	14.00	2.50	8.00	20.00	13.20
MC014_0.45-0.55	2.50	80.00	0.50	54.00	26.00	0.05	**22.00**	2.50	10.00	32.00	20.60
MC014_0.8-0.9	2.50	20.00	0.50	68.00	20.00	0.05	**30.00**	2.50	14.00	41.00	16.40
MC014_1.0-2.0	2.50	20.00	0.50	62.00	19.00	0.05	**26.00**	2.50	11.00	36.00	16.50
MC014_3.4-3.5	2.50	60.00	0.50	54.00	33.00	0.05	**30.00**	2.50	9.00	49.00	20.90
MC014_6.9-7.0	6.00	30.00	0.50	52.00	22.00	0.05	20.00	2.50	10.00	20.00	11.00
MC015_1.0-2.0m	2.50	20.00	0.50	52.00	24.00	0.05	**23.00**	2.50	11.00	46.00	18.20
MC015_0.45-0.55m	11.00	0.50	0.50	20.00	6.00	0.05	6.00	2.50	2.50	12.00	17.80
MC015_0.9-1.0m	9.00	60.00	0.50	27.00	9.00	0.05	8.00	2.50	2.50	13.00	18.40
MC015_3.4-3.5m	2.50	10.00	0.50	60.00	40.00	0.05	**34.00**	2.50	14.00	48.00	16.90
MC015_6.4-6.5m	13.00	20.00	0.50	23.00	7.00	0.05	8.00	2.50	5.00	12.00	17.00
Minimum	2.50	0.50	0.50	17.00	5.00	0.05	6.00	2.50	2.50	7.00	11.00
Maximum	19.00	240.00	0.50	68.00	40.00	0.05	38.00	2.50	17.00	56.00	30.50
Mean	5.63	48.67	0.50	46.54	22.07	0.05	21.69	2.50	9.20	28.75	17.48
SD	4.27	52.25	0.00	11.39	9.09	0.00	8.50	0.00	3.52	11.83	3.17
n	72	72	72	72	72	72	72	72	72	72	72

NB: all units are mg/kg unless otherwise indicated; if a concentration was recorded as being below the LOR, half of that LOR is reported; bold text indicates that a concentration exceeds the NAGD Screening Level.

3 Results

Table 3-4 Analytical data and descriptive statistics for sediments in proposed dredge material placement sites.

Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	CaCO₃ (%)	MC (%)
Dredge Material Placement Site A	G40	5440	**24.50**	10.80	0.05	38.90	9.30	0.01	10.90	0.25	6.50	23.60				28.80
	G41	6040	**23.50**	8.60	0.05	45.40	10.00	0.01	11.80	0.25	6.80	24.70			33.10	25.10
	G42	5200	**29.00**	11.60	0.20	40.10	10.10	0.01	10.00	0.25	7.00	20.80			44.20	25.80
	G43	6510	**25.80**	8.50	0.05	45.40	10.80	0.01	12.60	0.25	10.60	26.60				27.10
	G44	5300	**24.70**	7.80	0.05	39.50	8.40	0.01	9.70	0.25	5.90	21.20			38.80	23.30
	G45	8210	**24.10**	11.10	0.05	55.10	14.70	0.01	16.50	0.25	8.60	32.60				34.10
	G46	6670	**24.10**	8.30	0.05	46.10	11.10	0.01	12.60	0.25	7.00	25.90	0.25	0.89	34.60	26.50
	G47	7110	**21.20**	10.00	0.05	47.30	13.20	0.01	14.10	0.25	7.60	29.50	0.25	0.15	35.80	26.60
	G48	5790	**31.60**	12.10	0.10	32.70	9.80	0.01	9.00	0.25	5.60	20.60				28.90
	G49	5120	**23.20**	8.60	0.05	34.90	8.40	0.01	8.50	0.25	5.40	19.80				25.60
Min		5120	21.20	7.80	0.05	32.70	8.40	0.01	8.50	0.25	5.40	19.80	0.25	0.15	33.10	23.30
Max		8210	31.60	12.10	0.20	55.10	14.70	0.01	16.50	0.25	10.60	32.60	0.25	0.89	44.20	34.10
Mean		6139	25.17	9.74	0.07	42.54	10.58	0.01	11.57	0.25	7.10	24.53	0.25	0.52	37.30	27.18
SD		994	3.01	1.57	0.05	6.61	2.01	0.00	2.48	0.00	1.56	4.21	0.00	0.52	4.39	2.94
n		10	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	2.00	2.00	5.00	10.00
Dredge Material Placement Site B	G30	4860	**33.90**	15.20	0.05	26.80	6.60	0.01	5.00	0.25	4.70	13.50				24.70
	G31	6110	**32.30**	14.20	0.05	34.70	8.60	0.01	8.20	0.25	6.20	18.60			62.60	30.20
	G32	6530	**24.00**	14.20	0.05	39.60	10.60	0.01	11.20	0.25	6.70	22.80				34.40
	G33	7180	**23.30**	9.10	0.05	46.60	12.20	0.01	13.80	0.25	7.20	29.00	0.25	0.14	37.80	27.90
	G34	6270	18.30	13.60	0.05	43.00	9.60	0.01	11.90	0.25	6.40	23.60				30.00
	G35	5630	17.40	9.80	0.05	36.80	8.10	0.01	8.60	0.25	5.50	20.00			45.20	30.60
	G36	4420	19.40	12.00	0.05	40.30	7.10	0.01	8.00	0.25	5.80	17.80				26.60
	G37	6120	18.10	10.30	0.05	38.80	8.80	0.01	10.00	0.25	6.00	22.10				28.70

3 Results

Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
	G38	7130	**20.70**	12.70	0.05	41.00	9.90	0.01	11.50	0.25	6.70	23.50	0.25	0.15	37.80	31.20
	G39	3120	12.60	15.30	0.05	13.40	4.10	0.01	0.00	0.25	2.80	8.70			81.40	25.30
Min		3120	12.60	9.10	0.05	13.40	4.10	0.01	0.00	0.25	2.80	8.70	0.25	0.14	37.80	24.70
Max		7180	33.90	15.30	0.05	46.60	12.20	0.01	13.80	0.25	7.20	29.00	0.25	0.15	81.40	34.40
Mean		5737	22.00	12.64	0.05	36.10	8.56	0.01	8.82	0.25	5.80	19.96	0.25	0.15	52.96	28.96
SD		1273	6.67	2.26	0.00	9.56	2.27	0.00	3.97	0.00	1.27	5.73	0.00	0.01	18.85	2.95
n		10	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	2.00	2.00	5.00	10.00
Dredge Material Placement Site C	G1	4130	**29.60**	13.70	0.05	22.80	5.40	0.01	4.50	0.25	4.70	11.60				23.90
	G2	4650	**22.00**	12.10	0.05	28.20	4.60	0.01	3.90	0.25	4.60	12.40				32.20
	G3	4920	**21.50**	11.50	0.05	30.00	5.20	0.01	5.00	0.25	4.60	13.30				28.80
	G4	4240	**23.40**	11.90	0.05	26.00	4.00	0.01	3.00	0.25	4.30	10.70				30.40
	G5	4620	**21.00**	13.70	0.05	29.90	4.80	0.01	3.60	0.25	5.40	13.00				32.20
	G6	4280	**28.40**	12.90	0.05	28.80	4.40	0.01	4.40	0.25	5.00	12.00	0.25	0.14	68.80	29.40
	G7	4660	**27.30**	16.00	0.05	26.90	5.90	0.01	5.80	0.25	4.70	14.20				29.30
	G8	4900	**26.20**	20.60	0.05	25.80	5.90	0.01	5.90	0.25	4.70	14.00				26.10
	G9	4110	**24.70**	12.80	0.05	27.00	4.90	0.01	4.70	0.25	5.50	12.40	0.25	0.15	61.20	28.90
	G10	4360	**26.60**	12.40	0.05	29.80	4.80	0.01	4.90	0.25	4.80	12.80	0.25	0.15	65.60	29.80
	G11	4400	**32.30**	11.60	0.05	38.60	5.20	0.01	5.30	0.25	5.80	14.70				32.70
	G12	3950	**28.00**	11.60	0.05	30.40	4.00	0.01	4.00	0.25	4.70	11.50				28.50
	G13	4060	19.80	12.30	0.05	25.10	4.70	0.01	4.70	0.25	4.40	11.90	0.25	0.15	65.60	28.30
	G14	3690	**26.60**	11.00	0.05	24.70	3.80	0.01	3.40	0.25	4.30	11.20			69.70	29.00
	G15	4450	**25.40**	11.60	0.05	29.40	5.30	0.01	6.00	0.25	4.80	13.40				29.10
	G16	4090	**29.80**	11.30	0.05	28.70	4.40	0.01	4.80	0.25	4.70	12.20				29.10
	G17	4200	**25.00**	12.10	0.05	30.00	5.20	0.01	5.20	0.25	4.90	12.70				30.40
	G18	4210	**22.00**	13.10	0.05	25.60	4.50	0.01	3.80	0.25	5.20	12.20				34.00

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Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
	G19	5590	**24.80**	19.20	0.20	33.20	11.00	0.01	9.10	0.25	6.00	17.00				28.90
	G69	2790	19.20	10.20	0.05	22.40	3.70	0.01	5.10	0.25	4.30	10.60				30.30
	G70	2430	**27.30**	10.10	0.05	19.30	2.60	0.01	3.50	0.25	4.00	9.20				28.90
	G71	3600	**21.30**	11.00	0.05	28.90	5.30	0.01	7.20	0.25	5.20	14.10				31.50
	G72	3350	**21.10**	12.20	0.05	23.80	4.60	0.01	5.40	0.25	4.60	12.10				32.80
	G73	3440	**22.10**	14.10	0.05	21.80	4.90	0.01	5.70	0.25	4.50	13.10				32.20
Min		2430	19.20	10.10	0.05	19.30	2.60	0.01	3.50	0.25	4.00	9.20	0.00	0.00	0.00	28.90
Max		5590	29.80	19.20	0.20	33.20	11.00	0.01	9.10	0.25	6.00	17.00	0.00	0.00	0.00	34.00
Mean		3815	23.80	12.49	0.07	26.31	5.15	0.01	5.58	0.25	4.82	12.66	#DIV/0!	#DIV/0!	#DIV/0!	30.72
SD		901	3.23	2.66	0.05	4.40	2.22	0.00	1.62	0.00	0.56	2.07	#DIV/0!	#DIV/0!	#DIV/0!	1.83
n		10	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	10.00
Dredge Material Placement Site E	G50	3870	5.88	15.30	0.10	26.50	3.70	0.01	9.10	0.25	3.80	9.30	0.25	0.28	69.10	35.20
	G51	3990	5.42	14.10	0.20	28.60	3.80	0.01	9.10	0.25	3.80	16.30			70.30	33.60
	G52	3640	5.56	14.60	0.10	25.90	3.70	0.01	8.50	0.25	3.60	8.90			71.80	35.20
	G53	3500	7.49	13.20	0.10	25.00	3.00	0.01	8.10	0.25	3.60	9.00			72.40	32.30
	G54	3960	5.40	13.80	0.10	25.70	3.90	0.02	8.60	0.25	3.40	9.80				34.60
	G55	3120	5.94	13.00	0.10	22.50	2.80	0.02	7.20	0.25	3.40	7.90				33.20
	G56	3840	5.03	14.90	0.10	25.70	3.90	0.01	8.80	0.25	3.50	9.20				35.60
	G57	4270	5.21	14.70	0.10	29.40	4.00	0.01	10.00	0.25	3.80	10.80				36.40
	G58	4700	6.91	16.80	0.10	31.80	5.20	0.01	10.60	0.25	4.00	12.50	0.25	0.40	67.10	41.60
	G74	3590	5.06	13.90	0.10	24.00	3.60	0.01	8.20	0.25	3.20	8.50				34.60
Min		3120	5.03	13.00	0.10	22.50	2.80	0.01	7.20	0.25	3.20	7.90	0.25	0.28	67.10	32.30
Max		4700	7.49	16.80	0.20	31.80	5.20	0.02	10.60	0.25	4.00	16.30	0.25	0.40	72.40	41.60
Mean		3848	5.79	14.43	0.11	26.51	3.76	0.01	8.82	0.25	3.61	10.22	0.25	0.34	70.14	35.23
SD		434	0.81	1.11	0.03	2.73	0.64	0.01	0.97	0.00	0.24	2.50	0.00	0.08	2.13	2.54

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Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
n		10	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	2.00	2.00	5.00	10.00
Dredge Material Placement Site D	G59	2890	4.77	21.10	0.10	23.00	3.40	0.01	7.50	0.25	2.90	9.50			74.60	37.30
	G60	3230	7.16	14.80	0.10	22.80	3.20	0.01	7.20	0.25	3.40	8.20			70.40	36.00
	G61	2700	8.32	12.50	0.05	19.60	2.60	0.01	6.50	0.25	2.90	6.60			70.00	35.10
	G62	2640	9.11	13.30	0.05	20.60	2.50	0.01	5.90	0.25	2.90	6.60				35.20
	G63	2940	6.68	12.90	0.10	20.90	3.00	0.01	6.60	0.25	3.10	7.80				36.60
	G64	3040	7.83	13.60	0.10	22.20	3.00	0.01	6.90	0.25	3.20	7.70	0.25	0.20	71.40	35.60
	G65	3300	6.82	14.50	0.10	23.40	3.20	0.02	7.40	0.25	3.70	8.50				35.50
	G66	2950	7.60	13.10	0.05	20.70	3.10	0.01	6.60	0.25	3.00	7.40	0.25	0.22	69.40	34.70
	G75	2570	7.79	12.30	0.10	20.40	2.40	0.01	5.60	0.25	2.80	6.50				34.20
	G76	3350	7.99	14.10		23.20	3.20	0.01	7.50	0.25	3.40	8.40				35.30
Min		2570	4.77	12.30	0.05	19.60	2.40	0.01	5.60	0.25	2.80	6.50	0.25	0.20	69.40	34.20
Max		3350	9.11	21.10	0.10	23.40	3.40	0.02	7.50	0.25	3.70	9.50	0.25	0.22	74.60	37.30
Mean		2961	7.41	14.22	0.08	21.68	2.96	0.01	6.77	0.25	3.13	7.72	0.25	0.21	71.16	35.55
SD		274	1.17	2.55	0.03	1.38	0.34	0.00	0.66	0.00	0.29	0.98	0.00	0.01	2.06	0.90
n		10	10.00	10.00	9.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	2.00	2.00	5.00	10.00

NB: all units are mg/kg unless otherwise indicated; if a concentration was recorded as being below the LOR, half of that LOR is reported; bold text indicates that a concentration exceeds the NAGD Screening Level.

3.2.3 Concentrations and Distributions of Inorganic Contaminants of Potential Concern

Of the 11 metals and metalloids tested for in sediments, As, Cr and Ni were present in concentrations exceeding the NAGD Screening Levels. The spatial distribution of selected metals and metalloids are shown below (Figure 3-1 – Figure 3-6) and indicate concentrations of the COPCs in surface and near-surface sediments. Sediment grab sample locations from the Pilot Survey (URS 2009a) have been included in the spatial display of the data. Distributions of Cu, Zn and Ni in whole sediment were similar (Figure 3-1; Figure 3-3; Figure 3-4). Higher concentrations of these metals generally occurred within fine-grained material, present in the turning basin and close to shore. In comparison, higher $CaCO_3$ content in the sediment (>50%) was present in the seaward end of the proposed navigation channel and at the proposed Offshore Dredge Material Placement Sites D and E (Figure 3-5). $CaCO_3$ concentrations were lower in the nearshore are of the turning basin, reflecting the lack of shell material in the stiff red sandy-gravel clay.

The distribution of metals in sediments was concurrent with mud (silt and clay) content, and the percentage of mud decreased with distance from shore (Figure 3-6). Dilution by coarser grained and $CaCO_3$-rich material with less adsorptive capacity increases with distance from shore and concentrations of metals were therefore controlled by variability in sediment texture.

Concentrations of Ni in sediment exceeded the NAGD guideline value (21 mg/kg) within the clay units of the turning basin (Figure 3-4). In contrast, concentrations of As in sediments within the turning basin were relatively low (<15 mg/kg) (Figure 3-2). Concentrations of As in the proposed Nearshore Dredge Material Placement Sites A, B and C were similar to concentrations in the Dredge Area, but considerably higher than concentrations in the proposed Offshore Dredge Material Placement Sites D and E. This finding suggests that the absorption of As is controlled by factors other than grainsize.

3 Results

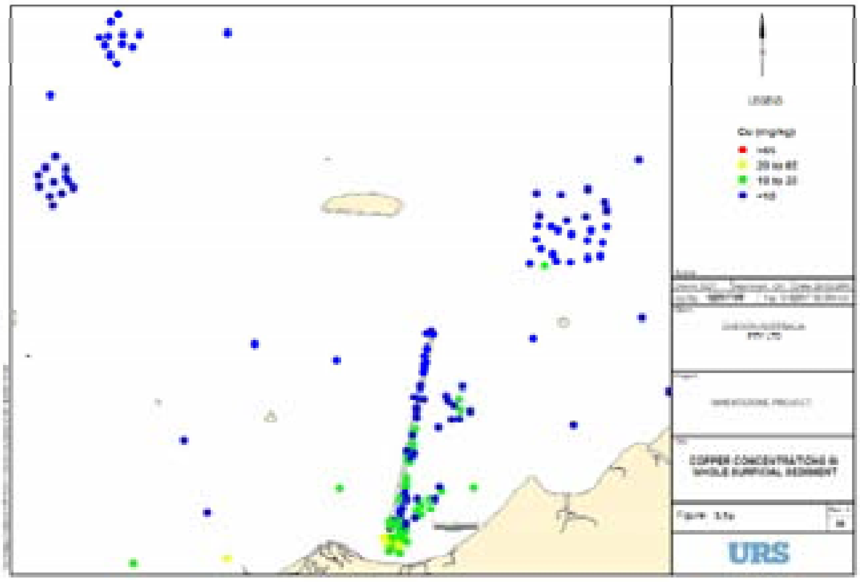

Figure 3-1 Spatial distribution of Cu at short core and grab sample sites.

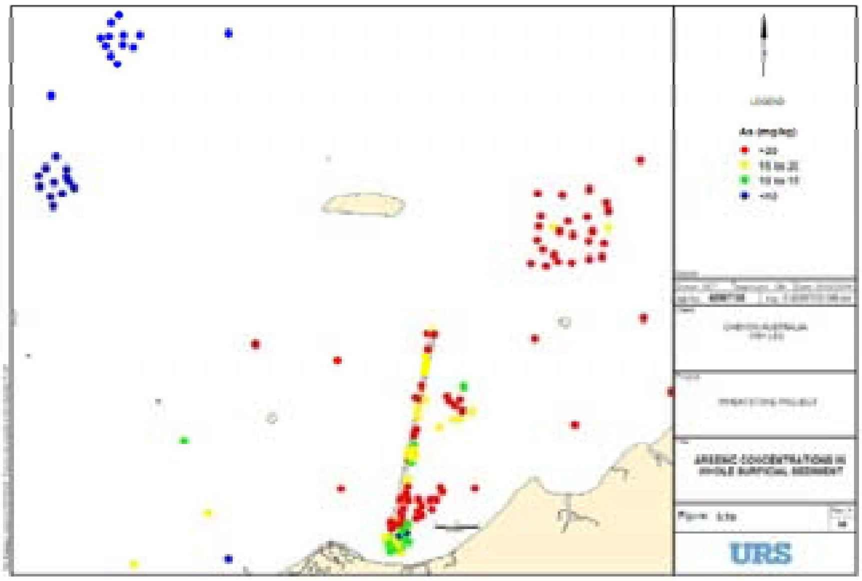

Figure 3-2 Spatial distribution of As at short core and grab sample sites.

3 Results

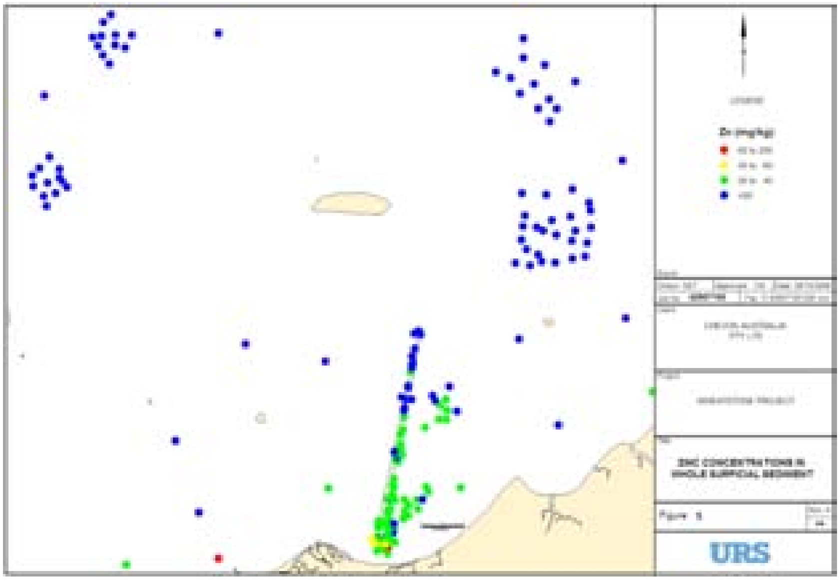

Figure 3-3 Spatial distribution of Zn at short core and grab sample sites.

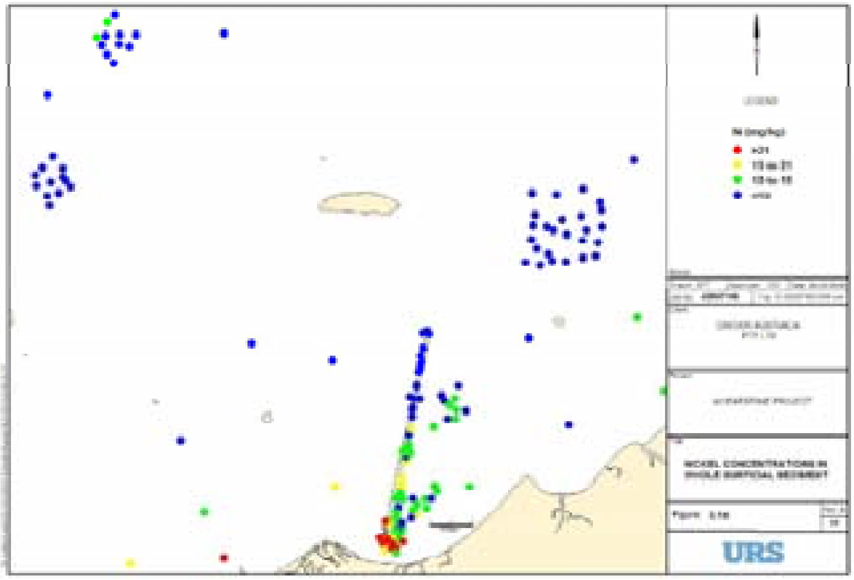

Figure 3-4 Spatial distribution of Ni at short core and grab sample sites.

3 Results

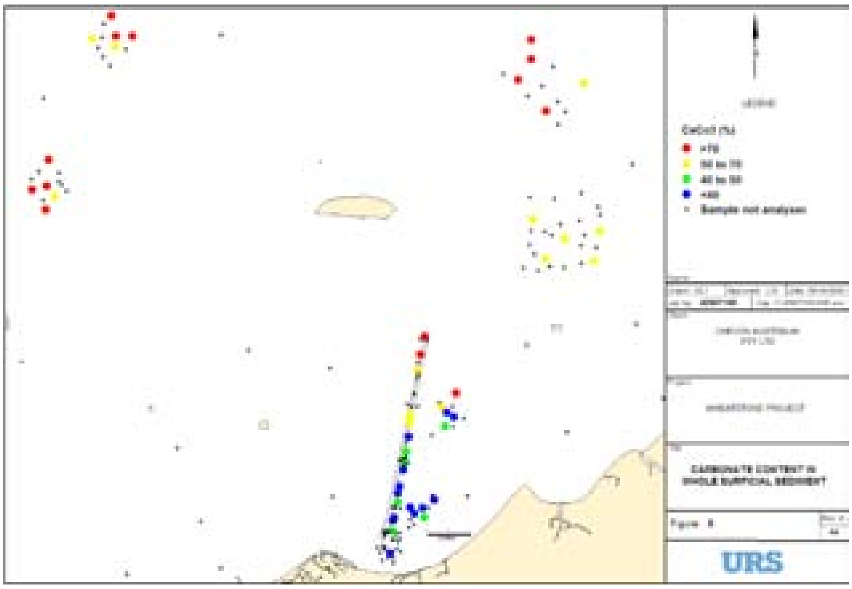

Figure 3-5 Spatial distribution of CaCO^3 content at short core and grab sample sites.

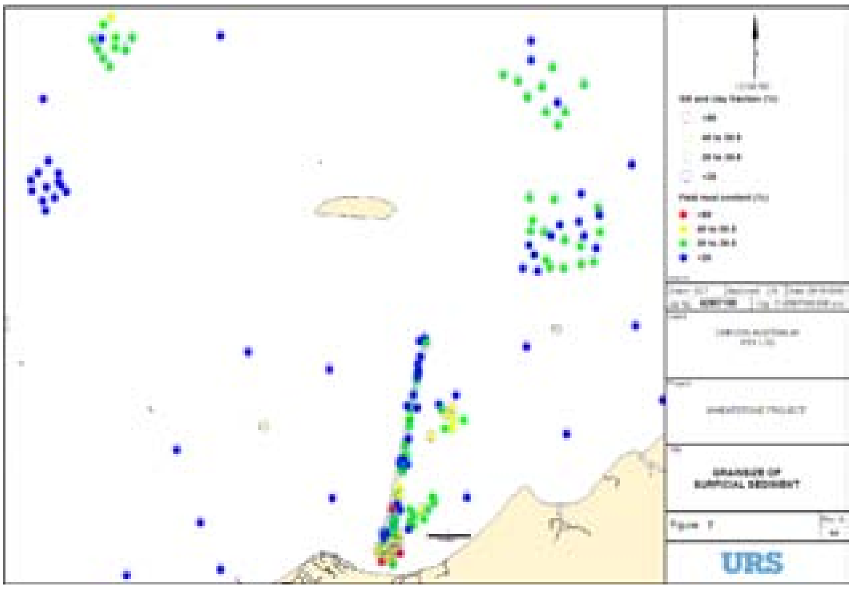

Figure 3-6 Spatial distribution of PSD at short core and grab sample sites.

3.2.4 Concentrations of Tributyltin

Concentrations of TBT were recorded as being below the analytical LOR (0.5 µgSn/kg) in all sediment samples from all locations, therefore a spatial assessment of TBT cannot be established.

3.3 Radionuclide Activity Analyses

Five short core sediment samples were analysed for radionuclide activity and results are shown in Appendix G. All five sediment samples analysed exhibited an activity of <0.5 Bq/g, which is below the NAGD Screening Level of 35 Bq/g.

3.4 Geochemical Data Validation Summary

The data validation indicates only a relatively small number of data quality non-conformances associated with the sediment analyses. Some of these non-conformances are commonly encountered during sediment quality assessment programs and analyses of sediments with variable MC and at concentrations that are approaching the analytical LOR. Individual QA/QC failures should be considered in the context of other QA/QC data and the contaminant concentrations present in the sample. None of the analyses of sediment samples were undertaken outside recommended holding times, presented in the NAGD.

LOR were at or below the PQLs recommended by the NAGD, except for analytes assessed in the deep cores, which exceeded the PQLs. However, the generally low concentrations of COPCs in sediments were confirmed in surficial sediments. Exceedances of NAGD Screening levels were not present in any sediment sample, with the exception of Ni, which frequently exceeds the NAGD Screening Level in deep core samples.

No analytes were detected above the LORs for any of the laboratory method blanks analysed. The trip blank sample reported In Batch EB0915491 indicated the presence of Al, As, Cr, Zn, Ba and Hg. Typically trip blanks are supplied by the laboratory to be used in conjunction with the transport of volatile samples and are used to ensure there has been no transfer of contamination between samples in transit. The likelihood of sample transfer for analytes other then volatiles (i.e. metals) is unlikely, which was confirmed by the laboratory. The laboratory results for this sample indicate the presence of the above analytes in the same concentrations.

The field replicates (duplicates and triplicates) reported elevated RPDs for some analytes, however these results were reported as acceptable by ALS as the samples were significantly heterogeneous. This was further confirmed by re-analysis of total metal results, which has been reported in batch EB0916628. The investigation identified that the correct Inter-Element Correction factors had been applied to account for the saline sample matrix. It also confirmed that repeat analysis showed the samples to be heterogeneous. The majority of results met the data quality objectives.

Inter-batch duplicate data was not required as all sediment samples were received by the lab in one batch.

Recovery monitoring using matrix spikes and surrogates indicated very good method efficiency and accurate representation of the sediment sampled.

LCS recoveries were within DQOs, indicating acceptable accuracy of analytical procedures. There were a few LCS exceedances, however these were reported as acceptable by ALS as all associated analyte results were reported as less than the LOR.

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The number of samples taken within the Dredge Area conformed with the number outlined in the SAP (Appendix A) and exceeded the required number within the proposed dredge material placement sites. However, deep core sediment samples MC001 to MC015 were not all obtained within the Dredge Area because of the requirement to collect these samples as part of the geotechnical investigation. However, the geochemical characterization of the deep core samples to a depth of up to 13.5 m has shown that the subsurface sediment geochemistry is similar and very homogeneous throughout the horizons sampled. Concentrations of COPCs were generally below those specified by the NAGD Screening Levels, excluding Ni which was present in higher levels within deep core sediments.

The completeness of DQO was assessed by determining the percentage of each data quality parameter that met the criteria specified in the NAGD, with the sum total of validated data exceeding the 95% completeness guideline. The percentage of DQO compliance for each data quality parameter is provided below (Table 3-5). The secondary data was used to validate the primary dataset and the overall completeness of Data Quality Objectives exceeding 95% meant that the primary data could be accepted. All primary data was used in calculation of 95% UCL of mean contaminant concentrations.

In summary, the detailed data validation process identified that although some data that did not meet the data quality objectives, URS considers that the data quality non-conformances do not represent significant data quality issues, on advice from ALS, and therefore do not affect the overall interpretation or classification of sediment quality.

Table 3-5 Completeness of data quality objectives.

Data Quality Parameter	Total number of results (all analytes)	DQO Compliant (%)
Core Splits	31	TBC
Field Triplicates	TBC	TBC
Inter-batch Duplicates	TBC	TBC
Laboratory Control Samples	63	100
Laboratory Duplicates	209	100
Matrix Spikes	102	91%
Method Blanks	63	100
Surrogate Spikes	TBC	TBC
Overall Completeness	TBC	TBC

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Discussion

4.1 Textural Units in the Dredge Area

The thickness of unconsolidated sediments is generally shallow, with all short cores having reached depths of refusal in hard substrate at 0.4 m or less (i.e. stiff clay, shelly reef, coral beds). The hard subsurface sedimentary deposits comprise sandy and gravelly clays, clayey sands, claystone and conglomerate, as shown in the deep core logs (Appendix D).

4.2 Assessment of Geochemical Dataset

Concentrations of COPCs in sediments within the Dredge Area were generally low. The geochemical dataset for the assessment of sediment quality in the Dredge Area comprises data collected at 60 short core sample locations and 15 deep core sample locations, with an additional 12 short core sample locations in areas adjacent to the Dredge Area. A total of 64 surface sediment grab samples were also collected in the five proposed dredge material placement sites.

4.3 Comparison with Previous Analytical Data

Previous contaminant assessments of sediment in the region near the Dredge Area have been summarized in the SAP (Appendix A) and include the initial Pilot Survey (URS 2009a). Previous investigation also confirms that concentrations of COPCs in sediments on the North-West Shelf, and in the Dredge Area, were low (i.e. below NAGD Screening Levels). Additionally, a majority of both organic and inorganic CPOCs were present at levels below the LOR.

4.4 Factors Influencing Contaminant Distributions

The spatial distribution of COPCs in sediments within and near the Dredge Area is likely to be mainly driven by a strongly positive correlation between contaminants and fine grained particles and/or TOC, which is known to increase the adsorptive capacity of sediment (e.g. Förstner, 1995; Matthai and Birch, 2000). Therefore, it is necessary to assess the relationship between concentration of COPCs in the sediment and the proportion of mud (silt+clay) fraction in the sediment, as exemplified by the positive correlation between Cu and mud content (Table 4-1). It is unlikely that the spatial distribution of COPCs in surface and near surface sediments is due to proximity of these sediments to anthropogenic contaminant sources (e.g. shipping activity), and more likely to be linked to PSD.

The relationship between concentrations of inorganic contaminants in sediment and Al (a proxy for mud content) for all 136 short core and grab samples are shown below (Figure 4-1 - Figure 4-3). Positive correlations existed between Al and all other metals tested for (Table 4-1), while statistically significant correlations existed between Al and Cr, Cu, Ni, and Zn ($r>0.72$; $n=136$; $p<0.001$). This confirms the capacity of muds and clays to adsorb metals and supports the notion that lower concentrations of metals would exist in sandy sediments. In addition, metal concentrations in surficial sediments generally decrease with greater distance from shore and at greater water depths due to a larger $CaCO_3$ component relative to the terrigenous component in deeper waters, as indicated by the correlation between Al and $CaCO_3$ (Figure 4-3).

This correlation between metals (excluding As) provides support for a common ‘diffuse’ source for these metals. If major point sources of contaminants existed this would not be the case, as the correlation between PSD and metal concentrations would be weakened by disproportionately high concentrations of these analytes relative to the PSD content in the sediments. In contrast, the correlation between mud content and As in whole sediment is close to zero ($r=-0.01$), suggesting that

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As may be more likely to be bound to the sand fraction of sediments, possibly as coprecipitates of FeO and oxyhydroxides and arsenopyrites.

The overall variability in magnitude of organic and inorganic contaminant concentrations in sediments in the Dredge Area and the proposed dredge material placement sites is generally low, when compared to other estuarine environments in urban and metropolitan areas (e.g. Port Phillip Bay, Sydney Harbour). These conditions, however, are similar to other high energy marine environments (e.g. Central NSW Continental margin) (Matthai and Birch, 2000). The increased variability and higher concentrations of contaminants in the shallow nearshore environment is likely to result from natural contributions from clay minerals rather than from anthropogenic enrichment. However, the concentrations of COPCs in these nearshore sediments are generally below the NAGD Screening Levels, with the exception of As and Ni.

Table 4-1 Correlations between metals and metalloids within sediment samples.

	Al	As	Ba	Cr	Cu	Ni	Pb	Zn
Al	n/a							
As	-0.01	n/a						
Ba	0.46	-0.16	n/a					
Cr	**0.93**	-0.08	0.46	n/a				
Cu	**0.92**	-0.13	0.58	**0.93**	n/a			
Ni	**0.90**	-0.27	0.58	**0.94**	**0.95**	n/a		
Pb	0.72	0.03	0.35	0.70	0.72	0.69	n/a	
Zn	**0.95**	-0.04	0.46	**0.95**	**0.96**	**0.92**	**0.74**	n/a

NB: bold data indicates a statistically significant correlation.

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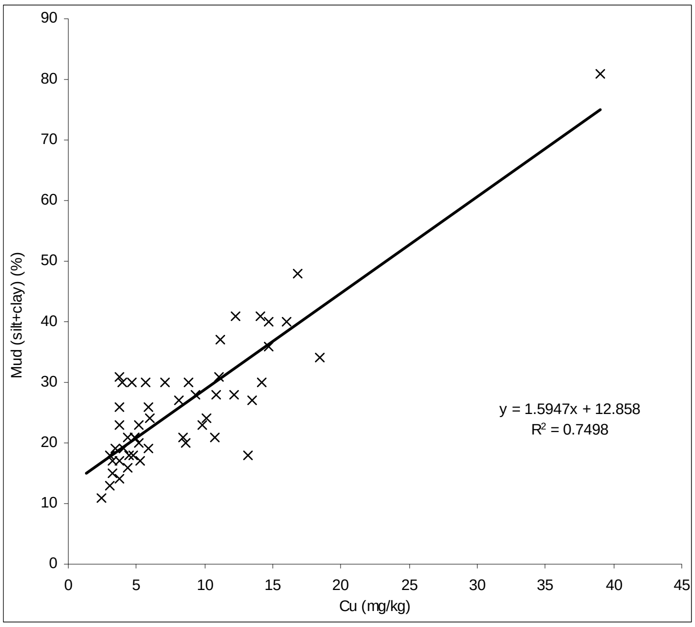

Figure 4-1 **Bivariate correlation between Cu and mud in grab samples and short core samples.**

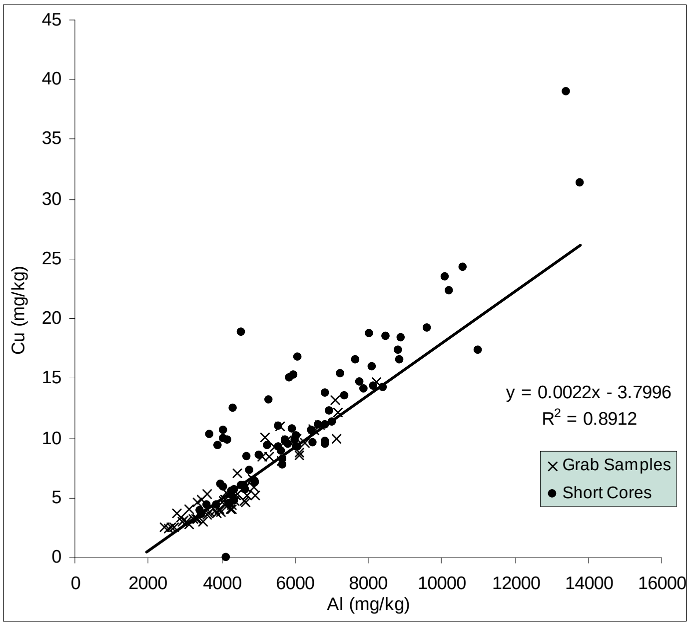

Figure 4-2 **Bivariate correlation between Al and Cu in grab samples and short core samples.**

4 Discussion

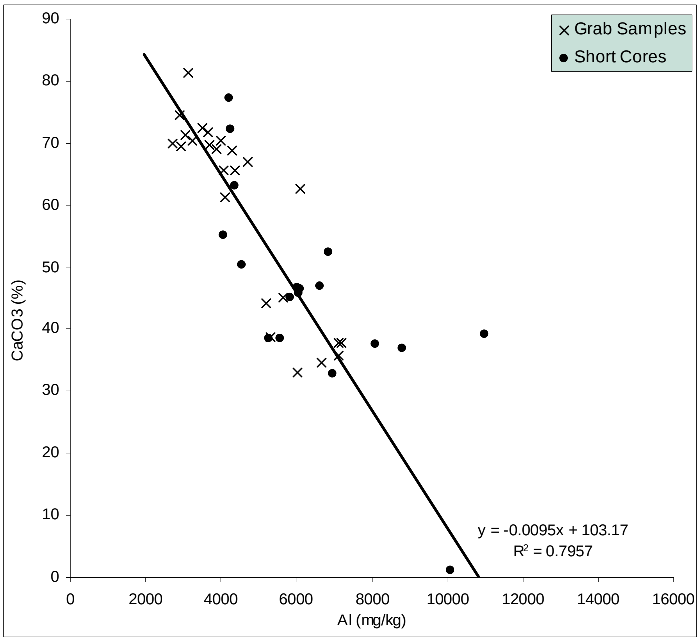

Figure 4-3 Bivariate correlation between Al and CaCO3 content in grab samples and short core samples.

4.5 Background Concentrations of Contaminants

4.5.1 Inorganic Analytes

Background concentrations may only be estimated for metals, although other inorganic analytes, including nutrients, and some organic contaminants (e.g. PAHs) are generally present naturally in the marine environment. Due to the relationship between the concentrations of metal in sediment and PSD, it is not possible to establish a single background concentration value for sediments in the Dredge Area without adopting a grain size normalisation approach.

By using the proportion of mud content as a proxy for grain size and plotting mud content against the concentration of metals in the total sediment, it may be possible to estimate a range of normalized background concentrations to minimise the confounding effects of variable sediment grain size. However, an assessment of background concentrations for sediments in the Dredge Area was not required as only one contaminant (Ni) exceeded mean concentrations of 95% UCLs of the NAGD Screening Levels in sediments within the Dredge Area (Section 4.6.4).

4.5.2 Nickel and Arsenic Concentrations in Dredge Area

The concentrations of Ni and As typically exceed the NAGD Screening Levels in otherwise uncontaminated sediments in large areas of south-eastern Australia and in many coastal regions throughout Australia. The exceedances of the NAGD Screening Levels in some sediment samples for these two contaminants in the Dredge Area (As and Ni in short core samples, Ni in deep core samples) is therefore unlikely to be related to anthropogenic contributions. In addition, the concentrations of As in sediments in the proposed dredge material placement sites and at regional sample locations (URS 2009a) have been shown to exceed the NAGD Screening Level for As in surficial sediments (20 mg/kg). The assessment of Ni concentrations in relation to the positive correlation between mud content and Ni, or Al and Ni, and the concentration of these elements in sediment has shown that the concentrations of Ni are also likely to be of natural origin and related to PSD.

Conversely, concentrations of As did not correlate with mud content (proxy Al) in sediments, which is likely due to the coprecipitation of As in FeO and oxyhydroxides or arsenopyrites onto sand-sized grains. Although the concentrations of As exceed the NAGD Screening Level (20 mg/kg) in many surficial sediment samples, elevated concentrations of As have been shown to be of natural origin and related to sediment mineralogy and diagenetic processes in south-eastern Australia (Davies, 1979). Naturally elevated concentrations of As (up to 180 mg/kg) have been found in sediments on the south-eastern Australian continental margin, suggesting that concentrations of As exceeding 20 mg/kg may not always be due to the presence of anthropogenic activity.

4.6 Sediment Quality in Dredge Area

4.6.1 Comparison with the NAGD Screening Levels

4.6.2 Dredge Area

Concentrations of As (21 samples), Cr (one sample) and Ni (five samples) from short core samples exceeded the NAGD Screening Levels for COPCs within the Dredge Area.

Concentrations of Ni (41 samples) from deep core samples exceeded the NAGD Screening Levels for COPCs within the Dredge Area.

4.6.3 Dredge Material Placement Sites

Concentrations of As from short core and grab samples exceeded the NAGD Screening Levels for COPCs within the proposed Nearshore Dredge Material Placement Site A (5 samples), Site B (22 samples), and Site C (22 samples).

4.6.4 95% UCL of Mean Concentrations

The secondary data was used to validate the primary dataset and the overall completeness of DQO exceeded 95%. This means that the primary data can be accepted. Primary data was used in calculating the 95% UCL of mean contaminant concentrations, using half the analytical LOR where concentrations are below the LOR. As the NAGD Screening Levels were exceeded for As, Cr and Ni concentrations at a number of sites, the 95% UCL of mean concentrations of COPCs were calculated for each contaminant for which a NAGD Screening Level exists and for which at least one concentration exceeds the analytical LOR (Table 4-2).

The 95% UCLs of the mean concentrations of As and Ni were below NAGD Screening Levels for all short core and the majority of deep core samples (Table 4-3), indicating that additional sediment assessment, including elutriate, bioavailability and toxicity testing, were not required. There was one exception for Ni concentrations in deep core samples (23.4 mg/kg), which exceeded the NAGD Screening Levels by 2.4 mg/kg.

Nickel in sediments is derived from non-anthropogenic sources. The 95% UCL Screening Level exceedance of the concentrations of nickel in deep core sediments is marginal, i.e. 23.4 mg/kg vs Screening Level of 21 mg/kg and the absence of a 95% UCL Screening Level exceedance in short core sediments, i.e. 14.4 mg/kg suggests that all of the nickel is of natural origin.

Concentrations of nickel in surface sediments collected at the potential disposal sites (muddy sands) are not suitable for assessing background concentrations of nickel in clays found at depth in the dredging areas.

Nickel concentrations in proposed dredging areas (based on our knowledge of sediment texture and contaminant concentrations) are unlikely exceed background concentrations in deeper sediments at the disposal ground.

Table 4-2 95% Upper Confidence Limits of Mean Contaminant Concentrations.

	# of Samples	As	Ba	Cr	Cu	Hg	Ni	Pb	Zn
NAGD Screening Level	n/a	20	n/a	80	65	0.15	21	50	200
Short Core Samples	61	19.40	26.40	45.50	13.30	0.01	14.40	8.10	26.50
Deep Core Samples	72	7.80	87.10	48.80	23.90	0.05	23.40	9.80	31.10

NB: all data in mg/kg.

4.6.5 Weak Acid Extractions

As stipulated in the SAP, if the 95% UCL of mean concentrations of COPCs in sediments exceed NAGD Screening Levels, a weak acid extraction using 1 M HCl needs to be undertaken for these COPCs. Although the 95% UCL of the mean concentrations does not exceed the NAGD Screening Level for As, a weak acid extraction and analysis of short core sediment samples within and near the Dredge Area (i.e. SC1-SC72) was still undertaken for As (19 samples), Ni (8 samples) and Cr (1 sample) (Table 4-3) (Appendix H).

Weak acid tests were undertaken to assess the significance of the observed nickel concentrations. The weak acid extracted an average of 17.8% of the "total" nickel in the analysed samples. The mean weak acid extractable concentration of nickel of 4.8 mg/kg is substantially less than the “total” mean nickel concentration of 26.8 mg/kg in the analysed samples.

The results of the weak acid-extractions indicate that the extractable proportion of As, Ni and Cr in near surface sediments is about 10% of the total extractable concentration, which is well below the actual NAGD Screening Levels in all samples analysed. The As and Ni in the sediments tested is therefore unlikely to be bioavailable at concentrations above which adverse effects on aquatic biota may be present. Therefore no further sediment quality assessment was required.

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Table 4-3 Analyses of weak acid-extractable (1 M HCl) As, Ni, and Cr in selected sediment short core samples.

Sample ID	As*	Cr*	Ni*	As^	Ni^	Cr^
SC1_0.0-0.27	13.2	67.8	**21.1**		1.0	
SC5	**21.4**	50.9	20.3			
SC7_0.0-0.10	**21.5**	38.2	10.2	1.7		
SC8_0.0-0.30	**21.7**	42.1	11.2	1.6		
SC9_0.0-0.20	**22.9**	55	16.3	1.8		
SC11_0.0-0.5	13.1	**82.1**	37		1.7	1.6
SC13	**20.9**	35	11.4	3.0		
SC16	**20.5**	34.1	9.4			
SC17_0.0-0.35	**22.6**	40.4	10.9	1.5		
SC18_0.0-0.30	**23.4**	40.8	11.2	1.4		
SC20_0.0-0.20	15.8	70	**24.4**		1.2	
SC23_0.0-0.25	**21.1**	42.9	11.8	1.4		
SC29_0.0-0.20	15.3	67	**22.3**		1.5	
SC31_0.0-0.20	**20.3**	23.3	3.6			
SC34_0.0-0.25	**28.5**	53	16	1.3		
SC35_0.0-0.5	**22.4**	34.1	8.7	1.9		
SC37_0.00.051	14.3	78.1	**35.4**		1.2	
SC40_0.0-0.31	**26.6**	50.6	15.9	1.4		
SC47_0.0-0.25	**23.8**	39.1	8.8	1.8		
SC50_0.0-0.23	**22.2**	51.8	15.5	1.5		
SC51	**47.4**	24.7	2.2		1.4	
SC54_0.0-0.20	**22**	48.4	17.8	1.5		
SC55_0.0-0.25	**22.8**	43.5	11	1.9		
SC57_0.0-0.5	17.6	77.4	**26.7**			
SC58_0.0-0.15	**24.9**	38.8	10.6	1.8		
SC59_0.0-0.23	**22**	41.6	11.7	1.7		
SC61_0.0-0.18	18.5	62.2	**23.4**		1.6	
SC62_0.0-0.1	13.3	71.2	**23.9**		<1.0	
SC65	**21.8**	19.1	1.5			
SC66	**26.1**	24.4	4			
SC67_0.0-0.15	**28.2**	24.9	3.7	2.5		
SC71	**24.7**	49.5	13.4	2.0		
SC72	**23.4**	41.4	10.5	2.2		

*NB: all units are mg/kg unless otherwise indicated; * indicates actual concentrations, ^ indicates the weak acid extraction concentration; if a concentration was recorded as being below the LOR, half of that LOR is reported; bold text indicates that a concentration exceeds the NAGD Screening Level.*

4.7 Sediments within Trunkline Route

No short or deep core sampling was undertaken within the Trunkline Route, however two grab samples (W15, W19) were taken from within the Trunkline Route, and several other grab samples were taken from within the vicinity of the Trunkline Route, during the Pilot Survey (URS 2009a) (Table 4-4). Geochemical characterisation of these samples were similar in COPCs composition to those taken from surface and deep samples collected from within the Dredge Area and the proposed dredge material placement sites.

Concentrations of As exceed the NAGD Screening Levels in the two sediment samples collected from the Trunkline Route during the Pilot Survey (URS 2009a), however these results were reflected in data collected as part of the current study. Additionally, the demonstrated correlation between grain size and concentration of metals in sediment provides support for the notion that sediments from within and in the vicinity of the Trunkline Route would not be geochemically different from the sediments collected as part of this study.

Using the means and calculated standard errors for concentrations of metals in sediments obtained from the Dredge Area and the proposed dredge material placement sites, the Pilot Survey (URS 2009a), the mean concentrations +2 times the SE are less than the NAGD Screening Levels for all analytes. Although sediments within the Trunkline Route have not been extensively sampled, the assessment of sediments in the Dredge Area and the proposed dredge material placement sites indicate that exceedances of the NAGD Screening Levels are unlikely.

Bivariate distributions of As and Cu concentrations from the proposed dredge material placement sites, the Dredge Area and regional surface sediments (URS 2009a) are presented below (Figure 4-4). The figure indicates that, generally, concentrations of As and Cu in surface sediments collected as part of this survey, are not significantly different from concentrations in the sediment collected from the Trunkline Route. Similarly, concentrations of other metals were similar in sediments collected as part of this assessment, to those collected during the Pilot Survey (URS 2009a) (Table 4-4). This exemplifies the regional spatial homogeneity of the sediment geochemistry and the generally uncontaminated nature of sediments within the regional area.

4 Discussion

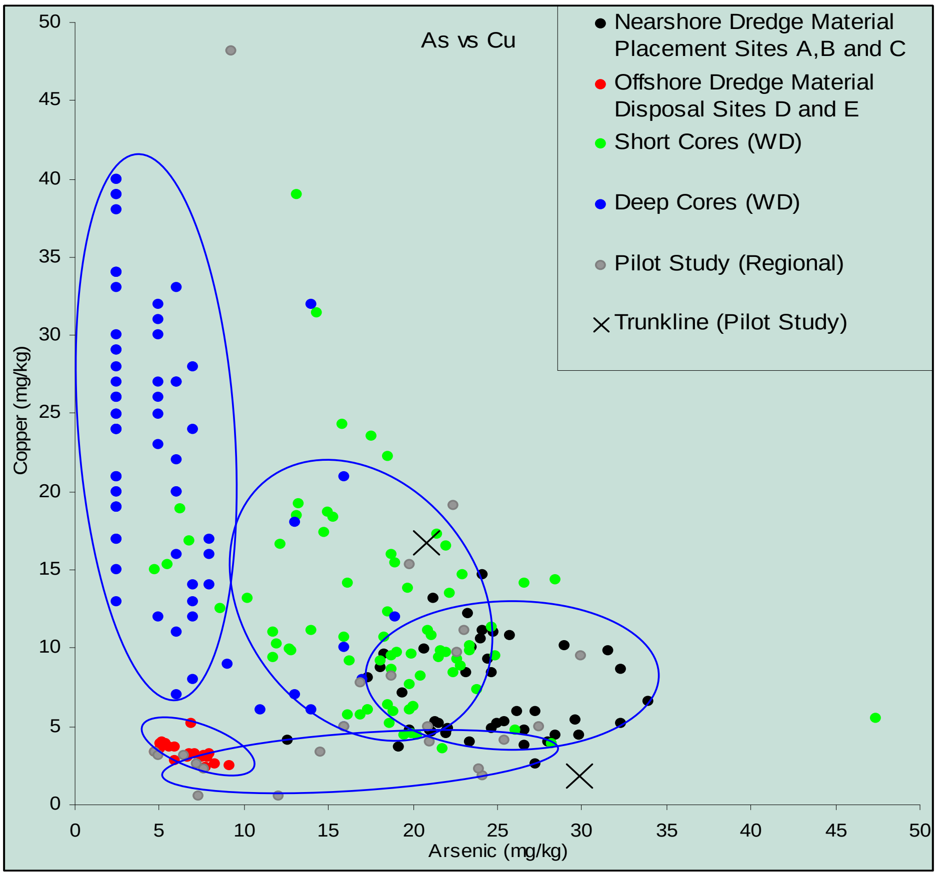

Figure 4-4 **Bivariate plot of As and Cu in sediments from the Dredge Area, the proposed dredge material placement sites and the Pilot Survey.**

Table 4-4 Descriptive statistics summary for concentrations of metals in the Dredge Area, the proposed dredge material placement sites and the Pilot Survey, in comparison to data for Trunkline Route samples.

Area/ Sample ID		As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn
Dredge Area/ Dredge Material Placement Sites/ Pilot Survey	Max	**47.40**	240	0.50	**82.10**	48.20	0.05	**42.20**	**2.50**	34.00	69.40
	Min	2.50	0.50	0.05	11.40	0.50	0.01	0.00	0.25	1.10	1.30
	SD	8.97	34.32	0.21	14.13	9.63	0.02	8.89	1.07	3.63	11.83
	SE	0.60	1.60	2.60	3.60	4.60	5.60	6.60	7.60	8.60	9.60
	Mean	14.37	25.16	0.20	39.04	12.97	0.02	13.82	1.03	6.98	22.11
	n	232	232	231	232	232	232	232	209	232	232
Trunkline Route	W15	**29.80**	7.10	0.05	15.10	1.80	0.01	3.80	n/a	3.00	4.50
Trunkline Route	W19	**20.80**	17.80	0.05	45.60	16.70	0.01	20.10	n/a	9.00	32.40

NB: all units are mg/kg; n/a = not tested for; if a concentration was recorded as being below the LOR, half of that LOR is reported; bold text indicates that a concentration exceeds the NAGD Screening Level.

4.8 Classification of Sediment in Dredge Area

The sediments in the Dredge Area have been classified based on the available geochemical results for sediment samples, in accordance with the SAP (Appendix A) and Figure 3 of the NAGD. Sediments at one or more sample locations exceeded the NAGD Screening Levels for As, Cr and Ni. Background concentrations of COPCs were demonstrated to be at ambient levels in sediment at the dredge material placement sites, and is expected to be unaffected by Placement of dredged material. Additionally, the 95% UCL for As and Ni did not exceed the NAGD Screening Levels, with the exception of Ni in deep cores. Therefore, a full assessment of the total number of sample locations recommended by the NAGD is not warranted. Neither a Phase III or a Phase IV assessment of acute and sub-acute toxicity was required to be undertaken on unconsolidated sediment collected in the Dredge Area. Sediments in the Dredge Area are acceptable for unconfined Placement at one or more of the proposed dredge material placement sites, and further geochemical, ecotoxicological, elutriate, bioavailability and toxicity testing is not warranted.

4.9 Assessment Limitations

Although deep cores were not all sampled within the proposed Dredge Area in strict accordance with the NAGD guidelines, the sampling and assessment of sediments in the Dredge Area provides an acceptable assessment of unconsolidated sediments at all short core locations to the depth of refusal in stiff clays or in limestone. Deep core locations generally confirmed the absence of unconsolidated sediments below a thin (<0.5 m deep) veneer of gravelly muddy to clayey sands. In addition, the concentrations of COPCs in deep core sediments were all below the NAGD Screening Levels for all COPCs assessed, with the exception of Ni, which has a demonstrably natural and grain-size-related origin. Exceedances of PQLs in deep core sample analyses and shorter sub-sampling intervals in the deep core samples are therefore unlikely to measurably affect the outcomes of this assessment, but should be noted in terms of non-compliance with the requirements outlined in the NAGD.

This investigation has not specifically targeted near surface sediments within the Trunkline Route. Based on the geochemical data obtained in the current and previous investigations, assessments of

4 Discussion

sediments in the Trunkline Route are not recommended and deemed unnecessary. Extrapolation, based on existing data, indicates that the probability that sediments in the Trunkline Route are contaminated above Screening Level concentrations for the COPCs is negligible.

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Limitations

URS Australia Pty Ltd has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron Australia Pty Ltd and only those third parties who have been authorised in writing by URS Australia Pty Ltd to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated September 2009.

The methodology adopted and sources of information used by URS Australia Pty Ltd are outlined in this report. URS Australia Pty Ltd has made no independent verification of this information beyond the agreed scope of works and URS Australia Pty Ltd assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS Australia Pty Ltd was false.

This report was prepared between October 2009 and May 2010 and is based on the conditions encountered and information reviewed at the time of preparation. URS Australia Pty Ltd disclaims responsibility for any changes that may have occurred after this time.

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Appendix A Sampling and Analysis Plan

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Sampling and Analysis Plan

Wheatstone Dredging Program

16 FEBRUARY 2010

Prepared for
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Introduction

1.1 Background

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant near Onslow on the Pilbara Coast to process gas from various offshore fields in the West Carnarvon Basin. The Wheatstone Project is referred to as the Project and 'Ashburton North' is the proposed site for the LNG and Domgas plants.

The initial Project is expected to consist of two LNG processing trains each with a capacity of between 4 to 7 million tonnes per annum (MTPA) per train. Approval is being sought for the maximum capacity of the plant of 25 MTPA for the site. The Domgas plant will have a capacity equal to 15% of LNG sales, or approximately 230 Terajoule/day (TJ/d) based on initial LNG sales of 10 MTPA. Domestic gas plant capacity will increase as LNG production increases.

As part of the proposal, the dredging of marine sediments is required to enable vessel access via a shipping channel and turning basin.

Preliminary sediment and geotechnical investigations (Appendix A; URS Australia Pty Ltd (URS) 2009a) have indicated that the top layer of marine sediments in this remote region are unlikely to be contaminated with anthropogenic contaminants and likely to be suitable for disposal at sea. Pilot surface sampling using sediment grabs (24 samples) has been completed and none of the analytes investigated exceeded NAGD Screening Levels (Commonwealth of Australia 2009).

A range of statutory approvals will be required under relevant State and Commonwealth legislation prior to the proposed development taking place.

In order to provide consistency in the description of the proposed Dredge Area, the entire area proposed for dredging will be referred to as the Dredge Area throughout this document. This Sampling and Analysis Plan (SAP), prepared with reference to the National Assessment Guidelines for Dredging (NAGD) (Commonwealth of Australia 2009), assesses the proposed dredging program and available historical data on the physical and chemical characteristics of sediments in the vicinity of the Dredge Area (Phase I assessment). In addition, the sampling and analysis of sediments in the Dredge Area for proposed Contaminants of Potential Concern (COPCs) listed on the Contaminants List and a comparison to Screening Levels (Phase II assessment) is detailed in the SAP.

Elutriate and bioavailability testing (Phase III) and assessment of toxicity and bioaccumulation (Phase IV) may not be required, depending on the outcomes of the Phase II assessments. However, if necessary, Phase III and Phase IV assessments, briefly described in this Sampling and Analysis Plan (SAP), would be undertaken in the event that mean concentrations of contaminants in sediment exceeded NAGD Screening Levels. If necessary the Dredge Area would be adjusted in certain areas to excise potential contaminant "hot spots", as required.

Geochemical testing of sediments in the Dredge Area is proposed to assess the distribution and variability of contaminant concentrations and compare the concentrations of COPCs to Screening Level values in the NAGD (Commonwealth of Australia 2009). The primary use of the sediment data will be to characterise the contaminant status of sediment and assist in the selection of disposal options. The new data, together with limited historic data (where current and appropriate), will be used to classify the sediments in a single dredge management unit, or if required, assess several distinct dredge management units.

1 Introduction

This SAP presents the methodologies to be employed during the investigation and covers the following aspects:

- Objectives;
- Brief description of proposed dredging program;
- Summary of historic data and existing information from previous studies (Appendix A; URS 2009a);
- Identification of contaminants of potential concern (COPCs);
- Identification of potential data gaps;
- Rationale for the proposed sampling design; and
- Scope of work including assessment methodology.

Field Methods and Procedures:

- Occupational Health and Safety (OH&S);
- Sampling contingency plan (adverse weather and equipment failure);
- Surveying;
- Documentation of field activities;
- Chain of custody (CoC) protocols;
- Equipment decontamination; and
- Field QA/QC samples.

Laboratory Analytical Program:

- Analytical testing laboratories;
- Analytical testing program;
- Sample handling, preservation and storage; and
- Analytical QA/QC and data validation.

It should be noted that not all field activities listed above will necessarily be included in the scope of works, however they are included to cover possible modifications or extensions to the proposed sampling program.

1.2 Objectives

Investigations to support the capital dredging program at the Dredge Area approximately 12 km west off the coast of Onslow have the following objectives:

- Complete a field and analytical program of sediment proposed for dredging in accordance with guidance provided in the National Assessment Guidelines for Dredging (NAGD) (Commonwealth of Australia 2009);
- Determine whether the quality and quantity of (previous and current) data gathered are sufficient to adequately characterise the contamination status of the sediments to assess disposal options; and
- Classify the sediment as acceptable, or otherwise for unconfined disposal at the proposed offshore disposal area.

An additional objective of this SAP is to collect samples to assess physical sediment properties to be used in modelling to predict sediment behaviour in dredge and disposal plumes.

This document comprises a review of existing information, and documents for the proposed sampling and analytical procedures in accordance with the NAGD (Commonwealth of Australia 2009). The purpose of this SAP is to describe the location and number of seafloor sediment samples, the

1 Introduction

sampling methodology, analytical and sample transport procedures to confirm the chemical characteristics of the sediments proposed to be dredged in the Dredge Area and the surface sediments at the proposed offshore disposal site.

2

Background

2.1 Proposed Dredging in Wheatstone Dredge Area

Capital dredging of sediments as part of construction of the Ashburton North Strategic Industrial Area (SIA) is the principal focus of this SAP. As part of the proposal, capital dredging of marine sediments is required to enable vessel access via a shipping channel and a turning basin.

The current bathymetry was compared against initial dredging estimates and design depths in order to determine the location, volume and depth of sediment to be dredged in the Dredge Area (Main Access Channel and Turning Basin). The design depth for the main access channel, the turning basin, the LNG and condensate jetty and the materials offloading facility (MOF) is up to 15 m below lowest astronomical tide (LAT), for the purposes of permitting. This does not necessarily reflect the final depths of all marine infrastructure.

The indicative area proposed for dredging is shown below (Figure 1) and estimated dredge volumes for capital dredging works are summarised (Table 1).

The indicative total *in situ* gross volume of sediment expected to be dredged in the MOF the main access channel and in the Turning Basin is 45,000,000 m^3 over an area of 11,500,000 m^2. It is proposed that the unconsolidated sediments will be disposed of at one of the five dredge material disposal grounds (Sites A – E).

Dredge volumes were calculated based on 1.25 m below development depth for tolerances and advanced maintenance dredging.

A combination of hopper and cutter suction dredge (CSD) will be used for all capital dredging in the MOF, main access channel and in the turning basin.

2 Background

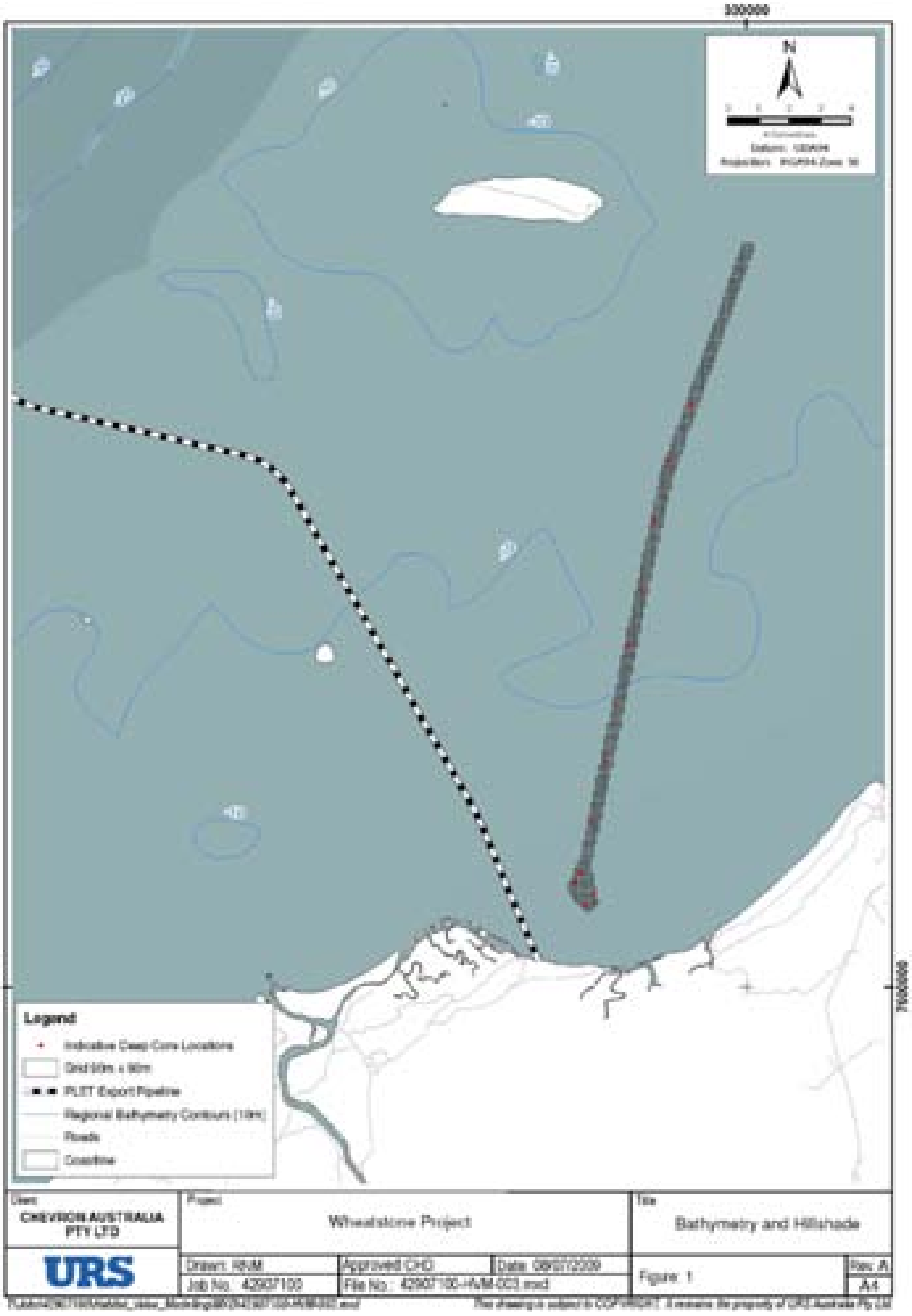


Figure 1: Proposed Dredge Area and deep core sampling locations.

Table 1: Wheatstone Dredge Area and dredge volumes.

Dredge Area	Total for Area
Temporary access channel	935 000
MOF areas	1 580 000
PLF areas	16 445 000
PLF Approach	20 160 000
Total Capital Dredge volume	39 120 000
Design uncertainties	5 880 000
Estimated total Capital Dredge volume	45 000 000

NB: all measurements are to LAT.

2.2 Project Area

Ashburton North is located to the east of the Ashburton River mouth and approximately 12 km southwest of Onslow in the Pilbara region of northwest Western Australia. The project area is largely undeveloped with the exception of a small boat harbour at Beadon Creek, a solar salt field with offshore loadout facilities to the west of Onslow, and the Roller oilfield in shallow coastal waters west of Onslow.

Solar salt fields are Onslow's newest industry, with Onslow Salt capable of producing 2.5 million tonnes of sodium chloride per annum. The project has handling facilities to transport, process store and load salt into ships for export. The offloading jetty is approximately 1.3 km long, situated off Sunset Beach (Shire of Ashburton 2009).

Western Australian Petroleum Pty Ltd developed the Roller oilfield around 20 km west of Onslow. The development consists of four monopod structures (Roller A, B, C and D), connected by pipelines to a gas separating plant located on Thevenard Island (Environmental Protection Agency 1991).

2.3 Environmental Setting

Dredging is proposed in shallow (<15 m), nearshore areas to the north of the mouth of the Ashburton River and Onslow town (Figure 1). The seafloor in this area is generally comprised of unconsolidated silt, sand and gravel, with patchy areas of macroalgae, seagrass, sponges, ascidians and hard and soft coral (P. Everson 2009, pers. comm., 25th June). The regional geology consists of Quaternary sedimentary, alluvial, shoreline and aeolian deposits (Department of Mines 1979).

The movement of contaminants associated with surficial sediments and resuspended fine particulates in shallow aquatic environments may be influenced by vessel movements, tidal movement and seasonal meteorological effects. Wind resuspension during extreme weather events (i.e. cyclones) is likely to contribute to the sporadic and efficient dispersal of particulate-bound contaminants on the inner continental shelf environment off the Ashburton River mouth, in particular in the less protected offshore area (Heyward et el. 2006).

The significance of erosion and sediment resuspension and transport as a result of cyclone-activity in tropical nearshore and inner shelf sediments on the Great Barrier Reef has been demonstrated by Gagan *et al*. (1988; 1990). Tropical storms and cyclones have shown to produce graded storm layers in sediments extending up to 30 km offshore in water up to 43 m deep, with extensive sediment transport as a result of the storm-induced high wave energy. Erosion depths of >6.9 cm were observed by Gagan *et al*. (1990), suggesting that tropical cyclones are capable of sporadic but efficient cross-shelf transport of suspended sediments and associated contaminants. The implications of this for subsurface sedimentary profiles in the Dredge Area are that on a shallow cyclone-prone shelf, such as the North West Shelf (NWS), suspended sediment may easily be exchanged between adjacent sedimentary facies. In ancient shelf sequences, the transport history of fine-grained sediments (muds) may be complex, and stratigraphically equivalent facies may have similar mud types but completely different sands. Similarly, high current energy may also result in physical resuspension of surficial sediments and transport of fine particulates to water depths >80 m, as observed on the middle shelf adjacent to Sydney (Matthai *et al*. 2002).

2.3.1 Bathymetry

The marine environment in which the Dredge Area is situated extends from the upper intertidal zone at the mainland, through to depths of 200 m, encompassing the upper part of the continental slope and the nearshore component of the continental shelf. The gas fields occur in water depths of between 70 and 200 m and the planned submarine pipeline (Figure 1) will traverse the upper slope of the continental shelf at water depths of between 50 and 100 m, before crossing the nearshore shelf to a shore crossing at the mainland. The nearshore shelf is shallow and has a variable topography that includes flat submarine plains and many small sea-mounts and islands, supporting a varied abundance of reef habitat.

2.3.2 Intertidal, Nearshore and Deepwater Habitats

The intertidal habitats at Ashburton North and surrounds comprise sandy beaches and clayey estuarine sediments. Preliminary field investigations of these habitats of Ashburton North indicate a low diversity of infauna species and an absence of rare or protected species. The sandy beaches with low diversity and productivity levels are representative of the Pilbara coastline (B. Wilson 2008, pers. comm., 21st November).

Many of the nearshore islands are surrounded by shallow intertidal platforms (e.g. Thevenard Island). These are sand veneered and primarily support macroalgae and scattered ephemeral seagrass species. Limestone pavement is exposed at Onslow near Beadon Point and in other places along the coast. Many of the fringing coral reefs in the area are likely to be exposed for short periods at low spring tide.

The nearshore area is defined as the marine environment from the low water mark to the 20 metre bathymetric contour. The broad area is recorded as having high diversity of infauna from intertidal mudflats and sandflats associated with fringing mangals in bays and lagoons. Due to the highly turbid water from the suspended sediments associated with large tidal range and infrequent cyclonic activity, the nearshore area lacks significant benthic primary producer habitat (Commonwealth of Australia 2006). A Department of Environment, Water Heritage and the Arts (DEWHA) database search resulted in three small seagrass patches on the eastern side of Thevenard Island. Coral communities are known to occur in localised areas, such as Ashburton Island and Ward Reef, approximately 5 km from the coast.

The Petroleum Titles are located 145 km offshore from the mainland (approximately 100 km north of Barrow Island) in water depths of around 200 m, which is the outer part of the NWS. The deepwater environment is defined as the offshore marine environment from the 20 metre bathymetric contour.

The ocean in this region is recorded as having diverse benthic invertebrate communities and fish fauna. These water depths are below the photic zone and therefore preclude the presence of benthic primary producers. Demersal and benthic fish communities are likely to be present (Commonwealth of Australia 2006).

2.3.3 Climate

The climate in this region is arid-tropical, with high summer temperatures, and large spatial and inter-annual variability in rainfall. Annual rainfall effectively varies from zero to 1,000 mm, although average rainfall is 200–350 mm. Rainfall occurs mainly from December to March, although there is some winter rainfall in the south-western parts of the region. Winds are predominantly south to south-westerly from September to February, light and variable over March and April, and from the east and south during May to August. Continental heating and cooling causes strong sea breezes in the summer and land breezes in winter (Black *et al.* 1994). The region is also subject to cyclones between November and April. On average, 2.5 cyclones a year occur within the region (Lourensz 1981), bringing heavy rains and strong winds. The cyclones originate in the Timor Sea and are unpredictable in their path, but typically travel parallel to the coast and, in two out of three cases, cross the coast and travel inland. The extreme winds associated with tropical cyclones generate waves exceeding 20 m, storm surges exceeding 6 m and currents of up to 6 knots, causing direct damage to the marine environment, and representing a risk of indirect damage due to contaminant release from coastal and offshore facilities (D.A. Lord and Associates 2002).

The average annual maximum and minimum temperature for Onslow is 31.3^{0}C and 18.1^{0}C, respectively, and the area receives low, but variable annual rainfall, with an average of 275 mm per annum (Bureau of Meteorology 2009). The area is subject to episodic rainfall events, especially during cyclones which occur at a frequency of three to four per year within the Pilbara region. Tidal range in the region is approximately 3 m (Bureau of Meteorology 2009).

2.3.4 Geology and Geomorphology

The basement rocks in the NWS region are granitic and volcanic rocks of Precambrian age (2,700–3,300 million years [ma]). These rocks are overlain to the west by Phanerozoic sediments (70–300 ma) of the Canning basin that also extend offshore and contain the petroleum reserves being exploited at present. At the coast, the Precambrian and Phanerozoic rocks are generally overlain by a veneer of predominantly limestone sediments deposited in the last 65 ma (Bird and Schwartz 1985).

Five major geomorphic elements can be distinguished for the NWS region:

- The coastal system, which has creek and bay lined mangroves backed by extensive tidal salt flats or by beaches and dunes that form a thick cover over limestone. The latter is often exposed to form limestone pavements in the intertidal or sub-tidal zones off beaches and islands, as well as forming reefs;
- The Ashburton River delta, which includes spits, tidal flats, distributary channels, and partly lithified dunes;
- The two coastal bays, Exmouth Gulf at the western end of the Shelf and Nickol Bay, flanked to the West by the Dampier Archipelago;
- The submarine shelf area. The inner shelf slopes gently to 20-m depths some 20 km offshore, except in the Barrow Island/Monte Bello area where the contour extends about 90 km offshore. It is underlain by limestone that outcrops as local limestone reefs and platforms, islands, cays and

shoals interspersed with a veneer of coarse and medium sands, gravels and locally with corals; and

- The Island Groups, which can be divided into three groups:
  1. Barrow and Muiron islands are the product of the folding of limestone;
  2. Thevenard and Airlie islands consist of predominately sandy deposits on a submarine limestone shelf; and
  3. Dampier Archipelago islands, some of which are comprised of rocks of Precambrian origin, and some of predominately limestone (D.A. Lord and Associates 2002).

At a regional scale, “coastal compartments” can be identified that are related to the regional geology, and secondarily related to coastal aspect and large coastal landforms such as deltas. Each compartment is comprised of a complex array of physical landforms and coastal processes in which the state of the environment is highly dynamic, varying over space and time. The primary compartment extends from Turbridgi Point to Cape Preston, encompassing the coast around Ashburton North.

Three distinct secondary compartments are discernable along this reach of coast, one of which is known as the Ashburton compartment and extends from Turbridgi Point, at the mouth of Exmouth Gulf, to Coolgra Point north-east of Onslow. This area is a single sediment cell extending over 70 km, and contains the active delta of the Ashburton River, long sandy beaches and dunes, and the island chains running approximately parallel to the shore. The western boundary of the compartment, a lithified chenier, marks a change from the west-north-west-facing shore of Exmouth Gulf to the north-north-west-facing coast of the Pilbara Region. There is also a change from the extensive saltflat, mudflat and tidal creek complex of eastern Exmouth Gulf to the partially lithified and unconsolidated sandy landscapes of the Ashburton compartment (Damara WA 2009).

Within the Ashburton compartment, the geomorphology changes with distance eastwards. Saltflats and mudflats increase in extent east of Beadon Point. Alongshore, the sandy beaches and dunes of the Ashburton compartment gradually give way to saltflats and mudflats associated with the active deltas of Robe River and Fortescue River, east of Coolgra Point. Offshore, the thin cover of sandy sediments over the pavement of the inner continental shelf appears to have been moved along and offshore to merge with the sandy shoals and islands abutting the Barrow Island ridge.

The function of the Ashburton compartment as a single sediment cell is especially relevant to marine and coastal management, because disruption of one part of the cell is highly likely to affect the stability of the coast downstream. A sediment cell is a reach of coast, including the nearshore terrestrial and marine environments, within which the movement of sediment is readily identifiable, if not largely self-contained (Komar 1996). Sediment cells are segments of the coast in which sediments derived from a common origin can be traced along transport paths to a sink, where they are temporarily or permanently lost to the coast. The Ashburton sediment cell has two sectors; the western shore between Tubridgi Point and the mouth of the Ashburton River, and the eastern shore from the river mouth to Coolgra Point. The net sediment movement within the cell is easterly, although reversible from time to time due to onshore winds. As a result, sediment in the western sector is largely sediment reworked by erosional processes and littoral drift along the shore. In contrast to this, sediment in the eastern sector is of fluvial origin and littorally reworked, as chenier spits migrating eastwards from the mouth of the Ashburton River.

Major sources of sediment in the eastern sector of the Ashburton compartment include:

- erosion of saltflats and mudflats by fluvial run-off and tidal creeks after flooding and tidal inundation;
- alluvial sediments discharged by the Ashburton River;
- erosion of dunes and rocky shores by nearshore processes; and
- bioproduction and reworking of material from the inner continental shelf.

The major transport path in the cell is along the shore, at the beachface, with much of the material being supplied as littoral drift along spits fed from the Ashburton River. There is also some evidence of sediment movement along slope breaks on the inner shelf and perhaps across the shelf pavement, although these are not as substantial as the littoral pathway. Sediment sinks include long chenier spits, coastal dunes and inshore shoals, as well as deposition on mudflats by tidal creeks (Damara WA 2009).

2.3.5 Oceanography

Currents are the most important oceanographic characteristic affecting the physical behaviour of contaminant inputs from human activities on the NWS. Currents (unlike waves) result in net water transport, and so affect the dilution and dispersion of water-borne contaminants. Currents are also important in the suspension and sorting of sediments and organic particulate matter.

Currents on the NWS are spatially and temporally variable, driven mainly by tides and wind stress and influenced by the complex bathymetry of the coast and around and between the islands (Osborne *et al* 2001a; 2001b). The tides are mainly semi-diurnal (i.e. undergoing two highs and two lows per day), and tidal range is large over much of the NWS, increasing in amplitude from south to north (e.g. spring tidal ranges of 2.5 m at Onslow, 4.5 m at Dampier and nearly 6 m at Port Hedland; Heywood *et al*. 2000).

In the NWS bioregion, wind stress, tides and bathymetry are also important, but there is the additional influence of the southwards-flowing Leeuwin Current and Indonesian throughflow. Tidal amplitude is still large in offshore waters, although smaller than in adjacent nearshore regions. Internal tides moving below the sea surface and up onto the shelf may also play an important role in transporting nutrients from the deep ocean to the surface.

An indication of typical current speeds at various NWS locations near oil/gas production facilities is provided by the following data (Buchan and Stroud 1993):

- Near Thevenard Island (15 m depth): mean current speed 5 m below sea surface of 0.28 m/s;
- Barrow Island (15 m depth): mean current speed of 0.42 m/s;
- Apache’s Harriet offshore production wells (near the Lowendal Islands, 22 m depth): mean current speed 7 m below sea surface of 0.23 m/s; and
- North Rankin production wells (offshore area, 124 m depth): mean current speed 13 m below surface of 0.21 m/s.

These current measurements indicate the presence of a high energy dispersive marine environment at water depths of <40 m.

2.3.6 Freshwater Discharge

Groundwater

Appleyard (2000) has estimated groundwater discharge to the NWS as 138,200 ML/yr, based upon a division of the coastline into six zones according to their aquifer characteristics:

1. North West Cape coast (90 km), discharge 14,000 ML/year;
2. Yanrey coast (140 km), discharge 16,000 ML/year;
3. Onslow coastal plain (170 km), discharge 21,000 ML/year (Dredge Area is located in this region);
4. Karratha coast (150 km), discharge 200 ML/year;
5. Port Hedland coastal plain (240 km), discharge 45,000 ML/year; and
6. South-western Canning Basin coast (70 km), discharge 42,000 ML/year.

Although the inter- and intra-annual variability of groundwater flow is probably considerable, no data on the variability of groundwater discharges are currently available.

Riverine runoff

Eleven major rivers with a combined catchment area of 171,490 km^2 discharge to the NWS (Ruprecht and Ivanescu 2000). River flow in the NWS region varies considerably due to the irregular nature of rainfall. The rivers on the NWS have little or no flow for most of the year, and many rivers dry up for at least part of the year. River flow mainly occurs from December to March (especially February). In northern Pilbara rivers there is little or no flow for nearly 50% of years. The interannual variability of river flow in southern Pilbara rivers is also considerable, as typified by data for the Ashburton River from 1973 and 1997: average annual flow was 440 GL, but less than 200 GL in eight years, and in one year reached 4,500 GL.

The Ashburton River is one of the largest rivers in the Pilbara, with a catchment area of approximately 78,777 km^2, and is the major feature of the Ashburton River Drainage Basin. The majority of the Ashburton River catchment area is undeveloped and covered by woodland, shrubby pasture and pasture (Department of Agriculture, Forestry and Fishing 2008). URS (2009b) indicates that the average annual flow of the Ashburton River is around 840,000 ML, although this is highly variable and dependent on rainfall.

During a year with “higher than average” flow, an estimated 5,100,000 tonnes of sediment would be deposited into the lower reaches of the Ashburton River, and the nearshore marine area. During an “average” flow year, deposition would be around 360,000 tonnes of sediment. Above-average flow events have become more common over recent years since the mid 1990s, occur roughly every three years. Sampling showed that particle sizes were generally small, with more than 90% of sediments classified as silts and clays (less than 0.063 mm diameter) (URS 2009b).

The significance of river discharge of fine sediments and nutrients to nearshore marine environments of the NWS is not well known. Flow velocities from the Ashburton River are likely to decline significantly over the river delta, due to the low gradients and open land surface. Due to the reduced stream velocity, sediment deposition will be maximised in this zone.

2.3.7 Marine Sediments

Much of the nearshore region adjacent to the Ashburton River mouth is covered by silt and sand sheets of varying thickness overlying Pleistocene limestone. Near areas of river discharge from the

Ashburton River, sediments are usually fine silts and clays with high silica content. Sediments become increasingly coarse and increase in calcium carbonate content with distance offshore, due to decreasing input of terrigenous silts and clays from river runoff and coastal erosion. Sediment re-suspension is frequent immediately seaward of the intertidal zone, and leads to considerable turbidity (Forde 1985). Resuspension is mainly due to wind-driven waves, whereas further offshore the sediment movement is a result of internal or subsurface waves (Heywood *et al*. 2000). Mainly coarse and medium-grained calcareous sandy sediments predominate to the 100 m depth contour, with a transition to continental slope muds around 100–150 m depth (Black *et al*. 1994).

2.4 Potential Contaminant Sources and Previous Investigations

On a regional scale, it is not possible to calculate the total loading of pollutants to the marine environment from industrial and domestic point sources on the NWS. Heyward *et al*. (2000) suggested that a regulatory government body, such as the Environmental Protection Authority (EPA), conduct a comprehensive inventory of contaminant inputs within the area of the NWS. There is a paucity of published literature directly relevant to the NWS, and a search of the bibliography of Jernakoff *et al*. (2006) reveals that of the 1,725 records, only 26 relate to chemistry. Only a further 15 are in the published literature. Due to the largely undeveloped nature of the Ashburton River catchment area and the Dredge Area, there are very few known sources of anthropogenic contaminants that can be identified. In addition, potential point sources of contamination to the Dredge Area are likely to result in a low level of contamination of surficial sediments, due to the highly dispersive nature of the NWS marine environment, and in particular due to the effects of cyclone activity on the resuspension and transport of sediments to water depths exceeding the depths of the Dredge Area (i.e. >13.5 m LAT).

Coastal issues related to domestic waste, such as sewage disposal, have been perceived as less significant in this region than elsewhere because of its low population density. However, recurring pollutants from diffuse sources in the region include heavy metals from antifoulants on shipping, harbour works, shore-based plants and cross-shelf pipelines. Several studies using local invertebrates, such as oysters and intertidal gastropods, have detected elevated levels of some metals (Heyward *et al*. 2006).

Sediment quality has been assessed in the vicinity of the Dredge Area on two previous occasions. In June 2005, marine sediments were sampled by the Department of Environment and Conservation (DEC) at four locations offshore of the mouth of the Ashburton River and at four locations offshore from Onslow to estimate the background concentrations for selected contaminants (Department of Environment and Conservation 2006). A primary assumption for this study was that no anthropogenic contamination had occurred in these areas, with sediments analysed for organotins, PAHs, Total Petroleum Hydrocarbons (TPH), BTEX compounds (benzene, toluene, ethylbenzene and xylene), organochlorine pesticides and Polychlorinated Biphenyls (PCBs), as well as total metals and metalloids (aluminium, arsenic, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, silver, vanadium and zinc) (Department of Environment and Conservation 2006). The results of this study confirmed that there was no discernible anthropogenic enrichment of contaminants in sediments offshore of the Ashburton River mouth or the town of Onslow. All concentrations of organotins, PAHs, TPH, BTEX compounds, OC pesticides and PCBs were reported as below the laboratory limit of reporting (LOR), although the LOR in that investigation exceeded the Australia and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) (2000) Screening Levels for some organic compounds. The DEC (2006) also estimated natural background concentrations of trace metals in marine sediments, noting that natural background concentrations of arsenic were above the ANZECC/ARMCANZ (2000) Screening Level. All other mean trace metal concentrations in sediments around the Ashburton River mouth and Onslow were below their relevant ANZECC/ARMCANZ (2000) Screening Levels (Department of Environment and Conservation 2006).

In February 2009, URS collected surface sediment samples for the Project at 17 nearshore sites in the vicinity of the proposed dredge area and at eight offshore sites around the proposed spoil disposal ground. Sediments were analysed for a suite of total trace metals (aluminium, arsenic, cadmium, chromium, copper, iron, manganese, mercury, nickel, lead, vanadium and zinc), TPH, BTEX compounds and TBT (Appendix A; URS 2009a). The results of this study agreed with those of the DEC (2006), with concentrations of TPH, BTEX compounds, TBT and trace metals being below the laboratory LOR or below the relevant NAGD Screening Levels (URS 2009a). Arsenic exceeded NAGD Screening Levels, which was also previously confirmed by the DEC (2006) investigation.

The concentrations of trace metals in whole sediments sampled in the pilot investigation (Appendix A; URS, 2009a) correlate strongly with the concentrations of aluminium, which is a proxy analyte for grainsize (i.e. clay mineral content) (Loring and Rantala 1992) (Figure 3; URS 2009a). Grain size is therefore likely to be the principal factor which determines the whole sediment concentrations of trace metals in these sediments and anthropogenic contributions in these sediments are not discernible. An exception is arsenic, which does not correlate strongly with aluminium (R^2=0.14; n=32; p>0.05) and which may be more strongly associated with the sediment sand fraction (>0.063 mm fraction) and the carboniferous and Fe-oxide sediment components (Davies 1979). Studies of the geochemistry and mobility of arsenic from sediments under different environmental conditions confirmed that large amounts of arsenic may be tightly bound to sediments due to iron/arsenic co-precipitation and the formation of insoluble precipitates at the water-sediment interface (Nikolaidis *et al*. 2004). Similarly, Devesa-Rey *et al*. (2008) found arsenic in sediments to be mainly associated with the least mobile fractions and bound to Fe-Al oxides and the residual mineral phase.

Once contaminants are introduced to the marine environment of the NWS they are subject to a range of physical, chemical and biological processes that influence their fate. A review of contaminant sources, impacts, pathways and effects on the NWS by Fandry *et al*. (2006) identified several contaminants of potential concern (COPCs) in the region, including:

- Trace metals (barium, cadmium, chromium, copper, lead, mercury and zinc), associated with shipment of minerals and runoff from onshore mining activities;
- Tributyltin (TBT), an antifouling constituent on ships;
- Nitrogen, a nutrient:
- A waste stream: Produced formation waters (PFW); and
- Hydrocarbons, associated with oil spills and chronic releases such as bilge and tank residues from ships.

As well as these identified COPCs, it was also considered conceivable that polycyclic aromatic hydrocarbons (PAHs) and organochlorine (OC) pesticides may have contaminated sediments via runoff from the Ashburton River (Department for the Environment, Water, Heritage and the Arts 2009). However, because of the undeveloped nature of the catchment and the sparse nature of farming activities, it was considered unlikely that these sources would make a substantial contribution to contaminant loads in offshore sediments on the NWS, in particular in the highly dispersive inner shelf environment (Department of Agriculture, Forestry and Fishing 2008).

2 Background

Significant dredging activity occurs in the NWS region, particularly in the major ports of Dampier and Port Hedland. During dredging operations, suspended sediment concentrations are very high for sustained periods. Monitoring suggests that the impact on existing adjacent macro-benthos communities is minimal, but there are no data to show the effects of suspended sediment on very small organisms and on new recruits such as juvenile corals. When synthetic olefin- and ester-based drilling muds are adopted for exploration purposes their effects will need to be studied, particularly in more sensitive areas. Little is known about the transport of cuttings on the NWS or about the implications for dispersion and degradation of the fluids (Heyward *et al*. 2006).

The effects of aromatic components of the Produced Formation Water (PFW) plume on the water column, and the fate of these compounds in the sea surface microlayer, given the high possibility of photo-oxidation, are not fully understood to date. The volume of PFW released will increase with the number and age of drilling platforms on the NWS. The fate and effects (if any) of the components other than hydrocarbons, including added chemicals such as corrosion inhibitors, are yet to be studied. Research will be required to determine the effects of chronic, low-level pollution loads on the NWS (Heyward *et al*. 2006).

2.4.1 Data Gaps

Due to the paucity of previous geochemical investigations in the offshore region adjacent to Onslow and the Ashburton River mouth, including the Dredge Area, there is an uncertainty of potentially elevated concentrations of organic and inorganic contaminants in sediments in this region. However, based on the available information and literature data and the dispersive nature of the NWS marine environment, an accumulation of contaminants in the sediments is unlikely. Naturally elevated concentrations of arsenic, and to a lesser degree nickel may occur in muddy areas adjacent to the Ashburton River mouth and in water depths greater than 40 m, where sporadic but efficient sediment resuspension due to cyclone activity and wave action is less likely.

The main limitations of the previous investigations highlight data gaps which can be summarised as follows:

- Lack of sufficient sampling density in URS (2009a) pilot investigation and limited sampling within the proposed dredge area;
- Insufficient geochemical data in sediments below 0.1 m depth;
- Sparse data for organic contaminant concentrations;
- Absence of available data for radionuclide activity (sum of gross alpha and gross beta) in sediments in the NWS region; and
- Lack of data regarding potential bioavailability of COPCs to marine organisms and the behaviour of sediment bound contaminants when material is disturbed, e.g. during dredging and disposal.

2 Background

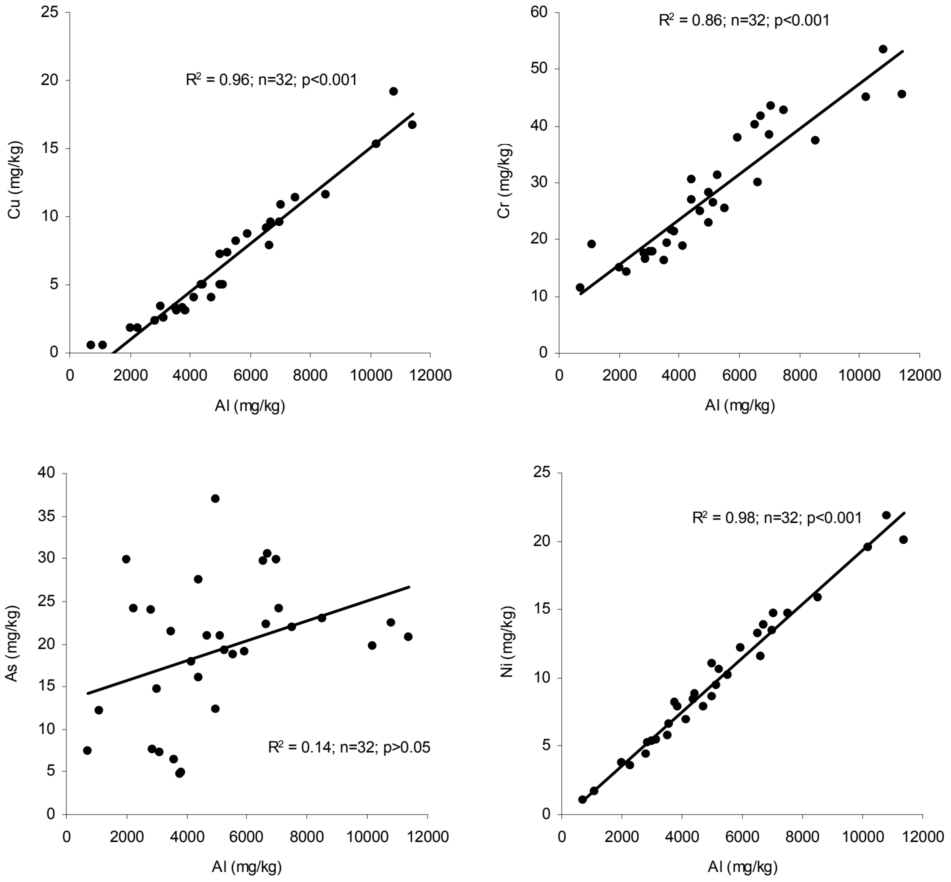


Figure 2: Trace metals and metalloids vs Al in sediments.

2 Background

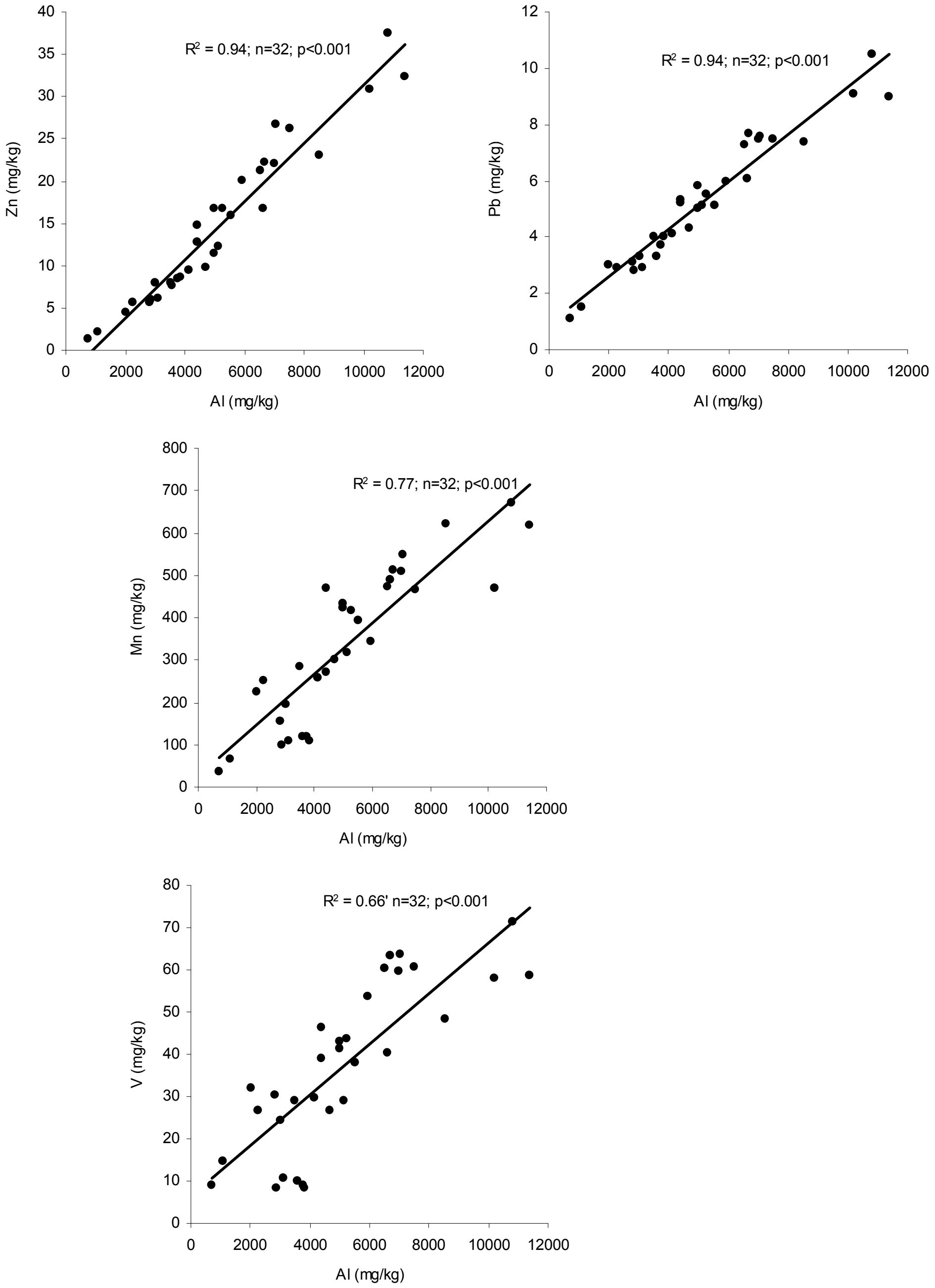


Figure 2: (cont'd): Trace metals and metalloids vs Al in sediments.

2.5 History of North West Shelf Development

A historical background to the NWS region has been provided by D.A Lord and Associates (2002). The Pilbara is the coastal province and hinterland to the NWS. It was first settled in the 1860s as pastoral land, and pastoral leases presently cover about a third of the region. There have been several gold rushes, and gold mining is still a viable industry today. Exploitation of the Pilbara's huge iron ore reserves commenced in 1960, and is serviced by export port facilities at Dampier, Cape Lambert (Port Walcott) and Port Hedland. Harvesting salt from seawater is also a major industry, established first at Karratha in 1972, and subsequently at Port Hedland and Onslow.

Oil was first found in the region in the Rough Range near Exmouth Gulf Station in 1953, and then at Barrow Island in 1964. Exploration and subsequent production grew exponentially from this time, with an overwhelming proportion of total production having taken place over the last 15 years. A third of Western Australia's oil production over the last thirty years has come from Barrow Island, another third from the Woodside Joint Venture's NWS Project, and the remainder from nine other projects. The equivalent production for natural gas has seen nearly 85% come from the NWS Project (Meaton 1999). The massive NWS reserves are accessed by three main operators: (1) Woodside Offshore Petroleum (mainly natural gas and liquefied natural gas); (2) West Australian Petroleum (WAPET) (oil) - now run by Chevron Australia Pty Ltd; and (3) BHP Petroleum (oil).

Other small but important industries to the NWS environment are commercial fishing; mainly prawning, some fin fishing, and increasingly, pearl shell aquaculture. National and international tourism based around marine attractions are also growing, particularly along the Onslow coast and within the Dampier Archipelago.

The population of the Pilbara is about 45,000 (Australian Natural Resources Atlas 2009), but was higher during the first (1976 and 1981) and second (1986 and 1991) phases of the NWS Project. Changes in employment patterns in the oil/gas industry (e.g. the adoption of 'fly in, fly out' policies for staff) have also affected population size.

Most of the population lives in the coastal towns of Port/South Hedland (13,300), Karratha (10,400), Roebourne (1,600), Wickham (1,500), Dampier (1,400), and Onslow (600) (Pilbara Development Commission 2001). The population is relatively young (over 30% between the ages of 25 and 40), and recreational activities centred around the marine environment (swimming, boating, diving and fishing) are very popular, particularly in the Dampier Archipelago (D.A. Lord and Associates 2002).

2.5.1 Contaminants from Land-based Activities

Land-based industries in the Pilbara region include construction, salt production, mining (mainly iron ore and gold), iron ore processing and petroleum products processing. The three most significant industrial activities on the coast are the salt production facilities at Dampier; the export facilities for iron ore at Dampier, Cape Lambert, and Port Hedland; and Woodside's gas processing facilities in Withnell Bay and supply base in King Bay on the Burrup Peninsula. There are also petroleum processing facilities on Thevenard Island, Airlie Island, Barrow Island, and Varanus Island (Figure 4; D.A. Lord and Associates 2002).

Major industry point source discharges from the land to the ocean are licensed by the environmental authorities, and include discharge from three outfalls at Hamersley Iron's Parker Point power station in Dampier (i.e. Dampier Salt: 3,800 ML/yr; Dampier domestic wastewater treatment plant: 50 ML/yr;

Woodside onshore treatment plant: 97.7 ML/yr; Hamersley Iron's Parker Point power station: ~90,000 ML/yr) (D.A. Lord and Associates 2002).

Airborne material carried offshore, particularly from materials stockpiles, may also be a source of contaminants to sediments in the Dredge Area, but this source has not been quantified and is likely to be insignificant due to the large area involved. Similarly, the Dampier wastewater treatment plant treats a very small volume of domestic sewage and is not considered a significant source of nutrients or contaminants to the offshore region. Contaminants discharged at levels above ANZECC/ARMCANZ (2000) guideline levels are copper (~150 µg/L) and zinc (~80 µg/L), but these concentrations would easily be diluted to below relevant guideline levels within the discharge mixing zone. The discharges from the other sources (i.e. outfalls at Hamersley Iron's Parker Point power station and domestic wastewater treatment plant in Dampier; Woodside onshore treatment plant; Hamersley Iron's Parker Point power station) are not considered to be relevant in the context of point source contributions to surficial sediments in the Dredge Area because of the large distance from these sources to the Dredge Area.

Fandry *et al*. (2006) identified that another potentially significant component of industrial wastewaters discharged into NWS waters is heavy metals. However, at all but Hamersley Iron Parker Point Power Stations, the reported annual loads are small and have decreased considerably over recent years. For example, at Woodside's onshore treatment plant at Withnell Bay, zinc discharges have decreased from 100 kg/yr in 1993 to 4.3 kg/yr in 2000. Discharges of copper have not exceeded 11 kg/yr (1995), while discharges of cadmium and lead were less than 5.5 kg/yr (1997) and 24.4 kg/yr (1995), respectively. In 2000 the discharge loads of copper and cadmium and lead were less than 0.8 kg/year, which is an insignificant input to the NWS offshore environment.

At the Parker Point sites in Dampier annual loads of cadmium, chromium, copper, lead and zinc ranged from 252 kg/yr for cadmium to 8,145 kg/yr for zinc. These are far higher than those at the other site and may be cause for concern, particularly for benthic habitats exposed to high concentrations of heavy metals that are likely to be accumulating in the bottom sediments. To determine the potential environmental impact, an investigation of heavy metals in sediments affected by the effluent discharges from the Parker Point Power Station was recommended by Fandry *et al*. (2006). However, this potential hot spot for heavy metals is more than 200 km from the proposed dredging area off the Ashburton River mouth and therefore unlikely to affect the concentrations of heavy metals in surficial sediments in the Dredge Area. Similarly, the accumulated levels of heavy metals in sediments around Woodside's onshore facilities at Withnell Bay and King Bay (Dampier) were also lower than the ANZECC/ARMCANZ (2000) Screening Levels, and are unlikely to contribute metals to sediments in the Dredge Area (Fandry *et al*. 2006).

At Hamersley Iron's Parker Point power station, the concentrations of metals in the discharge are low but the annual loads of cadmium, chromium, copper lead and zinc discharged are far larger than annual loads discharged from Woodsides' Offshore Treatment Plant. In 2000, estimated loads discharged from the Parker Point power station ranged from 252 kg/yr for chromium to 8,145 kg/yr for zinc, compared to loads from Woodsides' OTP of less than 0.8 kg/yr for cadmium, copper and lead, and less 5.5 kg/yr for zinc. Although the concentrations of metals in wastewater discharged at the Parker Point site are unlikely to cause adverse environmental effects, the loads are a cause for concern due to the potential for long-term trace metal accumulation in sediments. For this reason, an investigation of trace metals in sediments in the NWS region may be warranted, although the environmental effects, if any, are likely to be limited to the area in the vicinity of these sites.

2 Background

Potential environmental impacts associated with NWS port operations include those due to stockpiling (and associated airborne dispersion of particulates and surface runoff), loading spillages, and dredging (capital and maintenance).

There are no data on the environmental impacts of stockpiling, but given that the bulk of stockpiling is iron ore, with salt being the only other significant product, it is not expected that either of these cause pollution. Spillages while loading no doubt lead to contamination with iron particles in the vicinity of the loading jetties, but given the chemistry of iron in marine waters this is not considered likely to cause a significant environmental impact from a toxicological point of view (D.A. Lord and Associates 2002).

Dredging is not a direct source of contaminants, but can be an issue in terms of resuspension of contaminated sediment. Disposal of dredge spoil at sea may also temporarily introduce contaminants into the water column and into the sediments on a longer term basis. Ship movements can also cause redistribution of contaminated sediments due to propeller movements and associated resuspension of sediments.

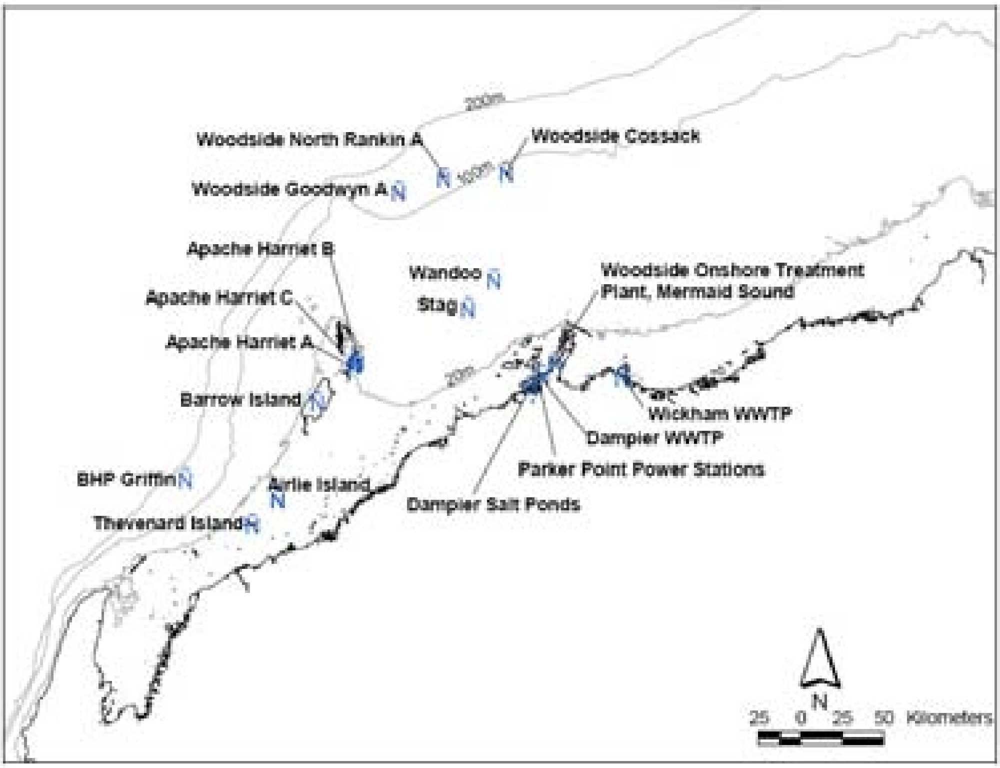


Figure 3: Locations of main anthropogenic sources of contaminants to the North West Shelf.

NB: ‘N’ is location of a sampling site.

2.5.2 Contaminants from Marine Based Activities

Contaminants which may potentially be contributed to the marine environment on the NWS from marine based activities include organic and inorganic contaminants from the oil and gas industry (i.e. drilling activities and production), shipping activities, commercial and recreational fishing activities aquaculture and tourism (D.A. Lord and Associates 2002).

Oil and Gas Industry

Exploitation of petroleum deposits on the NWS involves two principal activities; drilling (for both exploration and production), and oil/gas production from floating or fixed platforms. In addition there are a number of pipeline systems carrying product between platforms, or from platforms to offshore and onshore processing and/or shipping facilities.

Potential environmental effects from drilling are due to the dispersal of drilling fluids, drilling cuttings (mostly crushed rock), and to a much lesser extent onboard wastes (i.e. sewage and kitchen wastes). During the drilling process, drilling fluid is generally retained for re-use, with the cuttings separated out and discharged overboard, usually with some adherence of drilling fluid. Water-based drilling fluids are generally also discharged at intervals and/or at the end of the program.

Synthetic-based drilling fluids are expensive and so normally kept for reuse (URS 2001), although there is always some loss during the separation process from the drilling cuttings. The large majority of drilling fluids used on the NWS are water-based. Mixtures of drilling fluid and drilling cuttings are typically discharged from the bottom of a caisson, usually 10 m or more below sea level (or about 10 m above sea level in shallow waters). As the material falls to the seabed it splits into two downcurrent streams. One stream is the high density material which falls almost directly to the seafloor (most settling within 100 m of the drilling platform), and the other, estimated as approximately 5% of the solids, forms a visible turbid plume in the water column (D.A. Lord and Associates 2002).

Short-term environmental effects include physical processes such as burial, substrate modification, high turbidity and suspended solids loads on the seabed, and some exposure to chemicals of a potentially toxic nature. For exploration drilling, each well typically takes 7–30 days to complete (sometimes up to 75 days; URS 2001) depending on the target depth, depth of water, the difficulty of penetrating the geological formation and the amount of data required to assess the size of a discovery. For a series of development wells at a single production facility, drilling typically takes 12–18 months.

By 2002, approximately 300 wells, mostly for exploration purposes, had been drilled on the NWS (D.A. Lord and Associates 2002). An estimated 25 exploration wells are drilled for each successful production unit (Meaton 1999). Exploration wells are usually singular and widely dispersed. In contrast, development wells for production purposes are usually relatively small in number overall but at any individual production site there can be a significant number of wells, leading to a more concentrated environmental effect.

URS (2001) have reviewed the environmental findings of drilling programs at one site in Bass Strait, one in the Otway Basin, one in the Timor Sea and three on the NWS. URS (2001) concluded that:

- The main environmental effect of discharged drill cuttings is the temporary burial of seafloor organisms close to the well bore. The amount of drill cuttings produced during an exploration drilling programme is rarely more than 500 m^3 and does not normally result in a pile of drill cuttings on the sea floor except in shallow waters (i.e. <20 m). In deep waters (i.e. >50 m), cuttings are dispersed thinly across the seafloor. Where cuttings piles do form in shallow waters, they are usually redistributed by wave and current action within a 12 month period and recolonised by biota; and

- Water-based drilling fluids may be discharged into the marine environment because of their low toxicity to marine organisms. In general, synthetic-based drilling fluids exhibit low or no toxicity for water column organisms and moderate toxicity for sediment amphipods, but are rarely discharged because of their high cost.

D.A. Lord and Associates (2002) identified 28 fixed offshore platforms and three floating off-take vessels on the NWS. Except for small amounts of sewage, grey waste, deck drainage and cooling water, the main discharge from these production platforms is produced formation water (PFW). Although accidents at offshore production facilities can also result in oil spills, these have to date, been infrequent and small-scale on the NWS (e.g. 1,030 L of PFW were spilled in 1999, i.e. less than one tonne).

PFW comprises fossil water trapped in the petroleum-bearing rock, and injection water (seawater or formation water) used to increase production pressure. PWF usually contains elevated levels of some metals and petroleum hydrocarbons, naturally occurring radioactive materials (NORMs), suspended solids, organic acids and inorganic ions. It is also frequently has temperatures, salinities and dissolved oxygen concentrations that differ to ambient conditions. In addition, operational requirements may result in PFW including biosolids, corrosion inhibitors, emulsion inhibitors and-anti foaming agents (Swan *et al*. 1994).

PFW is normally separated from the oil/gas phase and then the primary oil stream is treated further to remove additional water which is added to the PFW stream. The PFW stream may also receive one or more additional treatments to remove oil and is then either re-injected back into reservoir, or discharged to the marine environment. Nine offshore production facilities have appreciable discharge of PFW, with concentrations of oil in water from 6-55 mg/L. The volume of PFW - and associated loads of oil - discharged from these facilities varied from about 65,000 m^3/yr to 6,020,000 m^3/yr, with corresponding oil volumes of 2.52 tonnes to 92.65 tonnes (D.A. Lord and Associates 2002).

The estimated load of oil to the NWS from PFW is about 214 tonnes/yr, which compares to an estimated 2-8 million tonnes of oil entering the marine environment worldwide each year: 45% from shipping; 38% from coastal, urban, municipal and river runoff; 8% from natural seepage; 6% from atmospheric fallout; and only 3% from offshore production (Minerals Council of Australia 1999).

Preliminary (and conservative) estimates based on available data indicate natural seeps on the NWS contribute at least 3,300 tonnes/yr (Fandry *et al*. 2006): for an oil/gas reservoir as large as the NWS, the contribution may conceivably be as high as those of the Californian, Alaskan and Gulf of Mexico reservoirs (i.e. 20,000–150,000 tonnes oil/yr). Available data thus indicate contributions from natural seeps far exceed the estimated contribution from PFW and the even lesser amounts discharged from occasional accidents at offshore facilities or from shipping operations (typically <1 tonne/yr).

Appropriately treated water-based PFW generally has a low to very low toxicity, and where there is attributable toxicity then this is often due to ammonia and sulphide, both of which are volatile and biodegradable, and therefore do not persist for extended periods in the environment (Swan *et al*. 1994). Few data on metal concentrations in NWS PFW are available, but data for the Harriet A, Airlie

Island and Cossack Pioneer facilities (Colman and West 2000) indicate that concentrations are either close to or below ANZEC/ARMCANZ (2000) guidelines for protection of 90% of species, or require little dilution to do so (e.g. 10-fold for most metals in Harriet A PFW, up to 50-fold for silver in Cossack Pioneer PFW, and 40–75 fold for copper in Airlie Island PFW). These dilutions would generally be achieved within the initial mixing zone of PFW discharge by the tidal and wind-driven currents. Adverse effects due to metal concentrations in PFW therefore appear unlikely.

To date there has been one comprehensive study of PFW on the NWS, at the Harriet A platform by Burns *et al*. (1999), and it provides a benchmark for similar studies. A combination of oceanographic techniques, geochemical tracer studies, chemical and biological assessment methods and dispersion modelling was used to describe the distribution and fate of the petroleum hydrocarbons and nutrients discharged in the PFW. Also, the Harriet A platform is in shallow water near the Lowendal Islands, and has one of the largest discharges of PFW, and so in relative terms has a higher potential for adverse environmental effects than many other facilities. Burns *et al*. (1999) determined that hydrocarbon uptake in oysters and inhibition of growth rates in natural marine bacterial and phytoplankton assemblages were confined to within 900 m of the discharge (corresponding to a PFW dilution of 1:5,000), with effects most apparent in the nearfield water column and in association with transient surface slicks. There were also measurable (albeit very low) levels of hydrocarbons in the sediments within 900 m of the discharge, but degradation and dissipation processes were fast enough to prevent any long-term buildup.

Shipping

The NWS region supports a number of significant ports and loading facilities which are managed by two Port Authorities; the Dampier Port Authority (DPA) and the Port Hedland Port Authority (PHPA). In 1998–1999 there were 2,231 shipping movements through Dampier Port and 616 through Port Hedland (D.A. Lord and Associates 2002). On a tonnages basis the two Ports shifted a total of 77% of exports for Western Australia in 1998–1999. The bulk of this export volume was iron ore (76% and 95% for Dampier Port and Port Hedland, respectively).

Shipping represents a potential source of contaminants from oil spills and from leaching of antifoulants (tributyltin – TBT) from hulls of vessels. The release of a large amount of bunker fuel is potentially more environmentally harmful than a similar volume from a NWS production facility, as the latter are typified by light oils that evaporate and degrade far more rapidly than heavy bunker fuels.

On a global basis the worst oil spills have been due to accidents at offshore wells, but these are less frequent than environmental disasters due to oil tanker accidents (Swan *et al*. 1994). The NWS has, however, experienced no major oil spills from either type of accident, nor have there been any major shipping accidents over the last 18 years (D.A. Lord and Associates 2002). The Australia Maritime Safety Authority database for the NWS region (to 2002) reports 44 minor spills from shipping operations, three from exploration activities, none from shore-based activities and 10 other reported spills or sheens reported. These spills ranged in size from 5 L to 30,000 L, with over 70% of spills less than 1,000 L (i.e. less than 1 tonne).

Commercial Fisheries

Significant commercial fisheries exist within the NWS region including the Onslow Prawn Managed Fishery, Nickol Bay Prawn Managed Fishery, Northern Demersal Scalefish Interim Managed Fishery, Pilbara Demersal Finfish Fishery and the North Coast Shark Fishery (Department of Fisheries 2000).

The main environmental impact associated with commercial fishing is habitat damage during trawling. Outside of the potential risk from the spillage of fuel while refuelling or due to boating accidents, commercial fishing activity is not considered a major source of contaminants. Some commercial vessels may exceed 25 m in length and therefore use TBT antifoulants. Smaller boats are likely to be using copper-based antifoulants. Contamination of sediments with TBT and copper is likely in areas where commercial fishing boats are moored (e.g. Beadon Creek port, Onslow) (D.A. Lord and Associates 2002).

Recreational Fishing and Aquaculture

In recent years the Pilbara has experienced significant growth in recreational fishing activity. Western Australia is also gaining an international reputation for the quality of its offshore pelagic sport and game fishing with the Dampier Classic fishing tournament being a State and national attraction. As for commercial fishing, recreational fishing activity is not considered a significant source of toxicants. There is likely to be some build up of metals in areas where boats are moored for long periods (e.g. the Hampton Harbour Boat and Sailing Club marina in Hampton Harbour).

Pearl oyster aquaculture—based on the production of pearls from the species *Pinctada maxima* - is the only form of aquaculture undertaken on the NWS at present. There are 13 lease sites in Exmouth Gulf, with an additional 14 sites between Onslow and Port Hedland (Department of Fisheries 2000). The oysters feed on naturally present plankton, and so there are no likely sources of contaminants from this activity, although there would be deposition of faecal material to the seabed beneath the aquaculture sites. The potential for nutrient build-up in sediments due to faecal material is considered low, but has not been studied on the NWS.

2.5.3 Recreation/Tourism

Recreational fishing, boating, diving and wildlife observation are popular activities with NWS residents, and are largely focused around the Montebello and Dampier Archipelago areas (Osborne *et al*. 2001a; 2001b). Pilbara coastal towns have the highest rate of boat ownership in the State, with over 1,200 boats registered in Karratha and Dampier alone. There was also an estimated 222,000 visitors to the Pilbara region in 1996, with the Dampier Archipelago and sections of the coastline being significant tourist attractions (Pilbara Development Commission 2001). These activities are not considered to be significant sources of contaminants, although there are other environmental degradation issues such as littering and habitat damage (D.A. Lord and Associates 2002).

2.6 Contaminants of Potential Concern on the North West Shelf

The following sections provide a brief outline of the contaminants which may potentially pose an environmental concern in relation to contributions to the offshore environment on the NSW.

2.6.1 Nutrients

Nutrient Dynamics

Nitrogen is generally the nutrient that limits the primary production of marine waters. Excessive nitrogen inputs to coastal environments can cause significant ecological changes (Windom 1992; Gijzen and Mulder 2001) such as seagrass or coral loss, and ‘blooms’ of nuisance species of phytoplankton. Such impacts are, however, typically due to the discharge of domestic sewerage from large urban settlements, large volumes of nutrient-rich industrial effluent, or nutrient-rich catchment runoff from fertilised agricultural land. None of these scenarios presently applies to the NWS and the Dredge Area. Estimates of the nutrient loads to the NWS from river runoff have been made by the Water and Rivers Commission and were reported by D.A. Lord and Associates (2002). The estimated nutrient load from the Ashburton River to the offshore environment is 172 tonnes/yr of nitrogen and 26 tonnes/yr of phosphorus, although these estimates may be an order of magnitude higher or lower, depending on the annual river flow, which in itself is highly variable between years (D.A. Lord and Associates 2002).

Within the NWS region there are four types of licensed point source discharge that contribute nutrients to the marine environment:

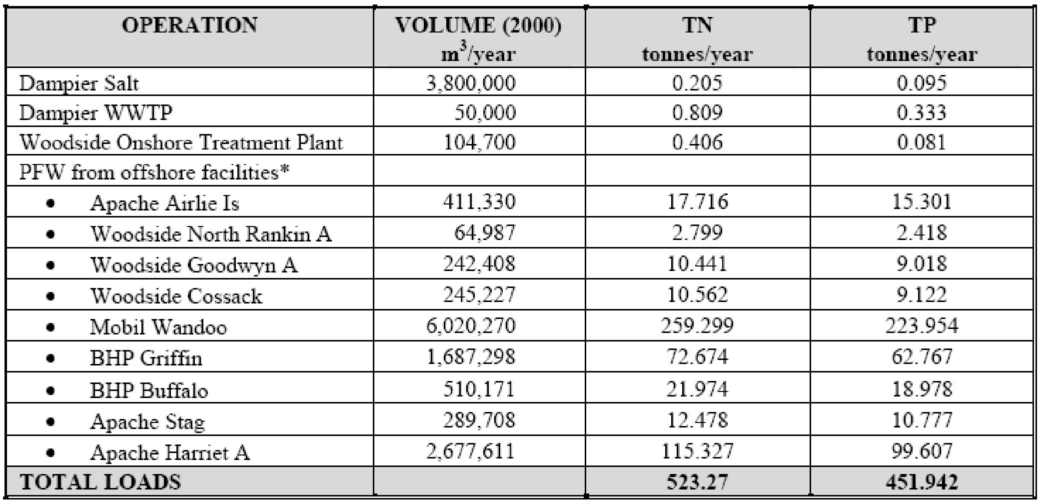
- Produced Formation water (PFW) discharges from offshore production platforms;
- A small sewage treatment plant at Dampier;
- The Woodside Onshore treatment processing Plant on the Burrup Peninsula; and
- Dampier Salt.

However, these point sources are too distant from the Dredge Area to have a potential effect on the concentrations of nutrients in surficial sediments in the Dredge Area. Estimated nutrient inputs from major point sources are shown in Table 2. The list of offshore facilities is relatively short, as some facilities process material from several oil/gas fields, while some large oil/gas production fields, such as Barrow Island and Saladin, re-inject PFW back into the reservoir rather than discharging to the ocean.

Holloway *et al.* (1985) estimated the oceanic exchange for the NWS area from semi-diurnal tidal flow and low frequency advective upwelling events, which contribute equally to an input of 12.5 kg N/day per metre of NWS front. This results in an estimated total nitrogen load across the 550 km of the NWS front of 2,509,000 tonne/year, which compares to about 523 tonnes of total nitrogen from offshore drill operations (Table 2; D.A. Lord & Associates 2002). Holloway *et al.* (1985) further estimated that a typical cyclone could entrain nitrogen onto the Shelf at 140 kg N per metre of shelf. Assuming 2.5 such cyclones a year, this mechanism equates to a nitrogen input of about 190 tonnes/year. Advective upwelling is therefore a principal source of nutrients (total nitrogen) to sediments on the NWS and substantially more important than anthropogenic contributions from oil production activities.

2 Background

Table 2: Total nitrogen and phosphorus loads from major point sources on the North West Shelf.



OPERATION	VOLUME (2000) m^3/year	TN tonnes/year	TP tonnes/year
Dampier Salt	3,800,000	0.205	0.095
Dampier WWTP	50,000	0.809	0.333
Woodside Onshore Treatment Plant	104,700	0.406	0.081
PFW from offshore facilities*			
• Apache Airlie Is	411,330	17.716	15.301
• Woodside North Rankin A	64,987	2.799	2.418
• Woodside Goodwyn A	242,408	10.441	9.018
• Woodside Cossack	245,227	10.562	9.122
• Mobil Wandoo	6,020,270	259.299	223.954
• BHP Griffin	1,687,298	72.674	62.767
• BHP Buffalo	510,171	21.974	18.978
• Apache Stag	289,708	12.478	10.777
• Apache Harriet A	2,677,611	115.327	99.607
TOTAL LOADS		**523.27**	**451.942**

* *Loads for all facilities calculated using NH_4 and PO_4 concentrations for Harriet A PFW reported in Apache's Varanus Island Hub 1999 Annual Report to the DEP.*

Urban areas

Municipal wastewater treatment plants (WWTPs), urban stormwater runoff and groundwater can discharge nutrients and toxic substances (metals, hydrocarbons, herbicides, pesticides) to nearshore waters, but Pilbara coastal settlements are not considered major sources (D.A. Lord and Associates 2002).

The only domestic wastewater treatment plant discharging to the coast is a small system at Dampier and all other treatment plants have land disposal through irrigation (due to the prevailing need to recycle water wherever possible) or evaporation. Stormwater runoff is unlikely to be a significant source of nutrients and metals due to a combination of factors. The urban population centres are relatively small, rainfall is sporadic and generally sparse, and stormwater drains are not channelled to the ocean (due to the first two of these factors, groundwater beneath urban centres is also unlikely to be significant source of nutrients and contaminants).

Runoff is likely to be limited to the very small area surrounding the point of discharge, as the water needs to cross the extensive tidal salt flats that typify the NWS. Otherwise, stormwater drains are structured to discharge to local drainage systems where it is likely that runoff is absorbed well before reaching the sea. Although some short-term accumulation of metals in sediments may occur, this is probably rapidly dispersed and diluted with the next flood event.

Agriculture

Pastoral leases cover about a third of the NWS region's hinterland land mass and are mainly for grazing cattle, with some sheep grazing on the coastal plain. The pastoral industry operates with unimproved pasture (i.e. no addition of fertiliser, pesticides or herbicides). The only likely source of nutrients will be the export of those occurring naturally with catchment runoff or leached through to the groundwater. The only likely source of contaminants is drenching sites, which are usually in close proximity to stock yards. Given the relative scale of such operations this is considered unlikely to be a significant source of contaminants.

2.6.2 Organic Contaminants

Concentrations of organochlorine pesticides (OCPs) in sediment are generally much higher than in water because these compounds readily partition from water onto particulate material, depending on the organic matter content of the sediment (Connell *et al*. 2002). A substantial amount of early work on OCPs in Australian aquatic environments has been conducted around sewage outfalls in the Sydney area (e.g. Thompson *et al*. 1992; Richardson 1996; Lincoln, Smith and Mann 1989a; 1989b). High concentrations of HCB were found in sediment (mean, 871 µg/kg) offshore from the Malabar deepwater ocean outfall, which contains the greatest proportion of industrial waste (Mortimer and Connell 1995). These do not appear to originate from pesticide usage, but rather historical manufacture of carbon tetrachloride and long-term storage of these historical wastes which contain HCB at Botany Bay, Sydney.

An indication of the decline in pesticide concentrations in marine and estuarine urban areas in Australia since the peak usage period of POPs in the mid-1970s is shown through the overall decrease in the maximum concentrations of OCPs in Brisbane River water and sediment between 1972 and 1987, which is consistent with the usage patterns for these compounds in the Australian environment (Connell *et al*. 2002). However, concentrations of OCPs and other POPs in sediments in high hydrodynamic energy areas and in shallow aquatic environments, particularly in urban areas, may be affected by resuspension events, such as storms, which can transport surficial sediments and result in a reworking and resurfacing of material at different concentrations from an earlier period. Thus the concentrations of POPs in sediment in urban areas may still be relatively high in some locations (e.g. Taylor *et al*. 2004).

Mueller *et al*. (1999) determined the concentrations of 2,3,7,8-chlorine-substituted PCDDs, PCDFs, selected PCB congeners and HCB in sediments from sites along the east coast of Queensland. PCDDs were detectable in all sediment samples while PCDFs, PCBs and HCB were mainly found in sediments from sites in the Brisbane metropolitan area, suggesting that an unidentified source for higher chlorinated PCDDs exists along the Queensland coast, which was confirmed by regional assessments of marine sediments by Gaus *et al*. (2001).

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous organic environmental contaminants that form during the incomplete combustion of organic matter. High temperature combustion sources result in a distinct assemblage of unbranched PAH compounds that are dominated by 4-6 ring structures (McCready *et al*. 2000) and these high temperature combustion PAH profiles have been observed in sediments at locations that are remote from urban and industrial activities. Bushfires are a natural source of PAHs, however, anthropogenic sources can also affect remote catchments due to aerial deposition of fine ash particles, which, in turn, may be transported long distances in water. PAH-laden particles in sediments (regardless of source) have the potential to cause adverse effects upon sediment-ingesting benthic species and demersal fish.

Organic contaminants in sediments within the Dredge Area, if present, are likely to be limited to fine grained sediments accumulating in lower energy areas. However, to date there has been no evidence that organic contaminants are likely to pose an environmental risk in the Dredge Area or in the adjacent marine areas on the NWS.

2.6.3 Tributyltin

There is marginal keel clearance for large ships in the dredged shipping channels leading into Port Hedland and through Mermaid Sound into Dampier, which increases both the likelihood of antifoulants (including TBT) contaminating shipping channel sediments and the redistribution of contaminated sediments by propeller wash.

The predominant contaminant of concern in ports is the antifoulant tributyltin (TBT), which is toxic to a wide range of marine organisms at low concentrations. Crawley (2000) estimated the potential loading of TBT from shipping to the ports of Cape Lambert, Port Hedland and Dampier as 1.3 kg/day, 3.3 kg/day and 4.8 kg/day, respectively, which represented a potential environmental concern. Hull cleaning is also a potential source of TBT and although there are presently no land-based hull cleaning facilities for large vessels in the NWS region, 'in-water' hull cleaning would also occur and contribute TBT.

The need for effective antifoulants, which prevent the settlement and growth of marine organisms on submerged structures, such as buoys, fish cages and ship's hulls, is recognised universally (Evans, Tsvetnenko & Woodworth 2000; Konstantinou and Albanis 2004). For many years, TBT compounds were the most widely used active ingredients in paint formulations. However, use of TBT has been regulated internationally since 1990 due to its severe impact on the aquatic ecosystem (Fent 1996) and the demonstrated effects of TBT on the disruption of the endocrine system by mimicking or inhibiting the action of gonadal steroid hormones, oestradiol and testosterone (Makita and Omura 2006).

Prolonged release of TBT from ship-bottom coatings has resulted in the imposition of male sexual characteristics upon female gastropods, or imposex, a phenomenon which was first described by Blaber (1970) in the United Kingdom. Imposex in marine gastropods has subsequently been linked to the exposure of these benthic biota to TBT in aquatic systems worldwide (e.g. Smith 1981a; 1981b; 1981c; Santos *et al*. 2004). This cause and effects relationship ultimately resulted in a global ban of TBT. The decline in the occurrence of imposex following worldwide bans has been used as a biomarker and biological indicator for environmental monitoring of TBT since the introductions of these bans in countries worldwide (Axiak *et al*. 2003). The ban on the use of TBT is primarily due to the adverse effects on the various shellfish, in particular the occurrence of imposex in aquatic biota (Foale 1993).

The use of TBT for antifouling was regulated from 1989 in Australia. TBT is banned from use on small vessels (i.e. less than 25 m in length) and is being phased out on larger and international vessels. However, despite the partial ban on the use of TBT in Australia, a survey of imposex in *Thais orbita* (Neogastropoda) along the NSW coast found imposex was still widespread 10 years after the introduction of the ban, in particular within harbour/bay areas, where contamination "hotspots" are still present and where physical remobilization and dispersion processes may be less pronounced compared to high-energy coastal areas (Gibson and Wilson 2003).

Australia is signatory to the *International Convention on the Control of Harmful Anti-fouling Systems on Ships* (International Maritime Organisation (IMO) 2001), which prohibits the use of harmful organotins in anti-fouling paints used on ships and which establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. Under the terms of the Convention, Parties to the Convention are required to prohibit and/or restrict the use of harmful anti-fouling systems on ships flying their flag, as well as ships not entitled to fly their flag but which operate under their authority and all ships that enter a port, shipyard or offshore terminal of a Party.

Ships of above 400 gross tonnage and above engaged in international voyages (excluding fixed or floating platforms, FSUs and FPSOs) will be required to undergo an initial survey before the ship is put into service or before the International Anti-fouling System Certificate is issued for the first time; and a survey when the anti-fouling systems are changed or replaced. Ships of 24 m or more in length but less than 400 gross tonnage engaged in international voyages (excluding fixed or floating platforms, FSUs and FPSOs) will have to carry a Declaration on Anti-fouling Systems signed by the owner or authorized agent.

The harmful environmental effects of organotin compounds were recognized by the IMO in 1989. In 1990 IMO's Marine Environment Protection Committee (MEPC) adopted a resolution which recommended that Governments adopt measures to eliminate the use of anti-fouling paint containing TBT on non-aluminium hulled vessels of less than 25 m in length and eliminate the use of anti-fouling paints with a leaching rate of more than 4 µg/d of TBT.

In November 1999, IMO adopted an Assembly resolution that called on the MEPC to develop an instrument, legally binding throughout the world, to address the harmful effects of anti-fouling systems used on ships. The resolution called for a global prohibition on the application of organotin compounds which act as biocides in anti-fouling systems on ships by 1 January 2003, and a complete prohibition by 1 January 2008.

By 1 January 2008 (effective date), ships either:

- shall not bear such compounds on their hulls or external parts or surfaces; or
- shall bear a coating that forms a barrier to such compounds leaching from the underlying non-compliant anti-fouling systems.

This applies to all ships (including fixed and floating platforms, floating storage units (FSUs), and Floating Production Storage and Offtake units (FPSOs).

Importantly, the presence of TBT is not necessarily linked to fine grained sediments (silt and mud) as TBT may occur in flakes that deposited in sandy areas.

The complex behaviour of TBT in the marine environment was illustrated by Reitsema and Spickett (1999), who surveyed TBT levels in water and biota at 18 sites along the coast of the Burrup Peninsula. They found TBT concentrations in water ranging from <0.3 to 25 ngSn/L, with 8 sites above the ANZECC/ARMCANZ (2000) guideline of 6 ngSn/L. TBT levels in the tropical neogastropods whelk, *Morula granulata*, ranged from <0.3 to 33 ngSn/g, and <0.3 to 80 ngSn/g in oysters. The highest concentration of TBT in water occurred at the site furthest from shipping activity, and high concentrations in water did not always correspond with high concentrations in biota. However, the degree of imposex in the whelk (which ranged from 0% to 57%) was correlated with distance to the nearest shipping activity, and so Reitsema and Spickett (1999) recommended its use as a bioindicator of TBT contamination.

2.6.4 Naturally Occurring Radioactive Materials (NORMs)

Naturally occurring radioactive materials (NORM) in PFW have long been a concern in the oil and gas industry (Hart *et al*. 1999). Production processes concentrate radium (Ra) isotopes in mineral scale inside production equipment, and this scale can build up over time (D.A. Lord and Associates 2002). Significantly elevated concentrations of ^{226}Ra/^{228}Ra eventuates in low specific activity (LSA) scale (Lysebo *et al*. 1999).

Exposure to these radium isotopes can result in the ingestion of alpha particles which have very low penetration but can cause significant cell damage over a short range (D.A. Lord and Associates 2002). Alpha particles also have an affinity for high-density tissue such as bone and will remain in the bone for a considerable time (D.A. Lord and Associates 2002). Other isotopes of the uranium and thorium decay series that may be present in PFW are ^{238}U, ^{232}Th, ^{235}U and the shorter lived daughter nuclides ^{222}Rn, ^{210}Po and ^{210}Pb (Szymczak 1999).

There are few data on the toxicity of LSA scale (Roddie *et al*. 1999), although there are data on the effects of low level radioactivity in general. On the NWS, the work of Colman and West (2000) for the Cossack-Pioneer offshore facility found PFW discharge was not causing any build-up of radionuclides in sediments around the facility. No other work on NORMS for the NWS is known at present.

2.7 Summary

After a preliminary evaluation of available literature information and in concordance with the NWS Joint Environmental Management Study (NWSJEMS) (Heywood *et al*. 2006), the following key contaminants may be considered to pose the highest risk to the environment in the NWS region:

- Trace metals (barium, cadmium, chromium, copper, lead, mercury and zinc);
- TBT;
- Nitrogen;
- Hydrocarbons (oil); and
- A waste stream: Produced Formation Water (PFW).

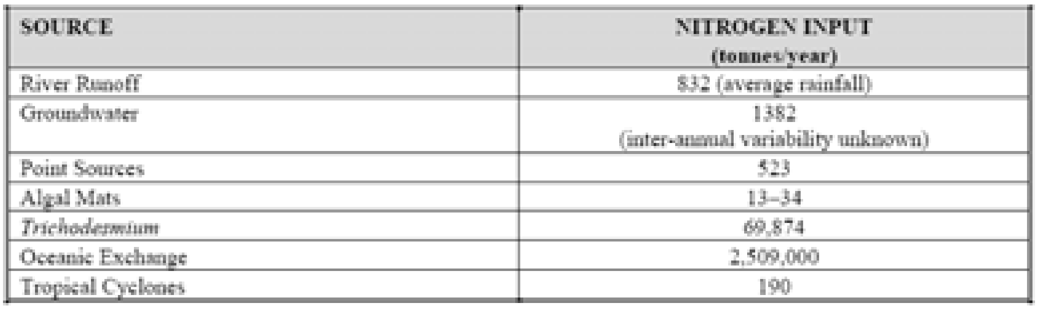
Additional contaminants of potential concern (COPC) may include aluminium (as a normalizing element and proxy for sediment grain size), nickel and arsenic (potential for natural enrichment in sediments).

Due to the dispersive and high energy nature of the receiving environment, the contributions of hydrocarbons, which have historically shown to be minor, to sediments within the Dredge Area are likely to be negligible and non-accumulating in surficial sediments. Similarly, the contributions of the PFW effluent stream would be limited to the vicinity of oil producing operations (i.e. within hundreds of metres) and are therefore highly unlikely to result in an accumulation of associated contaminants in sediments within the Dredge Area. In addition, anthropogenic nitrogen contributions from, for example, offshore PFW point source discharges, are likely to be minor compared to contributions from natural upwelling events, as has been suggested by D.A. Lord and Associates (2002) (Table 3).

Therefore the contaminants most likely to be of potential concern in sediments on the NWS and potentially within the Dredge Area, are the identified trace metals/metalloids arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel and zinc and the antifoulant TBT. Although the likelihood of concentrations of these contaminants to be present at concentrations that may pose an environmental and ecological risk in sediments in the Dredge Area is low, a Phase II investigation of sediments in accordance with the NAGD (Commonwealth of Australia 2009) may include these contaminants in the Contaminants List (Section 3).

2 Background

Table 3: Estimates of nutrient loads to the North West Shelf.



SOURCE	NITROGEN INPUT (tonnes/year)
River Runoff	832 (average rainfall)
Groundwater	1382 (inter-annual variability unknown)
Point Sources	523
Algal Mats	13–34
Trichodesmium	69,874
Oceanic Exchange	2,509,000
Tropical Cyclones	190

3

Rationale

The current Project Area requiring dredging may be subject to change (Figure 1). Recently deposited, surficial sediments proposed for dredging are the focus of the proposed sampling program in this SAP. The area proposed for dredging at the Ashburton North Strategic Industrial Area (SIA), approximately 12 km south-west of Onslow, has not been previously dredged and comprises the main navigational access channel, MOF and turning basin. The proposed activity therefore represents capital dredging of areas away from existing anthropogenic sources and potentially contaminating activities and disposal at sea.

The objective of the proposed sampling program is to assess sediment quality at sufficient locations to characterise representative concentrations of COPCs in sediment proposed for dredging. Insufficient data are available from previous sampling of marine sediments, including sediments in the Dredge Area, to adequately characterise the contaminant status of sediments. Therefore, a Phase II assessment is required following guidance provided in the NAGD.

For capital dredging, samples are needed from the full depth of contaminated as well as potentially contaminated sediment. Full depth is defined as at least the top 1 m of sediment, or more if contamination could be found deeper. The NAGD (Commonwealth of Australia 2009) states that “where a project involves capital dredging in a port or locality with existing contamination (e.g. one metre of contaminated or potentially contaminated sediment overlying 5 m of natural geological materials), rather than the total dredge volume, the number of sampling locations should be based on the volume of contaminated and potentially contaminated dredged material (which includes the three categories of ‘probably contaminated’, ‘suspect’ and ‘probably clean’).”

The number of sampling locations in the proposed sediment assessment has been based on the volume of the layer of recent sediments which *could* be contaminated, but does not include the volume of underlying natural geological materials which are, except for a thin boundary layer, expected to be uncontaminated. The upper 1 m of sediment is considered to be ‘probably contaminated’, whereas the sediments below a depth of 1 m are considered to be ‘probably clean’. A smaller number of deep cores penetrating to the depth of dredging will be collected to validate the assumption that the subsurface sediment is not contaminated.

A power analysis approach outlined in the NAGD is likely to result in collection of fewer samples, especially where the variance in the data is low, but requires pre-existing data on the chemistry of the sediments in the proposed dredge area (Commonwealth of Australia 2009).

It is proposed that surface sediments (up to 1.0 m depth; 0-0.5 m and 0.5-1.0 m depth intervals) will be sampled using percussion or vibro coring devices and analysed for total metals (aluminium, arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel and zinc), TBT and TOC (Contaminants List, Table 4). Subsurface, consolidated sediments and sediments deeper than 1 m below the sea floor will be sampled at fewer locations as part of geotechnical investigations to characterise the geological strata within the dredging area. Samples from these deep cores will be analysed for the same COPCs as the samples from the short (1 m cores) to determine natural background concentrations and confirm the uncontaminated status of these sediments.

Surface sediments will also be sampled at an offshore disposal ground (yet to be delineated) using a grab sampler, and analysed for the same COPCs as the short core sediment samples (i.e. metals, TBT, TOC).

The maximum area of proposed dredging is 11,500,000 m^2, with a total dredge volume of 45,000,000 m^3 (Figure 1). The volume potentially contaminated material at 1 m thickness is therefore

11,500,000 m^3 (i.e. the upper 1.0 m of sediment in the entire dredge area). As a result of the intermittent high wave energy and the frequent high current conditions, the net sediment deposition rate along the Pilbara coast is likely to be low (Dix 1989). Therefore the upper 1.0 m of the sedimentary profile is a conservative depth for the geochemical assessment of sediments which may potentially contain contributions from anthropogenic sources.

The NAGD (Commonwealth of Australia 2009) state that a minimum of 28 sampling locations are required to assess 468,000-509,000 m^3 of potentially contaminated material within a proposed dredge area, with the following equation to be used to determine the number of sampling locations at sites that exceed 500,000 m^3:

$$y = 0.025x + 15.547$$

where y is the number of sampling locations and x is the volume of dredge material (x 1,000 m^3) (Commonwealth of Australia 2009; p.60).

Assuming a volume of 11,500,000 m^3, the equation yields 303 sampling locations. The NAGD recommends that for large projects, where insufficient current information exists, a pilot study may be appropriate to determine the Contaminants List. In such a study, approximately 20% of the sampling locations required to characterise the sediments (randomly selected from the area to be dredged) would be analysed for all contaminants that are likely to be present, based on the site history (Commonwealth of Australia 2009). This SAP therefore proposes collection of 60 sampling locations (i.e. ~20% of 303 sampling locations) of surficial material. It is important to note that the thickness of sediment recovered at each short coring location will be dependent on the nature of the sediment, but is expected to be at least 1.0 m at most locations. No cores or cores shorter than 1.0 m may be retrieved in areas where rocky sediments are present alternative locations would be randomly selected to achieve a minimum number of sampling locations.

Should the mean concentrations of COPCs in sediments in the dredge area exceed one tenth of the Screening Level concentrations, these concentrations would be compared to background concentrations that are expected for sediments in the area. URS expects that arsenic and nickel may exceed one tenth of mean Screening Level concentrations. However, arsenic and nickel have shown to be naturally elevated in Australian marine sediments and concentrations of these two analytes would be compared to natural background levels for sediment of similar grainsize and adsorptive capacity. Further testing to assess the potential mobility of arsenic and nickel from sediments would also be undertaken via elutriate testing, if the concentrations of arsenic and nickel exceed one tenth of their respective Screening Levels in the proposed sediment investigation.

Elutriate tests involve the mixing of sediment with four times its volume of seawater under specified conditions, to estimate the amounts of contaminants that will be released during dredging and during sea disposal (Commonwealth of Australia 2009). Fandry *et al*. (2006) reported that the coastal waters of the NWS are generally of very high quality and that the concentrations of metals were low by world standards, with localised elevations of some metals adjacent to industrial centres and ports. Recommendations of this study were that ANZECC/ARMCANZ (2000) 99% species protection guidelines should be used to assess trace metals in this region. Elutriate test results would therefore be compared to the relevant ANZECC/ARMCANZ (2000) marine water quality trigger values for 99% protection, or subsequent updates to these values. If elutriate testing determined that the concentrations of one or more COPCs are likely to pose a risk to aquatic biota, further assessment of sediments at another 243 sampling locations (i.e. remaining 80% of locations) would be undertaken.

3 Rationale

Geochemical data from a previous pilot sampling program and analysis of sediments (Appendix A; URS 2009a) provide a preliminary indication of the sediment quality of surficial sediments in the Dredge Area, but only three samples were located within the proposed dredge footprint. The study indicates that low concentrations of COPCs are likely in sediments proposed for dredging. Sediment below 1 m depth is probably uncontaminated and unlikely to contain concentrations of COPCs that exceed NAGD Screening Levels, but this assumption would be tested and the entire thickness of sediment to be dredged would be assessed at a reduced number of deep core sampling locations.

In addition to collecting short cores of potentially contaminated material, sediments within the Dredge Area would be sampled and analysed to the maximum depth of dredging (13.5 m below LAT) at 12 sampling locations for all COPCs on the Contaminants List (except TBT) to test the assumption that underlying sediment is uncontaminated. If TBT were found in short cores, this analytes would be assessed in samples from deeper stratigraphic layers. The 12 proposed deep core locations are located in the nearshore southern end of the access channel and may not represent sediment proposed for dredging in the northern sections of the access channel.

In the unlikely event that concentrations of COPCs in sediment at depth were found to exceed NAGD Screening Levels, further sampling to characterise contaminant distribution to the full depth of dredging would be undertaken at additional deep core sampling locations.

In summary, sampling is proposed in order to:

- Undertake a detailed spatial assessment of sediment in the Dredge Area for NAGD Screening Level exceedances of COPCs (trace metals/metalloids and TBT) in the upper 1.0 m of sediment; and
- Undertake a representative assessment of probably clean sediment for NAGD Screening Level exceedances of analytes on the Contaminants List (except TBT) to the proposed depth of dredging (maximum 13.5 m below LAT) in the Dredge Area at 12 deep core sampling locations.

Phase II assessment of sediments within the Dredge Area are unlikely to trigger assessment of the bioavailability of sediment contaminants and their behaviour during dredging and disposal (elutriate tests) (Phase III) but these assessments would be undertaken, if triggered. In addition, toxicity/bioaccumulation assessments would be undertaken in accordance with the NAGD.

If Phase III and Phase IV assessments are triggered by Phase II assessment of sediments in the Dredge Area, new samples would be collected in accordance with the procedures outlined in NAGD (Commonwealth of Australia 2009). For elutriate, bioavailability and toxicity testing, lesser numbers of sample locations are required, as specified in Table 7 of the NAGD, although at each location, samples would be representative of the full depth of contaminated sediment (as identified in Phase II) to be dredged, except where a discrete ‘hot spot’ has been identified, in which case it would be sampled separately. Importantly, samples collected for Phase III and Phase IV assessments would be representative of the *overall* dredged material composition in the dredge area(s) which require these tests. Alternatively, if a defined sub-area of the dredge area has been selected for testing on the basis of elevated contamination levels, samples must be representative of this sub-area, including the most contaminated locations. The sample selection process for Phase III and Phase IV sampling and assessment would be fully documented but is dependant on outcomes of the Phase II assessment.

Three replicate samples would be collected at each sampling location for bioavailability analysis for the COPCs that have exceeded NAGD Screening Levels during the Phase II assessment.

Compositing of cores for this purpose is not recommended, as exposure to air may affect the integrity of samples for certain bioavailability tests.

Bioaccumulation results of the Phase IV assessments, if required, would be compared statistically to controls, and a minimum of three test locations and three reference locations would be selected in consultation with DEWHA, should this Phase IV assessment be required.

The likelihood of contamination triggering Phase III and Phase IV assessments is considered to be minimal in sediments of the Dredge Area. Chevron has elected to proceed with the Phase II assessment first, and follow up with subsequent Phase III and Phase IV assessments in a timely manner, as required,

3.1 Contaminants List

From consideration of a review of the available literature in the previous section, it is considered that the Dredge Area is sufficiently far removed from known existing and historical contaminant sources. Selection of the analytes was based on COPCs derived from the current understanding of site history (including urbanization and catchment wide industrial activities) and existing data. However, because of a lack of existing data for the Dredge Area and the disposal ground, it is proposed that potentially contaminated sediments (unconsolidated sediments to a depth of 1 m below the seafloor) would be analysed for the following COPCs:

- Trace metals and metalloid (arsenic, barium, cadmium, chromium, copper, mercury, nickel, lead, and zinc);
- Major elements (aluminium); and
- TBT.

The determination of total organic carbon (TOC) content (Leco) in each sediment sample is necessary to normalise concentrations of organic compounds (i.e. TBT) to 1% total organic carbon, as specified in the NAGD (PQL: 0.1 %). Moisture content will also be determined in each sediment sample (PQL: 0.1%).

An assessment of the radionuclides (sum of gross alpha and gross beta activity) has not been undertaken previously in sediments within the Dredge Area, nor in any other areas within the NWS region. It is therefore recommended that sediment samples from a select number of sampling locations within the Dredge Area are assessed for the sum of gross alpha and gross beta activity. It is proposed that radionuclides (gross alpha and beta activity) would be determined in a small number (n=5) of surface sediment samples (0-0.5 m depth) selected randomly from the total number of 60 short core sampling sites. Radionuclides may be associated with certain mining and mineral processing activities and the NAGD recommend analysis of radionuclides (NAGD Screening Level: 35 Bq/g) only once for any particular dredge area.

If the 95 per cent upper confidence limit (UCL) of a contaminant exceeds the relevant NAGD Screening Level, concentrations of these contaminants should then be compared to ambient (i.e. baseline) levels for sediments of comparable grainsize to assess whether contaminants in the assessment area are elevated through natural causes. This may be the case for arsenic and nickel, which have shown to be naturally elevated in Australian marine sediments.

The degree of contamination may then be divided into contaminants of potential concern (COPCs) and contaminants of concern (COCs). COPCs are those contaminants that exceed the background concentrations and the Screening Level (or elevated concentrations of contaminants for which guidelines do not exist). COCs are those contaminants which exceed the background concentrations and the NAGD Screening Level and for which the bioavailability, bioaccumulation or toxicity assessments indicate that significant effects from the contaminants are likely.

In addition to the short (1.0 m deep) sediment cores collected at 60 sampling locations, deep cores from a selected number of locations (12 sample locations) would be sampled to the full depth of dredging and analysed for all COPCs on the Contaminants List (except TBT). Short cores would be collected at 60 sampling locations and subsamples (0-0.5 m and 0.5 m-1.0 m depth) would be analysed for all COPCs on the Contaminants List (and TOC).

Table 4: Contaminants list for sediments in the Wheatstone Dredge Area.

Analytical Parameter	**Practical Quantitation Limit (PQL) (NAGD 2009)**	**Laboratory LOR (Investigation Level) (mg/kg)**	**NAGD Screening Level (ISQG Trigger Level) (mg/kg)**
Metals and Metalloids	**(in mg/kg)**	**(in mg/kg)**	**(in mg/kg)**
As	1	0.1	20
Ba	0.01	0.01	NS
Cd	0.1	0.1	1.5
Cr	1	0.1	80
Cu	1	0.1	65
Hg	0.01	0.01	0.15
Ni	1	0.1	21
Pb	1	0.1	50
Zn	1	0.1	200
Major Elements	**(in mg/kg)**	**(in mg/kg)**	**(in mg/kg)**
Al	50	50	NS
Organotins	**(in □gSn/kg)**	**(in □gSn/kg)**	**(in □gSn/kg)**
Tributyltin	1	0.5	9
Radionuclides	**(in Bq/g)**	**(in Bq/g)**	**(in Bq/g)**
Sum of gross alpha and gross beta activity	NS	1 (gross alpha); 0.5 (gross beta)	35

NB: 'NS' = not specified.

Scope of Work

4.1 Introduction

This section of the SAP details the procedures to be used in the proposed sediment investigation. By defining the procedures to be used, it is possible to develop a uniform approach to the investigations and thereby, minimise potential impacts on the quality and representativeness of the collected data.

The proposed assessment program is based on testing sediment in the Dredge Area to determine the concentrations of COPCs on the Contaminants List that have a potential to exceed NAGD Screening Levels.

4.2 Sampling Location Selection

4.2.1 Short Cores

Sampling locations were selected by placing a 90 x 90 m square grid over the entire area to be dredged, numbering each square (total 1,500) and selecting 60 squares using random numbers generated by internet sourced software (Urbaniak and Plous, 2009) (Figure 1). Samples will be collected as close as practicable to the centre of each of the selected grid squares. Samples in squares on the boundary of the Dredge Area will be collected from within the dredge area.

4.2.2 Deep Coring

The locations of deep cores were selected for geotechnical purposes and the proposed sampling locations are shown in Figure 1. The distribution of these deep core locations covers the Dredge Area evenly rather than selecting a randomly chosen set of deep coring locations (Figure 1).

4.2.3 Surface Sediment Sampling at Proposed Offshore Disposal Grounds

Up to 15 surficial sediment samples will be collected in each of the potential offshore sediment disposal grounds (i.e. Bechtel Spoil Ground Sites A, B and C, URS Spoil Ground Site A, Chevron Spoil Ground and Chevron Alternative Spoil Ground. Sediments will be sampled using a Van Veen (or equivalent) grab sampler (0 to 0.1 m depth) to characterise surface sediments. Sediment samples will be analysed for all COPCs on the Contaminants List (i.e. metals and TBT). The sampling locations would be chosen using the same methodology described above for the collection of short cores in the Dredge Area, although the actual location of the proposed disposal ground or disposal grounds is yet to be determined.

4.2.4 Radionuclide Assessment

Surface sediment samples (0.0-0.5 m depth) from five sampling locations within the Dredge Area would be assessed for the sum of gross alpha and gross beta activity. The sampling locations would be selected randomly from the total number of short core sampling sites.

4.3 Sediment Coring

Percussion or vibro cores in shallow water locations (<15 m) would be collected from a suitably sized workboat or barge that will be anchored at each sampling location. A barge-mounted coring rig would be used to collect deep cores for geotechnical investigations and subsamples for geochemical assessments. All sampling locations would be located using a global positioning system (GPS) with an accuracy of around 3 m. Positioning of the barge and locating of sampling positions will be the responsibility of the operators of the sampling vessel.

Short cores in the Dredge Area will be collected by highly experienced URS personnel using a percussion corer. This unique corer would be used to collect unconsolidated sediment to a maximum depth of 1.0 m below the seabed. A clean polycarbonate barrel (80 mm inner diameter) will be loaded into the corer and lowered to the seabed. The barrel is then remotely driven (using weights) into the sediment with a piston remaining at bed level to create a partial vacuum and draw sediment into the barrel. The corer is able to penetrate and retain the entire profile of soft sediments, but penetration is limited in dense sand, or clay units, in which case a vibro coring device would be used.

A vibro coring device would allow the penetration of aluminium core tubes to depths of up to 6 m into well-sorted compacted sandy and gravelly substrate, providing sediment samples in areas that cannot be sampled using other coring techniques. However, the disadvantage of this coring technique is the relatively slow rate of sampling efficiency, which is why other coring techniques (i.e. percussion coring) would be attempted first.

Core catchers may be used on either coring device for sandy and gravelly substrates to prevent core loss during retrieval from the seabed.

URS sampling staff will determine the acceptability of the core following collection which is based on the following criteria:

- No obvious loss of surficial sediment or sediment from the bottom of the core;
- Vertical penetration of core through the sedimentary profile to the required depth; and
- Continuous and undisturbed sediment stratigraphy.

The cores will each be logged and photographed (as required) through the clear core barrel prior to or after extraction.

In addition to the 1.0 m long short cores, deep cores will be collected at 12 sampling locations in the Dredge Area. The above acceptance criteria also apply to the deep cores, but each deep core must also reach the depth of proposed dredging (13.5 m below LAT) or refusal at calcareous rock, dense sand or clay.

The barge-mounted coring rig will be used at 12 sampling locations to obtain sediment samples to the depth of proposed dredging.

In summary sampling includes:

- Short core sampling using polycarbonate core tubes to a maximum depth of 1.0 m at 60 locations;
- Subsampling and homogenisation of sediment (as appropriate) from short cores (2 subsamples per core: 0.0-0.5 m; 0.5-1.0 m) (60 x 2 subsamples = 120 samples + QA/QC samples));
- Collection of 12 deep cores (to a maximum depth to 13.5 m LAT) or to refusal; and
- Subsampling and homogenisation of sediment (as appropriate) from 12 deep cores at intervals of 0.0-0.5 m, 0.5-1.0 m and subsequent 3 to 4 m intervals to end of core. The exact number of subsamples is dependent on stratigraphy encountered in the cores. Sediment from different stratigraphic units will be subsampled and analysed separately.

4.4 Sediment Subsampling

Samples from each location will be analysed to enable classification of the contaminant status of the sediments. Sample management procedures on the sampling barge include the careful collection of the sediment samples from the core tubes, following the recovery of the sediment core or grab from the seafloor. All sample handling and processing will be performed to minimise contamination and sample mix-ups. The workspace on the barge will be washed down regularly with ambient seawater to clean all surfaces and minimize dust contamination of samples. Nitrile gloves will be worn by all personnel handling the sediment and gloves will be disposed of after processing each core sample.

Photographs of the cores will be taken and URS personnel will log the geological/stratigraphic profile of the core. Cores will be logged following routine logging procedures in accordance with AS 1726-1993, before being split and subsampled. The core tube will be measured and the appropriate sample interval extruded and collected in a clean polyethylene basin for homogenisation.

Subsampling will be in accordance with the NAGD (Commonwealth of Australia 2009). The top 0.5 m of the core is to be used as a single sample for analysis. A second sample is to be taken from the 0.5 m –1.0 m interval. There is no reason to suspect contamination below 1.0 m depth in the cores and therefore no additional samples from a deeper sediment horizon would be collected at the short core sampling locations. Deep cores would be subsampled over intervals of 3 to 4 m below the upper 1 m depth interval (i.e. 0.0-0.5 m and 0.5-1.0 m sample intervals), due to the difficulty of subsampling and homogenisation of material over long intervals. Sediment in different stratigraphic units would be sampled separately, if these are more than 0.5 m thick.

Sample identifiers will include the location and depth interval, for example, MD101_0.50-1.00, would indicate that the sediment sample was collected from sampling location MD101 and over the interval from 0.50 m to 1.00 m.

4.5 Sample Handling

The sampler will maintain utmost care in ensuring that cross-contamination between samples is minimized. Samples collected from each interval will be homogenised and then placed into appropriately cleaned and preserved containers provided by the laboratories (Table 5). Sample containers will be filled with zero headspace and labelled immediately. Samples will then be stored in eskies on ice. All eskies will be filled to capacity and sealed with adhesive tape. A chain-of-custody (CoC) form will be included in the esky. Following return to shore, the samples will be delivered to the laboratory for processing and analysis.

Subsamples in deep cores will not transect different stratigraphic units as logged in the geological profile, therefore actual sample intervals are dependent on the stratigraphy encountered in the cores. A new sample would be collected at the top of each stratigraphic unit within the proposed dredge depth at that location.

Given that the analytical holding times for sediment, as specified in the NAGD, are 14 days for organics (TBT), 28 days for mercury and 6 months for other metals, submission of samples within 24 hours of sampling is not critical, provided the samples are chilled and kept in the dark. Similarly, any rinsate water samples required for quality control purposes have specified analytical holding times of 7 days (semi-volatile organics), 14 days (volatile organics (preserved) and mercury, and 6 months (metals) and a submission to the laboratory more than 24 hours post-sampling is therefore inconsequential.

The NAGD (Commonwealth of Australia 2002) states that “cores are to be split on recovery and subsampled on one split only. The other split is to be stored under appropriate conditions for further testing, if required”. This requirement would not be adhered to in this SAP, however, primary samples would be archived by the laboratory pending additional analyses. If significant contamination is observed in the composited core intervals, additional sampling may have to be scheduled and samples analysed at narrower intervals to determine the extent of contamination more accurately.

Table 5: Container type, number and sample volume required.

Analyte	Container	Amount (g, wet weight)	Maximum anticipated number of samples (excluding QA/QC samples)		
			Surface Sediments (<1.0 m)	Subsurface Sediments	Disposal Ground Sediments
Metals	250 ml Glass Jar	100	120	approx. 72	21
TBT	125 ml Glass Jar	200	120	0	21
TOC					
Gross □/□ activity	Ziplock Bag	500	4	1	21

NB: ‘NA’ = Not Applicable

4.6 Sediment Analyses

4.6.1 Chemical Analyses

All sediment subsamples from the 12 deep cores up to the maximum depth of dredging (13.5 m below LAT) and the short cores up to a depth of 1.0 m would be analysed for all COPCs on the Contaminants List (except gross alpha and gross beta analyses – five samples from five locations only and TBT in the deep core samples).

Whole sediment samples from the Dredge Area and the disposal ground will be submitted to ALS Environmental (NATA accredited for the proposed chemical analyses).

Radionuclide activity (sum of gross alpha and gross beta) activities in sediments are proposed to be measured at five sampling locations in the Dredge Area and radionuclide activity assessment will be undertaken by ANSTO, Lucas Heights, NSW or a designated subcontractor of ALS Environmental.

4.6.2 Quality Assurance and Quality Control (QA/QC)

- One daily trip blank sample (‘field blank’) comprising of water supplied by the analytical laboratory and analysis of COPCs (inorganic analytes only: Al, As, Ba, Cd, Cr, Cu, Hg, Ni, Pb, Zn);
- Field Triplicate samples at 10% or more of sampling locations (i.e. three separate samples taken at the same location and analysis for inorganic analytes only: Al, As, Ba, Cd, Cr, Cu, Hg, Ni, Pb, Zn);
- Interbatch samples requiring analysis of one sample from a previous batch (inorganic analytes only: Al, As, Ba, Cd, Cr, Cu, Hg, Ni, Pb, Zn);

- Split samples at 5% of sampling locations requiring analysis of samples split into three separate containers to assess laboratory variation (Note: an interlaboratory sample would be submitted and two of the three split samples would be analysed by ALS Environmental, with a third sample analysed by a separate reference laboratory. Split samples would be analysed for inorganic analytes only: Al, As, Ba, Cd, Cr, Cu, Hg, Ni, Pb, Zn) (i.e. 3 locations (5% of 60 locations) x 3 samples = 9 split samples). One split sample would be obtained from a deep core sample and analysed for all COPCs on the Contaminants List (except for gross alpha and gross beta activity and TBT);
- Daily submission of sediment samples to ALS, a NATA-accredited analytical laboratory; and
- Compilation of field records, chain-of-custody documentation, certificates of analysis, data validation reports (QA/QC reports).

4.6.3 Elutriate and Bioavailability Testing

The availability of COPCs to aquatic organisms in sediments in the Dredge Area would be assessed only if mean concentrations of COPCs in sediments in the Dredge Area exceed NAGD Screening Levels. However, should elutriate/bioavailability testing be required, the test results would be compared to the relevant ANZECC/ARMCANZ (2000) marine water quality trigger values (99% protection). If all contaminants are below the relevant guideline values after initial dilution, effects on organisms in the water column would not be expected during disposal. If any COPCs are present at levels above their relevant NAGD Screening Levels, loading and disposal could cause adverse effects on water quality, and loading and disposal controls are evaluated to determine if impacts can be mitigated. If they can be mitigated the assessment proceeds to bioavailability testing. If not, the dredged material is unacceptable for open water disposal. Elutriate and bioavailability testing would be conducted in accordance with the requirements in NAGD (Commonwealth of Australia 2009).

4.6.4 Toxicity and Bioaccumulation Testing

If any of the Contaminants of Potential Concern (COPC) were found to be bioavailable, toxicity testing would be undertaken in accordance with Appendix D of the NAGD (Commonwealth of Australia 2009).

Ideally, test species should be widely occurring, readily available, sensitive to the COPC, ecologically or economically important, tolerant of a broad range of sediment types and easily handled in the laboratory. Toxicity testing, if required, would be undertaken on a homogenised sample collected over the entire thickness of potentially contaminated sediment. This approach allows a depth-integrated assessment of sediment toxicity at each site. Toxicity samples can only be collected where soft silt is encountered and toxicity assessment would not be conducted at locations where the sediments comprise stiff clays or sands. Individual sample subject to toxicity assessment would be a composite sample mixed from a minimum of three cores collected from the one sample location.

Four ecotoxicity tests would be proposed for sediments in the Dredge Area and test species would be dependent on the seasonal availability of the following test organisms:

Acute whole sediment tests:

- Toxicity test using the juvenile amphipod *Melita plumulosa*; and
- Algal cell viability test using *Enteromoneis punctulata*.

Subacute porewater toxicity tests:

- Larval abnormality test using rock oyster using *Saccostrea commercialis*; and
- Larval development test using the sea urchin *Heliocidaris tuberculata*.

Where a toxicity test shows less than a 20% effect in the endpoint (e.g. survival, growth) relative to the negative control, the difference is not significant and no toxicity is indicated. A 20-50% effect in the endpoint compared to the control indicates a *significant* degree of toxicity, and a greater than 50% effect indicates a *high* degree of toxicity.

Evidence of contaminant bioaccumulation in organisms exposed to *in situ* dredge sediments versus controls will indicate whether metals are more bioavailable at these sites and are, therefore, a legitimate line of evidence. Bioaccumulation tests are generally run for 28 days, and use several test species. The requirements for these species are similar to those for toxicity testing, except that the organisms need not be sensitive to contaminants. In addition, test organisms must provide adequate biomass for analysis, ingest sediments and be inefficient metabolisers of contaminants, particularly PAHs. At least two bioaccumulation tests would occur on each sample. These would include a deposit feeding bivalve mollusc and a burrowing polychaete.

Alternatively, organisms collected from the site may be analysed, if appropriate animals are available, after a suitable gut depuration interval where whole organisms are to be analysed, typically 24 hours. Data would need to be compared to organisms from appropriate control sites. For example, Curtin University of Technology in Perth, WA, has developed a solid-phase bioassay using the amphipod *Grandidierella* sp., to better determine the impacts of drilling fluids to benthic infauna. Results from the developmental study show that the LC-50 of the ester-based fluids ranges from 682-1,501 mg/L; paraffin-based fluid has an LC-50 of 166 mg/L; and the toxicity of the iso-olefin-based fluid is 722 mg/L (Evans, Birchenough & Brancato 2000). These results are significantly lower than those obtained for Northern Hemisphere species (McIlroy 1999).

Guidelines on the number of bioaccumulation tests required, sampling and the degree of replication, are presented in Appendix D and Table 7 of the NAGD (Commonwealth of Australia 2009).

For bioaccumulation, if there are no significant differences in the bioaccumulation data relative to controls (treatments or sites), bioaccumulation of contaminants is not a concern. For any contaminant where bioaccumulated concentrations are statistically greater than that measured in the controls (treatments or sites), bioaccumulation is a possible concern. Where bioaccumulated concentrations are three or more times greater than those measured in the controls (treatments or sites), bioaccumulation is a significant concern. If the bioavailability, bioaccumulation or toxicity assessments indicate that significant effects from the contaminants are likely, they are considered to be Contaminants of Concern.

For any dredge area, where toxicity (or bioaccumulation) is rated as very significant or significant *in any of the tests on any of the samples*, and toxicity is not considered due to natural causes (e.g. ammonia in sediments), the toxicity would be further investigated by:

- Checking existing data to see if a coincident hot spot (i.e. a cluster of two or more samples exceeding the relevant criteria) can be defined using the existing chemistry and/or toxicity data, and
- If no hot spot can be identified, doing step-out sampling and testing (chemistry and toxicity) around the sample location where toxicity was found, to determine if a local hot spot is present.

There are three possible outcomes of this assessment:

- If any hot spots are identified, the sediments within them are considered toxic and unacceptable for unconfined ocean disposal, and therefore would require separate handling and disposal as per the existing hot spot provisions. The sediment outside the hot spots would be acceptable for ocean disposal;
- If no hot spots can be identified, and toxicity is only found in a single sample, the spoil may be considered acceptable for ocean disposal on the basis that the bulk composition of the dredge area, considering the initial toxicity testing plus step-out testing, indicates that it is non-toxic; and
- If no hot spots can be identified, yet toxicity is found at scattered locations throughout the dredge area, the toxicity of the sediments is still an issue. To resolve this, a Weight-of-Evidence assessment, which may include other lines of evidence, including benthic community assessment would be carried out with the agreement of DEWHA and follow the procedures set out in the Batley *et al*. (2008) draft Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines, or updates to that document.

4.7 Contingency Plan

The proposed sediment investigation outlined in this SAP will be undertaken outside the cyclone season in the Pilbara region, reducing the risk that adverse weather will delay the survey. However, in the event of adverse weather conditions rendering the sampling programme unsafe, there is a downtime contingency. If the sampling programme has commenced, then the survey team will return to shore and assess the likely duration of the adverse weather conditions. A decision will then be made to either remain ashore on stand-by at Onslow, or to return to the URS head office in Perth and re-mobilise at a later date. The scope of work-specific Health, Safety and Environment Plan (HSEP) will detail the appropriate actions to take in the event of adverse weather conditions.

Where possible, spare equipment will be available and ample time will be budgeted to undertake each survey, in the event that there is critical equipment failure. The township of Onslow is a small town and, in the majority of situations, major equipment repairs would have to occur in Karratha, the nearest industrial centre.

4.8 Health, Safety and Environment

Prior to the start of fieldwork a Hazard Identification (HAZID) workshop will be undertaken by key project personnel to identify potential risks to health, safety and environmental factors (including weather, depth, currents and waves, substrate type, wildlife and remoteness). After the HAZID workshop a scope specific risk-based HSEP, including Job Safety Analysis worksheets, will be prepared by URS, incorporating the previously identified hazards. The scope specific HSEP will then be reviewed by Chevron and finalised at least five days prior to commencement of the field sampling programmes. The HSEP will include issues, such as handling and storage of chemicals used in fieldwork, and management of waste.

Safety planning includes job hazard analyses to identify the conduct, personnel and equipment requirements of all survey tasks, vessel navigation duties and responsibilities, the use of routine and emergency communication channels, and the development of an approved Emergency Response Plan to be followed in the event of a serious accident. On-site vessel and other ‘tool-box’ safety meetings will be conducted before the start of each sampling task.

An HSEP for the barge-mounted coring programme will be developed and implemented by the drilling contractors, in accordance with the HSEP provisions and requirements of Chevron.

4.9 Field Records

Field notes will include the manual recording of field conditions (weather, tides, and currents), site locations, sampling methods and handling and storage methods, field sample numbers, date, time and identity of sampler.

Field description of sediments will include the physical appearance, texture, colour, and presence of foreign material, presence of shell fragments and or biota (for example, seagrass) and stratification. Where multiple samples are collected at a site, notes will be made on the variability between samples. Records will also be made detailing the unique sample identifier for each sample collected.

For the geotechnical component, sediments will be logged in accordance with AS 1726-1993.

4.10 Data Management and Reporting

Validation of analytical data will be undertaken as soon as results are received from the analytical laboratory. The relative standard deviation (RSD) will be determined for field triplicates and duplicates and the relative percentage difference (RPDs) will be determined for laboratory duplicates. In accordance with the NAGD (Commonwealth of Australia 2009) laboratory duplicates that have a RPD of greater than ±35% will be reanalysed, if possible, prior to the expiry of the analytical holding time. Likewise, field triplicates and duplicates that have an RSD of greater than ± 50% will be reanalysed. An interpretive quality control report will be provided by the analysing laboratory, highlighting any outliers to quality control procedures.

ProUCL^{TM} v4.0 statistical software will be applied in comparing the sediment chemical data against the NAGD Screening Levels (i.e. calculation of 95% UCLs as per Appendix A of the NAGD (Commonwealth of Australia 2009)).

To allow comparisons of organic compounds (TBT) against the Screening Levels, concentrations will be normalised to 1% TOC content. Data will be retained on a project specific database held at URS.

4.11 SAP Report

A SAP report will accompany the sea dumping permit application for the offshore disposal of sediments from the Dredge Area. The report will include a description of actual sampling locations and numbers, results including QA/QC assessment of both field and laboratory data, an assessment of the results in accordance to the NAGD and conclusions as to the suitability or otherwise of proposed dredged materials for unconfined ocean disposal. The field data and laboratory results will be tabulated with the actual field sample numbers used and the laboratory identification numbers and will include all quality assurance data. The original laboratory certificates will also be included.

Specifically, the assessment of the analytical data under the NAGD (Commonwealth of Australia 2009) will include:

- Documentation of all field procedures and data including core photographs and logs;
- Data validation;
- Analysis of contaminant concentrations in sediment in the Dredge Area and comparison against NAGD Screening Levels;
- Comparison of the 95% UCL of contaminant concentrations in sediment in the Dredge Area with NAGD Screening Levels;

- If NAGD Screening Levels are exceeded, mean sediment contaminant concentrations would be assessed against background concentrations;
- If background levels are exceeded, additional bioavailability and/or and toxicity assessments required under NAGD Phases II, III and IV (briefly outlined in this SAP) would be undertaken with prior approval of DEWHA;
- Comparison of current concentrations of contaminants in sediment with levels established in previous studies (Appendix A; URS 2009a) to identify possible sources and sinks of contaminants and provide input to assess dredge management options, as required;
- GIS interpretation of spatial trends of contaminant concentrations in sediments; and
- Classification of sediments as acceptable (or otherwise) for unconfined ocean disposal, based on the assessments above.

The sediment assessment report would be submitted as part of the application for a Sea Dumping Permit and lodged with the Department of the Environment, Water, Heritage and the Arts (DEWHA) for review and comment.

4.12 Estimated Time Lines for Sediment Assessment

The sediment assessment is proposed for the period 1 September 2009 to 30 November 2009, although the timing may vary depending on the approval of the SAP for the proposed work, the timing of the sediment sampling, which may be delayed due to poor weather, and the revisions of the Draft SAP Report by Chevron and the Regulatory Authority (DEWHA). URS will be available for additional clarification of the Final SAP Report and communications and meetings with the Regulatory Authority (DEWHA).

Following the preparation and submission of the SAP to DEWHA, and its approval, sampling would commence by 1 September 2009 and be completed as soon as practicable (weather dependent).

Proposed key dates for the project commencement, sampling, analysis, assessment and reporting (Draft SAP Report and Final SAP Report) are presented below (Table 6).

Table 6: Proposed dates for SAP & SAP report deliverables.

Deliverable	Date(s)
Preparation of Draft of SAP	to 13 July 2009
Commonwealth assessment of SAP	13 July to 13 Aug 2009
Sampling, analysis and data validation	1 Sep to 30 Sep 2009
Finalisation of SAP report and sea disposal permits	1 Oct 2009 to 28 Feb 2010
Commonwealth assessment of sea disposal permits	15 Oct to TBA
Disposal Permits issued (if no further assessments required	TBA

URS notes that bad weather during sampling and the timing of the permit review by Chevron may possibly delay the assessment process for sediments in the Dredge Area. Actual sampling dates are weather dependent and sampling may be postponed until such time when the weather conditions make time-efficient sampling feasible and do not pose Health and Safety concerns. The dates above may be subject to change if all parties are in agreement.

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6

Limitations

URS Australia Pty Ltd has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron Australia Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated October 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between October 2009 and February 2010 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

A

Appendix A Pilot Geochemical Survey

REPORT (DRAFT)

Pilot Marine Sediment Quality Report for the Wheatstone Project, Onslow WA

Prepared for

Chevron Australia Pty Ltd

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27 March 2009

42907170 - 2163 : R1359

PILOT MARINE SEDIMENT QUALITY REPORT FOR THE WHEATSTONE PROJECT, ONSLOW WA

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Status: Draft

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Executive Summary

Chevron Australia Pty Ltd (Chevron), as operator of the Wheatstone Project proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant near Onslow on the Pilbara Coast, north-west Australia, to process gas from various offshore fields in the West Carnarvon Basin. The Project is referred to as the Wheatstone Project and 'Ashburton North' is the proposed site for the LNG and Domgas plants.

The proposal includes capital dredging of marine sediments to enable vessel access via a shipping channel and turning basin, as well as through a feed-gas pipeline corridor.

URS Australia Pty Ltd (URS) was commissioned by Chevron to undertake a pilot sediment quality survey in and around the possible disturbance area to assess the physical and chemical characteristics of nearshore (in the possible disturbance area) and offshore (at the proposed disposal ground) sediments.

During this pilot marine sediment quality study, a total of 17 samples, representing nearshore sediments and eight samples representing offshore sediments were analysed for a range of metal and organic contaminants. Ninety-five percent Upper Confidence Limit (UCL) values for each contaminant of potential concern were assessed against the relevant National Assessment Guidelines for Dredging (2009) screening levels. All calculated 95% UCLs were below the screening level, with the exception of arsenic in nearshore sediments. However, this concentration is considered natural and likely to be related to the geology of the region.

Comparison of metals in sediments in nearshore and offshore areas has shown that, although offshore sediments are generally comprised of larger sized particles, sediments have similar chemical characteristics.

All analyses for organic compounds, including total petroleum hydrocarbons, tributyltin, benzene, toluene, ethylbenzene and xylene were reported below the laboratory practical quantitation limit or the relevant screening levels.

From the data gathered in this pilot sediment sampling program there are no contaminants of concern that occur in sediments in the potential disturbance zone for the Project, and sediments in the nearshore area are suitability similar to those in the offshore area to allow ocean disposal of dredged material.

Introduction Section 1

1.1 Background

Chevron Australia (Chevron), as operator of the Wheatstone Project proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant near Onslow on the Pilbara Coast, north-west Australia, to process gas from various offshore fields in the West Carnarvon Basin. The Project is referred to as the Wheatstone Project and 'Ashburton North' is the proposed site for the LNG and Domgas plants.

The proposal includes capital dredging of marine sediments to enable vessel access via a shipping channel and turning basin, as well as through a feed-gas pipeline corridor.

URS Australia Pty Ltd (URS) was commissioned by Chevron to undertake a pilot sediment quality survey in and around the possible disturbance area to assess the physical and chemical characteristics of the unconsolidated sediments (Figure 1).

1.2 Objective

The objective of the sampling program was to:

- Obtain a broad understand of sediment characteristics within and surrounding the project area.
- Determine baseline levels of metals and organic compounds.
- Establish whether dredge sediment type and sediment chemistry are compatible with surface sediments at the proposed spoil disposal area.

Sampling and Analysis Protocol

Section 2

2.1 Sampling Design

To make the best use of vessel and personnel field time, the pilot study sediment quality study was undertaken in conjunction with a subtidal survey, to assess the characteristics of nearshore and offshore areas within and surrounding the potential disturbance area (Figure 1). Nearshore sampling was carried out on the landward side of the 20 m depth contour, and included sampling in the proposed and alternative shipping channel, turning basin, feed-gas pipeline corridor as well as surrounding areas. Nearshore sampling was carried out to characterise sediments that may be disturbed during proposed dredging activities. Offshore sampling was carried out beyond the 30 m depth contour, in and around the proposed and alternative spoil grounds. The purpose of offshore sampling was to characterise surface sediments at proposed spoil grounds.

Samples were collected using a Van Veen grab, as the objective of this pilot program was to assess unconsolidated surface sediments. Characterisation of subsurface sediments will occur during a geotechnical drilling program to be undertaken at a later date.

Sampling was undertaken outside of the potential disturbance areas as it is considered that it aids the characterisation of the sediments in disturbance areas, as there is no reason to suspect that the contaminant levels by anthropogenic sources in these sediments would be any higher or lower than those in surrounding sediments.

2.2 Survey Details

Unconsolidated surface sediments were collected from a total of 25 locations, both nearshore (17 sites) and offshore (eight sites) (Table 1) between 9 and 12 February 2009. Sampling was undertaken by Paul Everson of URS, and the vessel and crew were provided by Broadsword Marine.

Sampling locations were chosen to be representative of nearshore and offshore sediments in and around the potential dredging area and spoil ground.

2.3 Sediment Collection

Sample collection was undertaken in accordance with the guidance provided in Appendix D: Sampling Methods and Design of Sampling Programs, of the National Assessment Guidelines for Dredging (NAGD) (Department of the Environment, Water, Heritage and the Arts [DEWHA], 2009). Unconsolidated surface sediments were collected using a Van Veen grab with a gape of 0.25 m^2, which typically sampled to a depth of 10-20 cm. The grab was operated via a hydraulic winch and crane. Once the grabs were retrieved onboard the vessel, the jaws were opened in a pre-cleaned area and sediments were transferred to a stainless steel mixing bowl for photographing and homogenisation. Sediments were then transferred into appropriate laboratory supplied sampling containers.

Prior to commencement of all sampling operations, an area of the support vessel was designated for sample handling. Potential contaminant sources in the vicinity of this area (e.g. galvanised or oily surfaces) were covered with appropriate material to reduce the potential for sample contamination.

Section 2 Sampling and Analysis Protocol

During sediment sampling, field personnel wore disposable latex gloves to minimise the potential for sample contamination by residues on the skin (e.g. hydrocarbons, sunscreen, etc.). Sterile Teflon plastic spatulas were used where direct contact with the sample was necessary. Smoking was not permitted in the vicinity of, or upwind from, the designated sample processing area. Where possible during sediment sampling, the vessel was anchored and engines turned off. When anchoring was not possible due to tidal currents and the location of sampling sites being close to shorelines, vessel exhaust systems were kept downwind of sampling areas by driving the vessel into the prevailing winds.

Sampling equipment was decontaminated between sites by thorough cleaning in seawater. If clayey sediments were encountered, then dilute hydrochloric acid solution was used to clean the sampling equipment, which was rinsed with seawater prior to use at the next site.

2.4 Sample Analysis

A total of 33 samples were forwarded to the Perth laboratory of ALS for analysis. The unique sample code for each sediment sample was recorded on a field data sheet and entered onto a URS Chain of Custody (CoC) form. Field data sheets were retained by URS for sample cross-referencing, while the CoC accompanied the samples to the receiving laboratory. Copies of URS CoC forms and field data sheets can be found in Appendix A and B respectively.

Sediment were analysed for the following;

- metals (aluminium, arsenic, cadmium, chromium, copper, iron, manganese, mercury, nickel, lead, vanadium and zinc)
- Total Petroleum Hydrocarbons (TPH)
- Benzene, Toluene, Ethylbenzene and Xylene (BTEX)
- Tributyltin (TBT)
- Total Organic Carbon (TOC).

As well as these parameters, sediments were also forwarded to CSIRO Minerals in Perth for analysis of Particle Size Distribution (PSD).

Both laboratories and all sampling methods were accredited by the National Association of Testing Authorities (NATA).

2.5 Data Assessment

Data were assessed against the appropriate screening levels and high levels provided in the NAGD (DEWHA, 2009). Screening levels are level of a substance in the sediment below which toxic effects on organisms are not expected. High levels are derived from sediment quality guidelines for bioaccumulating substances. If bioaccumulating substances are present above the high levels, bioaccumulation tests are required, and bioaccumulation may be of concern even where toxicity has not been identified.

2.6 Quality Assurance and Quality Control Data

In accordance with the guidance provided in Appendix F: Field and laboratory assurance and quality control of the NAGD (DEWHA 2009) field triplicates (three separate samples taken at the same site) were collected at three sites, while field duplicates (one sample mixed and split into two) were collected at two sites.

Relative Percentage Differences (RPDs) and Relative Standard Deviations (RSDs) were calculated for field duplicates and field triplicates respectively, and assessed against the NAGD (DEWHA, 2009) guideline of ±50%.

Laboratory quality assurance and Quality Control (QAQC) procedures included laboratory duplicates, method blanks, laboratory control samples and matrix spikes.

2.7 Statistical Analysis

All statistical analysis was undertaken in accordance with the guidance from NADG (2009) (Appendix A: Dredged material assessment – detailed guidelines). For each analyte, the standard mean, standard deviation and 95% Upper Confidence Limit (95%UCL) concentrations were calculated using ProUCL (Version 4.0) which is computer software developed by the United States Environmental Protection Agency (USEPA) for calculating UCLs based on environmental data sets. ProUCL calculates the most reliable 95% UCL value based on the specific distribution of data points within each data set, thereby accounting for normally distributed, gamma distributed and non-normally distributed data that are commonly encountered in environmental data. For data sets that appeared normally distributed, the Student's t-Test was used to calculate the 95% UCLs. However, if the data were log-normally distributed, the Jack-knife method was used.

At sites where field triplicate and duplicate samples had been collected and where laboratory duplicates or re-analysis had been undertaken, the data point for that set was represented by the mean concentration of the samples. This was undertaken to maintain even representation from each location when calculating the mean concentration and 95% UCL for the proposed dredging area.

Where values were less that the laboratory Practical Quantitation Limit (PQL) the value was taken as half the PQL for statistical analysis.

For analysis of organic compounds, results were first normalised to 1% TOC. However, normalisation is only appropriate over the TOC range 0.2-10 per cent, which equates to a multiplication factor of 5 times to 0.1 times respectively. For values outside of this range, the appropriate end value was used (e.g. for less that 0.2 per cent TOC a factor of 5 is used).

Because grain size is a dominant influence on naturally-occurring elements such as metals (DEWHA 2009), the concentration of iron was used to normalise metals, so comparisons can be made between two areas (nearshore and offshore) with differing PSD.

2.8 Data Validation

The primary objective of the data validation process is to ensure that the reported data can be used to achieve the project objectives. Analytical data were thoroughly checked by the laboratory prior to release. URS subsequently checked the analytical data against the data quality objectives of the project – comparing requested detection limits against PQLs, calculating RPDs and RSDs for field duplicates and triplicates, respectively, and comparing RPDs and RSDs with guideline recommendations.

Comparison of duplicates/triplicates through RPDs and RSDs may identify analytical results that appear to be unrealistically high (or low) and might prompt a request to the laboratory to reanalyse the samples as a further check of precision, or result in categorisation of those results as ‘estimates only’. High RPD/RSD values may also be an indication of high heterogeneity of sediment contaminant levels at the sample locations, or might result from widely varying characteristics of the sediments, such as particle size distribution and/or organic content.

Results and Discussion

Summary analytical data are presented in the tables section of this report. Original laboratory reports are included in Appendix C, while the laboratory interpretive quality control is included in Appendix D.

3.1 Metals

Analytical results for metals in sediments, taken in nearshore areas as well as the standard mean, standard deviation and 95% UCL calculations, are provided in Table 2. Table 3 presents a summary of the same results that have been normalised using the concentration of iron to allow comparison with offshore sediments as they have differing grain sizes. Table 4 presents the analytical results for metals in sediments, taken in offshore areas as well as the standard mean, standard deviation and 95% UCL.

3.1.1 Nearshore metals

The non-normalised concentration of metals were all below the relevant screening levels with the exception of arsenic and nickel (Table 2).

The concentration of arsenic exceeded the screening level of 20 mg/kg in the majority of samples, with a maximum recorded at W16 (36.9 mg/kg). Both the standard mean (21.5 mg/kg) and calculated 95% UCL value (23.6 mg/kg) were also marginally above the guideline.

The concentration of nickel exceeded the guideline value of 21 mg/kg at sites W9 (42.2 mg/kg) and W10 (21.9 mg/kg). However, the standard mean (13.0 mg/kg) and calculated 95% UCL value (18.6 mg/kg) were both below the screening level.

Elevated concentrations of arsenic and nickel are not unexpected as sediments in Australia commonly have high, naturally occurring levels (DEWHA 2009). A review of naturally-occurring background levels of metals in sediments in the Pilbara Coast by the Western Australian Deportment of Environment and Conservation (DEC) identified arsenic concentrations in sediments off Onslow and around the mouth of the Ashburton River with a medians of 34 mg/kg and 20 mg/kg respectively (DEC 2006). These concentrations are considered natural and likely to be related to the geology of the region (DEC 2006).

All calculated 95% UCL values for nearshore metals were within ranges recorded at sites around the mouth of the Ashburton River, or the town of Onslow during a study on the background quality of the marine sediments of the Pilbara coast (DEC, 2006).

3.1.2 Offshore metals

The concentrations of metals in sediments from the offshore area were all below the relevant screening levels, with the exception of arsenic at site W12 (23.9 mg/kg). Both the standard mean and calculated 95% UCL value for arsenic were below the screening level of 20 mg/kg (Table 4).

3.1.3 Comparison between nearshore and offshore metals

Calculated 95% UCL values for all non-normalised metal concentrations were higher in nearshore sediments than offshore sediments. After metals results were normalised using iron concentrations, the nearshore and offshore sediments had similar concentrations of metals. The calculated 95% UCL for aluminium, iron, arsenic, chromium, nickel and lead were higher in the offshore sediments, while copper, manganese, vanadium and zinc were higher in nearshore sediments.

3.2 Organic Compounds

Summary results as well as standard mean, standard deviation and calculated 95% UCL values for organic compounds for nearshore and offshore areas are presented in Tables 5 and 6 respectively.

3.2.1 TPH

The concentration of TPH in both nearshore and offshore sediments was reported below the screening level (Table 5 and 6). The calculated 95% UCL value for total (C_6-C_{36}) hydrocarbons normalised to 1% TOC for nearshore (141.6 mg/kg) and offshore sediments (235.5 mg/kg) was well below the screening level of 550 mg/kg. In comparison to these results a previous sediment study around the mouth of the Ashburton River and the town of Onslow did not report TPH above the laboratory PQL in any sample (DEC 2006). However, this study used a different analytical method which could not achieve as low PQLs (DEC 2006). All reported concentrations of TPH in this current study were still below the relevant PQLs of the DEC study.

3.2.2 BTEX compounds

The concentration of BTEX compounds was below the laboratory PQL in all samples (Tables 5 and 6). This result is consistent with findings of the DEC (2006) study on marine sediments in the region.

3.2.3 TBT

The concentration of TBT was below the laboratory PQL in all samples (Tables 5 and 6). This result is consistent with findings of the DEC (2006) study on marine sediments in the region. For normalisation of TBT to 1% TOC, it was assumed that all samples had a concentration of half the PQL (i.e. 0.25 µgSn/kg). After normalisation to 1% TOC, the calculated 95% UCL for TBT in nearshore (1.1 µgSn/kg) and offshore (1.16 µgSn/kg) sediments was well below the screening level of 9 µgSn/kg.

3.3 Particle Size Distribution

Generally nearshore sediments were comprised of small grained particles. On average, clay and silt accounted for 26.6% of sediments, while fine grained sand accounted for a further 28.0% (Table 7). These results are consistent with previous data, showing silt and clay content of 25.9% in nearshore sites around Onslow (DEC 2006). Offshore sediments were generally comprised of larger grained particles, with clay and silt accounting for only 9.5% of sediments (Table 8). The majority of offshore sediments were comprised of fine- (45.7%) and medium- (28.7%) grained sand.

3.4 Data Validation

The calculated RPD and RSD values for metals from field duplicates and field triplicates were all below the guideline of ±50% (Table 9). The calculated RPD and RSD values for organic compounds were all below the guideline, with the exception of C_{15}-C_{28} fraction petroleum hydrocarbons at site W16 (53.3%) and C_{26}-C_{36} fraction petroleum hydrocarbons at site W18 (62.9%). This high level of variability between the samples may have been caused by minor differences in concentration within the original sample or in laboratories, as concentrations of contaminants were very close to the laboratory PQL. Although these results are elevated above the guideline, they are not large enough to affect the interpretation of the results.

According to the laboratory interpretive quality control report, the only outlier for data analysis was an exceedence in holding time for moisture content analysis (Appenxix D). This is not likely to affect the interpretation of the results.

Conclusion Section 4

During this pilot marine sediment quality study, a total of 17 samples representing nearshore sediments and eight samples representing offshore sediments were analysed for a range of metal and organic contaminants. Ninety-five percent UCL values for each contaminant of potential concern were assessed against the relevant NADG (2009) screening levels. All calculated 95% UCL were below the screening level, with the exception of arsenic in nearshore sediments. However, this concentration is considered natural and likely to be related to the geology of the region (DEC 2006).

Comparison of metals in sediments in nearshore and offshore areas has shown that, although offshore sediments are generally comprised of larger sized particles, sediments have similar chemical characteristics.

All analysis for organic compounds, including TPH, BTEX compounds and TBT, were reported below the laboratory PQL or the relevant screening levels.

From the data gathered in this pilot sediment sampling program, there are no contaminants of concern that occur in sediments in the potential disturbance zone for the Project, and sediments in the nearshore area are suitability similar to those in the offshore area to allow ocean disposal of dredged material.

References

Section 5

DEC 2006, *Background quality of the marine sediments of the Pilbara coast – Marine Technical Report Series*, Department of Environment and Conservation, Western Australia.

DEWHA 2009, *National Assessment Guidelines for Dredging*, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia, Canberra.

Limitations Section 6

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron Australia Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works, and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared in between February and March 2009, and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

PILOT MARINE SEDIMENT QUALITY REPORT FOR THE WHEATSTONE PROJECT, ONSLOW WA

Tables

Prepared for Chevron Australia Pty Ltd, 27 March 2009
Ref: 42907170 – 2163 / R1395 / DK: M&C3064

Table 1: Sampling location descriptions

SITE_ID	DATE	TIME	Latitude	Longitude	S_Easting	F_Northing	DEPTH_M	DESCRIPTION
W1	9/02/2009	950	21.32'40.38"	115.06'40.38	304396	7616399	8	Westerly - fine, 5-10 knots, 1 m swell. Medium to dark brown coarse sand with fine shell fragments. No biota or odour.
W2	9/02/2009	1120	21.26'28.44	114.48'12.24	272346	7627423	40	Westerly - fine, 5-10 knots, 1 m swell. Dark to medium brown coarse to medium sand with fine silt layers. No shell fragments of biota.
W3	9/02/2009	1130	21.26'14.58	114.46'59.88	270257	7627820	47	Westerly - fine, 5-10 knots, 1 m swell. Brown medium sand with light brown veneer of silt. Occasional shell fragments. No biota or odour.
W4	9/02/2009	1155	21.23'12.6	114.47'31.74	271095	7633431	67	Westerly - fine, 5-10 knots, 1 m swell. Brown fine sand with light brown/grey silt veneer. Occasional shell fragments. No biota or odour.
W5	9/02/2009	1345	21.20'59.64	114.49'53.46	275122	7637577	67.2	Westerly - fine, 5-10 knots, 1 m swell. Sand with light grey/brown silt veneer. Few fine shell fragments. No biota or odour.
W6	9/02/2009	1420	21.20'57	114.54'37.56	283307	7637769	42	Westerly - fine, 5-10 knots, 1 m swell. Brown medium sand with light grey silt veneer. Sparse fine shell fragments. No biota or odour.
W7	10/02/2009	900	21.36'20.76	114.52'39.66	280295	7609309	10.5	South-westerly, 15-20 knots, 1.5 m swell and seas. Dark brown coarse sand with silt grey/brown veneer. Large to moderate shell fragments. Sparse coralline algae (possible *Halimeda* sp.).
W8	10/02/2009	920	21.39'5.34	114.53'34.08	281930	7604268	11.2	South-westerly, 15-20 knots, 1.5 m swell and seas. Dark brown coarse sand with red/brown silt veneer. Coarse shell fragments. No observed biota. No odour.
W9	10/02/2009	930	21.40'50.46	114.54'20.4	283305	7601053	4.6	South-westerly, 15-20 knots, 1.5 m swell and seas. Darkened silt veneer over dark brown fine sand silt matrix, overlay very dark black organic layer. Slight odour, some organic material.
W10	10/02/2009	1045	21.39'32.64	115.00'50.4	294487	7603594	6.4	South-westerly, 15-20 knots, 1.5 m swell and seas. Red silt veneer over dark brown silt to fine sand matrix with occasional layer fragments. No shells, biota or odour.
W11	10/02/2009	1345	21.41'1.32	114.50'35.16	276834	7600630	10.2	South-westerly, 15-20 knots, 1.5 m swell and seas. Reddish brown silt veneer over dark brown silt/fine sand matrix. No shell or odour. One small plant (possibly seagrass).
W12	10/02/2009	1415	21.23'54.12	114.45'36.66	267798	7632106	11.2	South-westerly, 15-20 knots, 1.5 m swell and seas. Gravel and large shell fragments with reddish brown silt veneer over coarse sand and silt matrix. Sparse *Halophila spinulosa and Halophila decipiens* (~10 leaves). One heart urchin, one small crustacean (crab).
W13	10/02/2009	1435	21.33'45.18	114.44'5.64	265172	7632344	13.2	South-westerly, 15-20 knots, 1.5 m swell and seas. Fine/coarse sand matrix. Very sparse H. spinulosa. One mole crab, fine shell fragments, no odour.
W14	11/02/2009	1045	21.30'4.8	114.44'45	266474	7620682	15.4	5-10 knots, 1 m swell. Medium/fine sand with fine shell fragments. No obvious silts present. Homogeneous matrix. No biota or odour.
W15	11/02/2009	1120	21.32'43.8	114.55'33.6	285210	7616050	13.5	5-10 knots, 1 m swell. Medium to fine sand with fine/coarse shell fragments. No obvious silts present, no veneer. One polychaete worm. No odour.
W16	11/02/2009	1135	21.33'24.9	114.58'48	290821	7614860	11.35	5-10 knots, 1 m swell. Reddish brown fine silt veneer over coarse/medium sand with medium shell fragments. No biota/odour.
W16 (T1)	11/02/2009	1140	21.33'24.9	114.58'48	290821	7614860	11.35	Triplicate 1: Some silt veneer, larger shell fragments, possible *Halimeda* sp.

Table 1: Sampling location descriptions

SITE_ID	DATE	TIME	Latitude	Longitude	S_Easting	F_Northing	DEPTH_M	DESCRIPTION
W16 (T2)	11/02/2009	1145	21.33'24.9	114.58'48	290821	7614860	11.35	Triplicate 2: Some silt veneer, larger shell fragments, possible *Halimeda sp*. Seagrass present (*Halophila spinulosa).*
W17	11/02/2009	1255	21.33'42.96	115.02'18.9	296896	7614382	12.2	5-10 knots, 1 m swell. Reddish brown very thin silt veneer over coarse to medium sand with occasional medium shell fragments. One macro-brown algae, plus possible seagrass (*Halophila ovalis)* .
W18	11/02/2009	1320	21.36'52.8	155.01'33.54	295665	7608526	10.2	5-10 knots, 1 m swell. Reddish brown silt veneer over moderate shell fragments and brown medium/fine sands. Some macro algae present and one pycnogonid (spider crab).
W18 (T3)	11/02/2009	1330	21.36'52.8	155.01'33.54	295665	7608526	10.2	Triplicate 3: Reddish brown silt veneer over moderate shell fragments and brown medium/fine sands. Some large shell fragments.
W18 (T4)	11/02/2009	1355	21.36'52.8	155.01'33.54	295665	7608526	10.2	Triplicate 4: Reddish brown silt veneer over moderate shell fragments and brown medium/fine sands.
W19	12/02/2009	1040	21.38'14.22	114.58'51.18	291028	7605962	8.2	South-westerly, 10 knots, 1 m seas. Reddish brown silt veneer over large bivalve (*Trisidos sp*). (1 live and 1 dead) with medium brown sand. No odour.
W20	12/02/2009	1130	21.38'16.98	115.04'12.72	300275	7605994	7.2	South-westerly, 10 knots, 1 m seas. Reddish brown silt over brown sand silt matrix. Occasional large shell fragments, one bryozoan.
W20 (R1)	12/02/2009	1130	21.38'16.98	115.04'12.72	300275	7605994	7.2	Replicate 1: Reddish brown silt over brown sand silt matrix. Occasional large shell fragments, one bryozoan.
W21	12/02/2009	1200	21.35'57.36	115.08'13.98	307161	7610373	7.9	South-westerly, 10 knots, 1 m seas. Reddish brown silt veneer over brown moderate sand and silt complex with large shell fragments. One crinoid and no odour.
W22	12/02/2009	1310	21.34'43.5	115.12'4.2	313757	7612723	7.2	South-westerly, 10 knots, 1 m seas. Reddish brown silt veneer over dark brown silt and sand matrix. No biota or odour. Some fine shell fragments.
W22 (T5)	12/02/2009	1315	21.34'43.5	115.12'4.2	313757	7612723	7.2	Triplicate 5: Reddish brown silt veneer over dark brown silt and sand matrix. No biota or odour. Some fine shell fragments.
W22 (T6)	12/02/2009	1325	21.34'43.5	115.12'4.2	313757	7612723	7.2	Triplicate 6: Reddish brown silt veneer over dark brown silt and sand matrix. No biota or odour. Some fine shell fragments.
W23	12/02/2009	1345	21.31'56.34	115.11'1.26	311887	7617843	10.2	South-westerly, 10 knots, 1 m seas. Reddish brown silt veneer over fine sand and silt brown matrix with occasional fine shell fragments. No biota or odour.
W23 (R2)	12/02/2009	1345	21.31'56.34	115.11'1.26	311887	7617843	10.2	Replicate 2: Reddish brown silt veneer over fine sand and silt brown matrix with occasional fine shell fragments. No biota or odour.
W24	12/02/2009	1408	21.28'35.16	115.07'41.76	306072	7623963	15.2	South-westerly, 10 knots, 1 m seas. Reddish brown silt veneer over brown fine sands and silt matrix. Occasional fine shell fragments. No biota or odour.
W25	12/02/2009	1435	21.25'57.24	115.10'57.24	311643	7628886	16.2	South-westerly, 10 knots, 1 m seas. Reddish brown silt veneer over brown fine sands and silt matrix. No biota or odour. Occasional fine shell fragments.

Table 2: Summary of metals results for nearshore sediments - February 2009

		Moisture Content	Al	Fe	As	Cd	Cr	Cu	Mn	Ni	Pb	V	Zn	Hg
	UNIT	%	mg/kg											
	PQL[a]	1	50	50	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2	0.1	0.01
Screening levels[b]			NG	NG	20	1.5	80	65	NG	21	50	NG	200	0.15
High levels[c]			NG	NG	70	10	370	270	NG	52	220	NG	410	1
Site ID	**Sample ID**													
W1	W1	26.5	2270	11900	24.1	<0.1	14.3	1.8	250	3.6	2.9	26.7	5.7	<0.01
W7	W7	26.2	3020	11300	14.6	<0.1	17.7	3.4	194	5.4	3.3	24.2	8.0	<0.01
W8	W8	23.9	5540	19300	18.8	<0.1	25.4	8.2	393	10.2	5.1	38.1	15.9	<0.01
W9	W9	39.6	18200	61900	9.3	0.1	77.5	48.2	1060	42.2	16.7	97.3	69.4	0.03
W10	W10	38.9	10800	39800	22.4	<0.1	53.5	19.1	670	21.9	10.5	71.3	37.5	0.01
W11	W11	35.3	10200	33100	19.8	<0.1	45.1	15.3	471	19.5	9.1	58.0	30.9	0.01
W15	W15	21	2010	12500	29.8	<0.1	15.1	1.8	225	3.8	3.0	32.0	4.5	<0.01
W16	W16	29.2	4140	15300	17.9	<0.1	18.9	4.0	257	6.9	4.1	29.6	9.5	<0.01
W16	T1[d]	31	4990	23900	36.9	0.1	22.9	5.0	422	8.6	5.0	42.9	11.5	<0.01
W16	T2[d]	28.7	3510	14500	21.4	<0.1	16.2	3.3	285	5.8	4.0	29.0	7.9	<0.01
W17	W17	30.7	4410	22000	16.0	<0.1	30.4	5.0	272	8.8	5.3	39.1	12.8	<0.01
W18	W18	27.9	5940	26500	19.1	<0.1	37.8	8.7	344	12.2	6.0	53.6	20.1	<0.01
W18	T3[d]	31.3	4990	21800	12.4	<0.1	28.1	7.2	434	11.0	5.8	41.3	16.8	<0.01
W18	T4[d]	26.7	5260	22100	19.3	<0.1	31.2	7.3	415	10.6	5.5	43.8	16.8	<0.01
W19	W19	31.9	11400	31400	20.8	<0.1	45.6	16.7	618	20.1	9.0	58.7	32.4	0.01
W20	W20	26.7	7510	34100	21.9	<0.1	42.6	11.4	465	14.7	7.5	60.7	26.2	0.01
W20	R1[e]	29.4	7060	35200	24.2	<0.1	43.6	10.9	550	14.7	7.6	63.6	26.7	<0.01

		Moisture Content	Al	Fe	As	Cd	Cr	Cu	Mn	Ni	Pb	V	Zn	Hg
	UNIT	%	mg/kg											
	PQL[a]	1	50	50	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2	0.1	0.01
Screening levels[b]			NG	NG	20	1.5	80	65	NG	21	50	NG	200	0.15
High levels[c]			NG	NG	70	10	370	270	NG	52	220	NG	410	1
Site ID	Sample ID													
W21	W21	27.4	4400	24300	27.5	<0.1	26.9	5.0	468	8.4	5.2	46.2	14.7	<0.01
W22	W22	30.2	7000	34300	29.8	<0.1	38.4	9.6	510	13.4	7.5	59.6	22.1	<0.01
W22	T5[d]	30.6	6700	35300	30.5	<0.1	41.8	9.6	511	13.9	7.7	63.2	22.3	0.01
W22	T6[d]	29.5	6540	34300	29.7	<0.1	40.1	9.2	472	13.2	7.3	60.4	21.3	<0.01
W23	W23	46.1	8530	27600	23.0	<0.1	37.4	11.6	622	15.9	7.4	48.5	23.0	<0.01
W23	R2[e]	38.6	6630	23300	22.3	<0.1	30.1	7.9	488	11.6	6.1	40.2	16.8	<0.01
W24	W24	36.2	5130	19000	20.9	<0.1	26.5	5.0	316	9.5	5.1	29.0	12.2	<0.01
W25	W25	31.8	4700	17800	21.0	<0.1	25.0	4.0	300	7.9	4.3	26.7	9.8	<0.01
standard mean			**6665**	**25906**	**21.4**	**0.1**	**33.6**	**10.3**	**442.1**	**13.0**	**6.6**	**46.8**	**20.6**	**0.008**
standard deviation			**4077**	**12643**	**5.4**	**0.0**	**16.1**	**11.0**	**211.5**	**9.3**	**3.4**	**19.4**	**15.9**	**0.006**
95% UCL			**9142**[g]	**32706**[g]	**23.6**[f]	**NA**	**40.5**[f]	**17.4**[f]	**550.5**[g]	**18.6**[g]	**6.3**[g]	**55.0**[f]	**31.1**[g]	**0.011**[h]

a Practical Quantitation Limit (detection limit)
b DEWHA 2009, National Assessment Guidelines for Dredging - level of substance in sediments below which toxic effects on marine organisms are not expected
c DEWHA 2009, National Assessment Guidelines for Dredging - bioaccumulation testing is required when concentrations of bioaccumulation substances exceeds this level.
d Field triplicate
e Field duplicate
f Data are normally distributed and the UCL was calculated using Student's t-Test method
g Data are lognormal and the UCL was calculated using 95% H-UCL
h Data are Gamma distributed and the UCL was calculated using the non-parametric Jack-knife method
NA Not Applicable - as there too few distinct data points for statistical analysis
NG No Guideline
\- Not Analysed
Note: At sites where field duplicates and triplicates were taken, the data point for that site was represented by the mean concentration in all samples

Table 3: Summary of nearshore metals results normalised using offshore iron concentrations - February 2009

		Moisture Content	Al	Fe	As	Cd	Cr	Cu	Mn	Ni	Pb	V	Zn	Hg
	UNIT	%	mg/kg											
	PQL[a]	1	50	50	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2	0.1	0.01
Screening levels[b]			NG	NG	20	1.5	80	65	NG	21	50	NG	200	0.15
High levels[c]			NG	NG	70	10	370	270	NG	52	220	NG	410	1
Site ID	Sample ID													
W1	W1	26.5	774	4059	8.2	<0.1	4.9	0.6	85.3	1.2	1.0	9.1	1.9	<0.01
W7	W7	26.2	1030	3854	5.0	<0.1	6.0	1.2	66.2	1.8	1.1	8.3	2.7	<0.01
W8	W8	23.9	1890	6583	6.4	<0.1	8.7	2.8	134.0	3.5	1.7	13.0	5.4	<0.01
W9	W9	39.6	6208	21113	3.2	0.03	26.4	16.4	361.5	14.4	5.7	33.2	23.7	0.010
W10	W10	38.9	3684	13575	7.6	<0.1	18.2	6.5	228.5	7.5	3.6	24.3	12.8	0.003
W11	W11	35.3	3479	11290	6.8	<0.1	15.4	5.2	160.6	6.7	3.1	19.8	10.5	0.003
W15	W15	21	686	4263	10.2	<0.1	5.2	0.6	76.7	1.3	1.0	10.9	1.5	<0.01
W16	W16	29.2	1412	5219	6.1	<0.1	6.4	1.4	87.7	2.4	1.4	10.1	3.2	<0.01
W16	T1[d]	31	1702	8152	12.6	0.03	7.8	1.7	143.9	2.9	1.7	14.6	3.9	<0.01
W16	T2[d]	28.7	1197	4946	7.3	<0.1	5.5	1.1	97.2	2.0	1.4	9.9	2.7	<0.01
W17	W17	30.7	1504	7504	5.5	<0.1	10.4	1.7	92.8	3.0	1.8	13.3	4.4	<0.01
W18	W18	27.9	2026	9039	6.5	<0.1	12.9	3.0	117.3	4.2	2.0	18.3	6.9	<0.01
W18	T3[d]	31.3	1702	7436	4.2	<0.1	9.6	2.5	148.0	3.8	2.0	14.1	5.7	<0.01
W18	T4[d]	26.7	1794	7538	6.6	<0.1	10.6	2.5	141.5	3.6	1.9	14.9	5.7	<0.01
W19	W19	31.9	3888	10710	7.1	<0.1	15.6	5.7	210.8	6.9	3.1	20.0	11.1	0.003
W20	W20	26.7	2562	11631	7.5	<0.1	14.5	3.9	158.6	5.0	2.6	20.7	8.9	0.003
W20	R1[e]	29.4	2408	12006	8.3	<0.1	14.9	3.7	187.6	5.0	2.6	21.7	9.1	<0.01
W21	W21	27.4	1501	8288	9.4	<0.1	9.2	1.7	159.6	2.9	1.8	15.8	5.0	<0.01
W22	W22	30.2	2388	11699	10.2	<0.1	13.1	3.3	174.0	4.6	2.6	20.3	7.5	<0.01
W22	T5[d]	30.6	2285	12040	10.4	<0.1	14.3	3.3	174.3	4.7	2.6	21.6	7.6	0.003
W22	T6[d]	29.5	2231	11699	10.1	<0.1	13.7	3.1	161.0	4.5	2.5	20.6	7.3	<0.01

		Moisture Content	Al	Fe	As	Cd	Cr	Cu	Mn	Ni	Pb	V	Zn	Hg
	UNIT	**%**	**mg/kg**											
	PQL[a]	1	50	50	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2	0.1	0.01
Screening levels[b]			NG	NG	20	1.5	80	65	NG	21	50	NG	200	0.15
High levels[c]			NG	NG	70	10	370	270	NG	52	220	NG	410	1
Site ID	**Sample ID**													
W23	W23	46.1	2909	9414	7.8	<0.1	12.8	4.0	212.2	5.4	2.5	16.5	7.8	<0.01
W23	R2[e]	38.6	2261	7947	7.6	<0.1	10.3	2.7	166.4	4.0	2.1	13.7	5.7	<0.01
W24	W24	36.2	1750	6481	7.1	<0.1	9.0	1.7	107.8	3.2	1.7	9.9	4.2	<0.01
W25	W25	31.8	1603	6071	7.2	<0.1	8.5	1.4	102.3	2.7	1.5	9.1	3.3	<0.01
standard mean			**2273**	**8836**	**7.3**	**0.04**	**11.5**	**3.5**	**150.8**	**4.4**	**2.2**	**16.0**	**7.0**	**0.005**
standard deviation			**1390**	**4312**	**1.8**	**0.01**	**5.5**	**3.8**	**72.1**	**3.2**	**1.2**	**6.6**	**5.4**	**0.002**
95% UCL			**3118**[g]	**11155**[g]	**8.1**[f]	**NA**	**13.8**[f]	**5.9**[g]	**187.7**[g]	**6.36**[g]	**2.8**[g]	**18.8**[f]	**10.7**[g]	**0.005**[h]

a	Practical Quantitation Limit (detection limit)
b	DEWHA 2009, National Assessment Guidelines for Dredging - level of substance in sediments below which toxic effects on marine organisms are not expected
c	DEWHA 2009, National Assessment Guidelines for Dredging - bioaccumulation testing is required when concentrations of bioaccumulation substances exceeds this level.
d	Field triplicate
e	Field duplicate
f	Data are normally distributed and the UCL was calculated using Student's t-Test method
g	Data are lognormal and the UCL was calculated using 95% H-UCL
h	Data are Gamma distributed and the UCL was calculated using the non-parametric Jack-knife method
NA	Not Applicable - as there too few distinct data points for statistical analysis
NG	No Guideline
-	Not Analysed
Note:	At sites where field duplicates and triplicates were taken, the data point for that site was represented by the mean concentration in all samples

Table 4: Summary of metals results for offshore sediments - February 2009

		Moisture Content	Al	Fe	As	Cd	Cr	Cu	Mn	Ni	Pb	V	Zn	Hg
	UNIT	**%**	**mg/kg**											
	PQL[a]	1	50	50	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2	0.1	0.01
Screening levels[b]			NG	NG	20	1.5	80	65	NG	21	50	NG	200	0.15
High levels[c]			NG	NG	70	10	370	270	NG	52	220	NG	410	1
Site ID	**Sample ID**													
W2	W2	34.4	3120	8130	7.3	0.1	17.7	2.6	109	5.5	2.9	10.8	6.2	<0.01
W3	W3	37.5	3590	9420	6.4	0.1	19.2	3.1	118	6.6	3.3	10.0	7.6	<0.01
W4	W4	38.3	3760	11600	4.7	0.1	21.6	3.3	119	8.2	3.7	8.9	8.5	<0.01
W5	W5	33	3840	14500	4.9	0.1	21.4	3.1	108	7.9	4.0	8.4	8.6	<0.01
W6	W6	31.5	2860	7500	7.7	<0.1	16.4	2.3	100	5.2	2.8	8.4	6.0	<0.01
W12	W12	26.3	2820	12300	23.9	<0.1	17.6	2.3	156	4.4	3.1	30.5	5.7	<0.01
W13	W13	24.8	730	2580	7.4	0.1	11.4	<1.0	37	1.1	1.1	9.1	1.3	<0.01
W14	W14	23	1100	4660	12.1	<0.1	19.0	<1.0	66	1.7	1.5	14.6	2.2	<0.01
standard mean			**2728**	**8836**	**9.3**	**0.1**	**18.0**	**2.2**	**101.6**	**5.1**	**2.8**	**12.6**	**5.8**	**<0.01**
standard deviation			**1187**	**3981**	**6.3**	**0.0**	**3.2**	**1.1**	**36.0**	**2.6**	**1.0**	**7.5**	**2.7**	**NA**
95% UCL			**7610^{g}**	**11503^{f}**	**15.0^{g}**	**NA**	**20.2^{g}**	**3.0^{g}**	**125.7^{g}**	**6.8^{f}**	**3.5^{f}**	**17.6^{g}**	**7.6^{f}**	**NA**

a Practical Quantitation Limit (detection limit)
b DEWHA 2009, National Assessment Guidelines for Dredging - level of substance in sediments below which toxic effects on marine organisms are not expected
c DEWHA 2009, National Assessment Guidelines for Dredging - bioaccumulation testing is required when concentrations of bioaccumulation substances exceeds this level.
d Field triplicate
e Field duplicate
f Data are normally distributed and the UCL was calculated using Student's t-Test method
g Data are lognormal and the UCL was calculated using 95% H-UCL
h Data are Gamma distributed and the UCL was calculated using the non-parametric Jack-knife method
NA Not Applicable - as there too few distinct data points for statistical analysis
NG No Guideline
\- Not Analysed
Note: At sites where field duplicates and triplicates were taken, the data point for that site was represented by the mean concentration in all samples

Table 5: Summary of organic compound results for nearshore sediments - February 2009

		TOC	Total Petroleum Hydrocarbons (mg/kg)						BTEX Compounds (mg/kg)					TBT	TBT[g]
		%	C_6-C_9	C_{10}-C_{14}	C_{15}-C_{28}	C_{26}-C_{36}	Total (C_{10}-C_{36})	Total (C_{10}-C_{36})[g]	Benzene	Toluene	Ethylbenzene	meta- & para-Xylene	ortho-Xylene	µgSn/kg	µgSn/kg
	PQL[a]	0.02	3	3	3	5	14	14	0.2	0.2	0.2	0.2	0.2	0.5	0.5
Screening levels[b]		NG	NG	NG	NG	NG	550	550	NG	NG	NG	NG	NG	9	9
High levels[c]		NG	100	500	1000	NG	NG	NG	NG	NG	NG	NG	NG	70	70
Site ID	Sample ID														
W1	W1	0.09	<3	<3	9	8	23	115*	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.25*
W7	W7	0.12	<3	<3	13	10	29	145*	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.25*
W8	W8	0.24	<3	<3	10	9	25	104	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.04
W9	W9	0.85	<3	6	54	33	96	113	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.29
W10	W10	0.35	<3	<3	25	16	47	134	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.71
W11	W11	0.33	<3	<3	18	14	38	115	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.76
W15	W15	0.16	22	<3	13	10	48	240*	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.25*
W16	W16	0.24	<3	4	21	13	41	171	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.04
W16	T1[d]	0.24	<3	<3	16	7	29	121	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.04
W16	T2[d]	0.21	<3	<3	6	<5	17	81	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.19
W17	W17	0.13	<3	<3	18	15	39	195	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.25*
W18	W18	0.21	<3	<3	12	13	31	148	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.19
W18	T3[d]	0.27	<3	<3	9	5	20	74	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.93
W18	T4[d]	0.23	<3	<3	8	<5	19	83	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.09
W19	W19	0.37	<3	5	25	16	49	132	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.68
W20	W20	0.27	<3	<3	12	9	27	100	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.93
W20	R1[e]	0.28	<3	<3	<3	<5	14	50	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.89
W21	W21	0.17	<3	<3	7	<5	18	90*	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.47
W22	W22	0.24	<3	<3	8	6	20	83	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.04
W22	T5[d]	0.25	<3	<3	9	<5	20	80	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.00
W22	T6[d]	0.19	<3	<3	8	<5	19	95*	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.32
W23	W23	0.34	<3	<3	14	9	29	85	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.74
W23	R2[e]	0.34	<3	<3	<3	<5	14	41	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.74
W24	W24	0.27	<3	<3	11	8	25	93	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.93
W25	W25	0.28	<3	<3	21	11	38	136	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.89
standard mean		**0.3**	**2.7**	**2.1**	**16.6**	**11.5**	**34.7**	**121.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.25**	**0.98**
standard deviation		**0.2**	**5.0**	**1.4**	**11.1**	**6.6**	**18.9**	**43.3**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.29**
95% UCL		**0.36**[i]	**NA**	**2.7**[j]	**21.2**[i]	**15.3**[i]	**42.72**[i]	**141.6**[i]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**1.10**[h]

a Practical Quantitation Limit (detection limit)

b DEWHA 2009, National Assessment Guidelines for Dredging - level of substance in sediments below which toxic effects on marine organisms are not expected

c DEWHA 2009, National Assessment Guidelines for Dredging - bioacumulation testing is required when concnetrations of bioaccumulating substances exceeds this level.

d Field triplicate

e Field duplicate

g Normalised to 1% TOC

h Data are normally distributed and the UCL was calculated using Student's t-Test method

i Data are lognormal and the UCL was calculated using 95% H-UCL

j Data are Gamma distributed and the UCL was calculated using the non-parametric Jack-knife method

NA Not Applicable - all concentrations below PQLs

NG No Guideline

* Normalisation is only appropriate over the TOC range 0.2-10 per cent (equates to multiplication factors of 5 times - 0.1 times, respectively. Outside this range the end value which applies is used (e.g. for less than 0.2 per cent TOC, 5 times the total TPH/TOC value is used.

Note: At sites where field duplicates and triplicates were taken, the data point for that site was represented by the mean concentration in all samples

Table 6: Summary of organic compound results for offshore sediments - February 2009

		TOC	Total Petroleum Hydrocarbons (mg/kg)						BTEX Compounds (mg/kg)					TBT	TBT[g]
		%	C_6-C_9	C_{10}-C_{14}	C_{15}-C_{28}	C_{26}-C_{36}	Total (C_{10}-C_{36})	Total (C_{10}-C_{36})[g]	Benzene	Toluene	Ethylbenzene	meta- & para-Xylene	ortho-Xylene	µgSn/kg	µgSn/kg
	PQL[a]	0.02	3	3	3	5	14	14	0.2	0.2	0.2	0.2	0.2	0.5	0.5
Screening levels[b]		NG	NG	NG	NG	NG	550	550	NG	NG	NG	NG	NG	9	9
High levels[c]		NG	100	500	1000	NG	NG	NG	NG	NG	NG	NG	NG	70	70
Site ID	Sample ID														
W2	W2	0.22	<3	<3	17	13	36	164	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.14
W3	W3	0.27	<3	<3	20	15	41	152	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.93
W4	W4	0.28	5	<3	18	16	42	150	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	0.89
W5	W5	0.25	21	<3	20	17	61	244	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.00
W6	W6	0.25	42	<3	16	12	73	292	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.00
W12	W12	0.23	<3	4	31	16	54	235	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.09
W13	W13	0.09	<3	<3	21	14	41	205*	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.25*
W14	W14	0.13	7	<3	13	9	32	160	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	1.25*
standard mean		**0.2**	**10.13**	**1.8**	**19.5**	**14.0**	**47.5**	**200.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.25**	**1.07**
standard deviation		**0.1**	**14.48**	**88**	**5.3**	**2.6**	**14.0**	**52.6**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.14**
95% UCL		**0.3**[i]	**19.82**[i]	**NA**	**23.1**[h]	**15.8**[h]	**56.8**[h]	**235.5**[i]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**1.16**[h]

a Practical Quantitation Limit (detection limit)
b DEWHA 2009, National Assessment Guidelines for Dredging - level of substance in sediments below which toxic effects on marine organisms are not expected
c DEWHA 2009, National Assessment Guidelines for Dredging - bioacumulation testing is required when concnetrations of bioaccumulating substances exceeds this level
d Field triplicate
e Field duplicate
g Normalised to 1% TOC
h Data are normally distributed and the UCL was calculated using Student's t-Test method
i Data are lognormal and the UCL was calculated using 95% H-UCL
j Data are Gamma distributed and the UCL was calculated using the non-parametric Jack-knife method
NA Not Applicable - all concentrations below PQLs
NG No Guideline
* Normalisation is only appropriate over the TOC range 0.2-10 per cent (equates to multiplication factors of 5 times - 0.1 times, respectively. Outside this range the end value which applies is used (e.g. for less than 0.2 per cent TOC, 5 times the total TPH/TOC value is used.
Note: At sites where field duplicates and triplicates were taken, the data point for that site was represented by the mean concentration in all samples

Table 7: Summary of particle size distribution results for nearshore sediments- February 2009

% Composition		**Clay**	**Silt**	**Fine Sand**	**Medium Sand**	**Coarse Sand**	**Gravel**	**Silt/Clay**
Site ID	**Sample ID**	<4 µ	4 - 62 µ	62 – 250 µ	250 – 500 µ	500 – 2000 µ	>2000 µ	%
W1	W1	1.6	2.2	44.7	38.6	10.4	2.5	3.8
W7	W7	7.8	13.7	24.1	20.8	15.3	18.3	21.5
W8	W8	13.7	18.5	4.5	21.9	30.9	10.5	32.2
W9	W9	34.5	54.5	8.8	0.0	0.4	1.8	89.0
W10	W10	22.3	32.1	26.6	12.0	3.2	3.8	54.4
W11	W11	15.7	23.9	44.2	14.5	1.6	0.1	39.6
W15	W15	1.4	1.3	2.9	46.3	30.9	17.2	2.7
W16	W16	6.3	8.5	6.2	15.8	41.5	21.8	14.7
W17	W17	5.9	8.4	41.6	28.8	8.8	6.6	14.3
W18	W18	9.3	10.2	13.0	26.4	17.9	23.3	19.5
W19	W19	9.4	11.3	4.3	1.7	4.3	69.1	20.7
W20	W20	13.5	18.1	32.0	22.5	8.4	5.5	31.6
W21	W21	5.6	6.3	32.5	31.8	11.8	12.0	11.9
W22	W22	6.4	8.8	46.5	26.9	7.0	4.5	15.2
W23	W23	12.3	24.5	50.6	10.7	1.6	0.2	36.9
W24	W24	8.4	15.6	53.0	16.1	5.0	1.9	24.0
W25	W25	6.5	14.4	41.1	17.3	12.3	8.4	20.9
standard mean		10.6	16.0	28.0	20.7	12.4	12.2	26.6
standard deviation		8.1	12.8	18.1	12.0	11.8	16.5	20.7

Table 8: Summary of particle size distribution results for offshore sediments - February 2009

% Composition		**Clay**	**Silt**	**Fine Sand**	**Medium Sand**	**Coarse Sand**	**Gravel**	**Silt/Clay**
Site ID	**Sample ID**	<4 µ	4 - 62 µ	62 – 250 µ	250 – 500 µ	500 – 2000 µ	>2000 µ	%
W2	W2	3.3	6.4	63.8	21.6	4.3	0.7	9.7
W3	W3	4.0	12.0	61.0	14.5	5.0	3.5	16.0
W4	W4	4.4	12.1	60.2	17.4	3.8	2.2	16.5
W5	W5	4.5	13.4	54.3	15.1	7.5	5.2	17.9
W6	W6	3.1	6.6	59.5	25.4	3.5	1.9	9.7
W12	W12	2.3	3.9	9.8	16.6	26.6	40.8	6.2
W13	W13	0.0	0.0	21.3	63.0	15.0	7.0	0.0
W14	W14	0.0	0.0	35.6	55.8	7.8	0.8	0.0
standard mean		2.7	6.8	45.7	28.7	9.2	7.8	9.5
standard deviation		1.8	5.3	20.8	19.4	8.0	13.5	7.2

Table 9: RPD/RSD calculations for metals from field duplicate and triplicate samples - Wheatstone pilot sediment sampling program

		Al	Fe	As	Cd	Cr	Cu	Mn	Ni	Pb	V	Zn	Hg
	UNIT	mg/kg											
	PQL[a]	50	50	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2	0.1	0.01
Site ID	**Sample ID**												
W16	W16	4140	15300	17.9	<0.1	18.9	4	257	6.9	4.1	29.6	9.5	<0.01
W16	T1[d]	4990	23900	36.9	0.1	22.9	5	422	8.6	5	42.9	11.5	<0.01
W16	T2[d]	3510	14500	21.4	<0.1	16.2	3.3	285	5.8	4	29	7.9	<0.01
RSD		17.6%	29.1%	39.8%	-	17.4%	20.8%	27.5%	19.9%	12.6%	23.2%	18.7%	-
W18	W18	5940	26500	19.1	<0.1	37.8	8.7	344	12.2	6	53.6	20.1	<0.01
W18	T3[d]	4990	21800	12.4	<0.1	28.1	7.2	434	11	5.8	41.3	16.8	<0.01
W18	T4[d]	5260	22100	19.3	<0.1	31.2	7.3	415	10.6	5.5	43.8	16.8	<0.01
RSD		9.1%	11.2%	23.2%	-	15.3%	10.8%	11.9%	7.4%	4.4%	14.1%	10.6%	-
W20	W20	7510	34100	21.9	<0.1	42.6	11.4	465	14.7	7.5	60.7	26.2	0.01
W20	R1[e]	7060	35200	24.2	<0.1	43.6	10.9	550	14.7	7.6	63.6	26.7	<0.01
RPD		6.2%	3.2%	10.0%	-	2.3%	4.5%	16.7%	0.0%	1.3%	4.7%	1.9%	-
W22	W22	7000	34300	29.8	<0.1	38.4	9.6	510	13.4	7.5	59.6	22.1	<0.01
W22	T5[d]	6700	35300	30.5	<0.1	41.8	9.6	511	13.9	7.7	63.2	22.3	0.01
W22	T6[d]	6540	34300	29.7	<0.1	40.1	9.2	472	13.2	7.3	60.4	21.3	<0.01
RSD		3.5%	1.7%	1.5%	-	4.2%	2.4%	4.5%	2.7%	2.7%	3.1%	2.4%	-
W23	W23	8530	27600	23	<0.1	37.4	11.6	622	15.9	7.4	48.5	23	<0.01
W23	R2[e]	6630	23300	22.3	<0.1	30.1	7.9	488	11.6	6.1	40.2	16.8	<0.01
RPD		25.1%	16.9%	3.1%	-	21.6%	37.9%	24.1%	31.3%	19.3%	18.7%	31.2%	-

RPD/RSD	Above the NAGD (2009) guideline of 50%
a	Practical Quantitation Limit (detection limit)
d	Field triplicate
e	Field duplicate
RSD	Realitive Standard Deviation
RPD	Realitive Percentage Difference
-	cannot calculate RSD/RPD due to results below the laboratory PQL

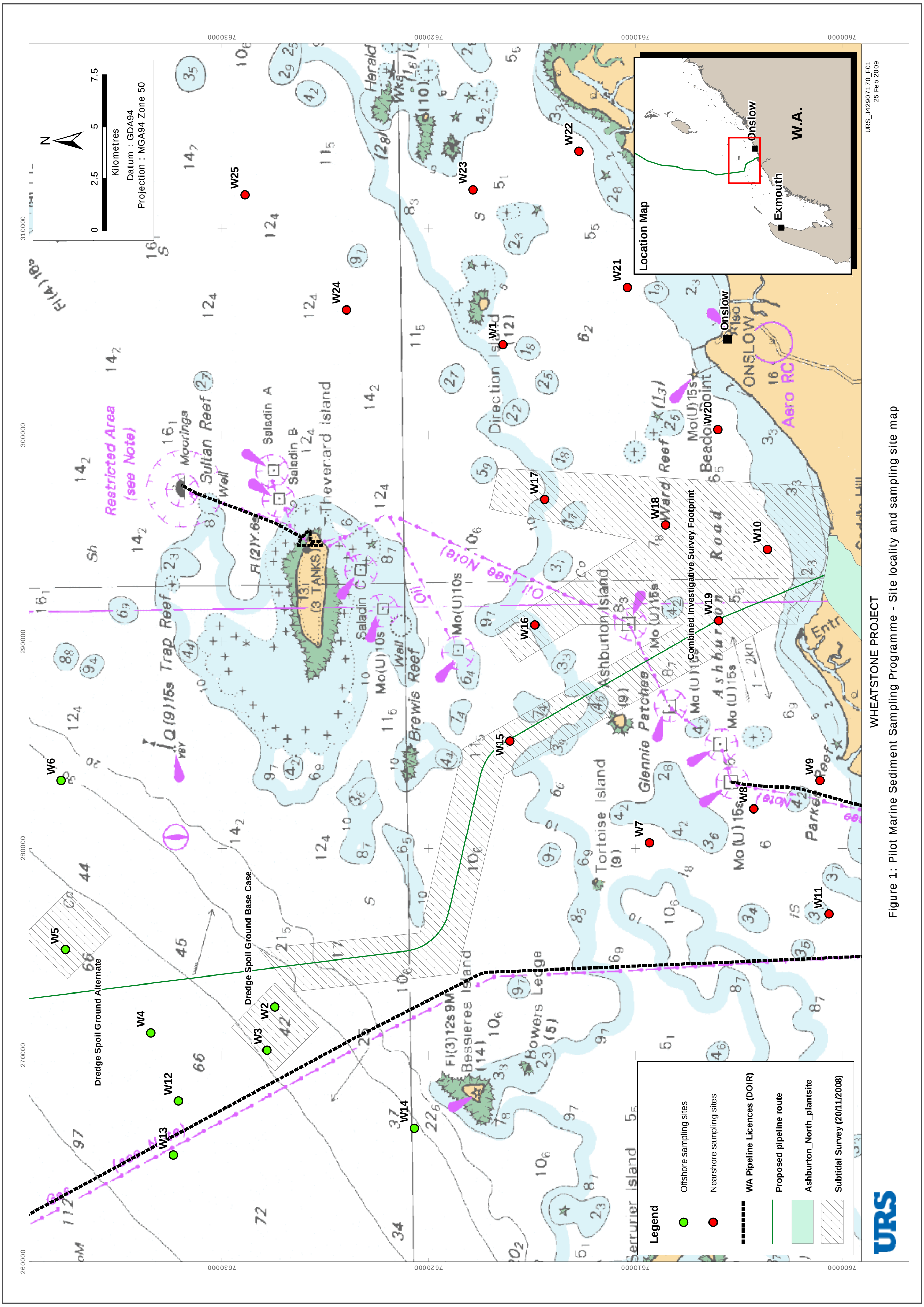
Table 10: RPD/RSD calculations for organic compounds from field duplicate and triplicate samples - Wheatstone pilot sediment sampling program

		TOC	Total Petroleum Hydrocarbons (mg/kg)				BTEX Compounds (mg/kg)					TBT
		%	C_6-C_9	C_{10}-C_{14}	C_{15}-C_{28}	C_{26}-C_{36}	Benzene	Toluene	Ethylbenzene	meta- & para-Xylene	ortho-Xylene	µgSn/kg
	PQL^{a}	0.02	3	3	3	5	0.2	0.2	0.2	0.2	0.2	0.5
Site ID	**Sample ID**											
W16	W16	0.24	<3	4	21	13	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
W16	T1^{d}	0.24	<3	<3	16	7	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
W16	T2^{d}	0.21	<3	<3	6	<5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
RSD		7.5%	-	-	53.3%	42.4%	-	-	-	-	-	-
W18	W18	0.21	<3	<3	12	13	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
W18	T3^{d}	0.27	<3	<3	9	5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
W18	T4^{d}	0.23	<3	<3	8	<5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
RSD		12.9%	-	-	21.5%	62.9%	-	-	-	-	-	-
W20	W20	0.27	<3	<3	12	9	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
W20	R1^{e}	0.28	<3	<3	<3	<5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
RPD		3.6%	-	-	-	-	-	-	-	-	-	-
W22	W22	0.24	<3	<3	8	6	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
W22	T5^{d}	0.25	<3	<3	9	<5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
W22	T6^{d}	0.19	<3	<3	8	<5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
RSD		14.2%	-	-	6.9%	-	-	-	-	-	-	-
W23	W23	0.34	<3	<3	14	9	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
W23	R2^{e}	0.34	<3	<3	<3	<5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5
RPD		0.0%	-	-	-	-	-	-	-	-	-	-

RPD/RSD	Above the NAGD (2009) guideline of 50%
a	Practical Quantitation Limit (detection limit)
d	Field triplicate
e	Field duplicate
RSD	Realitive Standard Deviation
RPD	Realitive Percentage Difference
-	cannot calculate RSD/RPD due to results below the laboratory PQL

PILOT MARINE SEDIMENT QUALITY REPORT FOR THE
WHEATSTONE PROJECT, ONSLOW WA

Figures



WHEATSTONE PROJECT

Figure 1: Pilot Marine Sediment Sampling Programme - Site locality and sampling site map

PILOT MARINE SEDIMENT QUALITY REPORT FOR THE WHEATSTONE PROJECT, ONSLOW WA

Appendices

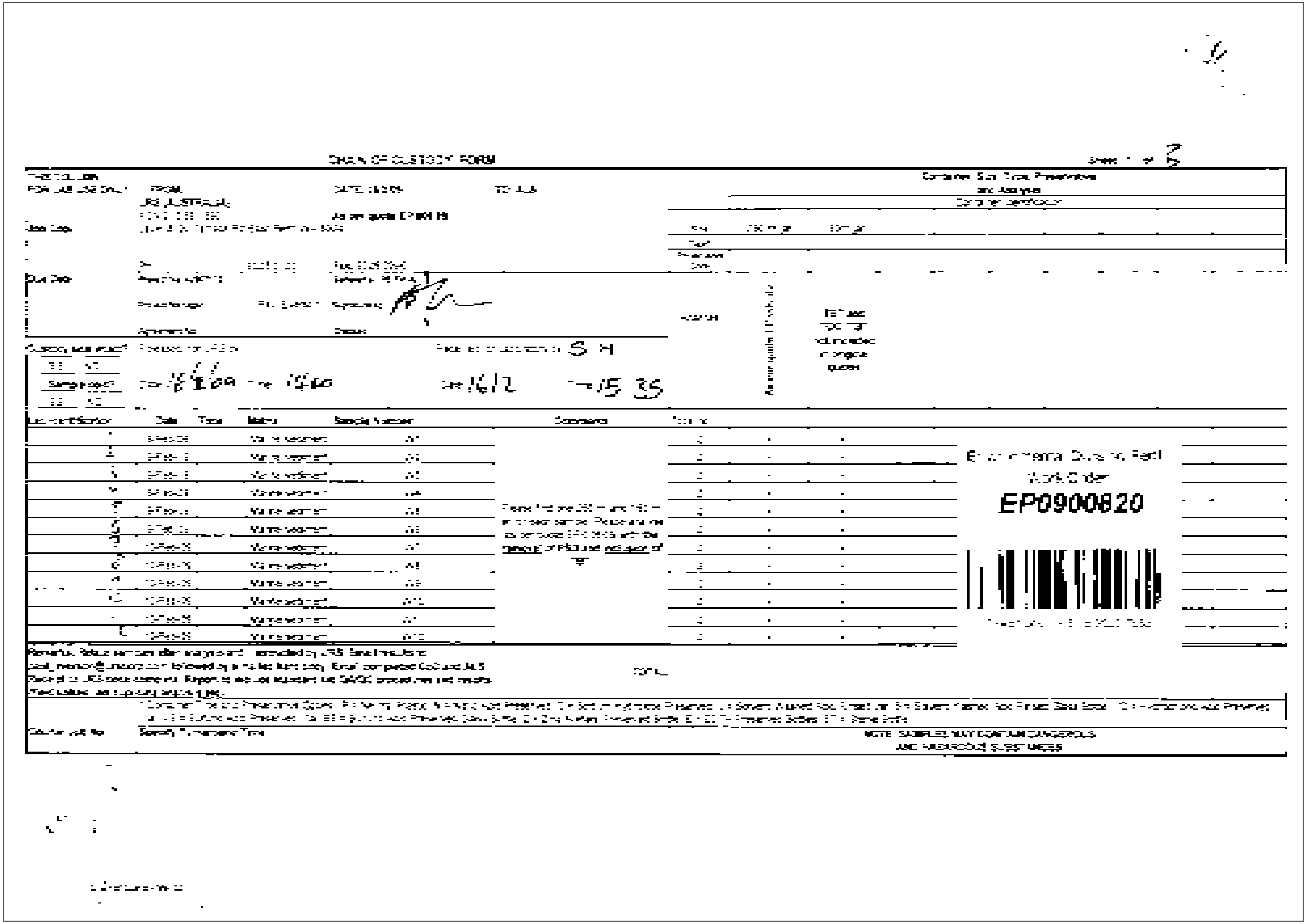
Prepared for Chevron Australia Pty Ltd, 27 March 2009
Ref: 42907170 – 2163 / R1395 / DK: M&C3064

PILOT MARINE SEDIMENT QUALITY REPORT FOR THE WHEATSTONE PROJECT, ONSLOW WA

URS Chain of Custody

Appendix A

Prepared for Chevron Australia Pty Ltd, 27 March 2009
Ref: 42907170 – 2163 / R1395 / DK: M&C3064



CHAIN OF CUSTODY FORM

Sheet 1 of 2

FOR LAB USE ONLY

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DATE: [illegible]

TO: ALS

Container Size, Type, Preservative and Analyses

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2	9-Feb-09		Marine sediment	A2		2
3	9-Feb-09		Marine sediment	A3		2
4	9-Feb-09		Marine sediment	A4		2
5	9-Feb-09		Marine sediment	A5		2
6	9-Feb-09		Marine sediment	A6		2
7	10-Feb-09		Marine sediment	A7		2
8	10-Feb-09		Marine sediment	A8		2
9	10-Feb-09		Marine sediment	A9		2
10	10-Feb-09		Marine sediment	A10		2
11	10-Feb-09		Marine sediment	A11		2
12	10-Feb-09		Marine sediment	A12		2

Date 16/2/09 Time 1500

Date 16/2 Time 15 35

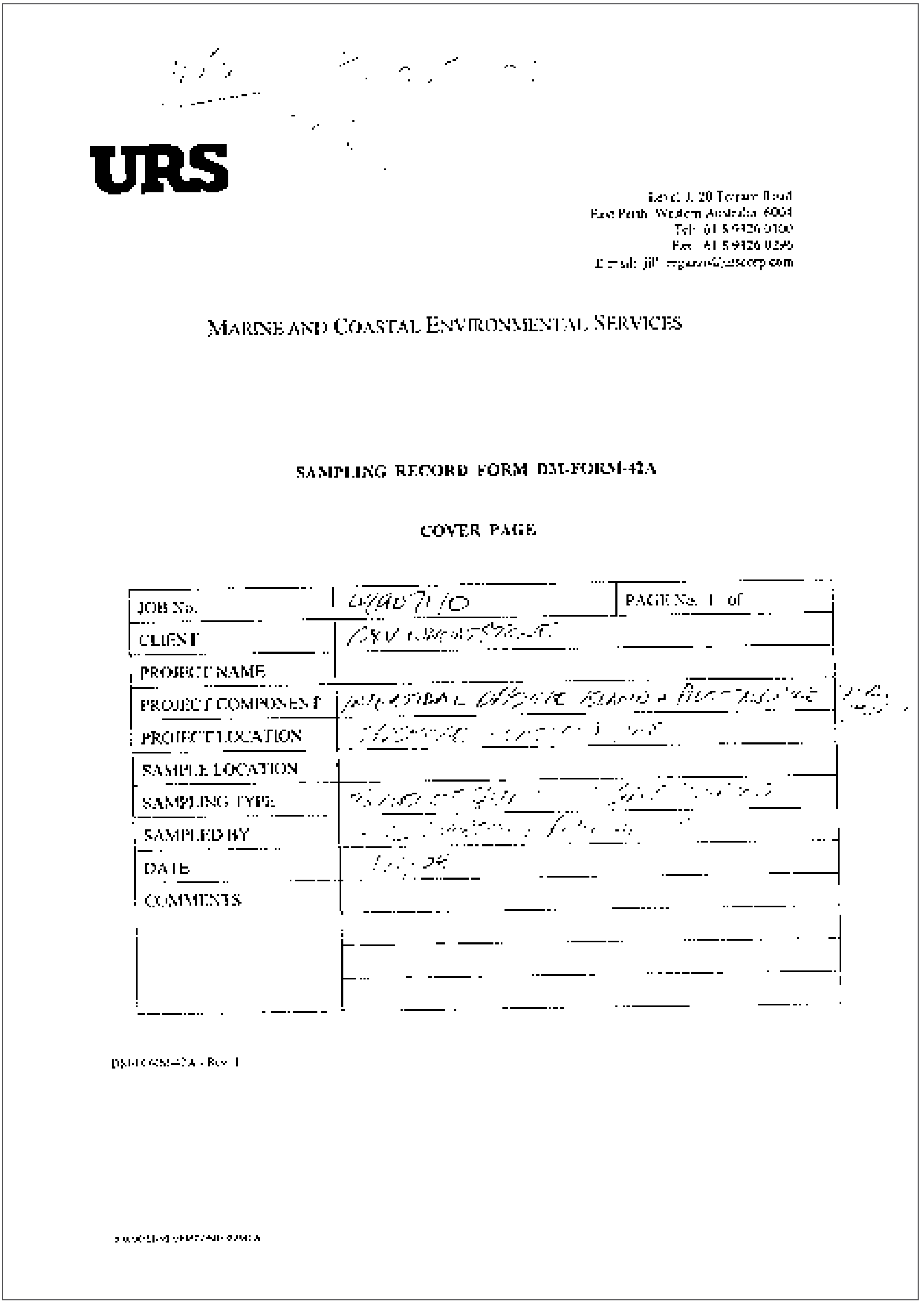
Environmental Division Perth
Work Order
EP0900820

Remarks:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

URS Field Data Sheets

Appendix B



URS

Level 3, 20 Terrace Road
East Perth Western Australia 6004
Tel: 61 8 9326 0100
Fax: 61 8 9326 0296
E-mail: jill [illegible]@urscorp.com

MARINE AND COASTAL ENVIRONMENTAL SERVICES

SAMPLING RECORD FORM DM-FORM-42A

COVER PAGE

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SAMPLE LOCATION		
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SAMPLED BY	[illegible]	
DATE	[illegible]	
COMMENTS		

DM-FORM-42A - Rev 1

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MAN

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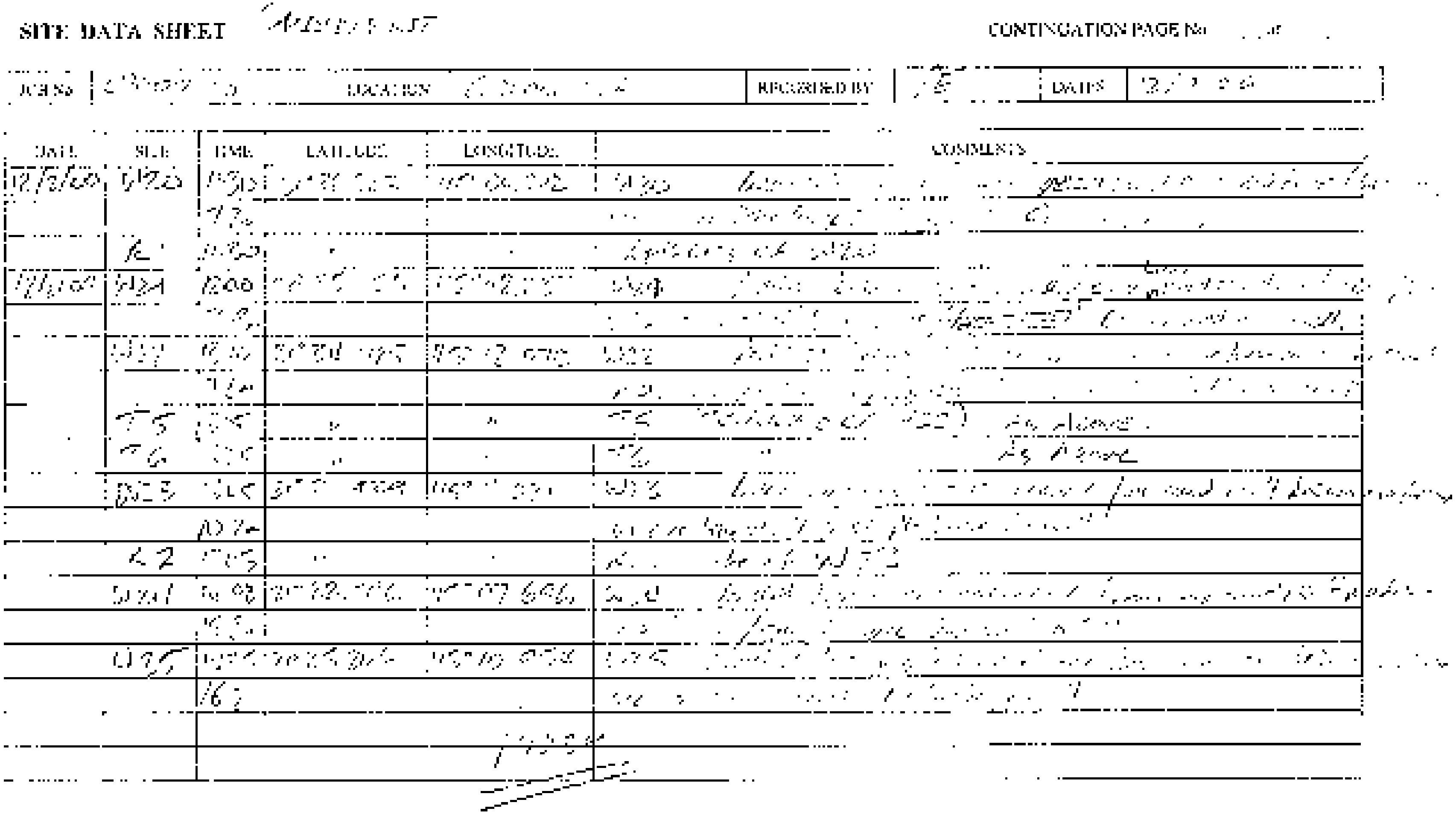

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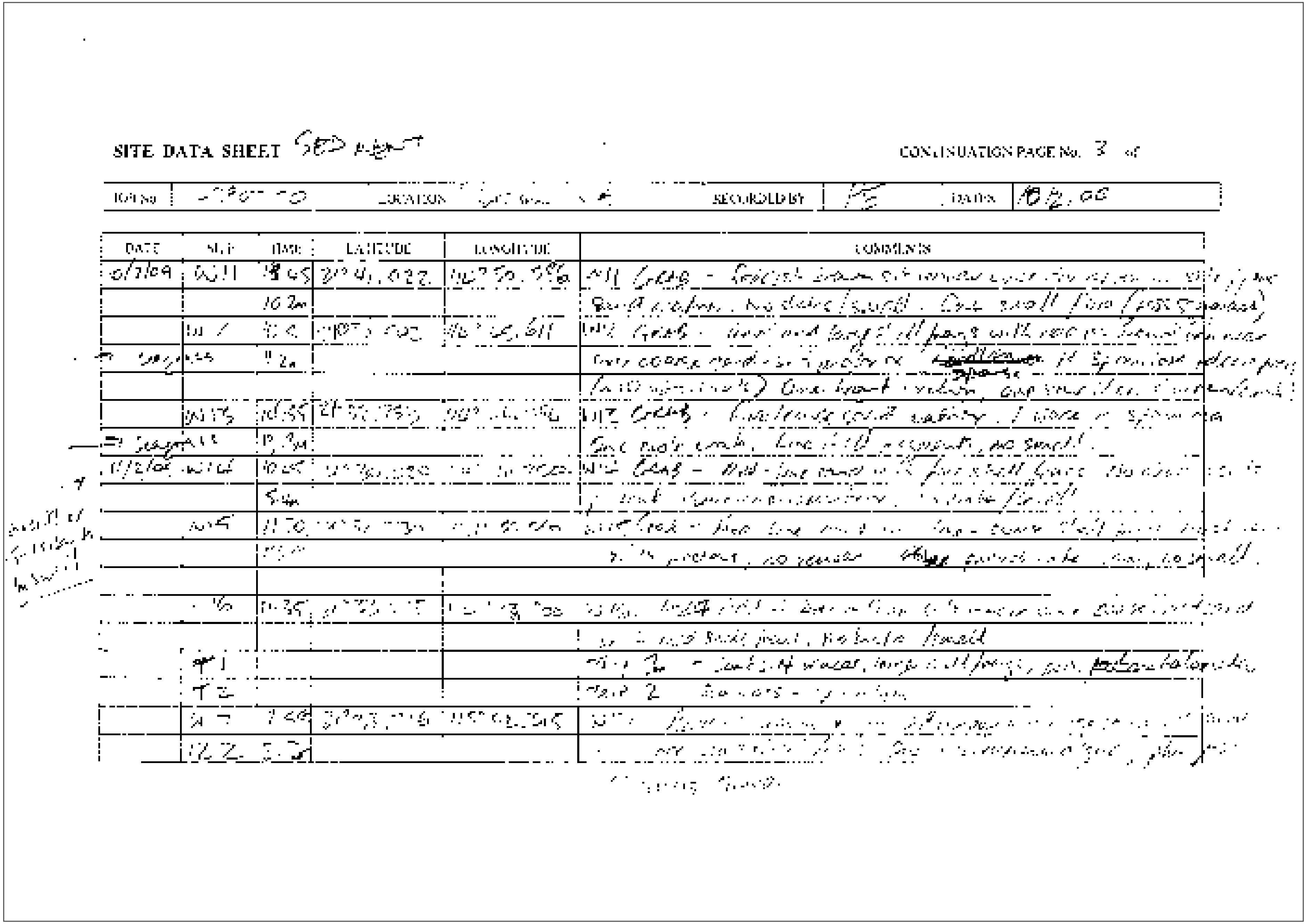

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0/2/09	W11	9:45	21° 41.022	114° 50.956	W11 Grab - Greyish brown silt [illegible]
		10.2m			[illegible], no [illegible] / smell. One small [illegible] ([illegible])
	W1[illegible]	[illegible]	[illegible]	114° [illegible], 611	W1[illegible] Grab - [illegible] and large shell frags with [illegible]
	[illegible]	11.2m			[illegible] coarse sand [illegible]
					([illegible]) One [illegible]
	W13	10:35	21° [illegible]	[illegible]	W13 Grab - [illegible]
		12.3m			[illegible], no smell.
11/2/09	W14	10:25	[illegible]	[illegible]	W14 Grab - Mid-fine sand [illegible] fine shell [illegible]
		5.4m			[illegible]
	W15	11:30	[illegible]	[illegible]	W15 Grab - [illegible]
		[illegible]			[illegible], no [illegible], no smell.
	W16	11:35	[illegible]	[illegible]	W16 [illegible]
					[illegible]
	T1				[illegible] - [illegible] large shell frags, [illegible]
	T2				Trap 2 [illegible]
	W17	[illegible]	21° [illegible]	11[illegible]° [illegible]	W17 [illegible]
	W[illegible]	5.[illegible]m			[illegible]

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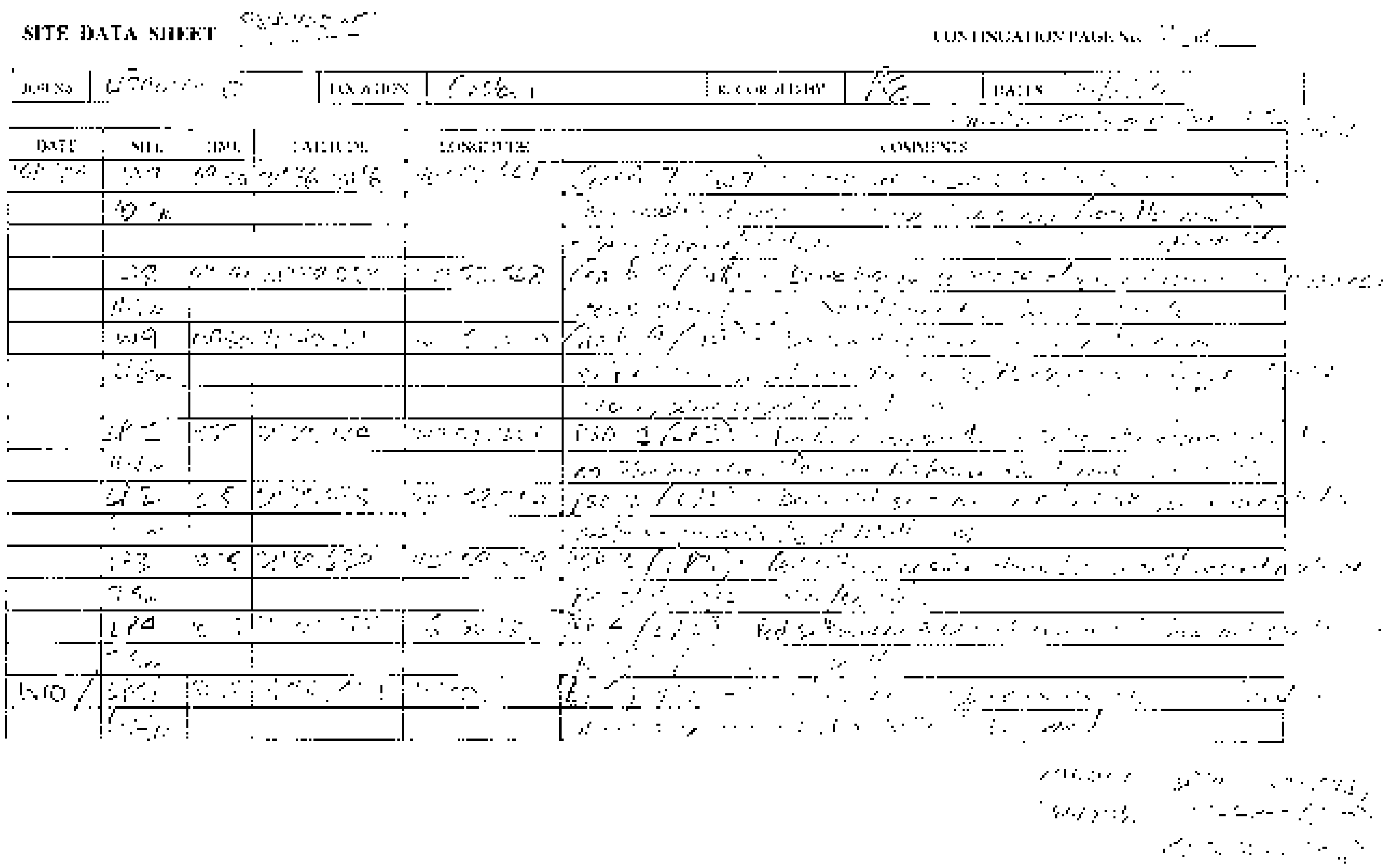

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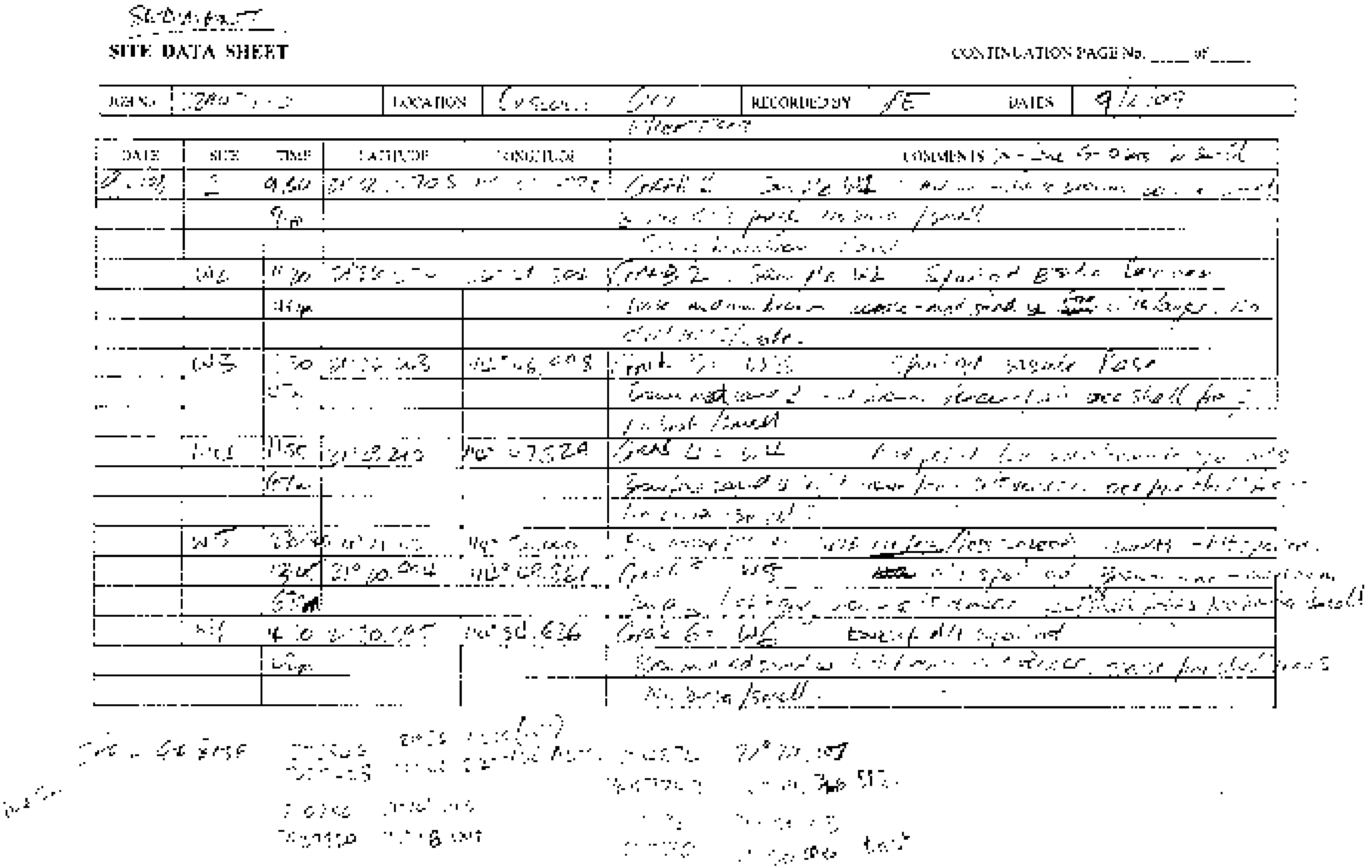

Sediment

SITE DATA SHEET

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		9.[illegible]			[illegible]
					[illegible]
	W2	11.30	[illegible]	[illegible] 308	Grab 2 . [illegible] Spatial [illegible]
		[illegible]			[illegible]
					[illegible]
	W3	1.30	21° [illegible] .443	115° 46.008	[illegible] W3 [illegible]
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					[illegible]
	[illegible]	11.50	21° 23.240	115° 07.524	Grab 2 [illegible]
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					[illegible]
	W5	[illegible]	21° [illegible]	115° [illegible]	[illegible]
		12.40	21° 20.804	115° 07.361	Grab 2 W5 [illegible]
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	W1	4.10	21° 20.185	115° 30.636	Grab 2 W6 [illegible]
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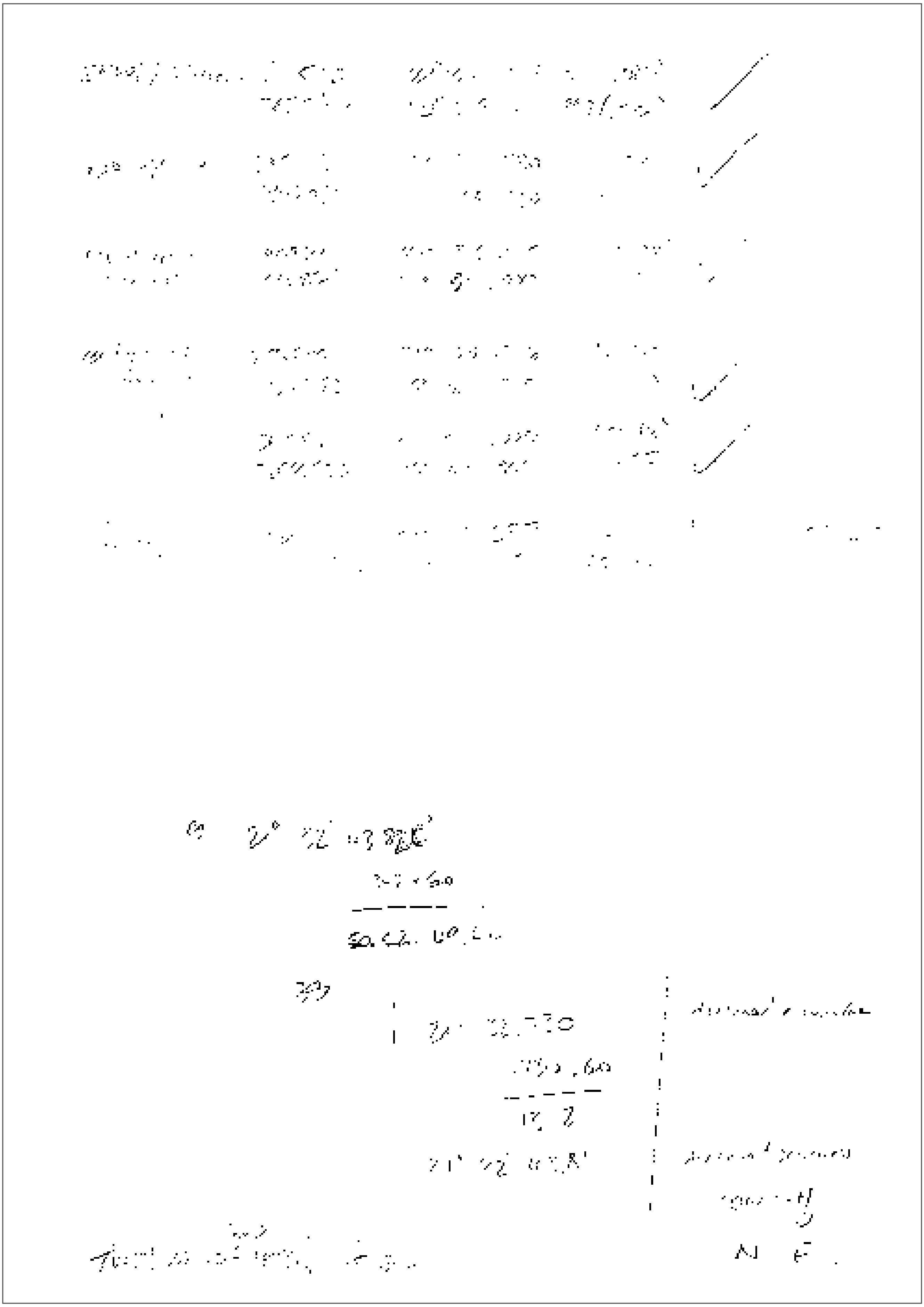
					[illegible]

[illegible]



PILOT MARINE SEDIMENT QUALITY REPORT FOR THE
WHEATSTONE PROJECT, ONSLOW WA

Original Laboratory Reports

Appendix C

Prepared for Chevron Australia Pty Ltd, 27 March 2009
Ref: 42907170 – 2163 / R1395 / DK: M&C3064

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EP0900820**

Client : **URS AUSTRALIA PTY LTD**
Contact : PAUL EVERSON
Address : LEVEL 3, HYATT CENTRE
20 TERRACE RD
EAST PERTH WA, AUSTRALIA 6004

E-mail : Paul_Everson@URSCorp.com
Telephone : +61 08 9326 0221
Facsimile : +61 08 9221 1639

Project : 42907170
Order number : ----
C-O-C number : ----
Sampler : PE & FW
Site : ----

Quote number : EN/001/08

Page : 1 of 19

Laboratory : Environmental Division Perth
Contact : Michael Sharp
Address : 10 Hod Way Malaga WA Australia 6090

E-mail : michael.sharp@alsenviro.com
Telephone : +61-8-9209 7655
Facsimile : +61-8-9209 7600

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 16-FEB-2009
Issue Date : 04-MAR-2009

No. of samples received : 35
No. of samples analysed : 35

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
		Organics
		Organics
Edwandy Fadjar	Senior Organic Chemist	Organics
Hoa Nguyen	Inorganic Chemist	Inorganics
Kim McCabe	Senior Inorganic Chemist	Stafford Minerals - AY
Sanjeshni Jyoyi Mala	Senior Chemist Volatile	Organics
Wisam Abou-Maraseh	Spectroscopist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EP080-SD:C6 -C9 positive for various samples due to presence of 2-methoxy-2-methyl-Propane.**
- **LCS recovery for some elements falls outside ALS Dynamic Control Limit. However, they are within the acceptance criteria based on ALS DQO. No further action is required.**

Page : 4 of 19
Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	W1	W2	W3	W4	W5
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-001**	**EP0900820-002**	**EP0900820-003**	**EP0900820-004**	**EP0900820-005**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**26.5**	**34.4**	**37.5**	**38.3**	**33.0**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**2270**	**3120**	**3590**	**3760**	**3840**
Iron	7439-89-6	50	mg/kg	**11900**	**8130**	**9420**	**11600**	**14500**
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	**24.1**	**7.26**	**6.44**	**4.70**	**4.94**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	**0.1**	**0.1**	**0.1**	**0.1**
Chromium	7440-47-3	1.0	mg/kg	**14.3**	**17.7**	**19.2**	**21.6**	**21.4**
Copper	7440-50-8	1.0	mg/kg	**1.8**	**2.6**	**3.1**	**3.3**	**3.1**
Cobalt	7440-48-4	0.5	mg/kg	**3.7**	**2.1**	**2.4**	**2.5**	**2.6**
Lead	7439-92-1	1.0	mg/kg	**2.9**	**2.9**	**3.3**	**3.7**	**4.0**
Manganese	7439-96-5	10	mg/kg	**250**	**109**	**118**	**119**	**108**
Nickel	7440-02-0	1.0	mg/kg	**3.6**	**5.5**	**6.6**	**8.2**	**7.9**
Vanadium	7440-62-2	2.0	mg/kg	**26.7**	**10.8**	**10.0**	**8.9**	**8.4**
Zinc	7440-66-6	1.0	mg/kg	**5.7**	**6.2**	**7.6**	**8.5**	**8.6**
EG020T: Total Metals by ICP-MS								
Barium	7440-39-3	0.1	mg/kg	**9.3**	**12.3**	**12.4**	**12.4**	**12.3**
Beryllium	7440-41-7	0.1	mg/kg	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	0.02	%	**0.09**	**0.22**	**0.27**	**0.28**	**0.25**
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	**5**	**21**
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**9**	**17**	**20**	**18**	**20**
C29 - C36 Fraction	----	5	mg/kg	**8**	**13**	**15**	**16**	**17**
EP080-SD: BTEX								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**84.7**	**96.3**	**105**	**111**	**81.4**

A Campbell Brothers Limited Company

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**W1**	**W2**	**W3**	**W4**	**W5**
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-001**	**EP0900820-002**	**EP0900820-003**	**EP0900820-004**	**EP0900820-005**
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
Toluene-D8	2037-26-5	0.1	%	**94.6**	**87.8**	**97.5**	**93.5**	**87.8**
4-Bromofluorobenzene	460-00-4	0.1	%	**90.6**	**82.1**	**88.7**	**99.2**	**92.3**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	**103**	**99.2**	**89.9**	**104**	**103**

Page : 6 of 19
Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**W6**	**W7**	**W8**	**W9**	**W10**
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-006**	**EP0900820-007**	**EP0900820-008**	**EP0900820-009**	**EP0900820-010**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**31.5**	**26.2**	**23.9**	**39.6**	**38.9**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**2860**	**3020**	**5540**	**18200**	**10800**
Iron	7439-89-6	50	mg/kg	**7500**	**11300**	**19300**	**61900**	**39800**
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	**7.65**	**14.6**	**18.8**	**9.29**	**22.4**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	**0.1**	<0.1
Chromium	7440-47-3	1.0	mg/kg	**16.4**	**17.7**	**25.4**	**77.5**	**53.5**
Copper	7440-50-8	1.0	mg/kg	**2.3**	**3.4**	**8.2**	**48.2**	**19.1**
Cobalt	7440-48-4	0.5	mg/kg	**2.0**	**3.4**	**7.7**	**23.7**	**15.5**
Lead	7439-92-1	1.0	mg/kg	**2.8**	**3.3**	**5.1**	**16.7**	**10.5**
Manganese	7439-96-5	10	mg/kg	**100**	**194**	**393**	**1060**	**670**
Nickel	7440-02-0	1.0	mg/kg	**5.2**	**5.4**	**10.2**	**42.2**	**21.9**
Vanadium	7440-62-2	2.0	mg/kg	**8.4**	**24.2**	**38.1**	**97.3**	**71.3**
Zinc	7440-66-6	1.0	mg/kg	**6.0**	**8.0**	**15.9**	**69.4**	**37.5**
EG020T: Total Metals by ICP-MS								
Barium	7440-39-3	0.1	mg/kg	**11.4**	**7.5**	**10.1**	**56.7**	**16.8**
Beryllium	7440-41-7	0.1	mg/kg	**0.2**	**0.2**	**0.3**	**0.8**	**0.6**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	**0.03**	**0.01**
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	0.02	%	**0.25**	**0.12**	**0.24**	**0.85**	**0.35**
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	**42**	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	**6**	<3
C15 - C28 Fraction	----	3	mg/kg	**16**	**13**	**10**	**54**	**25**
C29 - C36 Fraction	----	5	mg/kg	**12**	**10**	**9**	**33**	**16**
EP080-SD: BTEX								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**107**	**120**	**90.9**	**110**	**105**

A Campbell Brothers Limited Company

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**W6**	**W7**	**W8**	**W9**	**W10**
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-006**	**EP0900820-007**	**EP0900820-008**	**EP0900820-009**	**EP0900820-010**
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
Toluene-D8	2037-26-5	0.1	%	**104**	**99.6**	**107**	**89.7**	**91.6**
4-Bromofluorobenzene	460-00-4	0.1	%	**113**	**92.0**	**102**	**97.7**	**101**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	**103**	**86.4**	**104**	**96.0**	**99.4**

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	W11	W12	W13	W14	W15
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	EP0900820-011	EP0900820-012	EP0900820-013	EP0900820-014	EP0900820-015
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	35.3	26.3	24.8	23.0	21.0
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	10200	2820	730	1100	2010
Iron	7439-89-6	50	mg/kg	33100	12300	2580	4660	12500
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	19.8	23.9	7.38	12.1	29.8
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	45.1	17.6	11.4	19.0	15.1
Copper	7440-50-8	1.0	mg/kg	15.3	2.3	<1.0	<1.0	1.8
Cobalt	7440-48-4	0.5	mg/kg	13.3	2.2	<0.5	0.7	2.7
Lead	7439-92-1	1.0	mg/kg	9.1	3.1	1.1	1.5	3.0
Manganese	7439-96-5	10	mg/kg	471	156	37	66	225
Nickel	7440-02-0	1.0	mg/kg	19.5	4.4	1.1	1.7	3.8
Vanadium	7440-62-2	2.0	mg/kg	58.0	30.5	9.1	14.6	32.0
Zinc	7440-66-6	1.0	mg/kg	30.9	5.7	1.3	2.2	4.5
EG020T: Total Metals by ICP-MS								
Barium	7440-39-3	0.1	mg/kg	16.1	12.6	10.1	9.1	7.1
Beryllium	7440-41-7	0.1	mg/kg	0.5	0.2	<0.1	0.1	0.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	0.02	%	0.33	0.23	0.09	0.13	0.16
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	7	22
C10 - C14 Fraction	----	3	mg/kg	<3	4	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	18	31	21	13	13
C29 - C36 Fraction	----	5	mg/kg	14	16	14	9	10
EP080-SD: BTEX								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	115	115	104	106	115

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**W11**	**W12**	**W13**	**W14**	**W15**
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-011**	**EP0900820-012**	**EP0900820-013**	**EP0900820-014**	**EP0900820-015**
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
Toluene-D8	2037-26-5	0.1	%	**94.6**	**93.7**	**98.6**	**94.1**	**103**
4-Bromofluorobenzene	460-00-4	0.1	%	**100**	**100**	**92.4**	**90.2**	**101**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	**77.4**	**95.4**	**87.5**	**98.7**	**86.3**

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Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	W16	W17	W18	W19	W20
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	EP0900820-016	EP0900820-017	EP0900820-018	EP0900820-019	EP0900820-020
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	29.2	30.7	27.9	31.9	26.7
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	4140	4410	5940	11400	7510
Iron	7439-89-6	50	mg/kg	15300	22000	26500	31400	34100
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	17.9	16.0	19.1	20.8	21.9
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	18.9	30.4	37.8	45.6	42.6
Copper	7440-50-8	1.0	mg/kg	4.0	5.0	8.7	16.7	11.4
Cobalt	7440-48-4	0.5	mg/kg	5.0	7.3	10.3	12.6	13.5
Lead	7439-92-1	1.0	mg/kg	4.1	5.3	6.0	9.0	7.5
Manganese	7439-96-5	10	mg/kg	257	272	344	618	465
Nickel	7440-02-0	1.0	mg/kg	6.9	8.8	12.2	20.1	14.7
Vanadium	7440-62-2	2.0	mg/kg	29.6	39.1	53.6	58.7	60.7
Zinc	7440-66-6	1.0	mg/kg	9.5	12.8	20.1	32.4	26.2
EG020T: Total Metals by ICP-MS								
Barium	7440-39-3	0.1	mg/kg	9.9	8.8	11.0	17.8	12.4
Beryllium	7440-41-7	0.1	mg/kg	0.3	0.2	0.3	0.5	0.4
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	0.01	0.01
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	0.02	%	0.24	0.13	0.21	0.37	0.27
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	4	<3	<3	5	<3
C15 - C28 Fraction	----	3	mg/kg	21	18	12	25	12
C29 - C36 Fraction	----	5	mg/kg	13	15	13	16	9
EP080-SD: BTEX								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	120	116	90.0	113	101

A Campbell Brothers Limited Company

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	W16	W17	W18	W19	W20
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	EP0900820-016	EP0900820-017	EP0900820-018	EP0900820-019	EP0900820-020
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
Toluene-D8	2037-26-5	0.1	%	**95.3**	**105**	**90.5**	**102**	**91.2**
4-Bromofluorobenzene	460-00-4	0.1	%	**99.2**	**100**	**95.3**	**97.1**	**83.6**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	**112**	**124**	**97.8**	**115**	**110**

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Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**W21**	**W22**	**W23**	**W24**	**W25**
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-021**	**EP0900820-022**	**EP0900820-023**	**EP0900820-024**	**EP0900820-025**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**27.4**	**30.2**	**46.1**	**36.2**	**31.8**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**4400**	**7000**	**8530**	**5130**	**4700**
Iron	7439-89-6	50	mg/kg	**24300**	**34300**	**27600**	**19000**	**17800**
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	**27.5**	**29.8**	**23.0**	**20.9**	**21.0**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**26.9**	**38.4**	**37.4**	**26.5**	**25.0**
Copper	7440-50-8	1.0	mg/kg	**5.0**	**9.6**	**11.6**	**5.0**	**4.0**
Cobalt	7440-48-4	0.5	mg/kg	**10.5**	**12.7**	**10.7**	**6.6**	**5.4**
Lead	7439-92-1	1.0	mg/kg	**5.2**	**7.5**	**7.4**	**5.1**	**4.3**
Manganese	7439-96-5	10	mg/kg	**468**	**510**	**622**	**316**	**300**
Nickel	7440-02-0	1.0	mg/kg	**8.4**	**13.4**	**15.9**	**9.5**	**7.9**
Vanadium	7440-62-2	2.0	mg/kg	**46.2**	**59.6**	**48.5**	**29.0**	**26.7**
Zinc	7440-66-6	1.0	mg/kg	**14.7**	**22.1**	**23.0**	**12.2**	**9.8**
EG020T: Total Metals by ICP-MS								
Barium	7440-39-3	0.1	mg/kg	**8.0**	**10.2**	**13.8**	**11.4**	**12.5**
Beryllium	7440-41-7	0.1	mg/kg	**0.2**	**0.4**	**0.5**	**0.3**	**0.3**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	0.02	%	**0.17**	**0.24**	**0.34**	**0.27**	**0.28**
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**7**	**8**	**14**	**11**	**21**
C29 - C36 Fraction	----	5	mg/kg	<5	**6**	**9**	**8**	**11**
EP080-SD: BTEX								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**93.5**	**93.4**	**88.6**	**92.0**	**115**

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Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**W21**	**W22**	**W23**	**W24**	**W25**
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-021**	**EP0900820-022**	**EP0900820-023**	**EP0900820-024**	**EP0900820-025**
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
Toluene-D8	2037-26-5	0.1	%	**92.7**	**92.4**	**86.4**	**88.7**	**112**
4-Bromofluorobenzene	460-00-4	0.1	%	**90.5**	**90.9**	**83.8**	**95.9**	**110**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	**108**	**126**	**75.1**	**63.0**	**76.0**

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Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Analytical Results

Sub-Matrix: **SOIL**

Compound	*CAS Number*	*LOR*	*Unit*	T1	T2	T3	T4	T5
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
				EP0900820-026	**EP0900820-027**	**EP0900820-028**	**EP0900820-029**	**EP0900820-030**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**31.0**	**28.7**	**31.3**	**26.7**	**30.6**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**4990**	**3510**	**4990**	**5260**	**6700**
Iron	7439-89-6	50	mg/kg	**23900**	**14500**	**21800**	**22100**	**35300**
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	**36.9**	**21.4**	**12.4**	**19.3**	**30.5**
Cadmium	7440-43-9	0.1	mg/kg	**0.1**	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**22.9**	**16.2**	**28.1**	**31.2**	**41.8**
Copper	7440-50-8	1.0	mg/kg	**5.0**	**3.3**	**7.2**	**7.3**	**9.6**
Cobalt	7440-48-4	0.5	mg/kg	**6.8**	**4.8**	**10.3**	**9.5**	**12.5**
Lead	7439-92-1	1.0	mg/kg	**5.0**	**4.0**	**5.8**	**5.5**	**7.7**
Manganese	7439-96-5	10	mg/kg	**422**	**285**	**434**	**415**	**511**
Nickel	7440-02-0	1.0	mg/kg	**8.6**	**5.8**	**11.0**	**10.6**	**13.9**
Vanadium	7440-62-2	2.0	mg/kg	**42.9**	**29.0**	**41.3**	**43.8**	**63.2**
Zinc	7440-66-6	1.0	mg/kg	**11.5**	**7.9**	**16.8**	**16.8**	**22.3**
EG020T: Total Metals by ICP-MS								
Barium	7440-39-3	0.1	mg/kg	**13.4**	**10.6**	**10.6**	**10.7**	**9.9**
Beryllium	7440-41-7	0.1	mg/kg	**0.3**	**0.2**	**0.3**	**0.3**	**0.4**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	**0.01**
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	0.02	%	**0.24**	**0.21**	**0.27**	**0.23**	**0.25**
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**16**	**6**	**9**	**8**	**9**
C29 - C36 Fraction	----	5	mg/kg	**7**	<5	**5**	<5	<5
EP080-SD: BTEX								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**91.5**	**93.5**	**92.9**	**82.9**	**96.3**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**T1**	**T2**	**T3**	**T4**	**T5**
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-026**	**EP0900820-027**	**EP0900820-028**	**EP0900820-029**	**EP0900820-030**
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
Toluene-D8	2037-26-5	0.1	%	**92.7**	**94.4**	**94.0**	**95.5**	**93.2**
4-Bromofluorobenzene	460-00-4	0.1	%	**89.1**	**90.5**	**92.3**	**93.3**	**92.0**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	**85.7**	**74.7**	**68.3**	**56.0**	**87.6**

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Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**T6**	**R1**	**R2**	**Trip Blank**	----
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	[17-FEB-2009]	----
Compound	CAS Number	LOR	Unit	**EP0900820-031**	**EP0900820-032**	**EP0900820-033**	**EP0900820-035**	**----**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**29.5**	**29.4**	**38.6**	<1.0	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**6540**	**7060**	**6630**	<50	----
Iron	7439-89-6	50	mg/kg	**34300**	**35200**	**23300**	<50	----
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	**29.7**	**24.2**	**22.3**	<1.00	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----
Chromium	7440-47-3	1.0	mg/kg	**40.1**	**43.6**	**30.1**	<1.0	----
Copper	7440-50-8	1.0	mg/kg	**9.2**	**10.9**	**7.9**	<1.0	----
Cobalt	7440-48-4	0.5	mg/kg	**11.8**	**15.1**	**8.8**	<0.5	----
Lead	7439-92-1	1.0	mg/kg	**7.3**	**7.6**	**6.1**	<1.0	----
Manganese	7439-96-5	10	mg/kg	**472**	**550**	**488**	<10	----
Nickel	7440-02-0	1.0	mg/kg	**13.2**	**14.7**	**11.6**	<1.0	----
Vanadium	7440-62-2	2.0	mg/kg	**60.4**	**63.6**	**40.2**	<2.0	----
Zinc	7440-66-6	1.0	mg/kg	**21.3**	**26.7**	**16.8**	<1.0	----
EG020T: Total Metals by ICP-MS								
Barium	7440-39-3	0.1	mg/kg	**10.4**	**12.0**	**12.1**	<0.1	----
Beryllium	7440-41-7	0.1	mg/kg	**0.4**	**0.4**	**0.4**	<0.1	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	0.02	%	**0.19**	**0.28**	**0.34**	----	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	----
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	----
C15 - C28 Fraction	----	3	mg/kg	**8**	<3	<3	<3	----
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	----
EP080-SD: BTEX								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	----	----
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**94.6**	**93.1**	**90.0**	**116**	----

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Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

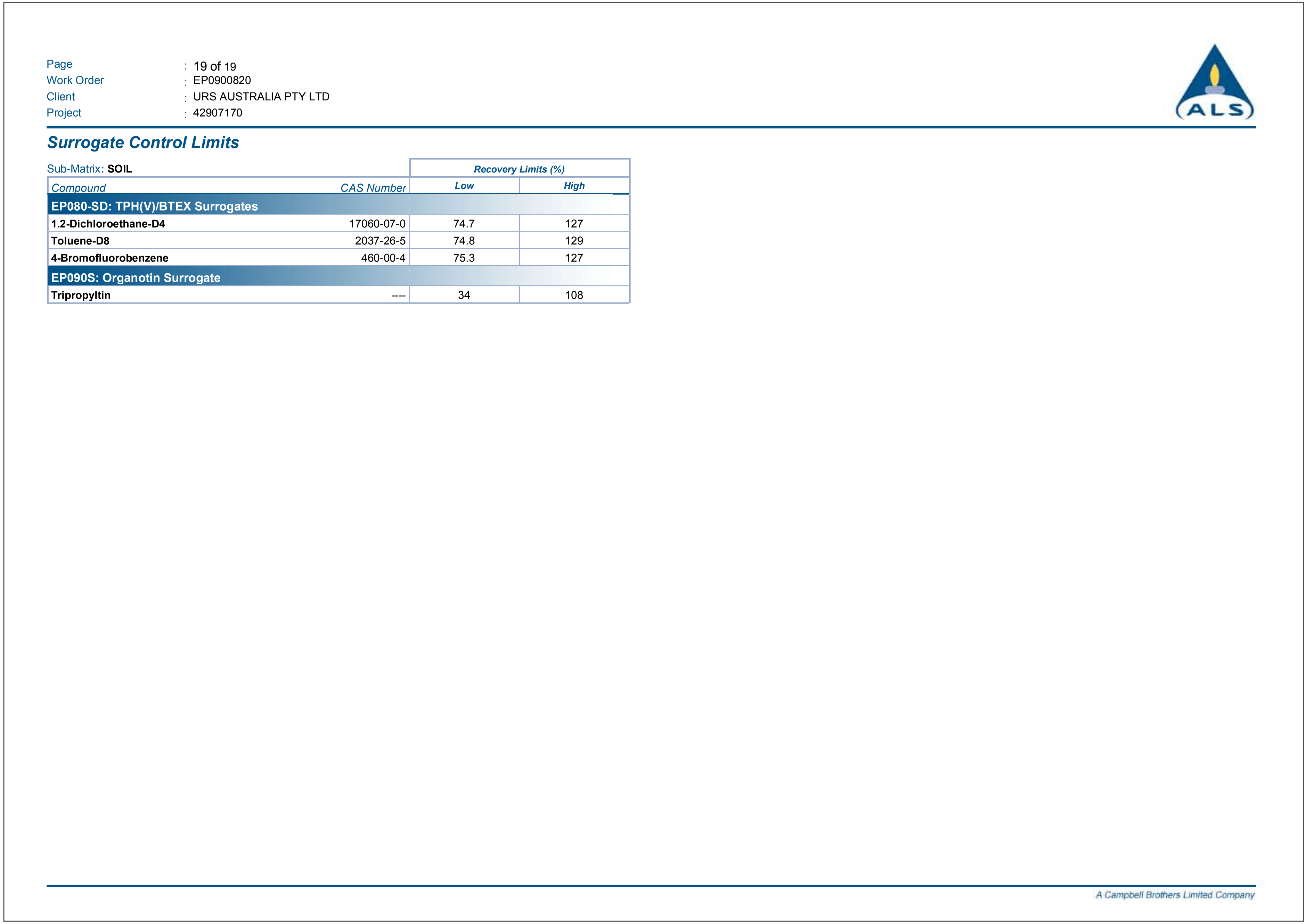
Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**T6**	**R1**	**R2**	**Trip Blank**	----
			Client sampling date / time	09-FEB-2009 15:00	09-FEB-2009 15:00	09-FEB-2009 15:00	[17-FEB-2009]	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-031**	**EP0900820-032**	**EP0900820-033**	**EP0900820-035**	**----**
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
Toluene-D8	2037-26-5	0.1	%	**88.0**	**88.2**	**85.6**	**110**	----
4-Bromofluorobenzene	460-00-4	0.1	%	**89.6**	**85.0**	**85.2**	**110**	----
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	**78.9**	**134**	**109**	----	----

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**Rinsate**	----	----	----	----
			Client sampling date / time	[17-FEB-2009]	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0900820-034**	**----**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Barium	7440-39-3	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	----	----	----	----



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Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	*CAS Number*	*Recovery Limits (%)*	
		Low	*High*
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	74.7	127
Toluene-D8	2037-26-5	74.8	129
4-Bromofluorobenzene	460-00-4	75.3	127
EP090S: Organotin Surrogate			
Tripropyltin	----	34	108

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PILOT MARINE SEDIMENT QUALITY REPORT FOR THE
WHEATSTONE PROJECT, ONSLOW WA

Laboratory Interpretive Quality Control Report

Appendix D

Prepared for Chevron Australia Pty Ltd, 27 March 2009
Ref: 42907170 – 2163 / R1395 / DK: M&C3064

URS

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: **EP0900820**	Page	: 1 of 14
Client	: URS AUSTRALIA PTY LTD	Laboratory	: Environmental Division Perth
Contact	: PAUL EVERSON	Contact	: Michael Sharp
Address	: LEVEL 3, HYATT CENTRE 20 TERRACE RD EAST PERTH WA, AUSTRALIA 6004	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: Paul_Everson@URSCorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0221	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9221 1639	Facsimile	: +61-8-9209 7600
Project	: 42907170	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 16-FEB-2009
Sampler	: PE & FW	Issue Date	: 04-MAR-2009
Order number	: ----		
		No. of samples received	: 35
Quote number	: EN/001/08	No. of samples analysed	: 35

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Interpretive Quality Control Report contains the following information:

- Analysis Holding Time Compliance
- Quality Control Parameter Frequency Compliance
- Brief Method Summaries
- Summary of Outliers

Page : 2 of 14
Work Order : EP0900820
Client : URS AUSTRALIA PTY LTD
Project : 42907170

Analysis Holding Time Compliance

The following report summarises extraction / preparation and analysis times and compares with recommended holding times. Dates reported represent first date of extraction or analysis and precludes subsequent dilutions and reruns. Information is also provided re the sample container (preservative) from which the analysis aliquot was taken. Elapsed period to analysis represents number of days from sampling where no extraction / digestion is involved or period from extraction / digestion where this is present. For composite samples, sampling date is assumed to be that of the oldest sample contributing to the composite. Sample date for laboratory produced leachates is assumed as the completion date of the leaching process. Outliers for holding time are based on USEPA SW 846, APHA, AS and NEPM (1999). A listing of breaches is provided in the Summary of Outliers.

Holding times for leachate methods (excluding elutriates) vary according to the analytes being determined on the resulting solution. For non-volatile analytes, the holding time compliance assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These soil holding times are: Organics (14 days); Mercury (28 days) & other metals (180 days). A recorded breach therefore does not guarantee a breach for all non-volatile parameters.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method	*Sample Date*	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)		*Date extracted*	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EA055: Moisture Content							
Soil Glass Jar - Unpreserved W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W19, W20	**09-FEB-2009**	**----**	----	----	**18-FEB-2009**	16-FEB-2009	×
Soil Glass Jar - Unpreserved W18, W21, W22, W23, W24, W25, T1, T2, T3, T4, T5, T6, R1, R2	**09-FEB-2009**	**----**	----	----	**19-FEB-2009**	16-FEB-2009	×
Soil Glass Jar - Unpreserved Trip Blank	**17-FEB-2009**	**----**	----	----	**19-FEB-2009**	24-FEB-2009	✓

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Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method ***Container** / Client Sample ID(s)*	***Sample Date***	*Extraction / Preparation*			*Analysis*		
		Date extracted	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EG005T: Total Metals by ICP-AES							
Soil Glass Jar - Unpreserved W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W18, W19, W20, W21, W22, W23, W24, W25, T1, T2, T3, T4, T5, T6, R1, R2	**09-FEB-2009**	**19-FEB-2009**	08-AUG-2009	✓	**19-FEB-2009**	08-AUG-2009	✓
Soil Glass Jar - Unpreserved Trip Blank	**17-FEB-2009**	**19-FEB-2009**	16-AUG-2009	✓	**19-FEB-2009**	16-AUG-2009	✓
EG020-SD: Total Metals in Sediments by ICPMS							
Soil Glass Jar - Unpreserved W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W18, W19, W20, W21, W22, W23, W24, W25, T1, T2, T3, T4, T5, T6, R1, R2	**09-FEB-2009**	**19-FEB-2009**	08-AUG-2009	✓	**19-FEB-2009**	08-AUG-2009	✓
Soil Glass Jar - Unpreserved Trip Blank	**17-FEB-2009**	**19-FEB-2009**	16-AUG-2009	✓	**19-FEB-2009**	16-AUG-2009	✓

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Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method		***Sample Date***	*Extraction / Preparation*			*Analysis*		
***Container** / Client Sample ID(s)*			***Date extracted***	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EG020T: Total Metals by ICP-MS								
Soil Glass Jar - Unpreserved								
W1, W3, W5, W7, W9, W11, W13, W15, W17, W19, W21, W23, W25, T2, T4, T6, R2	W2, W4, W6, W8, W10, W12, W14, W16, W18, W20, W22, W24, T1, T3, T5, R1,	**09-FEB-2009**	**19-FEB-2009**	08-AUG-2009	✓	**19-FEB-2009**	08-AUG-2009	✓
Soil Glass Jar - Unpreserved								
Trip Blank		**17-FEB-2009**	**19-FEB-2009**	16-AUG-2009	✓	**19-FEB-2009**	16-AUG-2009	✓
EG035T: Total Recoverable Mercury by FIMS								
Soil Glass Jar - Unpreserved								
W1, W3, W5, W7, W9, W11, W13, W15, W17, W19, W21, W23, W25, T2, T4, T6, R2	W2, W4, W6, W8, W10, W12, W14, W16, W18, W20, W22, W24, T1, T3, T5, R1,	**09-FEB-2009**	**19-FEB-2009**	08-AUG-2009	✓	**20-FEB-2009**	09-MAR-2009	✓
Soil Glass Jar - Unpreserved								
Trip Blank		**17-FEB-2009**	**19-FEB-2009**	16-AUG-2009	✓	**20-FEB-2009**	17-MAR-2009	✓

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Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method	*Sample Date*	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)		*Date extracted*	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EP005: Total Organic Carbon (TOC)							
Soil Glass Jar - Unpreserved							
W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W18, W19, W20, W21, W22, W23, W24, W25, T1, T2, T3, T4, T5, T6, R1, R2	**09-FEB-2009**	**20-FEB-2009**	09-MAR-2009	✓	**23-FEB-2009**	09-MAR-2009	✓

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Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method *Container / Client Sample ID(s)*	*Sample Date*	*Extraction / Preparation*			*Analysis*		
		Date extracted	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons							
Soil Glass Jar - Unpreserved W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W19, W20	**09-FEB-2009**	**18-FEB-2009**	23-FEB-2009	✓	**20-FEB-2009**	23-FEB-2009	✓
Soil Glass Jar - Unpreserved W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W18, W19, W20, W21, W22, W23, W24, W25, T1, T2, T3, T4, T5, T6, R1, R2	**09-FEB-2009**	**19-FEB-2009**	23-FEB-2009	✓	**02-MAR-2009**	31-MAR-2009	✓
Soil Glass Jar - Unpreserved W18, W21, W22, W23, W24, W25, T1, T2, T3, T4, T5, T6, R1, R2	**09-FEB-2009**	**19-FEB-2009**	23-FEB-2009	✓	**23-FEB-2009**	23-FEB-2009	✓
Soil Glass Jar - Unpreserved Trip Blank	**17-FEB-2009**	**19-FEB-2009**	03-MAR-2009	✓	**02-MAR-2009**	31-MAR-2009	✓
Soil Glass Jar - Unpreserved Trip Blank	**17-FEB-2009**	**19-FEB-2009**	03-MAR-2009	✓	**23-FEB-2009**	03-MAR-2009	✓

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Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method *Container / Client Sample ID(s)*	*Sample Date*	*Extraction / Preparation*			*Analysis*		
		Date extracted	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EP080-SD: BTEX							
Soil Glass Jar - Unpreserved W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W19, W20	**09-FEB-2009**	**18-FEB-2009**	23-FEB-2009	✓	**20-FEB-2009**	23-FEB-2009	✓
Soil Glass Jar - Unpreserved W18, W21, W22, W23, W24, W25, T1, T2, T3, T4, T5, T6, R1, R2	**09-FEB-2009**	**19-FEB-2009**	23-FEB-2009	✓	**23-FEB-2009**	23-FEB-2009	✓
Soil Glass Jar - Unpreserved Trip Blank	**17-FEB-2009**	**19-FEB-2009**	03-MAR-2009	✓	**23-FEB-2009**	03-MAR-2009	✓
EP090: Organotin Compounds							
Soil Glass Jar - Unpreserved W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W18, W19, W20, W21, W22, W23, W24, W25, T1, T2, T3, T4, T5, T6, R1, R2	**09-FEB-2009**	**20-FEB-2009**	23-FEB-2009	✓	**25-FEB-2009**	01-APR-2009	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

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Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method ***Container** / Client Sample ID(s)*	***Sample Date***	*Extraction / Preparation*			*Analysis*		
		Date extracted	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Natural Rinsate	**17-FEB-2009**	**19-FEB-2009**	16-AUG-2009	✓	**19-FEB-2009**	16-AUG-2009	✓

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Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(where) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Moisture Content	EA055-103	4	39	**10.3**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Organotin Analysis	EP090	4	33	**12.1**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS (Low Level)	EG035T-LL	4	34	**11.8**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	4	34	**11.8**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite X	EG020X-T	4	34	**11.8**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals in Sediments by ICPMS	EG020-SD	4	34	**11.8**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Organic Carbon	EP005	4	33	**12.1**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
TPH - Semivolatile Fraction	EP071-SD	4	34	**11.8**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
TPH Volatiles/BTEX in Sediments	EP080-SD	4	34	**11.8**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Organotin Analysis	EP090	2	33	**6.1**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS (Low Level)	EG035T-LL	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite X	EG020X-T	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals in Sediments by ICPMS	EG020-SD	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Organic Carbon	EP005	2	33	**6.1**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
TPH - Semivolatile Fraction	EP071-SD	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
TPH Volatiles/BTEX in Sediments	EP080-SD	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Organotin Analysis	EP090	2	33	**6.1**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS (Low Level)	EG035T-LL	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite X	EG020X-T	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals in Sediments by ICPMS	EG020-SD	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Organic Carbon	EP005	2	33	**6.1**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
TPH - Semivolatile Fraction	EP071-SD	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
TPH Volatiles/BTEX in Sediments	EP080-SD	2	34	**5.9**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Organotin Analysis	EP090	2	33	**6.1**	**5.0**	✓	ALS QCS3 requirement
Total Mercury by FIMS (Low Level)	EG035T-LL	2	34	**5.9**	**5.0**	✓	ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	2	34	**5.9**	**5.0**	✓	ALS QCS3 requirement
Total Metals by ICP-MS - Suite X	EG020X-T	2	34	**5.9**	**5.0**	✓	ALS QCS3 requirement
Total Metals in Sediments by ICPMS	EG020-SD	2	34	**5.9**	**5.0**	✓	ALS QCS3 requirement
TPH - Semivolatile Fraction	EP071-SD	2	34	**5.9**	**5.0**	✓	ALS QCS3 requirement
TPH Volatiles/BTEX in Sediments	EP080-SD	2	34	**5.9**	**5.0**	✓	ALS QCS3 requirement

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Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Total Metals by ICP-MS - Suite A	EG020A-T	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Total Metals by ICP-MS - Suite A	EG020A-T	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Total Metals by ICP-MS - Suite A	EG020A-T	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Total Metals by ICP-MS - Suite A	EG020A-T	1	20	**5.0**	**5.0**	✓	ALS QCS3 requirement

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Moisture Content	EA055-103	SOIL	A gravimetric procedure based on weight loss over a 12 hour drying period at 103-105 degrees C. This method is compliant with NEPM (1999) Schedule B(3) (Method 102)
Total Metals by ICP-AES	EG005T	SOIL	(APHA 21st ed., 3120; USEPA SW 846 - 6010) (ICPAES) Metals are determined following an appropriate acid digestion of the soil. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM (1999) Schedule B(3)
Total Metals in Sediments by ICPMS	EG020-SD	SOIL	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector. Analyte list and LORs per NODG.
Total Metals by ICP-MS - Suite X	EG020X-T	SOIL	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Mercury by FIMS (Low Level)	EG035T-LL	SOIL	AS 3550, APHA 21st ed., 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids are determined following an appropriate acid digestion. Ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (1999) Schedule B(3)
Total Organic Carbon	EP005	SOIL	In-house. Dried and pulverised sample is reacted with acid to remove inorganic Carbonates, then combusted in a LECO furnace in the presence of strong oxidants / catalysts. The evolved (Organic) Carbon (as CO2) is automaticaly measured by infra-red detector.
TPH - Semivolatile Fraction	EP071-SD	SOIL	(USEPA SW 846 - 8270B) Extracts are analysed by Capillary GC/MS and quantification is by comparison against an established 5 point calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Method 504)
TPH Volatiles/BTEX in Sediments	EP080-SD	SOIL	(USEPA SW 846 - 8260B) Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve. This method is compliant with NEPM (1999) Schedule B(3) (Method 501)
Organotin Analysis	EP090	SOIL	(USEPA SW 846 - 8270D) Prepared sample extracts are analysed by GC/MS coupled with high volume injection, and quanitified against an established calibration curve.
Total Metals by ICP-MS - Suite A	EG020A-T	WATER	(APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*

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Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Hot Block Digest for metals in soils sediments and sludges	EN69	SOIL	USEPA 200.2 Mod. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils. This method is compliant with NEPM (1999) Schedule B(3) (Method 202)
Methanolic Extraction of Soils for Purge and Trap	* ORG16	SOIL	(USEPA SW 846 - 5030A) 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS.
Tumbler Extraction of Solids for LVI (Non-concentrating)	ORG17D	SOIL	In house: 10g of sample, Na2SO4 and surrogate are extracted with 50mL 1:1 DCM/Acetone by end over end tumbling. An aliquot is concentrated by nitrogen blowdown to a reduced volume for analysis if required.
Organotin Sample Preparation	ORG35	SOIL	In house. 20g sample is spiked with surrogate and leached in a methanol:acetic acid:UHP water mix and vacuum filtered. Reagents and solvents are added to the sample and the mixture tumbled. The butyltin compounds are simultaneously derivatised and extracted. The extract is further extracted with petroleum ether. The resultant extracts are combined and concentrated for analysis.
Digestion for Total Recoverable Metals	EN25	WATER	USEPA SW846-3005 Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2)

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Summary of Outliers

Outliers : Quality Control Samples

The following report highlights outliers flagged in the Quality Control (QC) Report. Surrogate recovery limits are static and based on USEPA SW846 or ALS-QWI/EN/38 (in the absence of specific USEPA limits). This report displays QC Outliers (breaches) only.

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Duplicate outliers occur.**
- **For all matrices, no Laboratory Control outliers occur.**
- **For all matrices, no Matrix Spike outliers occur.**

Regular Sample Surrogates

- **For all regular sample matrices, no surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

This report displays Holding Time breaches only. Only the respective Extraction / Preparation and/or Analysis component is/are displayed.

Matrix: **SOIL**

Method		*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)		*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EA055: Moisture Content							
Soil Glass Jar - Unpreserved							
W1, W3, W5, W7, W9, W11, W13, W15, W17, W20	W2, W4, W6, W8, W10, W12, W14, W16, W19,	----	----	----	18-FEB-2009	16-FEB-2009	**2**
Soil Glass Jar - Unpreserved							
W18, W22, W24, T1, T3, T5, R1,	W21, W23, W25, T2, T4, T6, R2	----	----	----	19-FEB-2009	16-FEB-2009	**3**

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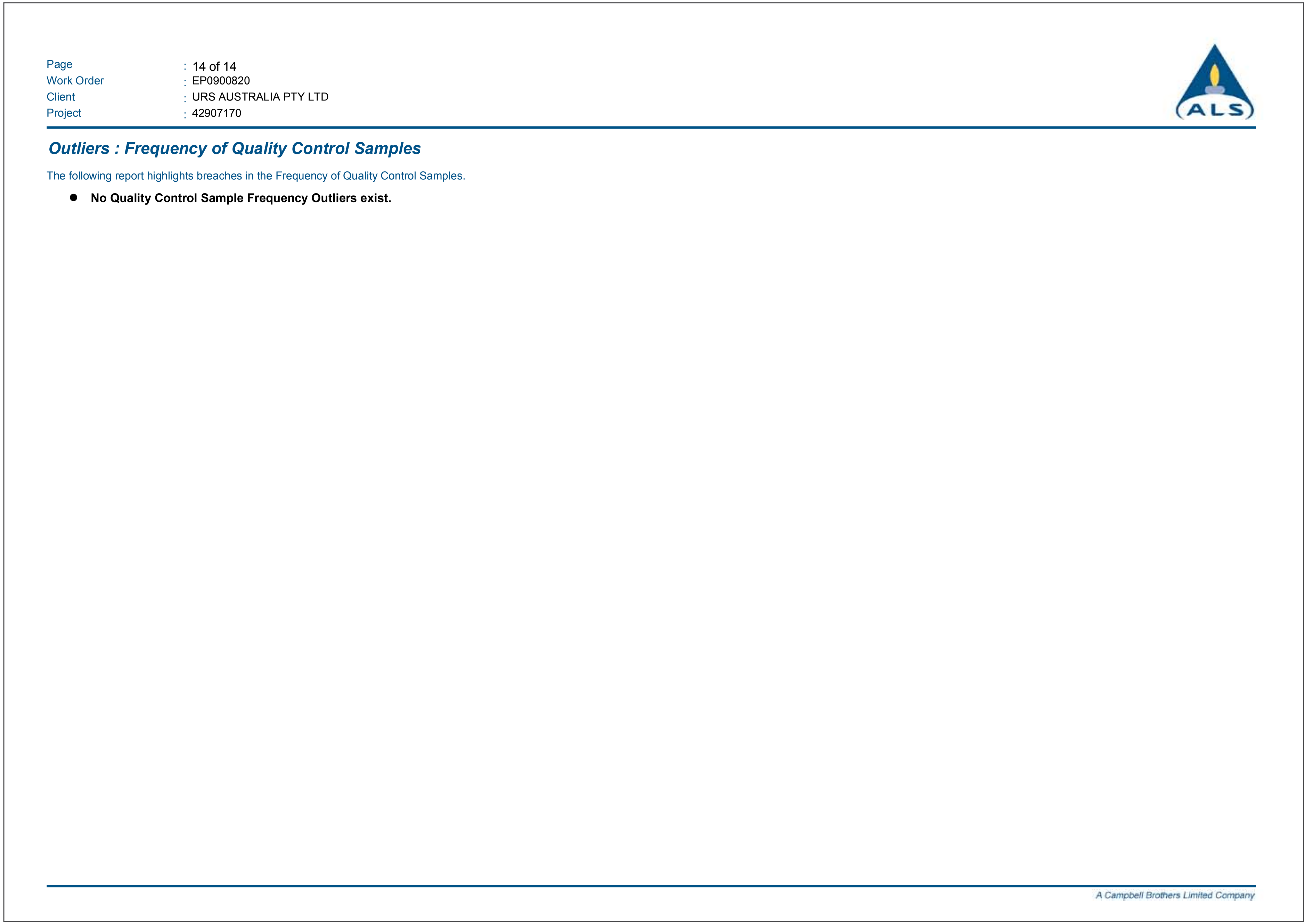

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Outliers : Frequency of Quality Control Samples

The following report highlights breaches in the Frequency of Quality Control Samples.

- **No Quality Control Sample Frequency Outliers exist.**

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Appendix B Short & Deep Core Logs & Photographs

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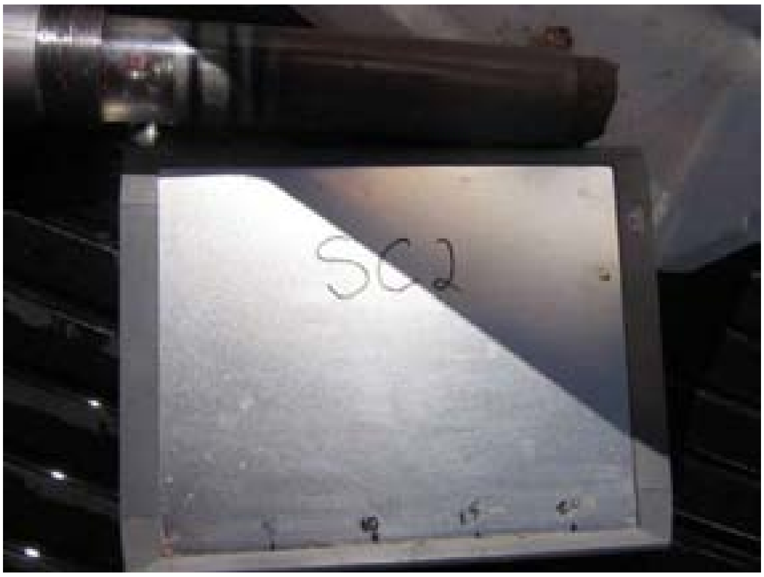
Short Core Photographs

(SC1 – SC17, SC19 – SC72)



Appendix B


SC 6

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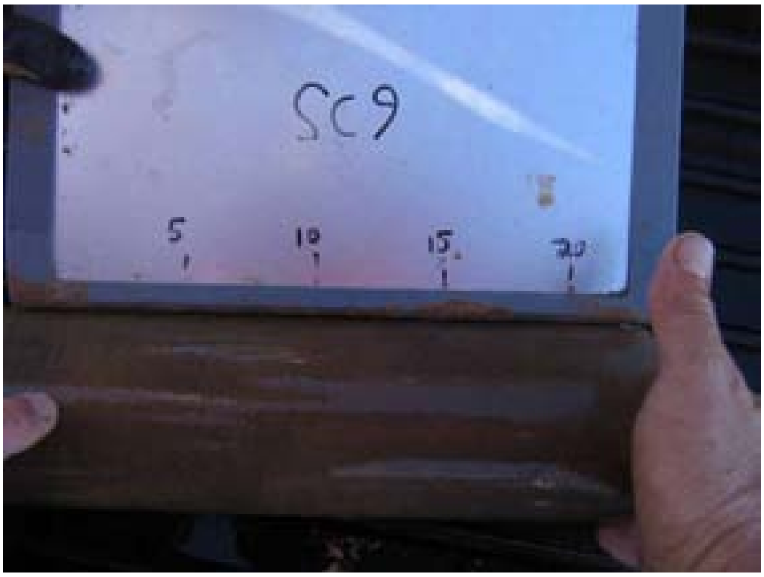
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SC10

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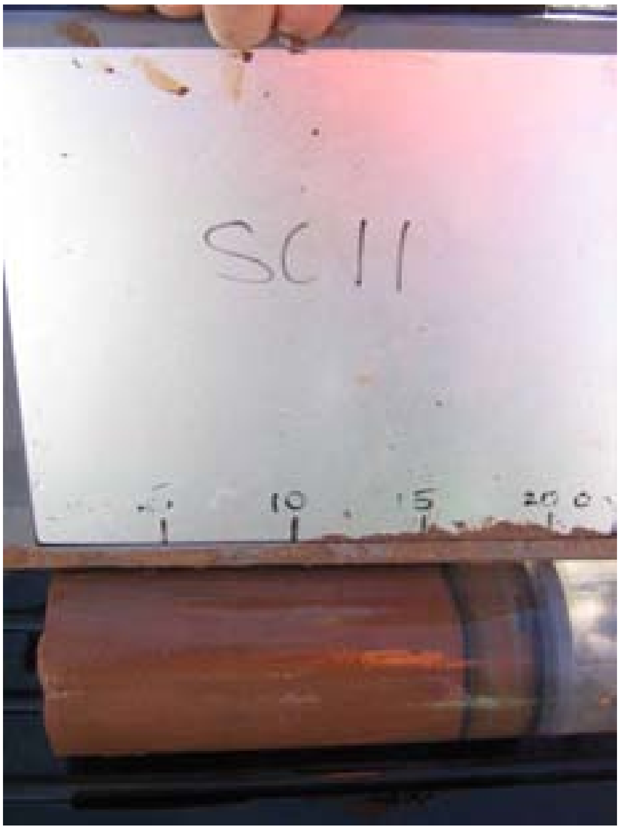

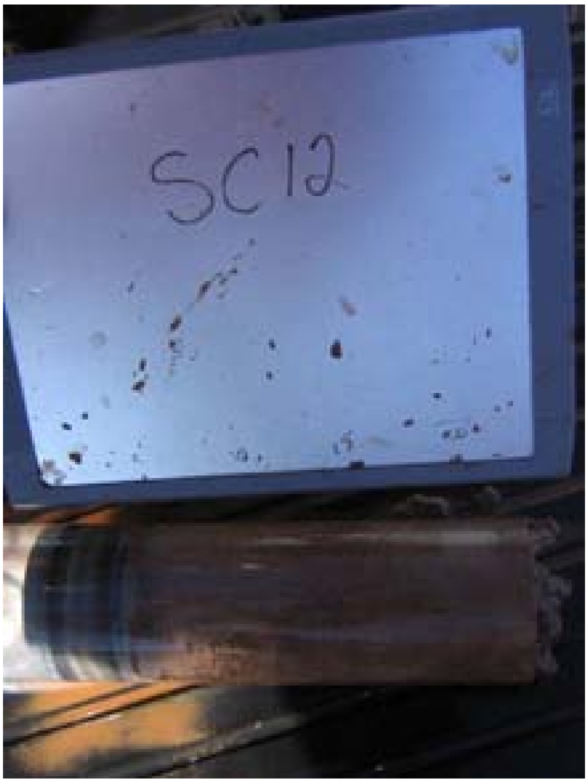
SC12


SC13

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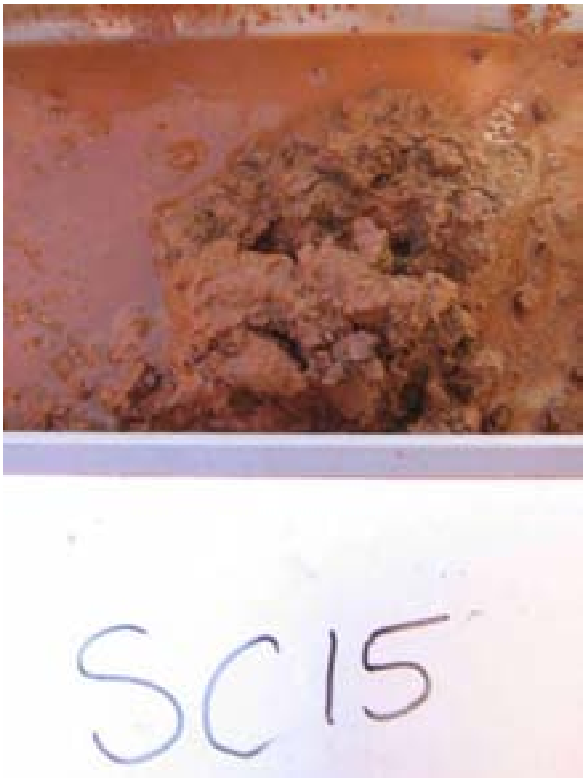

SC16 n/a

SC18 n/a

Appendix B


SC22
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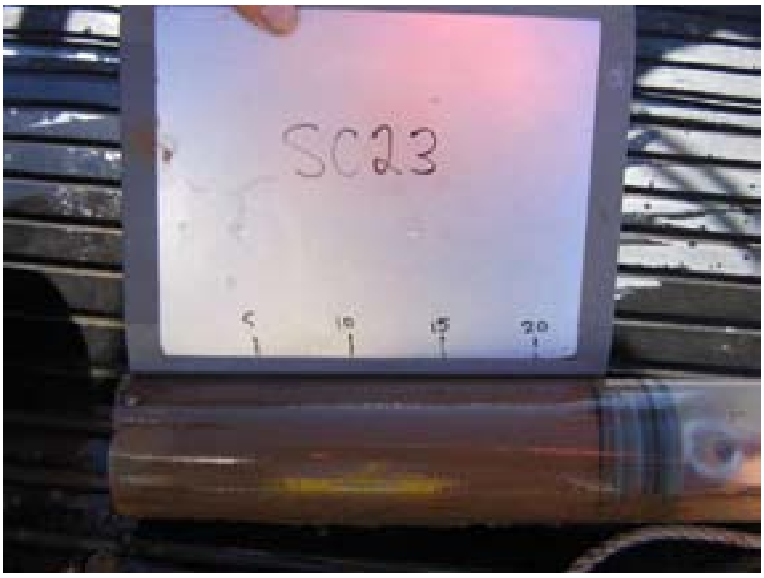
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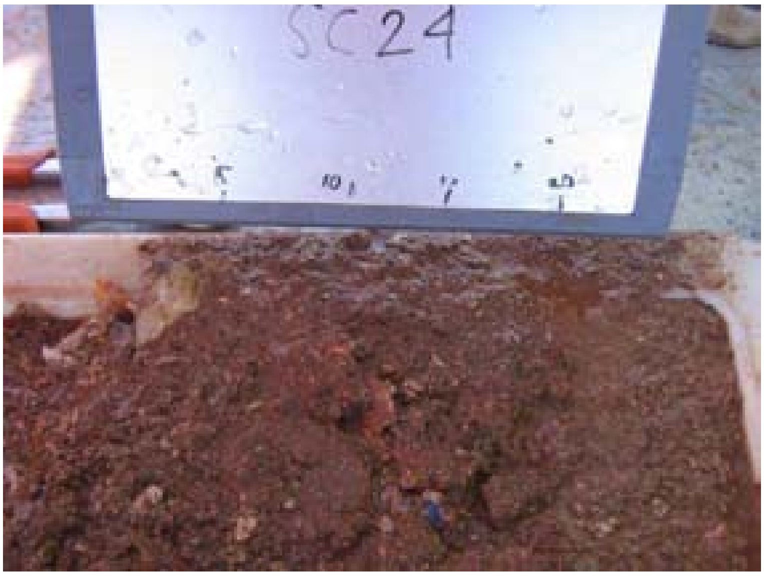
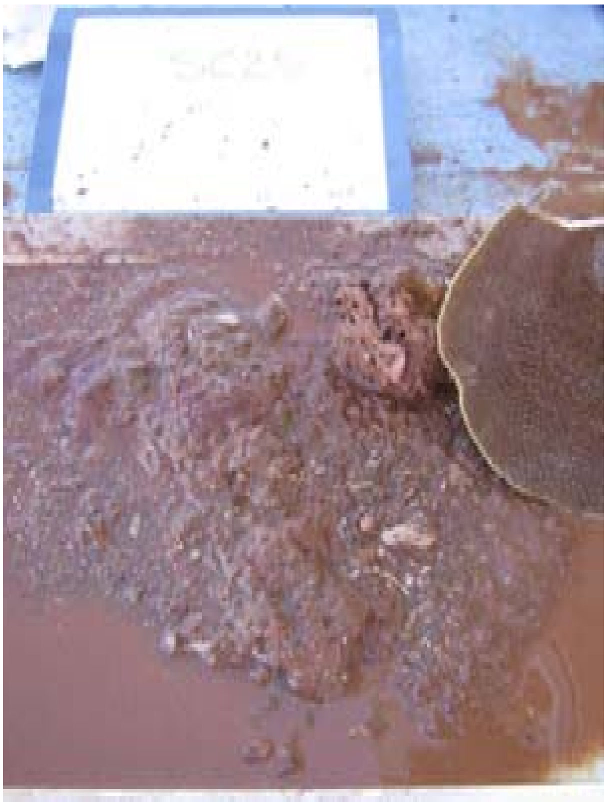
Appendix B






SC26


SC27

Appendix B


SC30
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SC31
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Appendix B


SC34
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SC35
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Appendix B


SC38
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SC39
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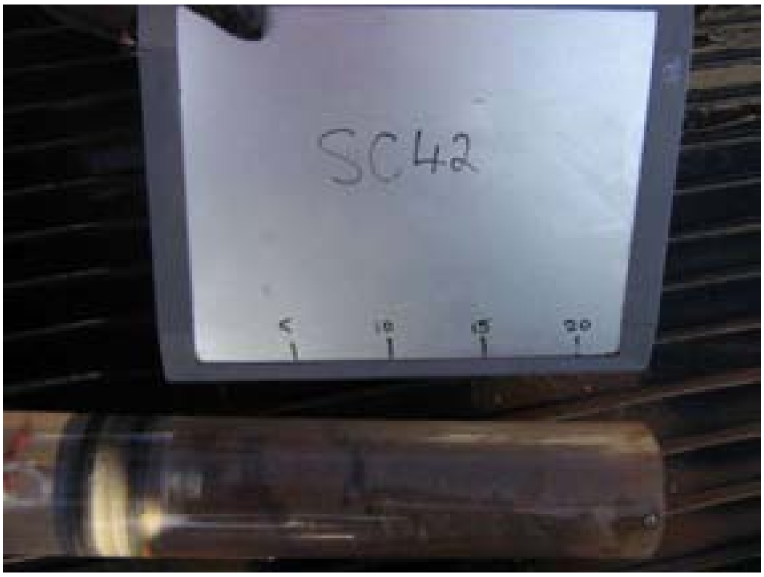
Appendix B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Appendix B


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SC47
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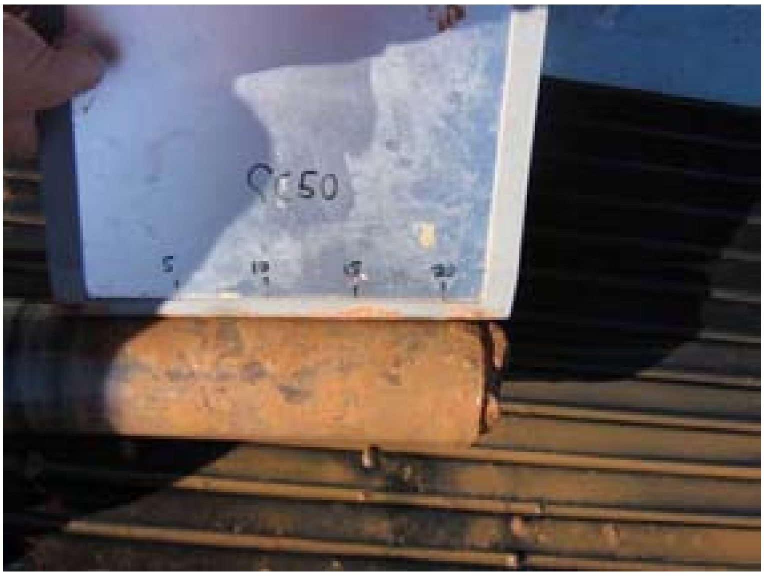
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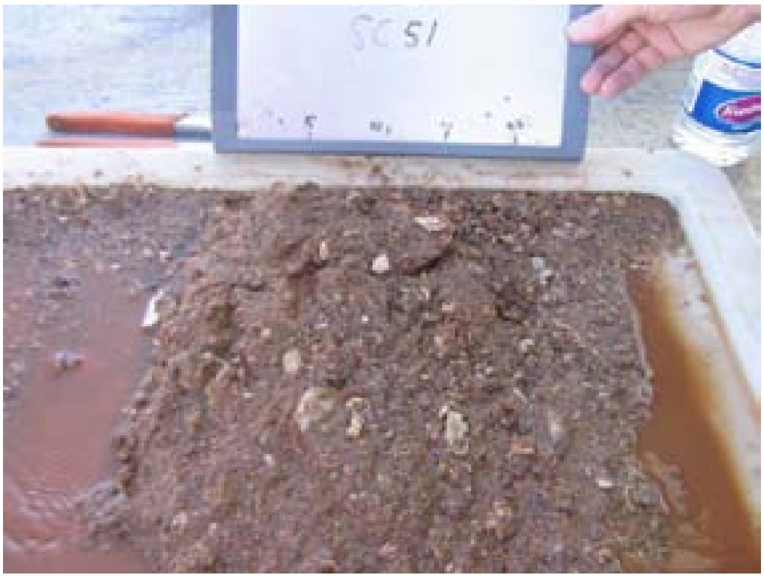
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SC55
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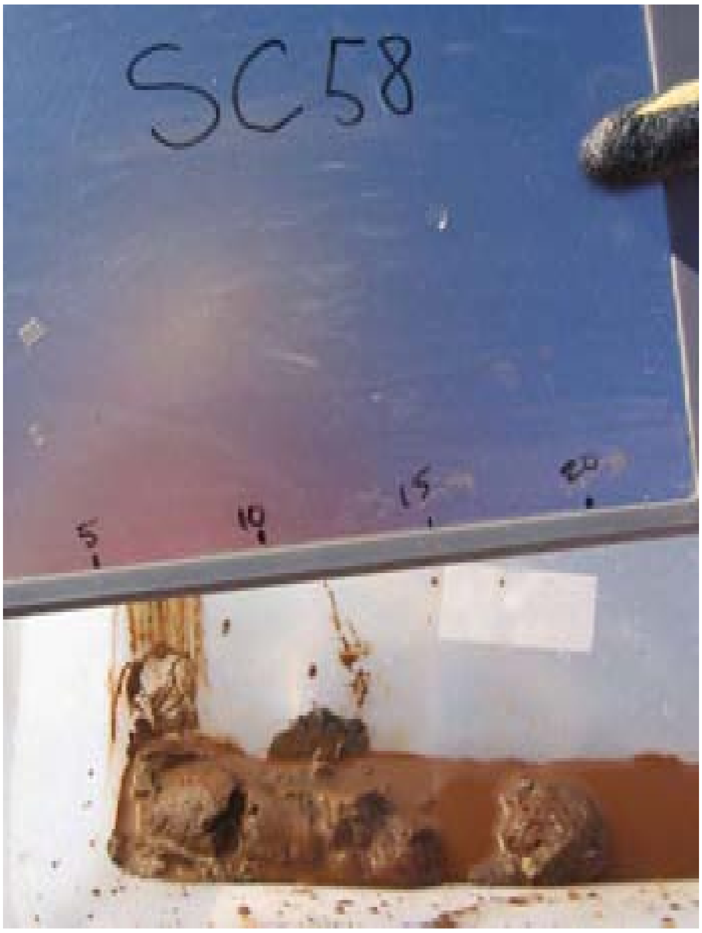
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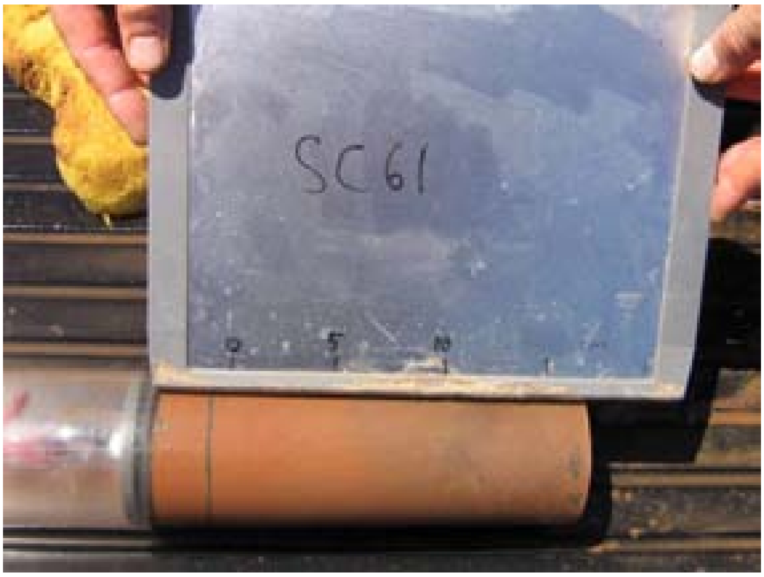
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SC62
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Appendix B


SC65
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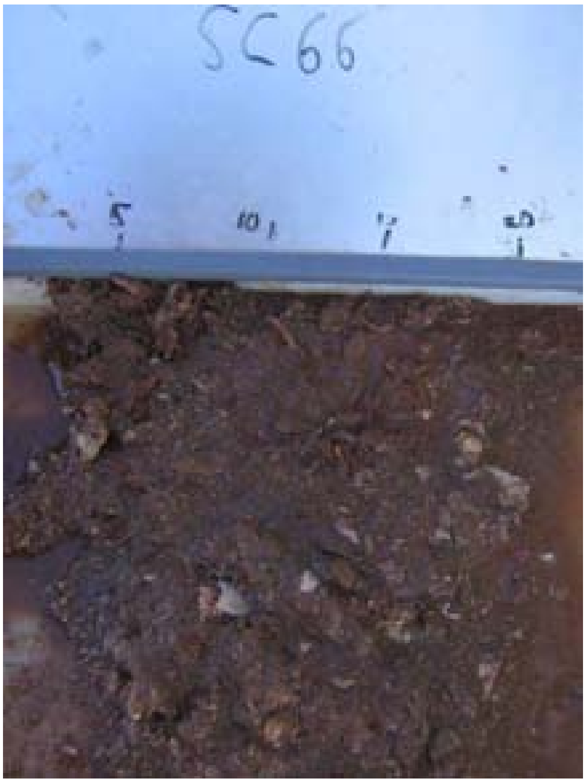
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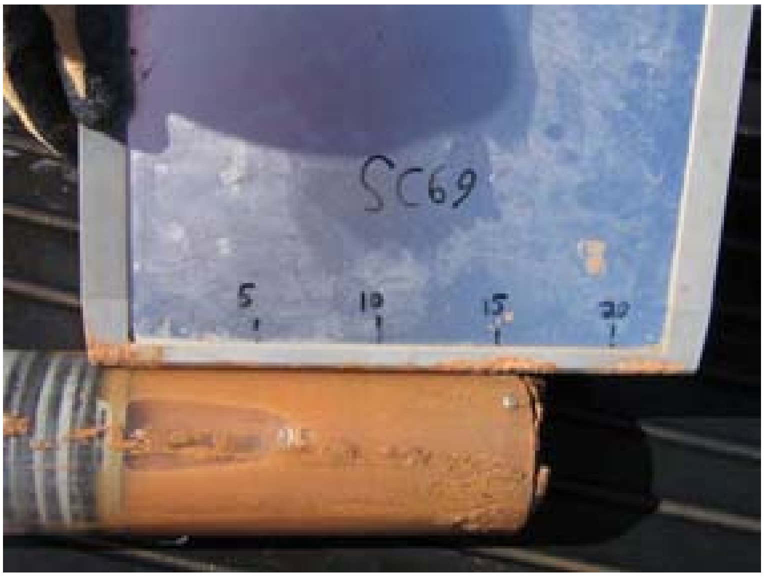
SC69
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SC70
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Appendix C Short Core and Grab Sample Descriptions

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Table C-1 Dredge Area short core (or grab sample) descriptions.

Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
SC1_0.0-0.27	26/09/2009	1700pm	4.1	Piston Core	QC118	0.27	45	50	quartz	5	nil	thin hydrous layer veneer (<1 cm - light brown); homogeneous dark red-brown stiff clayey sand; slightly gravelly; refusal at depth in gravelly mud/clay
SC2_0.0-0.22	23/09/2009	1050am	10.2	Piston Core		0.22	50	40		10		homogeneous sandy mud with gravelly shell fragments, red-brown to red; refusal at coral/rock (large 5 cm diameter coral fragment), refusal at depth
SC3_0.0-0.22	28/09/2009	1305pm	5.4	Piston Core	QC126 QC208	0.22	50	50	lithics	<5	nil	dark brown-red clayey sand; friable; dry organic charcoal-like fragments (soft) in clay; refusal in stiff clayey sand
SC4_0.0-0.25	24/09/2009	1145am	10.9	Piston Core		0.25	20	45	quartz; carbonate	35	shells	brown-red brown clayey gravelly sand; bivalves and coral fragments; refusal at depth
SC5	24/09/2009	1035am	10.4	Grab sample		0.08	10	20	quartz, carbonate	70	shells	gravelly-clayey red-brown to red; abundant bivalves up to 80 mm in length; bivalve bed; core refusal in shell bed at surface
SC6_0.0-0.2	28/09/2009	1145am	4.9	Piston Core	QC124 QC206	0.2	50	45	lithics	<5	trace lithic fragments	dark red clayey sand; homogeneous; light brown thin hydrous layer at surface; refusal in very

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
												stiff dark red friable clayey sand;
SC7_0.0-0.10	23/09/2009	1700pm	6	Piston Core		0.1	20	50	quartz, shells	30	bivalves, rock fragments	brown-red to brown clayey gravelly sand, abundant shell fragments, armoured bed, large >50 mm diameter shells and coral fragments at bottom of core; refusal at depth
SC8_0.0-0.30	25/09/2009	0815am	5.2	Piston Core	QC110	0.3	20	60	quartz; carbonate	20	shells	poorly developed light brown hydrous layer; red-red-brownish clayey gravelly sand; large lithic/coral fragments at bottom of core; refusal at depth;
SC9_0.0-0.20	25/09/2009	1620pm	5.9	Piston Core		0.2	20	65	carbonate detritus; quartz	15	shells	red-brown to red clayey muddy sand; shells and bivalves; refusal in coral/clay bed
SC10_0.0-0.10	24/09/2009	0915am	8.6	Piston Core		0.1	20	45	quartz, carbonate	35	shells	red to red-brown clayey gravelly sand abundant shell and coral/bivalves (>30 mm diameter); very stiff resistance and refusal at depth; lost bottom 5 cm of core
SC11_0.00.055	26/09/2009	1650pm	4.2	Piston Core		0.15	50	50	quartz	trace	nil	dark red-brown sandy clay; homogeneous; very stiff; refusal at depth;
SC12_0.0-0.15	24/09/2009	0855am	8.5	Piston Core		0.15	20	40	quartz, carbonate	40	shells	red-brown to red clayey gravelly sand with abundant coral assemblages; large

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
												bivalve and coral fragments in hard coral bed; lithic rock fragments (>50 mm diameter); refusal at depth
SC13	24/09/2009	0820am	8.5	Grab sample	QC105 QC202	0.08	20	50	quartz, carbonate	30	shells, bivalves	no core sample; refusal at surface; armoured bed; gravelly-clayey sand, re-brown to red; large shell fragments and rock/coral, lithic fragments; clayey matrix; 30-50 mm diameter shell fragments;
SC14_0.00.051	28/09/2009	1055am	4.6	Piston Core		0.11	45	50	lithics	<5	lithic fragments	dark red dry friable clayey sand; light brown near surface; refusal in very stiff clay
SC15_0.0-0.18	24/09/2009	0745am	7.1	Piston Core		0.18	40	30		20		red-brown to red gravelly muddy clay, large bivalves and shells (>50 mm diameter); very stiff clay at bottom of core; refusal at depth; large corals and rock fragments at depth;
SC16	24/09/2009	1015am	10.2	Grab sample	QC107 QC203	0.08	20	50	quartz, carbonate	30	shells	large bivalves (>50 mm diameter); little core penetration (<0.1m) and lost core; refusal at 0.1 m depth; red-red-brown gravelly clayey sand collected using a grab sampler
SC17_0.0-0.35	25/09/2009	0745am	5.4	Piston Core	QC109	0.35	30	50	quartz,	20	shells	poorly developed

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Sample ID	**Sample Date**	**Sample Time**	**Depth (m)**	**Sample Method**	**QC Sample**	**Sample Depth (m)**	**Visual Mud (%)**	**Visual Sand (%)**	**Sand Comp.**	**Visual Gravel (%)**	**Gravel Comp.**	**Description**
					QC204				carbonate			hydrous layer at surface; red-brown to red gravelly clayey sand; large shell fragments; refusal at depth;
SC18_0.0-0.30	25/09/2009	0830am	5.2	Piston Core		0.3	30	40	quartz; carbonate	30	shells	light brown poorly developed hydrous layer; red-brown to red clayey gravelly sand; large bivalves/shells up to 50 mm diameter and coral fragments; shell fragments; refusal at depth;
SC19_0.00.052	24/09/2009	0:00:00	12.2	Piston Core		0.12	15	70	quartz, carbonate	15	shells	red to red-brown gravelly clayey sand; shell fragments; some coral fragments (<20 mm diameter); refusal at depth
SC20_0.0-0.20	27/09/2009	1430pm	5.5	Piston Core		0.2	20	70	quartz	10	shells	dark red-brown clayey sand; some gravel shell fragments; refusal in stiff clayey sand
SC21_0.0-0.15	24/09/2009	0800am	8.4	Piston Core		0.15	30	40	quartz, carbonate	30	shells, bivalves	red-brown to red clayey gravelly mud, large shell fragments and bivalves (>50 mm diameter), clay matrix very stiff at bottom; refusal at depth;
SC22_0.00.053	28/09/2009	1200pm	5.2	Piston Core		0.13	50	50	lithics	<5	lithic fragments	dark red-brown clayey sand; very dry and friable; refusal in stiff dark red-brown clayey sand potentially top of

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
												weathered basement rock
SC23_0.0-0.25	25/09/2009	0855am	5.2	Piston Core		0.25	25	45	quartz; carbonate; lithic fragments	30	shells, bivalves	2 cm deep hydrous layer (light brown); red to red-brown clayey gravelly sand; carbonate-rich; large shells/coral fragments at bottom of core; stiff clay and refusal of corer at bottom;
SC24	24/09/2009	1455pm	12.9	Grab sample		0.05	5	45	carbonate, quartz trace	50	shells, bivalves	red to red-brown slightly muddy sandy gravel; shells and coral fragments up to 50 mm diameter; core refusal in armoured bed and grab sample collection;
SC25	24/09/2009	0845am	7.4	Grab sample		0.05	20	50	quartz, carbonate	30	shells	red-brown to red coral bed; large corals and shells; clayey matrix; no core, refusal at surface; hard armoured bed; coral fragment with 20 cm diameter collected
SC26_0.00.051	28/09/2009	1125am	4.7	Piston Core		0.11	50	50	lithics	<5	trace lithic fragments	dark red-brown clayey sand; very stiff; refusal at depth
SC27_0.0-0.32	27/09/2009	1400pm	5.1	Piston Core		0.32	40	55	quartz; lithic fragments	5	nil	thin 2-3 cm deep hydrous layer (light brown); dark red-brown clayey sand; friable/dry; some lithic gravelly rock fragments (angular); refusal in stiff clayey sand

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
SC28_0.0-0.25	23/09/2009	1530pm	8.7	Piston Core	QC104	0.25	30	40	quartz, carbonate shells,	30	shells, bivalves	red-brown homogeneous clayey muddy sand, abundant bivalves and shell fragments up to 80 mm diameter, refusal at depth
SC29_0.0-0.20	27/09/2009	1315pm	4.9	Piston Core		0.2	50	50	lithic fragments	<5	nil	dark red clayey sand; very stiff; trace shell fragments; friable; refusal in stiff clay at depth
SC30_0.0-0.20	24/09/2009	1055am	10.6	Piston Core		0.2	20	60	quartz, carbonate	20	shells	brown-red clayey gravelly sand, shell fragments (<50 mm diameter)
SC31_0.0-0.20	24/09/2009	1130am	10.2	Piston Core		0.2	25	45	quartz, carbonate	30	shells	red-brown to red clayey gravelly sand; shells (<50 mm length); refusal at depth
SC32_0.00.05	28/09/2009	1250pm	5.4	Piston Core		0.1	50	45	lithics	<5	lithics	dark red-brown clayey sand; large shell fragments; re-crystallized shells; very stiff and dry/friable; refusal in rock
SC33_0.0-0.33	25/09/2009	0910am	5.4	Piston Core		0.33	15	50	quartz; carbonate	35	shells; lithic fragments	well developed light brown hydrous layer; red-red-brown clayey gravelly sand; abundant gravelly coral fragments and shells; refusal at depth; stiff clay and shelly gravel at bottom;
SC34_0.0-0.25	25/09/2009	0925am	5.3	Piston Core		0.25	25	65	carbonate and quartz	10	shell fragments	red-brown to red gravelly clayey sand; shell fragments and bivalves; shelley gravel at bottom;

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Sample ID	**Sample Date**	**Sample Time**	**Depth (m)**	**Sample Method**	**QC Sample**	**Sample Depth (m)**	**Visual Mud (%)**	**Visual Sand (%)**	**Sand Comp.**	**Visual Gravel (%)**	**Gravel Comp.**	**Description**
												refusal at depth;
SC35_0.00.055	23/09/2009	1645pm	6.1	Piston Core		0.15	30	40	quartz, carbonate, shells	30	shells, bivalves	red to brown-red clayey muddy gravelly sand; abundant shell fragments; abundant shells/bivalves and coral fragments at bottom of core; very stiff clay and refusal at bottom of core
SC36_0.00.050	24/09/2009	1320pm	11.9	Piston Core		0.1	20	70	quatz, carbonate	10	shells	red to red-brown gravelly clayey sand; shell fragments (<50 mm length); refusal at depth
SC37_0.00.051	27/09/2009	1245pm	4.7	Piston Core		0.11	50	45	lithic fragments	5	shell fragments	light brown hydrous layer (~2-3 cm deep); dark red-brown clayey sand with gravelly sandy clay at bottom; refusal in gravelly clayey sand
SC38_0.0-0.40	28/09/2009	1330pm	5.6	Piston Core	QC127 QC209	0.4	40	50	lithics	10	shells	homogeneous dark red-brown clayey sand; friable; stiff and dry; refusal in stiff clayey sand
SC39_0.00.050	24/09/2009	1300pm	11.2	Piston Core		0.1	15	75	carbonate, quartz	10	shells	red to brown-red clayey gravelly sand, shell fragments; refusal at depth
SC40_0.0-0.31	25/09/2009	1540pm	6.3	Piston Core		0.31	15	75	carbonate detritus; quartz	10	shells	red-brown gravelly muddy sand; some shells and coral reef fragments; refusal at depth in stiff clay
SC41_0.0-0.30	27/09/2009	1415pm	5.3	Piston Core		0.3	50	45	lithic and	5	rock	dark red-brown clayey

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
									quartz		fragments	sand; friable; very stiff; 60 mm diameter coral accretions (dark gray-green); refusal in stiff clay
SC42_0.0-0.25	25/09/2009	0725am	6.8	Piston Core		0.25	20	50	carbonate, quartz	30	shells	red to red-brown clayey gravelly sand; some shells and abundant shell fragments in sand fraction; refusal of core at depth
SC43_0.0-0.23	28/09/2009	1220pm	5.3	Piston Core	QC125 QC207	0.23	50	45	lithics	5	nil	dark red-brown clayey sand; friable and dry; refusal in stiff clay red brown in colour
SC44_0.00.052	28/09/2009	1040am	4.6	Piston Core		0.12	50	45	lithics	5	trace lithic fragments	dark red-brown clayey sand; brown-red near surface; dry and friable; refusal in very stiff clayey sand;
SC45_0.0-0.20	24/09/2009	1115am	10.7	Piston Core		0.2	20	50	quartz, carbonate	30	shells	red-brown clayey gravelly sand, large up to 50 mm diameter shells/coral fragments, refusal at depth
SC46_0.0-0.25	24/09/2009	0955am	9.3	Piston Core	QC106	0.25	20	50	quartz, carbonate	30	shells	red brown clayey gravel; shells/corals (<50 mm diameter); refusal in very stiff clay
SC47_0.0-0.25	25/09/2009	1605pm	6.3	Piston Core		0.25	15	70	carbonate; quartz	15	detrital shells	red-brown to red gravelly muddy sand; some shell and detrital carbonate fragments (~30 mm diameter); refusal in coral fragments and stiff clay

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
SC48_0.00.050	24/09/2009	1350pm	12.3	Piston Core		0.1	15	65	quartz, carbonate	20	shells	red to red-brown clayey gravelly sand; shell fragments (<20 mm diameter)
SC49_0.00.050	24/09/2009	1425pm	12.6	Piston Core		0.1	15	45	quartz, carbonate	40	shells	gravelly clayey sand; red-red-brown; large shell fragments and bivalves (<50 mm diameter); refusal at depth
SC50_0.0-0.23	25/09/2009	1550pm	6.3	Piston Core		0.23	15	75	carbonate detritus; quartz	10	shalls; coral fragments	light brown to red-brown gravelly muddy sand with some shell fragments; carbonate detritus; stiff clay at depth; refucal in coral bed and stiff clay
SC51	24/09/2009	1440pm	11.9	Grab sample		0.05	5	55	carbonate, quartz, rock	40	shell/bivalves	slightly muddy sandy gravel; brown to red-brown; abundant shell fragments and bivalves; core refusal at surface; armoured bed; coral fragments and large bivalve oyster (~8 cm length);
SC52_0.00.050	24/09/2009	1335pm	12.1	Piston Core		0.1	20	70	quartz, carbonate	10	shells	red to red-brown clayey gravelly sand with shell fragments; some lithic rock fragments (<50 mm length); refusal at depth
SC53_0.00.055	28/09/2009	1350pm	6.8	Piston Core	QC128 QC210	0.15	50	40	lithics	10	shells	dark red-brown clayey sand; gravelly clay; rocky bottom
SC54_0.0-0.20	23/09/2009	1550pm	8.3	Piston Core		0.2	40	50		<10		sandy mud, clayey, red-brown , high stiffness,

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
												shell fragments, stiff clay at bottom of core, 80 mm diameter bivalve shell at bottom; refusal at depth
SC55_0.0-0.25	25/09/2009	0710am	6.4	Piston Core		0.25	30	60	quartz; carbonate	10	shells	red-brown to red clayey gravelly sand; bivalves up to 50 mm diameter; refusal at depth
SC55_0.0-0.30	24/09/2009	0940am	8.7	Piston Core		0.3	30	40	quartz, carbonate	30	shells	red-brown gravelly clayey sand, large shell and coral assemblages (~30-50 mm diameter); refusal at depth; very stiff clay
SC56_0.0-0.31	28/09/2009	1110am	4.6	Piston Core	QC123 QC205	0.31	50	40	lithics	10	lithic fragments	dark red homogeneous very stiff clayey sand; friable and dry; gravel/lithic and coral fragments fossilized/opaline shell fragments about 5 cm long; refusal in very stiff clayey sand
SC57_0.00.055	26/09/2009	1715pm	4.5	Piston Core		0.15	50	45	quartz; lithic fragments	5	nil	dark red sandy clay; homogeneous; some shell fragments; refusal at depth in stiff clay
SC58_0.0-0.15	23/09/2009	0850am	6.7	Piston Core		0.15						gravelly muddy sand, clayey, abundant shell fragments and bivalves, red to brown-red, unconsolidated
SC59_0.0-0.23	25/09/2009	0800am	5.4	Piston Core		0.23	25	65	quartz; carbonate	10	shells	gravelly clayey sand; red-red brown; abundant shells and coral fragments/bivalves (<50

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
												mm diameter); refusal at depth
SC60_0.0-0.20	25/09/2009	1445pm	9.8	Piston Core		0.2	15	60	carbonate detritus; quartz	25	shells	light brown to red brown gravelly muddy sand; abundant shell detritus and carbonate debris; large coral fragments and shells at bottom of core; refusal at depth;
SC61_0.0-0.18	27/09/2009	1300pm	5.3	Piston Core		0.18	55	40	quartz and lithic fragments	<5	nil	dark red-brown clayey sand; trace shell fragments; refusal in stiff clay
SC62_0.0-0.1	26/09/2009	1630pm	3.6	Piston Core		0.1	60	40	quartz; lithic fragments	<5	nil	dark red-brown sandy clay; very stiff; some carbonate shell fragments; refusal at depth; hydrous veneer (~1 cm)
SC63	25/09/2009	1710pm	4.4	Grab sample		0.05	30	65	quartz; carbonate	5	shells	slightly gravelly muddy sand with light brown hydrous layer (~1 cm deep)
SC64_0.0-0.15	27/09/2009	1235pm	3.9	Piston Core		0.15	60	40	quartz; carbonate	<5	nil	stiff dark red-brown clayey sand; slightly more hydrous in upper 2 cm; some shell fragments;
SC65	24/09/2009	1515pm	13.9	Grab sample		0.05	25	55	carbonate, trace quartz	20	shells/bivalves	coarse sandy gravel, slightly muddy; shells/bivalves; brown to red-brown; armoured bed and core refusal;
SC66	24/09/2009	1525pm	12.6	Grab sample		0.05	5	50	quartz,	45	shells	brown to red-brown

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
									trace and abundant carbonate			slightly muddy sandy gravel; shells and shell fragments
SC67_0.0-0.15	25/09/2009	1420pm	10	Piston Core		0.15	10	85	carbonate	<5	shell traces	red-brown slightly gravelly muddy sand; abundant sand-sized carbonate detritus; refusal at depth;
SC68_0.0-0.20	25/09/2009	1400pm	9.8	Piston Core		0.2	15	80	quartz, carbonate	5	shells	light red-brown, slightly gravelly muddy sand; carbonate fragments and shell detritus; refusal at depth
SC69_0.0-0.16	25/09/2009	1455pm	9.6	Piston Core		0.16	15	65	carbonate; quartz	20	shells/mussels	red-red-brown gravelly muddy sand with abundant shell and carbonate detritus; refusal at depth in hard coral bed/stiff clay; shells/mussels up to a depth of 10 cm
SC70_0.0-0.10	25/09/2009	1510pm	10	Piston Core		0.1	10	70	detrital carbonate and quartz	20	shells and mussels (50 mm diameter)	brown-red detrital-rich gravelly muddy sand; some shells; large shells and rock/algal bed at depth; refusal
SC71	25/09/2009	1655pm	6	Grab sample	QC112	0.05	60	40	detrital carbonate and quartz	<5	trace gravel	red-brown hydrous layer (1-2 cm deep with 10% sand and 90% mud); trace gravel and 60% mud/40% sand sandy mud; detrital carbonate fraction in sand component

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Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
SC72	25/09/2009	1650pm	6.6	Grab sample		0.08	15	50	detrital carbonate and quartz	35	shells	red-brown gravelly muddy sand; abundant shell fragments and detritus

Table C-2 Dredge material placement sites grab sample descriptions.

Area	Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
Site A	G40	22/09/2009	1720pm	6.2	Grab sample		0.05	25	45	quartz; lithic fragments	30	bivalves and shells	red-brown to reddish gravelly sandy mud with abundant shells and coral fragments; polychaete worms
Site A	G41	25/09/2009	1125am	6.3	Grab sample		0.08	35	50	quartz; carbonate	15	carbonate detritus	gravelly muddy sand (red to red-brown); some oyster shell fragments; small crab and bryozoans
Site A	G42	25/09/2009	1045am	5.2	Grab sample		0.05	20	50	quartz; carbonate	30	oyster shells	red-brown to red muddy clayey gravelly sand; carbonate-rich with oyster-armoured bed; jellyfish; sea grass

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Area	Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
Site A	G43	25/09/2009	1025am	5.4	Grab sample		0.05	30	50	quartz; carbonate fragments	20	shells	light brown to red-brown muddy gravelly sand; abundant oyster shells (~50 mm diameter);
Site A	G44	25/09/2009	1100am	6.2	Grab sample	QC111	0.05	30	40	carbonate; quartz detritus	30	shells	brown to red-brown clayey muddy gravelly sand; large oyster shells; armoured bed (shells up to 80 mm length);
Site A	G45	25/09/2009	1020am	5.2	Grab sample		0.05	20	35	quartz; carbonate	45	oyster shells	armoured bed; red-brown gravelly muddy sand; large oyster shells at surface (~50 mm diameter)
Site A	G46	25/09/2009	1115am	6.3	Grab sample		0.08	40	50	quartz; carbonate	10	shell detritus	dark reddish-grayish gravelly muddy sand; some organic (dark gray) subsurface sediments in anoxic layer; some seagrass
Site A	G47	25/09/2009	1040am	5.6	Grab sample		0.05	20	40	quartz; carbonate	40	shells; mussels; bivalves	armoured bed; abundant mussels and bivalves; shells up to 5 cm long; red-red-brown muddy gravelly sand

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Area	Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
Site A	G48	25/09/2009	1010am	5.2	Grab sample		0.05	10	40	carbonate/lithic fragments; shells	50	large oyster shells and coral fragments	hard coral bottom; armoured bed with abundant large (up to 80 mm diameter) bivalves; oysters and coral fragments;
Site A	G49	25/09/2009	1115am	5.9	Grab sample		0.05	30	55	quartz; shell detritus;	15	large oyster shells (~80 mm long)	red-brown to red gravelly muddy sand; some large oyster shells and carbonate detritus;
Site B	G30	25/09/2009	1325pm	10.7	Grab sample		0.1	15	15	carbonate detritus; shells; shell fragments	70	carbonate detritus; shells; bivalves	light brown muddy sandy gravel; abundant shell and carbonate detritus; bryozoans; shrimp; baby crabs
Site B	G31	25/09/2009	1315pm	11	Grab sample		0.12	20	30	detrital quartz and carbonate	50	abindant gravel and shells and bivalves	light brown muddy gravelly sand; abundant carbonate detritus and large shells (up to 80 mm long)
Site B	G32	24/09/2009	1705pm	10.5	Grab sample		0.1	45	50	quartz; carbonate; lithic fragments	<5	trace shells	muddy sand to sandy mud; red to brown-red to grayish;
Site B	G33	25/09/2009	1300pm	10.9	Grab sample		0.1	40	50	quartz; carbonate detritus	10	some shells/bivalves	light brown to red-brown muddy sand; slightly gravelly;

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Area	**Sample ID**	**Sample Date**	**Sample Time**	**Depth (m)**	**Sample Method**	**QC Sample**	**Sample Depth (m)**	**Visual Mud (%)**	**Visual Sand (%)**	**Sand Comp.**	**Visual Gravel (%)**	**Gravel Comp.**	**Description**
Site B	G34	22/09/2009	1710pm	9.8	Grab sample		0.08	40	40	quartz; shell fragments; lithic rock fragments	20	shells and bivalves and coral fragments (~5 cm in diameyer)	reddish-brown to red gravelly muddy sand; rock fragments abundant; polychaete works
Site B	G35	25/09/2009	1220pm	10.7	Grab sample		0.1	30	60	detrital carbonate and quartz	10	shell fragments	light brown to red-brown muddy sand; slightly gravelly; some bivalves up to 50 mm long;
Site B	G36	24/09/2009	1715pm	10	Grab sample	QC108	0.08	35	50	carbonate/lithic fragments; trace quartz	15	shells; bivalves	muddy gravelly sand; dark lithic fragments; top 2 cm very muddy (poorly developed hydrous layer); red-brown red
Site B	G37	25/09/2009	1250pm	10.6	Grab sample		0.1	40	50	detrital carbonate and quartz	10	abundant large shells/bivalves/mussels up to 50 mm long	muddy surface; red to brown-red slightly gravelly muddy sand
Site B	G38	25/09/2009	1240pm	11.4	Grab sample		0.15	40	55	detrital carbonate and quartz	5	detrital shell fragments	light brown to red muddy sand; some gravel; no large shells; thin hydrous layer (<1 cm deep)

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Area	Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
Site B	G39	22/09/2009	1650pm	8.4	Grab sample		0.05	<10	40	quartz; carbonate shells	50	large bivalves (up to 6 cm long)	gravelly sand; slightly muddy; reddish to red-brown;
Site C	G1	22/09/2009	1536pm	12	Grab sample		0.05	15	50	quartz; carbonate/lithic fragments	35	shell and coral fragments	coarse gravelly muddy sand; abundant shells and coral/bivalves; angular lithic rock fragments
Site C	G2	24/09/2009	1610pm	14.7	Grab sample		0.05	20	75	quartz; lithic fragments; carbonate	<5	trace gravel	red to red-brown muddy sand; carbonate-rich; fine-grained sandy mud fraction; amphipod and trace sea grass
Site C	G3	24/09/2009	1630pm	14	Grab sample		0.05	20	75	quartz; carbonate/lithic fragments	5	shells	red-brown to grayish-green muddy sand; some shells and shell fragments;
Site C	G4	24/09/2009	1625pm	14	Grab sample		0.08	15	80	carbonate and lithic fragments	<5	trace gravel/shells	muddy sand with trace gravel (shell fragments); red-brown to grayish brown;
Site C	G5	24/09/2009	1555pm	15.7	Grab sample		0.08	30	65	carbonate and lithic fragments	<5	trace gravel	muddy sand; brown to red-brown; well sorted;
Site C	G6	22/09/2009	1420pm	15	Grab sample		0.08	20	75	quartz; shell fragments	5	bivalve shells (traces)	gravelly sandy mud; red-brown; ferruginous

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Area	Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
Site C	G7	22/09/2009	1443pm	15	Grab sample		0.05	10	45	lithic and quartz fragments	45	large shells up to 5 cm in diameter	coarse gravelly muddy sand; abundant shells and rock fragments; brown to red-brown; tube-like organisms and bryozoans
Site C	G8	22/09/2009	1625pm	13.8	Grab sample		0.08	10	50	quartz; carbonate fragments	40	rock fragments (up to 5 cm diameter)	gravelly coarse sandy mud; reddish-brown; polychaete worms;
Site C	G9	22/09/2009	1605pm	12.8	Grab sample		0.08	25	70	carbonate shells; quartz	<10	shells; trace bivalves	brown to reddish-brown gravelly muddy sand;
Site C	G10	22/09/2009	1455pm	15	Grab sample		0.08	35	60	quartz; lithic rock fragments; dark gray	<5	shells; bivalve fragments	muddy slightly gravelly sand to sandy mud; brown to red-brown;
Site C	G11	22/09/2009	1348pm	14.5	Grab sample		0.08	10	80	quartz; lithic rock fragments	<10	bivalves; shells	ferruginous red to brown-red muddy sand; slightly gravelly; lithic and quartz fragments abundant; angular to sub-rounded quartz grains; seaweed roots; filamentous brown algae

Appendix C

Area	**Sample ID**	**Sample Date**	**Sample Time**	**Depth (m)**	**Sample Method**	**QC Sample**	**Sample Depth (m)**	**Visual Mud (%)**	**Visual Sand (%)**	**Sand Comp.**	**Visual Gravel (%)**	**Gravel Comp.**	**Description**
Site C	G12	22/09/2009	1333pm	15	Grab sample	QC100	0.05	<10	90	quartz, ferruginous , with shell fragments	<5	bivalves, shells	brown to green-brown slightly gravelly muddy sand; trace to <5% fines; some gravelly and Fe-oxide-coated sand
Site C	G13	22/09/2009	1523pm	13.5	Grab sample	QC102; QC103; QC201	0.1	20	70	quartz; lithic rock fragments;	10	shells	muddy sand; gravelly; red to brown;
Site C	G14	22/09/2009	1545pm	11.8	Grab sample		0.08	25	65	quartz and carbonate fragments	10	bivalve shells and whole shells	gravelly muddy sand; red-brown to reddish; abundant angular carbonate grains and shell fragments; polychaete worm
Site C	G15	22/09/2009	1555pm	12	Grab sample		0.1	30	60	quartz and carbonate fragments	10	shells	gravelly muddy sand; red-brown to red; shell fragments; green filamentous algae strings with green leaves (~5 cm length)
Site C	G16	22/09/2009	1510pm	15	Grab sample		0.08	20	70	quartz; rock fragments	10	shells	red-brown muddy sand; gravelly; lithic rock fragments; shells (bivalves); green algae
Site C	G17	22/09/2009	1400pm	14	Grab sample	QC101; QC200	0.08	15	80	quartz; lithic frock fragments	5	shells	red ferruginous muddy sand; medium-grained; some gravel;

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Area	Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
Site C	G18	22/09/2009	1430pm	15.5	Grab sample		0.08	20	75	quartz, lithic rock fragments	<5	shells	slightly gravelly muddy sand; brown to red-brown; lithogenic
Site C	G19	22/09/2009	1616pm	13	Grab sample		0.05	15	50	quartz and shells	35	bivalve shells	gravelly muddy sand; abundant shells; reddish to brown-red; polychaete worms
Site C	G69	26/09/2009	1450pm	14.6	Grab sample	QC116	0.08	30	60	carbonate fragments	10	shell fragments	light brown to grayish-green gravelly muddy sand; soft; detrital carbonate
Site C	G70	26/09/2009	1500pm	13.1	Grab sample		0.05	5	65	shell detritus	20	bivalves	light brown-red slightly muddy gravelly sand; large bivalves up to 50 mm long; soft
Site C	G71	26/09/2009	1520pm	12.5	Grab sample	QC117	0.05	35	60	shells; carbonate fragments	5	shell fragments	light brown sandy mud; some shell fragments; soft; macrophytes
Site C	G72	26/09/2009	1530pm	13.5	Grab sample		0.1	35	60	detrital shells; lithic fragments	5	shell fragments	light brown sandy mud; trace gravel; large sample; soft
Site C	G73	26/09/2009	1540pm	15	Grab sample		0.05	10	50	detrital carbonate and quartz	40	shells	light brown, slightly muddy sandy gravel; abundant shell fragments and bivalves;
Site D	G59	27/09/2009	0935am	48.3	Grab sample		0.05	15	75	shell detritus	10	shells	light olive gray-green to brown gravelly muddy

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Area	**Sample ID**	**Sample Date**	**Sample Time**	**Depth (m)**	**Sample Method**	**QC Sample**	**Sample Depth (m)**	**Visual Mud (%)**	**Visual Sand (%)**	**Sand Comp.**	**Visual Gravel (%)**	**Gravel Comp.**	**Description**
										and shell fragments			sand
Site D	G60	27/09/2009	1015am	45.5	Grab sample		0.03	10	90	carbonate	<5	trace shells	olive green muddy sand; trace gravel; well sorted; soft
Site D	G61	27/09/2009	1105am	40.1	Grab sample		0.05	10	85	carbonate shell fragments	<5	trace shells	olive gray-green well sorted sand; trace shells; soft
Site D	G62	27/09/2009	1035am	38.3	Grab sample		0.03	10	85	carbonate shell fragments	<5	trace shells	light olive green-gray muddy sand; well sorted
Site D	G63	27/09/2009	1000am	42.8	Grab sample	QC122	0.05	10	90	carbonate fragments	<5	nil	light green slightly muddy sand; well sorted; trace shells
Site D	G64	27/09/2009	1025am	43.6	Grab sample		0.05	10	85	carbonate shell fragments	<5	trace shells	well sorted olive gray-green muddy sand; soft
Site D	G65	27/09/2009	0945am	47.6	Grab sample	QC121	0.05	15	80	carbonate shell fragments	<5	shells	light gray muddy sand; some shell fragments
Site D	G66	27/09/2009	1050am	40.8	Grab sample		0.03	10	85	carbonate shell fragments	<5	trace shells	well sorted olive gray-green muddy sand; trace shells; light brown fine fraction
Site D	G75	27/09/2009	1050am	40.1	Grab sample		0.03	10	85	carbonate shell fragments	<5	trace shells	well sorted olive gray-green muddy sand; soft
Site D	G76	27/09/2009	1055am	42	Grab sample		0.05	10	85	carbonate shell fragments	<5	trace gravel	light olive green-gray slightly muddy sand; well sorted; soft

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Area	Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
Site E	G50	27/09/2009	0755am	64	Grab sample		0.08	30	65	carbonate shell fragments	<5	trace shells	light olive gray-green muddy sand with light brown hydrous layer (poorly developed); soft;
Site E	G51	27/09/2009	0715am	71.3	Grab sample		0.1	40	50	lithic green-gray shell fragments	10	coral fragments	olive green-gray muddy sand; trace shells; soft
Site E	G52	27/09/2009	0810am	65.3	Grab sample		0.08	20	75	carbonate shell fragments	<5	nil	light green to olive-gray muddy sand; mudslider in top 1-2 cm;
Site E	G53	27/09/2009	0820am	63	Grab sample		0.08	25	70	carbonate shell fragments	<5	nil	olive gray-green muddy sand; abundant surficial worm tubes; trace shell gravel; soft
Site E	G54	27/09/2009	0830am	61.3	Grab sample		0.08	30	65	carbonate shell fragments	5	lithic? And carbonate fragments	olive gray-green muddy sand; trace gravel; carbonate fragments in sand fraction; soft; feather star
Site E	G55	27/09/2009	0840am	61.6	Grab sample		0.08	20	75	carbonate	5	shell fragments	light olive gray-green muddy sand; some shell fragments; soft; squills (prawn killer) about 5 cm long

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Area	Sample ID	Sample Date	Sample Time	Depth (m)	Sample Method	QC Sample	Sample Depth (m)	Visual Mud (%)	Visual Sand (%)	Sand Comp.	Visual Gravel (%)	Gravel Comp.	Description
Site E	G56	27/09/2009	0745am	66.3	Grab sample	QC120	0.1	30	65	carbonate and shell fragments	<5	trace shells	olive green-gray muddy sand; carbonate-rich; slightly hydrous in upper 1 cm; light-brownish to olive-gray hydrous layer;
Site E	G57	27/09/2009	0725am	69.6	Grab sample	QC119	0.1	25	70	carbonate shell fragments	<5	nil	olive gray-green muddy sand; trace gravel; carbonate fragments in sand fraction; soft;
Site E	G58	27/09/2009	0740am	67.6	Grab sample		0.05	20	75	carbonate shell fragments and lithic fragments	<5	rtrace shells	light olive green-gray muddy sand; soft; one shrimp; yellow spongy coral
Site E	G74	27/09/2009	0850am	63	Grab sample		0.08	30	65	quartz trace; shell and carbonate fragments	<5	trace shells	olive gray-green muddy sand; trace shell; soft;

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Appendix D Short Core & Grab Sample Analytical & Physicochemical Data

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Appendix D

Table D-1 Short core & grab sample analytical data.

Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	CaCO$_3$ (%)	MC (%)
Dredge Area	SC1_0.0-0.27	8490	13.2	28	0.05	67.8	18.5	0.01	21.1	0.25	9.4	33.7	0.25	0.06		22.5
	SC10_0.00.050	6040	18.1	12.6	0.05	36.1	9.2	0.01	9.6	0.25	5.6	21.8	0.25	0.12	46.7	25.7
	SC11_0.00.055	13400	13.1	112	0.05	82.1	39	0.01	37	0.25	15.1	62	0.25	0.06		30.8
	SC12_0.00.055	6080	16.3	11	0.05	37.1	9.2	0.01	9.8	0.25	5.6	21.7	0.25	0.14	46.5	24.8
	SC13	6820	20.9	17.5	0.05	35	11.1	0.01	11.4	0.25	6.2	24	0.25	0.16		30.5
	SC14_0.00.051	5990	5.48	53.2	0.05	48.8	15.3	0.01	18.1	0.25	8.5	24.7	0.25	0.04		21.3
	SC15	6960	18.5	11.4	0.05	49.4	12.3	0.01	15	0.25	7.4	28.2	0.25	0.1	32.7	24.6
	SC16	5680	20.5	12.9	0.05	34.1	8.2	0.01	9.4	0.25	5.6	21.3	0.25	0.13		29
	SC17_0.0-0.35	5560	22.6	5.4	0.05	40.4	9.3	0.01	10.9	0.25	6.1	23	0.25	0.1	38.5	22.3
	SC18_0.0-0.30	6060	23.4	6	0.05	40.8	10.2	0.01	11.2	0.25	6.4	24.3	0.25	0.12	45.7	24.9
	SC19_0.00.052	4660	16.2	10.9	0.05	30.3	5.7	0.01	6.2	0.25	4.9	15	0.25	0.09		26.2
	SC2_0.0-0.22	4070	18.9	12.2	0.05	31.1	5.9	0.01	6.1	0.25	4.8	14.8	0.25	0.09	55.2	25
	SC20_0.0-0.20	10600	15.8	27.3	0.05	70	24.3	0.01	24.4	0.25	10.1	38.6	0.25	0.06		26
	SC21_0.00.055	8820	14.8	15.9	0.05	55	17.4	0.01	18.1	0.25	8.1	31.2	0.25	0.13	37	25.5
	SC22_0.00.053	4540	6.24	19.1	0.05	36.4	18.9	0.01	13.9	0.25	6.4	19.7	0.25	0.06		22.2
	SC23_0.0-0.25	5950	21.1	10.3	0.05	42.9	10.8	0.01	11.8	0.25	6.6	25.4	0.25	0.09		23.4
	SC24	4210	19.9	18.1	0.05	22.1	4.5	0.01	3	0.25	4.3	12.7	0.25	0.14	77.2	30.7
	SC25	3970	19.8	12.2	0.05	23.7	6.1	0.01	5.8	0.25	4.3	15.9	0.25	0.15		24.8
	SC26_0.00.051	6100	6.8	15.9	0.05	49.5	16.8	0.01	18.5	0.25	8.8	24.6	0.25	0.05	0.01	19.3
	SC27_0.0-0.32	5570	11.7	13.6	0.05	42.1	11	0.01	12.2	0.25	5.5	18.7	0.25	0.07		19.4
	SC28_0.0-0.25	8110	18.8	11.1	0.05	53.3	16	0.01	18.1	0.25	7.9	28.4	0.25	0.1	37.5	24.6
	SC29_0.0-0.20	8900	15.3	66.3	0.05	67	18.4	0.02	22.3	0.25	9.4	33.6	0.25	0.07		23.4

Appendix D

Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
	SC3_0.0-0.22	4050	18.3	10.2	0.05	35.3	10.7	0.01	10.4	0.25	6	21.8	0.25	0.34		27.4
	SC30_0.0-0.2	6850	18.8	12.8	0.05	33.7	9.5	0.01	9.7	0.25	6.1	21.9	0.25	0.16	52.4	27.3
	SC31_0.0-0.20	3860	20.3	10	0.05	23.3	4.4	0.01	3.6	0.25	4	11.8	0.25	0.1		25.1
	SC32_0.00.05	4040	12.7	10.6	0.05	30.7	9.9	0.01	9.4	0.25	5.6	20.1	0.25	0.1		21.7
	SC33_0.0-0.33	6850	19.1	8.4	0.05	42.8	9.7	0.01	11.2	0.25	6.5	23	0.25	0.15		29.7
	SC34_0.0-0.25	8140	28.5	9.2	0.05	53	14.4	0.01	16	0.25	8.5	33.2	0.25	0.14		34.3
	SC35_0.00.055	4710	22.4	12.6	0.05	34.1	8.4	0.01	8.7	0.25	5.6	20	0.25	0.01		24.4
	SC36_0.00.050	5660	19.8	13.6	0.05	33.5	7.7	0.01	8.1	0.25	5.4	21.9	0.25	0.17		25.8
	SC37_0.00.051	13800	14.3	45.6	0.05	78.1	31.4	0.02	35.4	0.25	13.4	57.7	0.25	0.1		28.8
	SC38_0.0-0.40	3920	11.7	8.6	0.05	31.7	9.4	0.01	9.6	0.25	5.5	19.4	0.25	0.11		23.8
	SC39_0.00.050	4910	20	10.3	0.05	32.6	6.3	0.01	6.9	0.25	5	16.2	0.25	0.14		29.2
	SC4_0.0-0.25	4270	18.6	10.5	0.05	27.5	5.2	0.01	4.5	0.25	4.4	13.4	0.25	0.13		27
	SC40_0.0-0.31	7890	26.6	7.8	0.05	50.6	14.1	0.02	15.9	0.25	8.1	32.4	0.25	0.17		26.3
	SC41_0.0-0.30	7250	19	20.1	0.05	59.1	15.4	0.01	17.8	0.25	8	29.7	0.25	0.09		22.6
	SC42_0.0-0.25	5020	18.8	7.5	0.05	31.8	8.6	0.01	7.8	0.25	5.2	17.6	0.25	0.09		24.1
	SC43_0.0-0.23	5300	10.2	21.8	0.05	39.2	13.2	0.01	13.6	0.25	6.8	24	0.25	0.09		22.5
	SC44_0.00.052	5860	4.69	31.9	0.05	50.7	15	0.01	19	0.25	8.8	23.1	0.25	0.06		20.5
	SC45	4540	17.4	11.2	0.05	30.3	6	0.01	5.7	0.25	4.7	15	0.25	0.15	50.3	24.7
	SC46_0.0-0.25	6640	14	13	0.05	38.3	11.1	0.01	12.6	0.25	6.1	23.8	0.25	0.08	46.9	23.4
	SC47_0.0-0.25	4770	23.8	5.4	0.05	39.1	7.3	0.01	8.8	0.25	5.6	20.1	0.25	0.1		22.2
	SC48_0.00.050	4360	16.9	11.4	0.05	25.5	5.7	0.01	5.7	0.25	4.7	14.4	0.25	0.11	63.2	26.6
	SC49_0.00.050	4610	17.4	12.7	0.05	26.9	6	0.01	5	0.25	4.7	14.7	0.25	0.11		26.9
	SC5	11000	21.4	17.7	0.05	50.9	17.3	0.01	20.3	0.25	9.3	38.9	0.25	0.34	39.1	40.6
	SC50_0.0-0.23	7350	22.2	7.3	0.05	51.8	13.5	0.01	15.5	0.25	8	29.8	0.25	0.13		22.8

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Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
	SC51	4270	47.4	20.9	0.1	24.7	5.5	0.01	2.2	0.25	4.5	11	0.25	0.09	72.2	25.6
	SC52_0.00.050	4920	18.5	12.1	0.05	36.2	6.4	0.01	7.1	0.25	5.5	16.2	0.25	0.11		30.4
	SC53_0.00.055	4180	12.8	9.8	0.05	33.5	9.8	0.01	10.4	0.25	6	19.7	0.25	0.1		27.9
	SC54_0.0-0.20	8880	22	14.8	0.05	48.4	16.5	0.01	17.8	0.25	34	34.1	0.25	0.16		31.7
	SC55_0.0-0.25	5620	22.8	7	0.05	43.5	8.9	0.01	11	0.25	6.6	22.3	0.25	0.11		24.3
	SC55_0.0-0.30	8400	16.2	20.9	0.4	46.3	14.2	0.01	14.1	0.25	7.1	25.3	0.25	0.12		26.2
	SC56_0.0-0.31	3670	12	15.9	0.1	39.4	10.3	0.01	11.5	0.25	6.8	20.4	0.25	0.06		18.8
	SC57_0.00.055	10100	17.6	37	0.05	77.4	23.5	0.01	26.7	0.25	11.8	46	0.25	0.07	1.23	25
	SC58_0.00.055	5820	24.9	11.5	0.05	38.8	9.5	0.01	10.6	0.25	6.4	23.4	0.25	0.11	45	25.4
	SC59_0.0-0.23	5760	22	6.4	0.05	41.6	9.7	0.01	11.7	0.25	6.2	23.6	0.25	0.11		22.9
	SC6_0.0-0.2	4310	8.65	20.7	0.05	41	12.5	0.01	12.7	0.25	6.6	19.4	0.25	0.04		22.4
	SC60_0.0-0.20	6460	16	7.3	0.05	47.3	10.7	0.01	13.2	0.25	6.6	23.4	0.25	0.09		26.7
	SC61_0.00.058	10200	18.5	24.8	0.05	62.2	22.3	0.02	23.4	0.25	9.7	40.6	0.25	0.12		29
	SC62_0.00.050	9600	13.3	34.5	0.05	71.2	19.2	0.03	23.9	0.25	10.5	36.1	0.25	0.07		22.3
	SC63	6820	19.7	9.4	0.05	52.9	13.8	0.02	14.9	0.25	8	29.2	0.25	0.16		24
	SC64_0.00.055	7680	12.2	14.2	0.05	61.7	16.6	0.01	18.5	0.25	8.3	26.8	0.25	0.07		23
	SC65	3470	21.8	12.6	0.05	19.1	3.6	0.01	1.5	0.25	3.9	11.1	0.25	0.13		28.7
	SC66	4360	26.1	13.5	0.05	24.4	4.7	0.01	4	0.25	4.7	13.4	0.25	0.14		26.2
	SC67_0.00.055	3430	28.2	5.4	0.05	24.9	3.9	0.01	3.7	0.25	4	10.7	0.25	0.07		24
	SC68_0.0-0.20	3590	19.5	7	0.05	27.4	4.4	0.01	3.5	0.25	4.2	11.6	0.25	0.08		24.3
	SC69_0.00.056	8020	15	15.2	0.1	51.2	18.7	0.01	17.8	0.25	8.1	31.6	0.25	0.09		26.6
	SC7_0.00.050	5270	21.5	10.6	0.05	38.2	9.4	0.01	10.2	0.25	6	23.1	0.25	0.11	38.5	20.1
	SC70_0.00.050	6510	19.9	10.2	0.05	40.7	9.6	0.01	10.8	0.25	6.3	22.3	0.25	0.11		29.4
	SC71	7020	24.7	7.6	0.05	49.5	11.3	0.01	13.4	0.25	7.4	27.1	0.25	0.12		28.1

Appendix D

Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
	SC72	6020	23.4	6.9	0.05	41.4	9.8	0.01	10.5	0.25	6.3	22.7	0.25	0.12		27
	SC8_0.0-0.30	5730	21.7	7	0.05	42.1	9.8	0.01	11.2	0.25	6.4	24.5	0.25	0.18		21.4
	SC9_0.0-0.20	7780	22.9	9.5	0.05	55	14.7	0.01	16.3	0.25	8.6	32.1	0.25	0.15		30.1
Dredge Material Placement Site A	G41	6040	23.5	8.6	0.05	45.4	10	0.01	11.8	0.25	6.8	24.7			33.1	25.1
	G42	5200	29	11.6	0.2	40.1	10.1	0.01	10	0.25	7	20.8			44.2	25.8
	G43	6510	25.8	8.5	0.05	45.4	10.8	0.01	12.6	0.25	10.6	26.6				27.1
	G44	5300	24.7	7.8	0.05	39.5	8.4	0.01	9.7	0.25	5.9	21.2			38.8	23.3
	G45	8210	24.1	11.1	0.05	55.1	14.7	0.01	16.5	0.25	8.6	32.6				34.1
	G46	6670	24.1	8.3	0.05	46.1	11.1	0.01	12.6	0.25	7	25.9	0.25	0.89	34.6	26.5
	G47	7110	21.2	10	0.05	47.3	13.2	0.01	14.1	0.25	7.6	29.5	0.25	0.15	35.8	26.6
	G48	5790	31.6	12.1	0.1	32.7	9.8	0.01	9	0.25	5.6	20.6				28.9
	G49	5120	23.2	8.6	0.05	34.9	8.4	0.01	8.5	0.25	5.4	19.8				25.6
Dredge Material Placement Site B	G30	4860	33.9	15.2	0.05	26.8	6.6	0.01	5	0.25	4.7	13.5				24.7
	G31	6110	32.3	14.2	0.05	34.7	8.6	0.01	8.2	0.25	6.2	18.6			62.6	30.2
	G32	6530	24	14.2	0.05	39.6	10.6	0.01	11.2	0.25	6.7	22.8				34.4
	G33	7180	23.3	9.1	0.05	46.6	12.2	0.01	13.8	0.25	7.2	29	0.25	0.14	37.8	27.9
	G34	6270	18.3	13.6	0.05	43	9.6	0.01	11.9	0.25	6.4	23.6				30
	G35	5630	17.4	9.8	0.05	36.8	8.1	0.01	8.6	0.25	5.5	20			45.2	30.6
	G36	4420	19.4	12	0.05	40.3	7.1	0.01	8	0.25	5.8	17.8				26.6
	G37	6120	18.1	10.3	0.05	38.8	8.8	0.01	10	0.25	6	22.1				28.7
	G38	7130	20.7	12.7	0.05	41	9.9	0.01	11.5	0.25	6.7	23.5	0.25	0.15	37.8	31.2
	G39	3120	12.6	15.3	0.05	13.4	4.1	0.01	0	0.25	2.8	8.7			81.4	25.3
Dredge Material Placement	G1	4130	29.6	13.7	0.05	22.8	5.4	0.01	4.5	0.25	4.7	11.6				23.9
	G2	4650	22	12.1	0.05	28.2	4.6	0.01	3.9	0.25	4.6	12.4				32.2

Appendix D

Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
Site C	G3	4920	21.5	11.5	0.05	30	5.2	0.01	5	0.25	4.6	13.3				28.8
	G4	4240	23.4	11.9	0.05	26	4	0.01	3	0.25	4.3	10.7				30.4
	G5	4620	21	13.7	0.05	29.9	4.8	0.01	3.6	0.25	5.4	13				32.2
	G6	4280	28.4	12.9	0.05	28.8	4.4	0.01	4.4	0.25	5	12	0.25	0.14	68.8	29.4
	G7	4660	27.3	16	0.05	26.9	5.9	0.01	5.8	0.25	4.7	14.2				29.3
	G8	4900	26.2	20.6	0.05	25.8	5.9	0.01	5.9	0.25	4.7	14				26.1
	G9	4110	24.7	12.8	0.05	27	4.9	0.01	4.7	0.25	5.5	12.4	0.25	0.15	61.2	28.9
	G10	4360	26.6	12.4	0.05	29.8	4.8	0.01	4.9	0.25	4.8	12.8	0.25	0.15	65.6	29.8
	G11	4400	32.3	11.6	0.05	38.6	5.2	0.01	5.3	0.25	5.8	14.7				32.7
	G12	3950	28	11.6	0.05	30.4	4	0.01	4	0.25	4.7	11.5				28.5
	G13	4060	19.8	12.3	0.05	25.1	4.7	0.01	4.7	0.25	4.4	11.9	0.25	0.15	65.6	28.3
	G14	3690	26.6	11	0.05	24.7	3.8	0.01	3.4	0.25	4.3	11.2			69.7	29
	G15	4450	25.4	11.6	0.05	29.4	5.3	0.01	6	0.25	4.8	13.4				29.1
	G16	4090	29.8	11.3	0.05	28.7	4.4	0.01	4.8	0.25	4.7	12.2				29.1
	G17	4200	25	12.1	0.05	30	5.2	0.01	5.2	0.25	4.9	12.7				30.4
	G18	4210	22	13.1	0.05	25.6	4.5	0.01	3.8	0.25	5.2	12.2				34
	G19	5590	24.8	19.2	0.2	33.2	11	0.01	9.1	0.25	6	17				28.9
	G69	2790	19.2	10.2	0.05	22.4	3.7	0.01	5.1	0.25	4.3	10.6				30.3
	G70	2430	27.3	10.1	0.05	19.3	2.6	0.01	3.5	0.25	4	9.2				28.9
	G71	3600	21.3	11	0.05	28.9	5.3	0.01	7.2	0.25	5.2	14.1				31.5
	G72	3350	21.1	12.2	0.05	23.8	4.6	0.01	5.4	0.25	4.6	12.1				32.8
	G73	3440	22.1	14.1	0.05	21.8	4.9	0.01	5.7	0.25	4.5	13.1				32.2
Dredge Material Placement	G50	3870	5.88	15.3	0.1	26.5	3.7	0.01	9.1	0.25	3.8	9.3	0.25	0.28	69.1	35.2
	G51	3990	5.42	14.1	0.2	28.6	3.8	0.01	9.1	0.25	3.8	16.3			70.3	33.6

Appendix D

Area	Sample ID	Al	As	Ba	Cd	Cr	Cu	Hg	Ni	Sb	Pb	Zn	TBT (µg Sn/kg)	TOC (%)	$CaCO_3$ (%)	MC (%)
Site E	G52	3640	5.56	14.6	0.1	25.9	3.7	0.01	8.5	0.25	3.6	8.9			71.8	35.2
	G53	3500	7.49	13.2	0.1	25	3	0.01	8.1	0.25	3.6	9			72.4	32.3
	G54	3960	5.4	13.8	0.1	25.7	3.9	0.02	8.6	0.25	3.4	9.8				34.6
	G55	3120	5.94	13	0.1	22.5	2.8	0.02	7.2	0.25	3.4	7.9				33.2
	G56	3840	5.03	14.9	0.1	25.7	3.9	0.01	8.8	0.25	3.5	9.2				35.6
	G57	4270	5.21	14.7	0.1	29.4	4	0.01	10	0.25	3.8	10.8				36.4
	G58	4700	6.91	16.8	0.1	31.8	5.2	0.01	10.6	0.25	4	12.5	0.25	0.4	67.1	41.6
	G74	3590	5.06	13.9	0.1	24	3.6	0.01	8.2	0.25	3.2	8.5				34.6
Dredge Material Placement Site D	G59	2890	4.77	21.1	0.1	23	3.4	0.01	7.5	0.25	2.9	9.5			74.6	37.3
	G60	3230	7.16	14.8	0.1	22.8	3.2	0.01	7.2	0.25	3.4	8.2			70.4	36
	G61	2700	8.32	12.5	0.05	19.6	2.6	0.01	6.5	0.25	2.9	6.6			70	35.1
	G62	2640	9.11	13.3	0.05	20.6	2.5	0.01	5.9	0.25	2.9	6.6				35.2
	G63	2940	6.68	12.9	0.1	20.9	3	0.01	6.6	0.25	3.1	7.8				36.6
	G64	3040	7.83	13.6	0.1	22.2	3	0.01	6.9	0.25	3.2	7.7	0.25	0.2	71.4	35.6
	G65	3300	6.82	14.5	0.1	23.4	3.2	0.02	7.4	0.25	3.7	8.5				35.5
	G66	2950	7.6	13.1	0.05	20.7	3.1	0.01	6.6	0.25	3	7.4	0.25	0.22	69.4	34.7
	G75	2570	7.79	12.3	0.1	20.4	2.4	0.01	5.6	0.25	2.8	6.5				34.2
	G76	3350	7.99	14.1		23.2	3.2	0.01	7.5	0.25	3.4	8.4				35.3

Table D-2 Short core & grab sample physicochemical data.

Area	Sample ID	Cobbles (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Dredge Area	SC1_0.0-0.27					
	SC10_0.00.050					
	SC11_0.00.055	0	2	17	53	28
	SC12_0.00.055					
	SC13	0	29	34	19	18
	SC14_0.00.051					
	SC15	0	24	35	22	19
	SC16					
	SC17_0.0-0.35					
	SC18_0.0-0.30					
	SC19_0.00.052	0	15	55	16	14
	SC2_0.0-0.22					
	SC20_0.0-0.20					
	SC21_0.00.055					
	SC22_0.00.053					
	SC23_0.0-0.25	0	18	54	11	17
	SC24	0	34	48	8	10
	SC25					
	SC26_0.00.051	0	5	47	15	33
	SC27_0.0-0.32	0	6	63	11	20
	SC28_0.0-0.25	0	8	52	19	21
	SC29_0.0-0.20	0	14	52	12	22
	SC3_0.0-0.22					
	SC30_0.0-0.2					
	SC31_0.0-0.20					
	SC32_0.00.05					
	SC33_0.0-0.33					
	SC34_0.0-0.25					
	SC35_0.00.055					
	SC36_0.00.050					
	SC37_0.00.051					
	SC38_0.0-0.40					
	SC39_0.00.050					
	SC4_0.0-0.25	0	7	70	10	13
	SC40_0.0-0.31	0	11	48	22	19
	SC41_0.0-0.30					
	SC42_0.0-0.25	0	19	61	6	14
	SC43_0.0-0.23					
	SC44_0.00.052					
	SC45	0	5	71	9	15
	SC46_0.0-0.25					

	SC47_0.0-0.25					
	SC48_0.00.050					
	SC49_0.00.050					
	SC5					
	SC50_0.0-0.23	0	3	70	13	14
	SC51					
	SC52_0.00.050					
	SC53_0.00.055					
	SC54_0.0-0.20					
	SC55_0.0-0.25					
	SC55_0.0-0.30	0	17	53	14	16
	SC56_0.0-0.31					
	SC57_0.00.055					
	SC58_0.00.055					
	SC59_0.0-0.23					
	SC6_0.0-0.2					
	SC60_0.0-0.20	0	33	46	10	11
	SC61_0.00.058					
	SC62_0.00.050					
	SC63					
	SC64_0.00.055					
	SC65					
	SC66					
	SC67_0.00.055					
	SC68_0.0-0.20					
	SC69_0.00.056					
	SC7_0.00.050					
	SC70_0.00.050					
	SC71					
	SC72					
	SC8_0.0-0.30	0	6	71	10	13
	SC9_0.0-0.20	0	13	51	15	21
Dredge Material Placement Site A	G41					
	G42	0	34	42	12	12
	G43					
	G44	0	11	68	6	15
	G45	0	2	58	12	28
	G46					
	G47	0	19	63	6	12
	G48					
	G49					

Dredge Material Placement Site B	G30					
	G31					
	G32					
	G33	0	13	59	10	18
	G34					
	G35	0	9	64	9	18
	G36	0	6	64	11	19
	G37	0	10	60	13	17
	G38					
	G39	0	25	56	8	11
Dredge Material Placement Site C	G1					
	G2					
	G3					
	G4					
	G5					
	G6	0	2	77	8	13
	G7	0	3	71	11	15
	G8	0	39	42	10	9
	G9	0	5	74	7	14
	G10	0	2	80	3	15
	G11					
	G12					
	G13	0	25	45	14	16
	G14	0	4	82	2	12
	G15					
	G16	0	1	83	4	12
	G17	0	2	78	4	16
	G18					
	G19					
	G69	0	2	81	5	12
	G70					
	G71	0	0	83	2	15
	G72					
	G73	0	25	54	10	11
Dredge Material Placement Site E	G50	0	10	59	10	21
	G51	0	2	75	11	12
	G52	0	2	72	14	12
	G53	0	5	77	9	9
	G54					
	G55					
	G56					

Appendix D

	G57	0	4	66	17	13
	G58					
	G74					
Dredge Material Placement Site D	G59	0	9	72	11	8
	G60	0	2	83	6	9
	G61					
	G62					
	G63					
	G64	0	2	85	5	8
	G65	0	1	82	8	9
	G66					
	G75	0	1	88	3	8
	G76					

E

Appendix E Deep Core Analytical & Physicochemical Data

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ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0903726**	Page	: 1 of 9
Client	: **COFFEY GEOTECHNICS**	Laboratory	: Environmental Division Perth
Contact	: MS CASSANDRA TURVEY	Contact	: Michael Sharp
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Project	: GEOTHERD08668AA	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 08-JUL-2009
Sampler	: CASSIE TURVEY	Issue Date	: 16-JUL-2009
Site	: WHEATSTONE NEARSHORE		
		No. of samples received	: 35
Quote number	: ----	No. of samples analysed	: 31

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
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Page : 2 of 9
Work Order : EP0903726
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Poor metal matrix spike recoveries due to matrix effects. Confirmed by re-extraction and re-analysis.**

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Work Order : EP0903726
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	MC012 0.45-0.55m	MC012 0.9-1.0m	MC012 (comp) 1.0-2.0m	MC012 4.0-4.1m	QA/QC
			Client sampling date / time	07-JUL-2009 15:00	07-JUL-2009 15:00	07-JUL-2009 15:00	07-JUL-2009 15:00	07-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	EP0903726-001	EP0903726-002	EP0903726-003	EP0903726-004	EP0903726-005
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**21.3**	**15.3**	**17.2**	**21.6**	**16.2**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**16**	**7**	**5**	<5	<5
Barium	7440-39-3	10	mg/kg	<10	**20**	**40**	**140**	**10**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	**1**	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**26**	**45**	**51**	**52**	**45**
Cobalt	7440-48-4	2	mg/kg	**11**	**8**	**14**	**19**	**9**
Copper	7440-50-8	5	mg/kg	**10**	**24**	**31**	**40**	**18**
Iron	7439-89-6	50	mg/kg	**26500**	**34600**	**44600**	**51600**	**40100**
Lead	7439-92-1	5	mg/kg	**6**	**8**	**11**	**13**	**8**
Manganese	7439-96-5	5	mg/kg	**403**	**186**	**462**	**1080**	**171**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**10**	**18**	**26**	**36**	**20**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**49**	**57**	**76**	**82**	**62**
Zinc	7440-66-6	5	mg/kg	**18**	**23**	**31**	**50**	**26**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Work Order : EP0903726
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC005** **0.45-0.55m**	**MC005** **0.9-1.0m**	**MC005 (comp)** **1-2m**	**MC005** **3.0-3.1m**	**MC005** **6.9-7.0m**
			Client sampling date / time	06-JUL-2009 15:00	06-JUL-2009 15:00	06-JUL-2009 15:00	06-JUL-2009 15:00	06-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903726-006**	**EP0903726-007**	**EP0903726-008**	**EP0903726-009**	**EP0903726-010**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**21.2**	**20.7**	**22.4**	**15.0**	**16.5**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**17**	**6**	<5	<5	<5
Barium	7440-39-3	10	mg/kg	<10	**230**	**20**	**100**	**20**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**30**	**48**	**42**	**47**	**43**
Cobalt	7440-48-4	2	mg/kg	**10**	**10**	**7**	**21**	**13**
Copper	7440-50-8	5	mg/kg	**8**	**27**	**15**	**30**	**24**
Iron	7439-89-6	50	mg/kg	**28100**	**37600**	**34400**	**42200**	**41100**
Lead	7439-92-1	5	mg/kg	**6**	**10**	**9**	**13**	**12**
Manganese	7439-96-5	5	mg/kg	**365**	**166**	**146**	**1290**	**355**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**9**	**23**	**19**	**29**	**28**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**53**	**66**	**51**	**73**	**63**
Zinc	7440-66-6	5	mg/kg	**17**	**31**	**24**	**35**	**35**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Work Order : EP0903726
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**MC004** **0.9-1.0m**	**MC004 (comp)** **1-2m**	**MC004** **3.9-4.0m**	**MC004** **8.0-8.1**	**MC003** **6.9-7.0m**
			Client sampling date / time	05-JUL-2009 15:00	05-JUL-2009 15:00	05-JUL-2009 15:00	06-JUL-2009 15:00	05-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903726-011**	**EP0903726-012**	**EP0903726-013**	**EP0903726-014**	**EP0903726-019**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**14.2**	**14.2**	**18.9**	**16.3**	**20.4**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**7**	**5**	**14**	<5	<5
Barium	7440-39-3	10	mg/kg	**60**	**20**	**20**	**80**	**20**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**34**	**36**	**20**	**38**	**46**
Cobalt	7440-48-4	2	mg/kg	**7**	**5**	**3**	**8**	**7**
Copper	7440-50-8	5	mg/kg	**14**	**12**	**6**	**13**	**17**
Iron	7439-89-6	50	mg/kg	**27100**	**24500**	**17300**	**27100**	**37100**
Lead	7439-92-1	5	mg/kg	**6**	**6**	<5	**7**	**8**
Manganese	7439-96-5	5	mg/kg	**129**	**121**	**270**	**276**	**214**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**12**	**12**	**6**	**15**	**19**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**52**	**50**	**43**	**48**	**67**
Zinc	7440-66-6	5	mg/kg	**14**	**14**	**7**	**16**	**26**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Work Order : EP0903726
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

Compound	*CAS Number*	*LOR*	*Unit*	**MC002 1.0-1.1m** 03-JUL-2009 15:00 **EP0903726-020**	**MC002 1.9-2.0m** 03-JUL-2009 15:00 **EP0903726-021**	**MC002 2.9-3.0m** 03-JUL-2009 15:00 **EP0903726-022**	**MC002 6.4-6.5m** 04-JUL-2009 15:00 **EP0903726-023**	**MC001 0.45-0.55m** 03-JUL-2009 15:00 **EP0903726-024**
			Client sample ID / *Client sampling date / time*					
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**20.1**	**12.9**	**25.3**	**17.6**	**14.8**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**8**	<5	<5	**7**	<5
Barium	7440-39-3	10	mg/kg	**20**	**140**	**40**	**20**	**30**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**43**	**44**	**56**	**31**	**46**
Cobalt	7440-48-4	2	mg/kg	**7**	**7**	**16**	**5**	**8**
Copper	7440-50-8	5	mg/kg	**17**	**17**	**34**	**8**	**19**
Iron	7439-89-6	50	mg/kg	**33300**	**36100**	**46200**	**24100**	**39100**
Lead	7439-92-1	5	mg/kg	**8**	**7**	**13**	**6**	**10**
Manganese	7439-96-5	5	mg/kg	**138**	**114**	**579**	**401**	**167**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**15**	**17**	**29**	**10**	**20**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**64**	**60**	**80**	**46**	**64**
Zinc	7440-66-6	5	mg/kg	**19**	**20**	**41**	**12**	**24**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Work Order : EP0903726
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC001 0.9-1.0m	MC001 (comp) 1.0-2.0m	MC001 3.4-3.5m	MC001 6.4-6.5m	MC015 0.45-0.55m
Client sampling date / time				03-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00	03-JUL-2009 15:00	02-JUL-2009 15:00
				EP0903726-025	**EP0903726-026**	**EP0903726-027**	**EP0903726-028**	**EP0903726-030**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**18.9**	**17.8**	**19.6**	**15.4**	**17.8**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**5**	<5	**8**	**6**	**11**
Barium	7440-39-3	10	mg/kg	**90**	**10**	**20**	<10	<10
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**61**	**52**	**29**	**34**	**20**
Cobalt	7440-48-4	2	mg/kg	**25**	**12**	**6**	**5**	**5**
Copper	7440-50-8	5	mg/kg	**25**	**39**	**14**	**16**	**6**
Iron	7439-89-6	50	mg/kg	**52000**	**46200**	**24200**	**27500**	**18200**
Lead	7439-92-1	5	mg/kg	**14**	**13**	**8**	**7**	<5
Manganese	7439-96-5	5	mg/kg	**221**	**229**	**334**	**119**	**369**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**38**	**30**	**13**	**12**	**6**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**84**	**57**	**47**	**49**	**36**
Zinc	7440-66-6	5	mg/kg	**39**	**38**	**18**	**15**	**12**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Work Order : EP0903726
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC015 0.9-1.0m**	**MC015 (comp) 1.0-2.0m**	**MC015 3.4-3.5m**	**MC015 6.4-6.5m**	**QA/QC**
			Client sampling date / time	02-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00	02-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903726-031**	**EP0903726-032**	**EP0903726-033**	**EP0903726-034**	**EP0903726-035**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**18.4**	**18.2**	**16.9**	**17.0**	**15.0**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**9**	<5	<5	**13**	**10**
Barium	7440-39-3	10	mg/kg	**60**	**20**	**10**	**20**	<10
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**27**	**52**	**60**	**23**	**20**
Cobalt	7440-48-4	2	mg/kg	**7**	**12**	**19**	**5**	**4**
Copper	7440-50-8	5	mg/kg	**9**	**24**	**40**	**7**	**7**
Iron	7439-89-6	50	mg/kg	**20600**	**42400**	**42700**	**20300**	**18000**
Lead	7439-92-1	5	mg/kg	<5	**11**	**14**	**5**	<5
Manganese	7439-96-5	5	mg/kg	**136**	**662**	**337**	**293**	**370**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**8**	**23**	**34**	**8**	**6**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**40**	**67**	**83**	**41**	**36**
Zinc	7440-66-6	5	mg/kg	**13**	**46**	**48**	**12**	**11**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**RINSATE**	----	----	----	----
			Client sampling date / time	03-JUL-2009 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903726-029**	**----**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS								
Antimony	7440-36-0	0.001	mg/L	**0.002**	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.006**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.006**	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.005**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.012**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.005**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	----	----	----	----
Tin	7440-31-5	0.001	mg/L	<0.001	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.010**	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.27**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EP0903742**

Client : **COFFEY GEOTECHNICS**
Contact : MS CASSANDRA TURVEY
Address : PO BOX 1810
WEST PERTH WA, AUSTRALIA 6872

E-mail : cassandra_turvey@coffey.com
Telephone : +61 08 9347 0321
Facsimile : ----

Project : GEOTHERD08668AA
Order number : ----
C-O-C number : ----
Sampler : CASSIE TURVEY
Site : WHEATSTONE NEARSHORE

Quote number : ----

Page : 1 of 7

Laboratory : Environmental Division Perth
Contact : Michael Sharp
Address : 10 Hod Way Malaga WA Australia 6090

E-mail : michael.sharp@alsenviro.com
Telephone : +61-8-9209 7655
Facsimile : +61-8-9209 7600

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 08-JUL-2009
Issue Date : 14-JUL-2009

No. of samples received : 23
No. of samples analysed : 23

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Scott James	Assistant Laboratory Manager	Perth Inorganics

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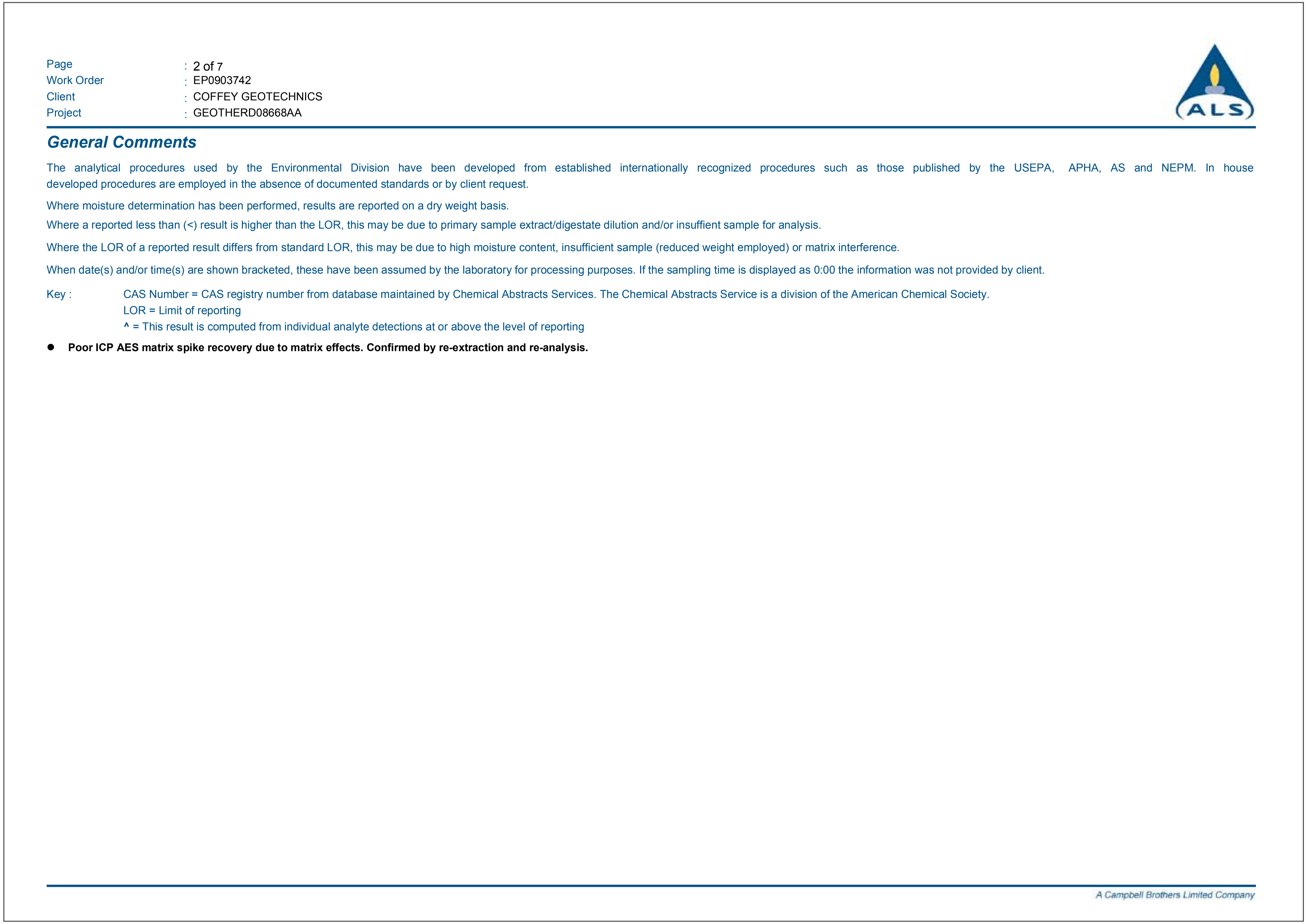
A Campbell Brothers Limited Company



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Work Order : EP0903742
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Poor ICP AES matrix spike recovery due to matrix effects. Confirmed by re-extraction and re-analysis.**

A Campbell Brothers Limited Company

Page : 3 of 7
Work Order : EP0903742
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**MC007** **0.45-0.55**	**MC007** **0.8-0.9**	**MC007** **1.0-2.0**	**MC008** **0.45-0.55**	**MC008** **0.8-0.9**
			Client sampling date / time	26-JUN-2009 15:00	26-JUN-2009 15:00	26-JUN-2009 15:00	25-JUN-2009 15:00	25-JUN-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903742-001**	**EP0903742-002**	**EP0903742-003**	**EP0903742-004**	**EP0903742-005**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**15.6**	**15.6**	**15.2**	**15.3**	**17.6**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	**6**	<5	<5	<5
Barium	7440-39-3	10	mg/kg	**50**	**50**	**30**	**40**	**110**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	**1**	**1**
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**52**	**58**	**48**	**58**	**62**
Cobalt	7440-48-4	2	mg/kg	**12**	**10**	**12**	**23**	**22**
Copper	7440-50-8	5	mg/kg	**21**	**27**	**26**	**27**	**28**
Iron	7439-89-6	50	mg/kg	**38700**	**44000**	**39100**	**49600**	**51700**
Lead	7439-92-1	5	mg/kg	**10**	**12**	**10**	**13**	**14**
Manganese	7439-96-5	5	mg/kg	**175**	**202**	**453**	**224**	**337**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**21**	**24**	**23**	**32**	**32**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**77**	**89**	**72**	**74**	**91**
Zinc	7440-66-6	5	mg/kg	**31**	**32**	**27**	**43**	**44**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Page : 4 of 7
Work Order : EP0903742
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC008 2.0-3.0**	**MC008 3.8-3.9**	**MC008 7.0-7.1**	**MC011 0.0-0.4**	**MC011 1.0-1.1**
			Client sampling date / time	25-JUN-2009 15:00	25-JUN-2009 15:00	25-JUN-2009 15:00	27-JUN-2009 15:00	27-JUN-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903742-006**	**EP0903742-007**	**EP0903742-008**	**EP0903742-009**	**EP0903742-010**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**12.6**	**17.8**	**18.8**	**30.5**	**18.8**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	**5**	**6**	**19**	<5
Barium	7440-39-3	10	mg/kg	<10	**30**	**10**	<10	**20**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**46**	**44**	**34**	**31**	**50**
Cobalt	7440-48-4	2	mg/kg	**8**	**8**	**3**	**13**	**12**
Copper	7440-50-8	5	mg/kg	**19**	**23**	**7**	**12**	**24**
Iron	7439-89-6	50	mg/kg	**35000**	**34000**	**19800**	**29700**	**48100**
Lead	7439-92-1	5	mg/kg	**8**	**8**	<5	**7**	**12**
Manganese	7439-96-5	5	mg/kg	**207**	**158**	**88**	**480**	**281**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**16**	**17**	**9**	**12**	**26**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	**3**	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**68**	**69**	**40**	**55**	**91**
Zinc	7440-66-6	5	mg/kg	**18**	**21**	**12**	**24**	**32**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Page : 5 of 7
Work Order : EP0903742
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC011** **2.0-3.0**	**MC011** **3.5-3.6**	**MC011** **7.5-7.55**	**MC013** **0.45-0.55**	**MC013** **0.8-0.9**
			Client sampling date / time	28-JUN-2009 15:00	28-JUN-2009 15:00	28-JUN-2009 15:00	29-JUN-2009 15:00	29-JUN-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903742-011**	**EP0903742-012**	**EP0903742-013**	**EP0903742-014**	**EP0903742-015**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**20.3**	**16.3**	**15.3**	**17.3**	**17.7**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	**5**	**5**	**16**	**8**
Barium	7440-39-3	10	mg/kg	**20**	**140**	**70**	**20**	**10**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**52**	**52**	**44**	**53**	**37**
Cobalt	7440-48-4	2	mg/kg	**12**	**14**	**14**	**13**	**11**
Copper	7440-50-8	5	mg/kg	**21**	**30**	**26**	**21**	**16**
Iron	7439-89-6	50	mg/kg	**40000**	**41700**	**37800**	**49800**	**33200**
Lead	7439-92-1	5	mg/kg	**8**	**9**	**13**	**12**	**9**
Manganese	7439-96-5	5	mg/kg	**289**	**587**	**590**	**181**	**306**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**24**	**27**	**23**	**22**	**16**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**67**	**77**	**70**	**80**	**59**
Zinc	7440-66-6	5	mg/kg	**38**	**40**	**30**	**31**	**25**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Page : 6 of 7
Work Order : EP0903742
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	MC013 1.0-2.0	MC013 3.4-3.5	MC013 6.9-7.0	MC014 0.45-0.55	MC014 0.8-0.9
			Client sampling date / time	29-JUN-2009 15:00	29-JUN-2009 15:00	30-JUN-2009 15:00	30-JUN-2009 15:00	30-JUN-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	EP0903742-016	EP0903742-017	EP0903742-018	EP0903742-019	EP0903742-020
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	16.5	19.1	13.2	20.6	16.4
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	5	<5	6	<5	<5
Barium	7440-39-3	10	mg/kg	60	200	<10	80	20
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	55	56	41	54	68
Cobalt	7440-48-4	2	mg/kg	15	33	6	9	15
Copper	7440-50-8	5	mg/kg	32	38	11	26	20
Iron	7439-89-6	50	mg/kg	48200	47900	32800	38400	51600
Lead	7439-92-1	5	mg/kg	14	14	8	10	14
Manganese	7439-96-5	5	mg/kg	373	1740	122	207	199
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	30	38	14	22	30
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	77	78	60	64	82
Zinc	7440-66-6	5	mg/kg	41	50	20	32	41
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Page : 7 of 7
Work Order : EP0903742
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC014 1.0-2.0	MC014 3.4-3.5	MC014 6.9-7.0	----	----
			Client sampling date / time	30-JUN-2009 15:00	30-JUN-2009 15:00	30-JUN-2009 15:00	----	----
				EP0903742-021	**EP0903742-022**	**EP0903742-023**	**----**	**----**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**16.5**	**20.9**	**11.0**	----	----
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	----	----
Arsenic	7440-38-2	5	mg/kg	<5	<5	**6**	----	----
Barium	7440-39-3	10	mg/kg	**20**	**60**	**30**	----	----
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	----	----
Chromium	7440-47-3	2	mg/kg	**62**	**54**	**52**	----	----
Cobalt	7440-48-4	2	mg/kg	**14**	**14**	**9**	----	----
Copper	7440-50-8	5	mg/kg	**19**	**33**	**22**	----	----
Iron	7439-89-6	50	mg/kg	**42600**	**46100**	**42400**	----	----
Lead	7439-92-1	5	mg/kg	**11**	**9**	**10**	----	----
Manganese	7439-96-5	5	mg/kg	**176**	**559**	**229**	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	----	----
Nickel	7440-02-0	2	mg/kg	**26**	**30**	**20**	----	----
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	----	----
Silver	7440-22-4	2	mg/kg	<2	<2	<2	----	----
Tin	7440-31-5	5	mg/kg	<5	<5	<5	----	----
Vanadium	7440-62-2	5	mg/kg	**89**	**76**	**73**	----	----
Zinc	7440-66-6	5	mg/kg	**36**	**49**	**20**	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	----	----

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EP0904656**

Client : **COFFEY GEOTECHNICS**
Contact : MS CASSANDRA TURVEY
Address : PO BOX 1810
WEST PERTH WA, AUSTRALIA 6872

E-mail : cassandra_turvey@coffey.com
Telephone : +61 08 9347 0321
Facsimile : ----

Project : Ex EP0903726 GEOTHERD08668AA
Order number : ----
C-O-C number : ----
Sampler : ----
Site : ----

Quote number : ----

Page : 1 of 3

Laboratory : Environmental Division Perth
Contact : Michael Sharp
Address : 10 Hod Way Malaga WA Australia 6090

E-mail : michael.sharp@alsenviro.com
Telephone : +61-8-9209 7655
Facsimile : +61-8-9209 7600

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 19-AUG-2009
Issue Date : 20-AUG-2009

No. of samples received : 4
No. of samples analysed : 4

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Scott James	Assistant Laboratory Manager	Perth Inorganics

Environmental Division Perth
Part of the **ALS Laboratory Group**
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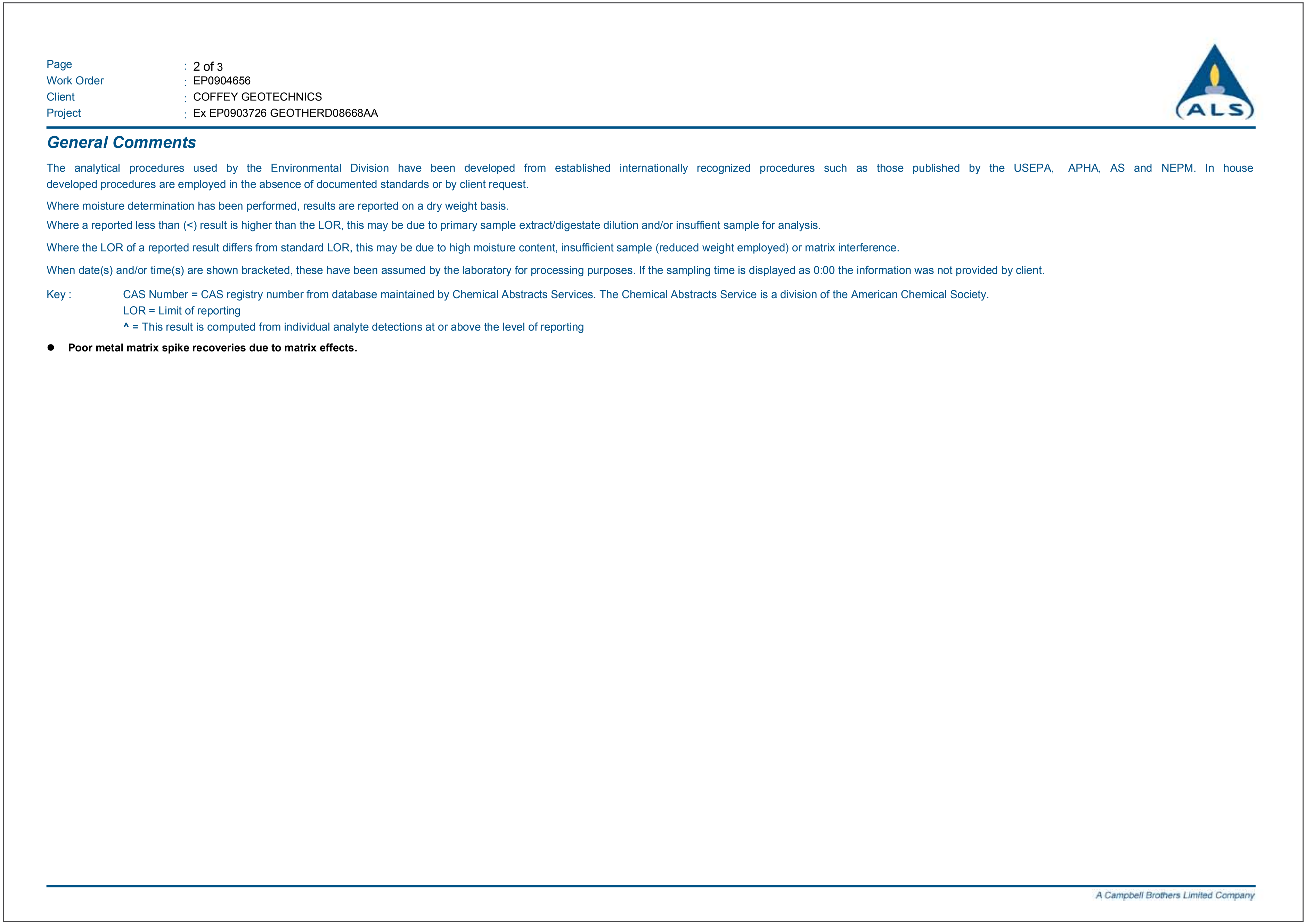
A Campbell Brothers Limited Company



Page : 2 of 3
Work Order : EP0904656
Client : COFFEY GEOTECHNICS
Project : Ex EP0903726 GEOTHERD08668AA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Poor metal matrix spike recoveries due to matrix effects.**

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Page : 3 of 3
Work Order : EP0904656
Client : COFFEY GEOTECHNICS
Project : Ex EP0903726 GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	MC003 0.45-0.55m	MC003 0.9-1.0m	MC003 (comp) 1-2m	MC003 3.4-3.5m	----
			Client sampling date / time	04-JUL-2009 15:00	04-JUL-2009 15:00	04-JUL-2009 15:00	04-JUL-2009 15:00	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904656-001**	**EP0904656-002**	**EP0904656-003**	**EP0904656-004**	**----**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**16.2**	**16.1**	**17.1**	**18.7**	----
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	----
Arsenic	7440-38-2	5	mg/kg	**6**	**5**	<5	<5	----
Barium	7440-39-3	10	mg/kg	**30**	**40**	**50**	**80**	----
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	**1**	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	----
Chromium	7440-47-3	2	mg/kg	**51**	**51**	**56**	**65**	----
Cobalt	7440-48-4	2	mg/kg	**10**	**12**	**14**	**17**	----
Copper	7440-50-8	5	mg/kg	**20**	**27**	**26**	**39**	----
Iron	7439-89-6	50	mg/kg	**39000**	**40800**	**45600**	**54500**	----
Lead	7439-92-1	5	mg/kg	**8**	**9**	**10**	**17**	----
Manganese	7439-96-5	5	mg/kg	**152**	**199**	**223**	**671**	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	----
Nickel	7440-02-0	2	mg/kg	**21**	**25**	**29**	**35**	----
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	----
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	----
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	----
Vanadium	7440-62-2	5	mg/kg	**82**	**71**	**83**	**85**	----
Zinc	7440-66-6	5	mg/kg	**26**	**31**	**37**	**54**	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----

A Campbell Brothers Limited Company

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EP0903870**
Client : **COFFEY GEOTECHNICS**
Contact : MS CASSANDRA TURVEY
Address : PO BOX 1810
WEST PERTH WA, AUSTRALIA 6872
E-mail : cassandra_turvey@coffey.com
Telephone : +61 08 9347 0321
Facsimile : ----
Project : GEOTHERD08668AA
Order number : ----
C-O-C number : ----
Sampler : CASSIE TURVEY
Site : WHEATSTONE NEARSHORE
Quote number : EN/007/09

Page : 1 of 9
Laboratory : Environmental Division Perth
Contact : Michael Sharp
Address : 10 Hod Way Malaga WA Australia 6090
E-mail : michael.sharp@alsenviro.com
Telephone : +61-8-9209 7655
Facsimile : +61-8-9209 7600
QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Date Samples Received : 14-JUL-2009
Issue Date : 22-JUL-2009
No. of samples received : 30
No. of samples analysed : 30

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Scott James	Assistant Laboratory Manager	Perth Inorganics

Environmental Division Perth
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Page : 2 of 9
Work Order : EP0903870
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

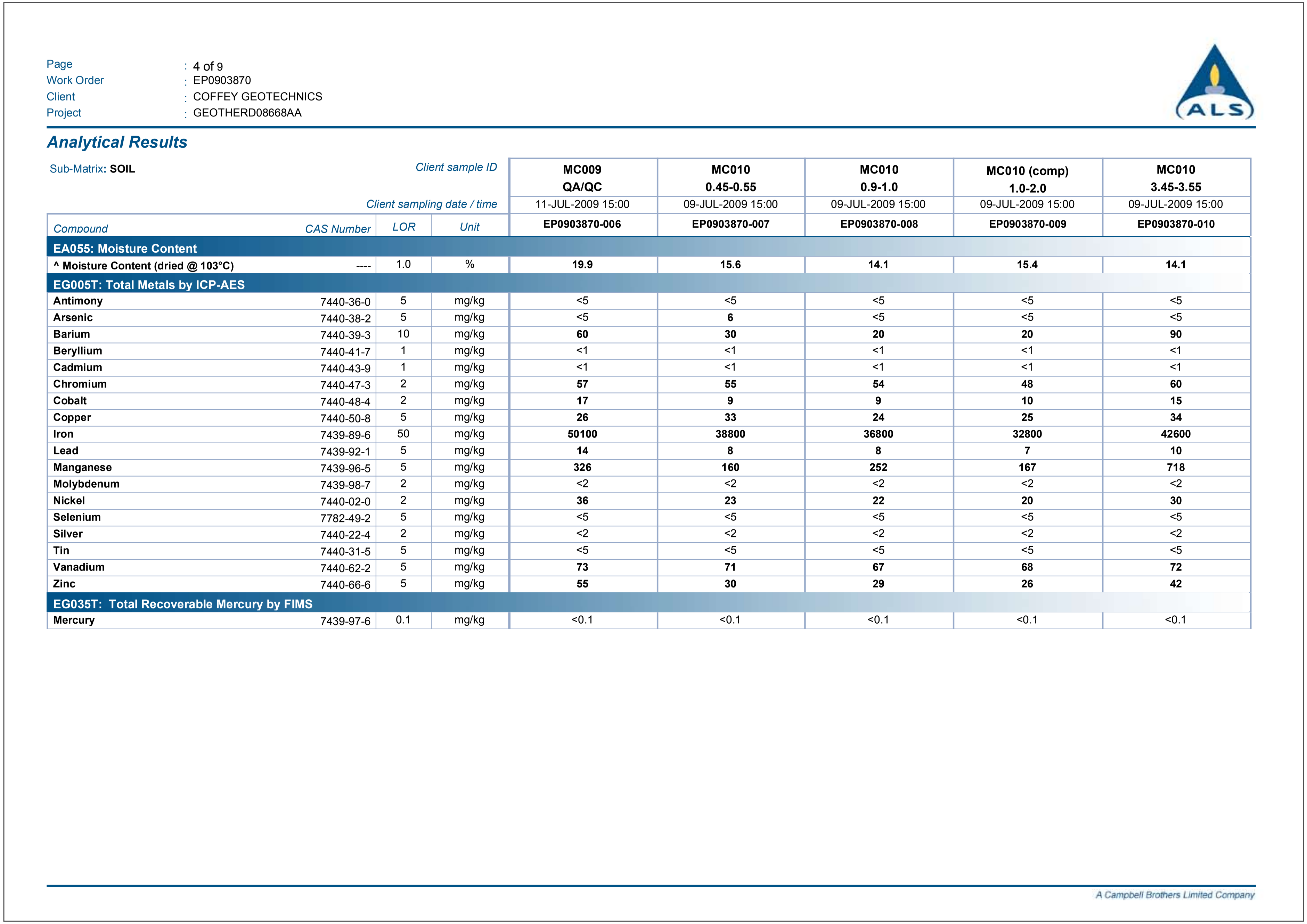
- **Ag not contained in LCS**
- **LOR raised due to high TDS**
- **Poor metal matrix spike recoveries for Antinomy due to matrix effects.**

Page : 3 of 9
Work Order : EP0903870
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC009 1.0-1.1	MC009 (comp) 2.0-3.0	MC009 3.9-4.0	MC009 8.9-9.0	MC009 13.4-13.5
Client sample ID				MC009 1.0-1.1	MC009 (comp) 2.0-3.0	MC009 3.9-4.0	MC009 8.9-9.0	MC009 13.4-13.5
Client sampling date / time				11-JUL-2009 15:00	11-JUL-2009 15:00	11-JUL-2009 15:00	12-JUL-2009 15:00	12-JUL-2009 15:00
				EP0903870-001	EP0903870-002	EP0903870-003	EP0903870-004	EP0903870-005
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**16.1**	**15.7**	**21.5**	**12.2**	**17.2**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**7**	<5	<5	<5	**16**
Barium	7440-39-3	10	mg/kg	**50**	**40**	**60**	**50**	<10
Beryllium	7440-41-7	1	mg/kg	<1	<1	**1**	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**48**	**51**	**62**	**48**	**17**
Cobalt	7440-48-4	2	mg/kg	**4**	**12**	**17**	**13**	**4**
Copper	7440-50-8	5	mg/kg	**13**	**21**	**29**	**25**	**5**
Iron	7439-89-6	50	mg/kg	**35900**	**42100**	**53000**	**39000**	**13100**
Lead	7439-92-1	5	mg/kg	**6**	**11**	**14**	**8**	<5
Manganese	7439-96-5	5	mg/kg	**137**	**234**	**389**	**456**	**95**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**15**	**29**	**38**	**23**	**6**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**64**	**64**	**76**	**75**	**40**
Zinc	7440-66-6	5	mg/kg	**21**	**40**	**56**	**25**	**7**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1



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Work Order : EP0903870
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

Client sample ID				**MC009** **QA/QC**	**MC010** **0.45-0.55**	**MC010** **0.9-1.0**	**MC010 (comp)** **1.0-2.0**	**MC010** **3.45-3.55**
Client sampling date / time				11-JUL-2009 15:00	09-JUL-2009 15:00	09-JUL-2009 15:00	09-JUL-2009 15:00	09-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903870-006**	**EP0903870-007**	**EP0903870-008**	**EP0903870-009**	**EP0903870-010**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**19.9**	**15.6**	**14.1**	**15.4**	**14.1**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	**6**	<5	<5	<5
Barium	7440-39-3	10	mg/kg	**60**	**30**	**20**	**20**	**90**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**57**	**55**	**54**	**48**	**60**
Cobalt	7440-48-4	2	mg/kg	**17**	**9**	**9**	**10**	**15**
Copper	7440-50-8	5	mg/kg	**26**	**33**	**24**	**25**	**34**
Iron	7439-89-6	50	mg/kg	**50100**	**38800**	**36800**	**32800**	**42600**
Lead	7439-92-1	5	mg/kg	**14**	**8**	**8**	**7**	**10**
Manganese	7439-96-5	5	mg/kg	**326**	**160**	**252**	**167**	**718**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**36**	**23**	**22**	**20**	**30**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**73**	**71**	**67**	**68**	**72**
Zinc	7440-66-6	5	mg/kg	**55**	**30**	**29**	**26**	**42**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Work Order : EP0903870
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MC010 7.9-8.0**	**MC010 10.9-11.0**	**MC012 9.4-9.5**	**MC006 0.45-0.55**	**MC006 0.9-1.0**
			Client sampling date / time	09-JUL-2009 15:00	11-JUL-2009 15:00	08-JUL-2009 15:00	08-JUL-2009 15:00	08-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903870-011**	**EP0903870-012**	**EP0903870-013**	**EP0903870-014**	**EP0903870-015**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**18.0**	**15.4**	**21.6**	**23.7**	**16.6**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**7**	**13**	**7**	<5	<5
Barium	7440-39-3	10	mg/kg	<10	**30**	**170**	**20**	**240**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**37**	**42**	**47**	**60**	**54**
Cobalt	7440-48-4	2	mg/kg	**7**	**6**	**26**	**16**	**17**
Copper	7440-50-8	5	mg/kg	**12**	**18**	**28**	**34**	**29**
Iron	7439-89-6	50	mg/kg	**22000**	**24400**	**40800**	**43300**	**40900**
Lead	7439-92-1	5	mg/kg	<5	<5	**16**	**10**	**10**
Manganese	7439-96-5	5	mg/kg	**76**	**228**	**1400**	**357**	**830**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**14**	**15**	**34**	**30**	**28**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**50**	**57**	**71**	**90**	**76**
Zinc	7440-66-6	5	mg/kg	**15**	**16**	**35**	**35**	**35**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MC006 3.26-3.36 08-JUL-2009 15:00 EP0903870-016	MC006 9.9-10.0 09-JUL-2009 15:00 EP0903870-017	MU021 0.45-0.55 13-JUL-2009 15:00 EP0903870-019	MU021 0.9-1.0 13-JUL-2009 15:00 EP0903870-020	MU021 (comp) 1.0-2.0 13-JUL-2009 15:00 EP0903870-021
			Client sample ID / Client sampling date / time					
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**14.0**	**18.4**	**21.5**	**16.9**	**18.2**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**6**	**14**	**18**	**7**	**8**
Barium	7440-39-3	10	mg/kg	**50**	**90**	**10**	**50**	**20**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**46**	**52**	**23**	**49**	**47**
Cobalt	7440-48-4	2	mg/kg	**9**	**18**	**10**	**12**	**11**
Copper	7440-50-8	5	mg/kg	**20**	**32**	**7**	**20**	**20**
Iron	7439-89-6	50	mg/kg	**33000**	**41800**	**22700**	**30000**	**36700**
Lead	7439-92-1	5	mg/kg	**6**	**14**	<5	**7**	**9**
Manganese	7439-96-5	5	mg/kg	**461**	**639**	**438**	**171**	**183**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**20**	**24**	**9**	**21**	**23**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**62**	**91**	**39**	**101**	**58**
Zinc	7440-66-6	5	mg/kg	**27**	**21**	**19**	**26**	**32**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

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Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MU025 0.45-0.55**	**MU025 0.9-1.0**	**MU025 (comp) 1.0-2.0**	**MU025 3.4-3.5**	**MU023 0.45-0.55**
			Client sampling date / time	12-JUL-2009 15:00	12-JUL-2009 15:00	12-JUL-2009 15:00	12-JUL-2009 15:00	13-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	**EP0903870-022**	**EP0903870-023**	**EP0903870-024**	**EP0903870-025**	**EP0903870-026**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**22.7**	**19.8**	**19.4**	**15.6**	**18.2**
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	**13**	**6**	**6**	**8**	<5
Barium	7440-39-3	10	mg/kg	**10**	**50**	**50**	**10**	**100**
Beryllium	7440-41-7	1	mg/kg	<1	**1**	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**44**	**62**	**64**	**44**	**49**
Cobalt	7440-48-4	2	mg/kg	**13**	**9**	**17**	**7**	**16**
Copper	7440-50-8	5	mg/kg	**18**	**39**	**32**	**13**	**30**
Iron	7439-89-6	50	mg/kg	**32400**	**43000**	**47700**	**30400**	**39700**
Lead	7439-92-1	5	mg/kg	**8**	**10**	**12**	**7**	**11**
Manganese	7439-96-5	5	mg/kg	**497**	**786**	**628**	**150**	**327**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	**18**	**26**	**30**	**18**	**31**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	**63**	**84**	**87**	**59**	**69**
Zinc	7440-66-6	5	mg/kg	**31**	**39**	**43**	**22**	**34**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	**0.1**	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SOIL**

Client sample ID				**MU023 0.9-1.0**	**MU023 (comp) 1.0-2.0**	**MU023 3.5-3.6**	**MC006 (comp) 1-2m**	----
Client sampling date / time				13-JUL-2009 15:00	13-JUL-2009 15:00	13-JUL-2009 15:00	13-JUL-2009 15:00	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903870-027**	**EP0903870-028**	**EP0903870-029**	**EP0903870-030**	**----**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**18.2**	**14.3**	**16.4**	**15.8**	----
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	----
Arsenic	7440-38-2	5	mg/kg	<5	<5	**12**	<5	----
Barium	7440-39-3	10	mg/kg	**120**	**330**	**60**	**20**	----
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	----
Chromium	7440-47-3	2	mg/kg	**57**	**62**	**19**	**48**	----
Cobalt	7440-48-4	2	mg/kg	**20**	**18**	**4**	**10**	----
Copper	7440-50-8	5	mg/kg	**33**	**36**	**13**	**20**	----
Iron	7439-89-6	50	mg/kg	**39500**	**44600**	**14200**	**35300**	----
Lead	7439-92-1	5	mg/kg	**13**	**10**	<5	**7**	----
Manganese	7439-96-5	5	mg/kg	**370**	**977**	**369**	**357**	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	----
Nickel	7440-02-0	2	mg/kg	**30**	**31**	**7**	**22**	----
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	----
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	----
Tin	7440-31-5	5	mg/kg	<5	<5	<5	<5	----
Vanadium	7440-62-2	5	mg/kg	**69**	**74**	**34**	**67**	----
Zinc	7440-66-6	5	mg/kg	**38**	**40**	**10**	**27**	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----

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Work Order : EP0903870
Client : COFFEY GEOTECHNICS
Project : GEOTHERD08668AA

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**Rinsate**	----	----	----	----
			Client sampling date / time	09-JUL-2009 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903870-018**	**----**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS								
Antimony	7440-36-0	0.001	mg/L	<0.005	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.005	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.005	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.065**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0005	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.005	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.005	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.026**	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.018**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.013**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.009**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.05	----	----	----	----
Tin	7440-31-5	0.001	mg/L	**0.008**	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.05	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.027**	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**2.41**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----

Appendix F Particle Size Distribution Analysis

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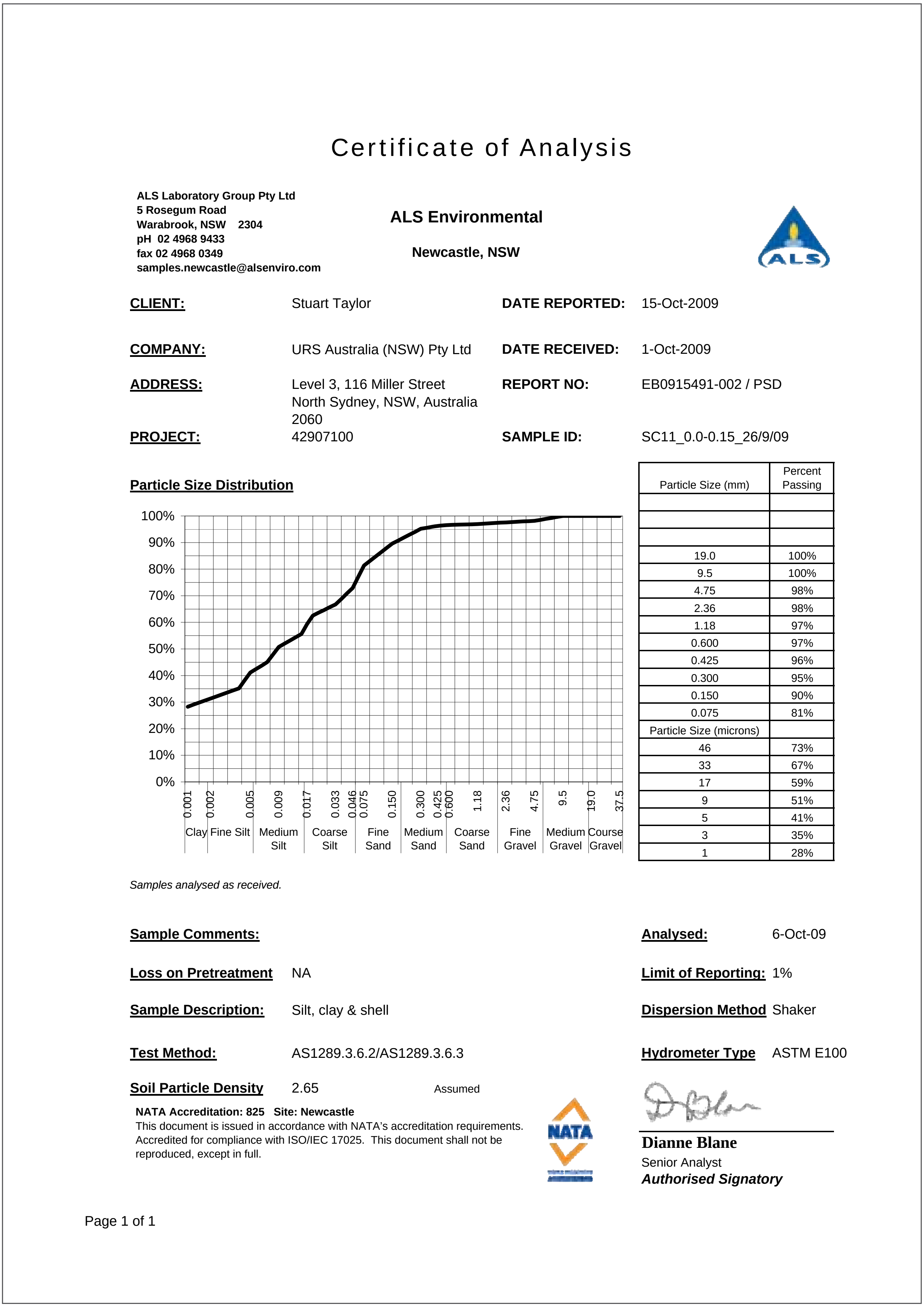

Certificate of Analysis

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ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-002 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC11_0.0-0.15_26/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	98%
2.36	98%
1.18	97%
0.600	97%
0.425	96%
0.300	95%
0.150	90%
0.075	81%
Particle Size (microns)	
46	73%
33	67%
17	59%
9	51%
5	41%
3	35%
1	28%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Silt, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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Dianne Blane
Senior Analyst
Authorised Signatory

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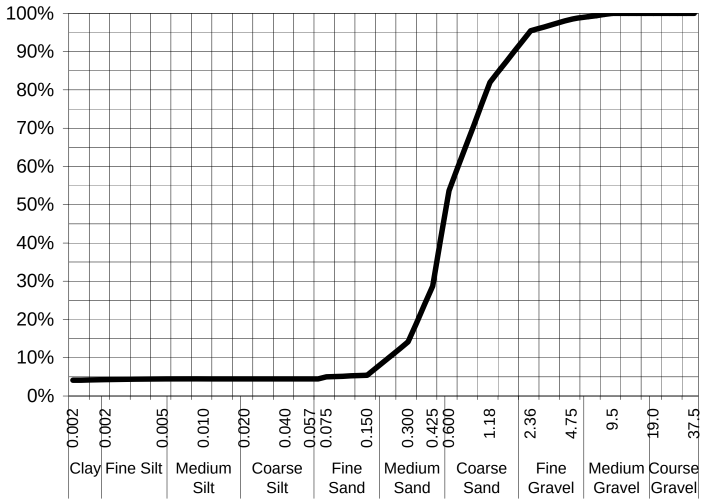
ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-005 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G20_26/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	95%
1.18	82%
0.600	54%
0.425	29%
0.300	14%
0.150	5%
0.075	5%
Particle Size (microns)	
57	4%
40	4%
20	4%
10	4%
5	4%
4	4%
2	4%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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Certificate of Analysis

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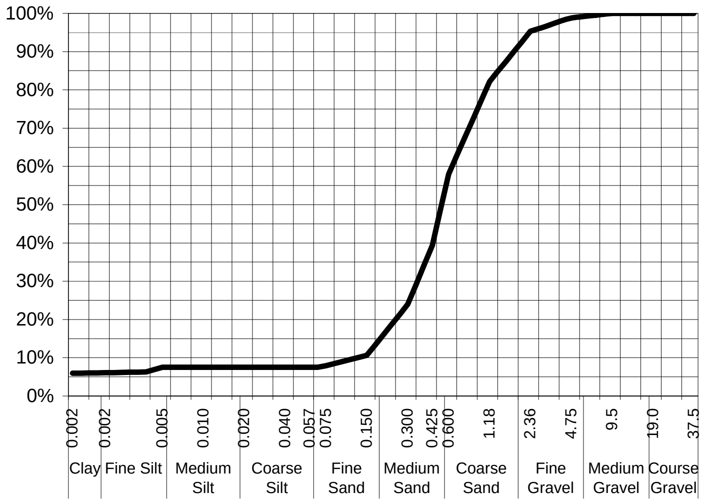
ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-006 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G21_26/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	95%
1.18	82%
0.600	58%
0.425	39%
0.300	24%
0.150	11%
0.075	8%
Particle Size (microns)	
57	8%
40	8%
20	8%
10	8%
5	8%
4	6%
2	6%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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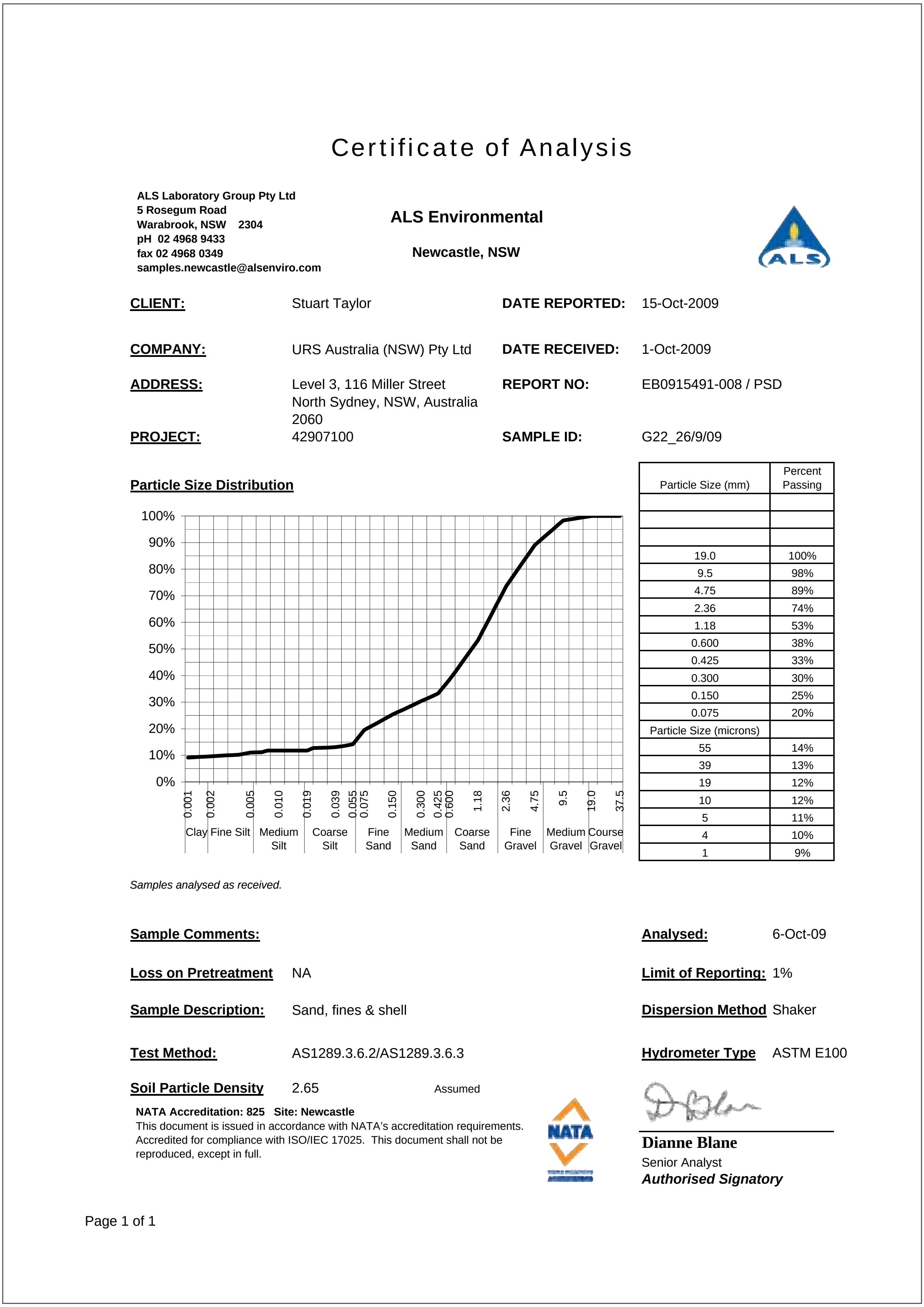

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ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-008 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G22_26/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	98%
4.75	89%
2.36	74%
1.18	53%
0.600	38%
0.425	33%
0.300	30%
0.150	25%
0.075	20%
Particle Size (microns)	
55	14%
39	13%
19	12%
10	12%
5	11%
4	10%
1	9%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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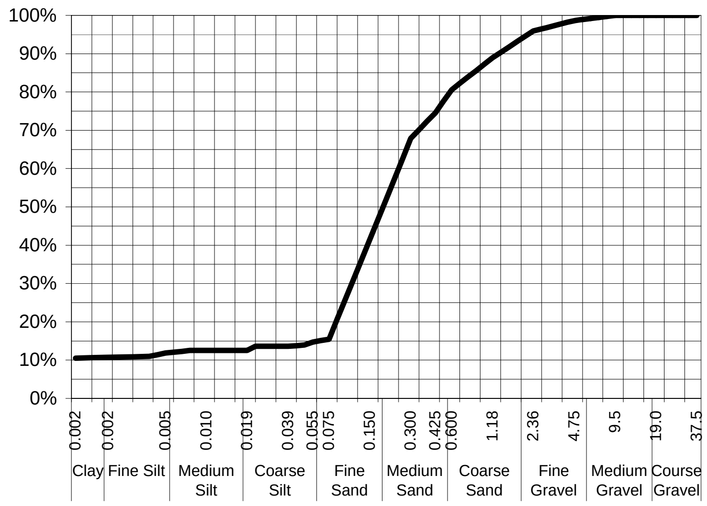
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-010 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G28_26/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	96%
1.18	89%
0.600	81%
0.425	75%
0.300	68%
0.150	41%
0.075	15%
Particle Size (microns)	
55	15%
39	14%
19	13%
10	13%
5	12%
4	11%
2	11%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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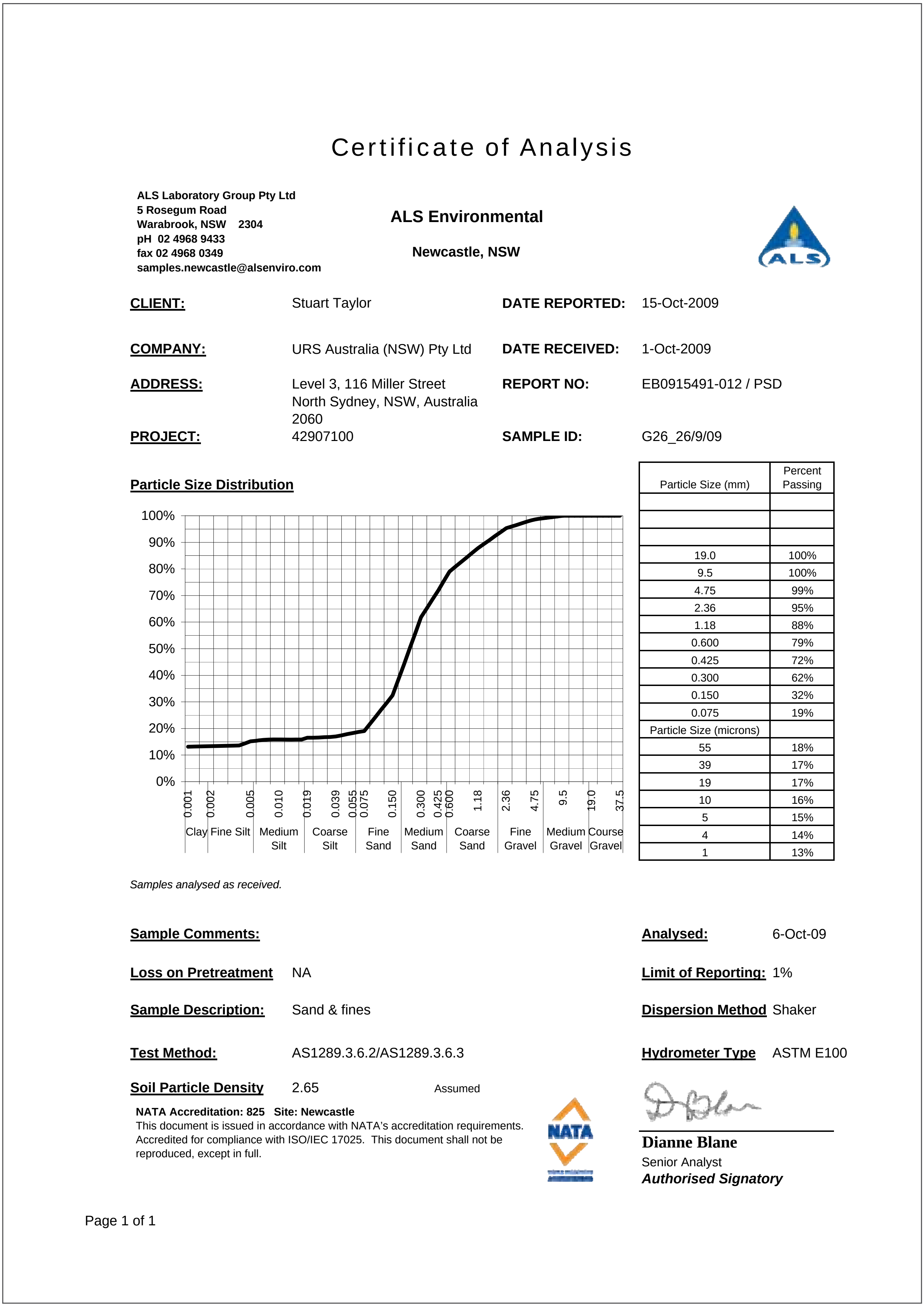

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-012 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G26_26/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	95%
1.18	88%
0.600	79%
0.425	72%
0.300	62%
0.150	32%
0.075	19%
Particle Size (microns)	
55	18%
39	17%
19	17%
10	16%
5	15%
4	14%
1	13%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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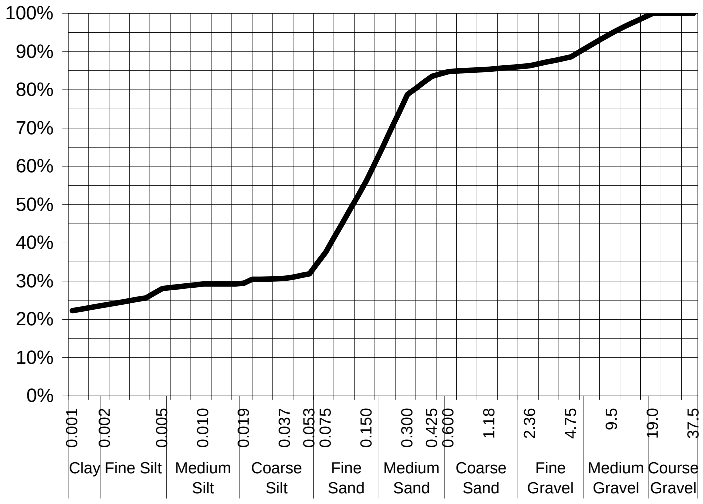
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-016 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC29_0.0-0.20_27/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	95%
4.75	89%
2.36	86%
1.18	85%
0.600	85%
0.425	84%
0.300	79%
0.150	56%
0.075	38%
Particle Size (microns)	
53	32%
37	31%
19	29%
10	29%
5	28%
3	26%
1	22%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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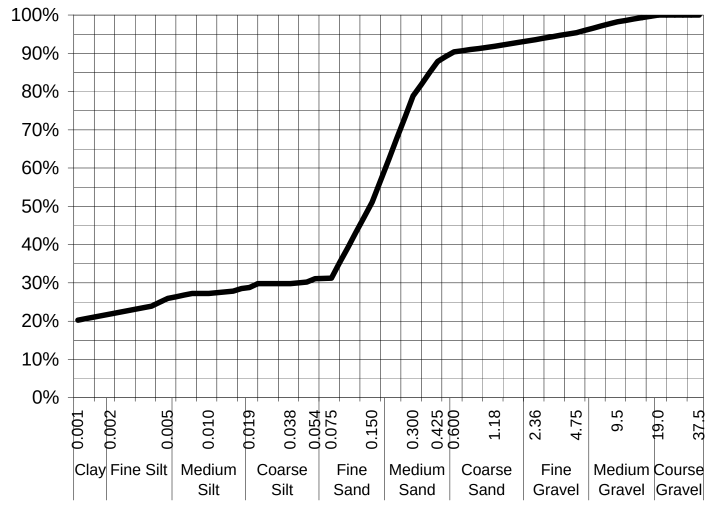
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-017 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC27_0.0-0.32_27/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	98%
4.75	95%
2.36	94%
1.18	92%
0.600	90%
0.425	88%
0.300	79%
0.150	51%
0.075	31%
Particle Size (microns)	
54	31%
38	30%
19	29%
10	27%
5	26%
4	24%
1	20%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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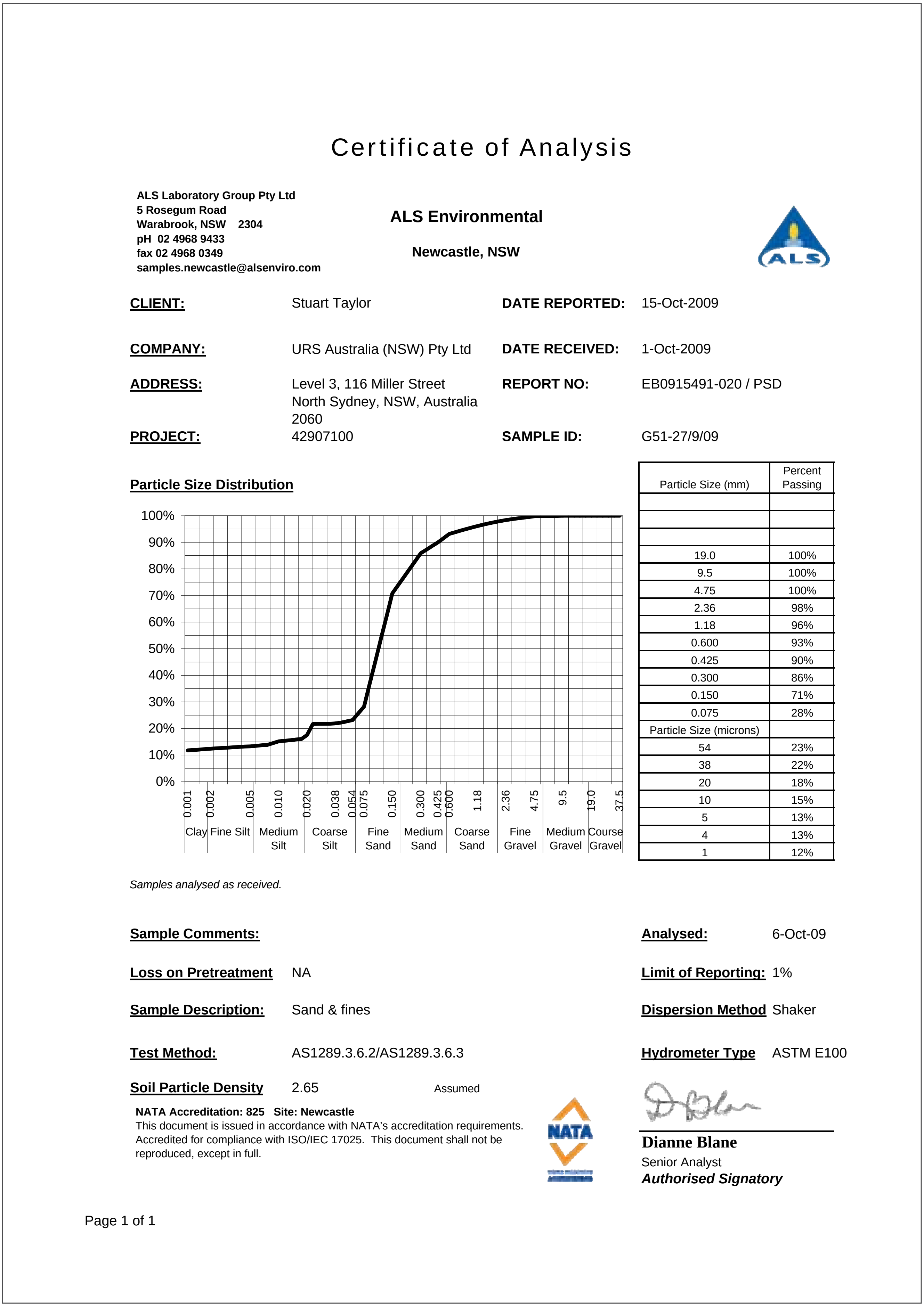

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COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-020 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G51-27/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	98%
1.18	96%
0.600	93%
0.425	90%
0.300	86%
0.150	71%
0.075	28%
Particle Size (microns)	
54	23%
38	22%
20	18%
10	15%
5	13%
4	13%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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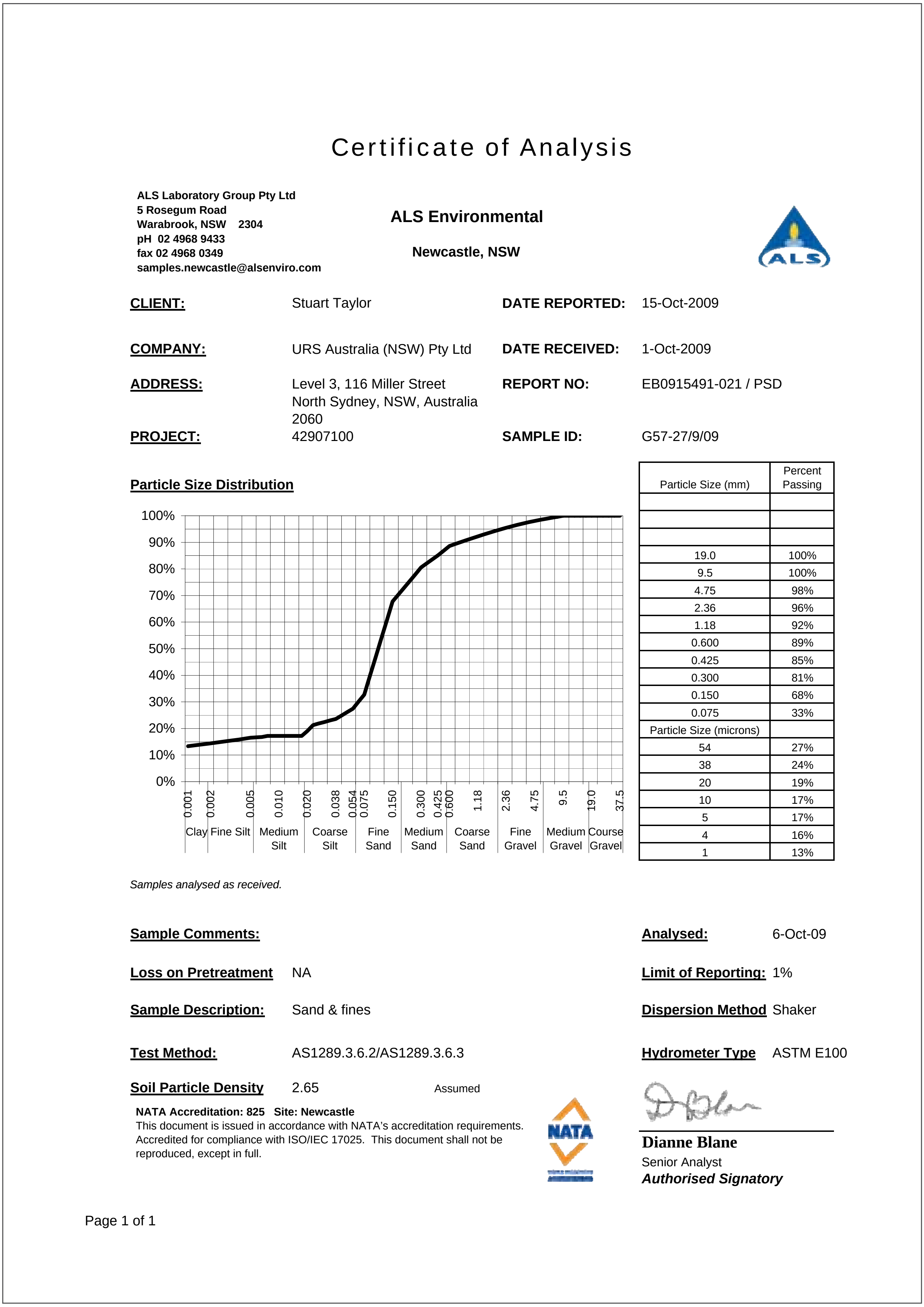

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-021 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G57-27/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	98%
2.36	96%
1.18	92%
0.600	89%
0.425	85%
0.300	81%
0.150	68%
0.075	33%
Particle Size (microns)	
54	27%
38	24%
20	19%
10	17%
5	17%
4	16%
1	13%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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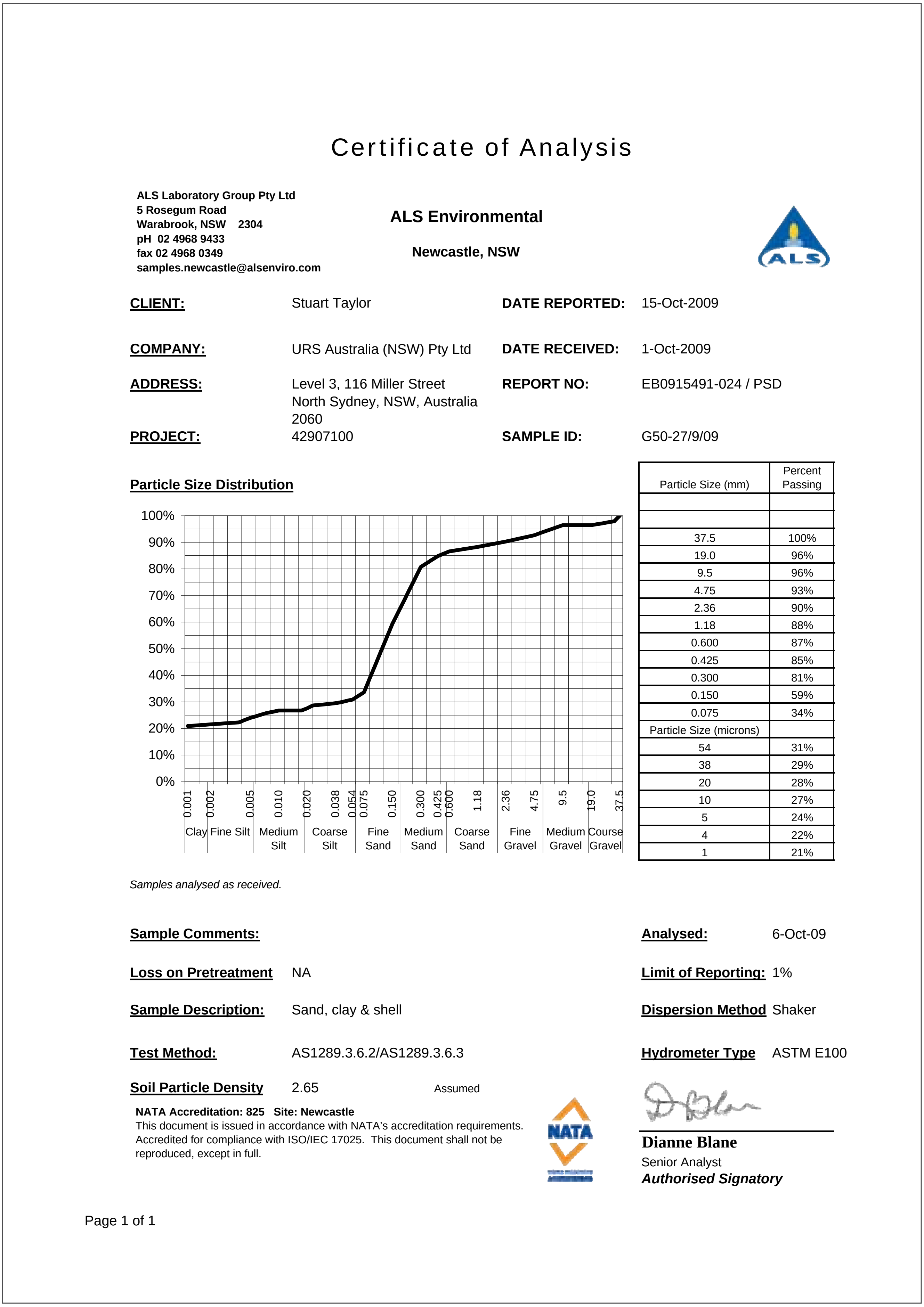

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-024 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G50-27/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
37.5	100%
19.0	96%
9.5	96%
4.75	93%
2.36	90%
1.18	88%
0.600	87%
0.425	85%
0.300	81%
0.150	59%
0.075	34%
Particle Size (microns)	
54	31%
38	29%
20	28%
10	27%
5	24%
4	22%
1	21%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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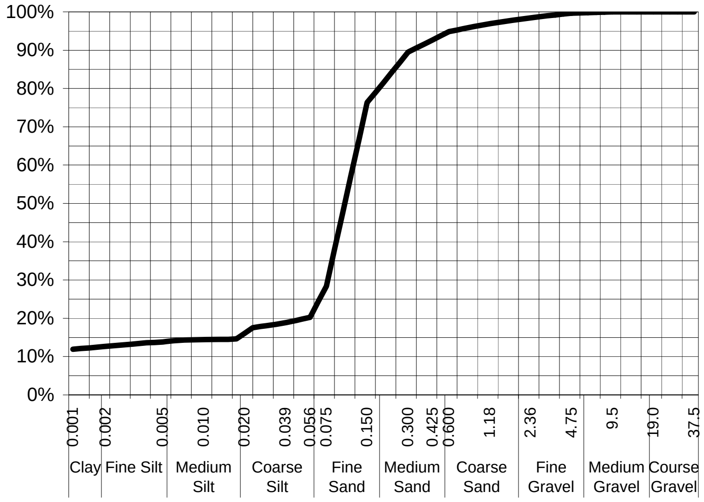
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-025 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G52-27/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	98%
1.18	97%
0.600	95%
0.425	93%
0.300	90%
0.150	76%
0.075	28%
Particle Size (microns)	
56	20%
39	19%
20	16%
10	14%
5	14%
4	14%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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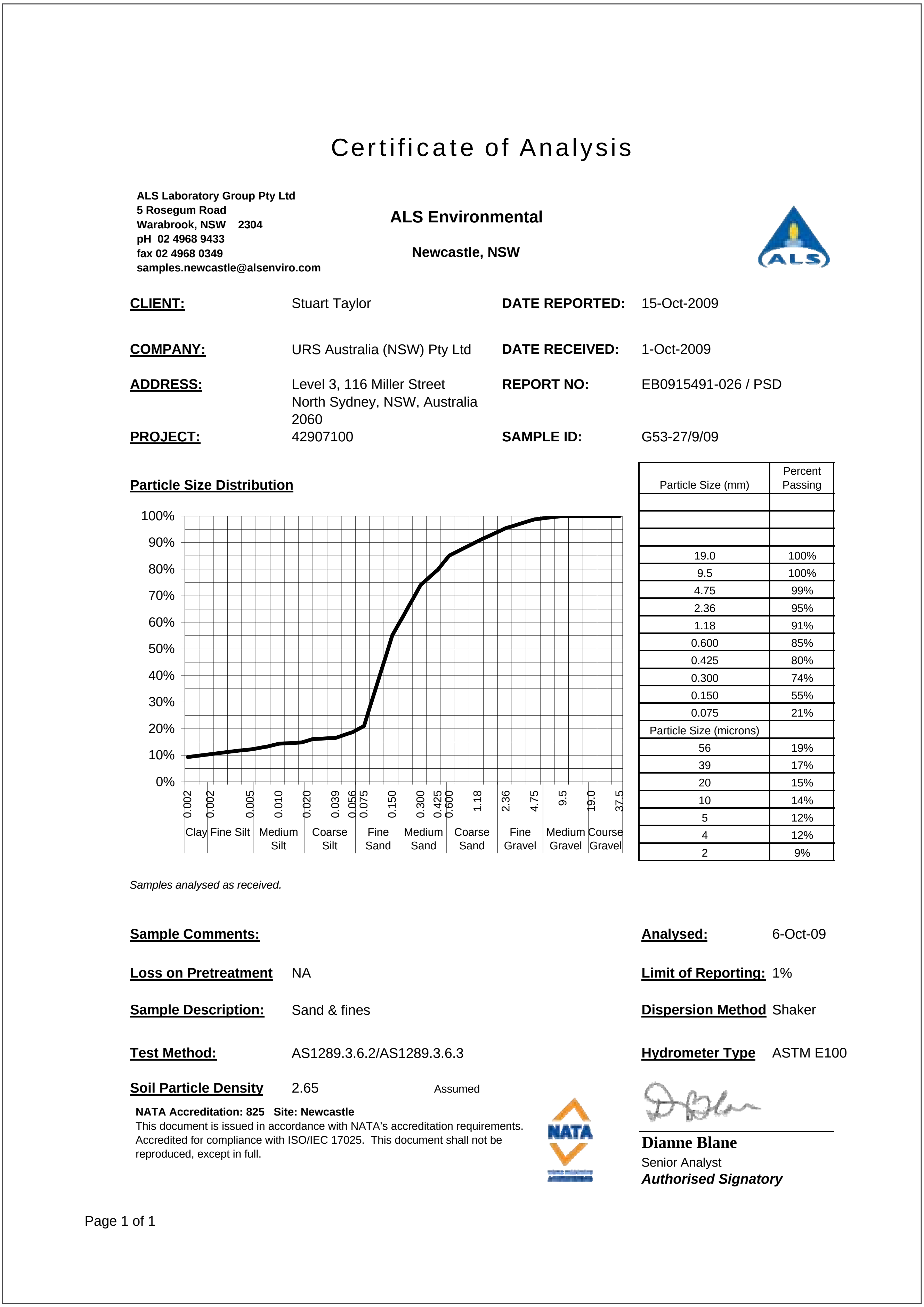

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-026 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G53-27/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	95%
1.18	91%
0.600	85%
0.425	80%
0.300	74%
0.150	55%
0.075	21%
Particle Size (microns)	
56	19%
39	17%
20	15%
10	14%
5	12%
4	12%
2	9%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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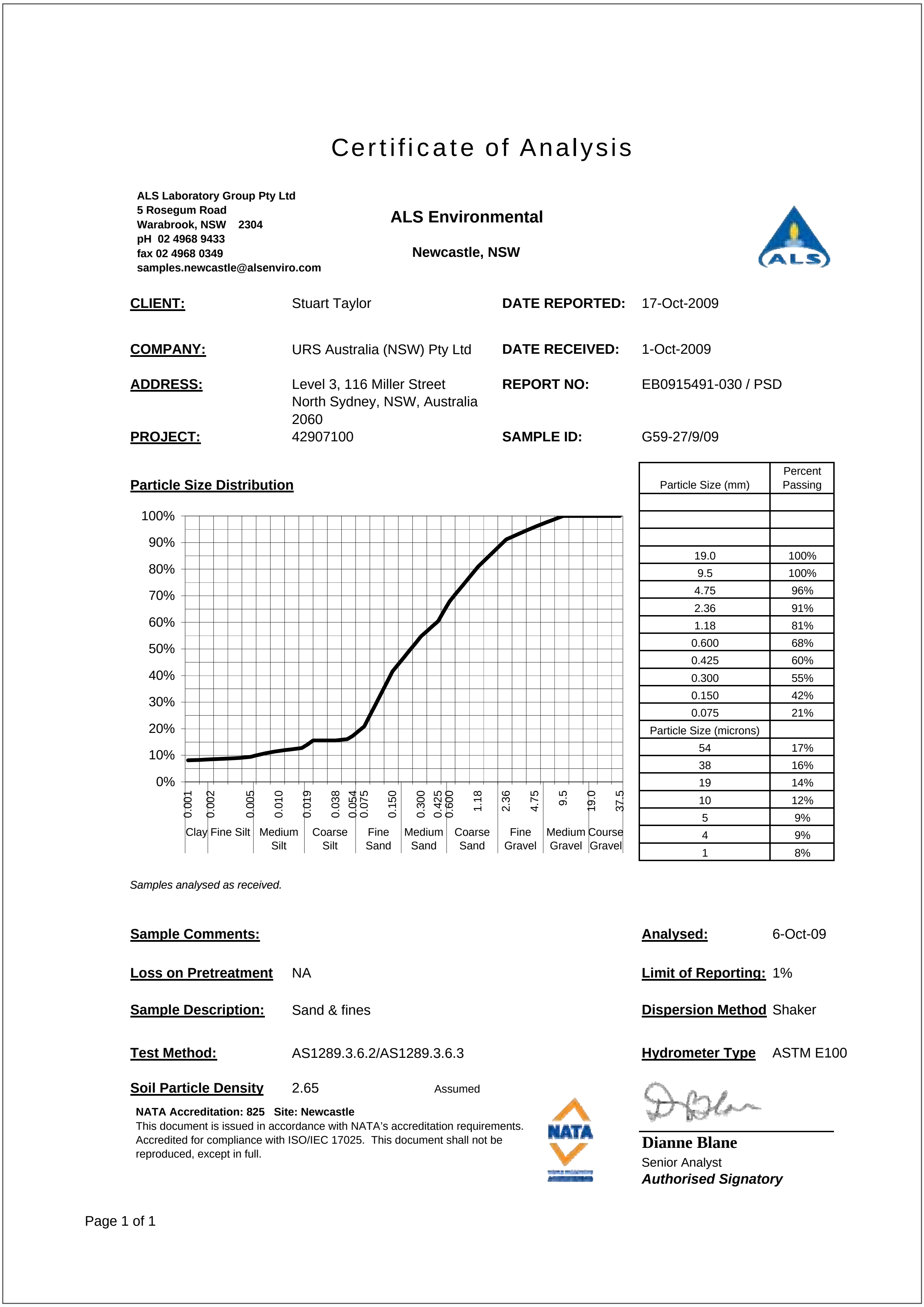

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	17-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-030 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G59-27/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	96%
2.36	91%
1.18	81%
0.600	68%
0.425	60%
0.300	55%
0.150	42%
0.075	21%
Particle Size (microns)	
54	17%
38	16%
19	14%
10	12%
5	9%
4	9%
1	8%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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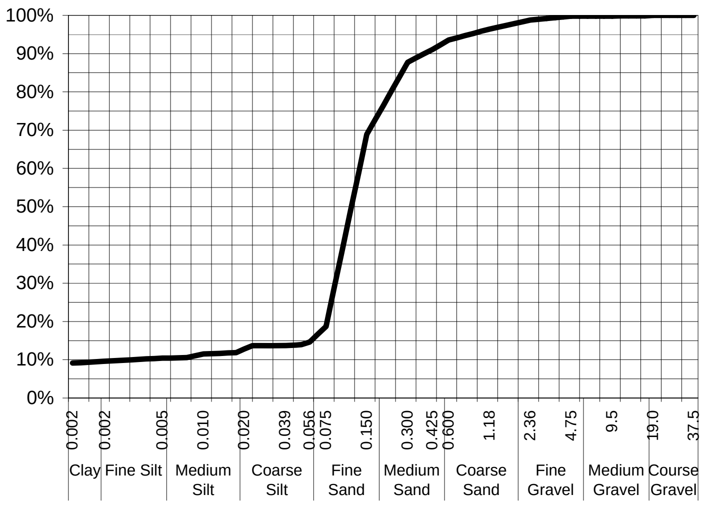
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-031 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G65-27/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	96%
0.600	94%
0.425	91%
0.300	88%
0.150	69%
0.075	19%
Particle Size (microns)	
56	15%
39	14%
20	13%
10	11%
5	10%
4	10%
2	9%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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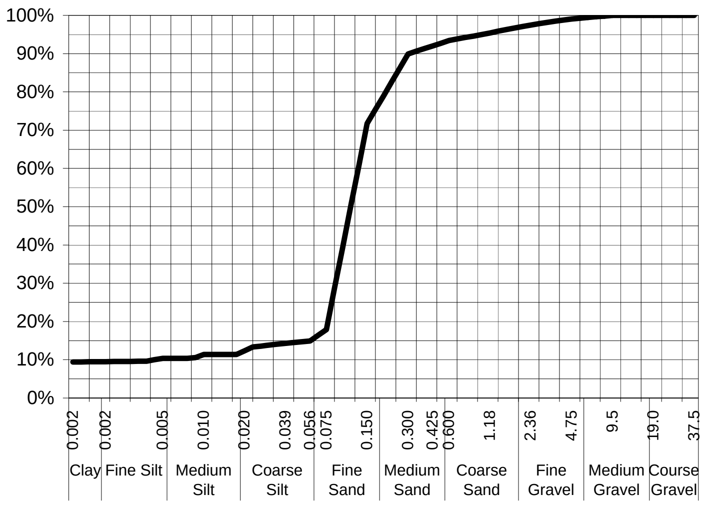
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-033 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G60-27/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	98%
1.18	95%
0.600	93%
0.425	92%
0.300	90%
0.150	72%
0.075	18%
Particle Size (microns)	
56	15%
39	14%
20	12%
10	11%
5	10%
4	10%
2	9%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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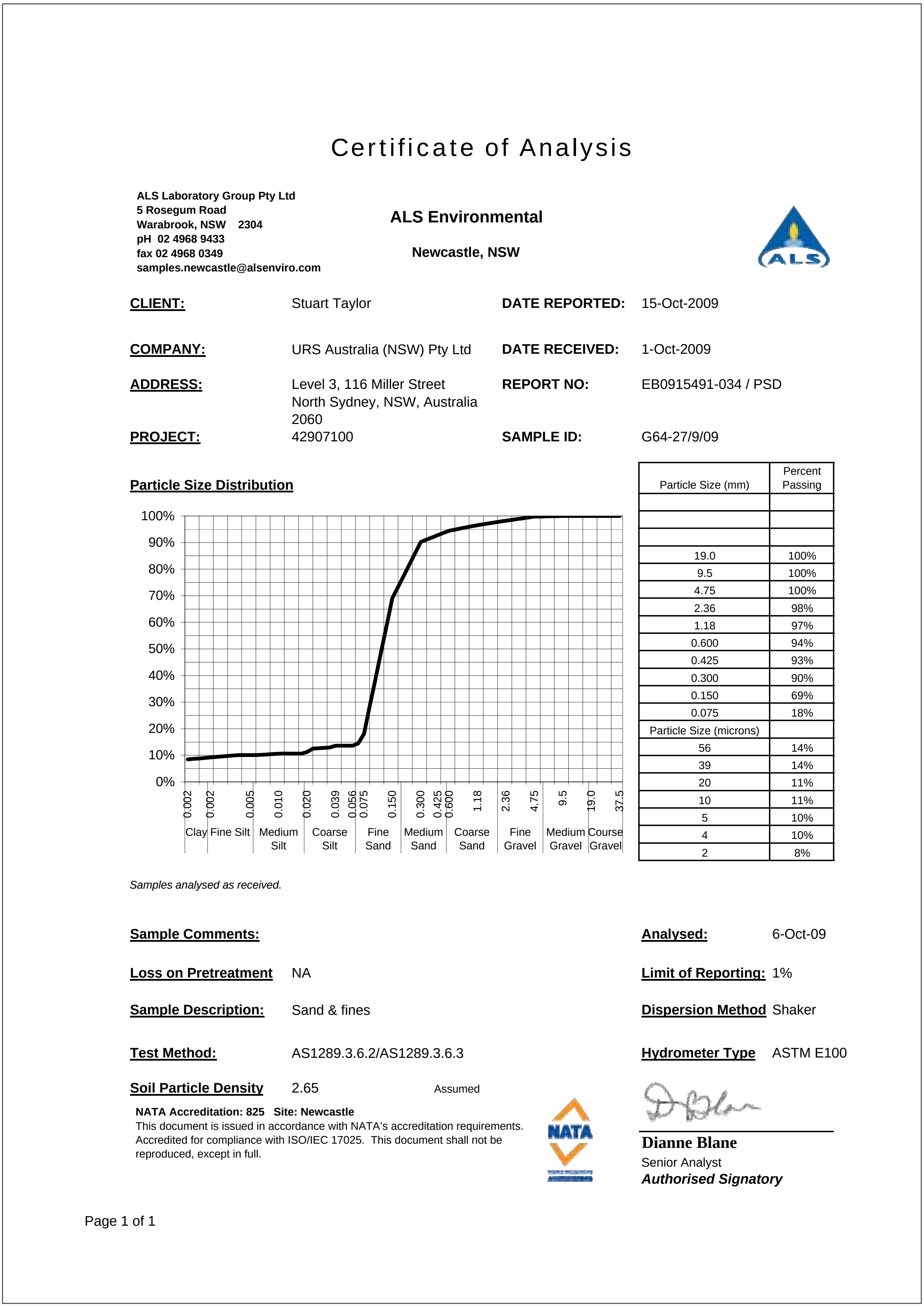

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ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-034 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G64-27/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	98%
1.18	97%
0.600	94%
0.425	93%
0.300	90%
0.150	69%
0.075	18%
Particle Size (microns)	
56	14%
39	14%
20	11%
10	11%
5	10%
4	10%
2	8%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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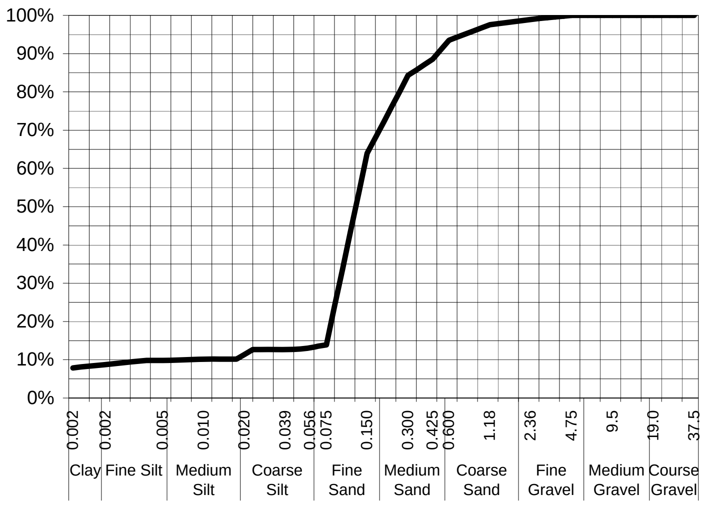
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-035 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G75-27/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	98%
0.600	94%
0.425	89%
0.300	84%
0.150	64%
0.075	14%
Particle Size (microns)	
56	13%
39	13%
20	11%
10	10%
5	10%
4	10%
2	8%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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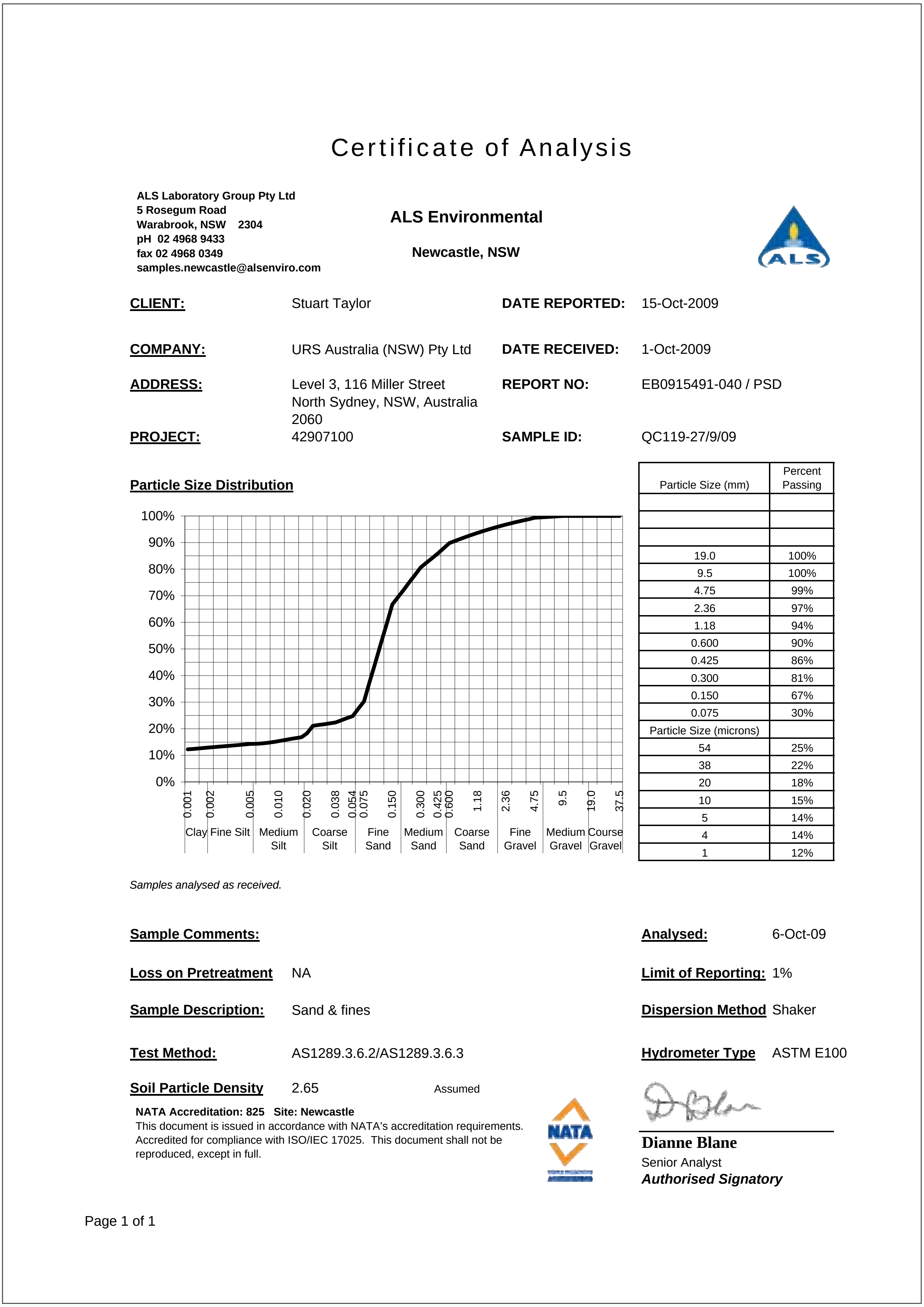

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COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-040 / PSD
PROJECT:	42907100	**SAMPLE ID:**	QC119-27/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	97%
1.18	94%
0.600	90%
0.425	86%
0.300	81%
0.150	67%
0.075	30%
Particle Size (microns)	
54	25%
38	22%
20	18%
10	15%
5	14%
4	14%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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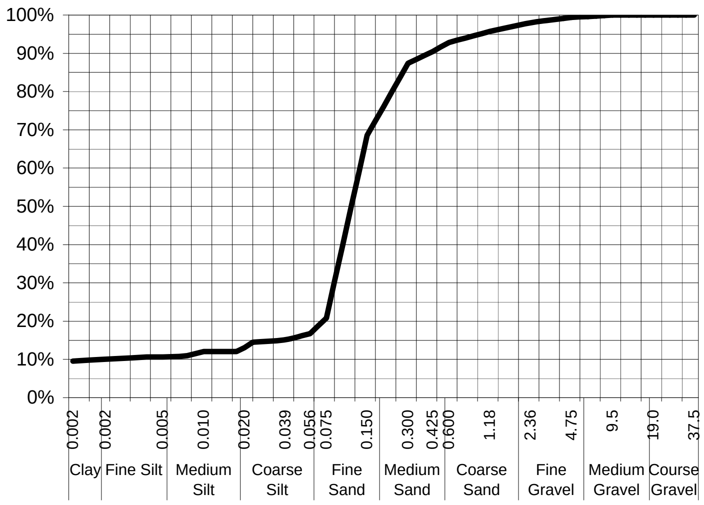
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-042 / PSD
PROJECT:	42907100	**SAMPLE ID:**	QC121-27/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	98%
1.18	96%
0.600	93%
0.425	90%
0.300	87%
0.150	69%
0.075	21%
Particle Size (microns)	
56	17%
39	15%
20	13%
10	12%
5	11%
4	11%
2	10%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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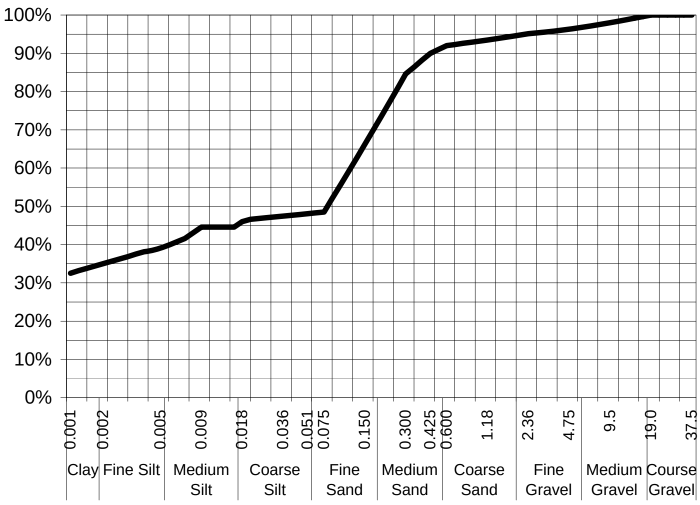
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915491-047 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC26_0.0-0.11_28/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	98%
4.75	96%
2.36	95%
1.18	93%
0.600	92%
0.425	90%
0.300	85%
0.150	66%
0.075	49%
Particle Size (microns)	
51	48%
36	47%
18	46%
9	45%
5	39%
3	38%
1	33%

Samples analysed as received.

Sample Comments:		**Analysed:**	6-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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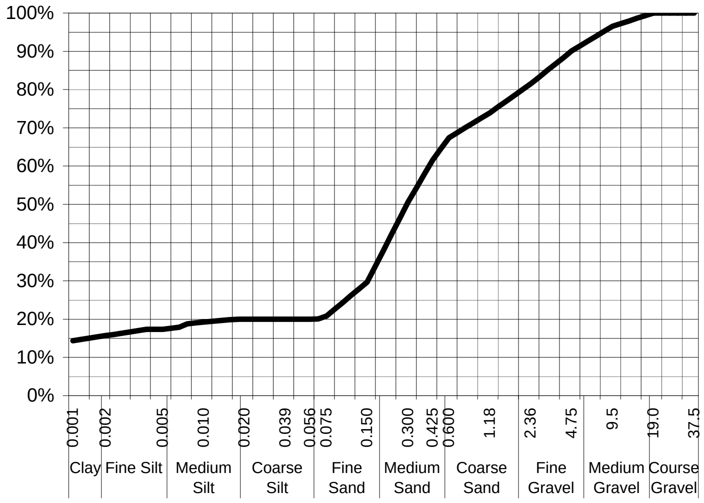
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-002 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC42_0.0-0.25_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	97%
4.75	90%
2.36	81%
1.18	74%
0.600	67%
0.425	62%
0.300	51%
0.150	30%
0.075	21%
Particle Size (microns)	
56	20%
39	20%
20	20%
10	19%
5	17%
4	17%
1	14%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, shell & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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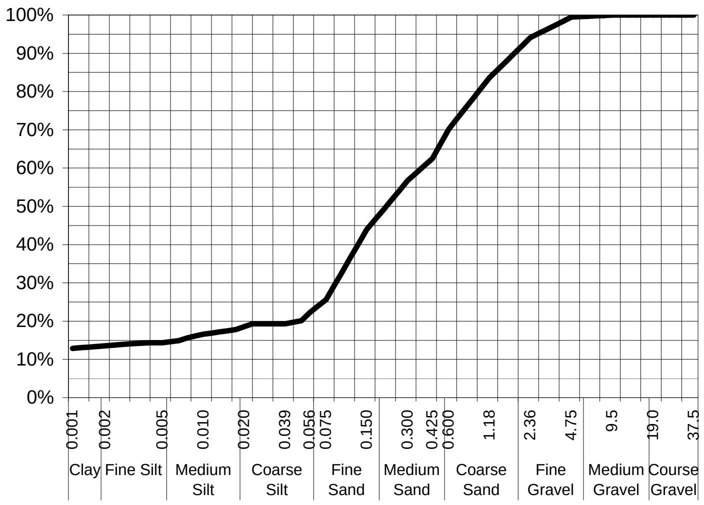
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-005 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC8_0.0-0.30_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	99%
2.36	94%
1.18	84%
0.600	70%
0.425	62%
0.300	57%
0.150	44%
0.075	26%
Particle Size (microns)	
56	22%
39	19%
20	19%
10	17%
5	14%
4	14%
1	13%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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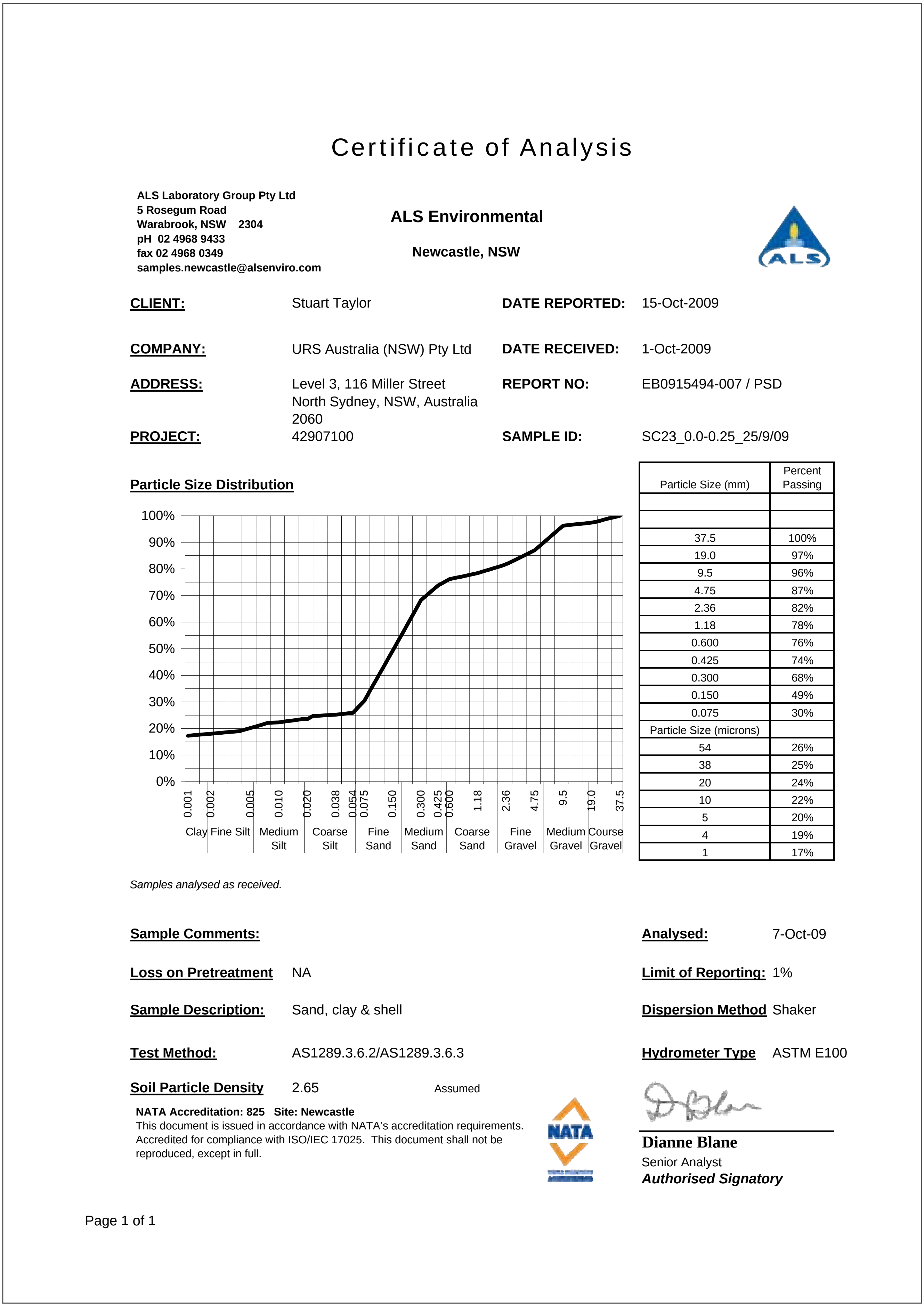

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COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-007 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC23_0.0-0.25_25/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
37.5	100%
19.0	97%
9.5	96%
4.75	87%
2.36	82%
1.18	78%
0.600	76%
0.425	74%
0.300	68%
0.150	49%
0.075	30%
Particle Size (microns)	
54	26%
38	25%
20	24%
10	22%
5	20%
4	19%
1	17%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-012 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC60_0.0-0.20_25/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	82%
4.75	73%
2.36	67%
1.18	65%
0.600	63%
0.425	61%
0.300	54%
0.150	39%
0.075	25%
Particle Size (microns)	
56	18%
39	18%
20	16%
10	16%
5	15%
4	14%
1	11%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, shell & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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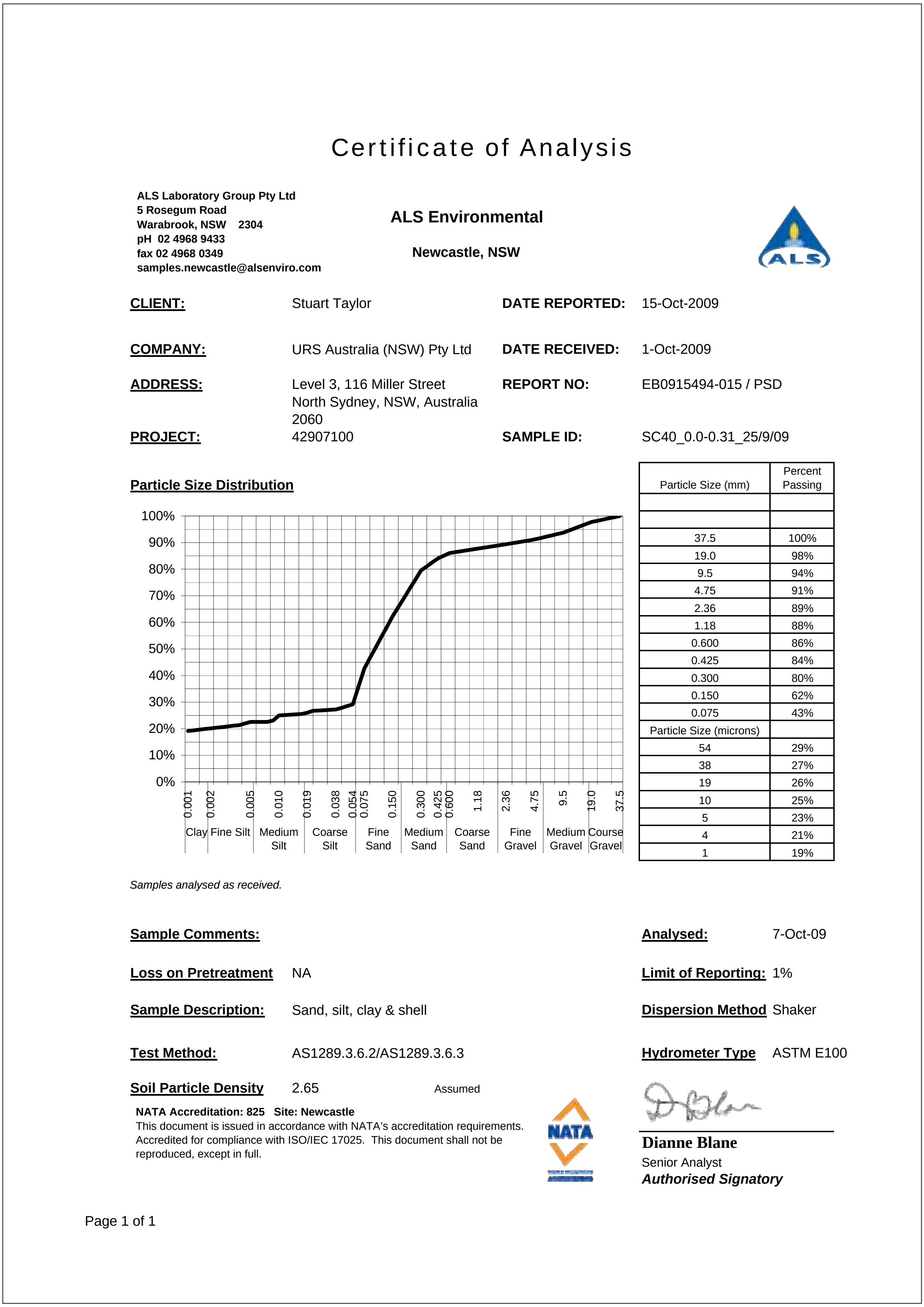

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COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-015 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC40_0.0-0.31_25/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
37.5	100%
19.0	98%
9.5	94%
4.75	91%
2.36	89%
1.18	88%
0.600	86%
0.425	84%
0.300	80%
0.150	62%
0.075	43%
Particle Size (microns)	
54	29%
38	27%
19	26%
10	25%
5	23%
4	21%
1	19%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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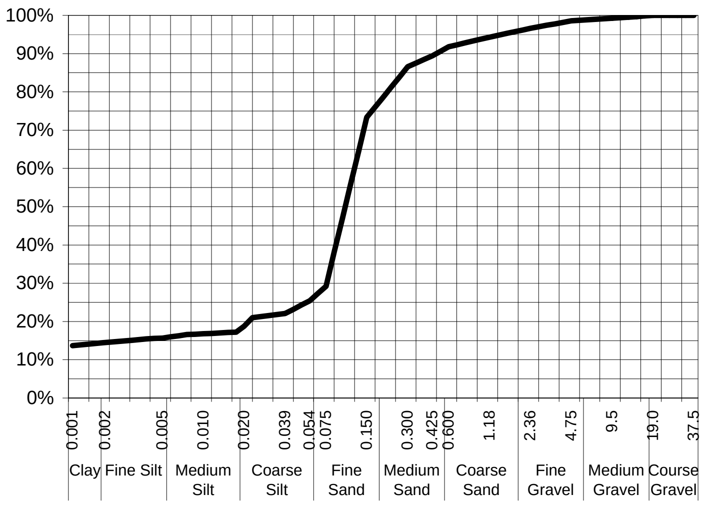
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-016 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC50_0.0-0.23_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	99%
4.75	99%
2.36	97%
1.18	94%
0.600	92%
0.425	89%
0.300	87%
0.150	73%
0.075	29%
Particle Size (microns)	
54	25%
39	22%
20	19%
10	17%
5	16%
4	15%
1	14%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-018 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC9_0.0-0.20_25/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
37.5	100%
19.0	94%
9.5	94%
4.75	91%
2.36	87%
1.18	84%
0.600	82%
0.425	80%
0.300	75%
0.150	56%
0.075	38%
Particle Size (microns)	
55	33%
39	32%
19	30%
10	29%
5	28%
3	27%
1	21%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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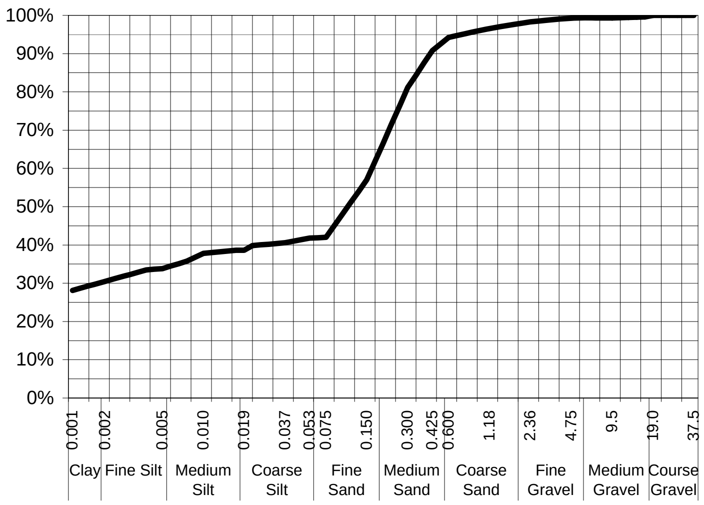
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-023 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G45_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	99%
4.75	99%
2.36	98%
1.18	97%
0.600	94%
0.425	91%
0.300	81%
0.150	57%
0.075	42%
Particle Size (microns)	
53	42%
37	41%
19	39%
10	38%
5	34%
3	33%
1	28%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, clay & silt	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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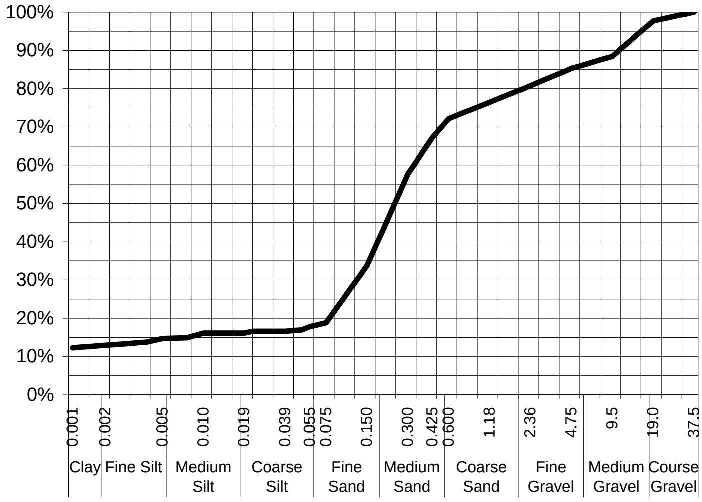
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-025 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G47_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
37.5	100%
19.0	98%
9.5	88%
4.75	85%
2.36	81%
1.18	76%
0.600	72%
0.425	67%
0.300	58%
0.150	34%
0.075	19%
Particle Size (microns)	
55	18%
39	17%
19	16%
10	16%
5	15%
3	14%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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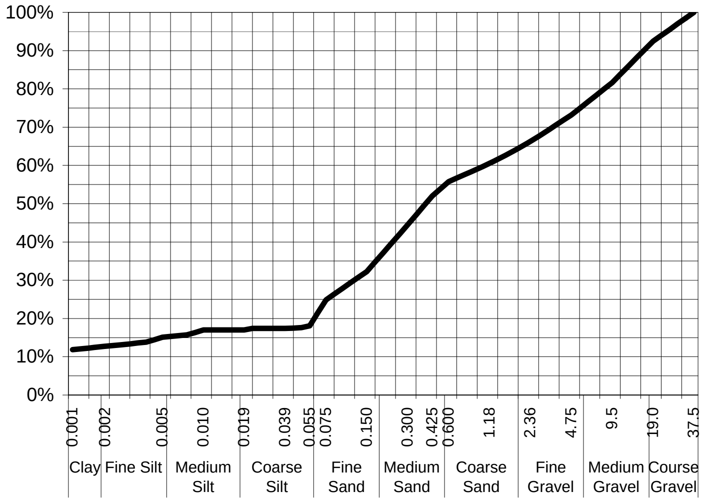
ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-026 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G42_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
37.5	100%
19.0	92%
9.5	82%
4.75	73%
2.36	66%
1.18	60%
0.600	56%
0.425	52%
0.300	45%
0.150	32%
0.075	25%
Particle Size (microns)	
55	18%
39	17%
19	17%
10	17%
5	15%
3	14%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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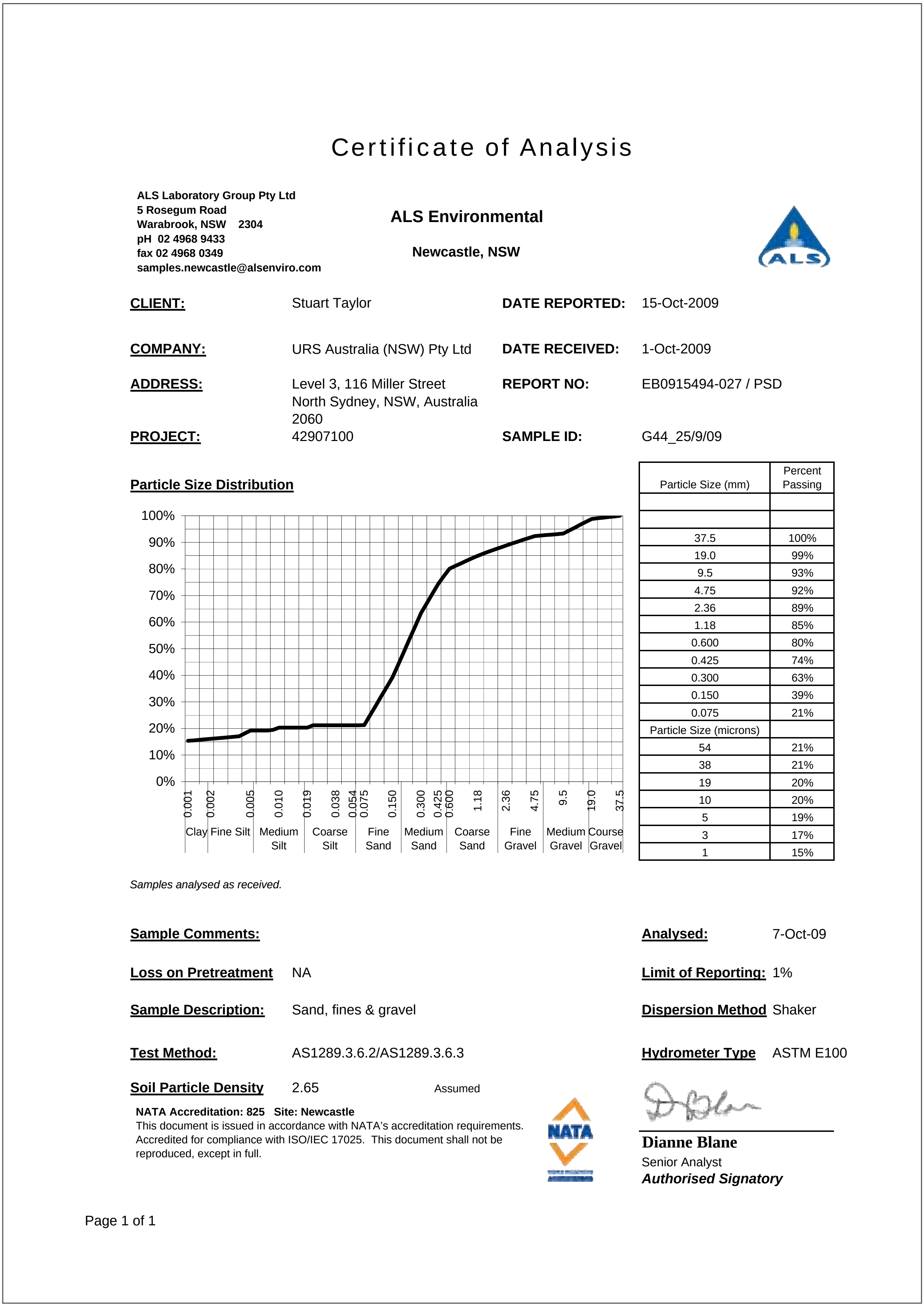

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-027 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G44_25/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
37.5	100%
19.0	99%
9.5	93%
4.75	92%
2.36	89%
1.18	85%
0.600	80%
0.425	74%
0.300	63%
0.150	39%
0.075	21%
Particle Size (microns)	
54	21%
38	21%
19	20%
10	20%
5	19%
3	17%
1	15%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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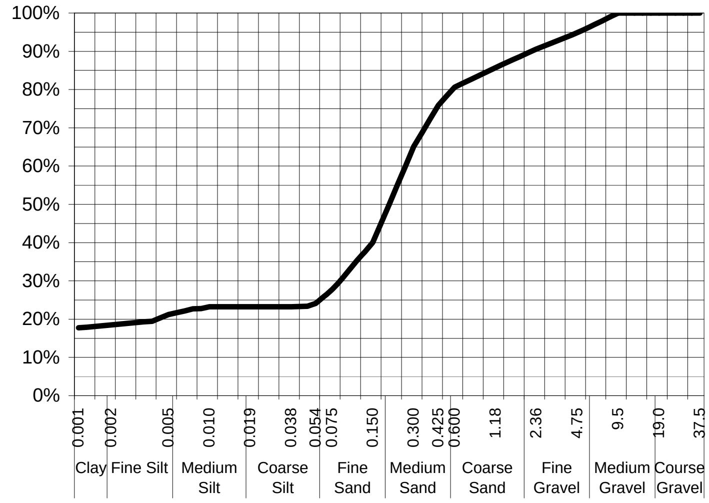
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-031 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G35_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	95%
2.36	91%
1.18	86%
0.600	81%
0.425	76%
0.300	65%
0.150	40%
0.075	28%
Particle Size (microns)	
54	24%
38	23%
19	23%
10	23%
5	21%
3	19%
1	18%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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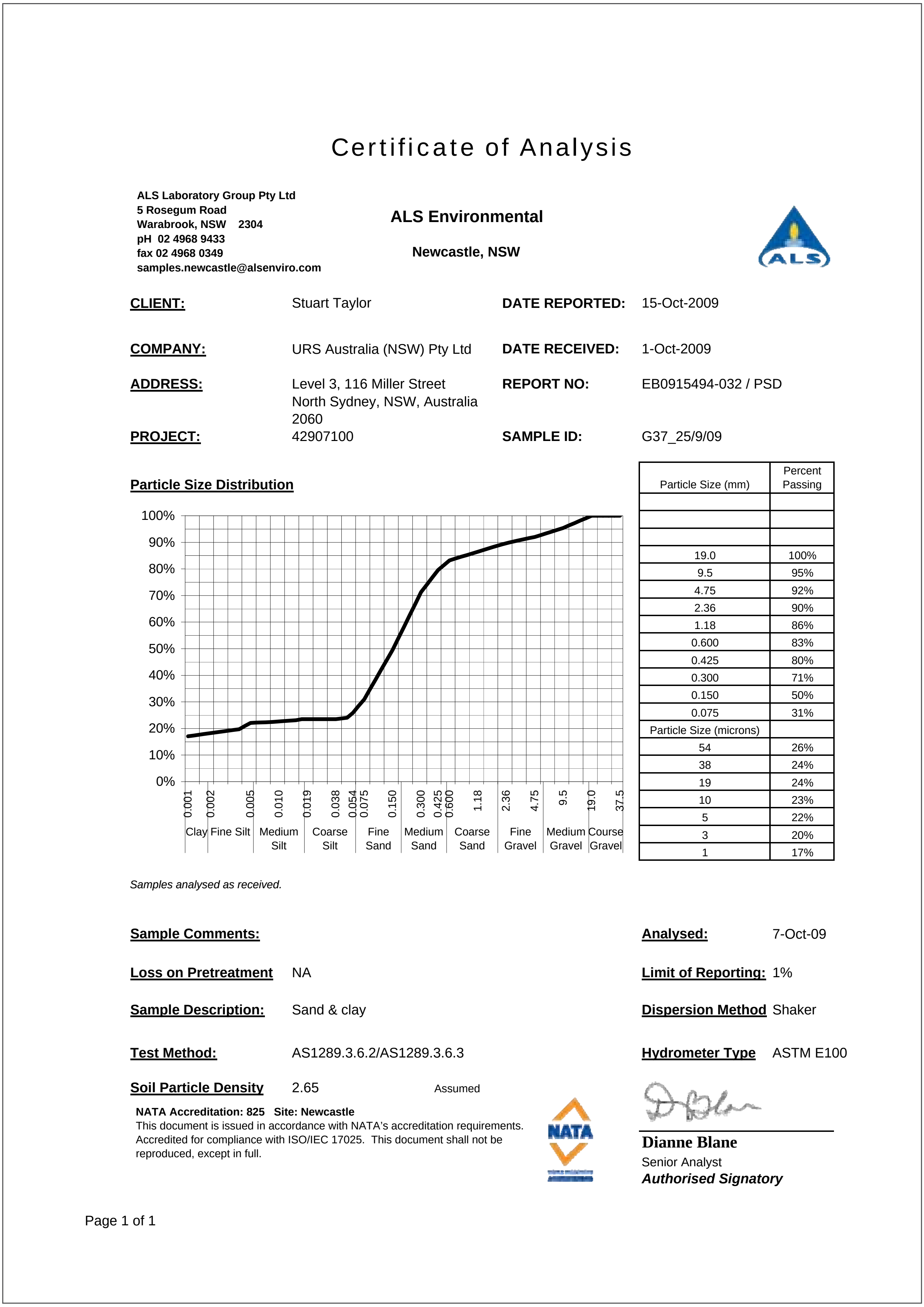

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COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-032 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G37_25/9/09

Particle Size Distribution

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

0.001 0.002 0.005 0.010 0.019 0.038 0.054 0.075 0.150 0.300 0.425 0.600 1.18 2.36 4.75 9.5 19.0 37.5

Clay | Fine Silt | Medium Silt | Coarse Silt | Fine Sand | Medium Sand | Coarse Sand | Fine Gravel | Medium Gravel | Course Gravel

Particle Size (mm)	Percent Passing
19.0	100%
9.5	95%
4.75	92%
2.36	90%
1.18	86%
0.600	83%
0.425	80%
0.300	71%
0.150	50%
0.075	31%
Particle Size (microns)	
54	26%
38	24%
19	24%
10	23%
5	22%
3	20%
1	17%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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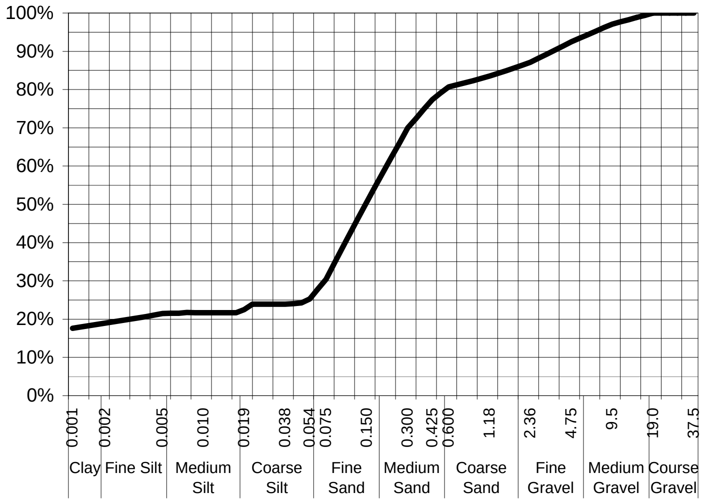
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-033 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G33_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	97%
4.75	92%
2.36	87%
1.18	83%
0.600	81%
0.425	77%
0.300	70%
0.150	51%
0.075	30%
Particle Size (microns)	
54	25%
38	24%
19	23%
10	22%
5	21%
3	21%
1	18%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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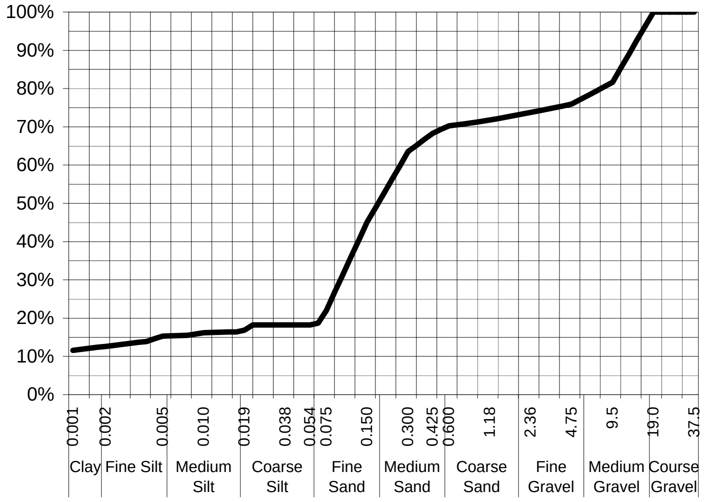
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-038 / PSD
PROJECT:	42907100	**SAMPLE ID:**	QC110_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	82%
4.75	76%
2.36	74%
1.18	72%
0.600	70%
0.425	68%
0.300	64%
0.150	45%
0.075	22%
Particle Size (microns)	
54	18%
38	18%
19	17%
10	16%
5	15%
3	14%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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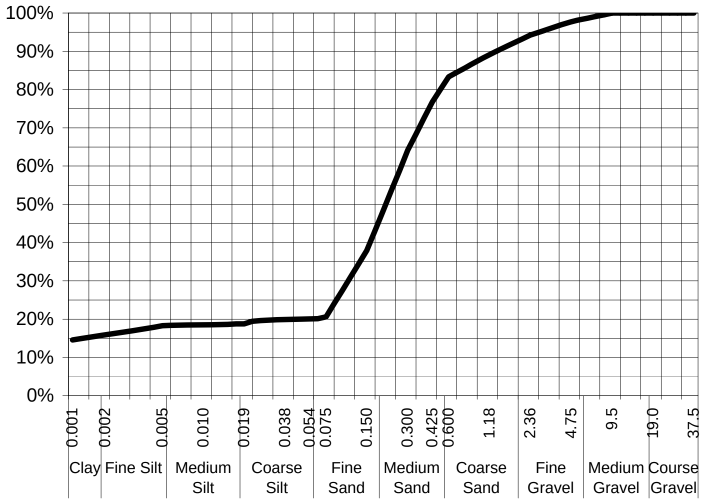
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-039 / PSD
PROJECT:	42907100	**SAMPLE ID:**	QC111_25/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	98%
2.36	94%
1.18	89%
0.600	83%
0.425	77%
0.300	64%
0.150	38%
0.075	21%
Particle Size (microns)	
54	20%
38	20%
19	19%
10	19%
5	18%
3	18%
1	15%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-042 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G24_26/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	97%
2.36	93%
1.18	86%
0.600	78%
0.425	70%
0.300	58%
0.150	32%
0.075	19%
Particle Size (microns)	
54	17%
38	17%
19	16%
10	15%
5	13%
3	13%
1	11%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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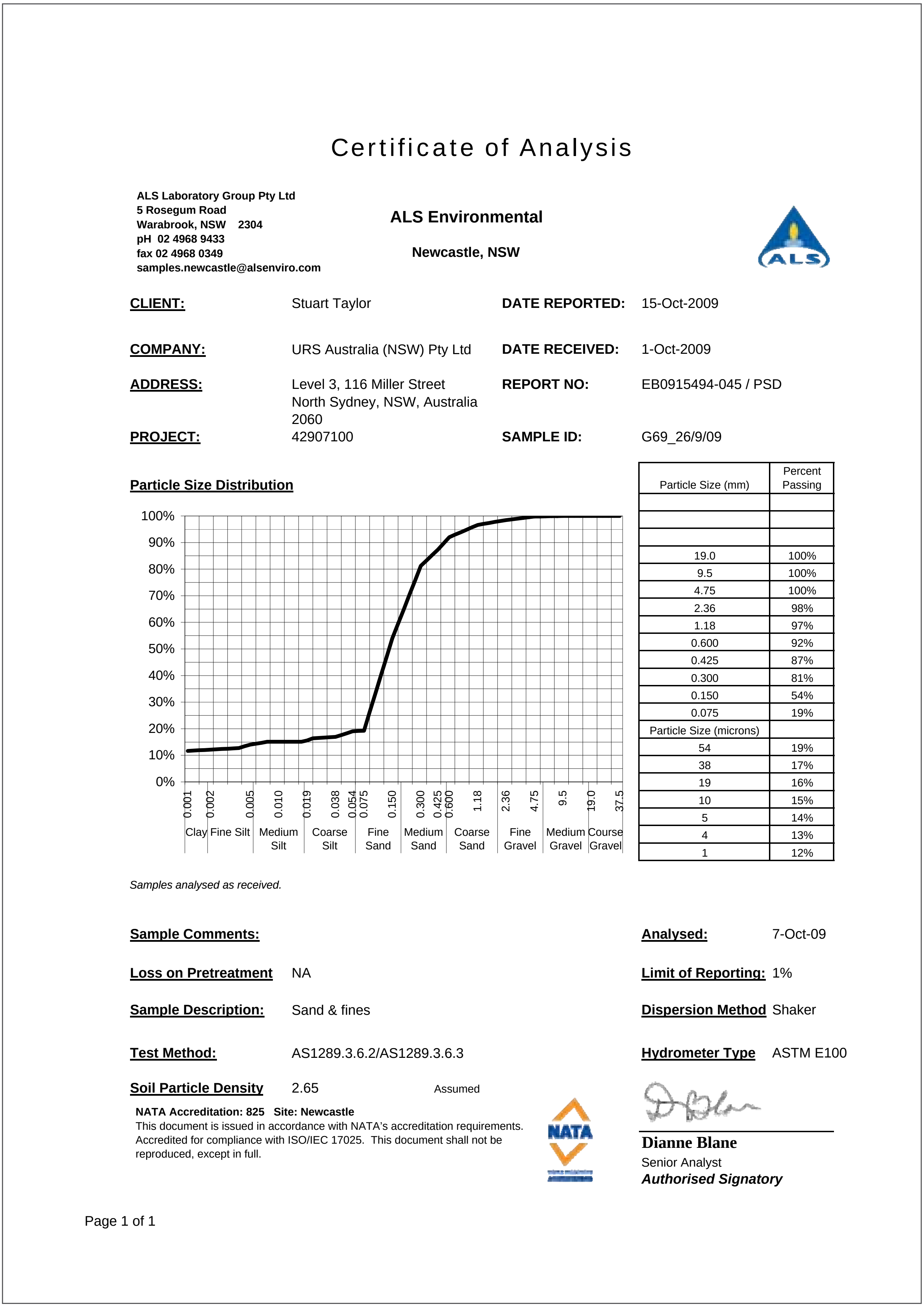

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-045 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G69_26/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	98%
1.18	97%
0.600	92%
0.425	87%
0.300	81%
0.150	54%
0.075	19%
Particle Size (microns)	
54	19%
38	17%
19	16%
10	15%
5	14%
4	13%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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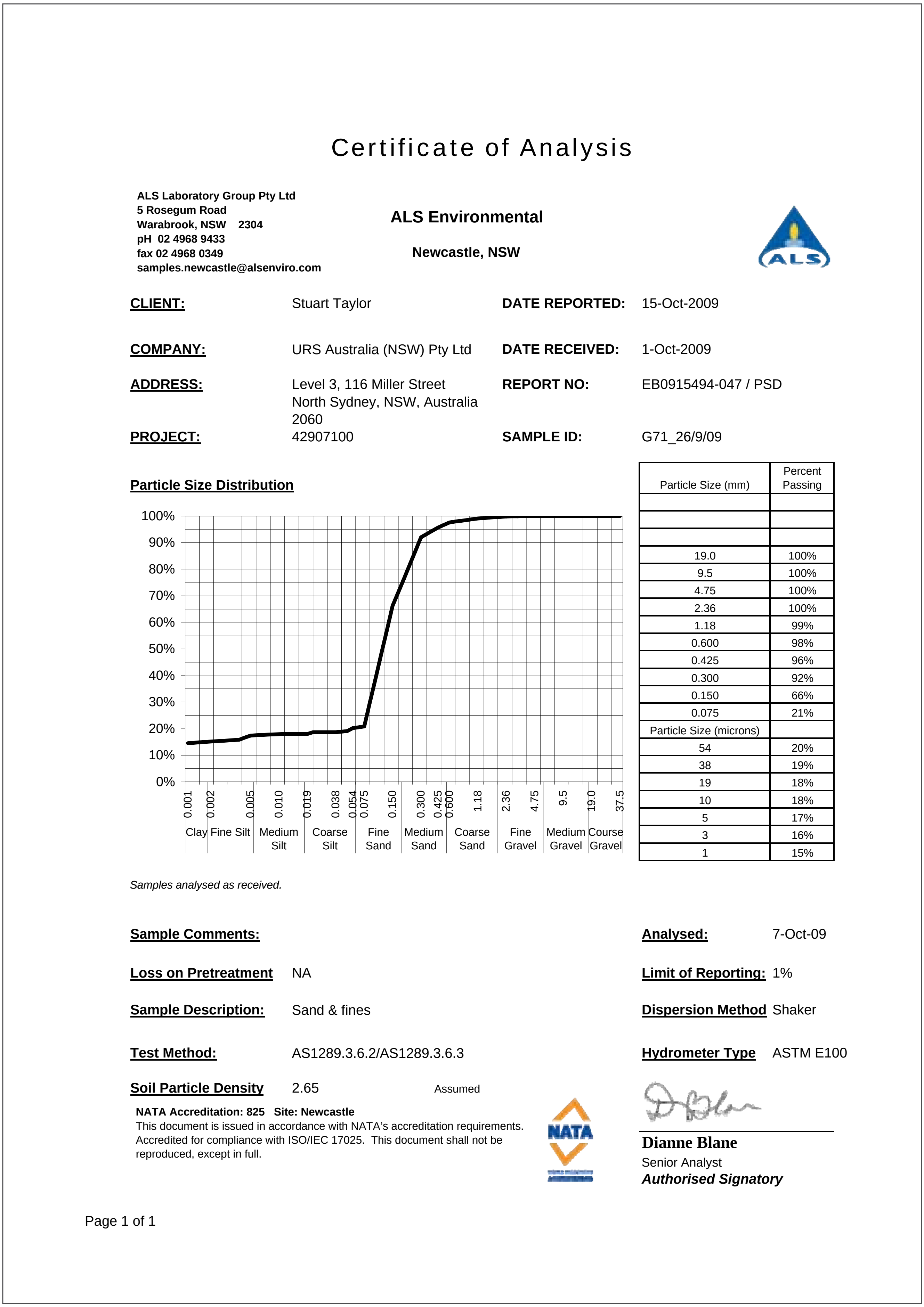

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-047 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G71_26/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	100%
1.18	99%
0.600	98%
0.425	96%
0.300	92%
0.150	66%
0.075	21%
Particle Size (microns)	
54	20%
38	19%
19	18%
10	18%
5	17%
3	16%
1	15%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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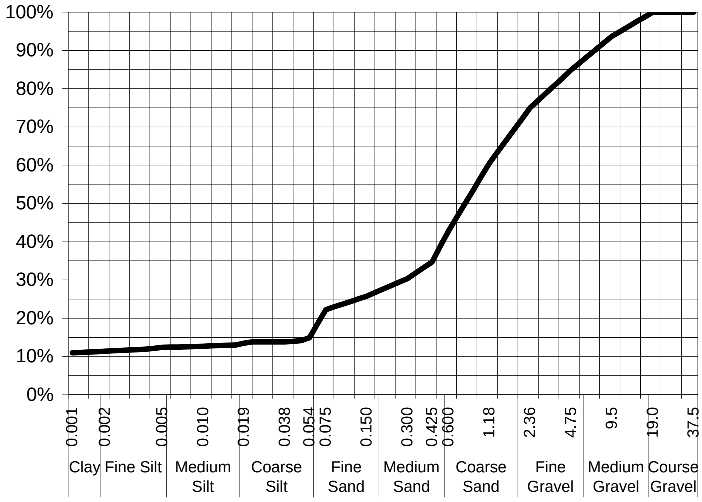
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-049 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G73_26/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	94%
4.75	85%
2.36	75%
1.18	61%
0.600	43%
0.425	35%
0.300	30%
0.150	26%
0.075	22%
Particle Size (microns)	
54	15%
38	14%
19	13%
10	13%
5	12%
3	12%
1	11%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-051 / PSD
PROJECT:	42907100	**SAMPLE ID:**	QC114_26/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	96%
1.18	89%
0.600	81%
0.425	74%
0.300	64%
0.150	35%
0.075	22%
Particle Size (microns)	
54	19%
38	19%
19	17%
10	17%
5	16%
3	14%
1	13%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, fines & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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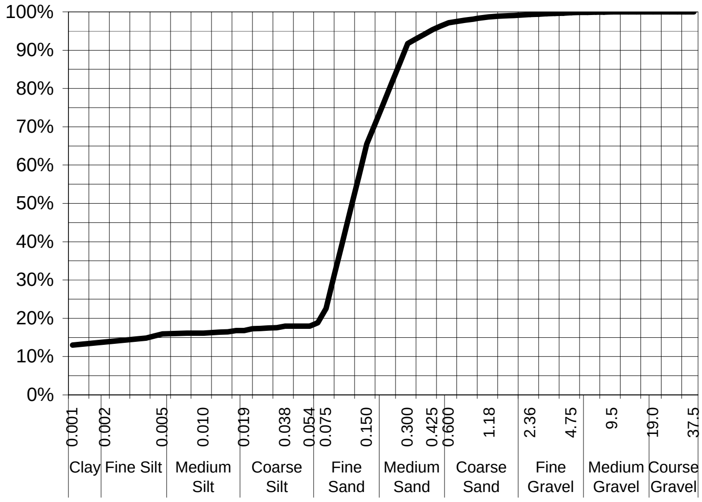
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915494-055 / PSD
PROJECT:	42907100	**SAMPLE ID:**	QC117_26/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	99%
0.600	97%
0.425	95%
0.300	92%
0.150	66%
0.075	23%
Particle Size (microns)	
54	18%
38	18%
19	17%
10	16%
5	16%
3	15%
1	13%

Samples analysed as received.

Sample Comments:		**Analysed:**	7-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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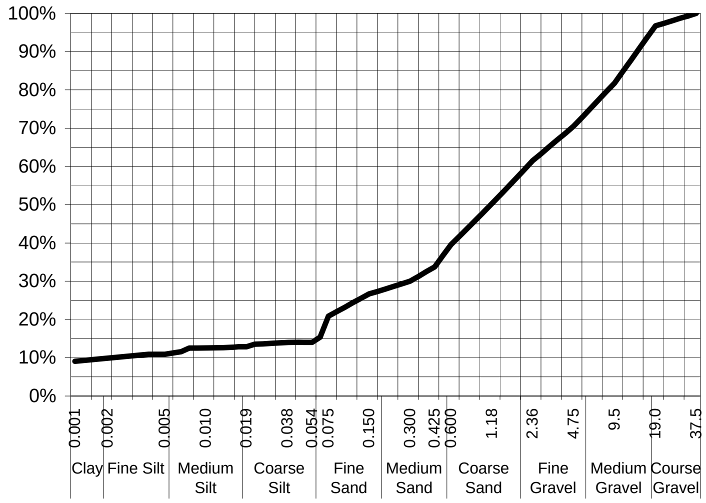
ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-001 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G8_22/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
37.5	100%
19.0	97%
9.5	82%
4.75	71%
2.36	61%
1.18	50%
0.600	40%
0.425	34%
0.300	30%
0.150	27%
0.075	21%
Particle Size (microns)	
54	14%
38	14%
19	13%
10	13%
5	11%
3	11%
1	9%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, shell & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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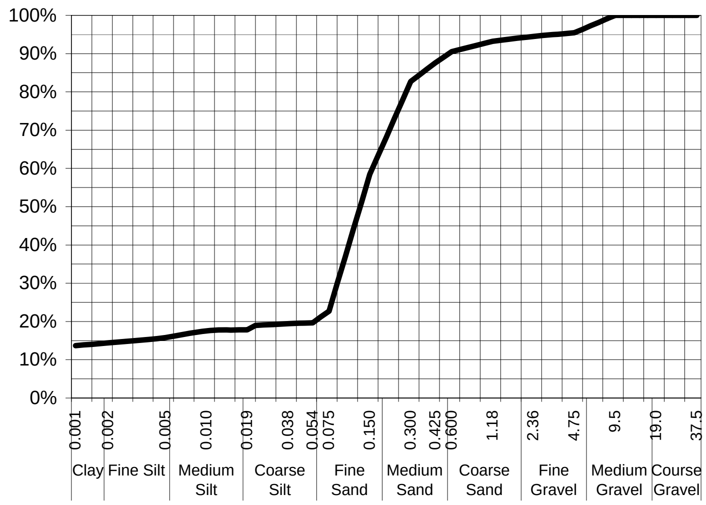
Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-002 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G9_22/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	95%
2.36	95%
1.18	93%
0.600	91%
0.425	88%
0.300	83%
0.150	58%
0.075	23%
Particle Size (microns)	
54	20%
38	19%
19	18%
10	18%
5	16%
3	15%
1	14%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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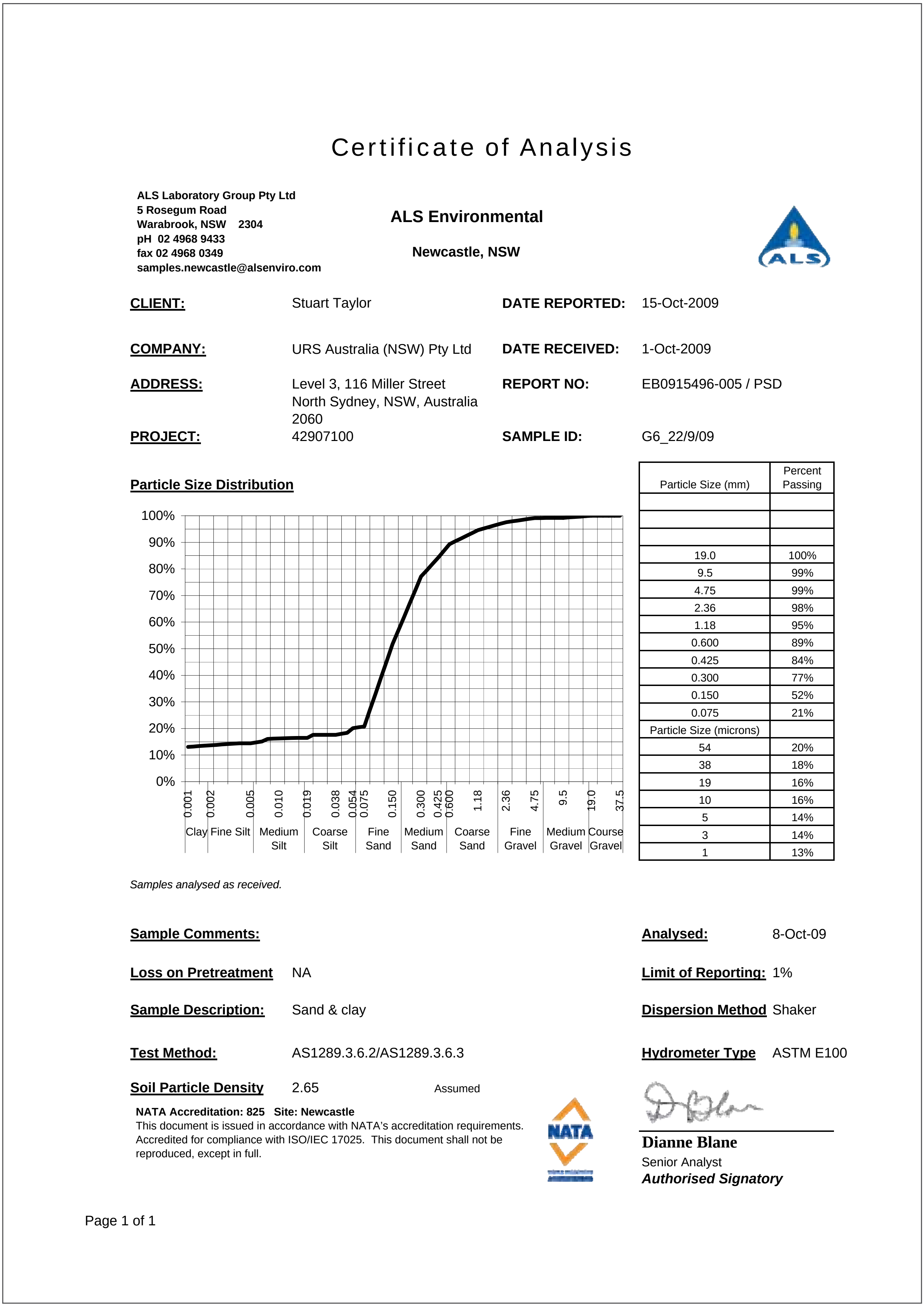

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-005 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G6_22/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	99%
4.75	99%
2.36	98%
1.18	95%
0.600	89%
0.425	84%
0.300	77%
0.150	52%
0.075	21%
Particle Size (microns)	
54	20%
38	18%
19	16%
10	16%
5	14%
3	14%
1	13%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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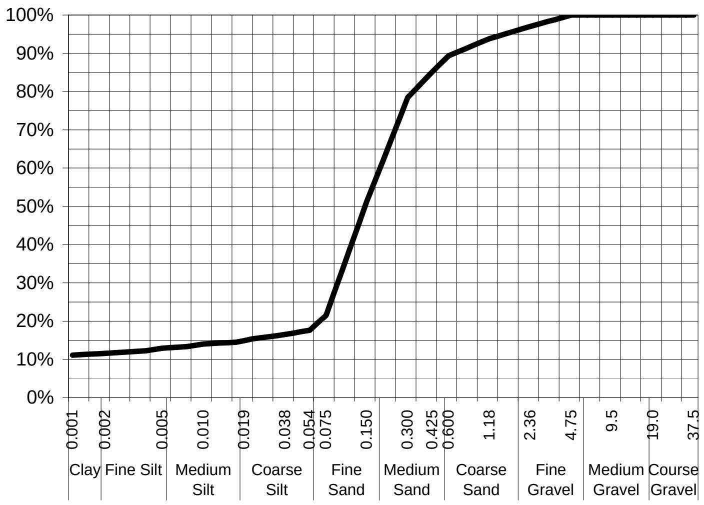
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-010 / PSD
PROJECT:	42907100	**SAMPLE ID:**	QC103_22/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	97%
1.18	94%
0.600	89%
0.425	85%
0.300	78%
0.150	51%
0.075	21%
Particle Size (microns)	
54	18%
38	17%
19	15%
10	14%
5	13%
3	12%
1	11%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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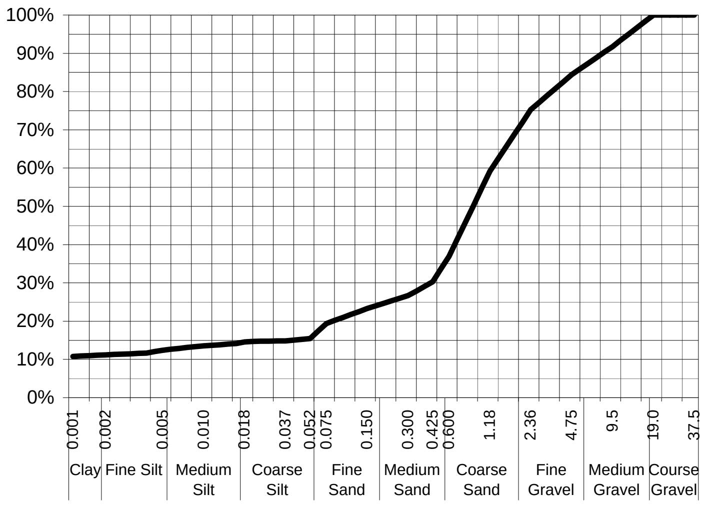
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-011 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G39_22/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	92%
4.75	84%
2.36	75%
1.18	59%
0.600	37%
0.425	30%
0.300	27%
0.150	23%
0.075	19%
Particle Size (microns)	
52	15%
37	15%
18	15%
10	14%
5	12%
3	12%
1	11%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, gravel & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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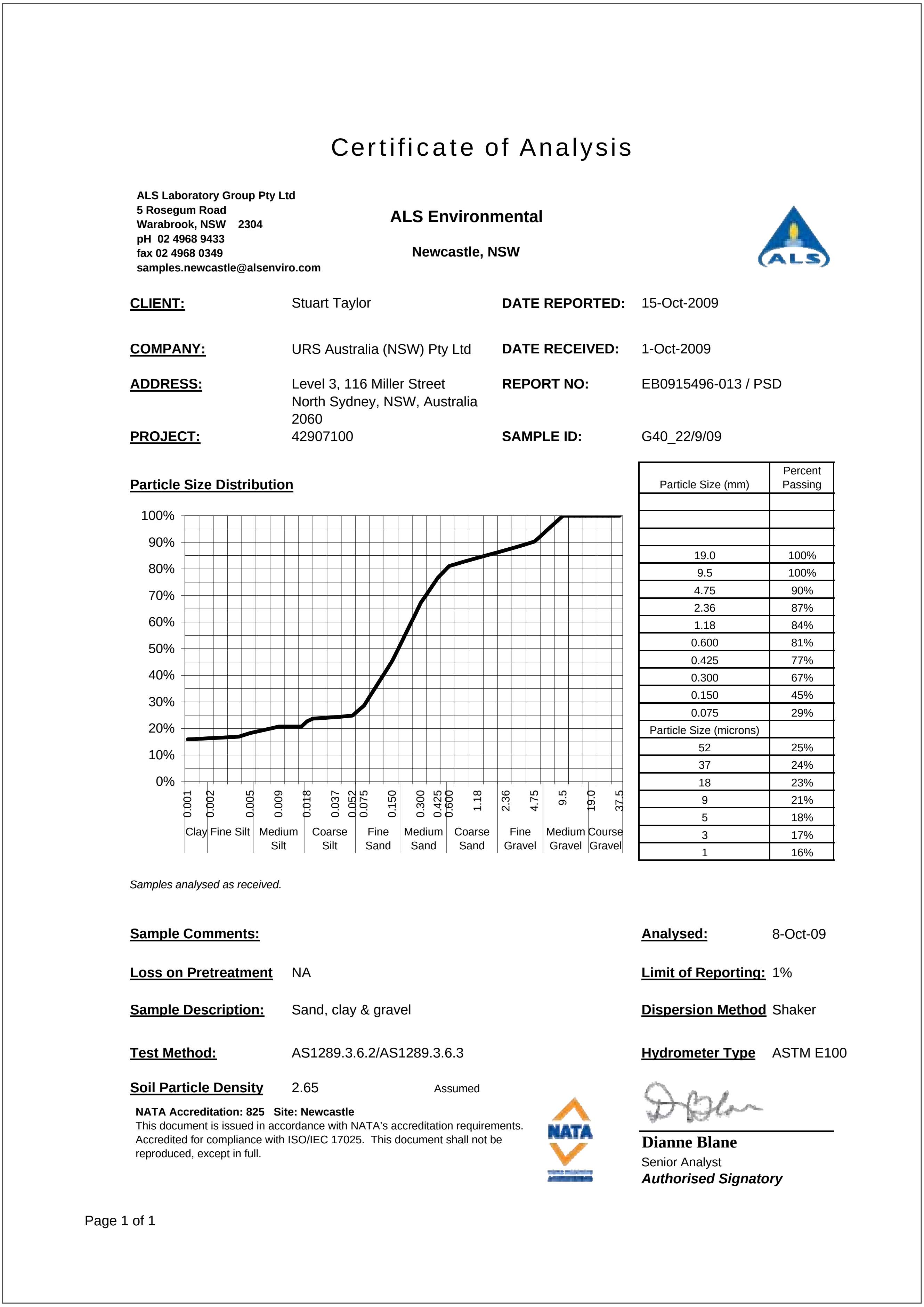

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-013 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G40_22/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	90%
2.36	87%
1.18	84%
0.600	81%
0.425	77%
0.300	67%
0.150	45%
0.075	29%
Particle Size (microns)	
52	25%
37	24%
18	23%
9	21%
5	18%
3	17%
1	16%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, clay & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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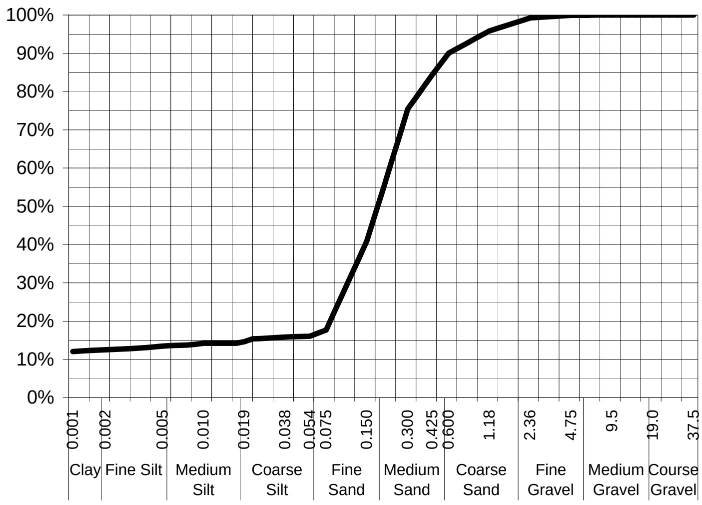
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-014 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G16_22/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	99%
1.18	96%
0.600	90%
0.425	84%
0.300	75%
0.150	41%
0.075	18%
Particle Size (microns)	
54	16%
38	16%
19	15%
10	14%
5	14%
3	13%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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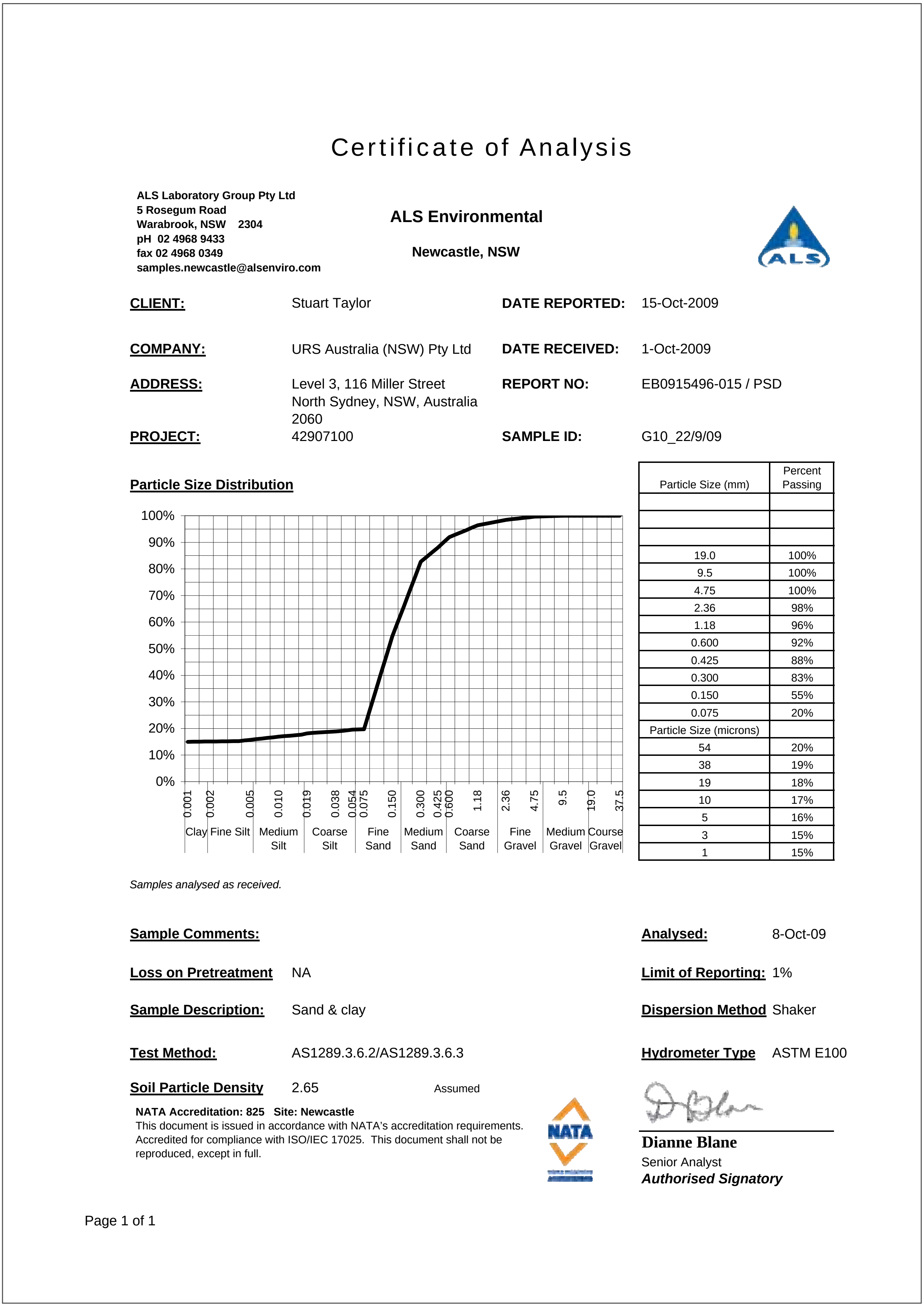

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-015 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G10_22/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	98%
1.18	96%
0.600	92%
0.425	88%
0.300	83%
0.150	55%
0.075	20%
Particle Size (microns)	
54	20%
38	19%
19	18%
10	17%
5	16%
3	15%
1	15%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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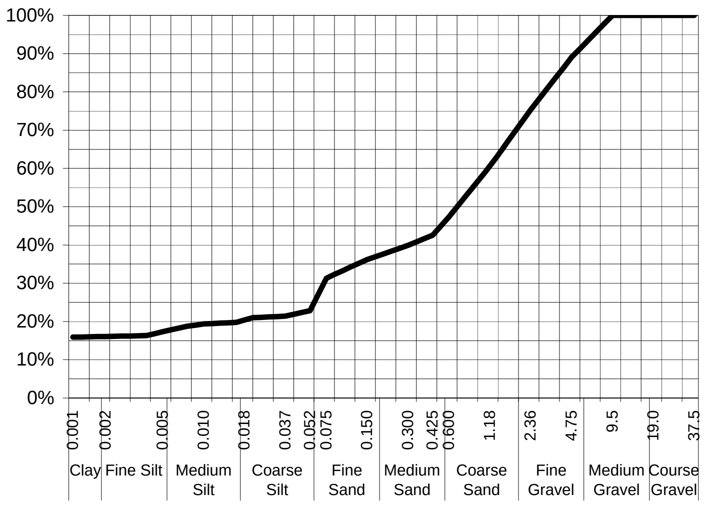
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-016 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G13_22/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	89%
2.36	75%
1.18	61%
0.600	47%
0.425	43%
0.300	40%
0.150	36%
0.075	31%
Particle Size (microns)	
52	23%
37	21%
18	20%
10	19%
5	17%
3	16%
1	16%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, clay & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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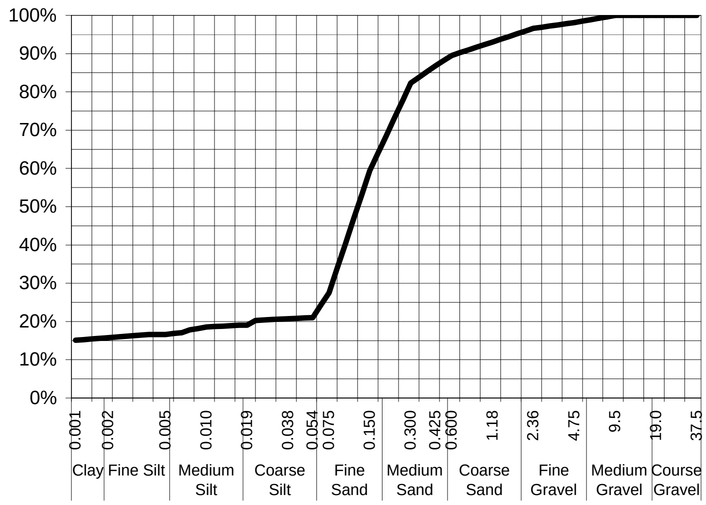
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-019 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G7_22/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	98%
2.36	97%
1.18	93%
0.600	90%
0.425	87%
0.300	82%
0.150	59%
0.075	27%
Particle Size (microns)	
54	21%
38	21%
19	19%
10	19%
5	17%
3	17%
1	15%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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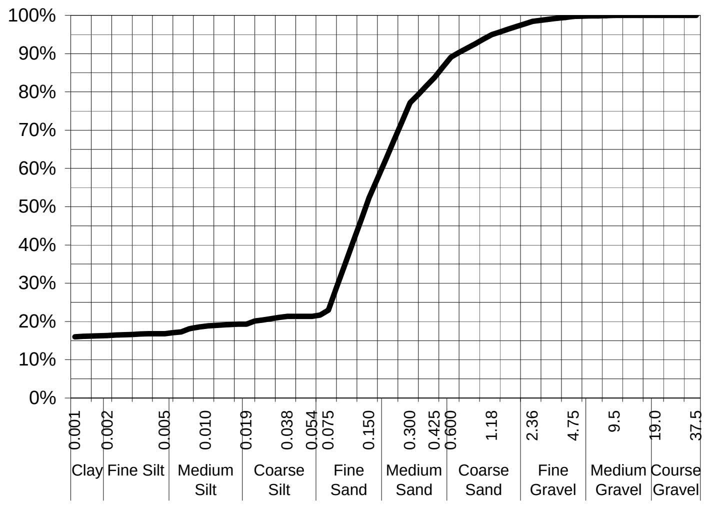
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-020 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G17_22/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	100%
2.36	98%
1.18	95%
0.600	89%
0.425	84%
0.300	77%
0.150	52%
0.075	23%
Particle Size (microns)	
54	21%
38	21%
19	19%
10	19%
5	17%
3	17%
1	16%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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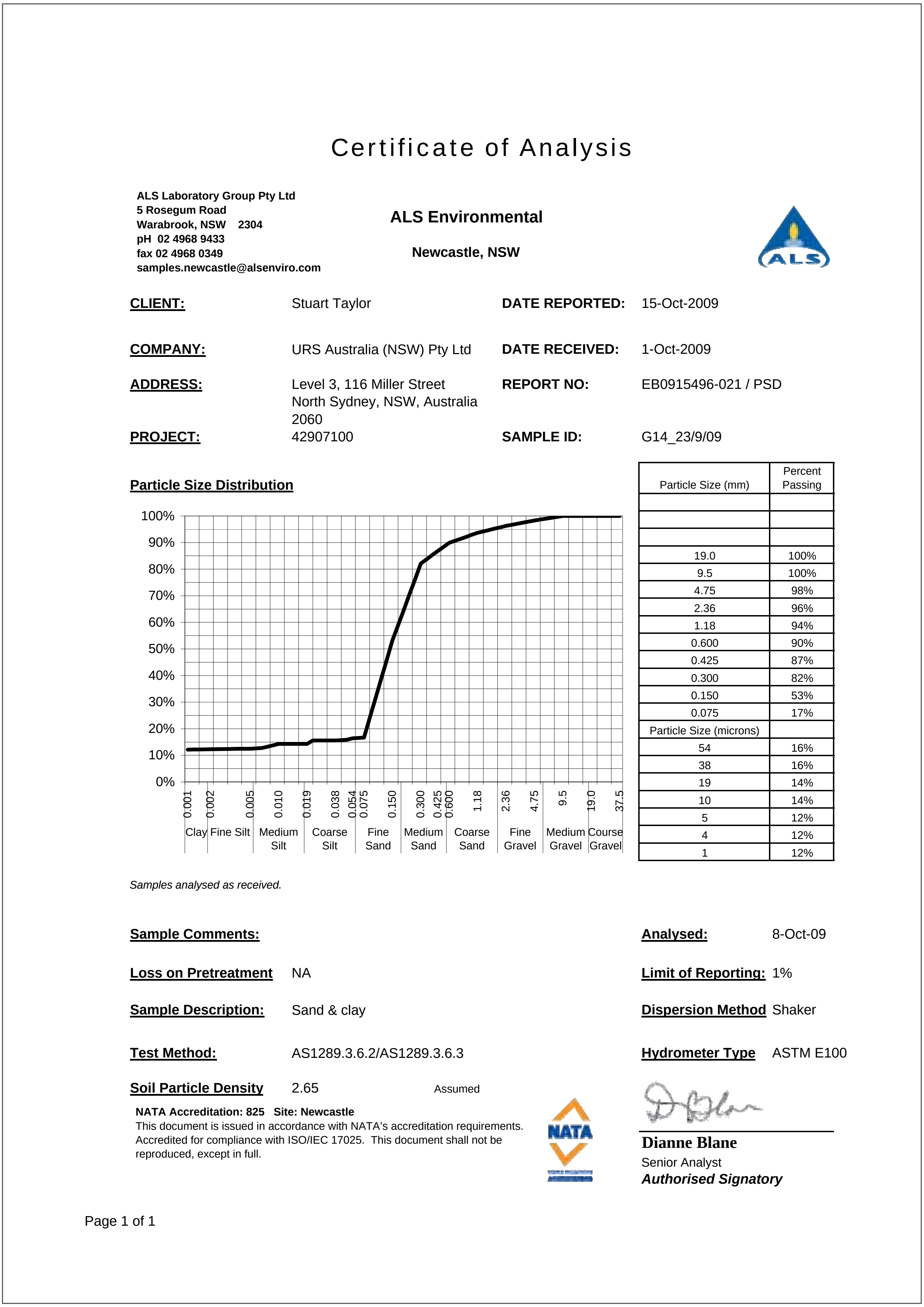

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CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-021 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G14_23/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	98%
2.36	96%
1.18	94%
0.600	90%
0.425	87%
0.300	82%
0.150	53%
0.075	17%
Particle Size (microns)	
54	16%
38	16%
19	14%
10	14%
5	12%
4	12%
1	12%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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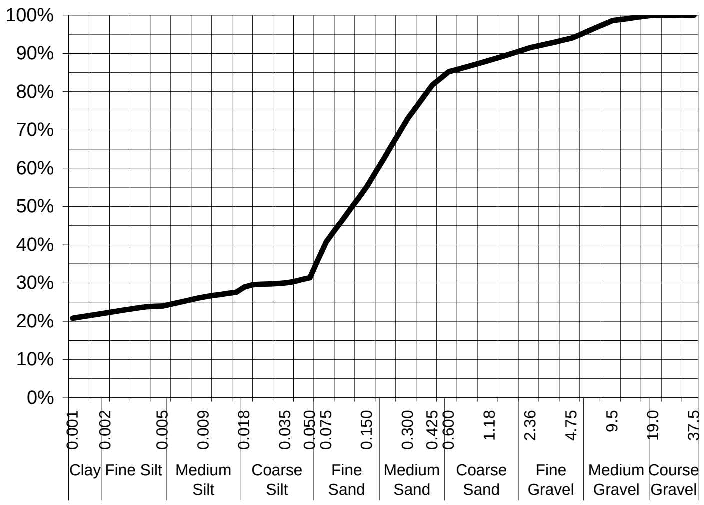
CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-028 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC28_0.0-0.25_23/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	99%
4.75	94%
2.36	92%
1.18	88%
0.600	85%
0.425	82%
0.300	73%
0.150	55%
0.075	41%
Particle Size (microns)	
50	31%
35	30%
18	29%
9	26%
5	24%
3	24%
1	21%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt & clay	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

NATA Accreditation: 825 Site: Newcastle
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Senior Analyst
Authorised Signatory

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Certificate of Analysis

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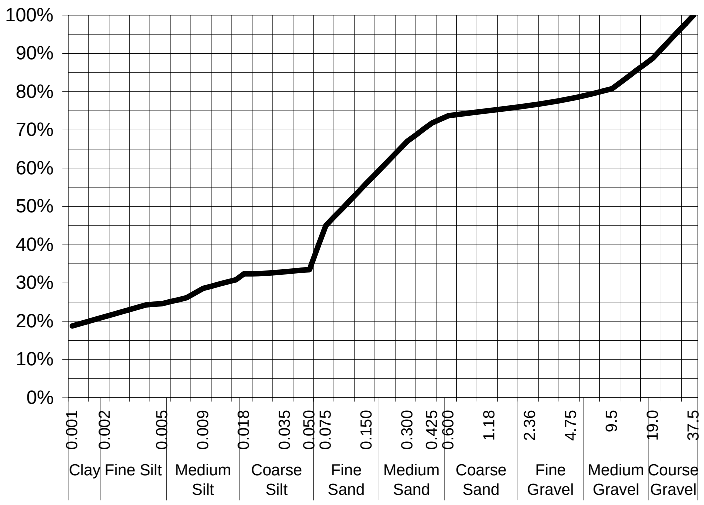
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-030 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC15_24/9/09_0.0-0.18

Particle Size Distribution



Particle Size (mm)	Percent Passing
37.5	100%
19.0	89%
9.5	81%
4.75	78%
2.36	76%
1.18	75%
0.600	74%
0.425	72%
0.300	67%
0.150	56%
0.075	45%
Particle Size (microns)	
50	33%
35	33%
18	32%
9	29%
5	25%
3	24%
1	19%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

NATA Accreditation: 825 Site: Newcastle
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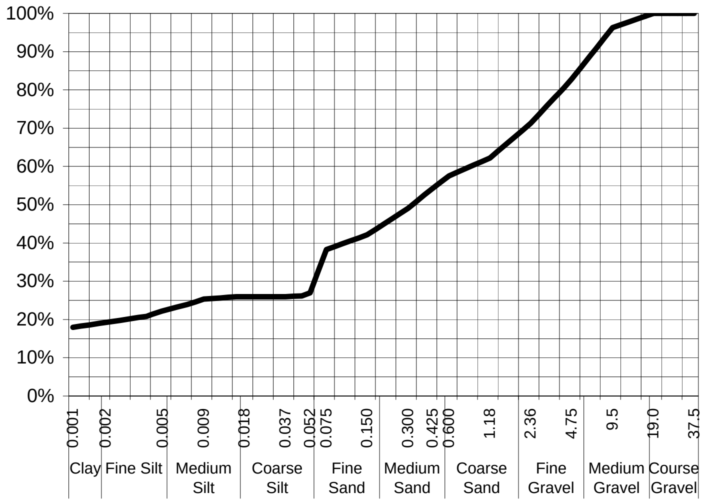
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-032 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC13_24/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	96%
4.75	83%
2.36	71%
1.18	62%
0.600	58%
0.425	54%
0.300	49%
0.150	42%
0.075	38%
Particle Size (microns)	
52	27%
37	26%
18	26%
9	25%
5	22%
3	21%
1	18%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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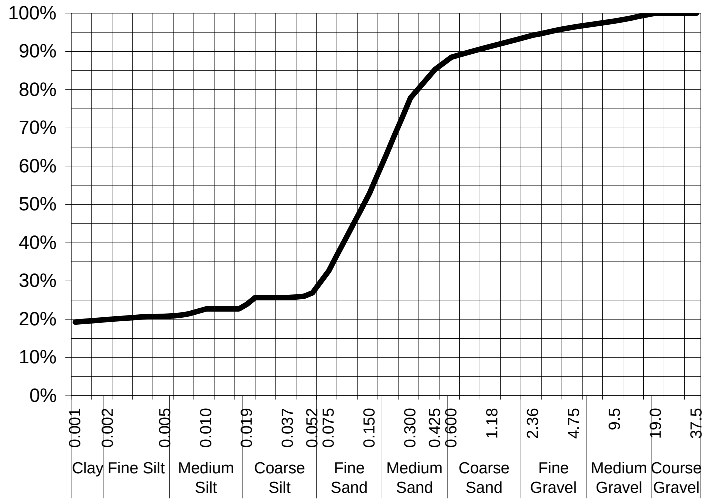
ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-035 / PSD
PROJECT:	42907100	**SAMPLE ID:**	G36_24/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	98%
4.75	96%
2.36	94%
1.18	91%
0.600	88%
0.425	85%
0.300	78%
0.150	53%
0.075	33%
Particle Size (microns)	
52	27%
37	26%
19	24%
10	23%
5	21%
3	21%
1	19%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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Senior Analyst
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Certificate of Analysis

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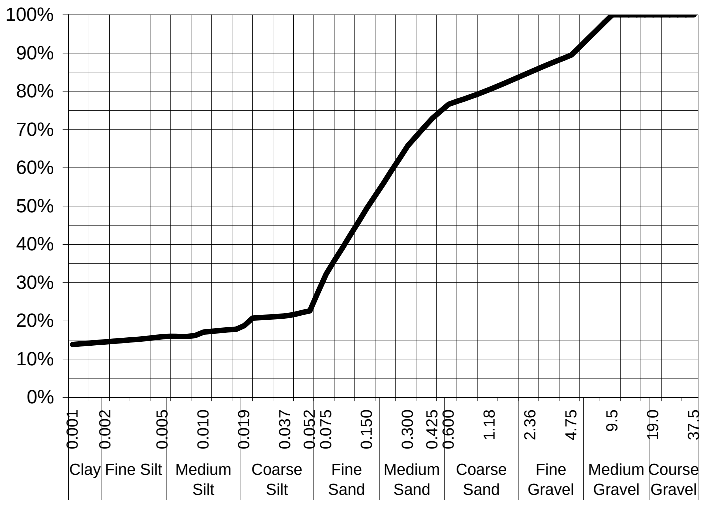
ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-042 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC19_0.0-0.12_24/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	90%
2.36	85%
1.18	80%
0.600	77%
0.425	73%
0.300	66%
0.150	49%
0.075	32%
Particle Size (microns)	
52	23%
37	21%
19	19%
10	17%
5	16%
3	15%
1	14%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & gravel	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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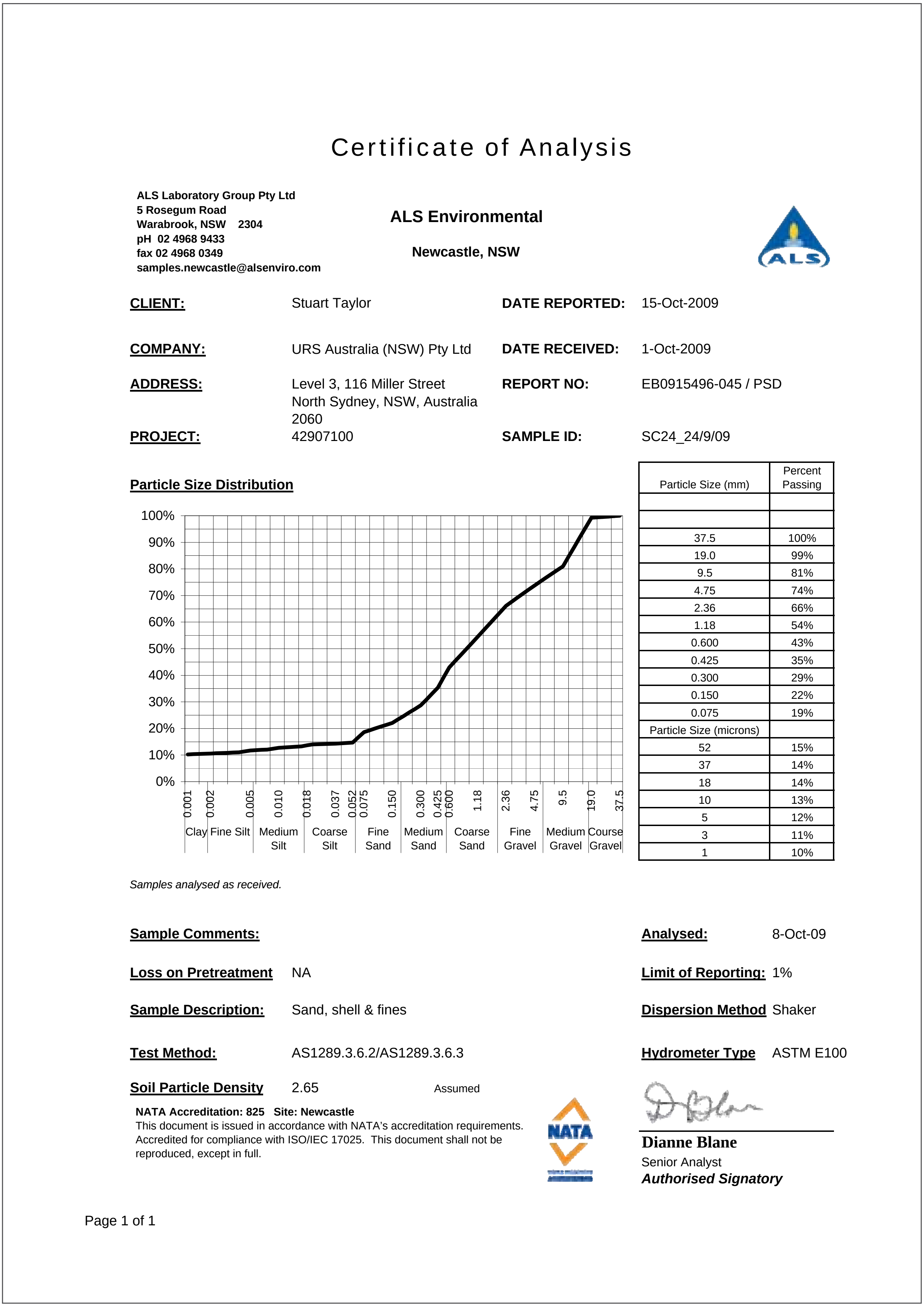

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ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-045 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC24_24/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
37.5	100%
19.0	99%
9.5	81%
4.75	74%
2.36	66%
1.18	54%
0.600	43%
0.425	35%
0.300	29%
0.150	22%
0.075	19%
Particle Size (microns)	
52	15%
37	14%
18	14%
10	13%
5	12%
3	11%
1	10%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, shell & fines	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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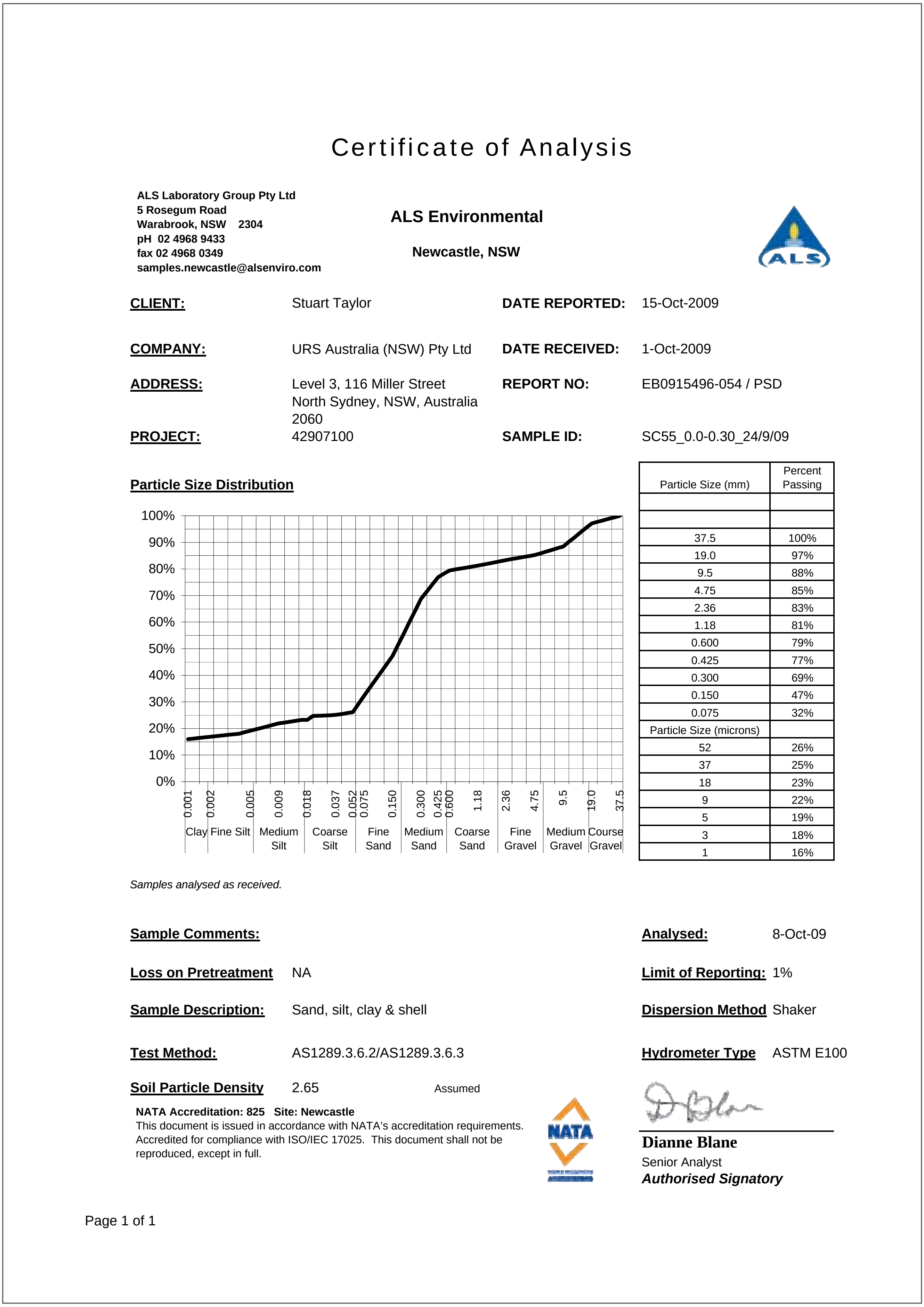

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ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-054 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC55_0.0-0.30_24/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
37.5	100%
19.0	97%
9.5	88%
4.75	85%
2.36	83%
1.18	81%
0.600	79%
0.425	77%
0.300	69%
0.150	47%
0.075	32%
Particle Size (microns)	
52	26%
37	25%
18	23%
9	22%
5	19%
3	18%
1	16%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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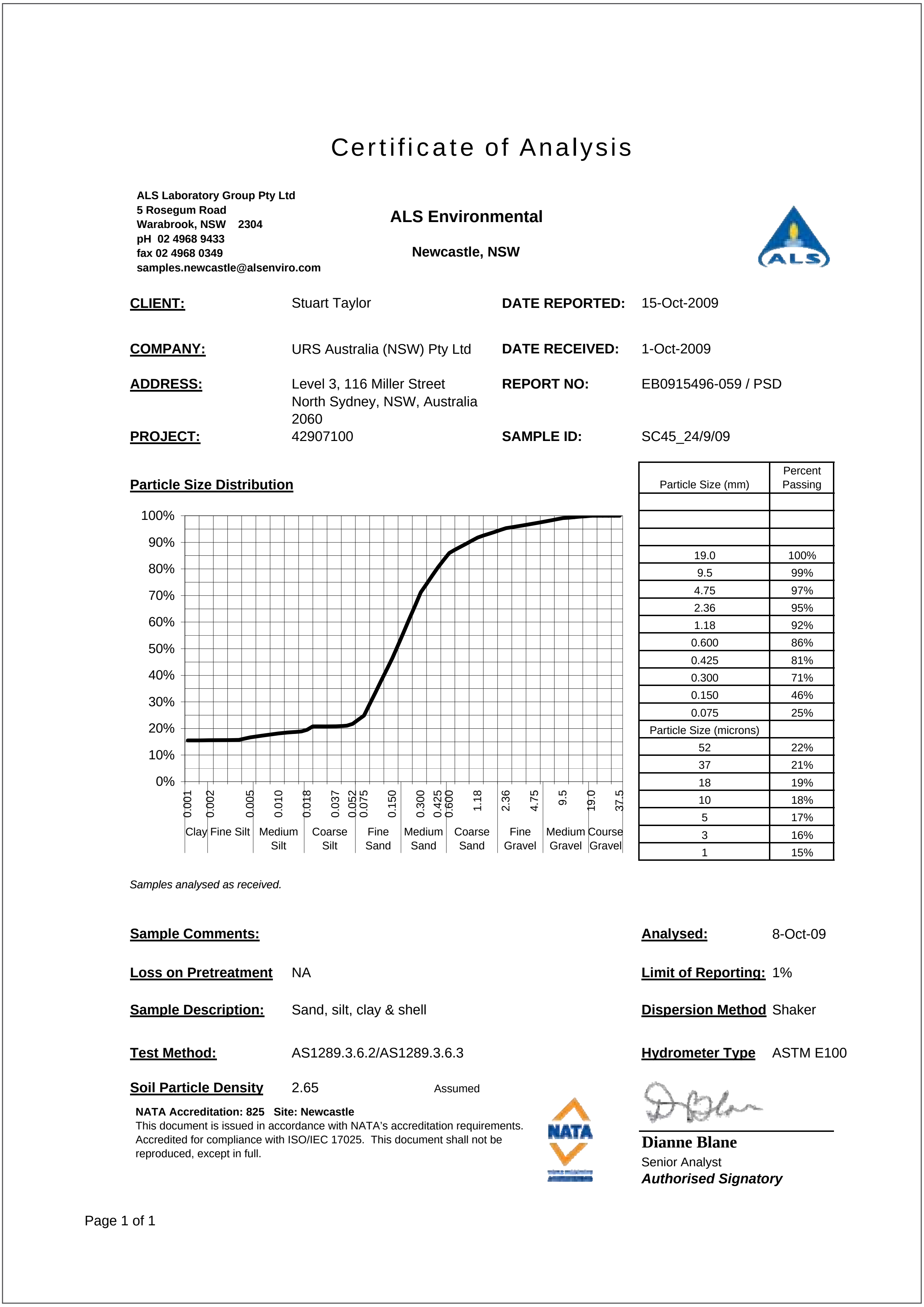

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samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-059 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC45_24/9/09

Particle Size Distribution

Particle Size (mm)	Percent Passing
19.0	100%
9.5	99%
4.75	97%
2.36	95%
1.18	92%
0.600	86%
0.425	81%
0.300	71%
0.150	46%
0.075	25%
Particle Size (microns)	
52	22%
37	21%
18	19%
10	18%
5	17%
3	16%
1	15%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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Warabrook, NSW 2304
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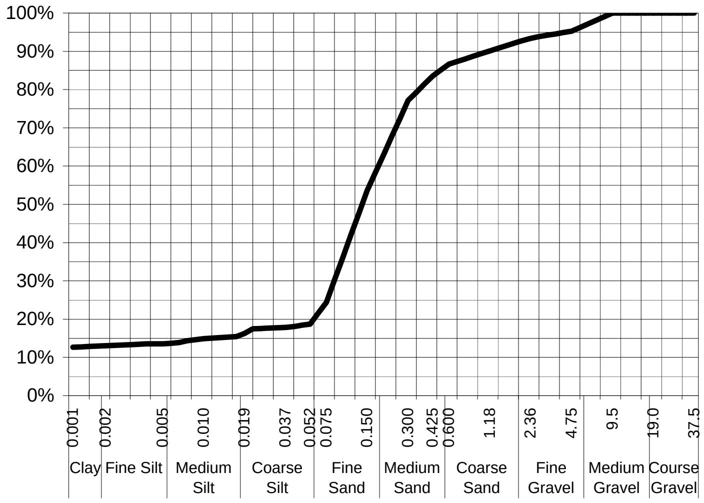
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	Stuart Taylor	**DATE REPORTED:**	15-Oct-2009
COMPANY:	URS Australia (NSW) Pty Ltd	**DATE RECEIVED:**	1-Oct-2009
ADDRESS:	Level 3, 116 Miller Street North Sydney, NSW, Australia 2060	**REPORT NO:**	EB0915496-061 / PSD
PROJECT:	42907100	**SAMPLE ID:**	SC4_0.0-0.25_24/9/09

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.5	100%
4.75	95%
2.36	93%
1.18	90%
0.600	87%
0.425	84%
0.300	77%
0.150	54%
0.075	24%
Particle Size (microns)	
52	19%
37	18%
19	16%
10	15%
5	14%
3	14%
1	13%

Samples analysed as received.

Sample Comments:		**Analysed:**	8-Oct-09
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	Sand, silt, clay & shell	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3	**Hydrometer Type**	ASTM E100
Soil Particle Density	2.65 Assumed		

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Appendix G Radionuclide Analysis

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ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EB0916564**

Client : **URS AUSTRALIA PTY LTD**
Contact : MR CARSTEN MATTHAI
Address : Level 3, 113 MILLER STREET
NORTH SYDNEY NSW, AUSTRALIA 2060

E-mail : Carsten_Matthai@urscorp.com
Telephone : ----
Facsimile : ----

Project : 42907100
Order number : ----
C-O-C number : ----
Sampler : E Heiden, S Taylor
Site : Wheatstone

Quote number : SY/374/09 V2

Page : 1 of 3

Laboratory : Environmental Division Brisbane
Contact : Tim Kilmister
Address : 32 Shand Street Stafford QLD Australia 4053

E-mail : Services.Brisbane@alsenviro.com
Telephone : +61-7-3243 7222
Facsimile : +61-7-3243 7218

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 01-OCT-2009
Issue Date : 26-OCT-2009

No. of samples received : 5
No. of samples analysed : 5

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*

Environmental Division Brisbane
Part of the **ALS Laboratory Group**
32 Shand Street Stafford QLD Australia 4053
Tel. +61-7-3243 7222 Fax. +61-7-3243 7218 **www.alsglobal.com**
A Campbell Brothers Limited Company

Page : 2 of 3
Work Order : EB0916564
Client : URS AUSTRALIA PTY LTD
Project : 42907100

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Radiological work undertaken by ALS Laboratory Group (Ceska Lipa) under CAI accreditation No. L1163. Report No. CS0904944 and CS0904945. NATA and CAI accreditations' are both recognised under ILAC.**

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Page : 3 of 3
Work Order : EB0916564
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**SC17_0.0_0.35_25/9/09 EB0915494-3**	**SC33_0.0_0.35_25/9/09 EB0915494-8**	**SC13_24/9/09 EB0915496-32**	**SC55_0.0_0.30_24/9/09 EB0915496-54**	**SC5_24/9/09 EB0915496-57**
			Client sampling date / time	25-SEP-2009 15:00	25-SEP-2009 15:00	24-SEP-2009 15:00	25-SEP-2009 15:00	25-SEP-2009 15:00
Compound	CAS Number	LOR	Unit	**EB0916564-001**	**EB0916564-002**	**EB0916564-003**	**EB0916564-004**	**EB0916564-005**
Radionucleides / Activity								
Gross alpha	----	500	Bq/kg DW	<500	<500	<500	<500	<500
Gross beta	----	500	Bq/kg DW	<500	<500	<500	<500	**500**

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H

Appendix H Weak Acid Extraction Analysis

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ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **ES0915525**
Amendment : **1**

Client : **URS AUSTRALIA PTY LTD**
Contact : MR ADAM PHARAOH
Address : LEVEL 3, HYATT CENTRE
20 TERRACE RD
EAST PERTH WA, AUSTRALIA 6004

E-mail : adam_pharaoh@urscorp.com
Telephone : +61 08 9326 0100
Facsimile : +61 08 9221 1639

Project : 42907100 REBATCH OF EB0915491 EB0915494 & EB0915496
Order number : ----
C-O-C number : ----
Sampler : EH, ST
Site : WHEATSTONE

Quote number : EN-001-09

Page : 1 of 11

Laboratory : Environmental Division Sydney
Contact : Charlie Pierce
Address : 277-289 Woodpark Road Smithfield NSW Australia 2164

E-mail : charlie.pierce@alsenviro.com
Telephone : +61-2-8784 8555
Facsimile : +61-2-8784 8500

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 13-OCT-2009
Issue Date : 21-OCT-2009

No. of samples received : 37
No. of samples analysed : 37

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Celine Conceicao	Spectroscopist	Inorganics
Victor Kedicioglu	Business Manager - NSW	Inorganics

Page : 3 of 11
Work Order : ES0915525 Amendment 1
Client : URS AUSTRALIA PTY LTD
Project : 42907100 REBATCH OF EB0915491 EB0915494 & EB0915496

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key :
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Page : 4 of 11
Work Order : ES0915525 Amendment 1
Client : URS AUSTRALIA PTY LTD
Project : 42907100 REBATCH OF EB0915491 EB0915494 & EB0915496

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**SC62_0.0-0.10_26/9/09**	**SC11_0.0-0.15_26/9/09**	**SC1_0.0-0.27_26/9/09**	**SC57_0.0-0.15_26/9/09**	**SC37_0.0-0.11_27/9/09**
			Client sampling date / time	26-SEP-2009 15:00	26-SEP-2009 15:00	26-SEP-2009 15:00	26-SEP-2009 15:00	27-SEP-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915525-001**	**ES0915525-002**	**ES0915525-003**	**ES0915525-004**	**ES0915525-005**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**21.1**	**28.2**	**22.1**	**24.4**	**29.4**
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Chromium	7440-47-3	1.0	mg/kg	----	**1.6**	----	----	----
Nickel	7440-02-0	1.0	mg/kg	<1.0	**1.7**	**1.0**	**1.4**	**1.2**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**SC61_0.0-0.18_27/9/09**	**SC29_0.0-0.20_27/9/09**	**SC20_0.0-0.20_27/9/09**	**SC55_0.0-0.25_25/9/09**	**SC17_0.0-0.35_25/9/09**
			Client sampling date / time	27-SEP-2009 15:00	27-SEP-2009 15:00	27-SEP-2009 15:00	25-SEP-2009 15:00	25-SEP-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915525-006**	**ES0915525-007**	**ES0915525-008**	**ES0915525-009**	**ES0915525-010**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**28.2**	**26.4**	**27.6**	**26.8**	**22.0**
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Arsenic	7440-38-2	1.0	mg/kg	----	----	----	**1.9**	**1.5**
Nickel	7440-02-0	1.0	mg/kg	**1.6**	**1.5**	**1.2**	----	----

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Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**SC59_0.0-0.23_25/9/09**	**SC8_0.0-0.30_25/9/09**	**SC18_0.0-0.30_25/9/09**	**SC23_0.0-0.25_25/9/09**	**SC34_0.0-0.25_25/9/09**
			Client sampling date / time	25-SEP-2009 15:00	25-SEP-2009 15:00	25-SEP-2009 15:00	25-SEP-2009 15:00	25-SEP-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915525-011**	**ES0915525-012**	**ES0915525-013**	**ES0915525-014**	**ES0915525-015**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**24.3**	**24.8**	**23.5**	**26.2**	**25.5**
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Arsenic	7440-38-2	1.0	mg/kg	**1.7**	**1.6**	**1.4**	**1.4**	**1.3**

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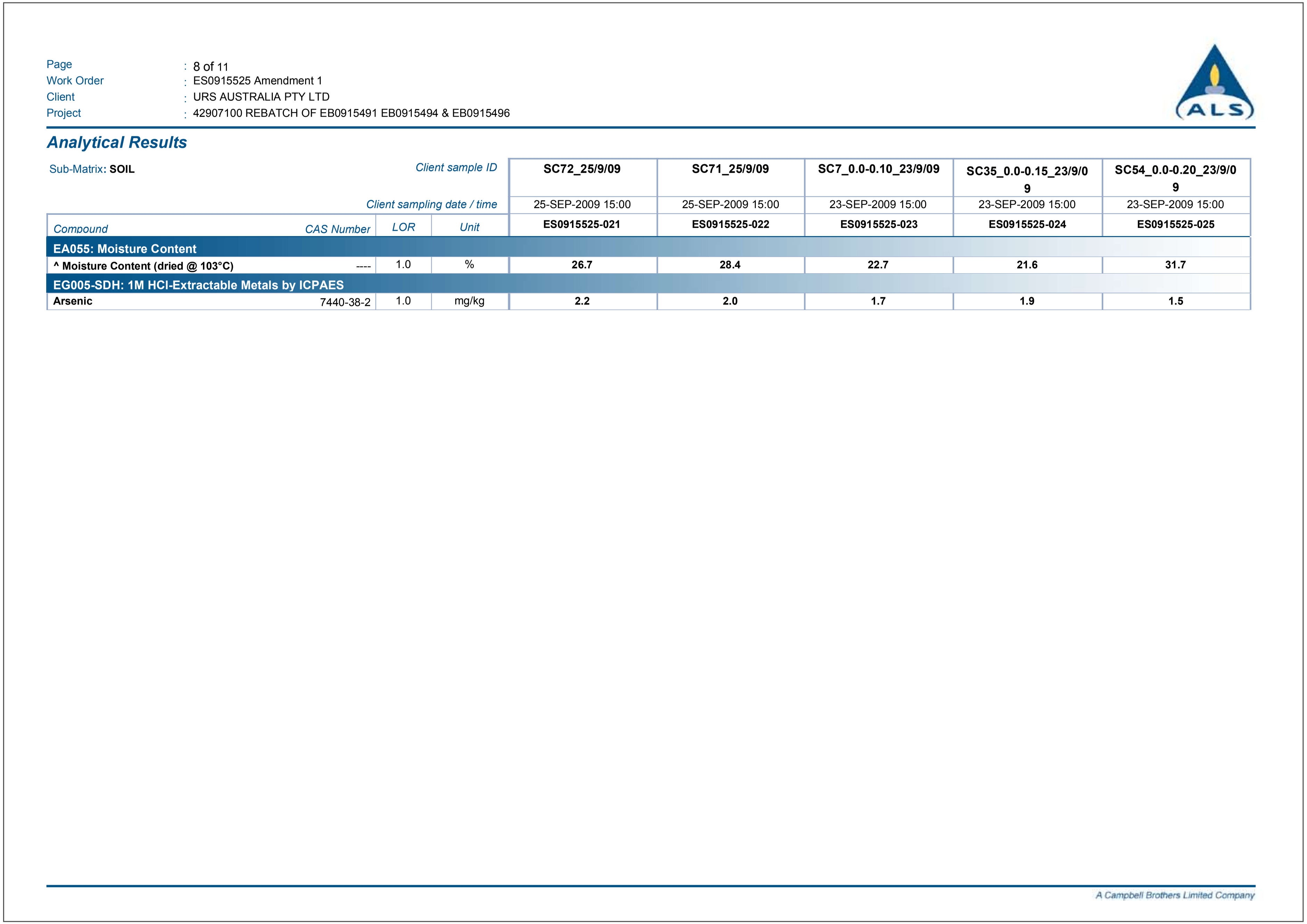
Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**SC67_0.0-0.15_25/9/09**	**SC40_0.0-0.31_25/9/09**	**SC50_0.0-0.23_25/9/09**	**SC47_0.0-0.25_25/9/09**	**SC9_0.0-0.20_25/9/09**
			Client sampling date / time	25-SEP-2009 15:00	25-SEP-2009 15:00	25-SEP-2009 15:00	25-SEP-2009 15:00	25-SEP-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915525-016**	**ES0915525-017**	**ES0915525-018**	**ES0915525-019**	**ES0915525-020**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**22.1**	**24.6**	**27.7**	**21.4**	**30.8**
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Arsenic	7440-38-2	1.0	mg/kg	**2.5**	**1.4**	**1.5**	**1.8**	**1.8**



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Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**SC72_25/9/09**	**SC71_25/9/09**	**SC7_0.0-0.10_23/9/09**	**SC35_0.0-0.15_23/9/09**	**SC54_0.0-0.20_23/9/09**
			Client sampling date / time	25-SEP-2009 15:00	25-SEP-2009 15:00	23-SEP-2009 15:00	23-SEP-2009 15:00	23-SEP-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915525-021**	**ES0915525-022**	**ES0915525-023**	**ES0915525-024**	**ES0915525-025**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**26.7**	**28.4**	**22.7**	**21.6**	**31.7**
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Arsenic	7440-38-2	1.0	mg/kg	**2.2**	**2.0**	**1.7**	**1.9**	**1.5**

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Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**SC58_0.0-0.15_23/9/09**	**SC13_24/9/09**	**QC105_24/9/09**	**QC106_24/9/09**	**QC107_24/9/09**
			Client sampling date / time	23-SEP-2009 15:00	24-SEP-2009 15:00	24-SEP-2009 15:00	24-SEP-2009 15:00	24-SEP-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915525-026**	**ES0915525-027**	**ES0915525-028**	**ES0915525-029**	**ES0915525-030**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**22.6**	**31.8**	**29.9**	**24.3**	**24.4**
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Arsenic	7440-38-2	1.0	mg/kg	**1.8**	**3.0**	**3.0**	**1.9**	**2.0**

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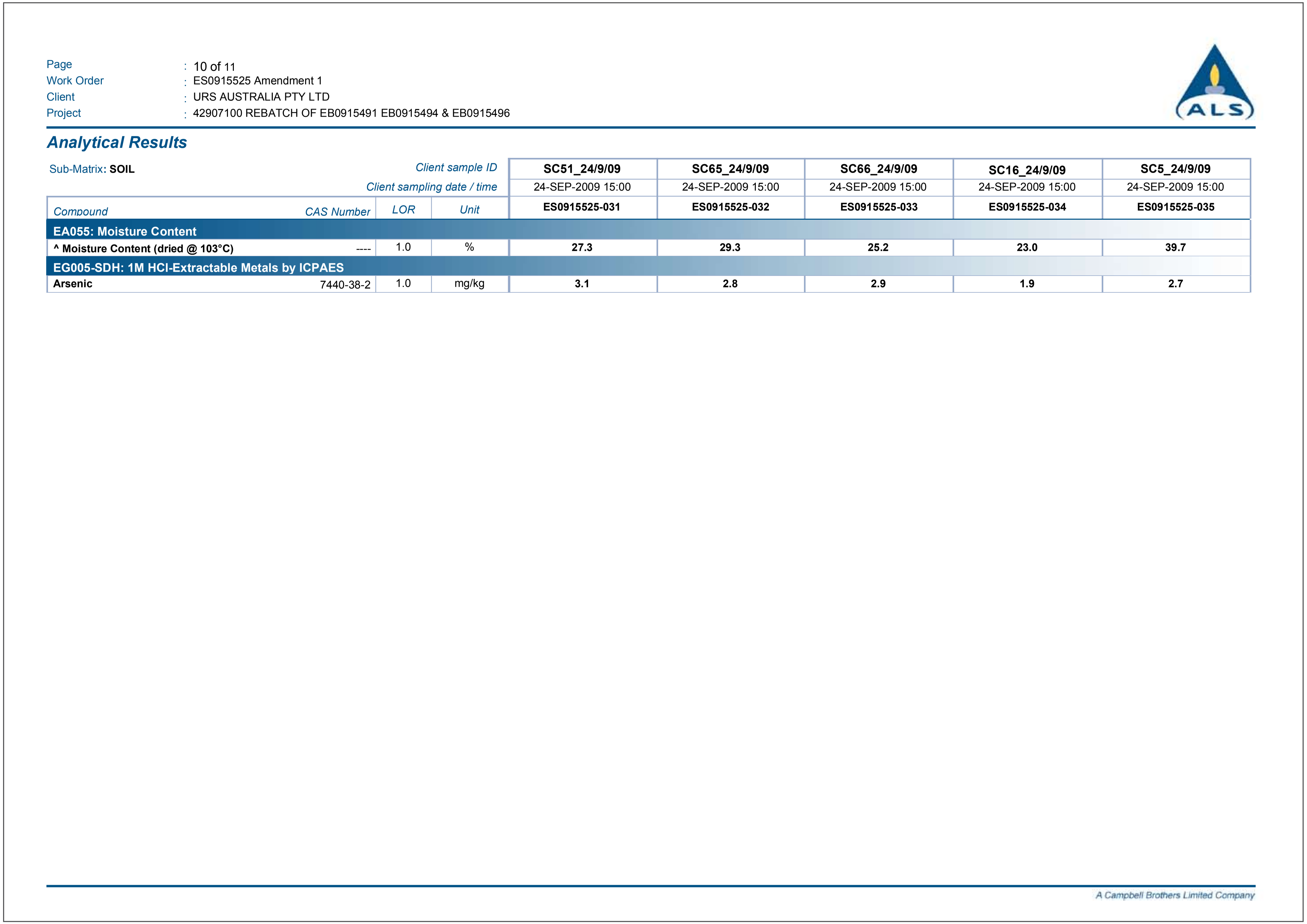

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**SC51_24/9/09**	**SC65_24/9/09**	**SC66_24/9/09**	**SC16_24/9/09**	**SC5_24/9/09**
			Client sampling date / time	24-SEP-2009 15:00	24-SEP-2009 15:00	24-SEP-2009 15:00	24-SEP-2009 15:00	24-SEP-2009 15:00
Compound	CAS Number	LOR	Unit	**ES0915525-031**	**ES0915525-032**	**ES0915525-033**	**ES0915525-034**	**ES0915525-035**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**27.3**	**29.3**	**25.2**	**23.0**	**39.7**
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Arsenic	7440-38-2	1.0	mg/kg	**3.1**	**2.8**	**2.9**	**1.9**	**2.7**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**SC31_0.0-0.20_24/9/09**	**SC39_0.0-0.10_24/9/09**	----	----	----
			Client sampling date / time	24-SEP-2009 15:00	24-SEP-2009 15:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES0915525-036**	**ES0915525-037**	**----**	**----**	**----**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**23.7**	**26.7**	----	----	----
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Arsenic	7440-38-2	1.0	mg/kg	**2.1**	**2.0**	----	----	----

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