Technical Appendices
G1, H1, I1, I2, J1, K1, L1 and M1

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

July 2010

Wheatstone Project

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Appendix G1 to M1

Appendix G1

Wheatstone Project Surface Water Studies

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Abbreviations

Abbreviation	**Description**
AHD	Australian Height Datum
approx	Approximately
ARI	Average Recurrence Interval
bgl	Below ground level
DEM	Digital Elevation Map
Domgas	Domestic Gas
DoW	Department of Water
DPI	Department for Planning and Infrastructure
EC	Electrical Conductivity
EOH	End of hole
GEV	Generalised Extreme Value
HAT	Highest Astronomical Tide
HRT	Highest Recorded Tide
ID	Inside diameter
L/s	Litres per second
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
LRT	Lowest Recorded Tide
m	Metres
m bgl	Metres below ground level
m btc	Metres below top of casing
mg/L	Milligrams per litre
mins	Time in minutes
mm	Millimetres
mS/cm	MilliSeimens per centimetre
na	Not available
N/A	Not applicable
NTU	Nephelometric Turbidity Units
OD	Outside diameter
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PVC	Polyvinyl chloride
sec	Time in seconds
SPT	Standard penetration test
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
%	Percent or percentage
µS/cm	MicroSeimens per centimetre

Abbreviations (cont’d)

Abbreviation	**Description**
ARDFS	Ashburton River Delta Flood Study
CGARDAA	Coastal Geomorphology of the Ashburton River Delta and Adjacent Areas
BSQLA	Baseline Soil Quality and Landforms Assessment
HCFSSR	Hooley Creek Flood Study Summary Report
LRP1	Live Report Phase 1 Environmental Drilling Programme
LRP2	Live Report Phase 2 Environmental Drilling Programme
PARPW	The Potential for Aquifer Re-Injection of Produced Water by DWI
PCWS	The Pilbara Coast Water Study (T. D. Haig)
WSOAWP	Water Source Option Assessment for Wheatstone Project

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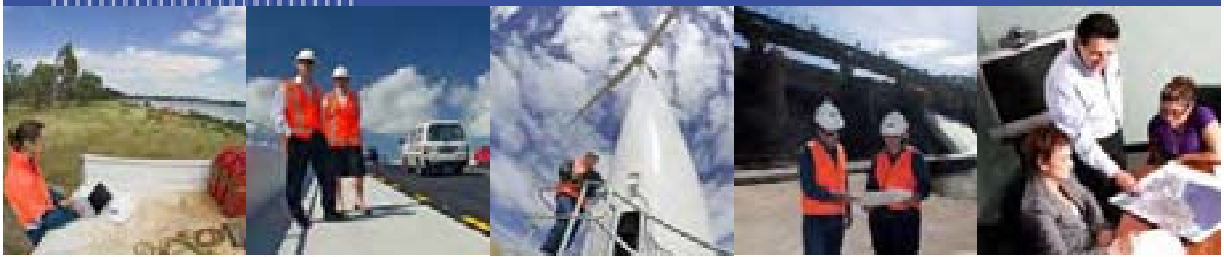

Report

Wheatstone Project Surface Water Studies

20 MAY 2010

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Executive Summary

Chevron Australia Pty Ltd propose to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km southwest of Onslow on the Pilbara Coast. The proposed plant site is located just behind the coastal dunes on the flood plain of the Ashburton River Delta, partly within the tidal zone. Land cover and land form in the project area are strongly controlled by tidal influences.

Due to the potential of flooding and tidal surges, the plant will be located on a constructed pad (Plant Pad) with an approximate finished elevation of 7.5 m AHD. Construction of the pad would be engineered using borrow material. Within the pad, there may be a dredge material placement area. Clearing and earthworks will be required throughout Ashburton North during construction and installation of infrastructure. The earthworks are expected to include cut to fill excavations and importation of fill material together with compaction activities. Cut to fill excavations and large volumes of fill material being brought into Ashburton North would alter the local landforms. Elevation platforms for the Plant Pad, Shared Infrastructure Corridor and Accommodation Village and excavation of borrow pits within the Hooley Creek tidal embayment would alter the local catchments and intersect natural drainage lines.

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). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

The main objectives of this study are to assess the surface water hydrology of the existing environment, and predict any potential impact of the proposed Wheatstone Project on the environment. This report aims to characterise the existing environment of Ashburton North to establish a baseline for the aspects of the surface water environment most likely to be impacted by the development of the Wheatstone Project.

Regional Hydrology

Ashburton North is located in the Ashburton River Catchment. The Ashburton River is has a catchment area of approximately 78,777 km^2 and ephemeral flows, typically flowing only in response to significant rainfall. River flows are gauged at Nanutarra Bridge (Department of Water, Gauging Station No. 706003), approximately 100 km inland from the river mouth. Recorded flows widely vary between nil and 12,600 m^3/s, with annual flow volumes from 3 to 4,500 GL (2007 and 1997). Major flows occur every one to three years in response to cyclonic rainfall. River flows are typically short-lived. Runoff is channelled in the upper reaches of the catchment. When in flow, the Ashburton River is typically fresh, with salinity of about 130 mg/L TDS, and turbid. The turbidity for river flow ranges from less than 10 NTU at low flows of 30 m^3/sec, to 3,300 NTU at a flow rate of around 250 m^3/sec. The flow weighted turbidity for the Ashburton River is 1,705 NTU (about 2,550 mg/L TSS).

Local Baseline Hydrology

Ashburton North is located within the Ashburton River Delta. The Ashburton River Delta comprises the Hooley Creek, Southwest, Ashburton River Mouth and Northeast Catchments and is recognised as an important, high conservation value and regionally significant ecosystem. Ashburton North is located on the catchment divide between the Southwest and Hooley Creek Catchments.

The mean annual rainfall at Onslow (Station No. 005017) is about 320 mm. Rainfall events predominantly occur during October through to April, linked to cyclonic activity, but are sporadic and typically limited to about 16 days each year. Stream flow only occurs in response to significant rainfall events, and typically is short-lived. Cyclonic and other high intensity rainfall events cause shallow catchment boundaries to be submerged. Typically this occurs about every two years. Accordingly, the terrestrial setting is inherently dry. Local watercourses Hooley Creek West, Hooley Creek East, Eastern Creek and 4 Mile Creek are dry, except for tidal reaches.

Water quality in the tidal Ashburton River Delta, including tidal reaches of the Southwest and Hooley Creek Catchments, is widely varied due to storm runoff, tidal and storm influences. The baseline evidence suggests that the local surface waters are widely variable in turbidity and salinity. Wide variations occur in response to stream flow, residence time in storage within clay pans and the broader catchment, depth to the water table with possible groundwater interactions and, proximity to marine influences. Sampled baseline salinity concentrations may be linked to fresh stream flow, dissolution and mobilisation of salt in storage within clay pans and/or shallow soil profile, mixing with groundwater discharge, concentration effects due to evaporation and mixing with seawater.

Measurements of turbidity at Ashburton North show a range from <10 to 6,000 NTU over a six week period from 5 March 2009 to 17 April 2009 after earlier significant rainfall events. Typically, it is expected that turbidity would be less than 20 NTU except during and after flood events. Measured salinities range from fresh to hypersaline.

Conceptual Hydrological Model

The conceptual hydrological model interprets that the Ashburton River Delta and local catchments are dynamic, with natural changes to landforms and watercourses actively occurring through erosion and deposition driven by both fluvial and marine processes. The Ashburton River typically breaks its banks every second year, leading to flood waters flowing from the river onto low-lying areas of the Ashburton River Delta and Ashburton North becoming part of a regional coastal flood plain. As such, the catchments of the Ashburton River Delta are discreet only during low intensity rainfall events. When flow occurs, sediment is mobilised and may be transported to floodplain and marine environments at comparatively high concentrations.

The local surface water environment is influenced by several factors including:

- Local and regional cyclonic rainfall occurrence and intensity within the Ashburton River Catchment.
- Flooding of the Ashburton River.
- Tidal and storm surge forces.

Surface water receptors include the habitats of the Ashburton River Delta, inclusive of the tidal reaches of Hooley Creek.

Potential Surface Water Impacts

The Project is unlikely to influence the regional surface water environments. The potential impacts to the surface water environment linked to Ashburton North are local effects that do not propagate beyond the catchments of the Ashburton River Delta. The potential impacts relate to:

- Altered hydrology.
- Changes to water quality.

Altered Hydrology

The altered landforms may change catchment responses to rainfall and channel flow, surface water flow directions, flow velocities and potentials for diversion of flood flows to adjoining catchments. The elevated platforms for the Project infrastructure would:

- Intercept the watercourse of the Hooley Creek West, locally restricting surface water flows and constraining the flow path to the ocean and ingress of tidal waters.
- Intersect 16 major drainage lines of the Hooley Creek Catchment along the alignment of the Shared Infrastructure Corridor and Accommodation Village. The drainage infrastructure design for the Shared Infrastructure Corridor accommodates a 1:25-year ARI event. For less frequent events, there is potential for retardation and temporary storage of surface water flows.
- Isolate about 390 ha of the northern Southwest Catchment associated with dredge material emplacement, thus reducing the flood water storage capacity of this catchment.

The excavation of the proposed borrow pits would tend to removed natural constrictions to the flow of flood waters and tides. The assumed bottom of borrow pit elevations are 1.0 to 1.2 m AHD.

The methodology for the assessment of potential impacts due to altered hydrology focuses on predicted differences between interpreted characteristics of the baseline and altered surface water flow and floods linked the development of the Wheatstone Project. The altered landforms may change catchment responses to rainfall and channel flow, surface water flow directions, flow velocities and potentials for diversion of flood flows to adjoining catchments. The MIKE 21 model developed to simulate the baseline surface water environments has been adapted to predict the potential impacts of the altered hydrology based on:

- Changes to flood depths and elevations.
- Variations of flow velocities.
- Potential inundation of portions of the Shared Infrastructure Corridor. In order to minimize the potential impacts on the baseline, drainage infrastructure (culverts) have been incorporated into the MIKE 21 model at all 16 drainage crossings.
- Diversion of flood flows to adjoining catchments.
- Changes to areas inundated by tides.
- Water shed from the dredge material placement area.

The simulations of the altered hydrology have been completed for a range of storms including 5, 10, 25 and 100-year ARI events. These events have also been simulated in combination with mean sea level, Highest Recorded Tide and 1:100-year storm surge conditions. Typically, the simulated differences between the baseline and developed cases for events more frequent than 1:25-year ARI are small, within the range of the vertical resolution of the model.

The findings of the simulations include:

- Lowering of flood depths and elevations by up to 0.5 m for a 1:100-year ARI event. The predicted changes are interpreted to potentially impose short-term and temporary changes to the local surface water environments. It is expected that actual changes may not be measurable.
- Increases of flow velocities linked to encroachment of infrastructure on Hooley Creek West and flow retardation along the Shared Infrastructure Corridor. It is expected that actual changes would be minimal and may not be measurable.

- For a 1:100-year ARI event, the roadway overtops several drainage line crossings between the Accommodation Village and the connection to Onslow Road. At the crossings near the Accommodation Village, the conceptual design elevation of the roadway restricts the size and capacity of the culverts. Locally, the predicted flood elevations are marginally higher than the proposed 6 m AHD elevation of the raised platform. A minimum local Shared Infrastructure Corridor elevation of 7.0 m AHD would be required to achieve 1:100-year ARI operational criteria and limit the potential for overtopping of the Shared Infrastructure Corridor.
- The presence of the Project infrastructure causes a small delay in the diverting flood flows to adjoining catchments but does not cause a significant change the baseline characteristics of flow.
- The impact of the borrow pit excavations is to remove local obstructions to tidal forces and storm surge. The impacts include small-scale changes in water elevations in the areas extending up to about 5 km inland. The area south of the Onslow Salt crystallisation ponds is expected to have increased exposure to storm surge, with summated inundation up to 0.5 m depth. The 1:100-year storm surge is expected to cause inundation beyond the proposed Shared Infrastructure Corridor.
- The proposed onshore placement of dredge material may impose impacts linked to seepage of seawater expressing as surface water flows within the Southwest and Ashburton River Mouth Catchments. The predictive simulations show total seepage from the dredge material placement area peaks at a rate of about 2,200 kL/day. The predicted seepage rates rise progressively throughout the campaign of dredge material disposal onshore, peaking as the campaign ceases. Thereafter the seepage rates decay over a period of five to ten years to about 200 to 400 kL/day. The simulated seepage rates are sufficiently low that they may be predominantly intercepted by evaporation and low-lying storage areas of the Southwest Catchment and consequently not express as significant surface water flows on the ground surface.

Changes to Water Quality

The potential impacts on surface water quality predominantly stem from:

- Likely increases in local sediment and salt due to an increase in disturbed soils and the large volumes of fill materials to be brought to Ashburton North. The potential turbidity impacts may be mitigated through appropriate design and engineering initiatives to intercept sediment. Conceptual designs for the Plant Pad provide for sedimentation traps on local watercourses and silt fences on the perimeters of the construction area. Construction of the perimeter embankments would preferably occur during the predominantly dry winter months.
- Seepage of seawater from the dredge material placement area and accumulation of salt due to the retention and storage of flood waters upstream of the proposed Shared Infrastructure Corridor. Both of these potential impacts have been mitigated through conceptual designs of the dredge material placement area and Shared Infrastructure Corridor that respectively limit seepage and the retardation of surface water flows.
- Spills and leaks of contaminants. The interception of leaks and spills is addressed in the spill containment design for the Plant Pad.

The runoff to Hooley Creek and within the Southwest Catchment is likely to require the management of Total Suspended Solids concentrations and sediment loads for compatibility with the baseline environments and conservation of habitats of the Ashburton River Delta. As such, the ANZECC Guidelines, together with baseline data, have been used to develop indicative or guideline trigger values for turbidity and salinity. These indicative or guideline trigger values include turbidity of 20 to 80 NTU (dry-season to wet season) and salinity 33,000 mg/L TDS. The trigger values appear to be conservatively low based on the available data. The available baseline data are limited and consequently the indicative or guideline trigger values are intended to be adjusted, to reflect measured baseline values, once additional relevant data are recorded.

The implementation of the trigger values for the dry-season and wet-season needs to be supported by definitions of these periods given they would change from year to year and may be dependent on the ARI of storm events that seasonally influence surface water qualities. Invariably, a network of surface water control sites in receiving environments within the Hooley Creek, Southwest and Ashburton River Mouth Catchments would define the transitions from dry to wet to dry seasons and associated trigger values. The control sites would provide measures of baseline turbidity and salinity in domains that are not influenced by the proposed Ashburton North developments.

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1

Introduction

1.1 Project Description

Chevron Australia Pty Ltd propose to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km southwest of Onslow on the Pilbara Coast (Figure 1-1). The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future 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 plants. The Project will require the installation of gas gathering, processing and export 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 proposed plant site is located behind the beach dunes on the coastal flood plain of the Ashburton River Delta, partly within the tidal zone. Land cover and land form in the Project area are controlled by tidal influences. The construction of the proposed plant will require building up an elevated area of land (Plant Pad) sufficient to accommodate the development of onshore and marine facilities and flood protection. The construction of a navigable channel will involve a large scale dredging program. 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). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

1.2 Wheatstone Project Construction and Operation Period

The proposed construction and operation periods for the Wheatstone Project are:

- Plant construction is from 2011 – 2016.
- Operation period is thirty (30) years.

1.3 Wheatstone Development

Ashburton North (Figure 1-2) is located on the coastal floodplain, straddling the local-scale catchment divide between the Hooley Creek Catchment, Southwest Catchment (southwest of the proposed Plant Pad) and the Ashburton River, each of which form part of the coastal delta area of the Ashburton River, termed the Ashburton River Delta. Ashburton North is exposed to tidal variation, intense rainfall and storm surges associated with tropical cyclones.

The Wheatstone Project comprises the construction of a Plant Pad, Shared Infrastructure Corridor and Accommodation Village. The Plant Pad will form an elevated platform constructed to approximately 7.5 m AHD. Within the footprint of the Plant Pad may be a dredge material placement area and runoff interception system. Both the Shared Infrastructure Corridor and Accommodation Village would be constructed on elevated platforms. Construction of the elevated platforms would be engineered using borrow material. Figure 1-2 shows the proposed Ashburton North Project Area. Borrow material for construction of the elevated platforms is proposed to be sourced from selected islands within and foreshore areas of the Hooley Creek Catchment. The selected islands and foreshore areas occur within tidal flats, mud flats and salt flats at Ashburton North.

1.3.1 Pad Construction

The proposed Plant Pad is located on the catchment boundary between the Southwest and Hooley Creek Catchments and has a finished elevation of approximately 7.5 m AHD. All Plant Pad permanent structures would be set above the 1:100-Year Average Return Interval (ARI) flood elevation.

Onshore Dredge Material Placement

The Wheatstone Project may include the onshore emplacement of dredge material. Under this option, dredge material would be transported hydraulically through a pipeline and placed into a dedicated placement Area forming the western portion of the Plant Pad. Alternative to the onshore emplacement would be disposal of all dredge material into offshore domains.

The dredge material handling and placement is described as follows:

- During an 18th month near-shore cutter suction dredging programme seawater slurry would drain into a discrete placement area where dredge material solids settle. A decant would intercept and divert the return supernatant seawater and suspended fines into a sump, with subsequent disposal.
- Dredge productivity is likely to be approximately 200,000 m^3/week of dredge material transported in 1,000,000 m^3/week of seawater. The ratio of dredge material solids to seawater is approximately 1:5.
- The capacity of the dredge material placement area is estimated to be approximately 12 Mm^3.
- The total volume of dredge material solids to be placed is estimated to be approximately 10 Mm^3.
- Perimeter embankments for the placement area would be constructed along the northern, southern and western boundaries to a crest elevation of approximately 6.5 m AHD, with 1 in 5 slopes and 20% compaction.
- During the dredge program decanted seawater would be disposed to a marine outfall in front of the Plant Pad.

Plant Pad Runoff Interception

The construction of storm water collection drains, sedimentation ponds and outfall structures would occur during the site clearing to ensure that they are in-place as soon as practicable during earthworks activities. The sedimentation pond designs would use a 1:10-year ARI, 6-hour rainfall event, which has an average rainfall of 18 mm/hour. The storm drainage criterion is based on a 1:25-year ARI with one-hour rainfall intensity of 80 mm. Surface area and displacement volume are determined by the expected flow and the settling velocity of the particle size to be captured. The volume will consist of a settling zone and a storage zone. The sedimentation ponds would collect and hold runoff to allow suspended sediment to settle out. The ponds would be designed with a principal pipe spillway to handle peak flow and an emergency spillway to convey large floods safely past sediment basins. After completion of construction, the sedimentation ponds may be filled and graded to natural contours, leaving only the drainage path.

No wastewater streams would be routed to sedimentation ponds.

1.3.2 Shared Infrastructure Corridor

The proposed finished elevation for the Shared Infrastructure Corridor from the existing Onslow Road, via the Accommodation Village to the Plant Pad is minimum 4.5 m AHD, with culverts designed to limit the retardation of surface water flows. The Shared Infrastructure Corridor may be temporarily submerged during rainfall runoff events that are less frequent than a 1:100-year ARI.

The proposed alignment of the Shared Infrastructure Corridor intersects several watercourses in the Hooley Creek Catchment. These watercourses shed local runoff from the Hooley Creek Catchment and periodically flood waters from the Ashburton River after significant rainfall events.

Design elements for the Shared Infrastructure Corridor include:

- Elevation of road at drainage line crossings is minimum 4.5 m AHD.
- Elevations of the road are intended to not overtop in a 1:100-year ARI event.
- Road cover above culvert structures is approximately 0.5 m. The minimum elevation of the top of the culverts is therefore 4.0 m AHD.
- Culvert structures designed for a 1:25-year ARI rainfall event.
- Culvert width would be determined by the width of the drainage channel at the location of the crossing, maximising flow-through rather than being limited by the design discharge associated with a 1:25-year ARI rainfall event.

1.3.3 Accommodation Village

The Accommodation Village is approximately 9 km inland. The proposed finished elevation of the village is approximately 6 m AHD, predominantly above the 1:100-year ARI flood elevation.

1.4 Objectives of the Study

The objectives of this study include:

- Assess the surface water hydrology of the existing environment.
- Develop a hydrological model that simulates the baseline surface water environment.
- Identify potential impacts of the proposed Wheatstone Project on the surface water environment. The impact assessments are predominantly inclusive of the option of onshore emplacement of dredge material. This option provides the largest onshore footprint and consequently presents the worst case for surface water impacts assessments.

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Background

2.1 Physiography

Ashburton North is located on the Onslow coast, near the mouth of Hooley Creek and approximately 8 km east of the mouth of the Ashburton River. An alluvial and aeolian depositional landscape comprises unconsolidated, undulating sand plains, clay pans and incised watercourses together with occasional north to south trending dunes. Locally, the topography is characterised by a series of low dunes and between the dunes are tidal and supratidal flats. The vegetation is predominantly open to dense shrub land and spinifex grassland. Occasional trees, including large Eucalypts, occur along local reaches of the nearby Ashburton River. Land use is mainly pastoral with the exception of the Onslow Salt Project, which is located approximately 4 km east of the Wheatstone Project.

2.2 Climate

The Pilbara coast climate is arid-tropical, with influences of both tropical maritime air from the Indian Ocean and continental air from the interior. The climate can be generalised into summer (October through April) and winter (May through September) patterns. Table 2-1 and Chart 2-1 provide a summary of rainfall, evaporation and temperature data from Onslow Airport. These data are sourced from the Bureau of Meteorology (BoM). Summer patterns are characterised by hot daytime temperatures, often between November and February exceeding 40^{o}C, and widely variable rainfall. Winter patterns are characterised by low rainfall and moderate temperatures (average daytime 25^{o}C). Coastal temperatures in both seasons tend to be moderated by the influence of onshore sea breezes.

Table 2-1 Average Monthly Climate Statistics (BoM, 2009)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Onslow Airport (Station No. 005017; 1940 to 2008)													
Mean Rainfall (mm)	34.5	60.3	77.8	13.0	54.9	45.5	20.3	9.9	1.3	0.9	3.1	3.0	321.9
Mean Number of Rain Days	0	2.6	2.3	1	2.6	2.3	1.6	1	0.3	0.1	0.3	0.3	16.4
Mean Monthly Pan Evaporation (mm)	351.7	292.3	295.3	232.5	172.1	134.4	145.3	180.7	247.5	319.3	341.3	369.9	3,082.3
Decile 1 Maximum Temperature (°C)	31.4	31.8	31.7	30.0	25.2	22.8	22.4	24.0	26.5	28.0	29.1	30.9	
Decile 9 Maximum Temperature (°C)	42.3	41.6	40.6	37.8	32.9	29.0	28.0	30.2	33.8	37.6	39.8	41.3	
Decile 1 Minimum Temperature (°C)	21.2	22.1	21.1	18.0	13.5	10.2	9.0	10.1	12.4	14.9	17.2	19.2	
Decile 9 Minimum Temperature (°C)	27.0	27.4	27.0	24.3	21.0	18.2	17.0	16.7	18.0	20.6	22.9	25.2	
Port Hedland Airport (Station No. 004032; 1967 to 2008)													
Mean Monthly Pan Evaporation (mm)	325.5	268.8	288.3	261	229.4	195	204.6	232.5	267	328.6	342	353.4	3,296.1

The average annual rainfall ranges from 230 to 350 mm and mainly occurs during January through April, linked to cyclonic activity. Rainfall patterns vary widely due to the influence of tropical cyclones.

2 Background

Rainfall may also be irregular and localised due to thunderstorm activity. Typically, rainfall intensity is highest near the coast and decreases inland.

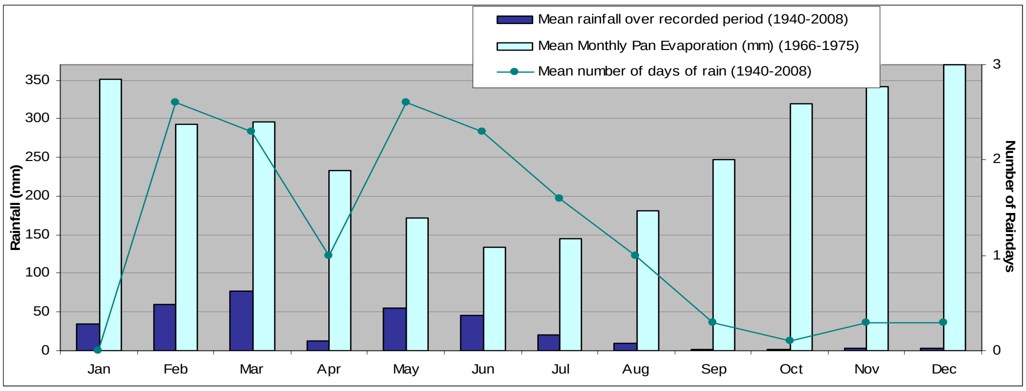

Chart 2-1 Rainfall, Number of Rain Days and Evaporation at Onslow Airport (BoM, 2009)

Evaporation rates average about 3100 mm/year, measured at Onslow Airport over a nine-year evaporation record from 1966 to 1975. The closest station with long-term (41 years) recorded evaporation rates is at Port Hedland, about 400 km northeast along the coast. Data from Port Hedland have been added to Table 2-1 to provide a comparison to the record for Onslow. Evaporation rates are strongly seasonal with average long-term mean monthly pan evaporation rates of 370 mm in December and 135 mm in June.

2.2.1 Tropical Cyclones

Onslow is located on a cyclone-prone part of the Australia coast (BoM 2009). The tracks of cyclones which have historically affected Onslow are displayed on Figure 2-1. Since 1910 a cyclone with wind gusts over 90 km/hr has on average impacted Onslow about once every two years (BoM 2009). The most severe tropical cyclones impacting upon Onslow include Trixie, in 1975, and Vance, in 1999 (Figures 2-1 and 2-2).

Originally, Onslow (now referred to as Old Onslow) was established near the mouth of the Ashburton River. The settlement was relocated east to the banks of Beadon Creek in 1925 because of changes in the channel of the Ashburton River, predominantly attributed to flooding during tropical cyclones (BoM 2008).

2.2.2 Climate Change

Rainfall

BoM rainfall records for Onslow have been analysed to determine long-term rainfall trends. Chart 2-2 displays annual rainfall, mean rainfall and 10-year and 30-year moving-average rainfall. The 10-year and 30-year moving averages have an upward trend, indicating a gradual increase in annual rainfall. This trend may indicate potential increases in annual rainfall in the future.

2 Background

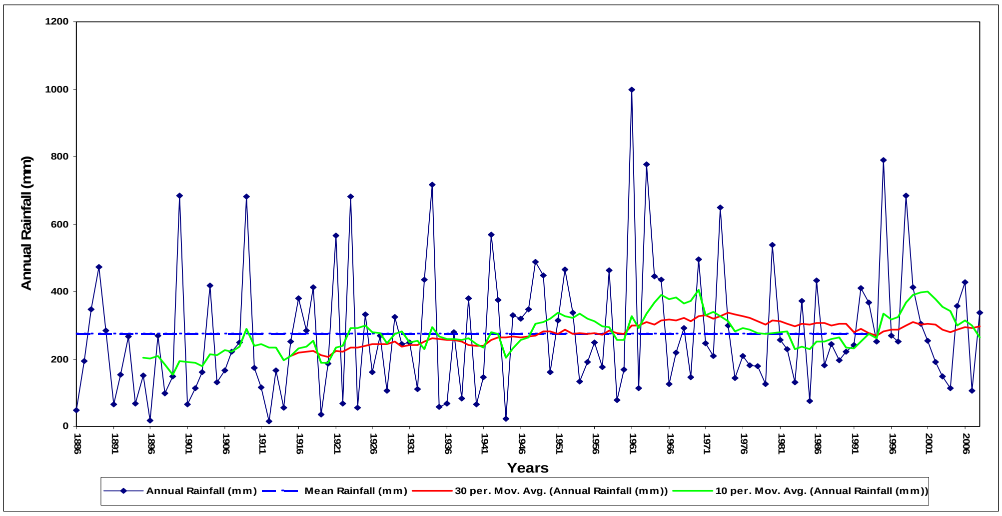

Chart 2-2 Annual and Mean Rainfall at Onslow (BoM Station 005017; 1886 to 2008)

Notwithstanding the annual rainfall trends at Onslow, Climate Change in Australia (2007) estimate the Pilbara will experience a decrease in annual rainfall of between 2 and 5% by 2030. Climate Change in Australia (2007) also estimate that changes in rainfall patterns will result in an increase in both rainfall intensity (rain per rain-day) and number of dry days in the future. As such, Ashburton North may experience longer dry spells interspersed by heavier rainfall events.

Cyclones

There is evidence from interpreted data and predictive models that cyclonic activity is changing as a result of global warming (BoM 2008). Analyses of cyclone data (Qi *et al.* 2008) suggest cyclone frequency over Western Australia has increased from 1905 to 2004 (Chart 2-3). Although data before the 1970's may be of lower reliability than that recently available from satellites, these analyses indicate that the frequency of cyclones may increase in the future.

Contrary to the findings by Qi et al (2008), a number of studies focussed on regional changes in cyclonic patterns suggest a future reduction in the occurrence of cyclones in Western Australia. An increase in the severity of cyclones is predicted, however, with the number of severe category systems escalating (Climate Change in Australia, 2007).

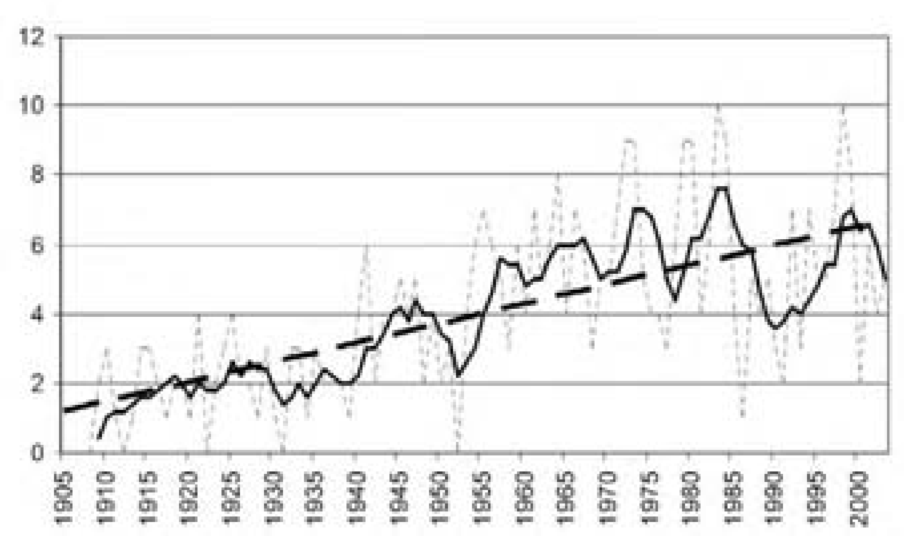

Chart 2-3 Annual Number of Cyclones in WA, Trend Line and 5-Year Moving Average (1905 to 2004, Qi et al, 2008)

Evaporation

CSIRO have estimated that temperatures in Australia are likely to increase by up to 1°C by 2030 and between 2°C to 5°C by 2070 (compared to 1980 to 1991 temperature records). It is anticipated that evaporation rates would increase as a result, although the likely effect is difficult to quantify. Increases in evaporation rates may be offset by increases in rainfall intensity.

2.3 Geology

Ashburton North is located on the Peedamullah Shelf within the Northern Carnarvon Basin. Major structural elements of the Peedamullah Shelf appear to control the thickness of sediments. Superficial successions of unconsolidated Quaternary alluvial and colluvial sediments of the Ashburton River Delta dominate the landscape. Superimposed on the superficial successions are intertidal flats and mangrove swamps, beaches, supratidal mudflats, coastal dunes and residual sand plains. The coastal dunes attain heights of 3 to 9 m and are typically underlain by coastal limestone that has irregular outcrop expression both on the local beach at Ashburton North and above the inter-tidal zone.

The local superficial formations stratigraphic profile is about 30 m in thickness and predominantly comprises silty and clayey alluvium. Underlying the superficial formations is Tertiary limestone and sandstone (Trealla Limestone); with thickness variable up to about 60 m. Beneath Trealla Limestone is a thick Cretaceous succession of the Gearle Siltstone.

2.4 Geomorphology

Semeniuk (1993) characterised the Pilbara coast as “a riverine coastal plain in a tropical arid setting”. Locally, Onslow coast is situated on the western end of the Pilbara coast and is part of the Northern Carnarvon Basin The hinterland of the Onslow coast, is low-lying with substantial domains of high tidal mud flats and supra-tidal salt flats. The Onslow Coast is a highly dynamic coastline that is characterised by an exposed, sandy shore with both constructional and erosional processes ongoing.

At a regional scale Ashburton North is located in a primary coastal geomorphology compartment (the Ashburton Compartment) extending from Tubridgi Point to Cape Preston (Damara 2009). It is a single sediment cell extending over 70 km. The net sediment movement within the Ashburton Compartment is easterly. The major transport path in the cell is along the shore at the beach face, with much of the material being supplied as littoral drift along spits fed from the Ashburton River. Sediment sinks include chenier spits, coastal dunes, inshore shoals and mudflats by tidal creeks (Damara 2009). Major sources of sediment in the Ashburton Compartment include:

- Erosion of salt flats 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 near-shore processes.
- Bio-production and reworking of material from the inner continental shelf.

At a finer scale, tidal creeks play a role in exchanging sediment between the terrestrial and marine environments. Inundation of the tidal creeks by runoff during floods reinforces ebb currents and may contribute to erosional scour of these watercourses as water levels fall after peak flows. In places where the flood-tide flows are dominant, the tidal creeks may deposit silty sands and mud on the mudflats.

Within the Ashburton Compartment, there are numerous landforms, including:

- Sandy beaches.
- Sand bars and shoals at the mouth of tidal creeks.
- Rocky shores.
- Mangroves.
- Lagoon flats and a large high tidal mudflat unit (i.e. mudflat areas located further landward of the mangrove fringed tidal creeks) which host bioturbated mudflats with samphire communities, algal mats and supratidal salt flats.

The frequency of tidal inundation across the intertidal zone is an important factor that influences the distribution of landforms.

In the vicinity of Ashburton North, a geomorphic classification of coastal habitats published by Semeniuk (1986) has been used to define three coastal geomorphic units:

- Onslow Coastal Tract.
- Ashburton River Delta.
- Hooley Creek – Four Mile Creek Tidal Embayment.

2 Background

Structure and distribution of intertidal habitats are predominantly controlled by the pre-existing geomorphology and underlying geology. Locally, the topography is characterised by a series of low dunes and between the dunes are tidal and supratidal flats. The aeolian and alluvial depositional landscape comprises north to south trending dunes, unconsolidated and undulating sand plains, clay pans and incised watercourses. The simplified coastal geomorphology is shown on Figure 2-3.

The Onslow Coastal Tract occurs between Tubridgi Point and Coolgra Point, forming an extensive system of sandy beaches backed by coastal dune systems, limestone barriers and tidal flats. Sandy beach and dune systems are interrupted only by the Ashburton River Delta and tidal entrances for the Hooley, Eastern and Four Mile Creeks (Figure 1-2). The tidal creeks breach gaps in the dune barrier systems and form networks of narrow drainage channels that enable tidal flows to (and from) expansive tidal flat embayments extending several kilometres landward of the beach. Localised areas of sand bars and shoals are formed at the mouths of tidal creeks and the Ashburton River, where fine to medium grained sands have been deposited and re-worked into delta-shaped formations. For the most part, the sandy beaches are backed by steep, vegetated fore-dunes forming the beach/dune geomorphic unit that characterises the Onslow coast. Throughout the Onslow coast, modern mangrove and tidal flat deposits are superimposed upon a Holocene and/or Late Pleistocene, semi-consolidated shell bed pavement.

The Ashburton River Delta is an accretionary sedimentary feature occupying about 9 km of the coastline from the mouth of the Ashburton River. The delta is characterised by a complex system of spits, cheniers, tidal flats, channels and coastal dune barriers. Eastward littoral transport has focussed depositional activity on the eastern delta, immediately adjacent to Ashburton North. A series of parallel sand deposits are separated by elongate lagoons which host subtidal, intertidal mangrove and mudflat deposits. The Ashburton River Delta supports 526 ha of mangroves and a diversity of mangrove assemblages. Landward of the mangrove zone, large areas of mudflats typically extend to the hinterland margin or merge with the supratidal salt flats. These mudflat areas occur in the upper sections of the intertidal zone and hence are not regularly inundated by tides. Two habitat types are recognised within the mudflats, these being bioturbated mudflats with samphire communities and algal mats.

The Hooley Creek – Four Mile Creek Tidal Embayment is broad tidal flat to the east of Ashburton North that includes narrow tidal creeks, with fringing mangroves, and extensive mudflats. It is drained to the sea by the west and east branches of Hooley Creek, Eastern Creek and Four Mile Creek. The distribution of habitats within the tidal embayment is a succession from tidal creek – mangroves – samphire and bioturbated high tidal mud flat – algal mat covered high tidal flat – salt flat – hinterland margin at the toe of the dunes. Mangroves occur at the river mouth and along the reaches of tidal creeks, forming a nearly continuous ribbon of fringing vegetation. At Hooley Creek, Eastern Creek and Four Mile Creek, mangroves are confined to a 10 to 20 m fringe adjacent to the creek channel.

2.5 Catchments

Ashburton North is located in the Ashburton River Catchment (Figure 2-4). The Ashburton River is one of the major rivers of the Pilbara and is ephemeral, flowing in response to significant local and regional rainfall events. Higher runoff potentials occur in the upper reaches of the catchment due to greater topographic relief. Downstream on the coastal plain, the Ashburton River fans out into a deltaic system, made up of wide and braided flow paths, before discharging into the Indian Ocean. The delta contains tidal creeks and pools, which are frequently inundated by the sea in the lower reaches. Major flows occur in the Ashburton River every one to three years. River flows predominantly occur during the cyclone season.

At a local scale (Figure 2-5), Ashburton North is located within the Ashburton River Delta, the near-coastal expression of the Ashburton River Catchment (Figures 2-4 and 2-5). The catchment area of the Ashburton River Delta comprises the Ashburton River Mouth, Southwest, Hooley Creek and Northeast Catchments. The proposed Plant Pad at Ashburton North is located on the catchment divide between the Southwest and Hooley Creek Catchments. Infrastructure associated with the Project would impose on both of these catchments. The Shared Infrastructure Corridor and the Accommodation Village are located in the Hooley Creek Catchment inland of the tidal zone, but the alignment of the Shared Infrastructure Corridor crosses a number of drainage lines within the catchment.

Three main components influence the hydrological characteristics of the Ashburton River Delta:

- Flooding of the Ashburton River.
- Localised rainfall events.
- Tidal inundation by seawater.

Catchment divides, between the Ashburton River Mouth, Southwest Catchment and Hooley Creek Catchment are of low topographical relief (Figure 2-6). During larger flood events (typically less frequent than 2-year ARI), stream flow from the Ashburton River spills from the main channels in the Ashburton River Mouth Catchment into the adjoining Southwest and Hooley Creek Catchments, forming a broad flood plain. As such, the Ashburton River affects flood levels and stream flows in both the Southwest and Hooley Creek Catchments.

At ARIs of less than two years, the local catchments function independently, with surface water flow directions linked with topography (Figure 2-6). A snap-shot of the effects of local flooding is provided by the rainfall events of early-2009; in particular the 1:2-year ARI event of 28 January. The flood impacts of this event are shown (Figure 2-7) to be widespread across both the Southwest and Hooley Creek Catchments, but not propagating across the local catchment divides.

2.6 Tides

2.6.1 Tidal Influence

Onslow is one of the national standard port tidal references (Station 62470), with a tide gauge located on Beadon Creek and, maintained by the WA Department of Transport. Along the Onslow coast, a mesotidal setting is characterised by mixed, mainly semi-diurnal tides, with a spring tide range of 1.9 m. Tidal variations have been recorded between 1.68 m AHD (Highest Recorded Tide, HRT) and -1.99 m AHD (Lowest Recorded Tide, LRT), with a mean sea level of 0.06 m AHD (DPI, 2004). Highest Astronomical Tide (HAT) is 1.55 m AHD and Lowest Astronomical Tide (LAT) is -1.42 m AHD. The tidal record associated with the Highest Recorded Tide on 8th of March 2000 was sourced from the Department of Transport Spatial Information Branch of the Operations Division. Table 2-2 summarises the local tidal ranges from Australian 'National Tide Tables' 2009.

Table 2-2 Summary of Tidal Planes

Tidal Plane	Elevation (m AHD)
Highest Astronomic Tide	+1.5 m AHD
Mean High Water Springs	+1.0 m AHD
Mean High Water Neaps	+0.3 m AHD
Mean Sea Level	0.0 m AHD
Mean Low Water Neaps	-0.3 m AHD
Mean Low Water Springs	-0.9 m AHD
Lowest Astronomic Tide	-1.5 m AHD

Processes affecting the coast near Onslow include tides, cyclonic surges and seasonal ranging and inter-annual mean sea level variations (National Tidal Facility 2004). The tidal forcing contains a range of cycles, including the semi-diurnal ranging, the monthly spring-neap cycle, a bi-annual cycle due to movement of the solar equator and a 4.4 year cycle developed from lunar elliptic motion (Damara 2009).

The seasonal variations of tides, surges and mean sea level are generally not in phase, namely:

- Tidal peaks occur near the equinoxes in March and September.
- Surge peaks mainly occur in January to March due to tropical cyclones, and from June to August due to mid-latitude systems.
- The seasonal mean sea level peaks during April.

This seasonal variation provides opportunity for comparatively high seawater level events (>1.0 m AHD) over the majority of the year. The relative timing of the tidal and sea level peaks provides increased potential for high seawater level events to occur as a result of late-season tropical cyclones, in March or April (Damara 2009).

Landforms at Ashburton North are influenced by tidal forces. Tidal fluctuations affect expressions of inundation in the lower reaches of the Ashburton River Mouth, Southwest and Hooley Creek Catchments. Downstream reaches of the Ashburton River and Hooley Creek are daily and temporally inundated by seawater. Figure 2-8 shows areas inundated by mean sea level. Figure 2-9 illustrates the influence of Highest Recorded Tide on the local landforms.

2.6.2 Storm Surge

Storm surge is a complex function of cyclone intensity and motion, extent of maximum winds, bathymetry and coastline shape. The worst-case storm surge occurs when a severe cyclone passes near the coast concurrent with a high tide. The associated seawater level, called the storm tide, is a combination of the storm surge and tidal variation. The storm tide may rise above the HAT; a 1:25-year ARI storm tide exceeds the inundation caused by the HAT.

The Onslow coast has been periodically inundated in the past by storm surge, particularly during the cyclones of 1934, 1958, 1961 and in 1999 (BoM 2009b). Cyclone Vance caused one of the largest recorded storm surges (+3.7 m AHD) on the Onslow coast (Global Environmental Modelling Systems [GEMS] 2000), which was in the order of a 1:45 to 1:50-year ARI event. This storm surge inundated much of the coast and caused widespread erosion (BoM 2009).

A study for the Shire of Ashburton at Onslow (GEMS, 2000) quantified storm surge risk. The 1:100-year ARI storm surge was estimated to be 4.7 m AHD in the vicinity of the Ashburton River mouth.

2.7 Water Table Settings

Water table settings from site investigations are shallow at Ashburton North. Beneath the coastal dunes and residual sand plains terrain, the depths to the water table typically range from 1 to 5 m. Elsewhere, beneath supratidal mudflats, intertidal flats, mangrove swamps and beaches, the water table occurs at depths typically less than 1 m. In depressions within the Southwest Catchment, the water table may be expressed on the ground surface for extended periods of time, reflecting localised groundwater discharge zones.

The water table elevations beneath the dunal terrain reflect the land surface topography, with discharge into the local Southwest and Hooley Creek Catchments and along the coast. Within the alluvial successions, groundwater discharges into the supratidal mudflats, intertidal flats, mangrove habitats and to the ocean.

Data from site investigations at Ashburton North indicate the shallow groundwater in the coastal dunes and alluvial successions is typically brackish to hypersaline, with Electrical Conductivity (EC) in the range 8.5 to 187.6 mS/cm @ 25 ^{0}C and Total Dissolved Solids (TDS) from about 5,800 to 188,000 mg/L. These data indicate the saturated profile is vertically salinity stratified, with lower salinity in the shallow water table zone beneath the dunal terrain linked to local rainfall infiltration.

Further information on the groundwater at Ashburton North is contained in the Groundwater Studies report, (URS 2010).

2.8 Receptors

Potential surface water receptors at Ashburton North include river ecosystems and mangrove habitats.

The salinities in mangrove and mud flats areas are linked closely to the relative influence of tidal inundation (as determined by tidal elevation, groundwater discharge and episodic rainfall and runoff). A natural gradient of salinities occurs across the tidal flat in response to differences in tidal inundation patterns (Semeniuk 1983). Salinity data on the Pilbara coast show that a gradient of increasing salinities exists from the seaward or tidal creek fringing mangrove zone through to the more landward mangrove zones and then out across high tidal mud flats and samphire zones. Salinity gradients are altered during flood events when the coastal areas are inundated with fresh runoff. Typically, the runoff carries sediment and nutrients.

Botanical surveys (Biota 2010 a, b and c and Bamford 2009) at Ashburton North have not identified ecosystems that are predominantly dependent on surface water flows.

3

Site Investigation

A site investigation was conducted from 20th April to 5th May 2009 to ratify topographic concepts and assumptions used in the Ashburton River and Ashburton North hydrological assessments. Several photographs were taken during the site investigation to provide a general impression of the surface water characteristics of Ashburton North. The sites of selected photographs are shown on Figure 3-1 together with the direction of the view. Selected photographs (Plates 1 to 10) are shown on Figures 3-2 to 3-5, inclusive.

3.1 Drainage and Surface Water Flows

During the site investigation the inland propagation of a spring tide was observed. It was found that the Hooley Creek Catchment was extensively inundated by the spring tide (Plate 1, Figure 3-2). The Southwest Catchment was not inundated by the spring tide, but (Plate 2, Figure 3-2) contained remnant pools from earlier rainfall events. As such, the Southwest Catchment may become flooded in response to rainfall but may not be inundated by normal tides.

Hooley Creek (West Branch) was examined both on an ebbing tide (Plates 3 and 5, Figure 3-3) at 1:30 pm on April the 22nd 2009 and a flooding spring tide (Plates 4 and 6, Figure 3-3) occurring at 11:25 am on the 25th of April 2009. Portions of the low-lying areas of Hooley Creek West were observed to be inundated by the spring tide. On downstream reaches, Hooley Creek West has a deeper main channel easily visible during an ebbing or low tides (Plates 3 and 5, Figure 3-3). This channel, together with three other tidal creeks (Hooley Creek East, Eastern Creek and Four Mile Creek), are the main outlets for the Hooley Creek Catchment. The floodplain of the Hooley Creek Catchment is wide and flat and extends approximately 5 km upstream from the ocean, forming a large tidal pool which is open to inundation from the sea.

The Ashburton River has a wide flat profile, with steep, high banks on its lower reaches (Plate 7, Figure 3-4). The river becomes wider and shallower closer to the mouth (Plate 8, Figure 3-4).

The existing roads and tracks to Ashburton North are unsealed and cross several tributaries of the Ashburton River, upstream of the Hooley Creek Catchment. Large culverts are located at several of these crossings. At the time of the site investigation, several locations along the road were damaged by flood waters from recent (January 2009) rainfall events during which the road was evidently overtopped by stream flows (Plate 9, Figure 3-5). At one crossing, the culvert had been dislodged (Plate 10, Figure 3-5), presumably during the recent flow events. Local roads and tracks were closed (Shire of Ashburton 2009) for almost two months from the 27th January to 20th March 2009 due to local rainfall. Communication with the Ashburton Shire indicates road closures occur regularly after significant local rainfall events.

3.2 Surface Water Quality

Surface water samples were taken on an opportunistic basis to develop a basic understanding of baseline surface water quality at selected locations (Table 3-1 and Figure 3-6). Water quality information from a separate study on clay pan fauna (Biota 2009) has also been used as a supplement to further develop this understanding of surface water quality.

3 Site Investigation

Table 3-1 Opportunistic Surface Water Quality Sample Locations

Date	Site Description	Coordinates		Water Quality Parameters
		Easting (m E)	Northing (m N)	
13/6/09	Salt pan on side of main highway	295022	7600697	EC, TDS, pH, major ions
14/6/09	West of main track	295289	7600440	EC, TDS, pH, major ions
21/6/09	Hooley Creek tidal zone	292864	7599255	EC, TDS, pH, major ions
18/2/10	Hooley Creek, western branch, tidal zone	294612	7599672	EC, TDS, pH, major ions, temperature, dissolved oxygen, turbidity
20/2/10	Ashburton Delta Mangrove	290500	7599491	EC, TDS, pH, major ions, temperature, dissolved oxygen, turbidity
21/2/10	Upper Hooley Creek Catchment, SE end of Shared Infrastructure Corridor	300899	7590582	EC, TDS, pH, major ions, temperature, dissolved oxygen, turbidity
14/2/09	Clay pan - CWP01	304505	7587310	EC, TDS, pH, temperature, dissolved oxygen, turbidity
10/3/09				
6/4/09				
14/2/09	Clay pan - CWP02	303667	7587774	EC, TDS, pH, temperature, dissolved oxygen, turbidity
10/3/09				
6/4/09				
10/3/09	Clay pan - CWP07	304348	7587203	EC, TDS, pH, temperature, dissolved oxygen, turbidity
10/3/09	Clay pan - CWP08	304220	7587164	EC, TDS, pH, temperature, dissolved oxygen, turbidity
10/3/09	Clay pan - CWP11	297891	7590302	EC, TDS, pH, temperature, dissolved oxygen, turbidity
10/3/09	Clay pan - CWP12	297819	7590294	EC, TDS, pH, temperature, dissolved oxygen, turbidity
10/3/09	Clay pan - CWP13	290500	7599014	EC, TDS, pH, temperature, dissolved oxygen, turbidity
10/3/09	Clay pan - CWP14	290420	7598961	EC, TDS, pH, temperature, dissolved oxygen, turbidity
6/4/09				
10/3/09	Clay pan - CWP16	291006	7595257	EC, TDS, pH, temperature, dissolved oxygen, turbidity
6/4/09	Clay pan - CWP21	298678	7590905	EC, TDS, pH, temperature, dissolved oxygen, turbidity

4

Baseline Surface Water Assessment

4.1 Hydrology and Drainage

4.1.1 Ashburton River Catchment

The Ashburton River Catchment is characterised by:

- A large area.
- Ephemeral flows (recorded discharge varies between nil and greater than 11,000 m^3/s; Department of Water (DoW), Nanutarra Bridge).
- Climatic conditions which are characterized by long dry periods and high intensity rainfall events, which generate significant stream flows.
- The magnitude of stream flow is predominantly determined by the ARI and distribution (widespread and limited) of the rainfall events.

The Ashburton River Catchment is approximately 78,777 km^2 in area (Figure 2-3) with many smaller sub-catchments. Overland flow is channelled in the upstream reaches of the catchment, due to greater topographic relief. At the coast, the river discharges through a network of tributaries within the Ashburton River Delta. Rainfall distribution, occurrence and intensity are known to widely vary across the Ashburton River Catchment, due both to the size of the catchment and nature of the cyclonic rainfall events. There is a trend observed from rainfall records of decreasing rainfall intensity further from the coast; reducing from hundreds of millimetres at the coast to tens of millimetres further inland.

Historical Flows and Flood Events

Flow in the lower reaches of the Ashburton River (Chart 4-1) has been monitored since 1972 at Nanutarra Bridge, approximately 100 km inland from the river mouth. The annual flow volumes in the Ashburton River are widely variable, being known to range from 3 GL in 2007 to 4,500 GL in 1997.

The largest flood event on record occurred in January 1997, produced when a rainfall total of 477 mm was recorded in 24 hours, with 415 mm being recorded within 5 hours in the Onslow area (Leighton & Mitchell 1997).

In mid-February 2009, Cyclone Dominic crossed the Pilbara coast about 12 km east of Onslow (BoM 2009). The cyclone deposited 276 mm of rainfall in 24 hours at Onslow; Onslow Airport recorded the wettest February day on record (BoM 2009). This rainfall event resulted in flows of the Ashburton River and localised flooding of roads. The cyclone quickly weakened after crossing the coast and intense rainfall was not observed at inland rainfall gauges, such as Paraburdoo.

The maximum flow rates on the Ashburton River (Chart 4-2) were obtained for every year using the annual maximum stream flow values

The flow event in February 2009, due to Cyclone Dominic, recorded a peak flow at the Nanutarra Bridge of 411 m^3/s. This flow event has an ARI of less than 2 years.

4 Baseline Surface Water Assessment

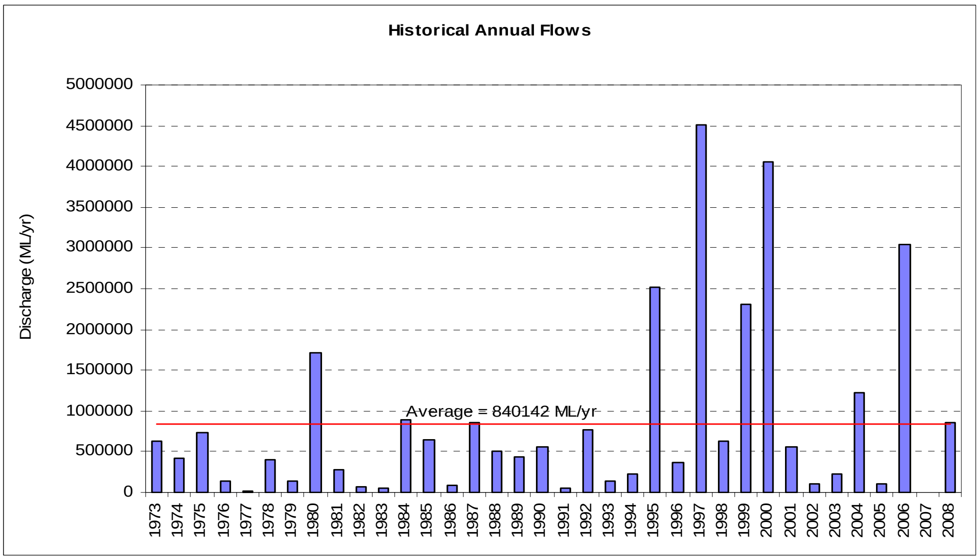

Chart 4-1 **Ashburton River Annual Flow Volumes (Nanutarra Bridge, 1973 to 2008)**

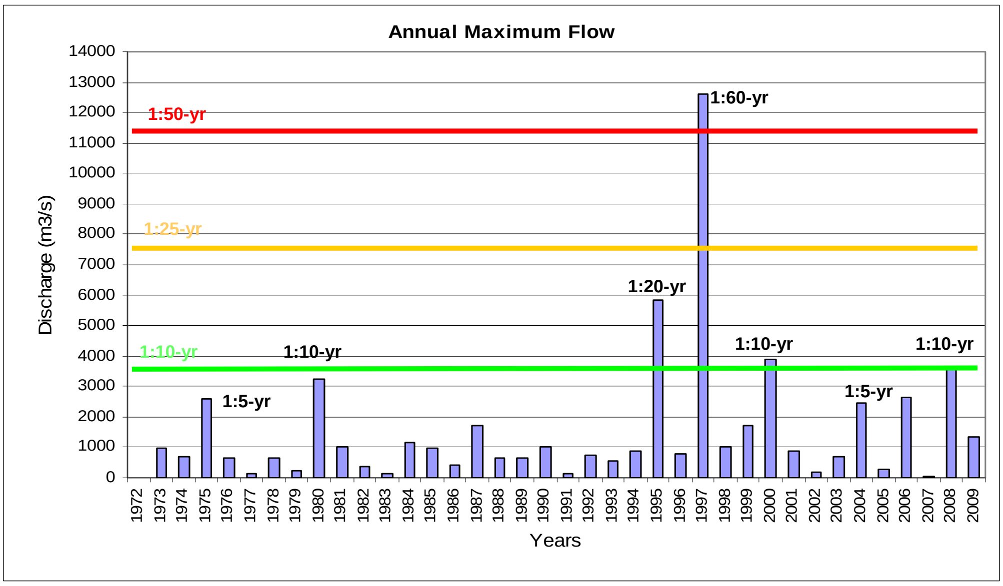

Chart 4-2 **Ashburton River Annual Maximum Flow Rates (Nanutarra Bridge, 1973 to 2008)**

4.1.2 Ashburton River Delta Catchment

The Ashburton River Delta is characterised by:

- A small catchment area relative to the overall Ashburton River Catchment.
- Ephemeral runoff is not measured but estimated to vary dependent on local and regional rainfall.
- Four sub-catchments, identified as Ashburton River Mouth, Southwest, Hooley Creek and Northeast Catchments (Figure 2-5).
- Four main watercourses (Hooley Creek West, Hooley Creek East, Eastern Creek and Four Mile Creek) discharging into the ocean.

The Ashburton River Delta Catchment is 190 km^2 in area within near-coastal settings of the Ashburton River (Figure 2-4). The predominant watercourse that influences the hydrology of the Ashburton River Delta is the Ashburton River. There are also numerous local small-scale watercourses that influence the hydrological characteristics of the Ashburton River Delta during flood events.

Under seasonal-dry conditions the sub-catchments of the Ashburton River Delta are discrete and surface water environments are independent. During and after significant cyclonic rainfall events, stream flows swell above the low-relief catchment divides and connect the individual catchments to form a coastal flood plain. Under such conditions the stream flow from the Ashburton River extends throughout the entire delta, contributing to flows within the Southwest, Hooley Creek and Northwest Catchments. At these times, flood heights in the local catchments rise significantly above those generated by the local catchment runoff.

The Ashburton River Delta Catchment is dynamic, with historical evidence indicating changes to the location of the main flow path of the Ashburton River through the delta and the river mouth. The most recent change occurred in 1921 when the main flow path shifted about seven kilometres west of its previous position (Damara, 2009). Such changes are caused by significant flood events that cause the deposition of large quantities of sediment. Deposition of sediment in the low-relief delta, consequent increase in flow path elevation and subsequent shallowing of channel slope causes stream flows to find an alternative path to the ocean.

Ashburton River Mouth Catchment

The Ashburton River Mouth Catchment is the area immediately surrounding the mouth of the Ashburton River (Figure 2-5). The Ashburton River flows in close proximity to both the Southwest and Hooley Creek Catchment boundaries. When the Ashburton River is in flood it breaks its banks, with flow spilling over both banks. Flood waters spilling over the east bank flows into the Southwest and Hooley Creek Catchments.

Southwest Catchment

The Southwest Catchment has several drainage lines that when in flood, flow into the adjacent Ashburton River Mouth and Hooley Creek Catchments.

Hooley Creek Catchment

The Hooley Creek Catchment consists of four main drainage lines, Hooley Creek West, Hooley Creek East, Eastern Creek and Four Mile Creek. Although Hooley Creek is identified as a discrete catchment, it has low relief and during flood events it is hydraulically connected to the Ashburton River and adjoining sub-catchments.

Northeast Catchment

The Northeast Catchment is located east of the Hooley Creek Catchment and drains directly into the ocean. The area is not strongly hydraulically connected to the Ashburton River and therefore receives flood waters from sub-catchments to the south during 25-year ARI or less frequent events. Runoff is also generated by local rainfall and water levels are influenced by tidal variation in the lower parts of the catchment.

4.2 Hydrological Models

Two methods were used to characterise the hydrology of the regional and local catchments of the Ashburton River: runoff routing and flood frequency analysis on the observed flows at Nanutarra Gauging Station (Nanutarra Bridge).

Runoff Routing

The hydrology of the Ashburton River Catchment and Ashburton River Delta was characterised in *xprafts* models to obtain hydrographs representing runoff contributing to stream flow. These hydrographs were used to generate flood maps for the Ashburton River Delta and Ashburton North for different potential rainfall ARIs and storm scenarios. The *xprafts* software is a runoff routing model, used extensively through Australia and the Asia Pacific Region. The model uses the Laurenson non-linear procedure to develop a sub-catchment hydrograph for either an actual event or design storm. The Muskingum-Cunge procedure is subsequently used to route hydrographs through channels or river reaches in order to provide realistic lagging of hydrographs.

Flood Frequency Analysis

A flood frequency analysis was undertaken to determine the frequency of flood flows recorded on the Ashburton River at Nanutarra Bridge. Such an analysis uses statistical methods to determine the likely recurrence interval of river flow events.

There are several flood frequency analysis techniques that could be used for this analysis. The flood frequency analysis method adopted is based on the recommendations from the proposed revision to Book 4 of Australian Rainfall and Runoff (ARR 2001). Therefore, the Generalised Extreme Value (GEV) theoretical probability distribution has been applied.

The analysis was also conducted using the Log Person III distribution. This was previously highlighted as the correct procedure to use in ARR for flood frequency analysis but recent research suggests that the GEV procedure has improved robustness. The GEV methodology is expected to become the Australian standard.

4.2.2 Ashburton River Catchment

Flows on the Ashburton River were characterised using an *xprafts* model of the Ashburton River Catchment. The sub-division of the catchment (Figure 2-3) used by the DoW was adopted for this assessment. Characteristics of the individual sub-catchments were used to generate single output hydrographs upstream of the Ashburton River Delta. To define the hydrological characteristics of the catchment, significant rainfall events with a widespread distribution over the Ashburton River Catchment were used. Widespread rainfall would be recorded at both Onslow and Paraburdoo rain stations (BoM 2009), with corresponding flows recorded at Nanutarra Bridge (DoW 2009). .Two significant widespread rainfall events 22nd March 1999 and 3rd March 2004 recorded at both Onslow and Paraburdoo BoM rain stations, with corresponding flows recorded at Nanutarra Bridge, were used to define hydrological characteristics. The March 2004 event had an ARI of approximately 1:10 years. Several other significant rainfall events were neglected for calibration purposes because they did not occur widespread throughout the Ashburton River Catchment.

The modelling applied rainfall records from each event and compared the simulated hydrograph with that recorded at the Nanutarra Bridge. Adjustments to initial and continuing loss factors were made during the modelling to enable calibration. A comparison between the simulated and the gauged (March 2004) hydrograph is shown in Chart 4-3.

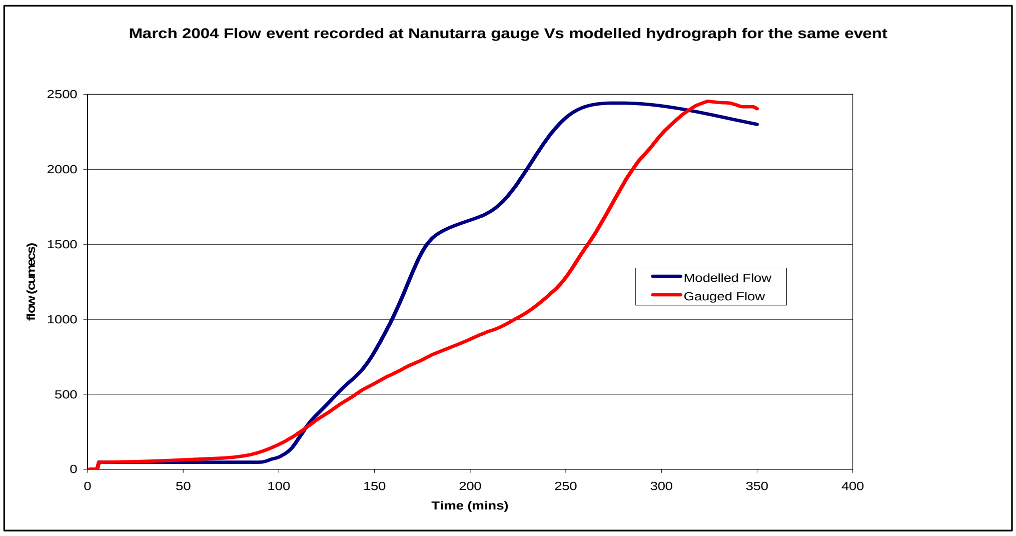

Chart 4-3 Comparison of Simulated and Gauged Flows, March 2004 at Nanutarra Bridge

Flood Frequency

The Nanutarra Bridge has 37 years (1972 to 2009) of flow record and gauges the majority of the Ashburton River Catchment. A complete annual maxima flow data set has been used in the flood frequency analysis. The flow record for 1972 was removed from the analysis as only 3 months of data was recorded during the dry season. An outlier analysis was conducted on the Nanutarra Bridge maxima data, with the highest flow recorded in 1997 being identified has a high outlier. This flow event has been included in the analysis as it is documented as caused by a slow-moving low pressure system that produced rainfall in excess of 400 mm within the Ashburton River Catchment. The DoW (2009) also highlights the Nanutarra Bridge flow record as being of a very good quality although assessment of the rating curve has not been undertaken. The result of GEV distribution with the 90 percent probability limits are shown in Chart 4-4.

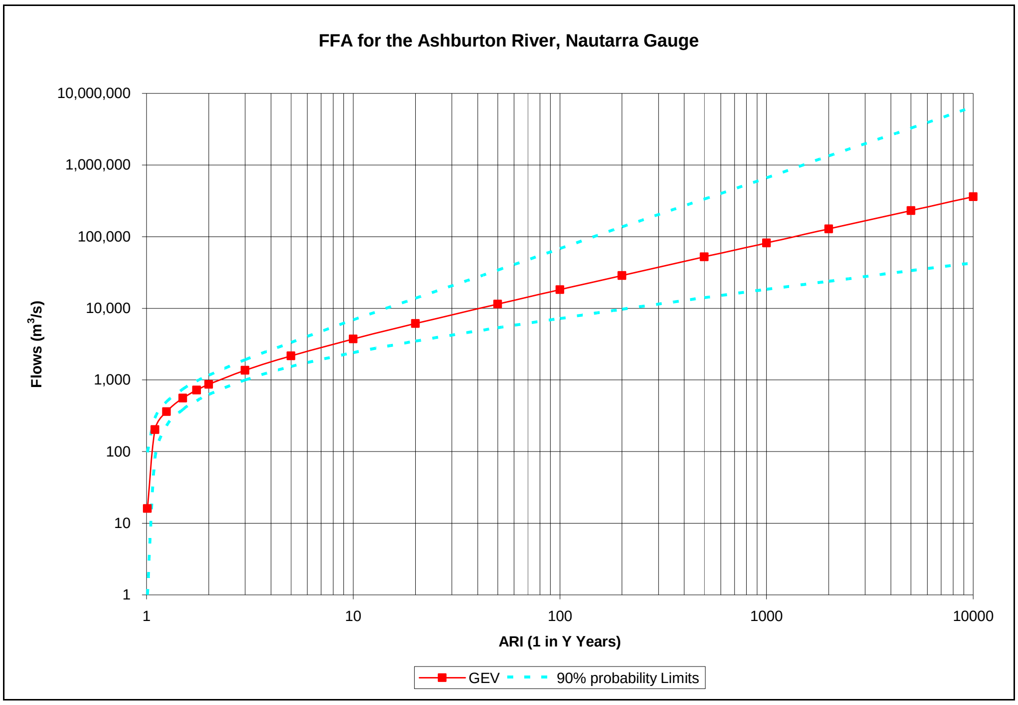

Chart 4-4 Ashburton River Flood Frequency Analysis, Nanutarra Bridge

The flows for various ARI events at Nanutarra Bridge, derived using the GEV distribution methodology are shown in Table 4-1.

Table 4-1 Estimated Peak Discharges for Varying ARI

ARI	Flows (m³/s)
2	868
5	2,168
10	3,730
20	6,134
50	11,469
100	18,187
200	28,679
500	52,118
1,000	81,721

Probable Maximum Flood

To understand the characteristics of a worst-case flood event, the Probable Maximum Flood (PMF) has been estimated for the Ashburton River Catchment and the Ashburton River Delta. PMF characteristics have been based on the BoM Generalised Tropical Storm Method (GTSMR) which estimates Probable Maximum Precipitation (PMP). The PMP has been defined by the World Meteorological Organisation as: "*the greatest depth of rainfall for a given duration, meteorologically possible for a given size storm area at a particular location at a particular time of year, with no allowance for climatic trends".* This definition is also referenced in the GSTMR.

The peak flow of the PMF on the Ashburton River at the Nanutarra Bridge is estimated to be 280,000 m^3/s.

4.2.3 Nanutarra Bridge to Ashburton River Delta

Flows generated in reaches of the Ashburton River between the Nanutarra Bridge and Ashburton River Delta Catchment have been accounted for in the Ashburton River Catchment hydrological model. Analysis of the general topography, satellite imagery and the Halpern Glick Maunsell (1997) report on the February 1997 flood event, suggest that during a significant storm, flows breakout of the main channel of the Ashburton River. Breakouts occur to the northwest and the northeast approximately 40 km downstream of the Nanutarra Bridge (Figure 4-1). Significant breakout flows to the northwest are likely to be predominantly temporarily stored in small interconnected depressions and further north within inter-dune swales. Flood waters not lost to infiltration or evaporation are likely to be discharged through drainage systems to the west of the main channel of the Ashburton River. Breakout flows to the northeast are also likely to be stored in depressions and interconnected inter-dune swales. An aerial survey of the February 1997 events (Halpern Glick Maunsell 1997), however, suggested a large proportion of the flood waters flowed east and discharged into the Hooley Creek.

The main breakout areas are located outside the hydrological model boundary (Figure 4-2). Further, relevant data are not available to estimate the potential temporary storage in the breakout areas and subsequent flow volumes into Hooley Creek. An assumption is made that significant portions of the flow volumes are lost on the flood plain. To account for loss of flows, particularly those that breakout to the northwest, it has been assumed that peak flows would be considerably less at Ashburton North than those estimated at Nanutarra Bridge by the flood frequency analysis.

Selection and Distribution of Flows

A key factor in realistically representing the hydrology of the Hooley Creek Catchment is understating the volumes and distributions of flood flows that breakout of the main channel of the Ashburton River. An aerial hydrological survey of the 1997 flood event (Halpern Glick Maunsell 1997), mapped flood flows including breakouts of the main channel of the Ashburton River. From this hydrological survey it has been estimated that breakouts to the northeast and northwest nominally accounted for one quarter and one third of the flood flow. The remainder of the flood flows was contained within the main channel of the Ashburton River.

Figure 4-3 shows the conceptual distribution of flood flows from a 1:100-year ARI event based on the 1997 hydrographic survey findings. Conceptually a peak breakout flow of 4,300 m³/s would discharge through the eastern portion of the Hooley Creek Catchment. This is a conservatively high discharge rate because the assessment does not take into account the low relief and potential storage of the floodplain.

4.2.4 Ashburton River Delta Catchment

The Ashburton River Delta Catchment is not gauged. Therefore, a hydrologic model (using *xprafts* software) was developed to estimate flows generated locally within the delta. This model has not been calibrated due to the absence of gauged records. Parameterisation of the Ashburton River Delta Catchment *xprafts* model is comparable with that of the calibration model for the Ashburton River Catchment. This approach enables a reasonable representation of loss values and generated flow in the Ashburton River Delta Catchment.

The loss values applied to the Ashburton River Delta model were derived from the calibrated Ashburton River Catchment model. This is considered a reasonable assumption given loss values commonly do not greatly differ within a catchment with similar geology, land-use and vegetation. Antecedent soils conditions were assumed for those catchments which are considered likely to be saturated during a rainfall event due to shallow water table, tidal ingress and low elevation. Characteristics such as topographical data, flow paths, roughness coefficients and channel dimensions identified in the site investigation were also applied to the model. Table 4-2 shows the parameter values for the model sub-catchments.

Table 4-2 Input Parameters for the Ashburton River Delta Hydrological Model

Ashburton River Delta Catchment	Area (km^2)	Catchment Slope (%)	Initial Loss	Continuing Loss
LAA10	12	0.0010	30	13.8
LAA11	29	0.0010	30	13.8
LAA12	23	0.0018	30	13.8
FCE01	226	0.0010	30	13.8
FCB01	42	0.0010	30	13.8
LCB02	6	0.0012	30	13.8
FCA01	12	0.0010	30	13.8
LCA02	18	0.0010	30	13.8
LCA03	42	0.0013	0*	0*
FCC01	14	0.0010	30	13.8
FCD01	27	0.0017	30	13.8
FCF01	35	0.0019	0*	0*
LCF02	23	0.0011	30	13.8

4.2.5 Tidal Variation

Data for the tide gauge at Beadon Creek were obtained from the WA Department of Transport. These were applied to the coastal boundary of the hydraulic model. Data used for the standard tide simulations are shown in Chart 4-5. Subsequently the varying extent to which the tide inundates the Ashburton River Delta Catchment was assessed using several days of tidal records in the hydrological models. These input data are associated with a period of high tides (maximum tide elevation 1.24 m AHD) recorded during January 2009.

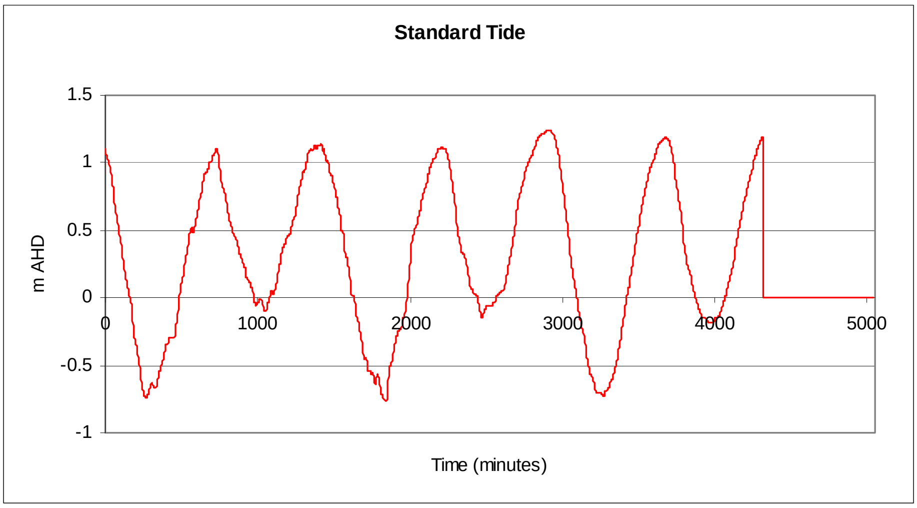

Chart 4-5 Standard Tide Sequence

4.2.6 Storm Surge

The storm surge study by GEMS (2000), estimates the 1:25-year and a 1:100-year ARI storm surge for the Onslow coast. The peak sea elevation for the 1:25-year and 1:100-year ARI events are estimated at 3.5 and 4.8 m AHD. The typical tidal record has been modified to represent both the 1:25-year and 1:100-year peaks for use in the hydrological models. The sea level sequences used to model the storm surge are shown below in Charts 4-6 and 4-7.

The storm surge analysis was simulated to coincide with the rainfall runoff event with a similar ARI. Although this is a highly unlikely sequence of events, it represents an extreme condition and provides an indication of the range of anticipated water levels at Ashburton North.

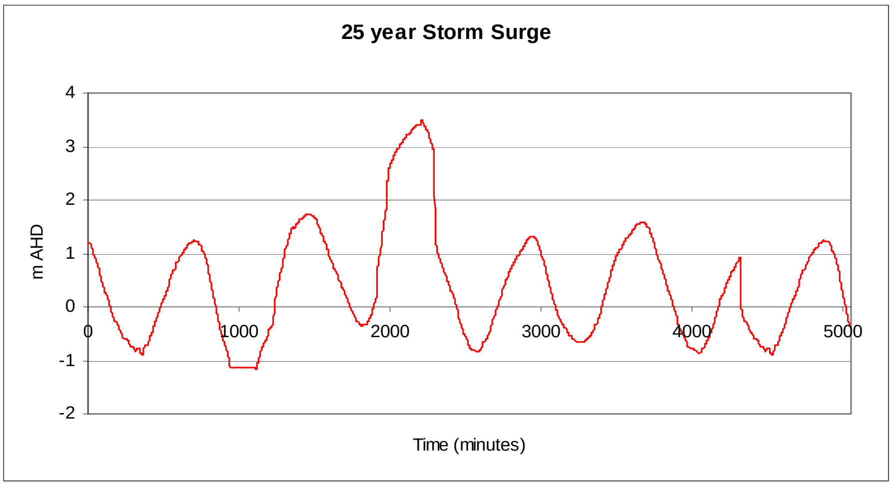

Chart 4-6 1:25- Year ARI Storm Surge Sequence

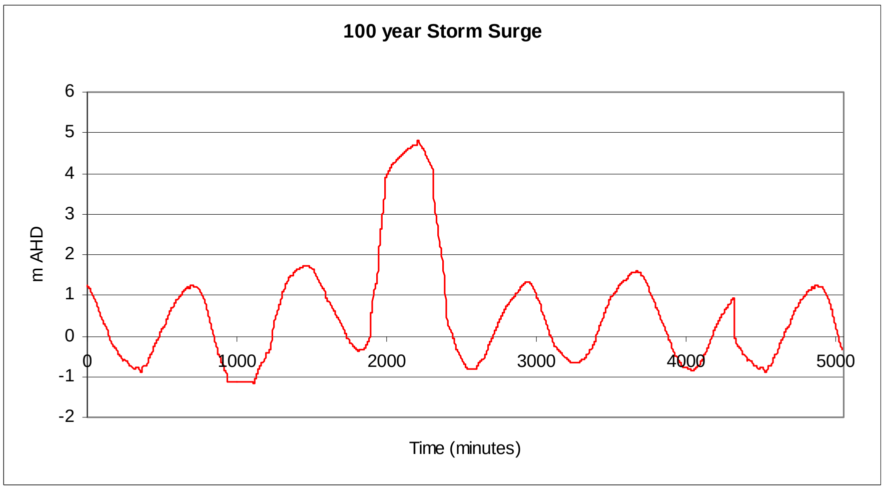

Chart 4-7 1:100-Year ARI Storm Surge Sequence

4.3 Hydraulic Model

In order to evaluate the hydraulic characteristics of Ashburton North it is necessary to separate the effects of flooding from the Ashburton River, tidal inundation and runoff generated by local rainfall. A two-dimensional hydraulic model of the Ashburton River Delta Catchment was developed, using MIKE 21 software, in order to assess these effects. This model was used for two sets of baseline simulations:

- Tidal inundation.
- Baseline flood profiles - existing environments.

Hydraulic Model Development

MIKE 21 simulates unsteady two-dimensional flow in marine, coastal and floodplain environments. The topographic grid represents the mean elevation from Digital Elevation Model (DEM) topographic data obtained from LiDAR and FUGRO LiDAR. The LiDAR data contains topographic data on a 1 m grid, with a vertical resolution of 0.3 m. The MIKE 21 model boundaries of the Ashburton River Delta model are the same as the LiDAR grid. Due to the relatively large domain and the computational limitations of the software, the model is based on a 40 m grid. The domain of the hydraulic model excludes the breakout areas from the main channel of the Ashburton River. The MIKE 21 model domain is shown on Figure 4-4.

Landsat 7 imagery was used to determine the hydrologic parameters and set catchment roughness values (1/Mannings N). The resolution provided by the images is considered sufficient for this assessment. The roughness map is shown on Figure 4-5.

The embankments of the Onslow Salt crystallisation ponds are not well represented in the LiDAR topographic grid. Therefore, artificial walls of infinite height were incorporated in the model grid around the crystallisation ponds. This approach isolates the Onslow Salt Project and is intended to deliver worst case predicted flood heights at Ashburton North.

Hydrographs simulated for both the Ashburton River Catchment and the Ashburton River Delta Catchment were used as input into the MIKE 21 model. Breakouts from the main channel of the Ashburton River that influence the Hooley Creek and Southwest Catchments are accommodated in the MIKE 21 model based on the interpreted distribution of the flows during the 1997 flood event (Halpern, Glick Maunsell 1997; Figure 4.2 and 4.3).

Tidal records (Department of Transport) were used to simulate the HRT. In order to isolate the effects of flooding of the Ashburton River from tidal inundation, several simulations were conducted using a fixed sea level boundary equivalent to mean sea level.

In the absence of historical flood height data for Ashburton North, the MIKE 21 model is not calibrated. This limits the ability of the model to predict absolute water levels for different flood events.

4.4 Assumptions and Limitations

Table 4-3 outlines several assumptions made and limitations of the models.

Table 4-3 Model Assumptions and Limitations

Component	Description
Assumptions	
Hydrology	No losses or storage of flood waters between the Nanutarra Bridge and Ashburton North.
	Catchments downstream of Nanutarra Bridge and at Ashburton North have similar characteristics to those of the upstream Ashburton River Catchment. Near saturated antecedent soil conditions prevail in low-lying catchments areas, due to shallow water table settings.
Hydraulic	Flows are distributed evenly across seven southern boundary locations of the model to represent flood breakouts from the Ashburton River.
	Tidal boundaries represent the tidal fluctuations and reasonably simulate extents of landward inundation from seawater. Sensitivity analyses of the locations of the tidal boundaries have been conducted to confirm the locations do not significantly affect the extents and depths of tidal inundation.
	No geomorphologic changes to channels or flood plains during large flow events.
	Closed eastern boundary based on watershed. The eastern boundary coincides with the catchment boundary and the extent of the available topographical survey.
Limitations	
Hydrology	There are no gauging stations between Nanutarra Bridge and Ashburton North
	The distribution of flood flows from breakouts between the Nanutarra Bridge and Ashburton North has not been quantified for various ARI events.
	The *xprafts* model has been calibrated to one recorded event.
Hydraulic	Simulated water levels have a vertical accuracy of 0.3 m averaged over 1600 m^2 (40 x 40 m grid). The vertical accuracy of the model is primarily determined by the accuracy of LiDAR data. This accuracy limits the confidence of flood heights obtained from MIKE 21 simulations.
	The MIKE 21 model is not calibrated at Ashburton North due to a lack of data on historic flood elevations.
	The LiDAR data does not extend far enough upstream on the Ashburton River, thus it limits the investigation and resolution of breakout zones and their distribution.

The grid size used allows a sufficient area to be modelled with sufficient resolution to simulate the connected hydraulics of the Southwest Catchment, Hooley Creek Catchment and Ashburton River. Further, as the MIKE 21 model is not calibrated it presents limitations in resolution of absolute flood elevations.

4.5 Simulated Baseline Environments

Design rainfall events (5, 10, 20 and 100-year ARI) were simulated in the baseline Ashburton River Catchment and Ashburton River Delta Catchment.

4.5.1 Flood Characteristics

Flood characteristics were simulated in the MIKE 21 model by using hydrographs for the Ashburton River, local runoff from the Ashburton River Delta Catchment and mean sea level. The simulated baseline flood depths and flood elevations are displayed on Figures 4-6 and 4-7.

The MIKE 21 model indicates that the Ashburton River breaks its banks in all four design rainfall event simulations. These breakouts occur along the Ashburton River downstream of Nanutarra Bridge, augmenting flows into low-lying areas of the Southwest and Hooley Creek Catchments. The areas and depths of inundation following a 1:100-year ARI rainfall event are extensive, with a large portion of the Ashburton River Delta Catchment being inundated. The baseline simulations indicate that flows from the Ashburton River may cause flooding at Ashburton North at recurrence intervals of less than two years. The simulated baseline depths of inundation following a 1:100-year ARI rainfall event with a range of low – frequency tidal and storm surge conditions are shown on Figures 4-8 and 4-9. The results of the model simulations show minor changes to the flood extent from baseline mean sea level conditions, with marginally greater depths of inundation.

4.6 Storm Surge

The flood hydrology of the Ashburton River Delta Catchment is affected by storm surges associated with cyclonic events. Typically, the low atmospheric pressure associated with cyclone causes a temporary surge in seawater elevations on the coast line.

After the cyclone has moved inland the sea level will subside to normal tidal fluctuations. With the cyclone moving inland, there typically may be a time delay between the peak of the storm surge and the peak flood flow generated by rainfall on the Ashburton River Catchment. It is therefore unlikely that the storm surge coincides with the flood peak. In a worst-case scenario, however, when a 1:100-year ARI storm surge (with a sea level estimated at 4.8 m AHD as in GEMS (2000), combined with a 1:100-year ARI flood event, the simulated depths of inundation at Ashburton North are predominantly dictated by the storm surge. The storm surge is expected to retard flood waters, causing inland backing-up of stream flow and consequent wider areas of inundation.

4.7 Tidal Influences

Tidal factors influence the drainage of surface water from the catchment. The extent of simulated tidal inundation is displayed on Figure 4-10. The simulations confirm the spring tide and normal tide inundation extent observed during the site investigation of April/May 2009. The simulations show relatively small changes to the flood extent as compared to the baseline 1:100-year ARI flood with mean sea level, but flood depths are greater. Figure 4-11 shows the simulated differences in flood depths linked to selected low-frequency tidal conditions and rainfall event ARI.

Ashburton River Delta Catchment

During a typical high tide, seawater propagates about 7 km upstream of the coast. At the HRT (1.73 m AHD) the simulated tidal influence reaches about 10 km upstream. During a 1:100-year storm surge (4.8 m AHD) a significant part of the delta is inundated and the simulated tidal influence reaches 15 km upstream.

Hooley Creek Catchment

During a typical high tide and HRT, the simulated tidal influences propagate about 2 and 4 km upstream of the coast. During a 1:100-year ARI storm surge, the simulated tidal influence reaches about 10 km upstream and inundates a significant part of the catchment.

Southwest Catchment

The Southwest Catchment is not subject to regular tidal inundation. Only exceptional tides propagate into the catchment. The simulated HRT inundates a small low-lying portion of the catchment. During a 1:100-year ARI storm surge, nearly the entire catchment area is inundated.

4.8 Climate Change

The baseline hydrology and drainage characteristics of Ashburton North may potentially change as a result of climate change. Climate change may gradually increase the frequency of cyclonic events and cause a rise in sea level.

Increased Frequency of Cyclones

The baseline hydrology is dominated by cyclonic events. A gradual increase in cyclone frequency may not significantly change the baseline hydrology characteristics, but may increase the frequency of significant rainfall and flood events.

Sea Level Rise

It is generally expected that the global mean sea level will rise throughout the 21st century (Indian Ocean Climate Initiative, 2005), due mainly to the continuing warming of the oceans and the resulting thermal expansion. The predicted increase is up to 0.3 m by 2040 and about 0.9 m by 2100. The impacts of sea level rise would include:

- Inundation of low-lying coastal regions.
- Decreased beach stability.

The potential inundation of Ashburton North has been simulated for the year 2100. The change in baseline inundation and flood elevations for the standard tide, 1:100-year ARI storm surge and the 1:100-year ARI flood under storm surge conditions are shown on Figure 4-7 (a to f). Under standard tidal forces (Figure 4-7, a and d), the rise in sea level causes a significant portion of Ashburton North to be added to the tidal zone, inundated daily. Under a 1:100-year ARI storm surge (Figure 4-7, b and e), the rise in sea level causes a significant increase in area of inundation, with almost all of Ashburton North under water. The 1:100-year ARI storm surge combined with a 1:100-year ARI flood event (Figure 4-7, c and f), causes additional rises in water levels at Ashburton North. Inundation and flood water elevations in the areas with an elevation greater than 6 m AHD are not affected by the forecast rises in sea level. These areas are predominantly located south of the proposed Shared Infrastructure Corridor.

For sandy beaches it is generally accepted (Indian Ocean Climate Initiative 2005) that a 0.01 m rise in mean sea level would be accompanied by a loss of about 1 m of beach. Based on the predicted sea level rise of 0.9 m, this would result in beach recession of about 90 m by 2100.

4.9 Surface Water Quality

Generally, stream salinities in the Pilbara regions are low. Most of the major rivers have annual-flow-weighted salinities between 50 and 200 mg/L (Ruprecht & Ivanescu 2000). Typically, stream salinity is higher with low flows and lower with high flows. The turbidity in the Pilbara rivers is typically comparatively low (50 to 100 NTU in Ashburton River Catchment) for average flow events. During flood events, however, high turbidity (3,200 NTU in Ashburton River Catchment) has been observed.

Surface water quality at Ashburton North is a mixture of tidal seawater, and runoff from local and regional catchments, including the Ashburton River Catchment. The surface water quality in proximity to the Shared Infrastructure Corridor and Accommodation Village is a mixture of runoff from local catchments during low rainfall events and regional flood waters from high rainfall events. The predominant surface water quality indicators include salinity from the tidal influence and turbidity (a proxy for suspended sediment) from stream flow. Surface water quality data for Ashburton North are sparse and incidental; the terrestrial domain is inherently dry and rainfall events are sporadic.

The DoW monitors surface water quality in the Ashburton River at Nanutarra Bridge These data are supported by opportunistic surface water samples collected at Ashburton North by URS (Table 3-1 and Figure 3-6) and Biota (2010b). Results of the Ashburton North surface water quality analyses are compared to quality of the Ashburton River and seawater in Tables 4-4 and 4-5.

Table 4-4 Opportunistic Surface Water Quality Comparison to Ashburton River and Seawater

Description	**Unit**	**Catchments**						
		Southwest	**Hooley Creek**	**Hooley Creek**	**Hooley Creek –**	**Ashburton River Mouth**	***Ashburton River[1]***	***Seawater[2]***
Date		14/06/09	21/06/09	18/02/10	21/02/10	20/02/10		
pH Value	pH	7.71	7.86	8.27	6.71	7.78	*6.7 - 8.8*	*8.1 - 8.4*
Electrical Conductivity @ 25°C	µS/cm	25,100	57,200	57,900	183,000	74,300		
Total Dissolved Solids	mg/L	16,700	48,700	43,400	347,000	64,600	*106 - 678*	*34,378*
Hydroxide Alkalinity as $CaCO_3$	mg/L	<1	<1	<1	<1	<1		
Carbonate Alkalinity as $CaCO_3$	mg/L	<1	<1	<1	<1	<1	*<2*	
Bicarbonate Alkalinity as $CaCO_3$	mg/L	46	134	118	202	169	*70 - 117*	*142*
Total Alkalinity as $CaCO_3$	mg/L	46	134	118	202	169	*40 - 196*	
Sulphate as SO_4	mg/L	2,720	6,000	3,520	3,190	4,560	*8 - 29*	*2,560*
Sulphur as S	mg/L	908	2,000	1,170	1,060	1,520	*1 - 35*	
Cl	mg/L	9,160	20,100	21,900	181,000	29,000	*7 - 285*	*18,980*
Ca	mg/L	905	765	494	2,850	705	*12 - 40*	*400*
Mg	mg/L	518	1,990	1,690	29,600	2,130	*5 - 42*	*1,272*
Na	mg/L	4,500	15,000	12,100	62,800	16,700	*7 - 149*	*10,560*
K	mg/L	227	802	625	9900	854	*4 - 7*	*380*
Total Suspended Solids	mg/L	na	na	142	553	na		
Turbidity	NTU	na	na	7	78	na	*2 – 3,200*	*1 - 20*
Total Anions	mg/L	316	694	693	5190	916		
Total Cations	mg/L	289	876	706	5560	958		
Ionic Balance	Percent	4.4	11.6	0.9	3.5	2.2		

Notes

1. At Nanutarra Bridge

2.Typical Seawater composition

Table 4-5 Surface Water Quality in Clay Pans (Biota, 2010b) Compared to Ashburton River and Seawater

Site	*Location*	Description	Date	*pH*	Electrical Conductivity (µS/cm)	*Salinity (mg/L)*	*Turbidity (NTU)*
CWP13	*Southwest Catchment*	Clear marine habitat	10.3.09	*9.56*	61,300	*41,820*	*0*
CWP14	*Southwest Catchment*	Clear marine habitat	10.3.09	*9.77*	47,600	*31,400*	*8.4*
CWP14	*Southwest Catchment*	Clear marine habitat	6.4.09	*8.54*	10,000	*NA*	*348*
CWP16	*Southwest Catchment*	Turbid clay pan	10.3.09	*8.96*	429	*200*	*>5,999*
CWP01	*Shared Infrastructure Corridor*	Freshwater habitat	14.2.09	*6.49*	60	*30*	*306*
CWP01	*Shared Infrastructure Corridor*	Freshwater habitat	10.3.09	*6.82*	219	*110*	*165*
CWP01	*Shared Infrastructure Corridor*	Freshwater habitat	6.4.09	*8.48*	385	*190*	*162*
CWP02	*Shared Infrastructure Corridor*	Turbid clay pan	14.2.09	*7.84*	166	*NA*	*>5,999*
CWP02	*Shared Infrastructure Corridor*	Turbid clay pan	10.3.09	*7.89*	169	*80*	*>5,999*
CWP02	*Shared Infrastructure Corridor*	Turbid clay pan	6.4.09	*9.04*	488	*230*	*>5,999*
CWP07	*Shared Infrastructure Corridor*	Turbid clay pan	10.3.09	*8.55*	126	*60*	*>5,999*
CWP08	*Shared Infrastructure Corridor*	Turbid clay pan	10.3.09	*8.54*	92	*50*	*>5,999*
CWP21	*Shared Infrastructure Corridor*	Turbid clay pan	6.4.09	*8.77*	531	*260*	*>5,999*
CWP11	*Accommodation Village*	Turbid clay pan	10.3.09	*8.74*	196	*100*	*>5,999*
CWP12	*Accommodation Village*	Turbid clay pan	10.3.09	*8.73*	164	*50*	*1,594*
	Ashburton River (Nanutarra Bridge)			*6.7 - 8.8*		*106 - 678*	*2 – 3,200*
	Seawater			*8.1 - 8.4*		*34,378*	*1 - 20*

4.9.1 Salinity

Ashburton River

The Ashburton River is generally fresh, with salinity about 130 mg/L TDS (Ruprecht & Ivanescu 2000). Salinity in the Ashburton River generally decreases with increasing flow, becoming more saline during times of low flow.

Salinity in others rivers in the Pilbara is similar, typically in the range 50 to 1,000 mg/L.

Ashburton River Delta

The Ashburton River Delta is predominantly subject to marine tidal and evaporation influence hence surface water is of similar or higher salinity than seawater. During river flow, salinity in the Ashburton River Delta decreases. At these times, seawater ingress is reduced and the delta becomes temporarily fresh. A surface water sample (20 February 2010, Table 4-4) from the upper reaches of the eastern side of the delta, close to northeast to southwest trending dune sands, showed a salinity almost twice that of seawater. The elevated salinity suggests either:

- Evaporation concentrating salts from remnant seawater isolated from tidal flushing.
- Discharge of hypersaline groundwater.

Southwest Catchment

A small portion of the Southwest Catchment is inundated by seawater during exceptional high tides. In the remainder of this catchment, surface water is from local runoff which has low salinity. The catchment is characterised by low-lying depressions and clay pans. Surface water runoff collects in these depressions or in clay pans and evaporates over time. As such, salinity of the surface water in the surface depressions and clay pans would accumulate over time. During flood events, the Ashburton River spills comparatively low salinity water into this catchment, which mobilises and temporarily dilutes the accumulated salinity.

Salinity measured as TDS in a clay pan after a recent rainfall event was approximately half that of seawater, indicating that salt present at the surface had been mixed with recent runoff. Major ions show a typical marine distribution. Salinity measurements in clay pans subject to tidal influences (CWP13, CWP14 on Figure 3.6) in March and April 2009 (Biota 2010b) are close to or above seawater, whilst further to the south (CWP16) and away from tidal influences, salinity in clay pans is low, indicating fresh water inundation (Table 4-5).

Hooley Creek Tidal Flats

Hooley Creek tidal flats receive water either from sporadic rainfall events, spring tides and storm surges. The propagation of tides in the Hooley Creek Catchment does not extend beyond the 2 m AHD contour. Above this elevation the catchment comprises undifferentiated mud flats and salt flats (Figure 2-3) that are subject to local rainfall and runoff events. Salinity measured in opportunistic surface water samples taken from the salt flats (June 2009 and February 2010, Table 4-4) were 1.2 to 1.4 times that of seawater, indicating loss of water from high evaporation rates and concentration of seawater salts. Major ions show an increase in sodium relative to chloride, suggesting that the salt flats preferentially bind sodium in the fine clay muds deposited during flood events.

Shared Infrastructure Corridor

Salinity measured in surface water samples taken from clay pans (CWP01, CWP02, CWP07, CWP08, CWP21 on Figure 3.6) in February, March and April 2009 along the Shared Infrastructure Corridor is low (Table 4-5). These data indicate the samples were fresh local runoff from recent rain events. Salinity in a small creek near the southeast of the Shared Infrastructure Corridor, however, is about ten times seawater, suggesting evaporation of seepage from high salinity groundwater.

Accommodation Village Area

Salinity measured in surface water samples taken from clay pans (CWP11, CWP12) in the vicinity of the Accommodation Village (March 2009) is low, indicating that the sample was predominantly influenced by fresh runoff from recent rain events (Table 4-5).

4.9.2 Turbidity (Suspended Sediments)

When in flow, the Ashburton River mobilises sediment and the amount of sediment in suspension or sediment load is measured as Total Suspended Solids (TSS). A proxy for suspended sediment is turbidity, which is a simpler measurement to undertake and can be related directly to suspended sediment. The total annual average sediment load of the Ashburton River has been interpreted to be in the order of 1.3 million tonnes (URS, 2009). This load is widely variable from year to year, dependent on river flow. The interpreted total annual sediment load between 1973 and 2008 ranged from 450 tonnes (in 2007 during a time of low rainfall and low flow) to 13.8 million tonnes (in 1997 during a major flood event).

The turbidity for the Ashburton River ranges from less than 10 NTU (about 15 mg/L TSS) at low flows of 30 m^3/sec, to 3 300 NTU (about 5 000 mg/L TSS) at a flow rate of around 250 m^3/sec (URS, 2009). The flow weighted turbidity for Ashburton River is 1,705 NTU, which is higher than other Pilbara rivers, which range from 10 to 587 NTU (Ruprecht & Ivanescu, 2000). Typically, there is a positive relationship between TSS and turbidity. In general, both TSS and turbidity increase with increased flows. For average flow rates, the turbidity in the Ashburton River is comparatively low (50 to 100 NTU). In flood events, however, high turbidity (up to 3,200 NTU) has been observed.

An estimated flow of 500 m^3/sec is required for the Ashburton River to break is banks and for flood water to spill into the Hooley Creek Catchment. At this and higher flow rates, TSS concentrations of 5,000 mg/L would be expected.

Turbidity measured (February 2010) in surface waters in Hooley Creek was low at 7 NTU, however, TSS was comparatively high at 142 mg/L TSS suggesting high colloidal material contents (Table 4-4). Turbidity measured in a creek near the southeast extent of the Shared Infrastructure Corridor was 78 NTU (552 mg/L TSS) consistent with concentration effects of evaporation, with clay suspension promoted by strong southwest winds. Turbidity measured in surface waters of clay pans at Ashburton North (Biota, 2010b; Table 4-5) between February and April 2009 ranged from 0 to above 5,999 NTU (about 9,000 mg/L TSS). Notably, turbidity in clay pans subject to tidal influences (CWP13, CWP14) in the Southwest Catchment was comparatively low between 0 to 348 NTU (about 0 to 520 mg/L TSS). Conversely, the fresh water clay pans (CWP16) in the south of the Southwest Catchment, Shared Infrastructure Corridor (CWP01, CWP02, CWP07, CWP08, CWP21) and Accommodation Village (CWP11, CWP12), were typically highly turbid, greater than 5,999 NTU (about 9,000 mg/L TSS).

Turbidity in the receiving waters can be expected to vary diurnally and seasonally due to marine, tidal and storm stressors.

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5

Surface Water Environmental Impacts Assessments

5.1 Potential Surface Water Impacts

At Ashburton North, the terrestrial environment is predominantly dry but situated on a dynamic floodplain of the Ashburton River that is undergoing frequent change due to fluvial and marine deposition and erosion processes. Local and regional baseline environments are characterised by typically low and sporadic rainfall, with rainfall events usually limited to about 16 days each year. Variations in rainfall locations, amounts and intensity across the local and regional catchments manifest in widely varied surface water flows. Stream flow is irregular and widely varied dependent on local and regional sources of rainfall and rainfall intensity. In many instances, the periods of flow would be less than a few days to one week each year. Local stream flow is commonly (about every second year) supplemented by flood flows in the Ashburton River and from adjoining sub-catchments on the coastal plain. As such, individual steam flow events are unique, with likely unique rainfall sources and flow paths.

The predominant potential surface water impacts at Ashburton North relate to changes to the local baseline hydrology and consequently to stream flow and quality of surface water discharge to receiving environments. The potential local surface water impacts at Ashburton North are linked to:

- Altered hydrology.
- Changes to water quality.

There are no identified surface water dependent ecosystems. As such, there are no forecast impacts on the Ashburton North terrestrial ecology linked to changes in the surface water environment. Further, footprints of proposed Ashburton North infrastructure occur on a local scale and hence the potential impacts on the surface water environments are expected to only occur locally.

The potential impacts of the development of the Wheatstone Project on the existing surface water environment are identified and assessed according to the proposed infrastructure components (Plant Pad, Shared Infrastructure Corridor, Accommodation Village and excavated borrow pits) of the Project. For the impact assessments, the proposed infrastructure includes the option of onshore dredge material emplacement as this presents a potential worst–case. In the absence of onshore dredge material emplacement the Project footprint would be reduced, with commensurate reduction of potential surface water impacts.

To limit potential risks to the habitats of the Ashburton River Delta, conceptual design of the proposed Ashburton North infrastructure have considered approaches that tend to maintain the baseline characteristics of stream flow frequency and sediment loads.

5.2 Predictive Model Assessment of the Altered Hydrology

Clearing and earthworks will be required throughout Ashburton North during construction and installation of infrastructure. The earthworks are expected to include cut to fill excavations and importation of fill material together with compaction activities. Cut to fill excavations and large volumes of fill material being brought into Ashburton North would alter the local landforms. Elevation platforms for the Plant Pad, Shared Infrastructure Corridor and Accommodation Village and excavation of local borrow pits within the Hooley Creek tidal embayment would alter the local catchments and intersect natural drainage lines. The altered landforms may change catchment responses to rainfall and channel flow, surface water flow directions, flow velocities and potentials for diversion of flood flows to adjoining catchments.

The elevations platforms for the Project infrastructure would:

- Intercept the watercourse of the Hooley Creek West, locally restricting surface water flows and constraining the flow path to the ocean and ingress of tidal waters. As a consequence, the Hooley Creek Catchment would be altered, with potential for changes to stream flow through the tidal reaches of East Hooley Creek, Eastern Creek and Four Mile Creek.
- Intersect 16 major drainage lines of the Hooley Creek Catchment along the alignment of the Shared Infrastructure Corridor and Accommodation Village. The drainage infrastructure design for the Shared Infrastructure Corridor accommodates a 1:25-year ARI event. For less frequent events, there is potential for retardation and temporary storage of surface water flows.
- Isolate about 390 ha of the northern Southwest Catchment, thus reducing the flood water storage capacity of this catchment.

The excavation of the proposed borrow pits (Figure 1-2) would tend to removed natural constrictions to the flow of flood waters and tides.

The methodology for the assessment of potential impacts due to altered hydrology focuses on predicted differences between interpreted characteristics of the baseline and altered surface water flow and floods linked the development of the Wheatstone Project. The MIKE 21 model developed to simulate the baseline surface water environments has been adapted to incorporate the proposed footprints of the Plant Pad (including the dredge material placement area), Shared Infrastructure Corridor, Accommodation Village and excavated borrow pits with appropriate design concepts applied.

The modelling predictions and assessments of potential altered hydrology impacts are based on:

- Changes to flood depths and elevations.
- Variations of flow velocities.
- Potential inundation of portions of the Shared Infrastructure Corridor. In order to minimize the potential impacts on the baseline, drainage infrastructure (culverts) have been incorporated into the MIKE 21 model at all 16 drainage crossings.
- Diversion of flood flows to adjoining catchments.
- Changes to areas inundated by tides.
- Water shed from the dredge material placement area.

5.2.1 Changes to Flood Depths and Elevations

The potential impacts of the altered hydrology on flood depths and elevations have been predicted for a range of storms including 5, 10, 25 and 100-year ARI events. These events have also been simulated in combination with mean sea level, HRT and 1:100-year storm surge conditions. Differences between the baseline and altered hydrology are assessed for each ARI event. The predicted impacts of altered hydrology are shown on Figure 5-1 (water depths) and Figure 5-2 (flood elevations) for the 10, 25 and 100-year ARI rainfall events.

The predicted differences between the baseline and altered hydrology include:

- For a 1:10-year ARI event (Figure 5-2, a and d), the constraints in Hooley Creek West are predicted to marginally increase flood elevations and locally increase flow velocities. Reduced storage in the Southwest Catchment is predicted to cause runoff to be transmitted into the Ashburton River Mouth Catchment sooner than under baseline conditions. This change is insignificant in terms of potential impacts. Changes to flood elevations within both the Hooley Creek and Southwest Catchments are predicted to be within the vertical resolution of the model. No significant impacts have been identified.
- For a 1:25-year ARI event (Figure 5.2, b and e), the developments in Hooley Creek West cause a decrease in flood depth and flood elevations in the tidal embayment of the Hooley Creek Catchment. Within the Southwest Catchment there is a further shortening of the residence time and consequent shortened response time for overflow into the Ashburton River Mouth Catchment. This change remains insignificant in terms of potential impacts. Along the Shared Infrastructure Corridor, flood flows are reaching the proposed design capacity of the drainage infrastructure. The simulations show comparatively small increased to upstream water elevations, indicating minor flow retardation. For the 1:25-year ARI event, the predicted impact is comparatively small. Typically, the predictive model indicates that changes in flood elevations are within the vertical resolution of the model. No significant impacts have been identified.
- For a 1:100-year ARI event (Figure 5-2, c and f), the larger flow rates accentuate changes in flood elevations. The developments in Hooley Creek tidal embayment are predicted to cause a decrease in flood elevations by up to 0.5 m. Along the Shared Infrastructure Corridor the design discharge capacity of the drainage infrastructure is exceeded. The simulations indicate retardation of the flow of flood waters, causing an increase in flood elevations upstream (south) of the Shared Infrastructure Corridor. The retardation of flows and associated flood levels, increase the potential for inundation of the roadway and village area and promote the diversion of flood flows into adjoining catchments.

The predicted changes to the flood depths, flood elevations, stream flow periods and peak flows would occur as long as the Project infrastructure remains in place. Given the Project area is situated within a naturally dynamic flood plain, the predicted changes are interpreted to potentially impose short-term and temporary changes to the local surface water environments. It is expected that actual changes may not be measurable.

5.2.2 Variations of Flow Velocities

The potential impacts of the altered hydrology on flow velocities have been predicted for 5, 10, 25 and 100-year ARI storm events. An increase in flow velocities is likely to represent an increase in scour and erosion of sediments whilst a decrease in flow velocity is likely to promote deposition of sediment. The predicted differences between the baseline and altered hydrology stream flow velocities are shown on Figures 5-3 and 5-4 and include:

- For a 1:10-year ARI event, the differences in simulated current velocities are within the resolution of the model. No significant impacts are predicted.
- For a 1:25-year ARI event, increases in flow velocities are predicted at several locations to the east of the Plant Pad in the Hooley Creek Catchment. The increased flow velocities are linked to encroachment of the Plant Pad embankment onto Hooley Creek.

- For a 1:100-year ARI event, the simulated flow velocities are accentuated and increasingly linked to flow retardation imposed by the Shared Infrastructure Corridor. Downstream of the Shared Infrastructure Corridor, flow velocities in the predominant watercourses increase due to constricted flows through the culverts beneath the roadway.

The predicted changes in flow velocities are relatively minor and localised. Changes to the flow velocities would occur as long as the Project infrastructure remains in place. In most instances, if not all, the differences are likely to occur over short periods coincident with times of peak discharges. As such, the changes are interpreted to potentially impose short-term and temporary changes to the local surface water environments. It is expected that actual changes would be minimal and may not be measurable.

5.2.3 Potential Inundation of Portions of the Shared Infrastructure Corridor

The potential for inundation of the Shared Infrastructure Corridor was assessed for 10, 25 and 100-year ARI storm events, with the tidal forces fixed at mean sea level. The flood water elevations along the alignment of the Shared Infrastructure Corridor and Accommodation Village for each of the drainage line crossings are outlined in Table 5-1 and shown on Figure 5-5.

Table 5-1 Predicted Maximum Culvert Discharges and Flood Water Elevations along the Shared Infrastructure Corridor

Culvert Structure	Maximum Discharge (m^3/s)			Maximum Flood Water Elevation (m AHD)		
	1:10-year ARI	1:25-year ARI	1:100-year ARI	1:10-year ARI	1:25-year ARI	1:100-year ARI
S1	290	535	1857	2.3	2.6	4.0
S2	0	0	47	3.6	3.6	5.0
S3	6	30	340	3.8	4.2	5.2
S4	3	57	250	3.4	4.0	5.0
S5	178	250	628	3.6	4.0	5.1
S6	119	206	532	3.6	4.0	5.1
S7	0	1	60	3.5	3.9	5.1
S8	0	3	125	3.4	3.6	4.8
S9	1	1	141	3.1	3.5	4.8
S10	10	27	196	3.7	3.9	4.9
S11	49	73	131	5.2	5.3	5.7
S11a	10	33	102	5.4	5.5	5.7
S12	30	57	88	5.6	5.8	6.2
S13	47	86	225	5.5	5.7	6.5
S14	71	122	407	4.5	4.8	5.8
S15	6	26	122	3.8	4.2	5.3
S16	117	283	985	3.9	4.2	5.4
S16a	380	447	658	3.9	4.3	5.5

The predicted potentials for inundation of the Shared Infrastructure Corridor and Accommodation Village include:

- For a 1:10-year ARI event, there is minimal change in flow patterns on project area scale. At individual drainage line crossings there may be minor changes which are smaller than the vertical resolution of the model. With the Shared Infrastructure Corridor at 6 m AHD, the roadway is not overtopped by flood waters. At drainage crossings S12 and S13 (Figure 5-6) near the Accommodation Village the culverts are fully submerged and are running at their full capacity. At both crossings the roadway elevation restricts the size and capacity of the culverts.
- For a 1:25-year ARI event, there is minimal change in flow patterns on project area scale, but minor changes at individual drainage line crossings which remain smaller than the vertical resolution of the model. The roadway is not overtopped by flood waters. At drainage crossings S12 and S13 (Figure 5-6) the culverts reach critical capacity. At these crossings a minimum road elevation of 7 m AHD should be considered to prevent the roadway being overtopped.
- For a 1:100-year ARI event, the roadway overtops at drainage line crossings S11a, S12 and S13 between the Accommodation Village and the connection to Onslow Road. At these locations, the 6 m AHD roadway elevation is insufficient to prevent overtopping due to the occurrence of flood flows in excess of the culvert capacity. At the crossings near the Accommodation Village, the conceptual design elevation of the roadway restricts the size and capacity of the culverts. Locally, the predicted flood elevations are marginally higher than the proposed 6 m AHD elevation of the raised platform.

A minimum local Shared Infrastructure Corridor elevation of 7.0 m AHD would be required to achieve 1:100-year ARI operational criteria and limit the potential for overtopping of the Shared Infrastructure Corridor. This higher elevation for the Shared Infrastructure Corridor would also partially mitigate restrictions on the size and capacity of the culverts at these crossings.

5.2.4 Diversion of Flood Flows to Adjoining Catchments

The impacts of the altered hydrology diverting flood flows to adjoining catchments were assessed for 1:25 and 1:100-year ARI storm events. The locations of the simulated main drainage lines are shown on Figure 6.6 and the discharge hydrographs for these locations for the simulated 1:25 and 1:100-year ARI events are shown on Figure 5-7.

The predicted potentials for diverting flood flows to adjoining catchments include:

- For a 1:25-year ARI event, the discharge hydrographs for the baseline and altered hydrology settings are similar in both shape and peak discharges. The presence of the Project infrastructure causes a small delay in the discharges but does not significantly change the baseline characteristics of the flow. The hydrographs for location XS5 indicate the drainage of flood water into the Northeast Catchment to the east of Ashburton North. The small difference between the baseline and developed case indicates that there is natural discharge into the Northeast Catchment for 1:25-year ARI storm events.
- For a 1:100-year ARI event, the discharge hydrographs for the baseline and altered hydrology settings are similar in both shape and peak discharges. The presence of the Project infrastructure only causes a small delay in the discharges but does not cause a significant change the baseline characteristics of flow, although more so than for the 1:25-year ARI event.

5.2.5 Changes in Tidal Inundation

The potential changes to areas of the Hooley Creek Catchment inundated by tides due to excavation of borrow pits has been assessed for standard tidal forces and 1:25 and 1:100-year ARI storm events.

For these assessments it has been assumed that the borrow pit bottom excavations (Figure 1-2) are to similar elevations as the surrounding floodplains. The assumed bottom of borrow pit elevations are:

- Island 1 (immediately east of Plant Pad): 1.0 m AHD.
- Island 2 (immediately south-east of Plant Pad): 1.0 m AHD.
- Island 3 (horseshoe-shaped island adjacent to Onslow Salt crystallisation ponds): 1.2 m AHD.
- Area 4 (peninsula south of horseshoe-shaped island): 1.2 m AHD.

The impact of the borrow pit excavations is to remove local obstructions to tidal forces. The impact is a predicted rise in tide elevations and increase in the area of tidal inundation. The predicted impacts of the excavation of the borrow pits include:

- For the standard tides (Figure 5-12, a and c), there is a comparatively small increase in tide elevation and the area exposed to regular tidal inundation.
- For a 1:25-year ARI storm surge (Figure 5-12, b and e), there is expected to be a be comparatively small decrease in water elevations in the areas extending up to about 5 km inland. The removal of flow obstructions causes tidal flows to reach further inland. The area upstream southeast of Island 3 is expected to have increased exposure to storm surge, with simulated inundation up to 0.2 m depth.
- For a 1:100-year ARI storm surge (Figure 5-12, c and f), there is expected to be an unmeasurable decrease in water elevations in the areas extending up to about 5 km inland. The area south of the Onslow Salt crystallisation ponds is expected to have increased exposure to storm surge, with summated inundation up to 0.5 m depth. The 1:100-year storm surge is expected to cause inundation beyond the proposed Shared Infrastructure Corridor.

5.2.6 Water Shed from the Dredge Material Placement Area

The dredge material placement area would be contained by perimeter embankments. Internally it would incorporate a sediment trap and sump (Figure 5-8). The perimeter embankments of the proposed facility are designed with sufficient height and freeboard to prevent uncontrolled release of decanted seawater or runoff. Seawater and runoff decanted from the emplaced dredge material would be disposed to a marine outfall north of the Plant Pad during the dredging program and consequently would not pose an impact on the local surface water environments. Once dredging has ceased, runoff captured within the dredge material placement area would initially be diverted to the sediment trap and sump within the facility and subsequently discharged into the Southwest Catchment.

Potential surface water impacts related to the proposed onshore placement of dredge material include:

- Seepage of seawater expressing as surface water flows within the Southwest and Ashburton River Mouth Catchments.
- Runoff from the final landform.
- Changes to areas inundated by tides.

Seepage of Seawater

Predictive simulations of the dredge material placement area (URS 2010) show the occurrence of seawater seepage from the emplaced dredge material. Seepage initially occurs as vertical infiltration, with saturation of the available storage beneath the dredge material, and subsequently as lateral flow through and beneath the facility embankments.

The predictive simulations show total seepage from the dredge material placement area peaks at a rate of about 2,200 kL/day. Contributions to the total seepage (Table 5-2) include a peak of about 200 kL/day through the facility embankments (Figure 5-9) and up to about 1,900 kL/day that propagates through the base of the facility and manifests as seepage on the embankment perimeters (Figure 5-10). The predicted seepage rates rise progressively throughout the campaign of dredge material disposal onshore, peaking as the campaign ceases. Thereafter the seepage rates decay over a period of five to ten years to about 200 to 400 kL/day. Predicted seepage rates above 1,000 kL/day occur for about one year.

Table 5-2 Predicted Distribution of Seawater Seepage

Time	Simulated Seawater Seepage (kL/day)		
	Embankments	Outside Perimeter of Embankments	Totals
30	15	288	303
60	22	326	348
101	36	500	536
209	26	503	529
301	47	768	815
398	123	1,395	1,518
485	163	1,696	1,895
666	83	1,028	1,111
786	68	904	972
1,031	36	629	665
5 years	11	382	393
10 years	4	276	280
50 years	2	203	205

The seepage through the base of the facility predominantly manifests as surface expressions of the water table within the Southwest Catchment. Substantially smaller scale seepage discharges occur on the perimeter of the other embankments. Figure 5-11 shows the predicted maximum seepage footprint. These seepage zones are all characterised by shallow water table settings that host limited storage potentials and form groundwater discharge zones. Deposition and accumulation of salt is expected at locations where the seepage expresses on the ground surface.

Within the Ashburton River Mouth Catchment (on the northwest perimeter toe of the dune sands that form a natural embankment for the dredge material placement area) the predicted seepage footprint (Figure 5-11) and seepage rates are comparatively small. Low rates of seepage discharge may, however, occur for up to ten years. Changes to the water and salt budgets of the Ashburton River Delta are anticipated to be insignificant.

The simulated seepage rates are sufficiently low that they may be predominantly intercepted by evaporation and low-lying storage areas of the Southwest Catchment and consequently not express as significant surface water flows on the ground surface.

Runoff

Runoff from the dredge material placement area would be diverted into sediment trap and sump within the facility (Figure 5-8) before overflow into Southwest Catchment. After completion of the dredge material placement, the runoff capture zone for the Southwest Catchment would approximate that of the baseline environment. Consequently, the volumes of runoff from the catchment would be similar to the baseline.

Impacts of Tidal Inundation on Southwest Catchment

The simulated impact of the dredge material placement area on the tidal flood water elevations is shown in Figure 5-12. For the standard tides and 1:25 and 1:100-year ARI storm surge, the potential changes from baseline settings are expected to be negligible.

5.3 Changes to Water Quality

The potential impacts on surface water quality predominantly stem from likely increases in local sediment and salt concentrations and loads due to an increase in disturbed soils and the large volumes of fill materials, including dredged materials, to be brought to Ashburton North to create elevated platforms. Runoff generated during rainfall events may cause exposed sediments to be mobilised and transported within surface water flows. Seepage from the dredge material placement area would contain salt. Further, the retention and storage of flood waters upstream of the proposed infrastructure may tend to accumulate salt due to concentration effects from evaporation. Other potential impacts on surface water quality during the construction and operational phases come from spills or leaks of contaminants. These contaminants may be transported into the natural surface water environment during rainfall events when sufficient runoff is generated. Receiving environments include Hooley Creek, Southwest and Ashburton River Mouth Catchments.

The baseline evidence suggests that the local terrestrial and tidal marine habitats are characterised by wide variations in turbidity and salinity. The variations in baseline turbidity and salinity are linked to the temporary and seasonal occurrence of stream flow and also to both tidal and storm stressors.

At times after significant flow events the surface water environments may remain turbid for extended periods. Measurements of turbidity at Ashburton North show a range from <10 to 6,000 NTU over a six week period from 5 March 2009 to 17 April 2009 (Table 4-5). Accordingly it may be assumed that:

- The baseline surface water turbidity varies widely dependent on the occurrence and frequency of significant stream flow events. At times during and in the short-term after flow events, the surface water is turbid. Conversely, in the periods between flow events, the surface water environment is comparatively quiescent and characterised by low turbidity waters.
- The local habitats have robustness in exposures to and potential impacts from sediment in stream flow and tidal reaches of the local watercourse.

5 Surface Water Environmental Impacts Assessments

Notwithstanding these aspects, sustained exposure to increased sediment concentrations and sediment loads to receiving environments of the West Hooley Creek and Ashburton River Delta may impact on local habitats. As such, the runoff to Hooley Creek and within the Southwest Catchment is likely to require the management of total suspended sediment concentrations and sediment loads for compatibility with the baseline environments.

The baseline evidence suggests that the local surface waters are widely variable in salinity, from fresh to hypersaline. The wide variation occurs in response to stream flow characteristics, residence time in storage within clay pans and the broader catchment, depth to the water table with possible groundwater interactions and, proximity to marine influences. Sampled baseline salinity concentrations may be linked to fresh stream flow, dissolution and mobilisation of salt in storage within clay pans and/or shallow soil profile, mixing with groundwater discharge, concentration effects due to evaporation and mixing with seawater.

Potential impacts on surface water quality have been assessed based on baseline quality data and application of the ANZECC & ARMCANZ Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). The ANZECC Guidelines default trigger values for salinity and turbidity in slightly disturbed ecosystems in tropical Australia, including northwest Western Australia, are shown in Table 5-3.

Further, the potential impacts to the surface water environment have been assessed cognisant that:

- The local environment typically hosts saline and hypersaline groundwater.
- The local environments form groundwater discharge zones, with the exception of the dune sands.
- The receiving environments occur predominantly at marine interfaces, where groundwater is discharging.
- The Ashburton River Delta is a regionally significant arid zone mangrove area (EPA, 2001).
- The Ashburton River Delta is assigned a 'Maximum' Level of Ecological Protection in "Pilbara Coast Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives; Department of Environment Marine Report Series, Report No 1. March, 2006".

URS (2010a and b) provide a baseline assessment of the intertidal habitats and impact assessments linked to the potential dredge material placement area at Ashburton North.

Table 5-3 ANZECC Guidelines for Salinity and Turbidity in Tropical Australia

Ecosystem Type	Salinity		Turbidity (NTU)
	Electrical Conductivity (µS/cm)	Equivalent Estimated TDS (mg/L)	
Upland and lowland rivers	20 – 250	10 - 150	2 - 15
Lakes, reservoirs and wetlands	90 – 900	50 - 550	2 - 200
Estuarine and marine	52,000	33,000	1 - 20

The ANZECC Guidelines, together with baseline data, have been used to develop site specific indicative or guideline trigger values for salinity and turbidity which should not be exceeded, in order to protect the local surface water environments and associated ecosystems. These indicative or guideline trigger values are provided in Table 5-4. The wet-season turbidity trigger values are based on limited data at times of stream flow, being predominantly derived from measurement of 78 NTU within the Hooley Creek Catchment during February 2010 (Table 4-4). The trigger value appears to be conservatively low based on the available data. The available baseline data are limited and consequently the indicative or guideline trigger values are intended to be adjusted, to reflect measured baseline values, once additional relevant data are recorded.

The implementation of the trigger values for the dry-season and wet-season needs to be supported by definitions of these periods given they would change from year to year and may be dependent on the ARI of storm events that seasonally influence surface water qualities. Invariably, a network of surface water control sites in receiving environments within the Hooley Creek, Southwest and Ashburton River Mouth Catchments would define the transitions from dry to wet to dry seasons and associated trigger values. The control sites would provide measures of baseline turbidity and salinity in domains that are not influenced by the proposed Ashburton North developments.

Table 5-4 Baseline Surface Water Trigger Values

Ecosystem type	Trigger Values Based on Baseline Concentrations and ANZECC Guidelines			
	Salinity (µS/cm)	Equivalent Estimated TDS (mg/L)	Dry-Season Turbidity (NTU)	Wet-Season Turbidity (NTU)
Upstream reaches of Ashburton North, including Southwest and Hooley Creek Catchments that discharge to tidal areas	52,000	33,000	20	80
Near-shore Marine	52,000	33,000	20	80

Turbidity

The potential turbidity impacts to surface water due to clearing and disturbing of surface soils during earthworks can be mitigated through the implementation of appropriate design aspects and management initiatives that will include the use of engineering controls to manage erosion and sediment concentrations. Conceptual designs for the Plant Pad provide for sedimentation traps on local watercourses and silt fences on the perimeters of the construction area. Construction of the perimeter embankments would preferably occur during the predominantly dry winter months.

Salinity

Potential salinity impacts may occur due to:

- Seepage from the dredge material placement area expressing as surface water flows. Typically, the seepage salinity would tend to reflect seawater, with possible changes over time due to potential concentration effects from evaporation.

- Retardation of flows behind altered landforms and infrastructure, such as the Shared Infrastructure Corridor and Plant Pad.

Both of these potential impacts have been mitigated through conceptual designs of the dredge material placement area and Shared Infrastructure Corridor that limit seepage and the retardation of surface water flows.

Spills and Leaks

There is potential for leaks and spills of hydrocarbons, wastes and other hazardous materials. Leaks and spills may occur in association with pipeline or equipment failure, storage and handling of product, fuels and chemicals, waste storage and disposal. There is also potential for spills and leaks of hydrocarbons, wastes and other hazardous materials during transport and transfer of products. Leaks and spills may enter the surface water environment, with transport to and fate within local watercourses of the Hooley Creek, Southwest and Ashburton River Mouth Catchments. The interception of leaks and spills is addressed in the spill containment design for the Plant Pad.

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Conclusions

The conclusions from the surface water studies in this report with regard to the baseline characteristics of Ashburton North and the potential impact of the development of the Project on the surface water environment are outlined below.

Baseline Hydrology and Drainage Characteristics

The mean annual rainfall at Onslow (Station No. 005017) is about 320 mm. Rainfall events predominantly occur during October through to April, linked to cyclonic activity, but are sporadic and typically limited to about 16 days each year. Stream flow only occurs in response to significant rainfall events, and typically is short-lived.

Ashburton North is located within the Ashburton River Delta Catchment of the Ashburton River Catchment. Processes affecting the coast and near-shore area at Ashburton North include tides and storm surges.

The Ashburton River has a catchment area of approximately 78,777 km^2 and ephemeral flows. River flows are gauged at Nanutarra Bridge (Department of Water, Gauging Station No. 706003), approximately 100 km inland from the river mouth. Recorded flows widely vary between nil and 12,600 m^3/s, with annual flow volumes from 3 to 4,500 GL (2007 and 1997). Major flows occur every one to three years in response to cyclonic rainfall. River flows are typically short-lived. Runoff is predominantly channelled in the upper reaches of the catchment. On the coastal plain, however, the river discharges through a network of tributaries and flood plain watercourse within the Ashburton River Delta. When in flow, the Ashburton River is typically fresh, with salinity of about 130 mg/L TDS, and turbid. The turbidity for the river flow ranges from less than 10 NTU at low flows of 30 m^3/sec, to 3,300 NTU at a flow rate of around 250 m^3/sec. The flow weighted turbidity for the Ashburton River is 1,705 NTU.

The Ashburton River Delta has a catchment area of approximately 190 km^2 and ephemeral flows which are not gauged. The broader catchment area comprises the Hooley Creek, Southwest, Ashburton River Mouth and Northeast Catchments. Ashburton North is located on the catchment divide between the Southwest and Hooley Creek Catchments. Catchment divides between the Ashburton River Mouth, Southwest Catchment and Hooley Creek Catchment are of low topographical relief. Cyclonic and other high intensity rainfall events cause shallow catchment boundaries to be submerged. Typically this occurs about every two years. As such, the catchments of the Ashburton River Delta are discreet between and during low intensity rainfall events. At these times, the terrestrial setting is inherently dry; local watercourses Hooley Creek West, Hooley Creek East, Eastern Creek and 4 Mile Creek are dry, except for tidal reaches. Water quality in the tidal Ashburton River Delta, including tidal reaches of the Southwest and Hooley Creek Catchments, is widely varied due to storm runoff, tidal and storm influences. The baseline evidence suggests that the local surface waters are widely variable in turbidity and salinity. Measurements of turbidity at Ashburton North show a range from <10 to 6,000 NTU over a six week period from 5 March to 17 April 2009 after earlier significant rainfall events. Typically, it is expected that turbidity would be less than 20 NTU except during and after flood events. Measured salinities range from fresh to hypersaline. Wide variations occur in response to stream flow, residence time in storage within clay pans and the broader catchment, depth to the water table with possible groundwater interactions and, proximity to marine influences.

6 Conclusions

Conceptual Hydrological Model

The conceptual hydrological model interprets that the Ashburton River Delta and local catchments are dynamic, with natural changes to landforms and watercourses actively occurring through erosion and deposition driven by both fluvial and marine processes. The Ashburton River typically breaks its banks every second year, leading to flood waters flowing from the river onto low-lying areas of the Ashburton River Delta and Ashburton North becoming part of a regional coastal flood plain. Significantly, individual steam flow events are unique, with likely unique rainfall sources and flow paths. Two main components influence the hydrological characteristics of the Ashburton River Delta:

- Flooding of the Ashburton River. At ARIs of less than two years, the local catchments function independently, with surface water flow directions linked with topography. During larger flood events (typically less frequent than 2-year ARI), stream flow from the Ashburton River spills into the Southwest and Hooley Creek Catchments, forming a broad flood plain. As such, the Ashburton River affects flood levels and stream flows in both the Southwest and Hooley Creek Catchments.
- Inundation by seawater due to tidal forces and storm surges. Tidal variations have been recorded between 1.68 m AHD (HRT) and -1.99 m AHD (LRT), with a mean sea level of 0.06 m AHD (DPI 2004). Storm surge is a complex function of cyclone intensity and motion, extent of maximum winds, bathymetry and coastline shape. The Onslow coast has been periodically inundated in the past by storm surge, particularly during the cyclones of 1934, 1958, 1961 and in 1999. GEMS (2000) estimates the 1:25-year and a 1:100-year ARI storm surge for the Onslow coast at 3.5 and 4.8 m AHD.

Under seasonal-dry conditions the sub-catchments of the Ashburton River Delta are discrete and surface water environments are independent. During and after significant cyclonic rainfall events, stream flows swell above the low-relief catchment divides and connect the individual catchments to form a coastal flood plain. Under such conditions the stream flow from the Ashburton River extends throughout the entire delta, contributing to flows within the Southwest, Hooley Creek and Northwest Catchments. At these times, flood heights in the local catchments rise significantly above those generated by the local catchment runoff.

A key factor in realistically representing the hydrology of the Hooley Creek Catchment is understating the volumes and distributions of flood flows that breakout of the main channel of the Ashburton River. Analysis of the available data suggests that during a significant storm, flows breakout of the main channel of the Ashburton River. Breakouts occur to the northwest and the northeast approximately 40 km downstream of the Nanutarra Bridge. An aerial survey of a 1997 flood event mapped flood flows including breakouts of the main channel of the Ashburton River. From this survey it has been estimated that breakouts to the northeast and northwest nominally accounted for one quarter and one third of the flood flow. The remainder of the flood flows was contained within the main channel of the Ashburton River. The aerial survey suggests a large proportion of the flood waters flowed east and discharged into the Hooley Creek.

Surface water receptors include the habitats of the Ashburton River Delta, inclusive of the tidal reaches of Hooley Creek. Potential surface water receptors at Ashburton North include river ecosystems and habitats of the Ashburton River Delta. Botanical surveys at Ashburton North have not identified ecosystems that are predominantly dependent on surface water flows. Habitats of the Ashburton River Delta are recognised as an important, high conservation value and regionally significant ecosystem.

When flow occurs, sediment is mobilised and may be transported to floodplain and marine environments of the Ashburton River Delta at comparatively high concentrations.

Potential Surface Water Impacts

The predominant potential surface water impacts at Ashburton North relate to changes to the local baseline hydrology and consequently to stream flow and quality of surface water discharge to receiving environments. Clearing and earthworks will be required throughout Ashburton North during construction and installation of infrastructure. The earthworks are expected to include cut to fill excavations and importation of fill material that would alter the local landforms. Elevation platforms for the Plant Pad, Shared Infrastructure Corridor and Accommodation Village and excavation of borrow pits within the Hooley Creek tidal embayment would alter the local catchments and intersect natural drainage lines. For the impact assessments, the proposed infrastructure includes the option of onshore dredge material emplacement as this presents a potential worst–case. In the absence of onshore dredge material emplacement the Project footprint would be reduced, with commensurate reduction of potential surface water impacts. There are no identified surface water dependent ecosystems. As such, there are no forecast impacts on the Ashburton North terrestrial ecology linked to changes in the surface water environment. Further, footprints of proposed Ashburton North infrastructure occur on a local scale and hence the potential impacts on the surface water environments are expected to only occur locally. The potential local surface water impacts at Ashburton North are linked to:

- Altered hydrology. The altered hydrology is linked to changes landforms that would:
  - Intercept the watercourse of the Hooley Creek West, restricting surface water flows in the vicinity of the Plant Pad and constraining the flow path to the ocean and ingress of tidal waters.
  - Intersect 16 major drainage lines of the Hooley Creek Catchment along the alignment of the Shared Infrastructure Corridor and Accommodation Village.
  - Isolate about 390 ha of the northern Southwest Catchment with embankments for the dredge material placement area, thus reducing the flood water storage capacity of this catchment.
  - Removal of natural constrictions to the flow of flood waters and tides by excavation of the proposed borrow pits. The assumed bottom of borrow pit elevations vary from 1.0 to 1.2 m AHD, corresponding to the elevations of the adjacent tidal flats.
- Changes to water quality. The potential impacts on surface water quality predominantly stem from:
  - Likely increases in local sediment and salt due to an increase in disturbed soils and the large volumes of fill materials to be brought to Ashburton North.
  - Seepage of seawater from the dredge material placement area and accumulation of salt due to the retention and storage of flood waters upstream of the proposed Shared Infrastructure Corridor.
  - Spills and leaks of contaminants.

6 Conclusions

The methodology for the assessment of potential impacts due to altered hydrology focuses on predicted differences between interpreted characteristics of the baseline and altered surface water flow and floods linked the development of the Wheatstone Project. The MIKE 21 model developed to simulate the baseline surface water environments has been adapted to incorporate the proposed footprints of the Project infrastructure. The simulations of the altered hydrology have been completed for a range of storms including 5, 10, 25 and 100-year ARI events. These events have also been simulated in combination with mean sea level, HRT and 1:100-year storm surge conditions.

The modelling predictions and assessments of potential altered hydrology impacts are based on:

- Changes to flood depths and elevations.
- Variations of flow velocities.
- Potential inundation of portions of the Shared Infrastructure Corridor.
- Diversion of flood flows to adjoining catchments.
- Changes to areas inundated by tides.
- Water shed from the dredge material placement area.

Typically, the simulated differences between the baseline and developed cases for events more frequent than 1:25-year ARI are small, within the range of the vertical resolution of the model.

The findings of the simulations of the altered hydrology include:

- Lowering of flood depths and elevations by up to 0.5 m for a 1:100-year ARI event. The predicted changes are interpreted to potentially impose short-term and temporary changes to the local surface water environments. It is expected that actual changes may not be measurable.
- Increases of flow velocities linked to encroachment of infrastructure on Hooley Creek West and flow retardation along the Shared Infrastructure Corridor. It is expected that actual changes would be minimal and may not be measurable.
- For a 1:100-year ARI event, the roadway overtops at drainage line crossings S11a, S12 and S13 between the Accommodation Village and the connection to Onslow Road. At the crossings near the Accommodation Village, the conceptual design elevation of the roadway restricts the size and capacity of the culverts. Locally, the predicted flood elevations are marginally higher than the proposed 6 m AHD elevation of the raised platform. A minimum local Shared Infrastructure Corridor elevation of 7.0 m AHD would be required to achieve 1:100-year ARI operational criteria and limit the potential for overtopping of the Shared Infrastructure Corridor.
- The presence of the Project infrastructure causes a small delay in the diverting flood flows to adjoining catchments but does not cause a significant change the baseline characteristics of flow.
- The impact of the borrow pit excavations is to remove local obstructions to tidal forces and storm surge. The impacts include small-scale changes in water elevations in the areas extending up to about 5 km inland. The area south of the Onslow Salt crystallisation ponds is expected to have increased exposure to storm surge, with summated inundation up to 0.5 m depth. The 1:100-year Storm Surge is expected to cause inundation beyond the proposed Shared Infrastructure Corridor.

6 Conclusions

- The proposed onshore placement of dredge material may impose impacts linked to seepage of seawater expressing as surface water flows within the Southwest and Ashburton River Mouth Catchments. The predictive simulations show total seepage from the dredge material placement area peaks at a rate of about 2,200 kL/day. The predicted seepage rates rise progressively throughout the campaign of dredge material disposal onshore, peaking as the campaign ceases. Thereafter the seepage rates decay over a period of five to ten years to about 200 to 400 kL/day. The simulated seepage rates are sufficiently low that they may be predominantly intercepted by evaporation and low-lying storage areas of the Southwest Catchment and consequently not express as significant surface water flows on the ground surface.

The potential impacts on surface water quality may be mitigated through appropriate design and engineering initiatives to intercept sediment. Conceptual designs for the Plant Pad provide for sedimentation traps on local watercourses and silt fences on the perimeters of the construction area. Construction of the perimeter embankments would preferably occur during the predominantly dry winter months. Conceptual designs of the dredge material placement area and Shared Infrastructure Corridor limit seepage and the retardation of surface water flows, respectively. The interception of leaks and spills is addressed in the spill containment design for the Plant Pad.

Notwithstanding the mitigation of surface water quality impacts through engineered designs, the runoff to Hooley Creek and within the Southwest Catchment is likely to require the management of total suspended sediment concentrations and sediment loads. The management objectives would be to maintain compatibility with the baseline environments, for conservation of habitats of the Ashburton River Delta. ANZECC Guidelines, together with baseline data, have been used to develop indicative or guideline trigger values for turbidity and salinity. These indicative or guideline trigger values include turbidity of 20 to 80 NTU (dry-season to wet season) and salinity 33,000 mg/L TDS. The trigger values appear to be conservatively low based on the available data. The available baseline data are limited and consequently the indicative or guideline trigger values are intended to be adjusted, to reflect measured baseline values, once additional relevant data are recorded.

The implementation of the trigger values for the dry-season and wet-season would need to be supported by definitions of these periods given they would change from year to year and may be dependent on the ARI of storm events that seasonally influence surface water qualities. Invariably, a network of surface water control sites in receiving environments within the Hooley Creek, Southwest and Ashburton River Mouth Catchments would define the transitions from dry to wet to dry seasons and associated trigger values. The control sites would provide measures of baseline turbidity and salinity in domains that are not influenced by the proposed Ashburton North developments.

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8

Limitations

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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.

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Appendix A Figures

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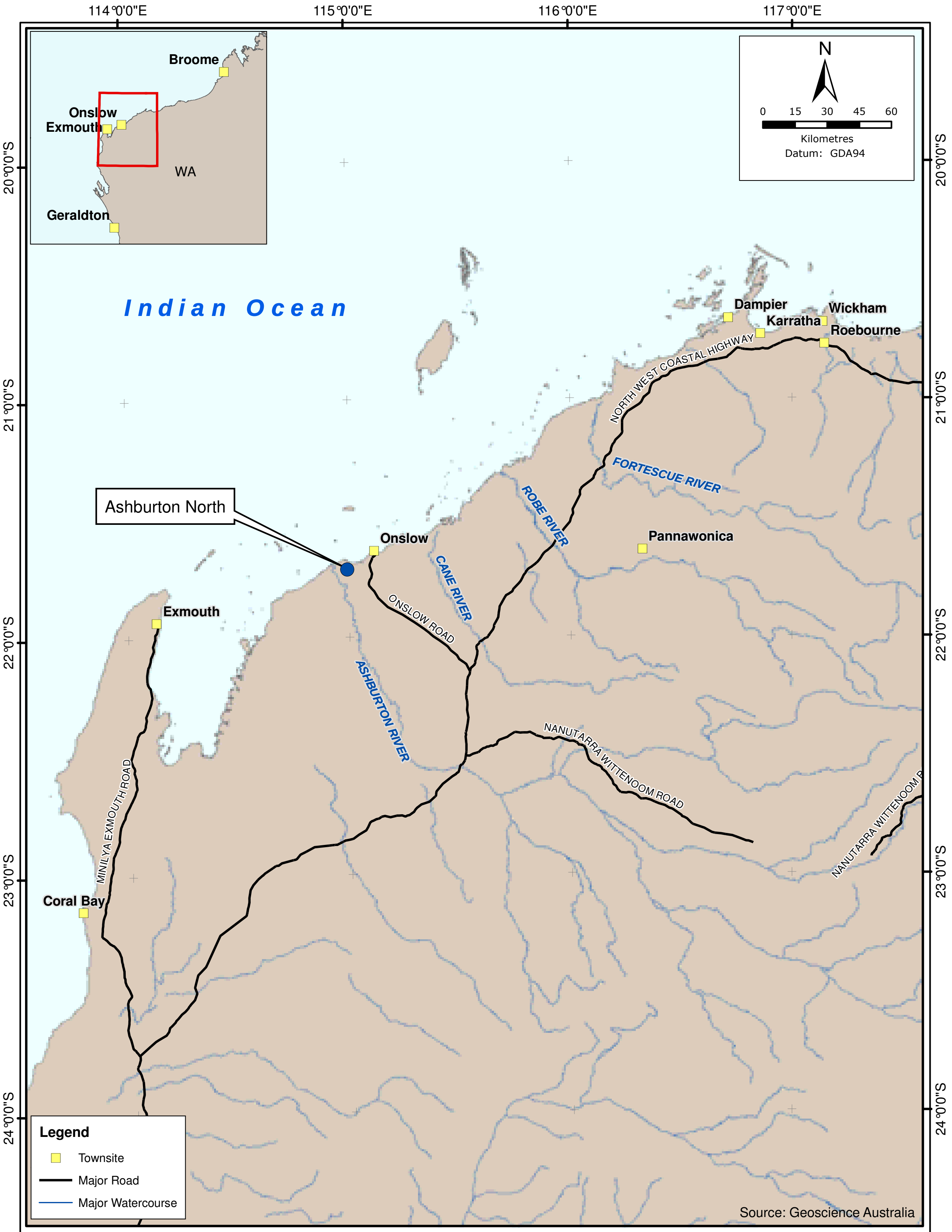

Source: Geoscience Australia

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	Job No.: 42907466 · File No.: 42907466-SW-001.mxd		A4

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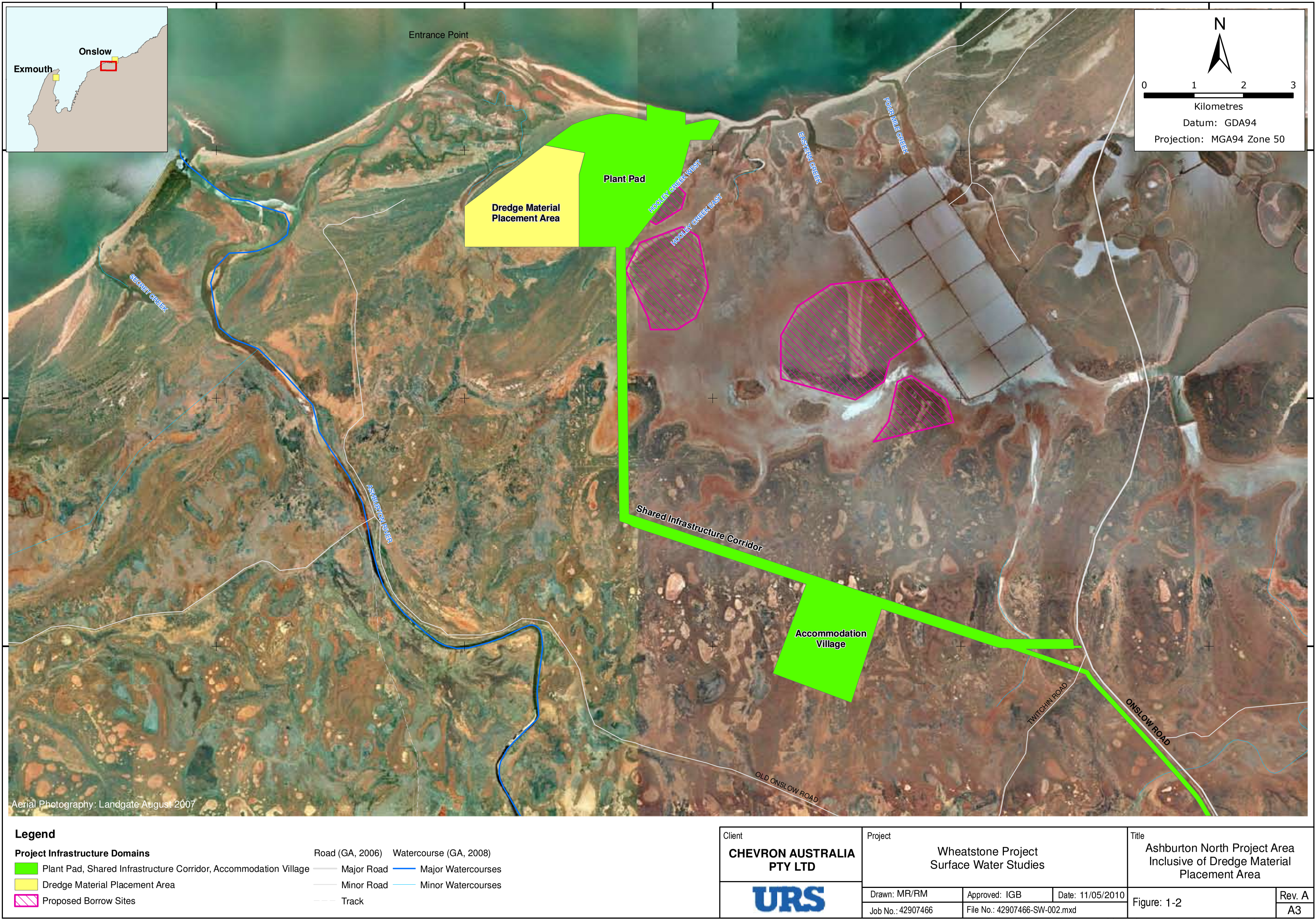

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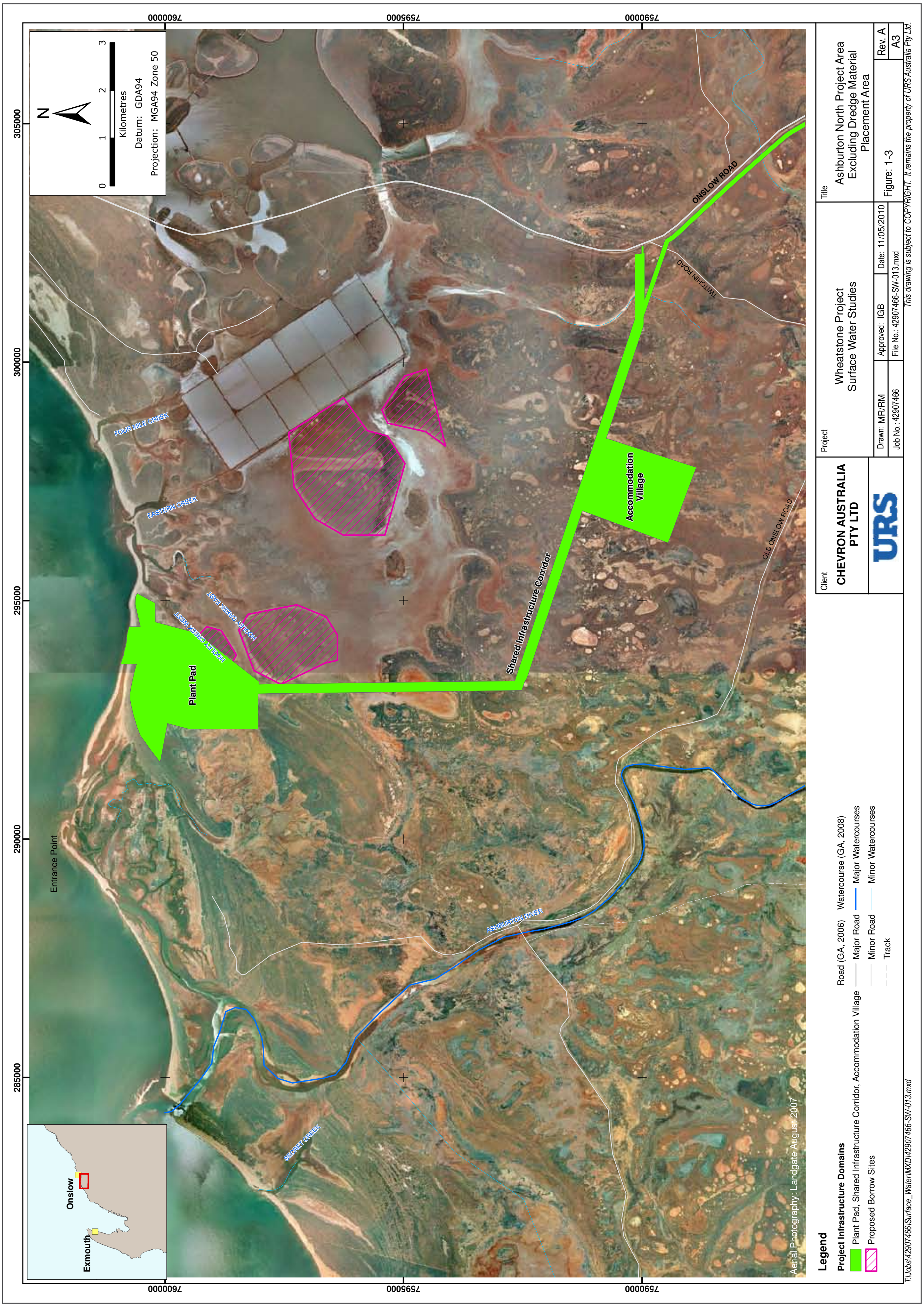
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Projection: MGA94 Zone 50
Onslow
Exmouth
Entrance Point
FOUR MILE CREEK
EASTERN CREEK
HOOLEY CREEK EAST
HOOLEY CREEK WEST
Plant Pad
Shared Infrastructure Corridor
Accommodation Village
ONSLOW ROAD
TWITCHIN ROAD
OLD ONSLOW ROAD
ASHBURTON RIVER
SECRET CREEK
Aerial Photography: Landgate August 2007
Legend
Project Infrastructure Domains
🟩 Plant Pad, Shared Infrastructure Corridor, Accommodation Village
▨ Proposed Borrow Sites
Road (GA, 2006)
Major Road
Minor Road
Track
Watercourse (GA, 2008)
Major Watercourses
Minor Watercourses
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project Surface Water Studies
Drawn: MR/RM
Approved: IGB
Date: 11/05/2010
Job No.: 42907466
File No.: 42907466-SW-013.mxd
Title
Ashburton North Project Area Excluding Dredge Material Placement Area
Figure: 1-3
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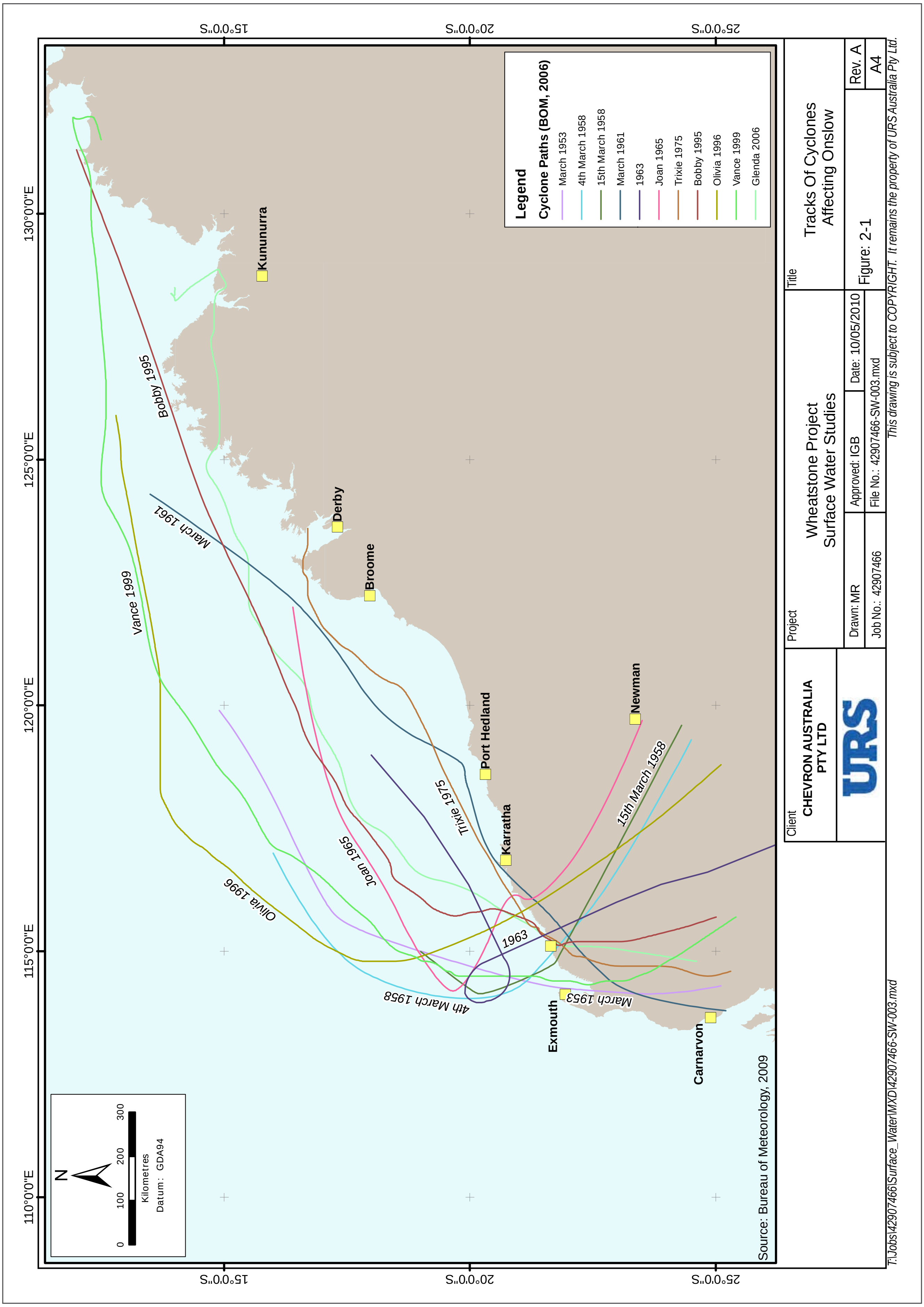
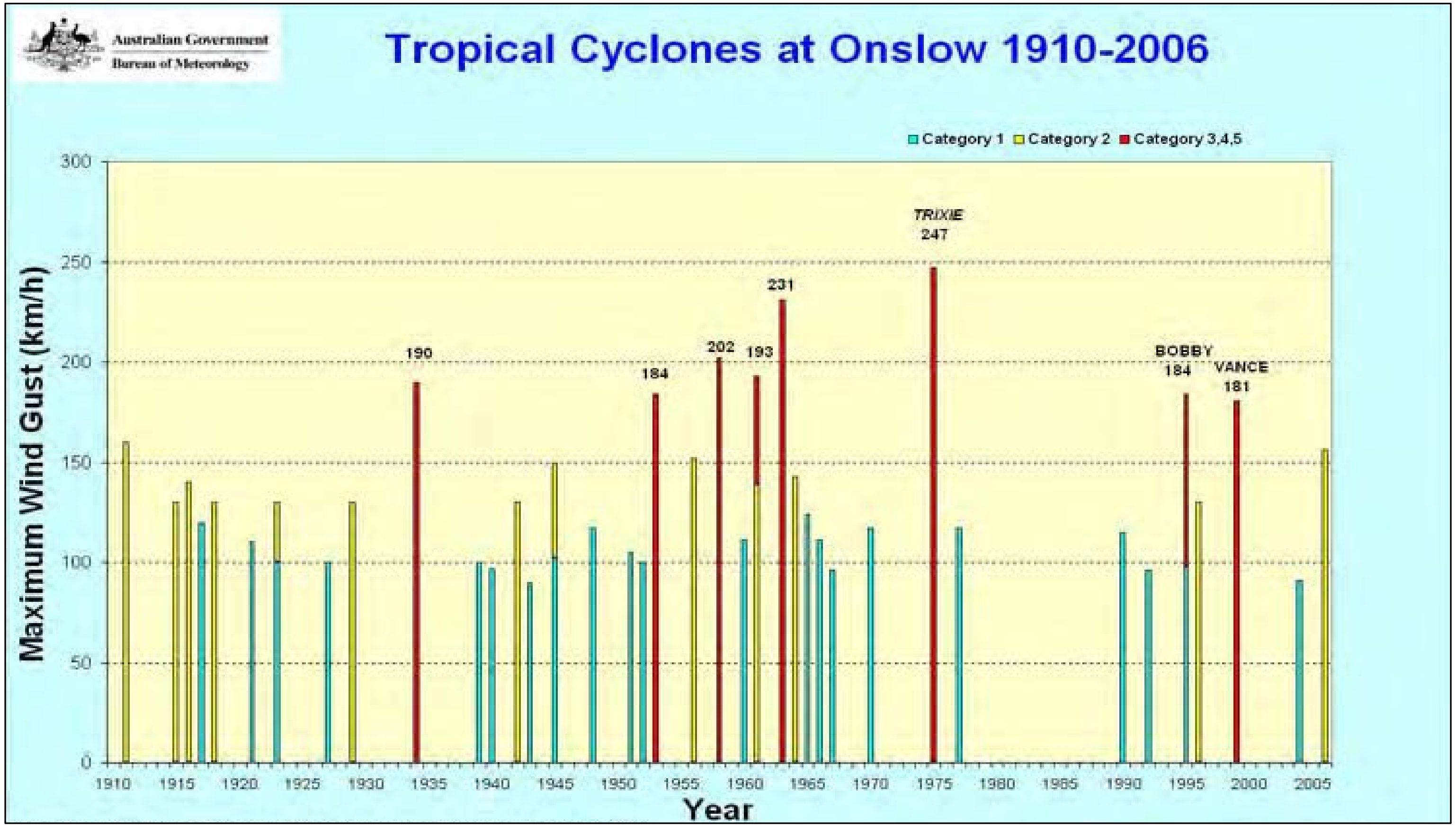


Figure: 2-1 Tracks Of Cyclones Affecting Onslow

Source: Bureau of Meteorology, 2009



Note: Category relates to the impact at the town not to the intensity of the cyclone.
Wind instrumentation and official sites have changed over the years.
The accuracy of wind gust values early in the record are usually less reliable than those in more recent times.

Source: Bureau of Meteorology Website, 2009.

Client:
CHEVRON AUSTRALIA PTY LTD

URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Historical Cyclone Wind Gusts
at Onslow (1910 to 2006)

Drawn:	RM	Approved:	IGB	Date:	17/05/2010	Figure:	2-2	Rev. A
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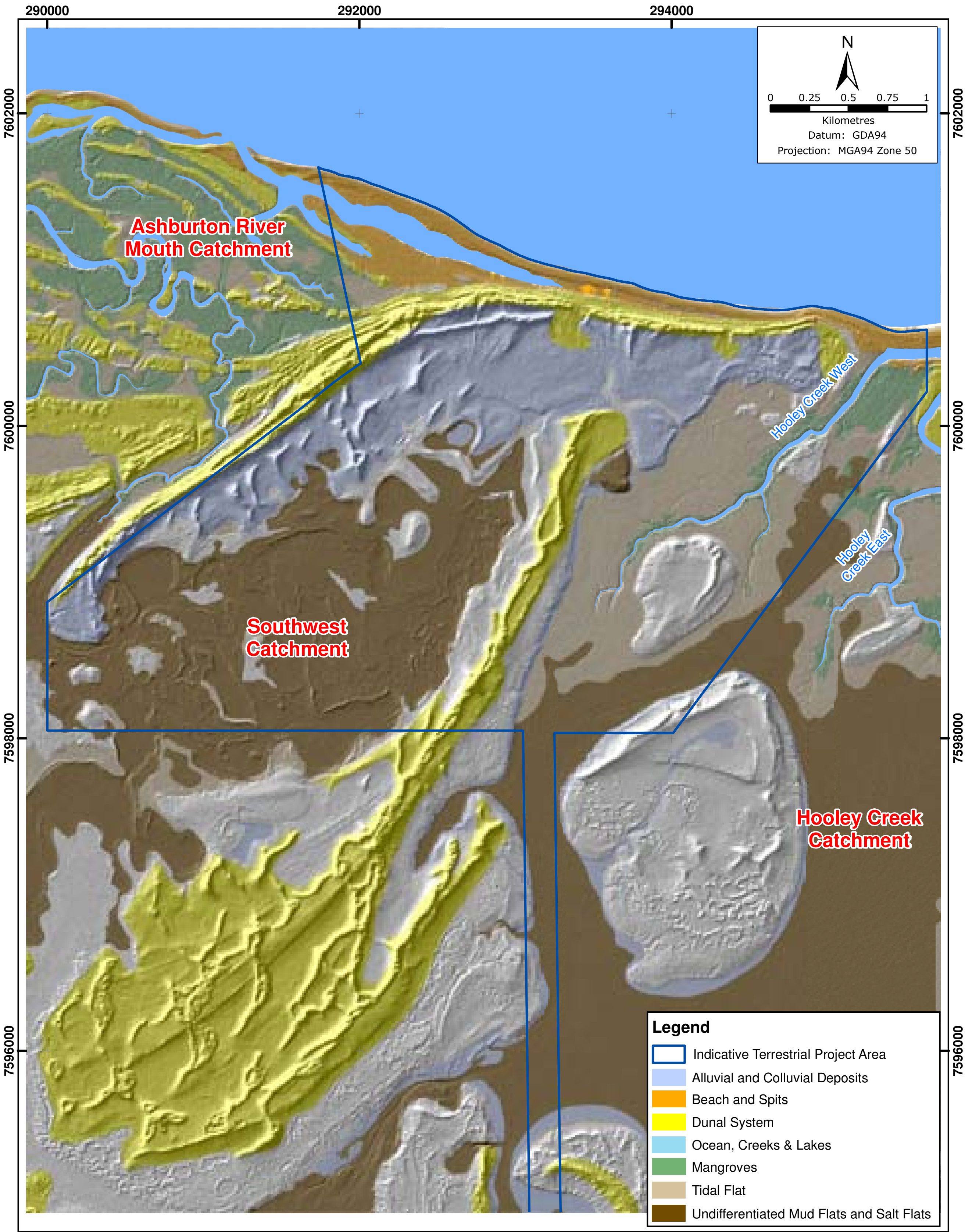

Client
CHEVRON AUSTRALIA PTY LTD

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Project
Wheatstone Project
Surface Water Studies

Title
Simplified Coastal Geomorphology

Drawn: MR
Approved: IGB
Date: 10/05/2010
Job No.: 42907466
File No.: 42907466-SW-004.mxd
Figure: 2-3
Rev. A
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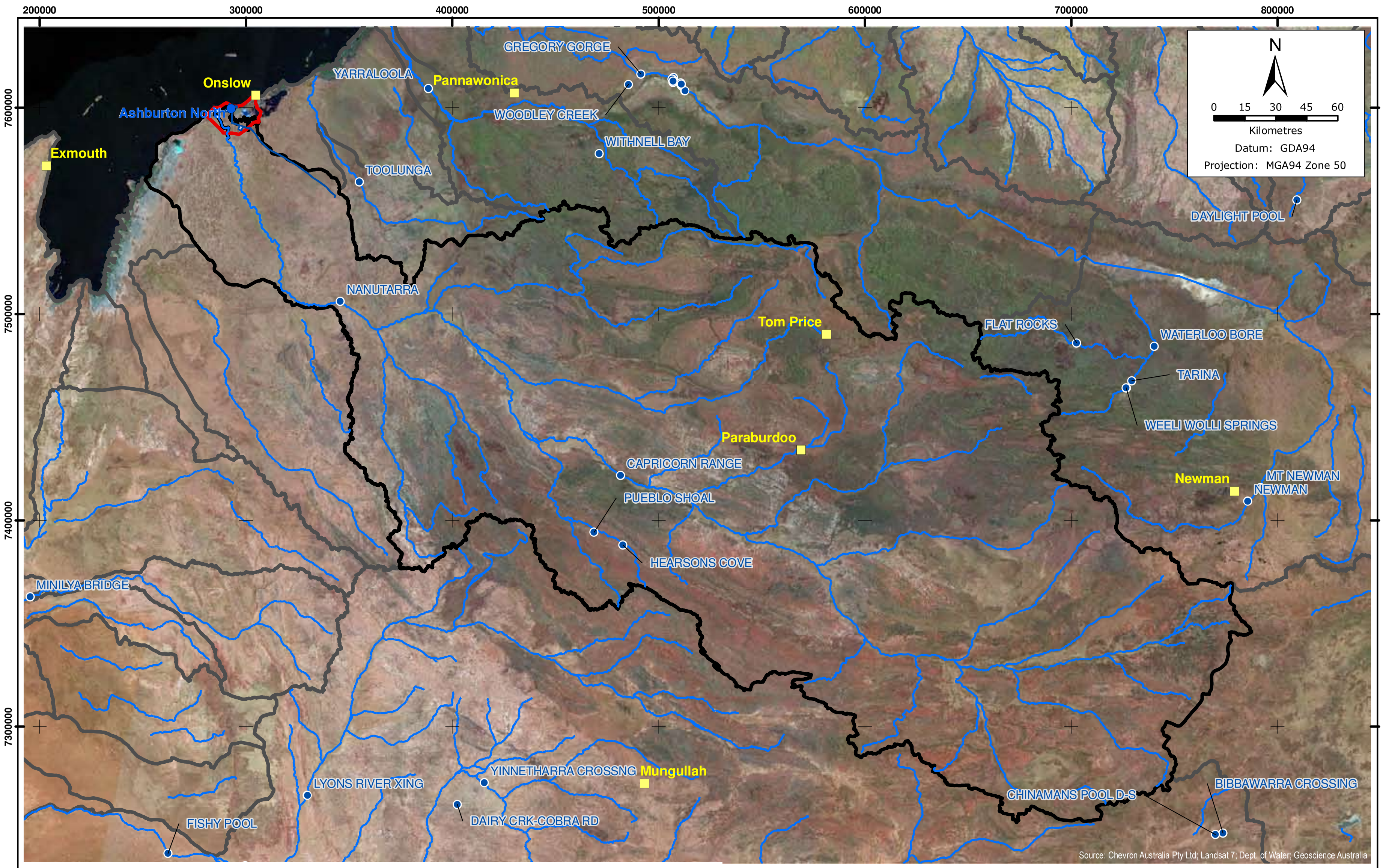

Source: Chevron Australia Pty Ltd; Landsat 7; Dept. of Water; Geoscience Australia

Legend

🟨	Townsite	🟦	Indicative Terrestrial Project Area	▢	Ashburton River Catchment
●	WIN Surface Water Sites - DoW	🟥	Ashburton River Delta Catchment	▢	Surface Water Catchments
—	Major Watercourses				

Client CHEVRON AUSTRALIA PTY LTD URS	Project Wheatstone Project Surface Water Studies			Title Ashburton River Catchment
	Drawn: RNM	Approved: IGB	Date: 10/05/2010	Figure: 2-4 — Rev. A — A4
	Job No.: 42907466	File No.: 42907466-SW-005.mxd		

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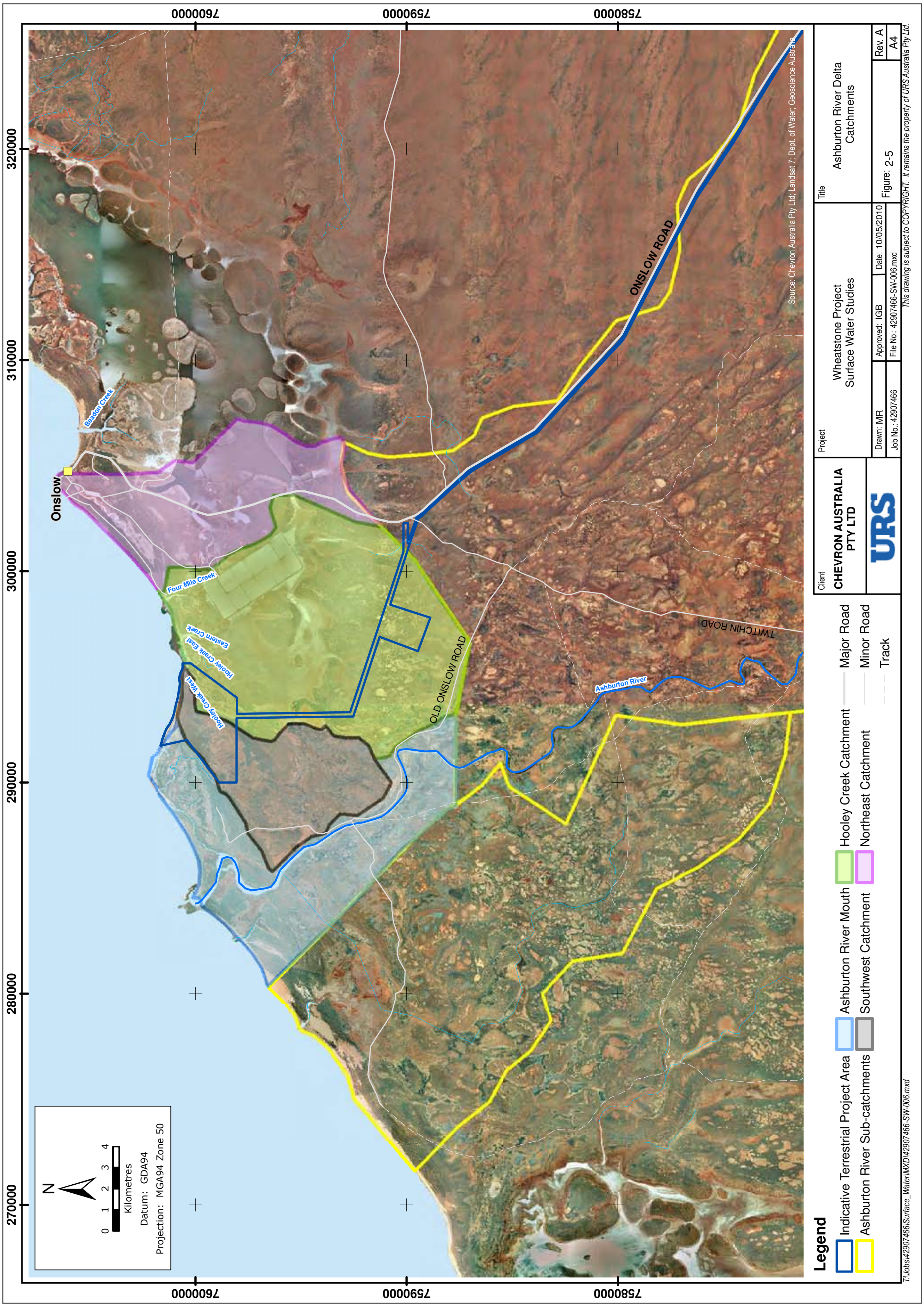
Onslow
Beadon Creek
Four Mile Creek
Eastern Creek
Hooley Creek East
Hooley Creek West
ONSLOW ROAD
OLD ONSLOW ROAD
TWITCHIN ROAD
Ashburton River
7600000
7590000
7580000
270000
280000
290000
300000
310000
320000
N
0 1 2 3 4
Kilometres
Datum: GDA94
Projection: MGA94 Zone 50
Source: Chevron Australia Pty Ltd; Landsat 7; Dept. of Water; Geoscience Australia
Legend
Indicative Terrestrial Project Area
Ashburton River Sub-catchments
Ashburton River Mouth
Southwest Catchment
Hooley Creek Catchment
Northeast Catchment
Major Road
Minor Road
Track
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project Surface Water Studies
Title
Ashburton River Delta Catchments
Drawn: MR
Approved: IGB
Date: 10/05/2010
Figure: 2-5
Rev. A
A4
Job No.: 42907466
File No.: 42907466-SW-006.mxd
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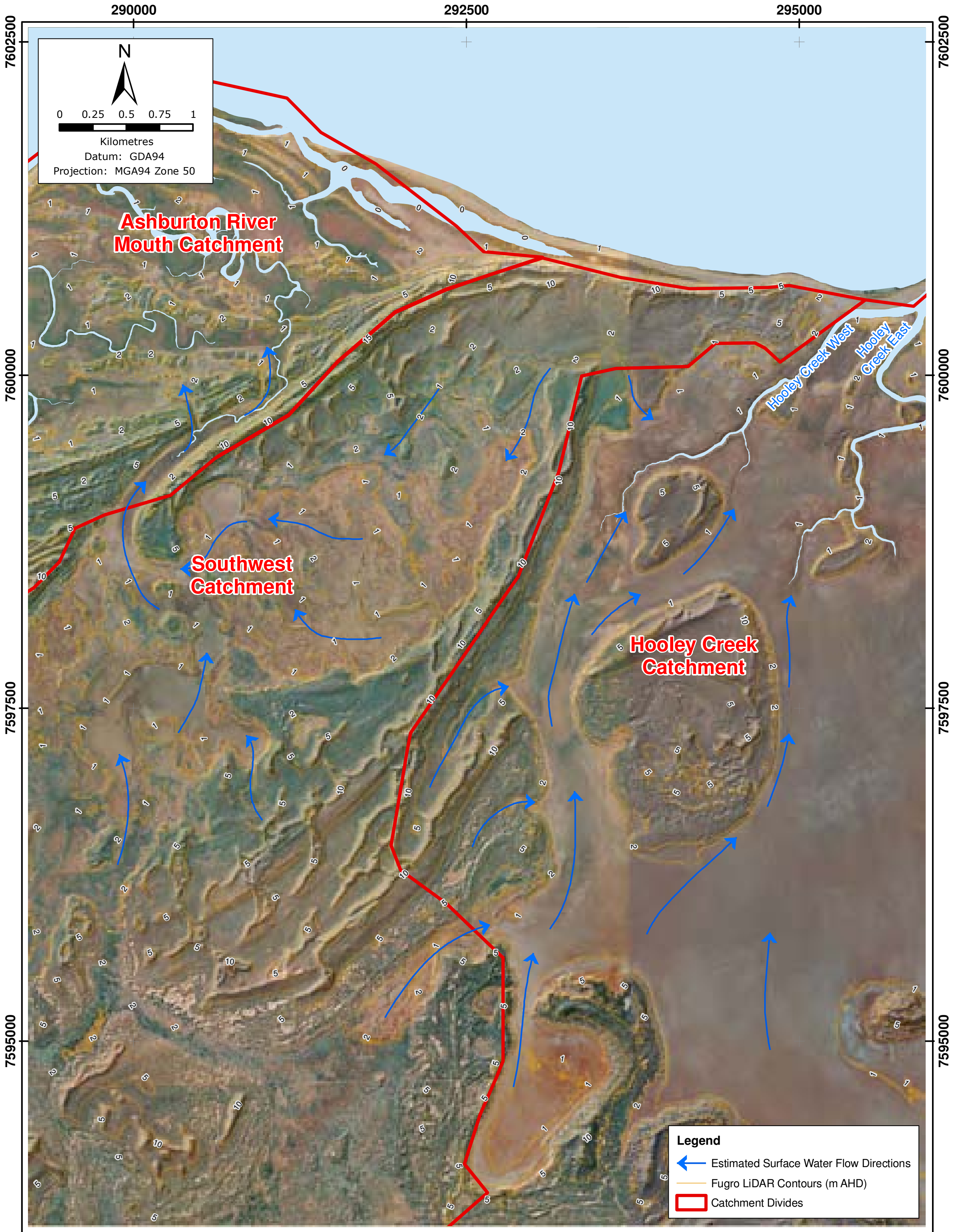

Client
CHEVRON AUSTRALIA PTY LTD

URS

Project
Wheatstone Project
Surface Water Studies

Title
Local Catchment Divides
and Surface Water
Flow Directions

Drawn: JL
Approved: IGB
Date: 10/05/2010
Job No.: 42907466
File No.: 42907466-SW-007.mxd
Figure: 2-6
Rev. A
A4

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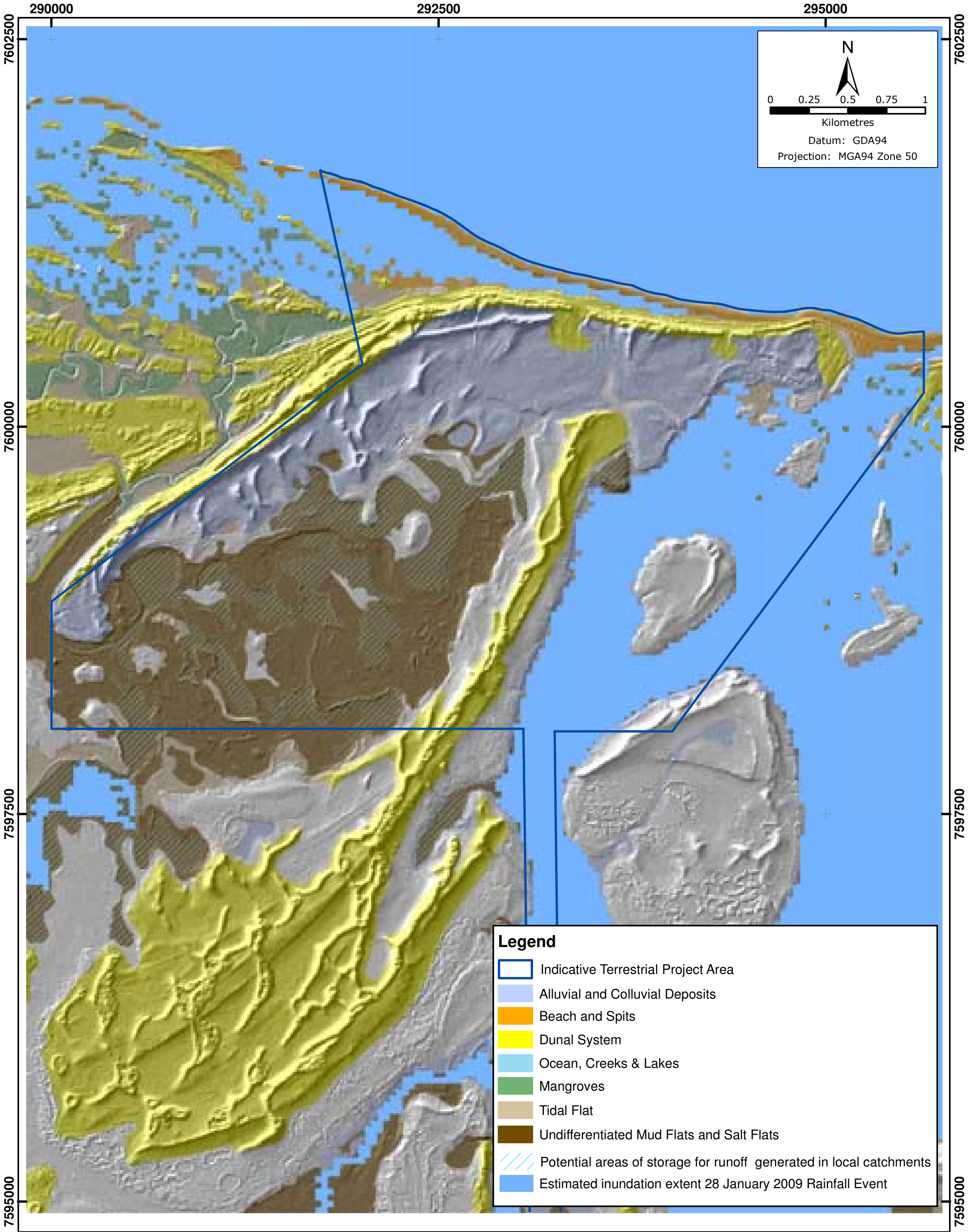

Client
CHEVRON AUSTRALIA PTY LTD

URS

Project
Wheatstone Project
Surface Water Studies

Title
Maximum Estimated Flooding from 28/01/09 1: 2 - Year ARI Rainfall Event with Tidal Record

Drawn: JL
Approved:IGB
Date: 10/05/2010
Job No.: 42907466
File No.:42907466-SW-008.mxd
Figure: 2-7
Rev.A
A4

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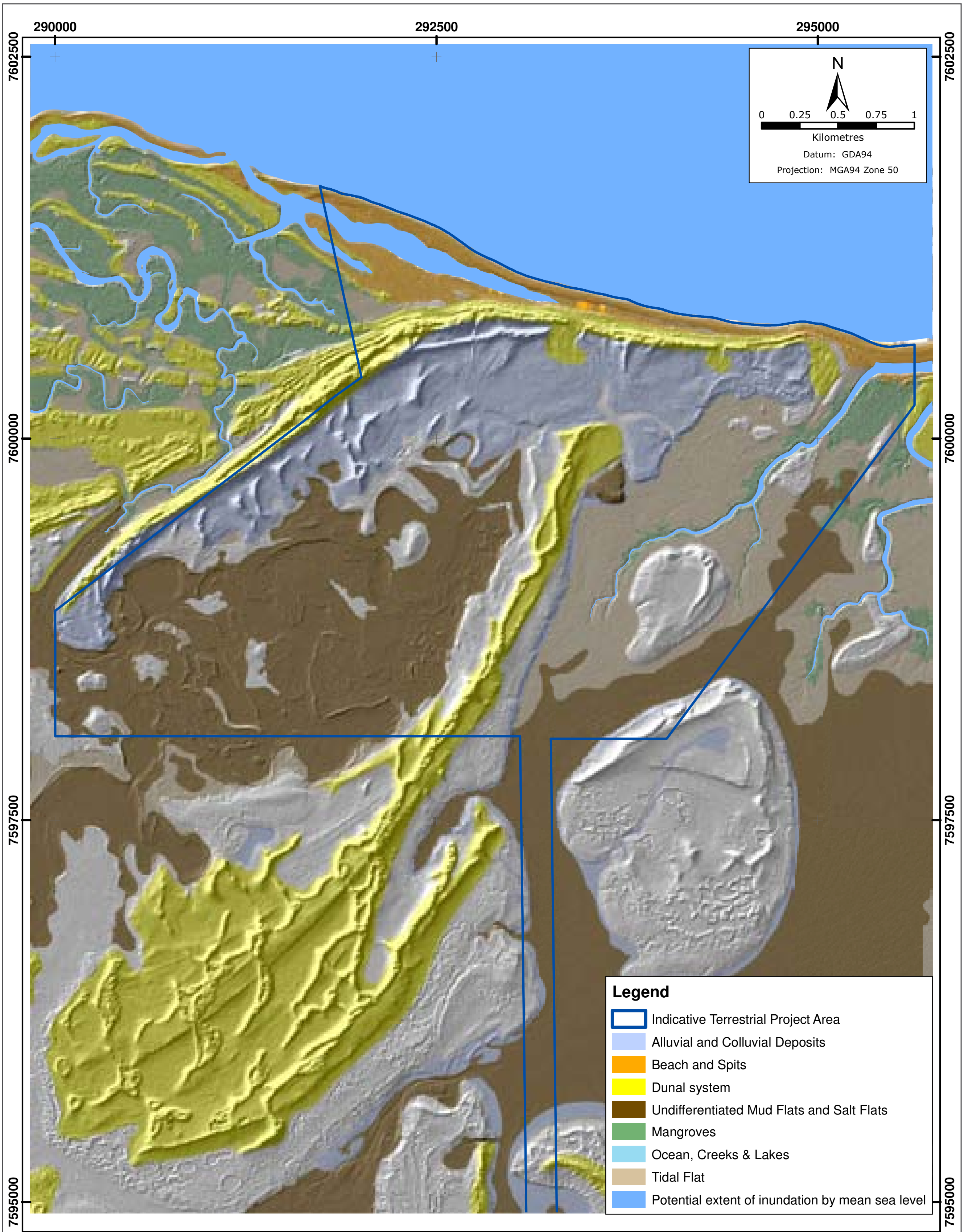

Client CHEVRON AUSTRALIA PTY LTD	Project Wheatstone Project Surface Water Studies		Title Indicative Terrestrial Projects Area With Mean Sea Level
URS	Drawn: JL	Approved:IGB	Date: 10/05/2010
	Job No.: 42907466	File No.:42907466-SW-009.mxd	Figure: 2-8 Rev.A A4

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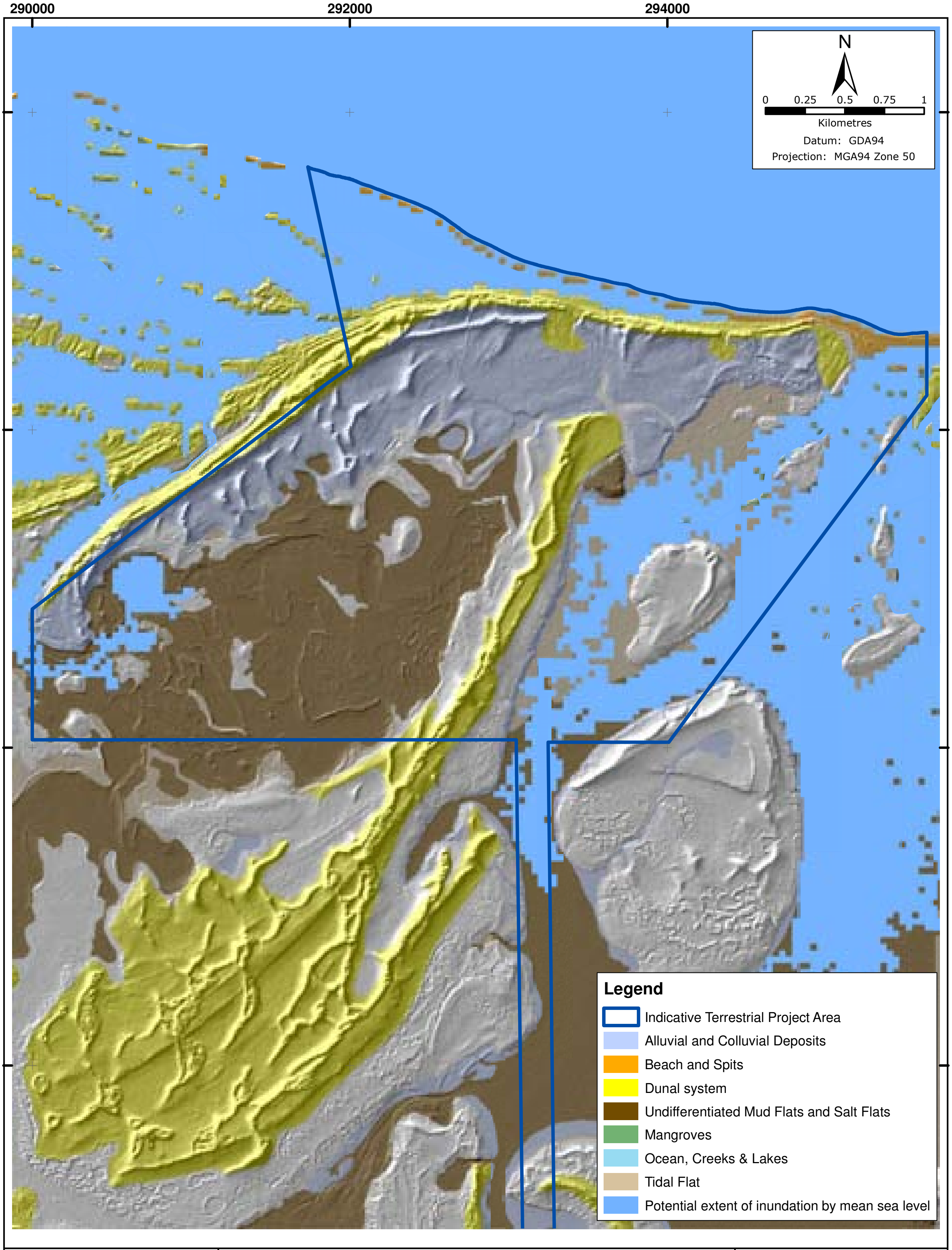

Client
CHEVRON AUSTRALIA PTY LTD

URS

Project
Wheatstone Project
Surface Water Studies

Title
Indicative Terrestrial Project Area Footprint With Highest Recorded Tide

Drawn: MR	Approved: IGB	Date: 11/05/2010	Figure: 2-9	Rev. A
Job No.: 42907100	File No.: 42907466-SW-010.mxd			A4

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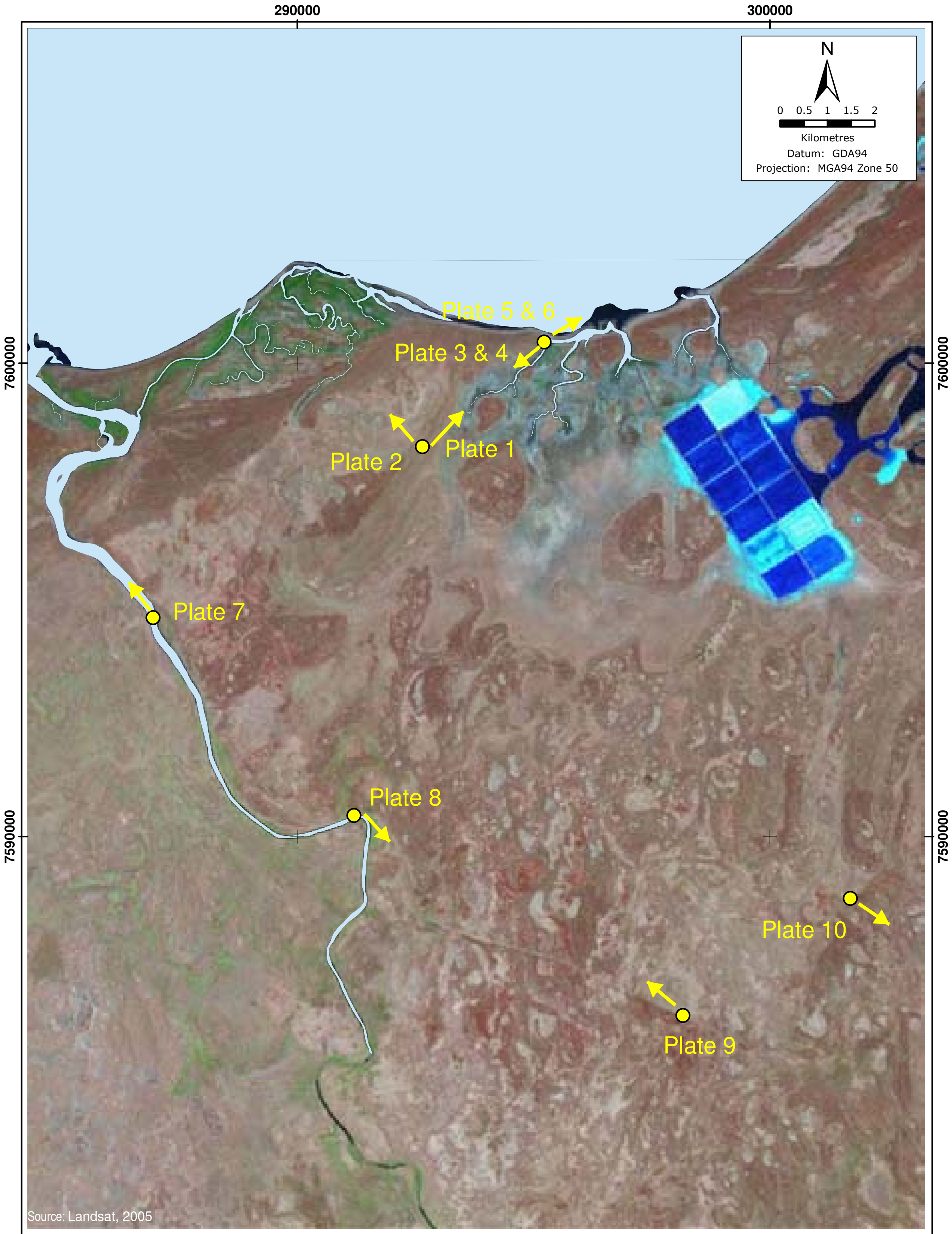

Source: Landsat, 2005

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Surface Water Studies	Photograph Sites and Direction of View	

URS

Drawn: MR	Approved: IGB	Date: 11/05/2010	Figure: 3-1	Rev. A
Job No.: 42907466	File No.: 42907466-SW-011.mxd			A4

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Plate 1: South-east area looing north-east at spring tide (Location E 0292648, S 7598233 at 11:51am 25/04/09)

Plate 2: South-west area looking north-east at spring tide (Location E 0292648, S 7598233 at 11:51am 25/04/09)

Client:	Project:		Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Surface Water Studies		Photograph Sites Plates 1 and 2	
URS	Drawn: MOS	Approved: IGB	Date: 11/05/2010	Figure: 3-2	Rev. A
	Job No. 42907466	File No. 42907466-SW-010.xls			A4

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Plate 3

Plate 4

Plate 5

Plate 6

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Surface Water Studies	Title: Photograph Sites Plates 3, 4, 5 and 6
URS	Drawn: MOS Job No. 42907466	Approved: IGB File No. 42907466-SW-009.xls

Date: 11/05/2010

Figure: 3-3

Rev. A

A4

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Plate 7

Plate 8

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Surface Water Studies		Title: Photograph Sites Plates 7 and 8
URS	Drawn: MOS	Approved: IGB	Date: 11/05/2010
	Job No. 42907466	File No. 42907466-SW-008.xls	Figure: 3-4
			Rev. A A4

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Plate 9


Plate 10

Client:	Project:	Title:
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Surface Water Studies	Photograph Sites Plates 9 and 10
URS	Drawn: MOS Job No. 42907466	Approved: IGB File No. 42907466-SW-007.xls

Date: 11/05/2010	Figure: 3-5	Rev. A A4

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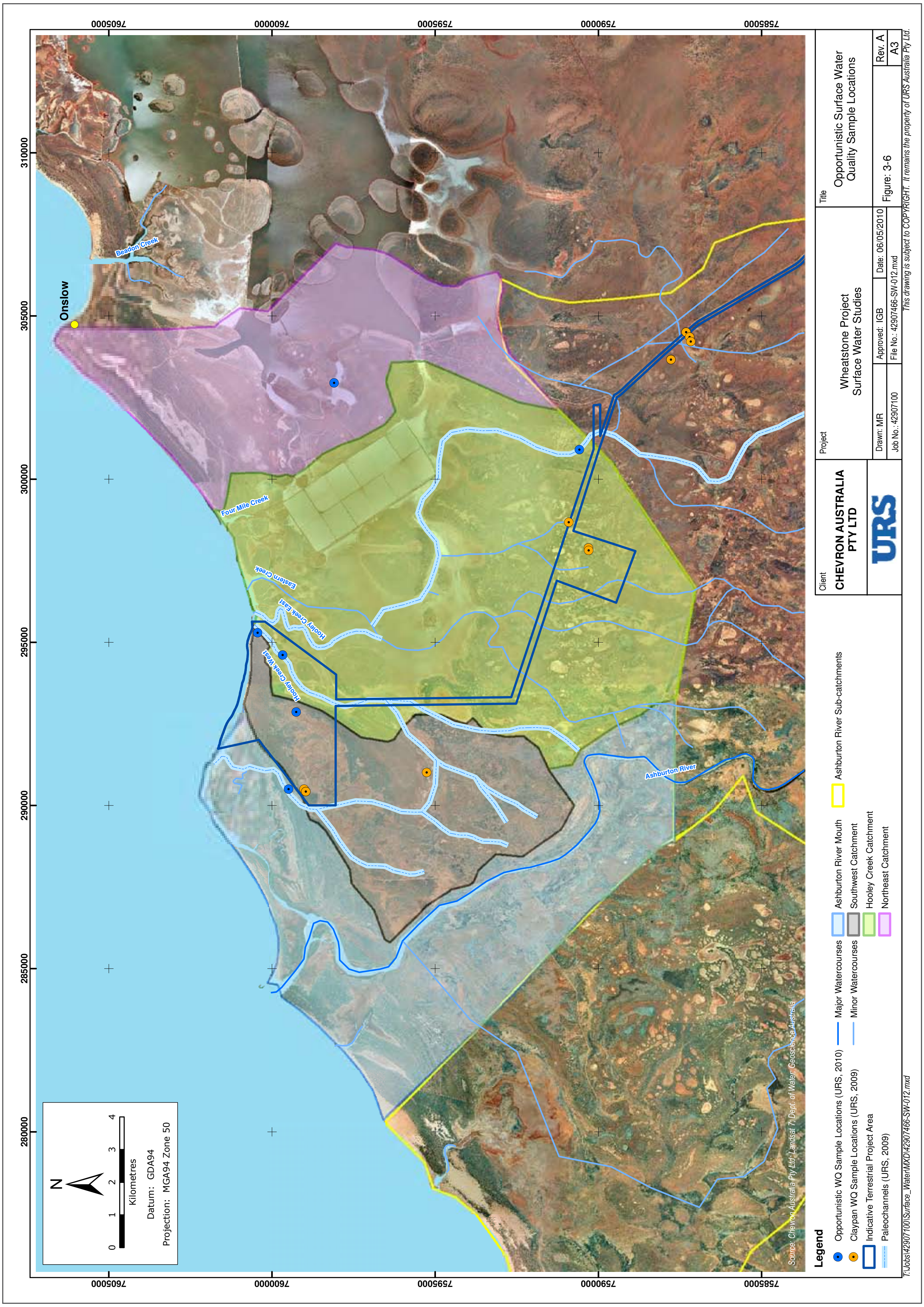
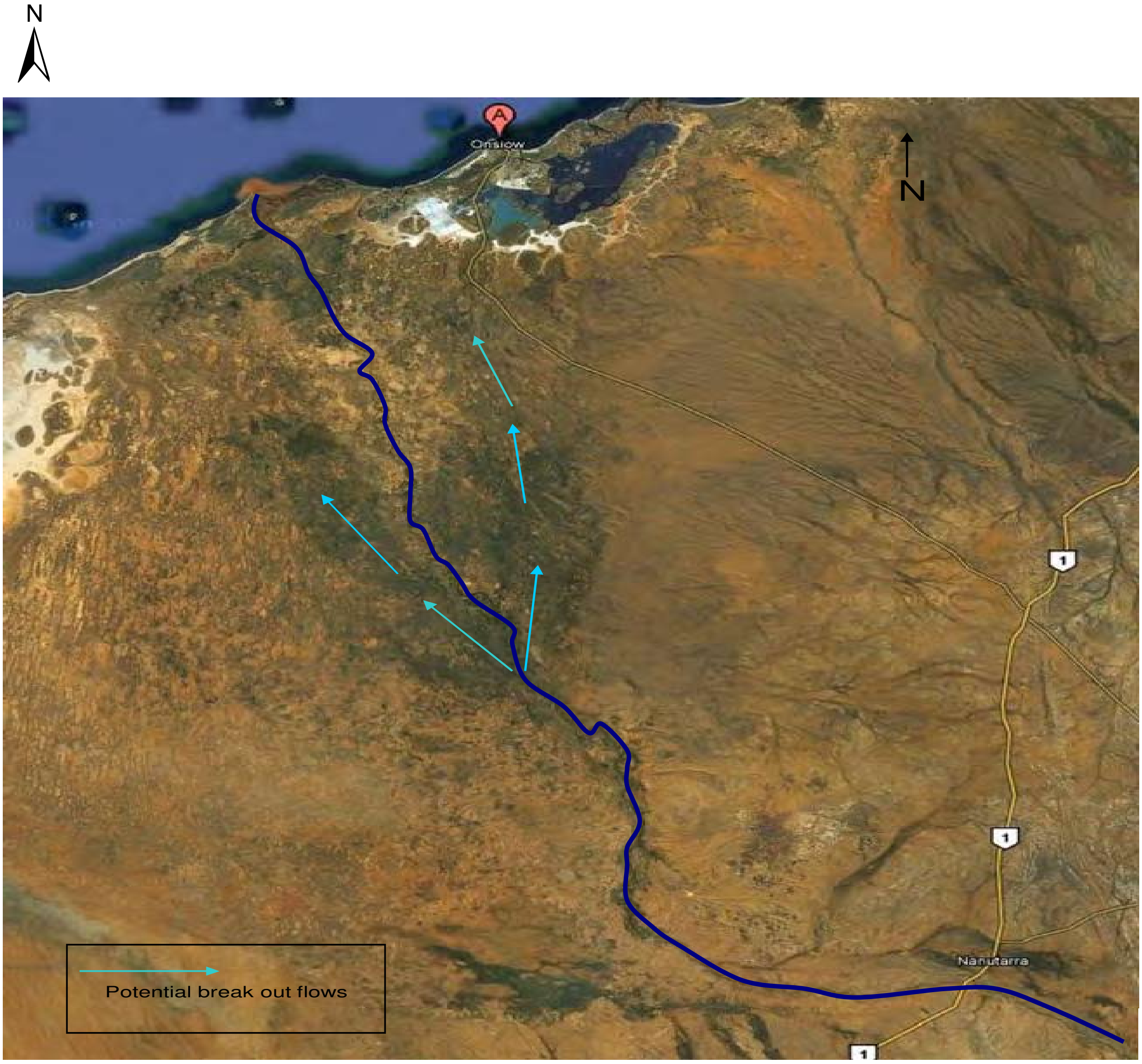


Opportunistic Surface Water Quality Sample Locations

Figure: 3-6

Source: Chevron Australia Pty Ltd; Landsat 7; Dept. of Water; Geoscience Australia



Note: Schematic, not to scale.

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Surface Water Studies	Title: Satellite Image showing Potential Breakout Flows from the Ashburton River
URS	Drawn: AM Approved: IGB Date: 5/05/2010 Job No. 42907466 File No. 42907466-SW-012.xls	Figure: 4-1 Rev. A A4

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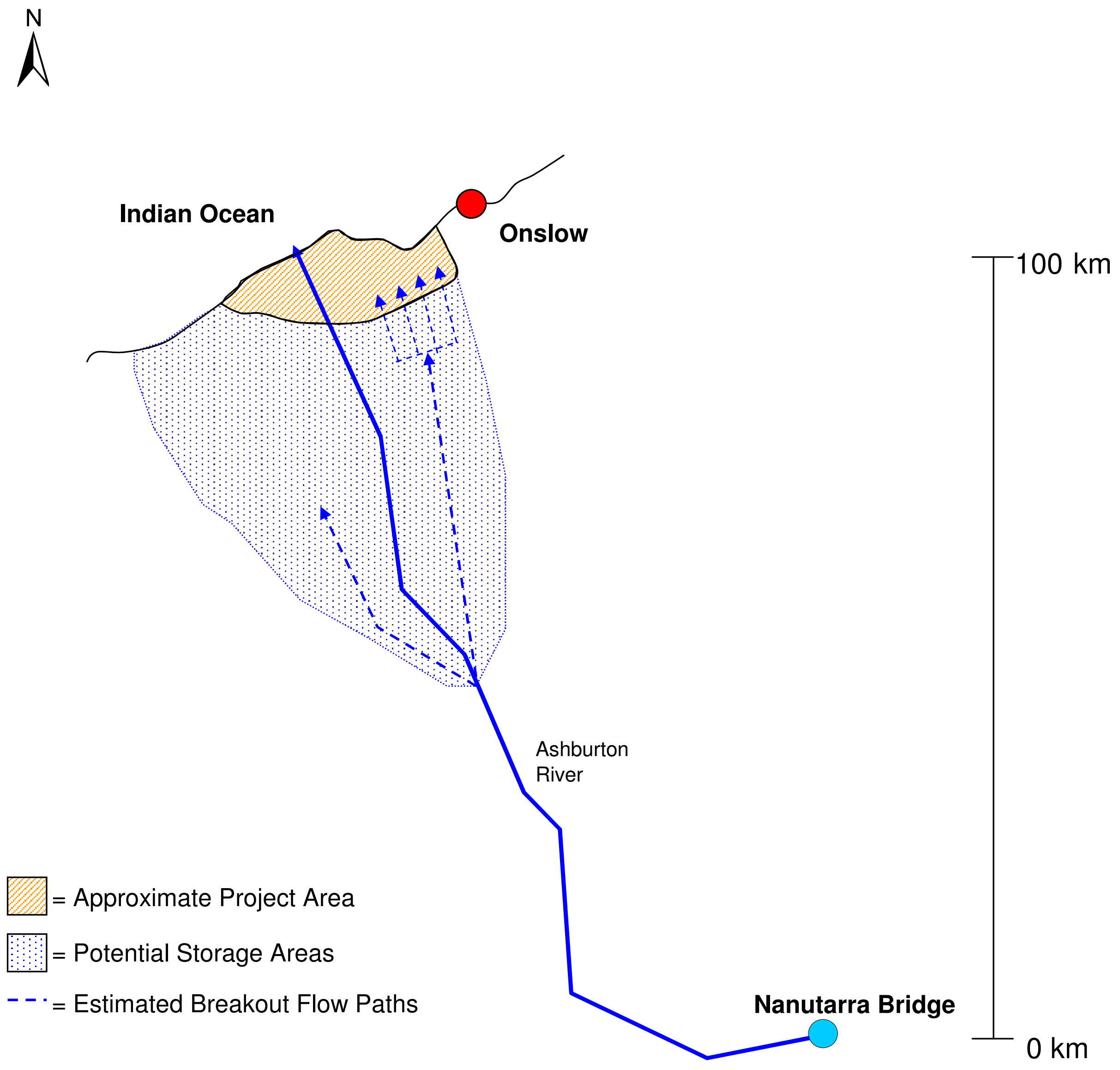

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Surface Water Studies	Title: Conceptual Model of the Ashburton River - Nanutarra Bridge to the River Mouth

URS	Drawn: AM	Approved: IGB	Date: 5/05/2010	Figure: 4-2	Rev. A
	Job No. 42907466	File No. 42097466-SW-013.xls			A4

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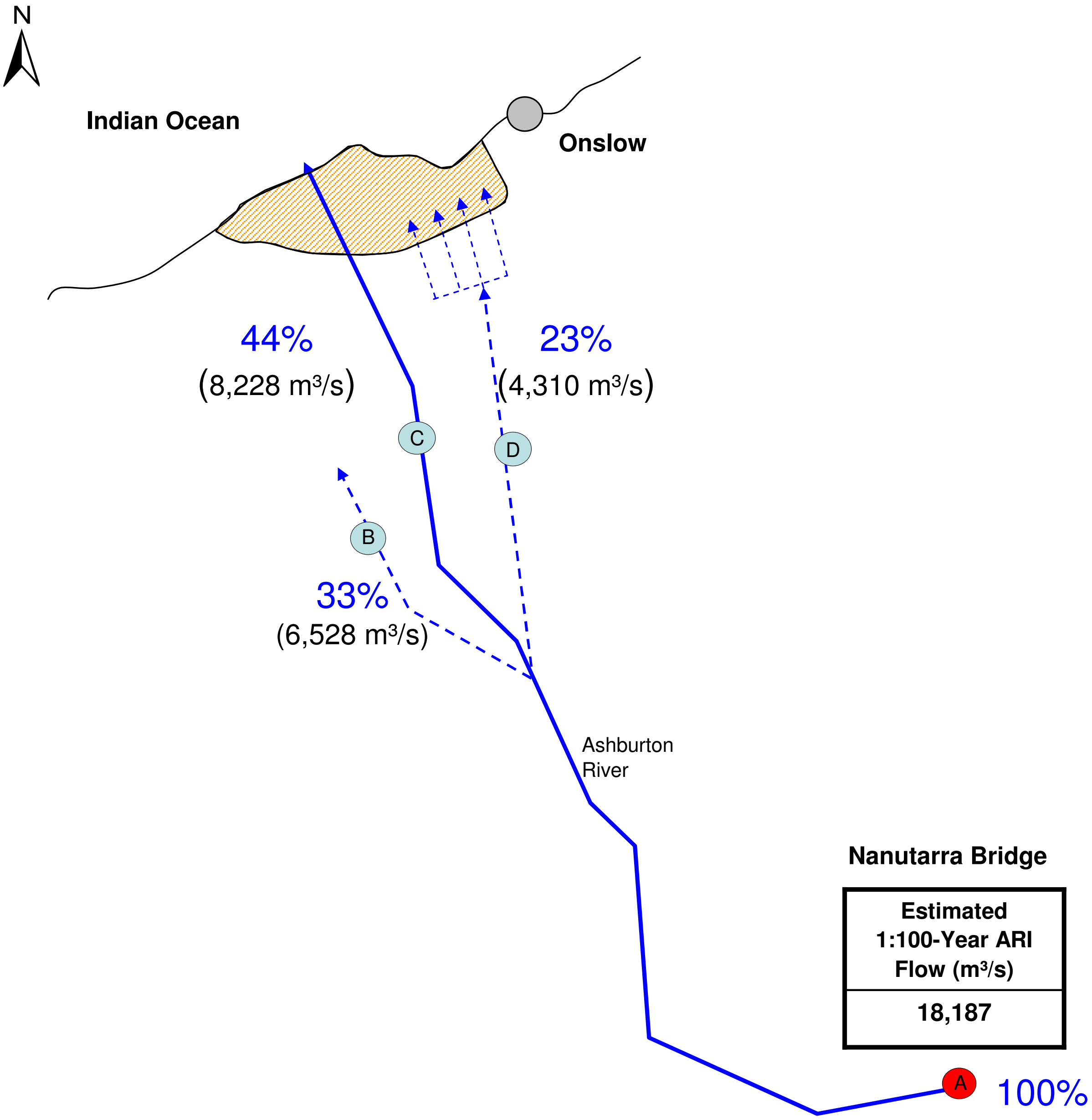

Client:
CHEVRON AUSTRALIA PTY LTD

Project:
Wheatstone Project
Surface Water Studies

Title:
Conceptual Flow Distribution for a 1:100 - Year ARI Event

Drawn: AM
Approved: IGB
Date: 5/05/2010
Job No. 42907466
File No. 42907466-SW-014.xls
Figure: 4-3
Rev. A
A4

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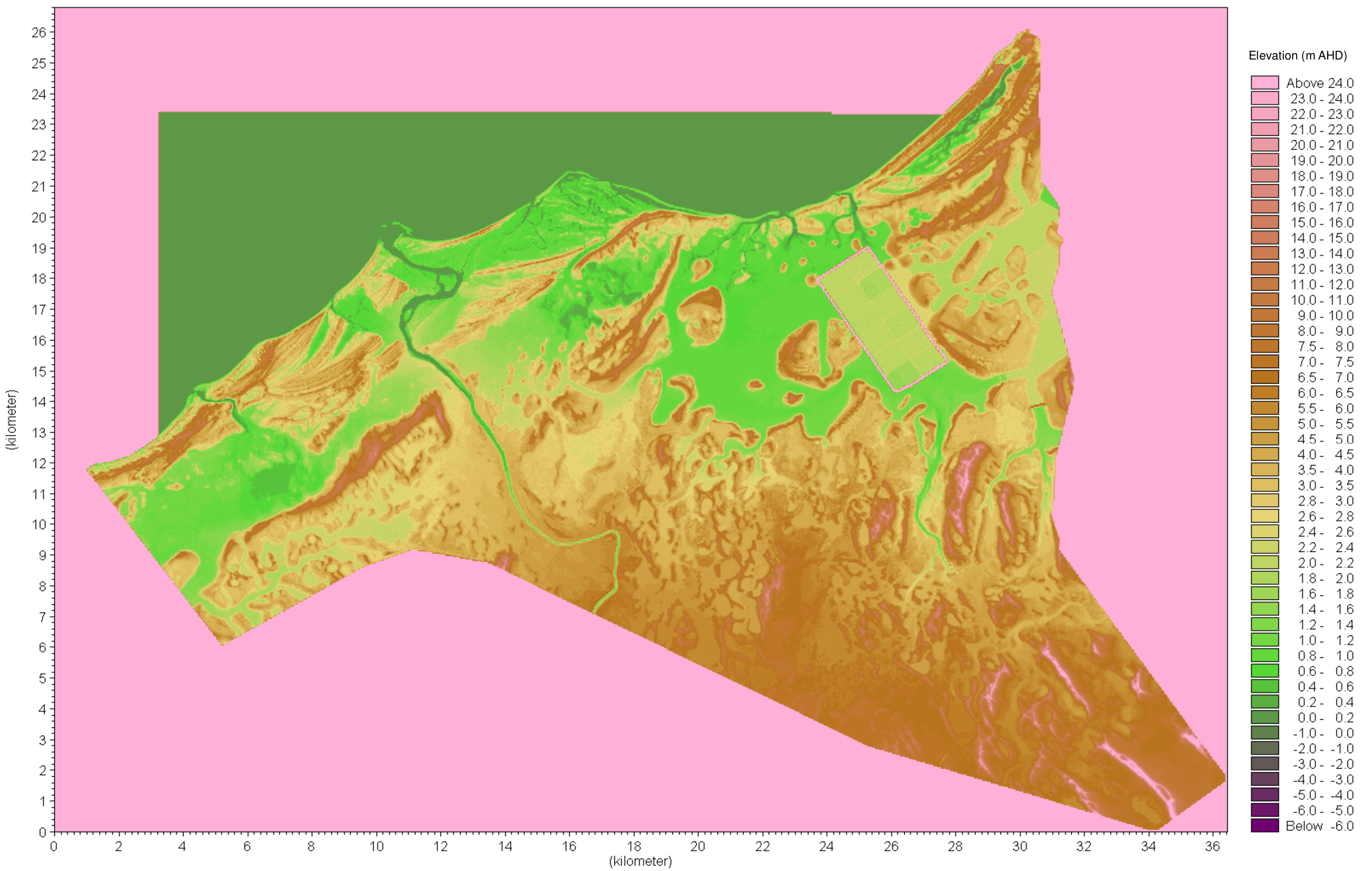

Client:
CHEVRON AUSTRALIA PTY LTD

URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Hydraulic Model Domain

Drawn: AM
Approved: IGB
Date: 18/05/2010
Job No. 42907466
File No. 42907466-SW-015.xls
Figure: 4-4
Rev. A
A4

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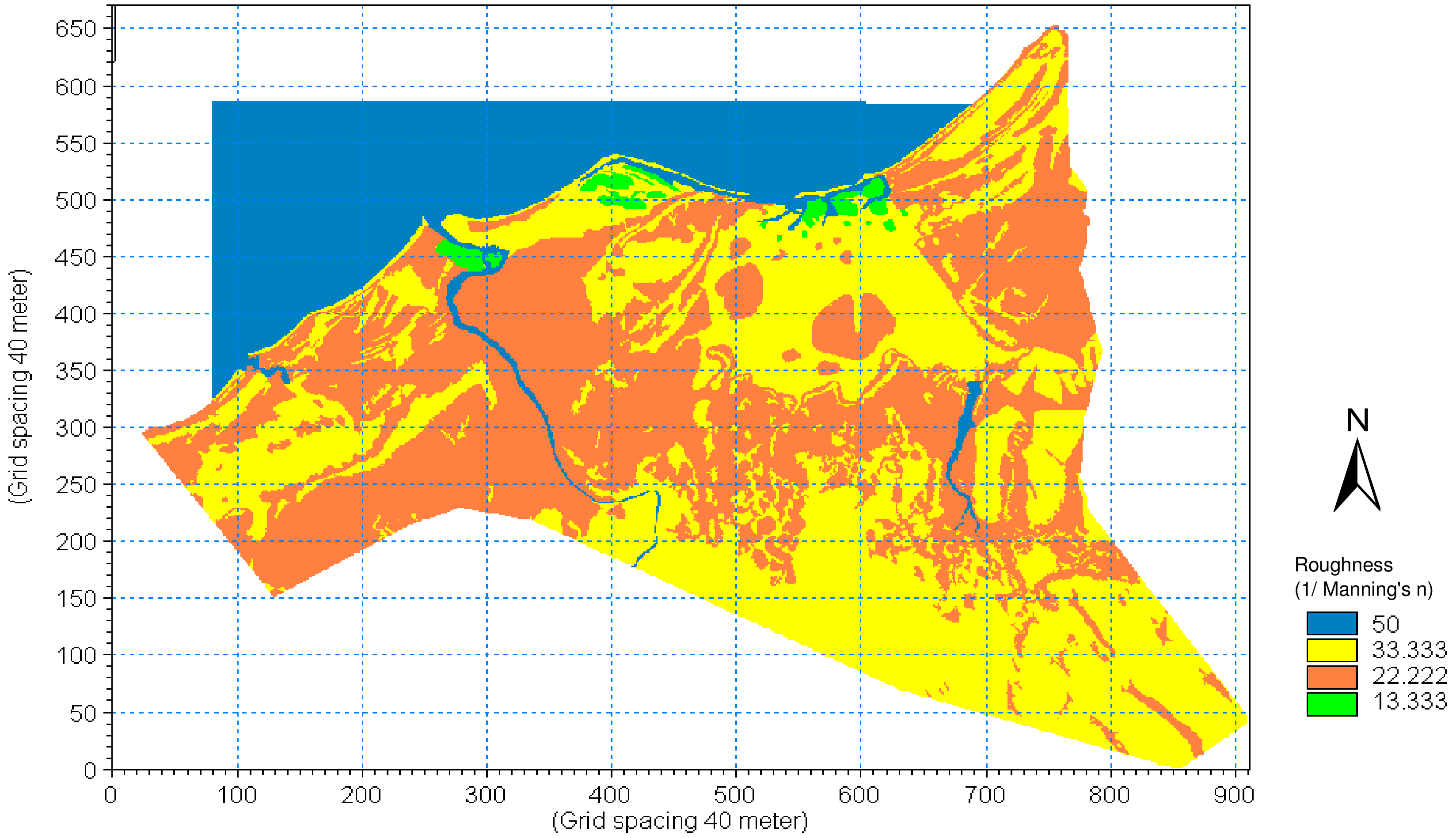

Client:
CHEVRON AUSTRALIA PTY LTD

URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Hydraulic Model Roughness Map

Drawn: AM
Approved: IGB
Date: 18/05/2010
Job No. 42907466
File No. 42907466-SW-016.xls
Figure: 4-5
Rev. A
A4

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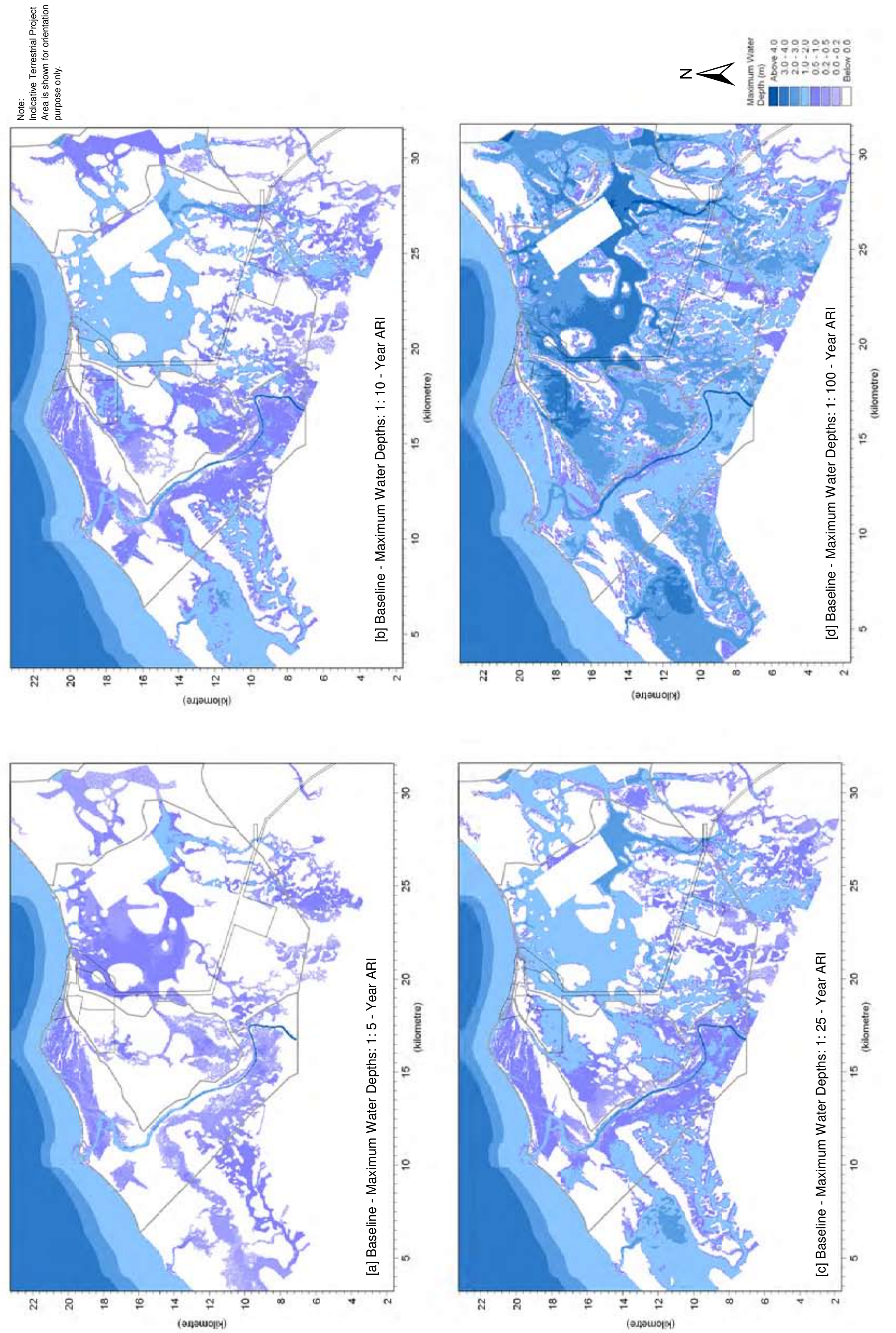

Client: **CHEVRON AUSTRALIA PTY LTD**

Project: Wheatstone Project Surface Water Studies

Title: Baseline Characteristics - Simulated Maximum Water Depths (Standard Tide)

Drawn: MOS | Approved: IGB | Date: 11/05/2010

Job No. 42907466 | File No. 42907466-SW-001.xls

Figure: 4-6 | Rev. A | A3

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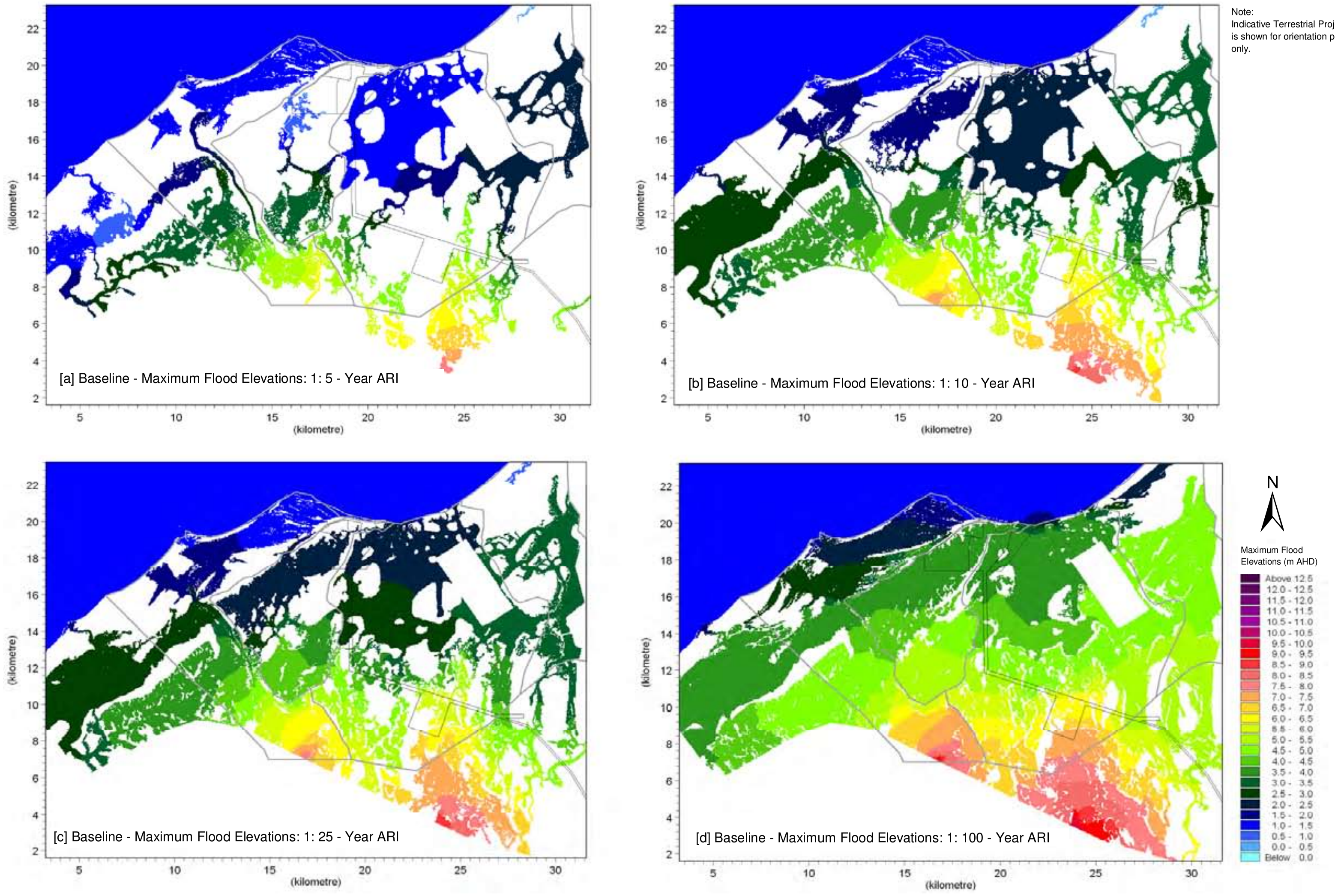
Note:
Indicative Terrestrial Project Area is shown for orientation purpose only.


[a] Baseline - Maximum Flood Elevations: 1: 5 - Year ARI

[b] Baseline - Maximum Flood Elevations: 1: 10 - Year ARI

[c] Baseline - Maximum Flood Elevations: 1: 25 - Year ARI

[d] Baseline - Maximum Flood Elevations: 1: 100 - Year ARI

Client:
CHEVRON AUSTRALIA PTY LTD

Project:
Wheatstone Project
Surface Water Studies

Title:
Baseline Characteristics -
Simulated Maximum Flood Elevations
(Standard Tide)

Drawn: JB
Approved: IGB
Date: 11/05/2010
Job No. 42907466
File No. 42907466-SW-002.xls
Figure: 4-7
Rev. A
A3

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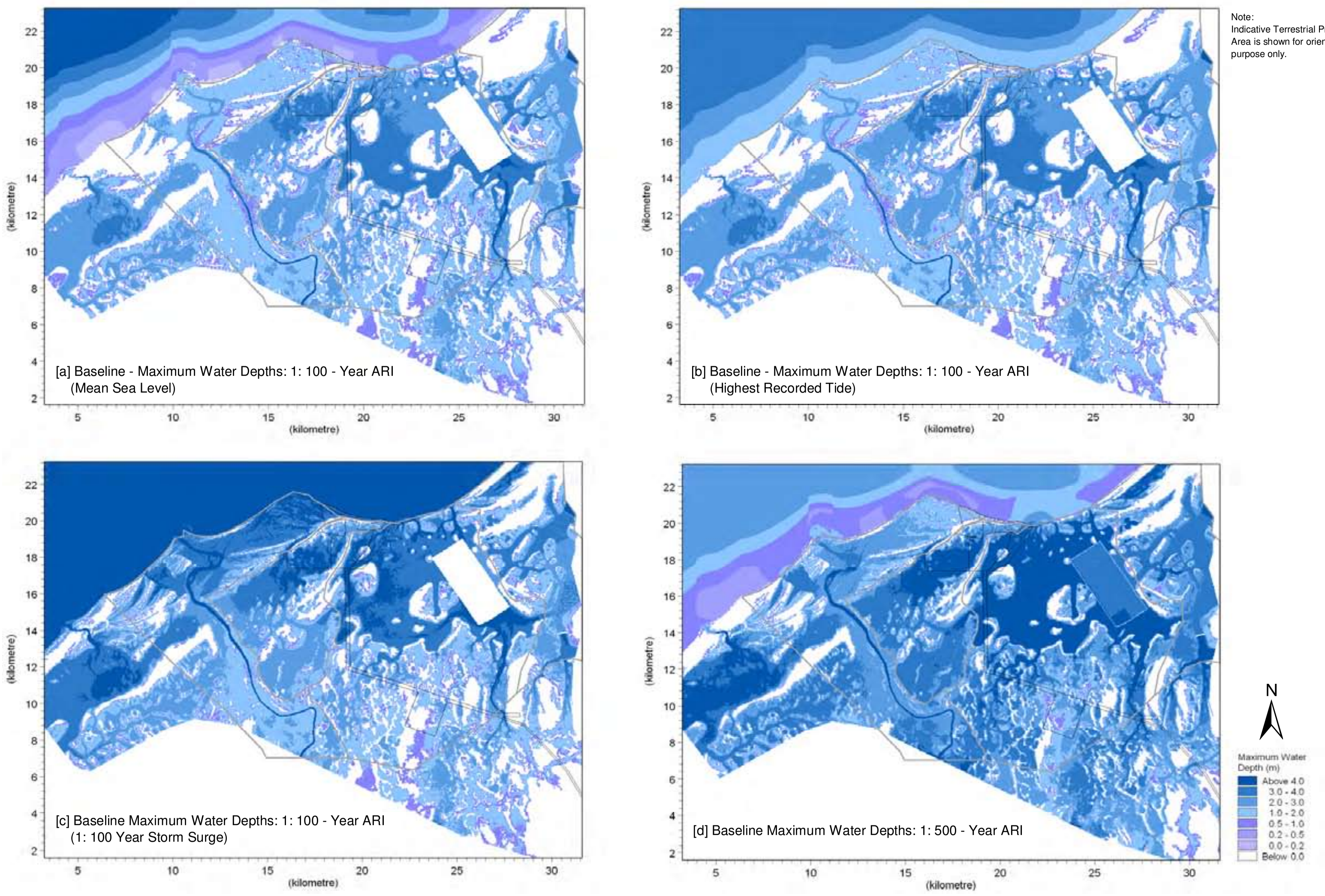

[a] Baseline - Maximum Water Depths: 1: 100 - Year ARI
(Mean Sea Level)

[b] Baseline - Maximum Water Depths: 1: 100 - Year ARI
(Highest Recorded Tide)

[c] Baseline Maximum Water Depths: 1: 100 - Year ARI
(1: 100 Year Storm Surge)

[d] Baseline Maximum Water Depths: 1: 500 - Year ARI

Client:
CHEVRON AUSTRALIA PTY LTD
URS

Project:
Wheatstone Project
Surface Water Studies

Drawn: MOS
Approved: IGB
Date: 11/05/2010
Job No. 42907466
File No. 42907466-SW-003.xls

Title:
Baseline Characteristics -
Simulated Maximum Water Depths
(Extreme Events)

Figure: 4-8
Rev. A
A3

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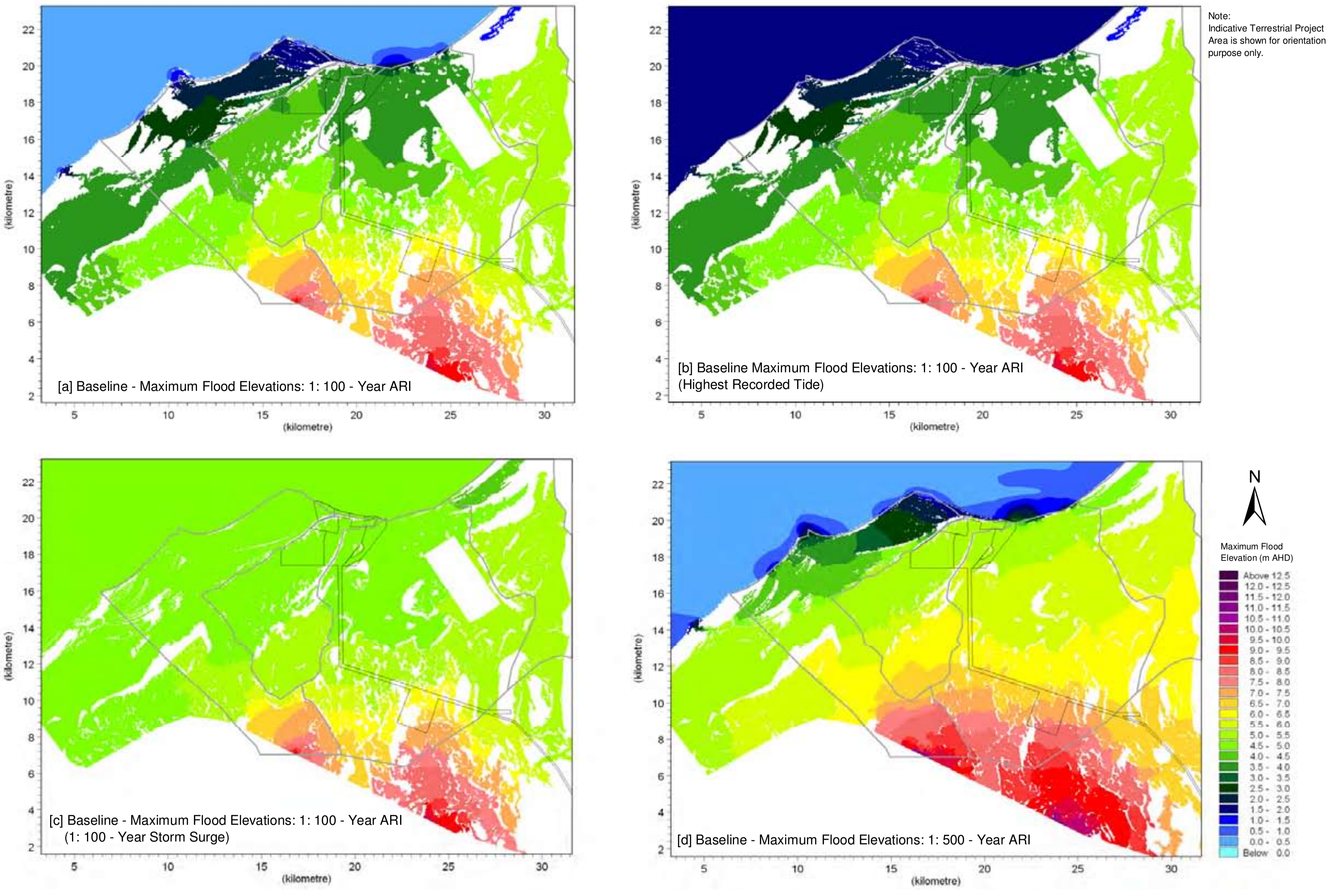

[a] Baseline - Maximum Flood Elevations: 1: 100 - Year ARI

[b] Baseline Maximum Flood Elevations: 1: 100 - Year ARI
(Highest Recorded Tide)

[c] Baseline - Maximum Flood Elevations: 1: 100 - Year ARI
(1: 100 - Year Storm Surge)

[d] Baseline - Maximum Flood Elevations: 1: 500 - Year ARI

Note:
Indicative Terrestrial Project Area is shown for orientation purpose only.

Client:
CHEVRON AUSTRALIA PTY LTD

URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Baseline Characteristics -
Simulated Maximum Flood Elevations
(Extreme Events)

Drawn: MOS
Approved: IGB
Date: 11/05/2010
Job No. 42907466
File No. 42907466-SW-004.xls
Figure: 4-9
Rev. A
A3

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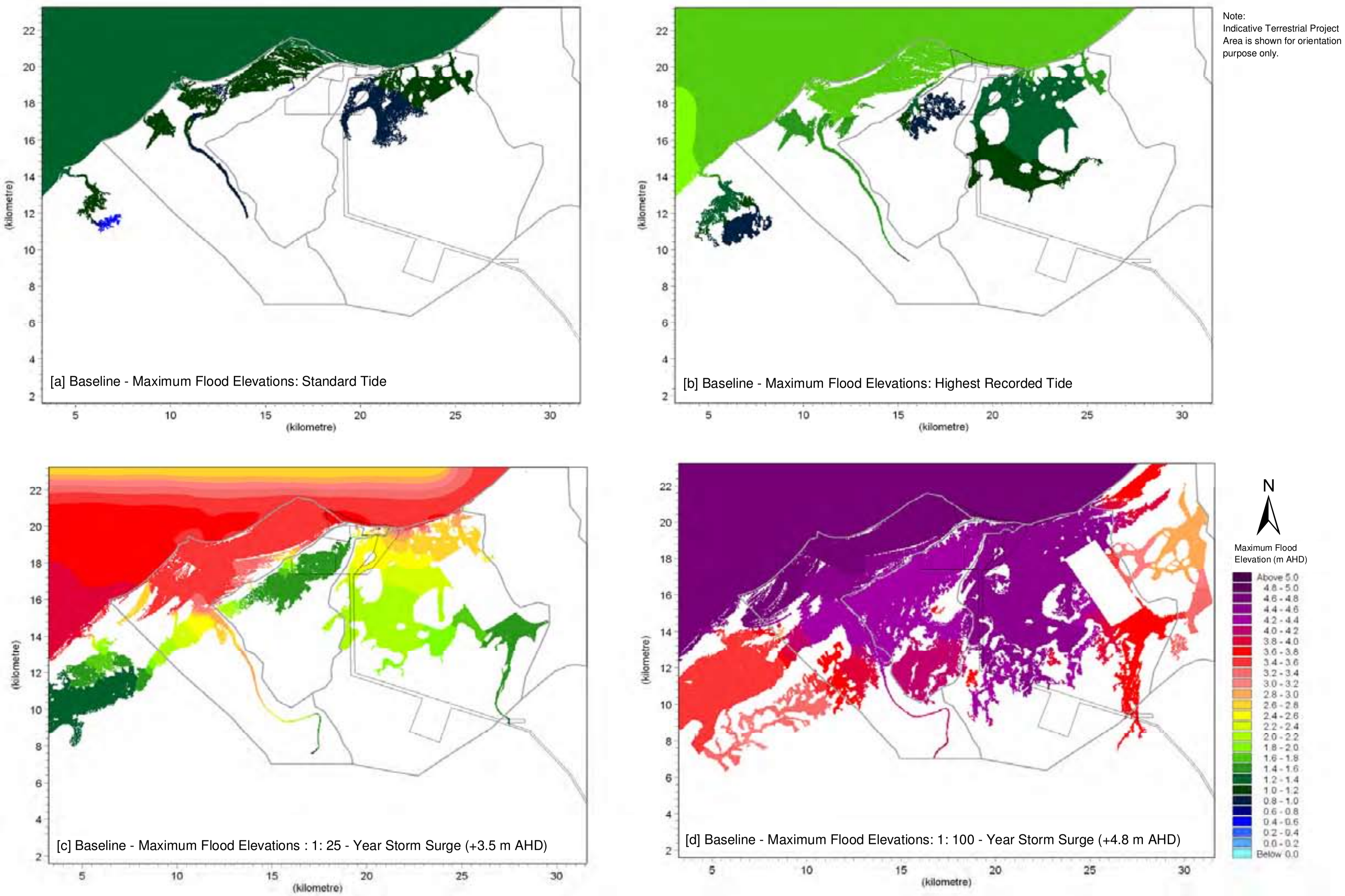
Note:
Indicative Terrestrial Project Area is shown for orientation purpose only.



[a] Baseline - Maximum Flood Elevations: Standard Tide

[b] Baseline - Maximum Flood Elevations: Highest Recorded Tide

[c] Baseline - Maximum Flood Elevations : 1: 25 - Year Storm Surge (+3.5 m AHD)

[d] Baseline - Maximum Flood Elevations: 1: 100 - Year Storm Surge (+4.8 m AHD)

Client:
CHEVRON AUSTRALIA PTY LTD

Project:
Wheatstone Project
Surface Water Studies

Title:
Baseline Characteristics -
Simulated Maximum Flood Elevations
(Various Tides and Storm Surges)

Drawn: MOS
Approved: IGB
Date: 11/05/2010
Figure: 4-10
Rev. A
Job No. 42907466
File No. 42907466-SW-005.xls
A3

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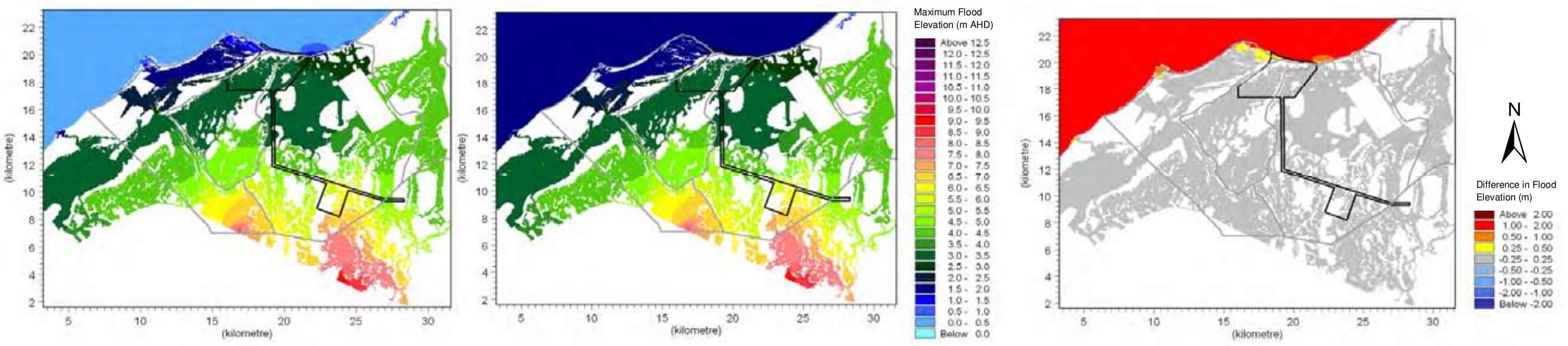
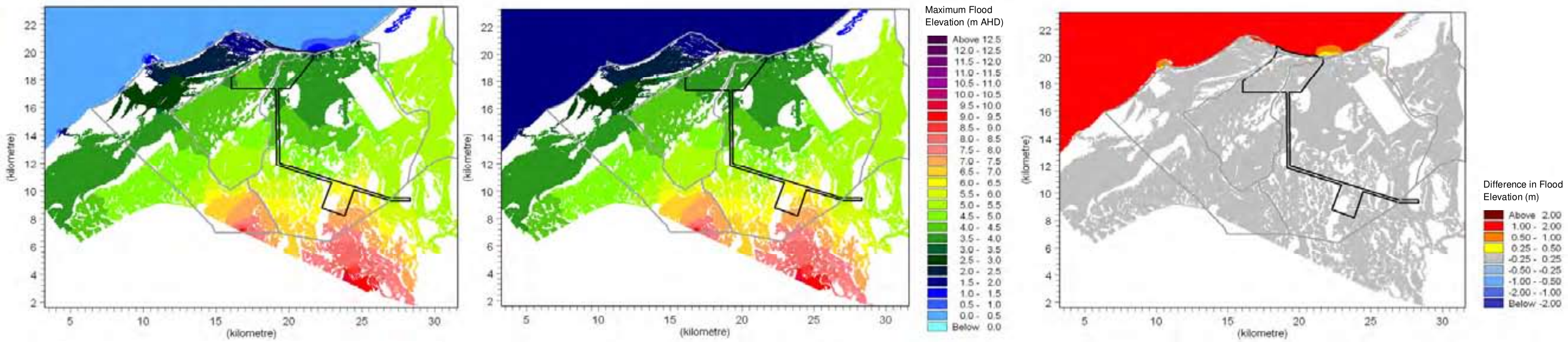


[a] Baseline - Maximum Flood Elevations: 1: 25 - Year ARI
(Mean Sea Level)

[b] Baseline - Maximum Flood Elevations: 1: 25 - Year ARI
(Highest Recorded Tide)

[c] Baseline - Change in Maximum Flood Elevations: 1: 25 - Year ARI
(Highest Recorded Tide minus Mean Sea Level)

Note:
Indicative Terrestrial Project Area is shown for orientation purpose only.



[d] Baseline - Maximum Flood Elevations: 1: 100 - Year ARI
(Mean Sea Level)

[e] Baseline - Maximum Flood Elevations: 1: 100 - Year ARI
(Highest Recorded Tide)

[f] Baseline - Change in Maximum Flood Elevations: 1: 100 - Year ARI
(Highest Recorded Tide minus Mean Sea Level)

Client:	Project:			Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Surface Water Studies			Baseline Characteristics - Simulated Tidal Influence on Flood Elevations	
URS	Drawn: MOS	Approved: IGB	Date: 11/05/2010	Figure: 4-11	Rev. A
	Job No. 42907466	File No. 42907466-SW-006.xls			A3

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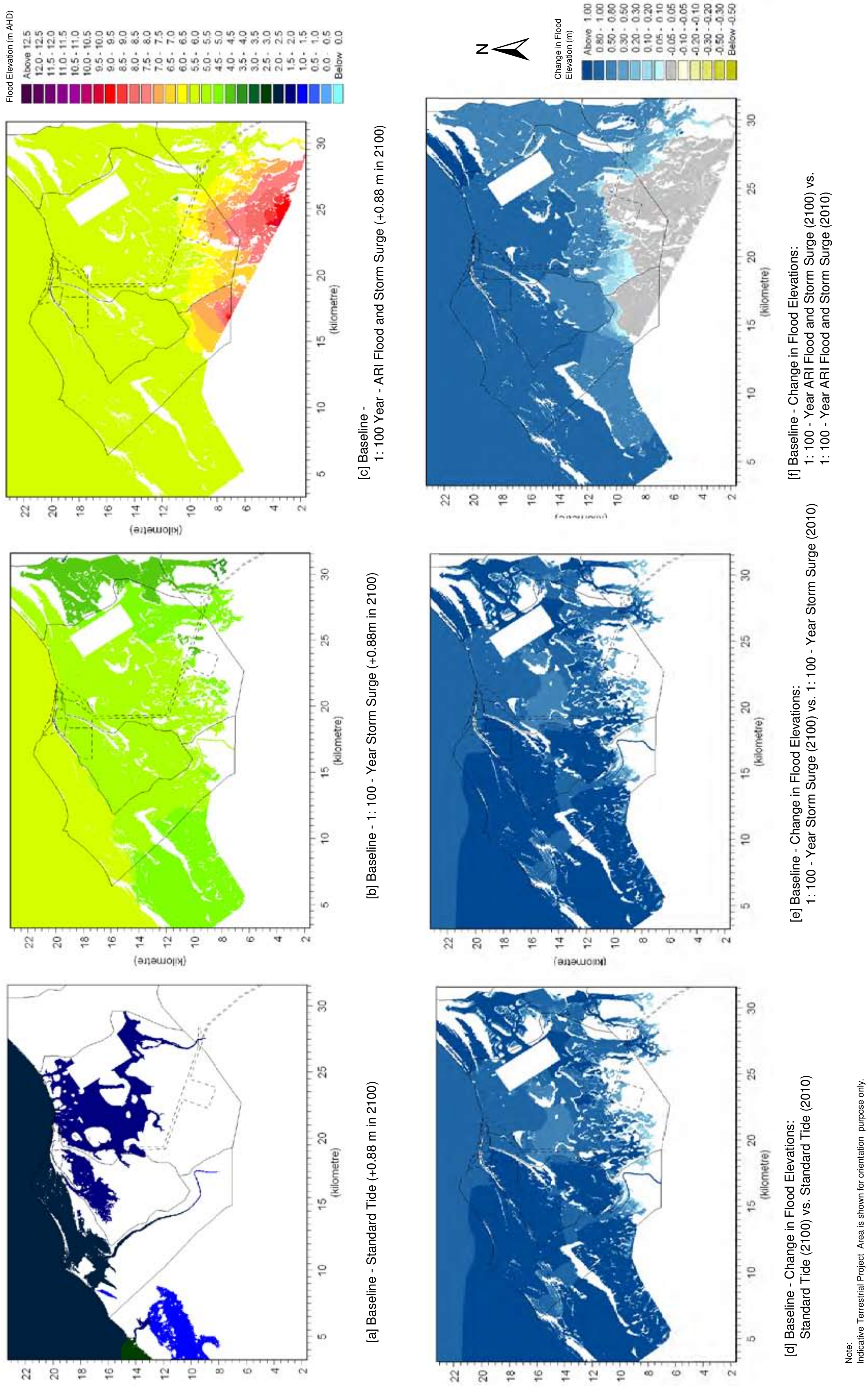

[a] Baseline - Standard Tide (+0.88 m in 2100)

[b] Baseline - 1: 100 - Year Storm Surge (+0.88m in 2100)

[c] Baseline -
1: 100 Year - ARI Flood and Storm Surge (+0.88 m in 2100)

[d] Baseline - Change in Flood Elevations:
Standard Tide (2100) vs. Standard Tide (2010)

[e] Baseline - Change in Flood Elevations:
1: 100 - Year Storm Surge (2100) vs. 1: 100 - Year Storm Surge (2010)

[f] Baseline - Change in Flood Elevations:
1: 100 - Year ARI Flood and Storm Surge (2100) vs.
1: 100 - Year ARI Flood and Storm Surge (2010)

Note:
Indicative Terrestrial Project Area is shown for orientation purpose only.

Client: **CHEVRON AUSTRALIA PTY LTD** URS	Project: Wheatstone Project Surface Water Studies		Title: Baseline Characteristics Impacts of Climate Change on Flood Elevations in 2100
	Drawn: MOS	Approved: IGB	Date: 11/05/2010
	Job No. 42907466	File No. 42907466-SW-023.xls	Figure: 4-12
			Rev. A A3

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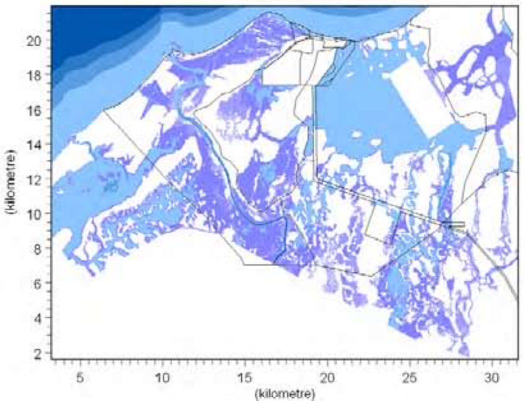
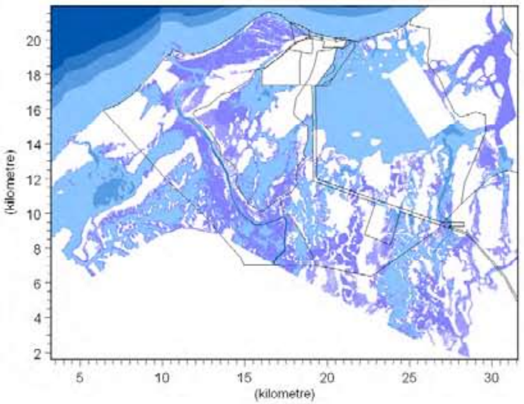
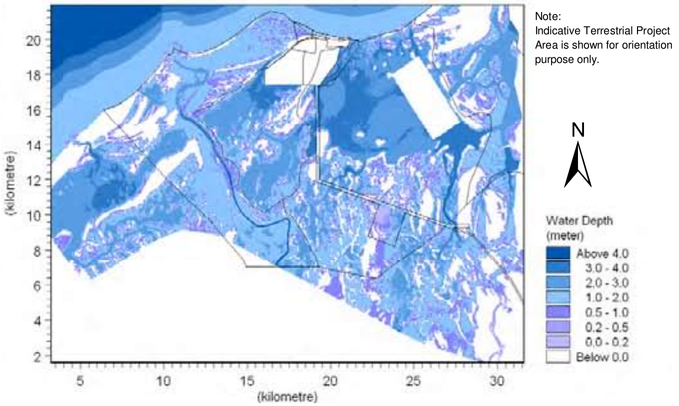


[a] Developed - Wheatstone Project:
Maximum Water Depths: 1: 10 - Year ARI

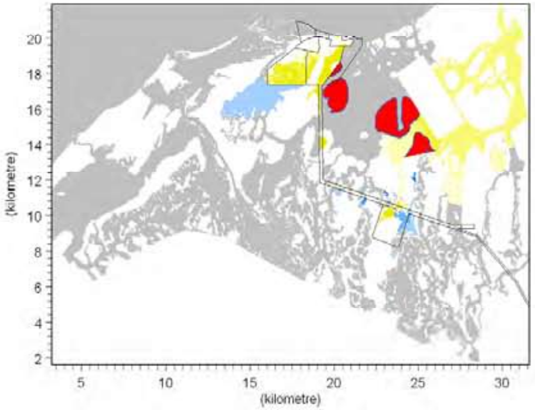


[b] Developed - Wheatstone Project:
Maximum Water Depths: 1: 25 - Year ARI

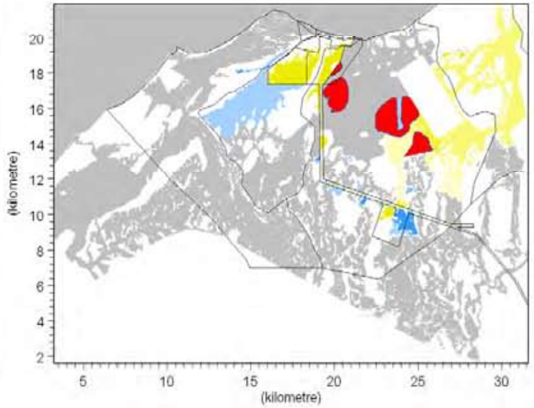


Note:
Indicative Terrestrial Project Area is shown for orientation purpose only.

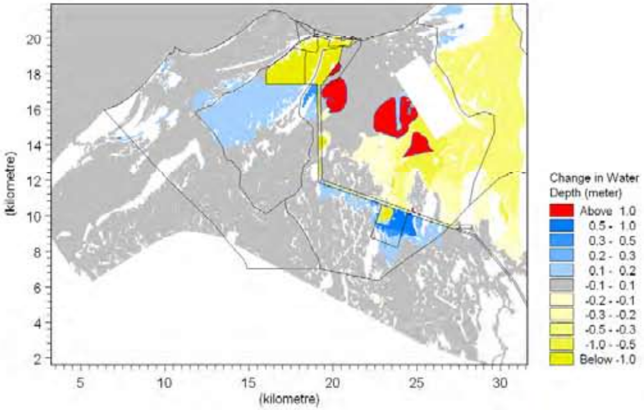
[c] Developed - Wheatstone Project:
Maximum Water Depths: 1: 100 - Year ARI



[d] Developed - Wheatstone Project:
Change in Maximum Water Depths: 1: 10 - Year ARI



[e] Developed - Wheatstone Project:
Change in Maximum Water Depths: 1: 25 - Year ARI



[f] Developed - Wheatstone Project:
Change in Maximum Water Depths: 1: 100 - Year ARI

Client:
CHEVRON AUSTRALIA PTY LTD

Project:
Wheatstone Project
Surface Water Studies

Title:
Impacts Assessment -
Impacts of Wheatstone Project on Water Depths (Standard Tide)

Drawn: JB
Approved: IGB
Date: 11/05/2010
Job No. 42907466
File No. 42907466-SW-024.xls
Figure: 5-1
Rev. A
A3

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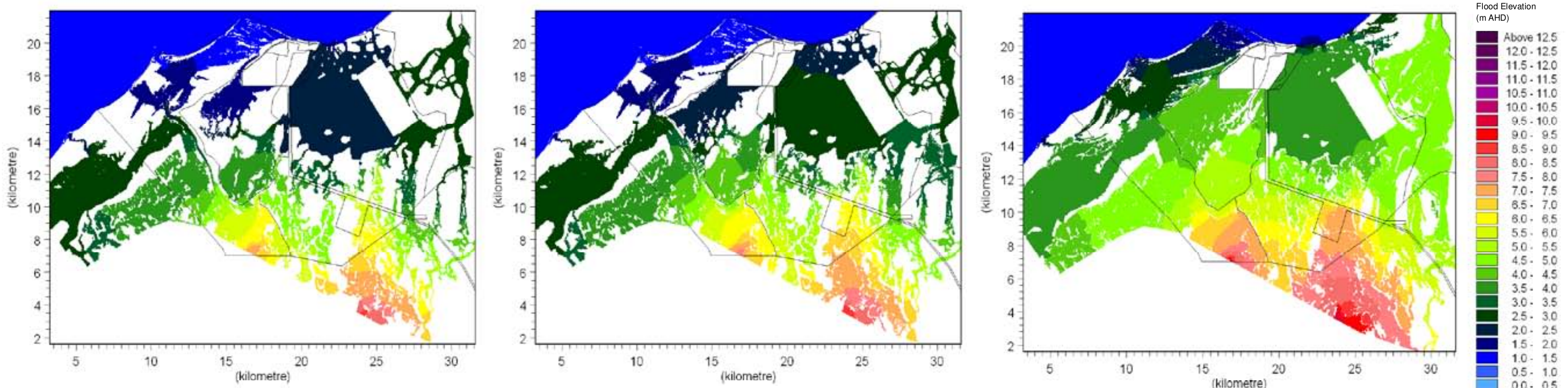
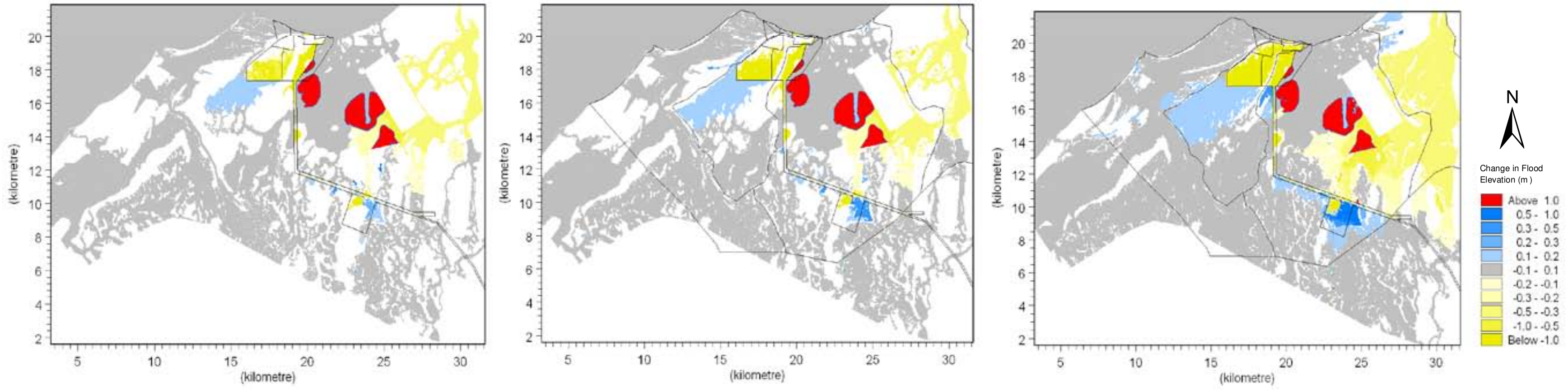


[a] Developed - Wheatstone Project:
Maximum Flood Elevations: 1: 10 - Year ARI

[b] Developed - Wheatstone Project:
Maximum Flood Elevations: 1: 25 - Year ARI

[c] Developed - Wheatstone Project:
Maximum Flood Elevations: 1: 100 - Year ARI



[d] Developed - Wheatstone Project:
Change in Maximum Flood Elevations: 1: 10 - Year ARI

[e] Developed - Wheatstone Project:
Change in Maximum Flood Elevations: 1: 25 - Year ARI

[f] Developed - Wheatstone Project:
Change in Maximum Flood Elevations: 1: 100 - Year ARI

Note:
Indicative Terrestrial Project Area is shown for orientation purpose only.

Client:
CHEVRON AUSTRALIA PTY LTD
URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Impacts Assessment -
Impact of Wheatstone Project on Flood Elevations (Standard Tide)

Drawn:	JB	Approved:	IGB	Date:	11/05/2010	Figure: 5-2	Rev. A
Job No.	42907466	File No.	42907466-SW-026.xls				A3

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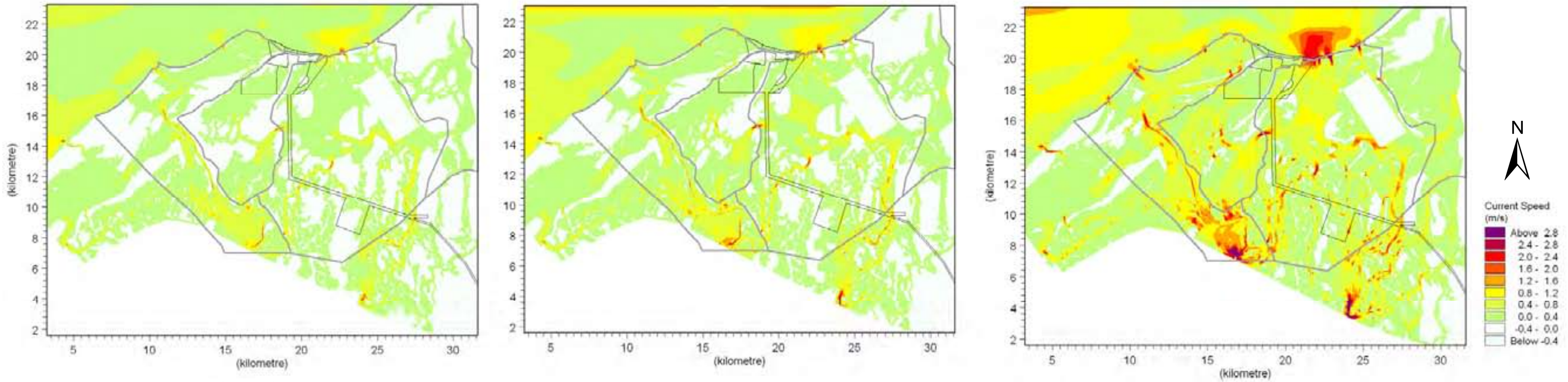
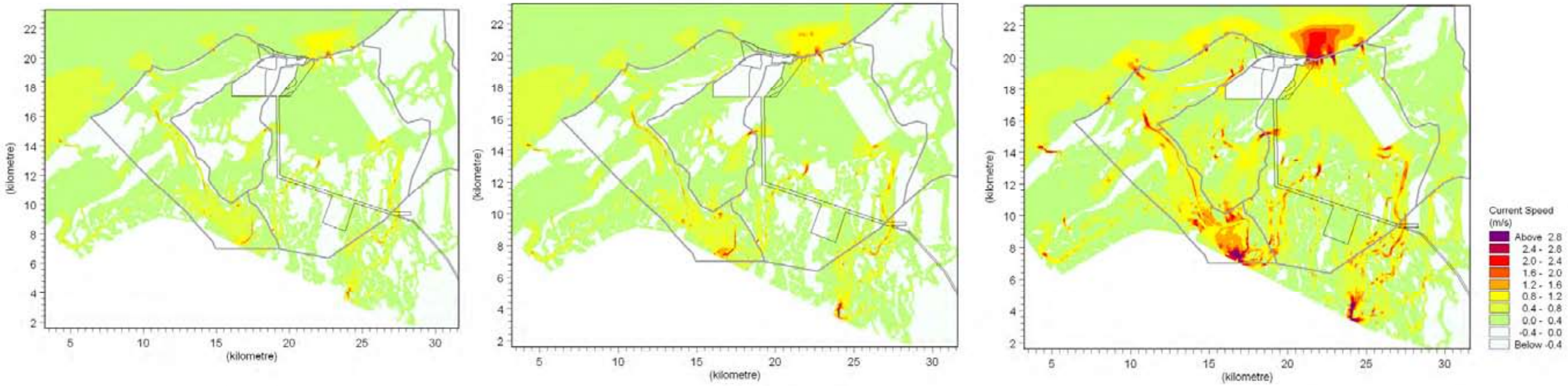


[a] Baseline - Maximum Current Speeds: 1: 10 - Year ARI

[b] Baseline - Maximum Current Speeds: 1: 25 - Year ARI

[c] Baseline - Maximum Current Speeds: 1: 100 - Year ARI



[d] Developed - Maximum Current Speeds: 1: 10 - Year ARI

[e] Developed - Maximum Current Speeds: 1: 25 - Year ARI

[f] Developed - Maximum Current Speeds: 1: 100 - Year ARI

Note: Indicative Terrestrial Project Area is shown for orientation purpose only.

Client:
CHEVRON AUSTRALIA PTY LTD

URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Impacts Assessment - Baseline and Post Project Development on Current Speeds (Standard Tide)

Drawn: JB
Approved: IGB
Date: 11/05/2010
Job No. 42907466
File No. 42907466-SW-027.xls
Figure: 5-3
Rev. A
A3

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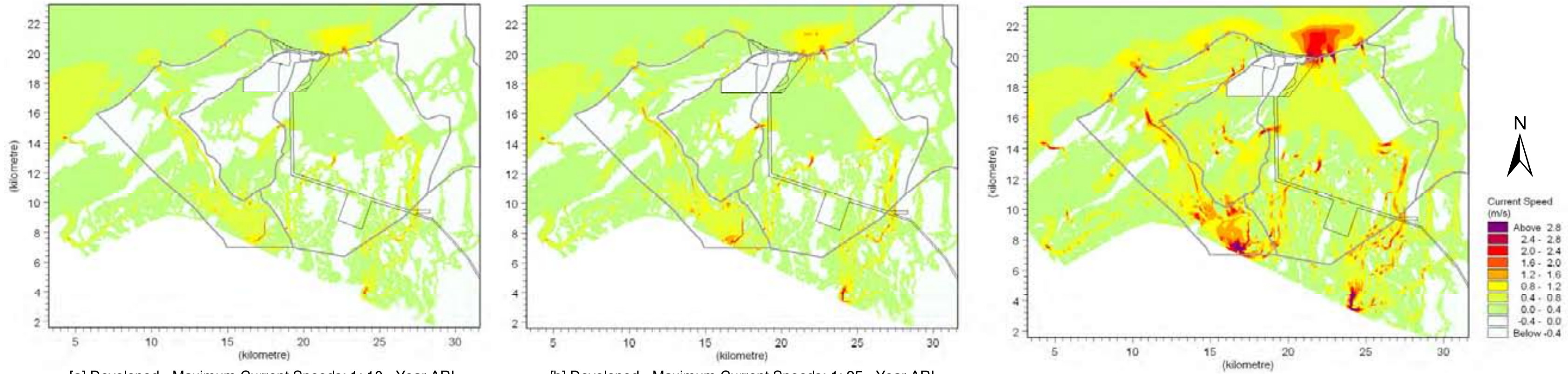
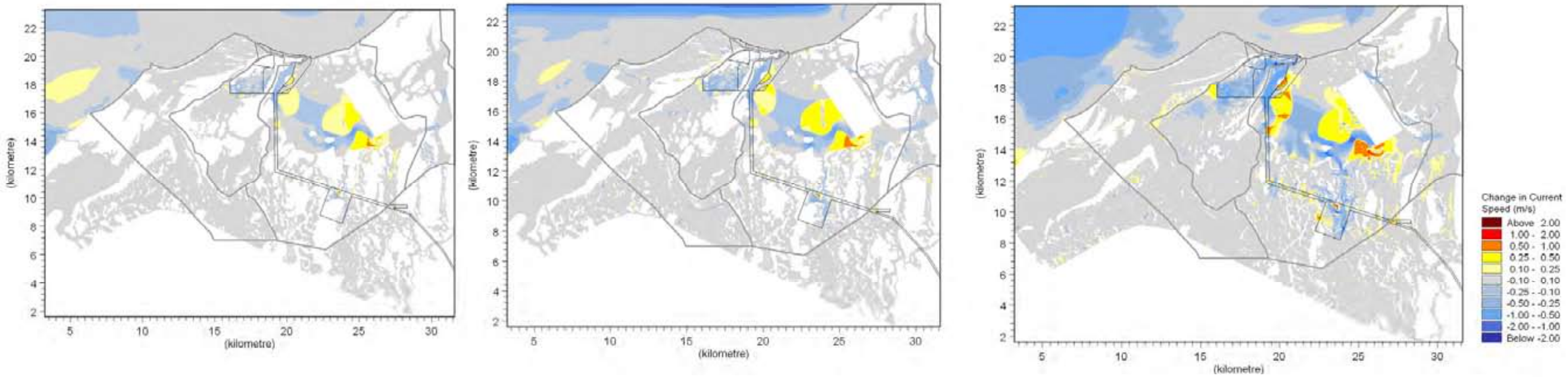


[a] Developed - Maximum Current Speeds: 1: 10 - Year ARI

[b] Developed - Maximum Current Speeds: 1: 25 - Year ARI

[c] Developed - Maximum Current Speeds: 1: 100 - Year ARI



[d] Developed - Wheatstone Project:
Change in Maximum Current Speeds: 1: 10 - Year ARI

[e] Developed - Wheatstone Project:
Change in Maximum Current Speeds: 1: 25 - Year ARI

[f] Developed - Wheatstone Project:
Change in Maximum Current Speeds: 1: 100 - Year ARI

Note: Indicative Terrestrial Project Area is shown for orientation purpose only.

Client:
CHEVRON AUSTRALIA PTY LTD
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Project:
Wheatstone Project
Surface Water Studies

Drawn: JB
Approved: IGB
Date: 11/05/2010
Job No. 42907466
File No. 42907466-SW-028.xls

Title:
Impacts Assessment -
Impacts of Wheatstone Project on
Current Speeds (Standard Tide)

Figure: 5-4
Rev. A
A3

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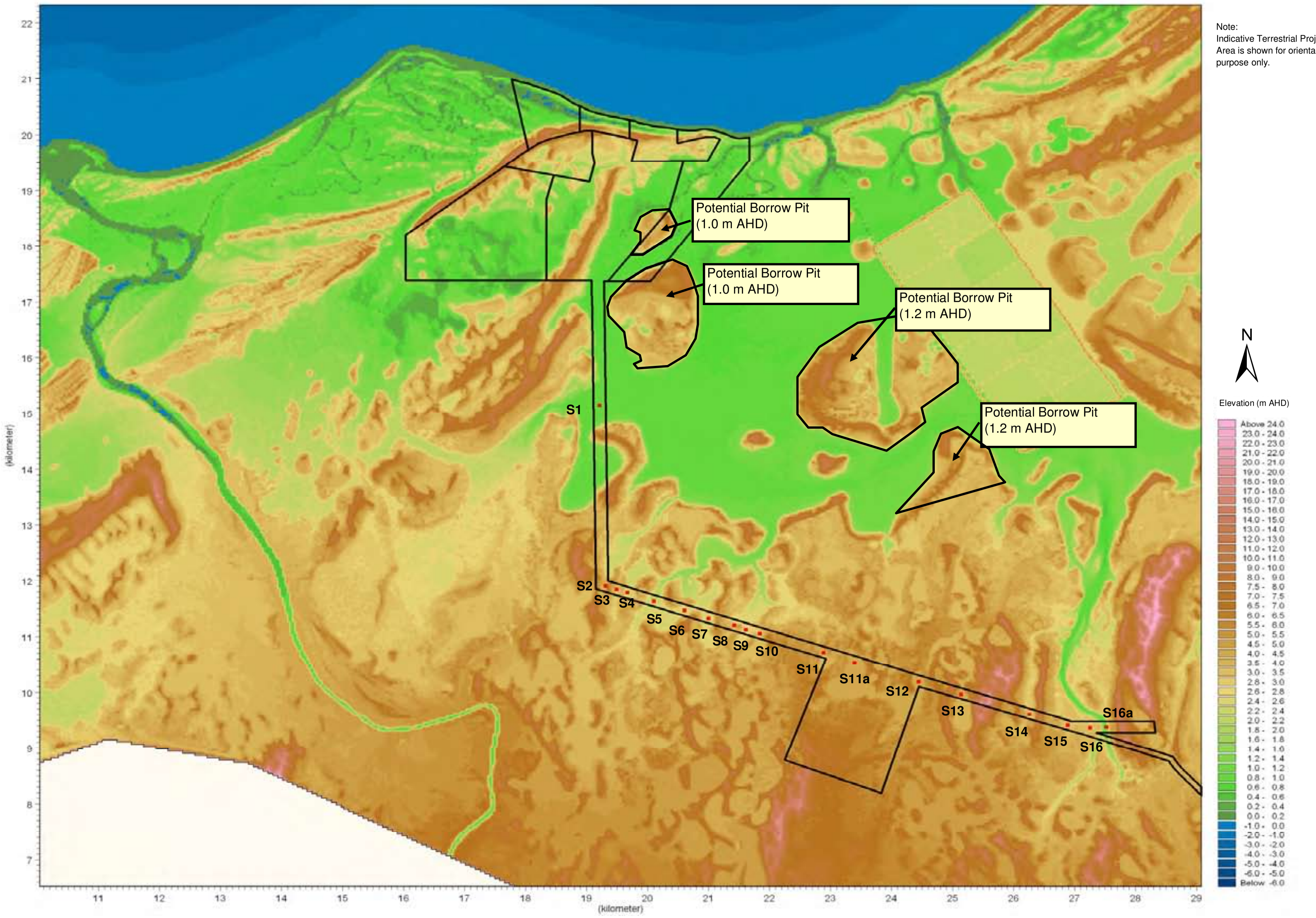

Note:
Indicative Terrestrial Project
Area is shown for orientation
purpose only.

Client:
CHEVRON AUSTRALIA PTY LTD

URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Impacts Assessment
Locations of Shared Infrastructure
Corridor Drainage Structures.

Drawn:	JB	Approved:	IGB	Date:	17/05/2010	Figure: 5-5	Rev. A
Job No.	42907466	File No.	42907466-SW-022.xls				A3

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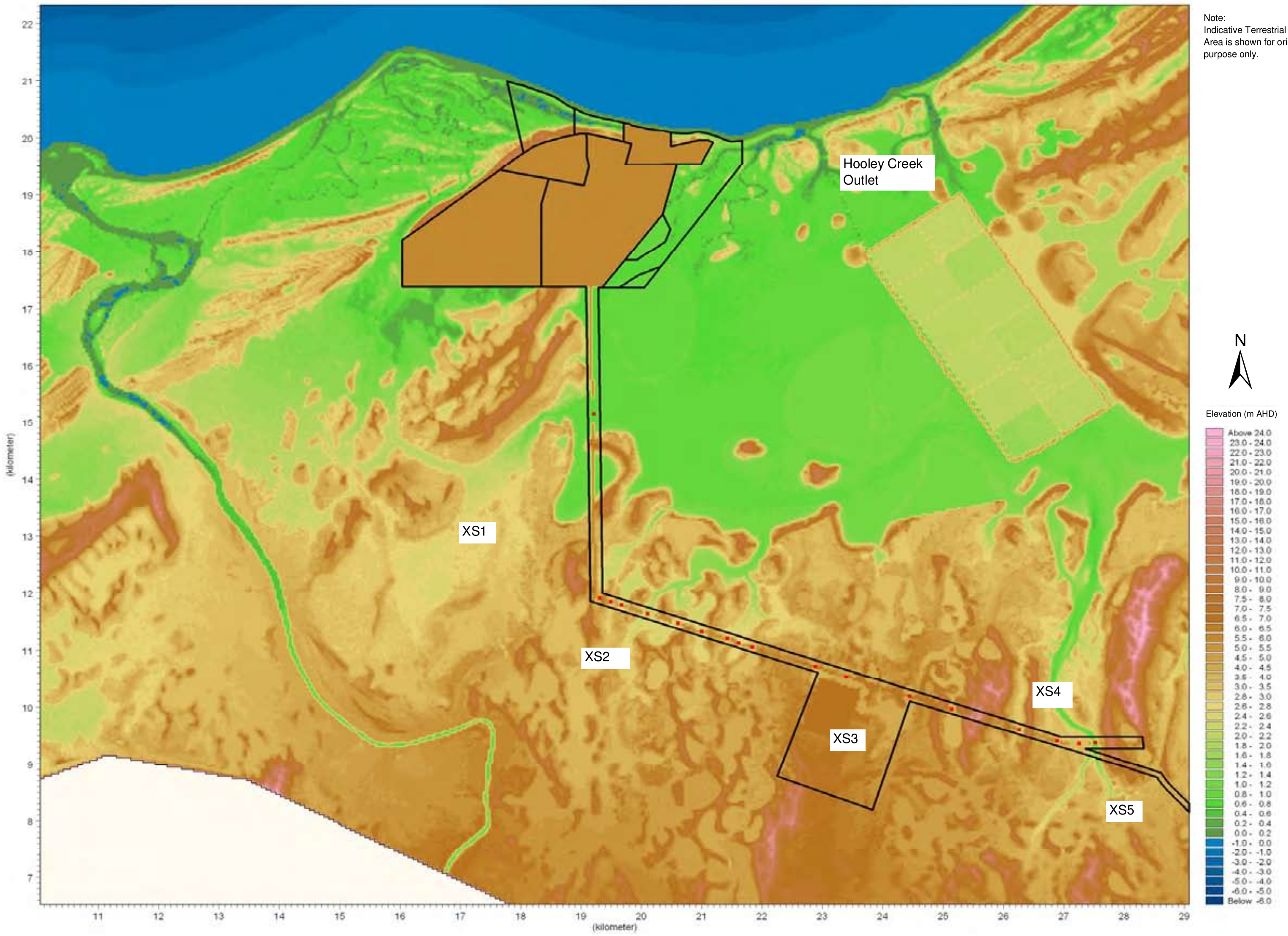

Note:
Indicative Terrestrial Project
Area is shown for orientation
purpose only.

Client:
CHEVRON AUSTRALIA PTY LTD

URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Impacts Assessment
Locations of Discharge Hydrographs

Drawn: JB
Approved: IGB
Date: 17/05/2010
Job No. 42907466
File No. 42907466-SW-021.xls
Figure: 5-6
Rev. A
A3

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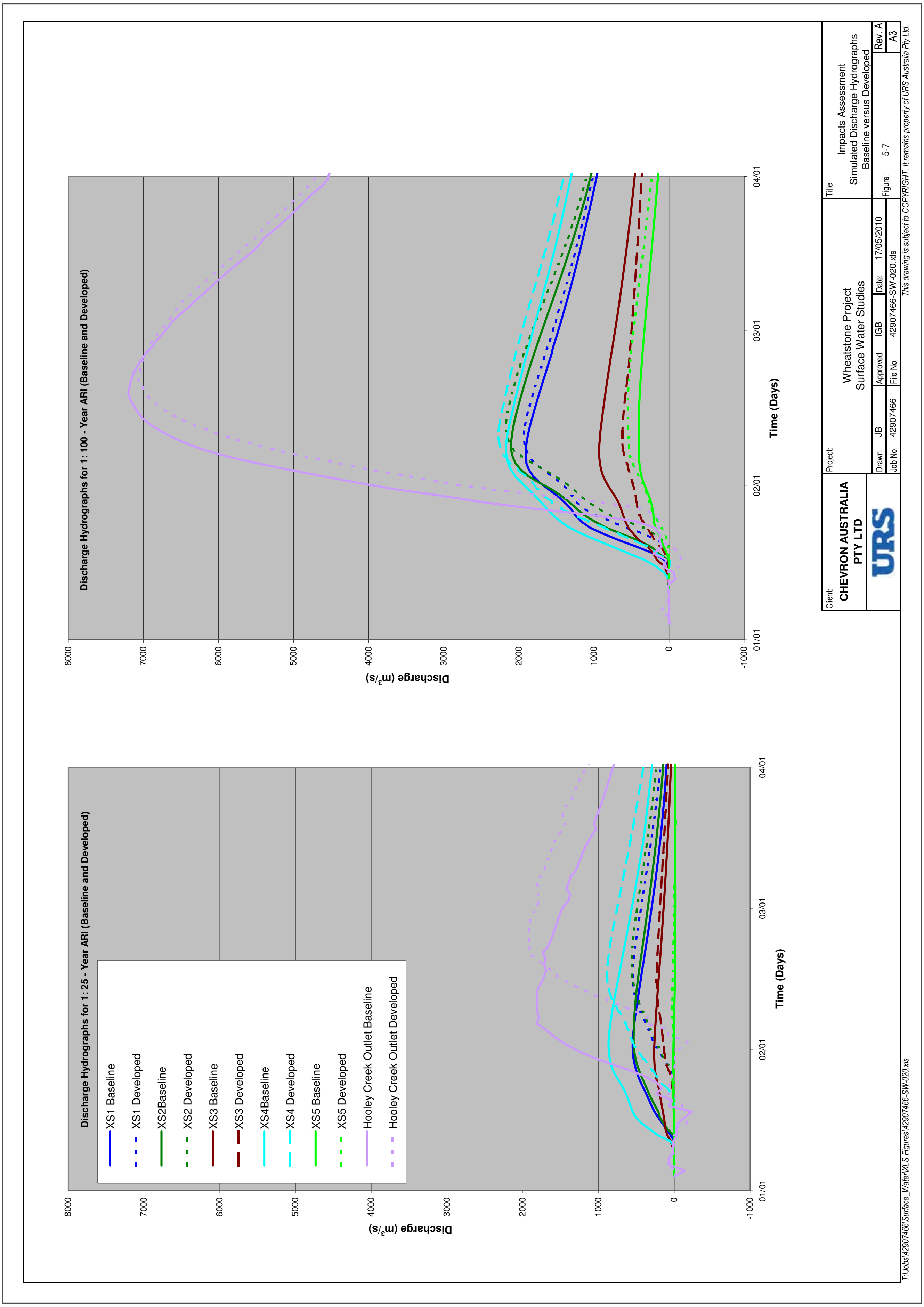
Discharge Hydrographs for 1 : 25 - Year ARI (Baseline and Developed)
Discharge (m³/s)
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
01/01
02/01
03/01
04/01
Time (Days)
XS1 Baseline
XS1 Developed
XS2Baseline
XS2 Developed
XS3 Baseline
XS3 Developed
XS4Baseline
XS4 Developed
XS5 Baseline
XS5 Developed
Hooley Creek Outlet Baseline
Hooley Creek Outlet Developed
Discharge Hydrographs for 1 : 100 - Year ARI (Baseline and Developed)
Discharge (m³/s)
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
01/01
02/01
03/01
04/01
Time (Days)
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Surface Water Studies
Title:
Impacts Assessment
Simulated Discharge Hydrographs
Baseline versus Developed
Drawn: JB
Approved: IGB
Date: 17/05/2010
Figure: 5-7
Rev. A
Job No. 42907466
File No. 42907466-SW-020.xls
A3
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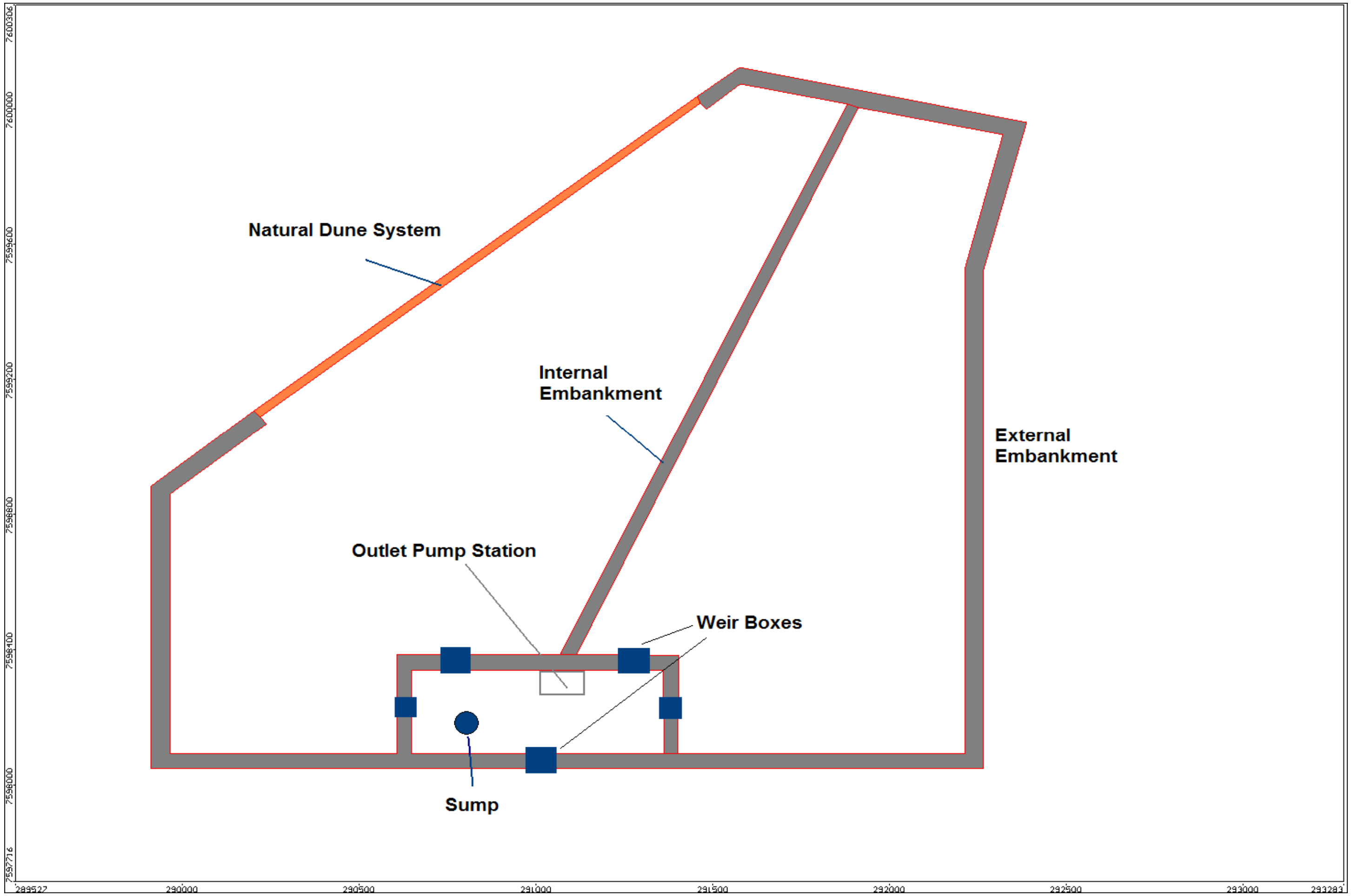

Client:
CHEVRON AUSTRALIA PTY LTD

Project:
Wheatstone Project
Surface Water Studies

Title:
Dredge Material Placement Area

Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-SW-017.xls
Figure: 5-8
Rev. A
A4

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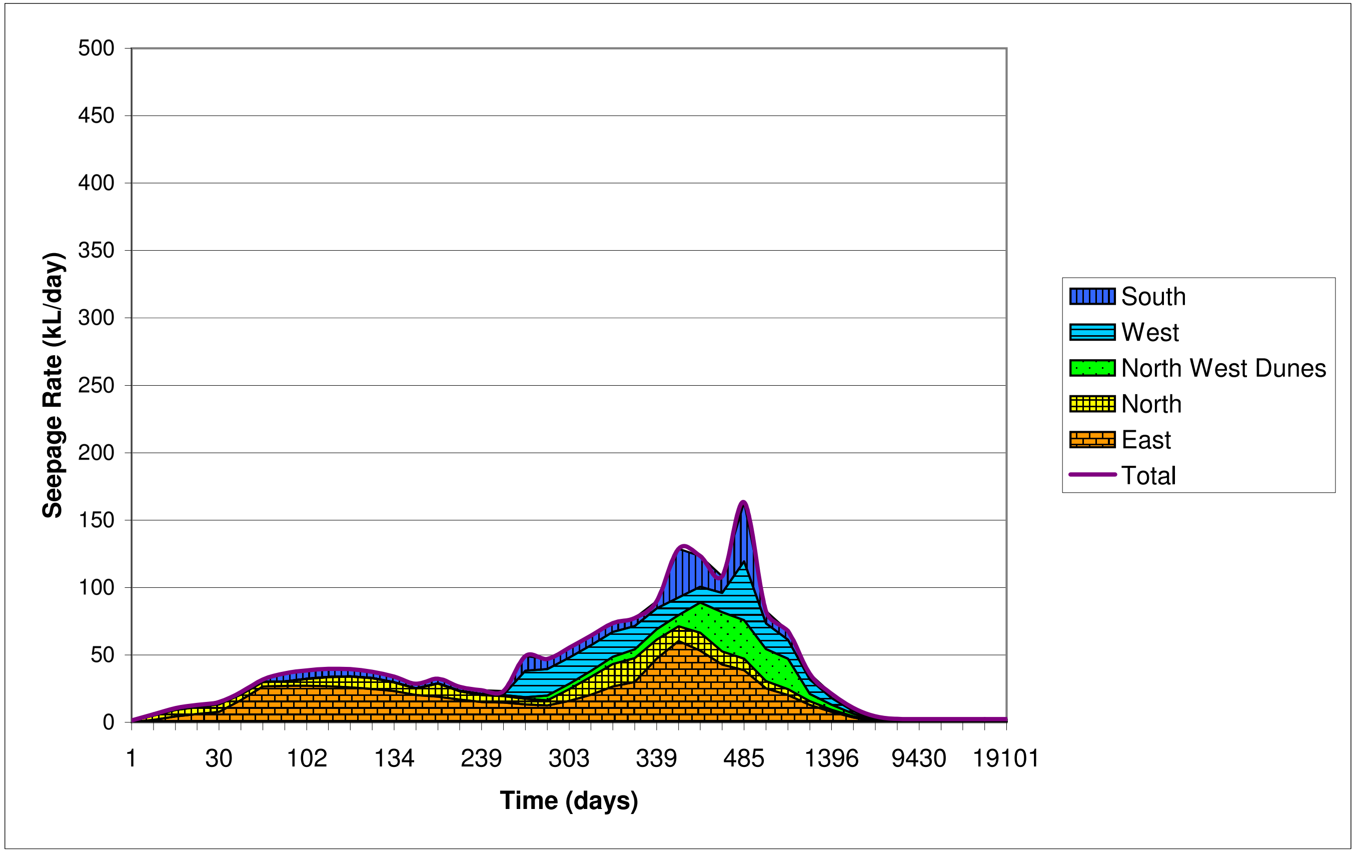

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Surface Water Studies	Title: Predicted Seepage Through the Dredge Material Placement Area Embankments
	Drawn: WY Job No. 42907466	Approved: IGB Date: 13/05/2010 File No. 42907466-GW-018.xls
		Figure: 5-9 Rev. A A4

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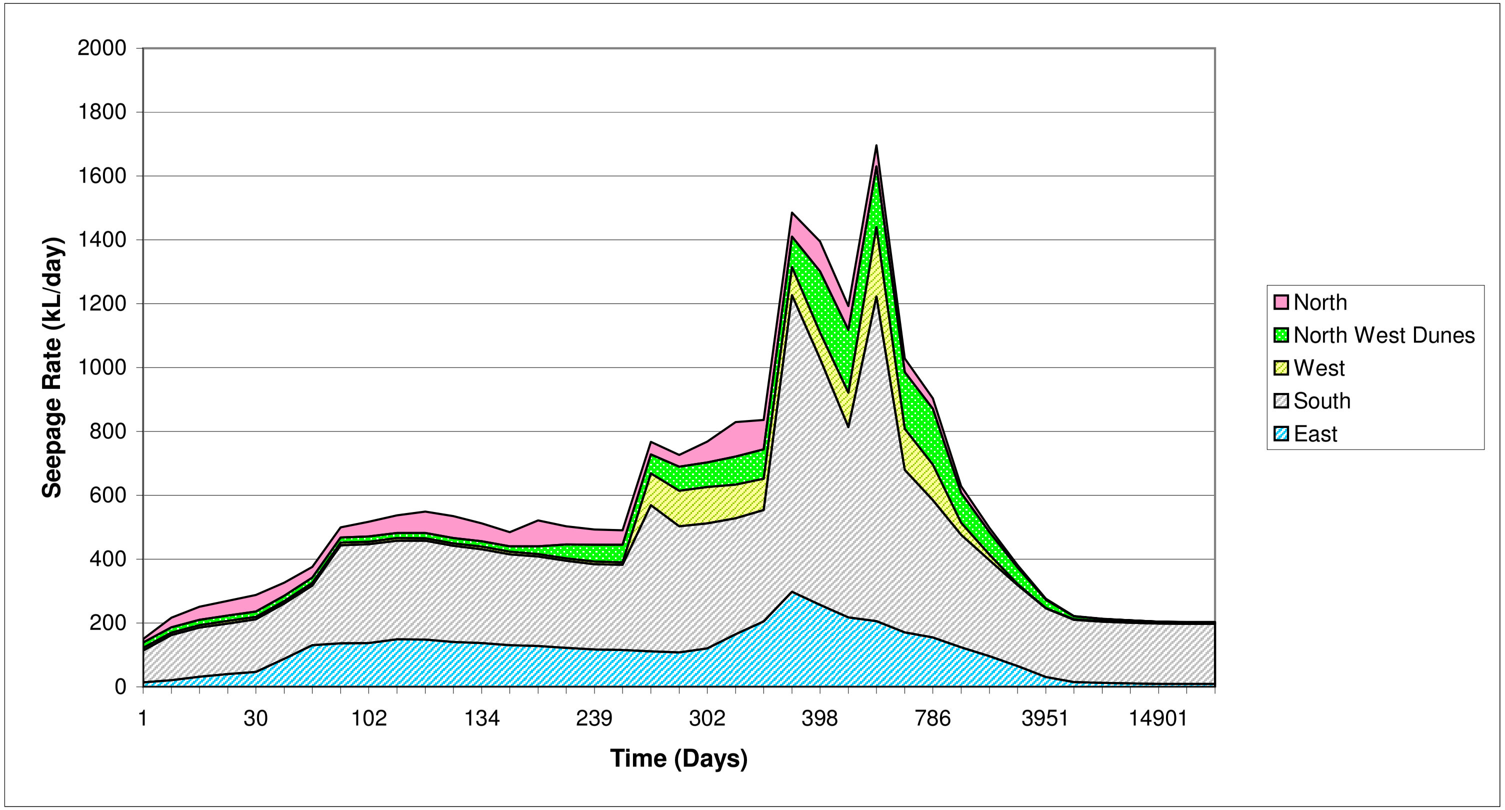

Client:
CHEVRON AUSTRALIA PTY LTD

Project:
Wheatstone Project
Surface Water Studies

Title:
Predicted Seepage to the Water Table Outside of the Dredge Material Placement Area Embankments

Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-SW-019.xls
Figure: 5-10
Rev. A
A4

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Client:	Project:				Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Surface Water Studies				Seepage Footprint 485 Days after Commencement of Dredge Material Placement	
URS	Drawn: WY	Approved: IGB	Date: 5/05/2010		Figure: 5-11	Rev. A
	Job No. 42907466	File No. 42907466-SW-025.xls				A4

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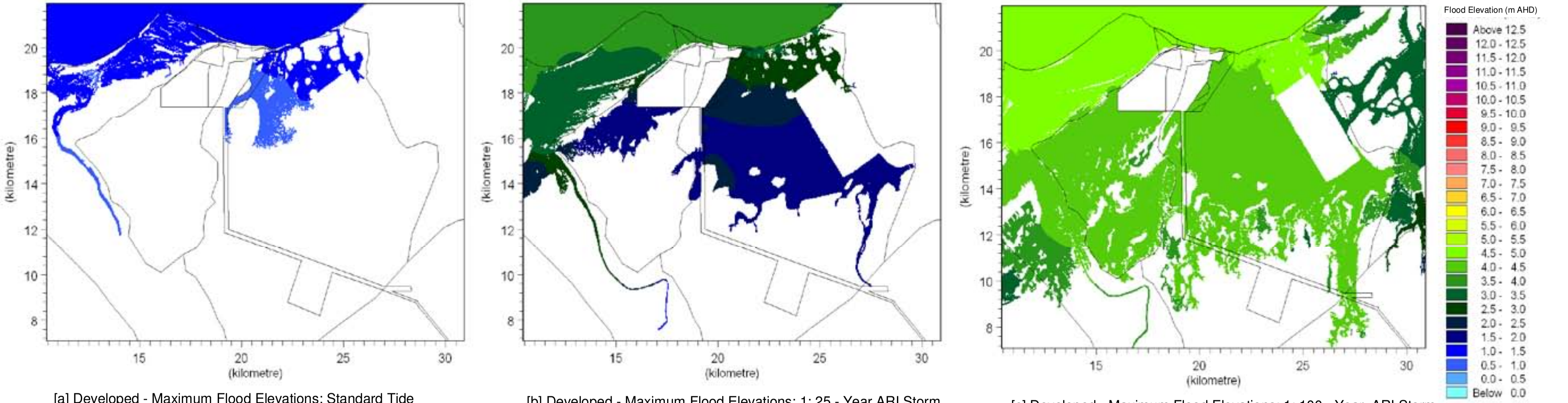
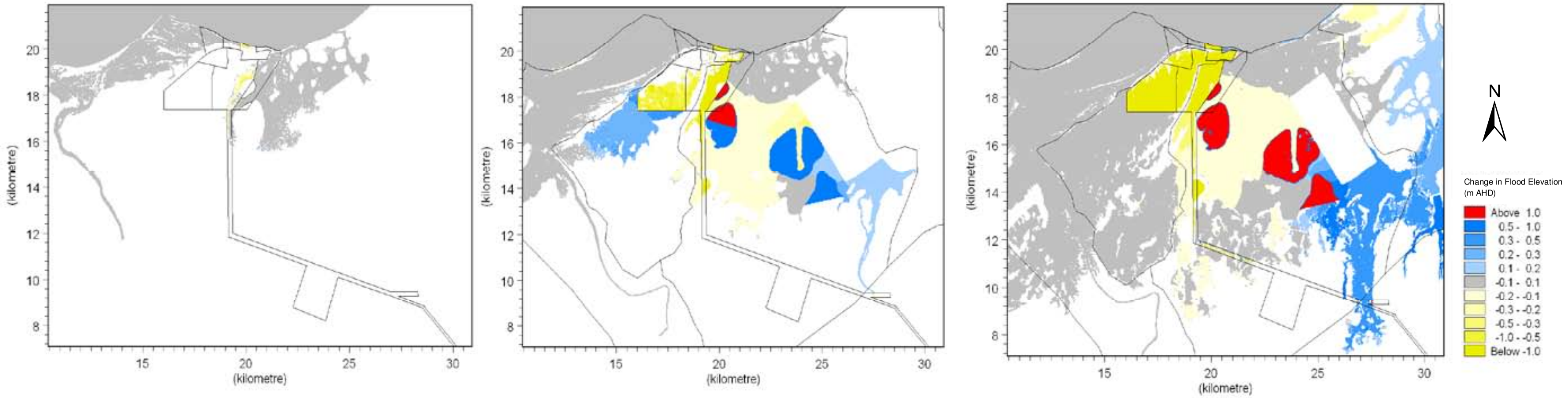


[a] Developed - Maximum Flood Elevations: Standard Tide

[b] Developed - Maximum Flood Elevations: 1: 25 - Year ARI Storm Surge

[c] Developed - Maximum Flood Elevations: 1: 100 - Year ARI Storm Surge



[d] Change in Maximum Flood Elevations: Standard Tide

[e] Change in Maximum Flood Elevations: 1: 25 - Year ARI Storm Surge

[f] Change in Maximum Flood Elevations: 1: 100 - Year ARI Storm Surge

Note: Indicative Terrestrial Project Area is shown for orientation purpose only.

Client:
CHEVRON AUSTRALIA PTY LTD
URS

Project:
Wheatstone Project
Surface Water Studies

Title:
Impacts Assessment -
Impacts of Wheatstone Project on
Tidal Inundation

Drawn:	JB	Approved:	IGB	Date:	11/05/2010	Figure: 5-12	Rev. A
Job No.	42907466	File No.	42907466-SW-029.xls				A3

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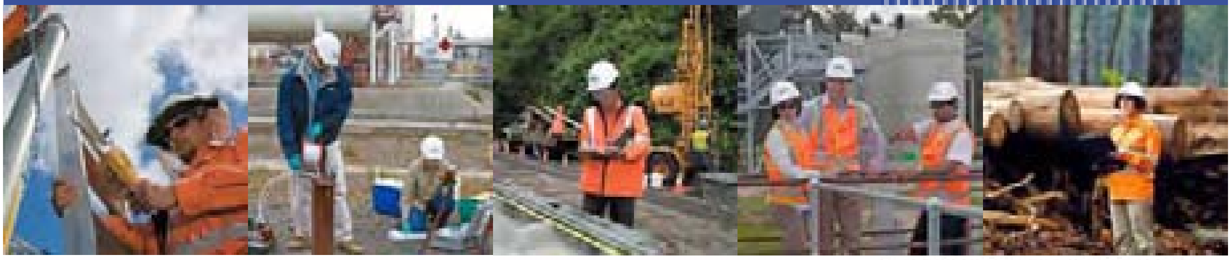

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Appendix H1

Baseline Soil Quality and Landforms Assessment

Tables

Figures

Plate

Plate (cont’d)

Appendices

Abbreviations

Abbreviation	**Description**
AHD	Australian Height Datum
ALS	Australian Laboratory Services
ANC	Acid Neutralising Capacity
ANZECC	Australian and New Zealand Environment and Conservation Council
ASS	Acid Sulfate Soil
BSQ	Baseline Soil Quality
CSIRO	Commonwealth Scientific and Research Organisation
DEC	Department of Environment and Conservation
DEWHA	Department of Environment, Water, Heritage and the Arts
Domgas	Domestic Gas
EIL	Ecological Investigation Level
EPA	Environment Protection Authority
ERMP	Environmental Review and Management Programme
GSWA	Geological Survey of Western Australia
HIL	Health Investigation Levels
LNG	Liquefied Natural Gas
MBO	Monosulfidic Black Ooze
MOF	Marine Offloading Facility
MTPA	Million Tonnes Per Annum
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
NEPM	National Environment Protection Measure
PASS	Potential Acid Sulfate Soil
SAP	Sampling and Analysis Plan
SIC	Shared Infrastructure Corridor
SD	Standard Deviation
TPA	Titratable Peroxide Acidity
TSA	Titratable Sulfidic Acidity
URS	URS Australia Pty Ltd
WA	Western Australia

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Final Report

Baseline Soil Quality and Landforms Assessment

19 MAY 2010

Prepared for

Chevron Australia Pty Ltd

QV1, 250 St Georges Terrace
Perth, Western Australia, 6000

WHST-STU-ET-RPT-0068

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Date: **19 May 2010**
Reference: WHST-STU-ET-RPT-0068/ / 0
Status: Final

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Executive Summary

URS Australia Pty Ltd (URS) was commissioned by Chevron Australia Pty Ltd to undertake a baseline soil quality and landforms assessment for the proposed Wheatstone Project which includes Ashburton North and surrounds, the Shared Infrastructure Corridor, Domgas Pipeline, Accommodation Village and the Construction Area (collectively known as the Terrestrial Assessment area).

The following report details the works completed for Ashburton North and surrounds, the Shared Infrastructure Corridor (SIC study area) the Domgas Pipeline (Domgas study area), Accommodation Village (Camp study area) and the Construction Area (Construction study area, which includes Horseshoe Island and the borrow pit to the south east). This assessment was completed, in part, as a desktop study comprising a review of land systems and landforms at a regional scale, followed by a site specific assessment of landforms and baseline soil quality (including potential acid sulfate soils [PASS]), completed between March and October 2009.

A series of seven land systems were defined within the Terrestrial Assessment area and include the Littoral, Dune, Onslow, Giralia, Stuart and Uaroo land systems. Ashburton North and surrounds and the Construction study area is generally comprised of the Littoral land system which is dominated by landforms including intertidal creeks, mangrove swamps and supratidal salt flats on the north eastern boundary and samphire flats and claypans along the north western boundary.

Alluvial/colluvial plains and clayey plains, generally dominate the remainder of the Terrestrial Assessment area. The alluvial/colluvial plains are characterised by low swales and slopes with soils comprising dark reddish brown sands and sandy loams along the northern boundary of the SIC study area and the Construction study area.

Linear inland dunes, comprising of parallel dunes, trending north-south, are intermittently encountered along the northern boundary of the SIC study area and Domgas study area and throughout the Construction study area.

As part of the Ashburton North and surrounds investigation, a total of 18 soil bore and nine hand auger locations were investigated to a depth ranging between 0.3 and 4.6 mbgl. Analytical testing for a suite of heavy metals, and for the soil's potential acid generating capacity, was completed on 38 and 44 primary samples, respectively, to a maximum depth of 3.0 mbgl, on representative soil profiles identified across Ashburton North and surrounds. In addition, a further 107 geotechnical borehole cores were inspected, and the results used to refine the PASS areas identified through laboratory testing.

Ten hand auger locations ranging in depths from 1.5 to 1.6 mbgl were completed along the SIC study area. In total, 37 primary samples were collected during the intrusive investigation of which 12 were submitted for analysis.

As this investigations primary objective is to identify baseline soil quality, and because there has been no land disturbance or industrial activity of the Terrestrial Assessment area, assessment of soil data against threshold levels is not required. However, as a means of comparison and to also provide an assessment of whether naturally occurring compounds (metals) may pose a risk to human health, a comparison against relevant Western Australian (WA) guidelines has been made.

Executive Summary

Analytical results reported elevated metal concentrations against adopted assessment criteria for Ecological Investigation Levels (EIL) (Department of Environment and Conservation [DEC], 2003) for arsenic, chromium, manganese and nickel, in the north western to north eastern section of Ashburton North and surrounds. Reported analytical results were all below the adopted Health Investigation Levels (HIL).

Comparison of the these results against an assessment of heavy metals completed by Oceanica (2005) and URS (2008) along the Pilbara coastline of similar deltaic systems, also reported elevated concentrations of arsenic, chromium and nickel. The elevated metals encountered are comparable suggesting that the high background levels are likely a result of the weathering of terrestrial origin.

The results of the field and analytical investigations and geotechnical bore review indicate that PASS is present at shallow depths ranging between 0.5 mbgl and 4.5 mbgl with a thickness ranging between 0.2 and 3.5 m predominantly along the north eastern extent of Ashburton North and surrounds. Corresponding soil profiles were typically characterised as low to high plasticity CLAY to clayey SAND/SAND, low to high plasticity, brown to dark grey; fine to medium grained, mottling may range from yellow and orange, firm to very soft.

These soils are considered to be of marine/organic origin and are generally located within landform units associated with the intertidal flats, tidal creek and mangrove swamp of the Littoral land system. PASS was also identified in landforms associated with samphire flats, alluvial/colluvial plains and fringing and coastal dunes.

The acid neutralising capacity (ANC) of the Terrestrial Assessment area is generally high, however is typically absent in soil profiles identified as PASS. Soils with the highest ANC throughout Ashburton North and surrounds generally comprised of sands and sand clays with shell, limestone and/or sandstone interbedded throughout. ANC of the SIC study area was significantly lower with highest buffering capacity detected in the red clayey sands.

A PASS map was produced identifying areas of low, moderate and high risk for PASS for the Terrestrial Assessment area. Based on the results of the PASS assessment, high risk for intercepting PASS is located in the north eastern extent of Ashburton North and surrounds and is typically associated with marine/mangrove deposits. Although PASS is typically not associated with landform units associated with the fringing and coastal dunes, it is believed that shallow marine/organic deposits underlying these landform units may be associated with the bordering Ashburton River delta and the Hooley Creek catchment. Therefore where PASS has been identified below these landforms, the PASS Map has identified them as high risk.

There is a moderate risk of intercepting PASS (assuming incidental excavation for these areas) for landform units associated with the samphire flats where PASS typically comprised of dark brown to dark grey SAND/clayey SAND/CLAY at shallow depths. The supratidal salt flats, which are located adjacent to the intertidal flats, tidal creek and mangrove swamp are considered moderate risk for intercepting PASS, particularly where algal mats and MBO have been identified. Moderate risk of PASS is also correlated with proximity to mangroves and tidal creeks, which provide a source of marine/ organic material.

.The minor islands located along the north western boundary of the Construction study area, which are bound by the supratidal salt flats, the area immediately south of islands, and the clayey plains south of Ashburton North have been conservatively classified as moderate risk for PASS given that only a desktop study has been undertaken. However, given that the landforms identified at the above locations are typically not associated with PASS, it is unlikely that PASS would be intercepted

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Introduction

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train liquefied natural gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future yet-to-be determined gas fields. The project is referred to as the Wheatstone Project and Ashburton North and is the proposed site for the LNG and Domgas plants. 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). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

URS Australia Pty Ltd (URS) was commissioned by Chevron Australia Pty Ltd to undertake a baseline soil quality and landforms assessment for the proposed Wheatstone Project which includes Ashburton North and surrounds, the Shared Infrastructure Corridor, Domgas Pipeline, Accommodation Village and the Construction Area (collectively known as the Terrestrial Assessment area).

This report presents results from the desktop and intrusive works completed for Ashburton North and surrounds, the SIC and the Domgas study areas, and a desktop review of landforms and soils for the Camp and Construction study area.

1.1 Objectives

The objective of the programme was to provide sufficient information for an Environmental Review and Management Programme (ERMP) level of assessment, in accordance with the *Guidelines for Preparing a Public Environmental Review/ Environmental Review and Management Programme* (Environmental Protection Authority [EPA, 2009]) as requested for the Wheatstone Project, by the Western Australian (WA) EPA.

Specifically, the objectives of the desk top reviews and field works were to:

- Complete a regional review and a site specific assessment of the soils and landforms identified for Ashburton North and surrounds, the SIC and Domgas study area.
- Complete a regional review and desktop assessment of the soils and landforms of the Camp and Construction study area.
- Identify baseline metal concentrations of the surface and subsurface profile within Ashburton North and surrounds and the SIC study area.
- Identify generalised limitations of soils encountered for use in rehabilitation.
- Assess the general extent of PASS and the associated risks upon encountering such soils in general accordance with the definitions set out by Ahern *et al* (1998) and DEC Acid Sulfate Soils (ASS) Guidelines Series (updated May 2009).

The objectives outlined above, and works completed to date, are in accordance with the, Environmental Scoping Document.

1.2 Scope of Works

To meet the above objectives, the following scopes of works were completed:

- A desktop review of published and available data including geotechnical logs in areas of interest, topographic maps, PASS maps, geological and environmental maps and completed surveys of the Terrestrial Assessment area as they become available.
- An assessment of aerial photography (for coarse landform assessment) and available soils investigations and associated geochemical data covering the Terrestrial Assessment area and the surrounding Onslow region.
- A sampling and analysis programme (**Appendix A),** detailing the field methodologies, procedures and laboratory analyses completed for the assessment of landforms and BSQ of the Terrestrial Assessment area.
- *In situ* field tests to assess PASS and soil stability including field pH (pH_f), field peroxide pH (pH_{fox}), a calcareous reaction test (effervescence or fizz test) and field dispersion testing of the surface and subsurface profile at sample locations.
- Analytical testing of existing and potential acidity of the soil using Chromium method in accordance with the Department of Environment and Conservation (DEC) Identification and Investigation of Acid Sulfate Soils (2009a) and the Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland 1998 (Ahern *et al*. 1998).
- Analytical testing for a suite of metals including aluminium (Al), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), manganese (Mn), nickel (Ni), vanadium (V) and zinc (Zn).
- Laboratory testing of selected soil samples at a National Association of Testing Authorities (NATA) accredited laboratory Analytical Laboratory Services of Perth (ALS).
- Production of this interpretative report which presents the soils and landforms identified within the Terrestrial Assessment area, including baseline soil quality and characterisation of the potential risks associated with ASS, to meet the requirements of the '*ASS Guidelines Series'* (2004) as adopted by the DEC (updated May 2009).

Environmental Setting

2.1 Location

The Wheatstone Project is located within the Pilbara Region of Western Australia approximately 1400 km north of Perth, and 12 km south west of Onslow. The Wheatstone Project components include Ashburton North and surrounds, the Shared Infrastructure Corridor, the Accommodation Village, the Domgas Pipeline and the Construction Area.

Ashburton North and surrounds is located along the coastal boundary of the Wheatstone Project and is bound by the Indian Ocean to the north, the Ashburton River to the west, and Hooley Creek to the east (**Figure 1)**.

The Shared Infrastructure Corridor commences along the south eastern boundary of Ashburton North and generally proceeds in a south easterly direction where it meets Onslow Road approximately 12 km from Ashburton North. The Accommodation Village is located approximately mid point along the Shared Infrastructure Corridor over an area of approximately 460 ha. The Domgas Pipeline follows the route of the Shared Infrastructure Corridor before running parallel to Onslow Road for a further 53 km in a south east direction.

The Construction Area is located over an area of approximately 838 ha and incorporates land that may be disturbed for construction roads and borrow pits.

2.2 Topography

The topography of the Wheatstone Project consists of undulating dunal systems (including longitudinal, coastal and fringing dunes), alluvial/colluvial plains, and low lying coastal systems (including supratidal flats, samphire/salt flats, claypans, tidal creeks, intertidal flats and mangroves).

The greatest ‘spot’ heights of the Terrestrial Assessment area range between approximately 5 and 21 mAHD (Landgate, 2007) and are associated with the longitudinal coastal and fringing dunes. Similarly, areas of low relief are associated with the supratidal flats, claypans, tidal creeks, intertidal flats and mangroves which are generally below 5 mAHD.

2.3 Geology and Stratigraphy

A geological mapping programme undertaken by the Geological Survey of Western Australia (1975) produced a 1:250,000-scale map series and geological descriptions in Bulletin 133. These geological data and interpretations were substantially updated by publications by Iasky and Mory (1999) and Iasky *et.al* (2003). The following interpretation was adapted from the URS (2009) desktop assessment of this information.

The Palaeozoic-Recent Northern Carnarvon Basin is a large, mainly offshore basin on the northwest shelf of Australia developed during four successive periods of extension and thermal subsidence. The Wheatstone Project is located on the Peedamullah Shelf within 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.

2 Environmental Setting

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 source.

The geology and stratigraphy beneath the Wheatstone Project is presented in **Table 2-1** below, as interpreted from the Jade 1 petroleum exploration well for the Department of Industry and Resources, Western Australia (Information Request for Jade 1, 1993). The Jade 1 petroleum exploration well was located within the Terrestrial Assessment area and is considered representative of the geology of the region. The geological core log is attached as **Appendix B**.

Table 2-1 Interpreted Stratigraphy

Formation		Age	Lithology
Superficial Formations Dune Sands		Recent/Quaternary	Gravelly sand, calcareous sandstone and sand variably lithified and consolidated.
Superficial Formations Ashburton River Delta Alluvium		Recent/Quaternary	Poorly consolidated claystones and minor limestone.
----------Unconformity----------			
Trealla Limestone		Tertiary	Interbedded limestones and claystones with siltstone, sand and limestone at the base.
----------Unconformity----------			
Winning Group	Gearle Siltstone	Early-Cretaceous	Argillaceous siltstone, grading to a silty claystone; commonly pyritic, glauconitic and micaceous.
	Windalia Radiolarite	Early-Cretaceous	Radiolariean siltstone.
	Muderong Shale	Early-Cretaceous	Argillaceous siltstone with thin lenses of siltstone and fine sandstone.
	Mardie Greensand Member	Early-Cretaceous	Glauconite-rich sandstones and minor interbedded claystone, silica cemented.
	Birdrong Sandstone	Early-Cretaceous	Glauconitic sandstone with minor interbedded claystone.
Mungaroo Formation		Triassic	Quartzose sandstones, siltstones and shale.

The superficial sediments of quaternary age are generally 4.5 to 25.0 m in thickness and are dominated by unconsolidated sediments comprising intertidal flats and mangrove swamps (calcareous clay, silt and sand) beaches and coastal dunes (reddish-brown to yellow quartz sand) and residual sand plains and alluvium associates within the Ashburton River System (Geological Survey of Western Australia (GSWA), 1982) (**Figure 2**).

2.4 Hydrogeology

Within the Northern Carnarvon Basin, unconfined aquifers are known to be formed by alluvial palaeochannel successions associated with ancient watercourses beneath reaches of most of the major rivers (URS, 2009). Unconfined aquifers are also known to form as alluvial successions beneath the wide coastal river valleys and deltas associated with the drainage basins formed by the Yannarie, Ashburton, Cane, Robe and Fortescue Rivers. Local minor aquifers may potentially be present below dune beach sands.

Groundwater is also hosted in confined aquifers in the deeper Carnarvon Basin successions. Confined aquifers underlying the Wheatstone Project are known to be formed by the Trealla Limestone (semi-confined by the superficial formations), and Birdrong Sandstone (confined by the Gearle Siltstone and Muderong Shale) (Wills and Dogramaci, 2000).

The Birdrong Sandstone is the most significant regional confined aquifer in the Carnarvon Basin and is intersected by both artesian and sub-artesian water supply bores. Historically, it has been used to supply predominantly brackish (1,000 to 12,000 mg/L TDS) groundwater to pastoral and salt industries.

2.5 Hydrology

The Ashburton River is considered to be one of the major rivers of the Pilbara Region with a catchment area of approximately 78 777 km^2. Stream flow is typically ephemeral, occurring in response to significant local and regional rainfall events.

Runoff is generated in the upper reaches of the catchment due to greater topographic relief of the low rugged ranges (URS, 2009). Downstream on the coastal plain, the Ashburton River fans out into a deltaic system made up of wide and braided flow paths before discharging into the Indian Ocean. The delta contains tidal creeks and pools, which are frequently inundated by the sea in the lower reaches. Major flows occur in the Ashburton River every one to three years. River flows predominantly occur during the cyclone seasonal and are typically short-lived.

The Wheatstone Project is on a local-scale catchment divide between the Hooley Creek Catchment, Southwest Catchment (southwest of the proposed Wheatstone LNG plant) and the Ashburton River, each of which are hosted by the coastal delta area of the Ashburton River, termed the Ashburton River Delta. The Wheatstone Project is located in the tidal zone and is exposed to rainfall and storm surge associated with cyclones.

2.6 Landforms

At a regional scale, the Wheatstone Project is part of the Western Region soil-landscape covering about half of the total area of Western Australia. The boundaries of the Western Region extend from the Indian Ocean to the edge of the Sandy Desert and Central Southern Regions and comprise of landforms including undulating plateaux, plains, hills and ranges and coastal plains

The Western Region has been divided into 10 soil-landscape provinces. The majority of the Wheatstone Project is located within the Exmouth soil-landscape Province, while the south eastern boundary of the Wheatstone Project, along the Domgas study area, is located within the Ashburton Province. These boundaries are based on Jennings and Mabbutt (1977).

The Exmouth Province occupies about 25,100 km^2 with landforms generally comprising of alluvial plains or sand plains with coastal flats and dunes (and some ranges and stony plains) on sedimentary rocks. The Ashburton Province is located to the south east of the Exmouth Province and occupies about 188,375 km^2. The Ashburton Province is comprised of a mosaic of hilly terrain and stony plains, with rugged ranges, hills, ridges and plateaux are found on the sedimentary rocks.

2.7 Soils

Soils are varied over the Western Region as a result of a wide range of parent materials and climatic conditions encountered. Major soils encountered within the Western Region have been defined by the Soils Group of Western Australia (Schoknecht, 2002). As reported by Tille (2006) and as defined by Schoknecht (2002), soils of the Exmouth Province generally comprise of Red deep sands and Red deep sandy duplexes and Red sandy earths dominating the broad, sandy surfaced plains and dune landscape.

Component zones associated with Exmouth Province include the Yannery Plains and Onslow Plains. Sandplains and alluvial plains (and some floodplains) of the Yannery Plains comprise red deep sands with red/brown non-cracking clays and red deep sandy duplexes with some hard cracking clays. These soils have been identified in the north-west coast between the Ashburton and Lyndon rivers.

Coastal mudflats (with some sandplains and coastal dunes) of the Onslow Plains comprise tidal soils with Calcareous deeps sands and some red deep sands, red/brown non-cracking clays and salt lake soils. These soils are located in the north-west coast between Cape Preston and the Exmouth Gulf.

Soils of the Ashburton Province generally comprise of Stony soils dominating the hilly terrain, and Red shallow loams, Red brown non-cracking clays, Red loamy earths and Red deep sandy duplexes of the stony plains.

2.8 Acid Sulfate Soils

Acid sulfate soils are naturally occurring soils, sediments and peats that contain iron sulfides, predominantly in the form of pyrite materials. These soils are most commonly found in low-lying land bordering the coast, estuarine and saline wetlands in soils comprising of Holocene marine muds and sands in protected low-energy environments.

Acid sulfate soils are formed when seawater or sulfate-rich water mixes with land sediments containing iron oxides and organic matter in a waterlogged situation, in the absence of oxygen.

In an undisturbed anoxic state, these materials remain benign, and do not pose a significant risk to human health or the environment and are referred to as PASS. However, the disturbance of PASS, and its exposure to oxygen, leads to the production of acidic conditions which have the potential to cause significant environmental and economic impacts including fish kills and loss of biodiversity in waterways; contamination of groundwater by acid, leaching of arsenic and heavy metals and corrosion of concrete and steel infrastructure by acidic water.

The probability of encountering acid-generating material in the region ranges from “extremely low” to “high”, according to acid sulfate soils risk mapping completed by the DEC (2009). The high probability areas are generally located in low lying areas of 0 to 3 m above Australian Height Datum (AHD) including Holocene intertidal flats, supratidal salt flats and mangrove swamps. Low probability areas are generally associated with deposits of coastal dune, beaches and longitudinal dunes (**Figure 3**). Probable layers of organic and marine deposits are located at shallow depths, and low probability areas and associated with the coastal dunes and Red earths.

2.9 Contaminated Soils

Based upon the information derived from the publicly accessed DEC Contaminated Sites Database (accessed May 2009), which references the underdeveloped nature of the area; and the fact there are no known historical contaminating land use practices within the footprint of the Terrestrial Assessment area , it is considered unlikely.

A review of recent aerial photography indicates that land use to the east of the Terrestrial Assessment area is used for solar salt manufacturing. Onslow Salt Pty Ltd (Onslow Salt) is licenced under the Environmental Protection Act 1986-Licence. The premises are classified as solar salt manufacturing (category 14) and bulk material loading and unloading (category 58) under the Environmental Protection Regulations 1987. While there are likely to be sections of the Onslow Salt operations that have the potential to contaminate (such as petroleum hydrocarbon storage and use, plant/machinery workshops, waste disposal etc) these areas of the Onslow Salt operations are located to the north east of the salt ponds. Therefore due to the distance from the Terrestrial Assessment area these operations are considered unlikely to have an adverse impact on the Terrestrial Assessment area.

A search of the DEC Contaminated Sites Databases indicates there is no known contamination history reported for these operations.

2.10 Vegetation

The majority of the Wheatstone Project lies within the Cape Yannarie Coastal Plain of the Cape Range subregion of the Carnarvon Botanical District (Beard, 1975) and to a lesser extent, the Onslow Coastal Plain of the Roebourne subregion of the Fortescue Botanical District (Beard, 1975) located along the Domgas study area.

The Cape Yannarie Coastal Plain generally comprise mangrove dominant vegetation along the coastal parts of the Wheatstone Project, including *Avicennia marina* as the principal species and some *Rhizophora stylosa* (Biota, 2009 and Outback Ecology Services [OES], 2010*)*. Behind the tidal creeks and mangrove swamps are bare saline mud flats or intertidal flats, which sometimes floods with spring tides. This zone is generally devoid of any vegetation, although some samphire communities occur locally (*Tecticornia* species).

Inland of the tidal mud flats area (supratidal salt flats) is a zone mapped as shrub steppe on sandhills with numerous small claypans. The shrub steppe is typically dominated by *Triodia* species (*T. epactia/pungens*) with *Acacia bivenosa, A. synchronicia, A. tetragonophylla* and *A. xiphophylla* the most common shrub species present.

Vegetation of the Onslow Coastal Plain is dominated by *Acacia victoriae, A. xiphophylla* in shrubland *and Acacia pyrifolia* in open shrubland with *Triodia pungens, T. basedowii* in open hummock grassland and mixed grassland.

2.11 Conservation Reserves

The Cane River Conservation Park (C-Class Reserve) is located approximately 100 km south of Onslow and 4.5 km to the east of the eastern end of the Domgas study area. The National Reserves System Co-operative Program, however, is proposing to include extensions to the Cane River Conservation Park to include the Mt Minnie Pastoral Lease, Ashburton (110 921ha), and part of the Nanutarra Pastoral Lease, Ashburton (70 030 ha). This may occur in 2015, and once implemented, the eastern 44 km section of the Domgas study area will be located within the Park.

Some of the conservation values of the Cane River Conservation Park include (DEC 2009c):

- Landforms and vegetation types of particular interest not found in other conservation reserves in the Pilbara.
- Contrasting granite outcrops and sandstone ranges including the Parry Range and Mt Minnie.

According to the DEC (2009c), “conservation parks are managed for their scenic, cultural and biological values, to conserve wildlife and the landscape, for scientific study and to preserve features of archaeological, historical or scientific interest”. It has been identified by the DEC that conservation parks require ongoing management to protect biodiversity values, control weeds and feral animals, manage fire and to provide for visitor access and facilities.

Land Systems of the Terrestrial Assessment Area

Land systems mapping for the Terrestrial Assessment area, have been adapted from Payne *et al.* (1988) and van Vreeswyk *et al.* (2004). Land systems are comprised of repeating patterns of topography, soils, and vegetation (Christian and Stewart 1953)

A series of seven land systems have been identified within the boundaries of the Terrestrial Assessment area and include the Onslow, Littoral, Dune, Minderoo, Giralia, Stuart and Uaroo land systems (**Figure 4)**.

The land systems are described as follows:

- The Onslow land system comprises sandplains, dunes and clay plans supporting soft spinifex grasslands and minor tussock grasslands.
- The Littoral land system comprises coastal mudflats with mangroves on seaward fringes, samphire flats, sandy islands, coastal dunes and beaches.
- The Dune land system comprises dune fields supporting soft spinifex grasslands and depositional surfaces such as sand dunes and swales.
- The Minderoo land system comprises alluvial plains supporting tall shrublands and tussock grasslands and sandy plains supporting hummock grasslands.
- The Giralia land system comprises linear (parallel) dunes up to 30 m in height, sandy, broad non-saline and calcrete plains supporting hard spinifex pastures.
- The Stuart land system comprises gently undulating plains, minor hills and broad lower plains supporting hard and soft spinifex and stony chenopod.
- The Uaroo land system comprises low hills, low stony rises and pebbly, sandy and calcrete plains supporting hummock grasslands of soft and hard Spinifex.

These land systems and associated geomorphologic characteristics within the Terrestrial Assessment area are presented in **Table 3.1** as adapted from Payne *et al* (1988).

Table 3-1 Land Systems and Associated Geomorphology Occurring Within the Terrestrial Assessment Area

Land System	**Associated Geomorphology**	**Components of the Terrestrial Assessment area Occurring In This Land System**	**Approximate Coverage of Land System Within The Terrestrial Assessment Area**	
			Area (ha)	**% of Total**
Onslow	Depositional surfaces include sandy plains, with non saline clay plains subject to sheet flow, narrow drainage zones and minor depression. Coastal fringes of low sand plains interspersed with slightly lower saline samphire flats and minor claypans, coastal dunes and beaches of relief of up to 20m in height.	Ashburton North and surrounds, Shared Infrastructure Corridor, Accommodation Village, Construction Area and northern extent of Domgas Pipeline.	**1779**	**47**
Littoral	Depositional surfaces include saline coastal flats such as estuarine and littoral surfaces, with extensive bare saline mudflats that are subject to infrequent tidal inundation and slightly higher elevated samphire flats. Intense dissection patterns are identified where mangrove seaward fringes and tidal creeks are present. Minor linear dunes and sand plains of relief up to 6m in height are also present.	Ashburton North and surrounds, Construction Area and north western extent of Shared Infrastructure Corridor.	**1138**	**30**
Dune	Depositional surfaces include dune fields which comprise of sand dunes of relief of up to 1 m in height, and swales with no organised drainage. Minor claypans, swamps and depressions are also identified.	Ashburton North and surrounds and minor representation along the Shared infrastructure Corridor and Construction Area.	**275**	**7**
Minderoo	Depositional surfaces include alluvial plains which comprise of old floodplains associated with the Ashburton River and plains formed by sheet flood and deflation with no organised drainage. Sand plains, of relief of up to 20m in height, claypans, swamps and depressions are also identified.	Southern extent of the Accommodation Village and Construction Area.	**116**	**3**
Giralia	Depositional surfaces include sandy plains formed by sheet flood and wind action, broad non-saline plains with thin sand cover and linear dunes trending N-S with no organised drainage but through flow areas receiving more concentrated sheet flow than adjacent plains.	Northern extent of the Domgas Pipeline and Construction Area.	**140**	**3**
Stuart	Erosional surfaces include gently undulating plains and minor hills, broad lower plains. Relief up to 25m.	South eastern extent of Domgas Pipeline.	**71**	**2**
Uaroo	Depositional surfaces include sandy and non-saline sandy plains approximately 10km in extent, with little organised drainage. Pebbly surfaced plains and plains with calcrete at very shallow depth and minor low stony hills and rises. Relief is mostly less than 5m in height although isolated sills can be up to 30m.	Broad section of the central part of the Domgas Pipeline	**291**	**8**

Landforms and Soils of Ashburton North and Surrounds

The following landform units and soil profiles were derived from the completion of the desktop assessment of Ashburton North and surrounds and of the field programme undertaken between March to June 2009.

Landforms typically encountered within the boundary of Ashburton North and surrounds are shown in **Figure 5-1** and include:

- Tidal Creeks, Intertidal Flats and Mangrove Swamp.
- Supratidal Salt Flat.
- Samphire Flats.
- Claypans and Clay Plains
- Alluvial/Colluvial Plains.
- Fringing and Coastal Dunes.
- Longitudinal Dunes and Interdunal Swales.
- Mainland Remnant Dunes.

Landforms and soils typically encountered within the Ashburton North and surrounds study area is presented below:

4.1 Tidal Creeks, Intertidal Flats and Mangrove Swamp

The landform units identified as the tidal creeks, intertidal flats and mangrove swamp (**Plates 4-1 to 4-4**) form a major bio-physical system along the north western boundary of Ashburton North and surrounds as part of the Ashburton River delta, and to a lesser extent, near Hooley Creek. These landform units are generally associated with the Littoral land system.

Together, these landform units are characterised by sinuous tidal creeks and intertidal mud/sand flats characterised by surficial salt scalding and significant surface and shallow subsurface shell deposition. Relatively high tidal ranges lead to regular flooding of the shallow sloping shores.

A number of palaeochannels have been identified within Ashburton North and surrounds, with the most significant for this landform unit being adjacent to Hooley Creek, migrating inland along the western boundary of the longitudinal dunal network (Damara, 2009). The creeks associated with this landform unit, typically form a wide mouth which narrows and becomes shallow upstream via a sinuous channel, becoming dendritic toward the supratidal salt flats. Damara (2009) reported that water flow through the tidal creeks provides the major exchange of sediment between the nearshore marine and terrestrial areas.

Shallow soils of the low lying intertidal flats, tidal creek and mangrove swamp consists mainly of neutral and alkaline (saline) red brown surface soils grading dark brown to light brown, grey sandy clays, clays and fine to coarse grained silty sands. Carbonate concentrations are moderate (reflecting shelly material in the sediments) and the concentration of organic material is variable, but generally high.

At shallow depths, the accumulation of sediment beneath the mangrove swamp (due to trapping and baffling by vegetation) has resulted in strongly reducing conditions, poorly- to moderately-sorted silts and clays, with generally high concentrations of organic material. These clayey subsurface soils have the potential to generate acidity, with a thickness reported up to 0.85 m.

4 Landforms and Soils of Ashburton North and Surrounds

Vegetation varies between densely vegetated mangrove swamp along the creek banks, to sparse spinifex grasses and algal mats in areas completely devoid of vegetation. Mangroves form a fringe along the tidal creeks, reducing in density with distance from the edge of the creeks.

Intertidal flat and mangrove swamp deposits generally consist of the following:

- SAND: fine to medium grained, red brown with some clay, trace of gravel, trace shell fragments.
- Sandy CLAY: medium plasticity, brown, some occasional black mottling with depth, sand is fine grained.
- CLAY: high plasticity, dark brown, occasional black mottling.
- Silty SAND/SAND: silty, fine to coarse grained, brown, moderately sorted, quartz sand, minor feldspar.

Figure 6 illustrates a generalised cross-section (B-B^1) of the soils intercepted at shallow depths (3 mbgl) extending across from the fringing dune network to the west along the intertidal flats to the east. PASS was detected as a shallow lens of marine/organic deposits up to 0.95m thick.

Plate 4-1 Hooley Creek-Tidal Creek

Plate 4-2 Salt Scalding of Intertidal Mud Flat

Plate 4-3 Tidal Creek with Mangroves

Plate 4-4 Intertidal Flats

4.2 Supratidal Salt Flat

The supratidal salt flats are typically encountered in the Littoral land system, and are located up gradient of Hooley Creek to the north west, and are characterised by surficial salt crusting, the result of intense evaporation due to a dry evaporative environment that undergoes infrequent inundation.

The supratidal flats are dominated by low gradient, and mostly featureless, bare open mud/algal flats (**Plate 4-5**) that generally occur above the spring high water mark and hence are rarely inundated by marine waters, except in the event of cyclonic storm surge. A thin veneer of decomposing black organic gel-like matter, indicative of iron monosulfides, was observed beneath the ground surface where algal mats had colonised along the edges, as a result of recent flooding associated with heavy rainfall.

These iron monosulfides, or as they are typically described, mono-sulfidic black ooze (MBO) can occur in the protected upper reaches of tributaries of PASS environments (e.g. intertidal flats) where organic matter (e.g. algal mats) contribute large amounts of decaying organic debris.

MBO materials are subaqueous or waterlogged mineral or organic materials that contain mainly oxidisable monosulfides rather than pyritic sulfides. They usually have a field pH of 4 or more but may become acid (pH <4) when disturbed due to hydrolysis of ferrous iron. When disturbed and mixed with water, the iron monosulfide can react within minutes to completely consume dissolved oxygen causing the degradation of water quality.

In the natural environment of Ashburton North and surrounds, it is anticipated that the presence of carbonates of calcium, magnesium and sodium in soils where MBO materials are present, will neutralise the acidity as it forms, through the sequence of natural processes.

Shallow soils/sediments comprise of alkaline (saline) red brown clayey sand, grading to slightly acidic light brown sandy clay of variable plasticity with depth. Surface carbonate concentrations are generally high, and concentrations of organic matter are generally low.

Soils associated with the supratidal salt flats generally consist of the following:

- Clayey SAND: fine to medium grained, red brown, some black mottling.
- Clayey SAND: fine to medium grained, light brown, clay is low plasticity.
- Sandy CLAY: low to medium plasticity, light brown/cream, sand is fine grained.

4.3 Samphire Flats

The samphire flats are also predominantly encountered within the Littoral land system and are generally located along the west and north (**Plate 4-6**) of the Terrestrial Assessment area.

The surface of the samphire flats are generally salt encrusted with a thin lens of variably decomposed black organic matter beneath the soil surface. This high nutrient environment, together with the activity of algae and micro-organisms, generates reducing conditions, which results in the formation of black MBO. MBO is discussed in greater detail above in **Section 4.2.**

The samphire flats are typically characterised by salt tolerant vegetation which ranges between very scattered to moderately dense salt tolerant Samphire species, and low shrublands.

Shallow soils generally consist of neutral to acidic red-brown sandy clay and plastic clays grading brown to grey as shallow groundwater is intercepted.

Soils associated with the samphire flat generally consist of the following:

- Sandy CLAY/CLAY: variable plasticity, red/brown with grey mottling. Sand is fine to medium sands with shell fragments clay.
- CLAY: Moderate to high plasticity, brown /grey/yellow mottled.

Plate 4-5 Salt Encrusted Supratidal Flat

Plate 4-6 Samphire Flat with Samphire

4.4 Claypans and Clay Plains

There are numerous localised areas of claypan dominated terrain (**Plates 4-7 and 4-8**), ranging in size from 100-200 m^2 to 1 500 m^2 within Ashburton North and surrounds. These isolated claypans form a discontinuous network within the boundaries of the alluvial/colluvial landform units adjacent the longitudinal dune network.

Sinuous bare claypans, flanked by samphire flats, were identified south east of the north western extent of the Terrestrial Assessment area and fringing the islands associated with the mainland remnant dunes along the eastern boundary (**Figure 5-1**). Claypan dominated terrain typically consists of neutral plastic clays overlying variably cemented calcareous material.

The claypans are generally defined as bare (devoid of vegetation), regularly inundated or irregularly inundated (both of which support soft spinifex *sp.* and salt tolerant plants) (Biota, 2009).

Claypan dominated terrain typically consists of neutral to alkaline plastic clays with variably cemented carbonate material.

Soils associated with claypan generally comprise of:

- CLAY: high plasticity, red brown
- Silty sandy CLAY/silty CLAY: low plasticity, very fine to medium grained sand, red brown.
- Sandy CLAY: medium plasticity, sand is fine to medium grained, red/brown.
- Silty SAND: red brown grading with limestone fragments and bands.

Plate 4-7 Discontinuous Claypan Pocket

Plate 4-8 Sinuous Bare Claypan

4.5 Alluvial/Colluvial Plains

Alluvial sediments of the low lying alluvial/colluvial plains (**Plate 4-9 and 4-10**) are closely associated with the lateral migration of clay-pan and dune deposits. Subtle changes in surface material and depositional characteristics are highlighted by the highly variable surface soils. The alluvial/colluvial plains of Ashburton North and surrounds are typically encountered adjacent to the longitudinal dunes and claypans of the Dune land system, and on the southern boundary of the fringing and coastal dunes of the Onslow land system.

Vegetation typically encountered included hummock grasslands such as soft Spinifex species and some hard Spinifex species with sparse low shrubs such as *Acacia.*

Shallow soils are highly variable grading between poorly sorted alkaline red earth silt, and sand and gravel with both cracking and non cracking clay soils, overlying the shallow sandstone bedrock formation.

Recent marine deposits, characterised as moderate to high plasticity brown to grey clay, were intercepted at shallow depth (~2.0 mbgl), where the plains fringed the intertidal flats of the mangrove/tidal creek landform unit along the north eastern extent of Ashburton North and surrounds.

Soils associated with the alluvial/colluvial plains generally consist of the following:

- CLAY: moderate plasticity, brown to grey with yellow mottles.
- Clayey SAND: fine to medium grained, red brown, some black mottling at surface.
- Gravelly SAND: sub angular to angular gravel to 20mm, fine to medium grained, red/brown.
- Silty SAND: grading fine to medium grained, red brown.
- Silty CLAY: high plasticity, mottled, minor quartz present, red/brown.
- Sandy clayey GRAVEL: fine to coarse grained gravels, brown to red brown and grey black.
- Gravelly sandy CLAY: medium plasticity, angular sandstone, gravels 5 to 10mm, red/brown.
- SAND: grading fine to coarse grained, brown to red brown.
- Sandy CLAY/sandy silty CLAY: firm, sand very fine grained, red/brown and light brown.
- SANDSTONE: moderately to very well cemented, fine to coarse grained sands, pale brown, high shell content and fossils.

Plate 4-9 Colluvial/Alluvial Plain

Plate 4-10 Colluvial/Alluvial Plain with Spinifex

4.6 Fringing and Coastal Dunes

The fringing dune landform unit (**Plate 4-11 and 4-12**), which comprise of beach and low dune ridges of variable stability, generally commence from the northern boundary (ocean) and extend in a southerly direction for approximately 200 m. The low dune ridges are typically formed from the deposition of wind blown sands and through sand supplied by storm surges, and are generally located above the high water mark.

4 Landforms and Soils of Ashburton North and Surrounds

Coastal dunes (**Plate 4-13 and 4-14**), in the order of 6 to 7 m in height were identified in the field, and with slopes of 20 to 35 degrees, were identified along the northern and western part of Ashburton North and surrounds, adjacent to the fringing dunes.

Soils along the coastal fringe mainly consist of neutral to alkaline sands and shell fragments overlying carbonate sandstone. Along the northern extent of Ashburton North and surrounds, the interception of marine deposits comprising of low plasticity grey clay, at shallow depths of around 0.8 mbgl of up to 0.95 m thick and identified as PASS, suggest the presence of an underlying chenier (a continuous ridge of beach material built upon marine deposits) and hence the potential for the presence of potentially acid generating material at shallow depths.

This is further supported by Damara (2009) who reported that a more recently formed pavement of marine origin commonly sits above the Red deep sand and is exposed at the Ashburton River Delta and fringing beaches. The pavement has a variety of lithified geomorphic features associated with fluvio deltaic and nearshore marine processes and includes the landforms of mid delta environments: channel gorges, topographic rises and basins.

Vegetation of the low dune ridges of the fringing dune landform unit, typically support hummock grasses with isolated to scattered shrubs while the beaches are generally devoid of vegetation. The coastal dunes also support hummock grasses, and are moderately vegetated with shrubs of 1 to 2 m in height.

Soils associated with the fringing and coastal dunes generally comprise the following:

- SAND/silty SAND: fine to medium grained, poor to well sorted, red brown, with shell fragments.
- Sandy CLAY/gravelly CLAY: low to moderate plasticity, red brown, fine to medium grained.
- CLAY: Medium to high plasticity, cream/brown to grey, yellow mottles.
- Calcareous SANDSTONE: moderately to well cemented, fine to medium grained quartz, some small shell fragments, cream/white.

Figure 6 illustrates a generalised cross-section (C-C^1) of the soils intercepted at shallow depths (3 mbgl) extending across the alluvial/colluvial plains and coastal dunes located adjacent the Ashburton River delta along the western boundary of the Terrestrial Assessment area. No PASS was identified along this cross section.

Plate 4-11 Fringing Dunes-Beach

Plate 4-12 Fringing Dune-Low Ridges

Plate 4-13 Coastal Dune

Plate 4-14 Coastal Dune with Spinifex

4.7 Longitudinal Dunes and Interdunal Swales

Longitudinal dunes and interdunal swales (**Plate 4-15 to 4-18**) were typically encountered within the central part of Ashburton North and surrounds, orientated generally in a north-south direction. The dunes, which range in height from 5 to 21 mAHD, display network patterns with a high level of variability along the length of the dune. These landforms are generally associated with the Dune land system.

The majority of the contemporary surface of the longitudinal dunes is a function of degradation and sand mobilisation over time. The longitudinal dunes have generally formed from residual sand, alluvial, colluvial and claypan deposits that were eroded and redeposited as dunes. The interdunal areas of the longitudinal dune network are generally either stable or vegetated, or form deflation zones and claypans which have probably been reworked historically by colluvial and aeolian processes. Longitudinal dunes and interdunal swales typically support hummock grasslands with low to mid-height shrubs of up to 1 m in height.

Soils associated with the longitudinal dunes and interdunal swales generally comprise the following:

- SAND: fine to medium grained, poorly sorted, light brown to red brown.

- Silty sandy GRAVEL: weathered limestone, angular gravels of 20-30 mm, some shell partially cemented.
- Silty SAND: fine to medium grained, moderately sorted, red brown, some shell.
- Sand/Calcareous SANDSTONE: fine to medium grained quartz, variable lithified, some shell fragments brown grey to pale brown.

Figure 6 illustrates a generalised cross-section (A-A^1) of soils intercepted at shallow depths (3 mbgl) along the longitudinal dune and interdunal swale landform unit located centrally of Ashburton North and surrounds.

Plate 4-15 Longitudinal Dunes in Distance

Plate 4-16 Interdunal Swales

Plate 4-17 Inland Dune

Plate 4-18 Interdunal Swale

4.8 Mainland Remnant Dunefield

Mainland remnant dunes of the Dune land system were identified along the eastern boundary of Ashburton North and surrounds on islands isolated by the supratidal salt flats and fringing claypan dominated terrain.

These features are remnants of an ancient dunefield landscape and now remain isolated by the supratidal salt flats following a small marine transgression/regression. Hence, the majority of the remnants contain a physical framework typical of the ancient dunefield landscape, in particular, longitudinal dunes and interdunal swales and claypans.

4 Landforms and Soils of Ashburton North and Surrounds

These soils are of similar composition as the soils of the longitudinal dunes and interdunal swales based on the typical framework associated with these landform units.

Landforms and Soils of the SIC, Camp, Construction and Domgas Study Areas

A desktop review was completed of soils and landforms along the SIC, Camp, Construction and the Domgas study area. The desktop review, was predominantly based on works completed by Biota Environmental Sciences (Biota), (undertaken in April 2009) and of OES, (undertaken in May 2010). Use of aerial photography and land system mapping (as adapted from Payne *et al.* [1988] and van Vreeswyk *et al.* [2004]) were also used to aid in the identification of typical landforms of the area in question. Methodology used in the desktop review of available literature is presented in **Appendix A.**

A landforms assessment of the SIC and Domgas study area was completed between 19 and 23 October 2009. Heritage surveys had not been completed for the Camp study area at the time of writing, and therefore a desktop review of this area has only been completed to date.

The following section summarises these initial findings.

5.1 Landform Units of the Shared Infrastructure Corridor Study Area

Land systems identified within the boundaries of the SIC study area include the Onslow, Littoral and Dune land systems with the dominant system being the Onslow land system. The Littoral land system is represented along the north east boundary of the SIC study area and the Dune land system at the southern end, adjacent Onslow Road.

Landforms typically encountered within the boundary of the SIC study area are shown in **Figure 5-2** and include the following:

- Alluvial/Colluvial Plains.
- Supratidal Salt Flats.
- Saline Flats.
- Longitudinal Dunes and Interdunal Swales.
- Claypans and Clay Plains
- Samphire Flats.

The dominant landform unit of the SIC study area comprise of broad scoping alluvial/colluvial plains (**Plate 5-1**) interspersed with continuous and discontinuous pockets of claypan depressions and clay plain. The alluvial/colluvial surfaces generally comprise of undulating sand plains up to 3km in extent with micro-relief of up to 2 m in height and support hummock grasslands.

As with the alluvial/colluvial plains of Ashburton North and surrounds, subtle changes in surface material and depositional characteristics (drainage lines and sheet apparent).are highlighted by the highly variable surface soils.

Soils of the alluvial/colluvial plains of the SIC study area typically comprise of the following:

- Clayey SAND/Clayey SAND: fine to medium grained, low plasticity, red brown, surface soils are loose, minor gravels are cemented (calcrete).
- Silty SAND: very fine grained, light brown, surface soils are loose.

Samphire flats (**Plate 5-2**) were commonly encountered adjacent the low lying claypan areas. Unlike the more coastal samphire flats of Ashburton North and surrounds, these areas are not subject to as frequent flooding other than during heavy rainfall events. Groundwater was only intercepted at one soil bore location at 2.29mbgl and there was no evidence of PASS or MBO, unlike the more reactive soils reported for Ashburton North and surrounds. It should be noted, however, that there is still a potential for the interception of PASS material at depths below where groundwater is intercepted, based on an assessment of samphire flats across the Terrestrial Assessment area.

Soils of the samphire flats along the SIC study area typically comprise of the following:

- Clayey SAND/sandy CLAY: fine grained sands, low to medium plasticity clays, red brown, moderately tight.
- CLAY/clayey SAND: Sub rounded sandstone gravels (3 mm - 10 mm diameter) fine grained, brown, low plasticity.
- Limestone: (at 26 mbgl) Calsilutite creamy white, clay to claystone infill variable, fresh, few fractures, hard, few vugs, grades into more days and conglomeritic, sandy patches and fractures frequent.

Plate 5-1 Alluvial/ Colluvial with adjacent Longitudinal dunes

Plate 5-2 Samphire Flats

Plate 5-3 Supratidal Salt Flat

Plate 5-4 Saline Flat

The supratidal salt flats (**Plate 5-3**) were typically encountered along the northern boundary of the SIC study area and are part of the supratidal unit adjacent to Hooley Creek, along the north eastern extent of Ashburton North and surrounds. This landform unit is typically similar in composition to that described for Ashburton North and surrounds.

The shallow soils encountered along this area include:

- Sandy CLAY: medium plasticity, fine to medium grained, red brown, alkaline
- Sandy CLAY: moderate plasticity, fine to medium grained, organic matter, grey with some yellow mottling, reactive. These soils are considered PASS.

Small dentric tributaries, associated with the supratidal salt flats of Ashburton North and surrounds, called saline flats, were identified along the north eastern boundary of the SIC study area and again adjacent to Onslow Road. These tributaries are typically devoid of vegetation and are rarely inundated by marine waters unless in the event of cyclonic conditions which may result in storm surge and heavy rainfall. The saline flats are typically dominated by low gradient, and mostly featureless, bare open mud flats (**Plate 5-4**) with a salt encrusted surface.

Soils of the saline flat runoff areas encountered along the SIC study area will be of similar composition as those reported closer to the coast, although with less marine/organic deposits. It is considered that PASS will be encountered where groundwater is intercepted (~2-3 m bgl) although these are very minor in extent.

The claypans (and clayey plains as described by Biota [2009]), range in shape from circular, oval to irregularly shaped and in degree of connectivity with tidal areas. The claypans are typically bare to sparsely vegetated sealed (hardened crust) surfaces with steep marginal slopes of up to 3 m in height adjacent to alluvial/colluvial plains (**Plates 5-5** and **5-6**).

Soils encountered within the claypans typically comprise of the following:

- Silty SAND: fine to medium grained, red brown, minor gravels, sub angular
- Sandy CLAY/Clayey SAND: fine to medium grained sands, low to moderate plasticity clays, tight, red brown.

Plate 5-5 Sparsely Vegetated Claypan

Plate 5-6 Bare Claypan

A network of relatively low longitudinal dunes and interdunal swales were encountered throughout the boundary of the SIC study area ranging in height from 5 m to 10 m. Typically, these dunes were orientated in a north south direction and are of similar composition to the network identified within Ashburton North and surrounds. This landform unit typically supports hummock grasslands and small shrubs while the interdunal swales typically support tall shrubs.

Surface soils encountered within the longitudinal dunes of the SIC study area include:

- SAND: fine to medium grained, poorly sorted, light brown to red brown.
- Silty SAND: fine to medium grained, moderately sorted, red brown, some shell.

5.2 Landform Units of the Camp Study Area

Land systems identified within the boundaries of the Camp study area and surrounds include the Onslow, Dune and Minderoo land systems. The dominant land system is the Onslow land system while the Dune and Minderoo land systems are mainly present along the southern most boundary of the Camp study area.

It is anticipated that landform units located within the boundaries of the Camp study area, which are shown in **Figure 5-2**, include the following:

- Alluvial/Colluvial Plains.
- Claypans and Clay Plains
- Longitudinal Dunes and Interdunal Swales.
- Samphire Flats.

The dominant landform unit comprises alluvial/colluvial plains and are typically similar in formation as those encountered along the SIC study area. Soils typically comprise dark reddish brown sands and sandy loams while a nominal number of bare and vegetated claypans were identified along the south western boundary of the Camp study area. Samphire flats and longitudinal dunes and interdunal swales were identified in the south western boundary of the Camp study area.

Based on the DEC (2009) Ass Risk Map and a desktop assessment, the area has been mapped as moderate to no known risk for PASS. The moderate to low areas generally coinciding with areas associated with samphire flats.

5.3 Landform Units of the Construction Study Area

Land systems identified within the boundaries of the Construction study area are dominated by the Littoral and Onslow landsystems and to a lesser extent the Dune, Minderoo and Girala land systems.

Landforms typically encountered within the boundary of the Construction study area are shown in **Figure 5-1 and Figure 5-2** and include the following:

- Supratidal Salt Flats.
- Mainland Remnants
- Claypans and Clay Plains
- Alluvial/Colluvial Plains.

- Longitudinal Dunes and Interdunal Swales.
- Samphire Flats.
- Saline Flats (Drainage Line).

The northern part of the Construction study area is bound by Horseshoe Island to the east and Ashburton North and surrounds to the west by typically bare to sparsely vegetated (Tecticornia spp.) supratidal salt flats. The supratidal salt flats dominate the north eastern boundary of the terrestrial study area typically comprising low gradient, and mostly featureless, bare open mud/algal flats.

It is anticipated that the features identified on Horseshoe Island, which is located along the north eastern boundary of the Construction study area, are remnants of an ancient dunefield landscape, as identified for the minor islands located within Ashburton North and surrounds, and now remain isolated by the supratidal salt flats following a small marine transgression/regression. Hence, the majority of the remnants contain a physical framework typical of the ancient dunefield landscape, in particular, longitudinal dunes and interdunal swales and claypans.

Where the Construction study area extends south towards the SIC study area, the landscape is typically dominated by alluvial/colluvial plains and claypans (bare and partially vegetated) scattered throughout the Construction study area ranging in size, and with degree of connectivity with tidal areas (connected and seasonally inundated or isolated).

Similarly, broad clayey plains were present throughout the Construction study area ranging in size and connectivity as heavy clay plains in low-lying areas, adjacent to the SIC study area, to broad ranging plains of up to 2-3km in length as identified south of Ashburton North and surrounds. Permeability of the clayey soil types, which ranged between red brown, high plasticity clay to red brown, low plasticity, very fine to medium grained silty sandy clay, will potentially impact the degree of water holding potential (lending some to hold water for several weeks, while others of similar sized were dry).

The degree of vegetative cover on the claypans was varied, but most were fringed by a narrow band of ephemeral grasses, sedges and herbs. It is considered that the claypans will become ‘less saline’ with proximity from the coastline (the northern boundary of the Terrestrial Study area) (OES, 2010). The clayey plains typically support tussock grasses, tall shrublands and various Spinifex species (hard and soft)

The alluvial/colluvial plains dominate the southern boundaries of the Construction study area and are comprised of flat to gently undulating sandy inland plains which were broadly dominated by soft Spinifex and hummock grasses (OES, 2010). This is typical of alluvial/colluvial plains identified throughout the Terrestrial Study area as discussed in detail in **Section 4.5**.

Inland longitudinal dunes and swales were encountered throughout the southern component of the Construction study area, where it runs adjacent with the SIC and Camp study area, and to a lesser extent south of Horseshoe Island and to the south of Ashburton North and surrounds. Unlike the dune systems located within Ashburton north and surrounds, these linear dune systems are typically of lower relief (of approximate heights of 5 m to 10 m) trending north south and range in length to up to approximately 100m in length.

The soils associated with the longitudinal dunes and interdunal swales include light brown to red brown, fine to medium grained sand, to a red brown, fine to medium grained silty sand. OES (2010) reported that dominant vegetation species of the consolidated red sand dunes included hummock grasses and *Triodia* spp. The narrow swales typically featured scattered tall shrubs of the dominant species from the dunes along with higher density of Acacia.

Samphire flats are present intermittently across the Construction study area, although are most dominant along the construction road located to the west of Ashburton North and surrounds and along the western boundary of the Construction study area located south of Ashburton North and surrounds. The samphire flats are typically characterised by salt tolerant vegetation which ranges between very scattered to moderately dense salt tolerant Samphire species, and low shrublands. Typically, shallow soils encountered within the samphire flats comprise of neutral to acidic red-brown sandy clay and plastic clays grading brown to grey as shallow groundwater is intercepted.

Small dentric tributaries called saline flats which are associated with the supratidal salt flats of Ashburton North and surrounds extend south across the Construction study area north and south of the SIC study area. The saline flats are typically devoid of vegetation and are rarely inundated by marine waters unless in the event of cyclonic conditions which may result in storm surge and heavy rainfall. The saline flats are typically dominated by low gradient, and mostly featureless, bare open mud flats with a salt encrusted surface in areas.

Based on the DEC (2009) ASS Risk Map (Figure 3) and the landform assessment, the Construction study area is considered moderate risk typically along the northern boundary where the supratidal salt flats and samphire flats are encountered and low to no risk for PASS along the southern boundaries.

5.4 Landform Units of the Domgas Study Area

The dominant land system identified within the boundary of the Domgas study area is the Uaroo land system. The Onslow and Giralia land systems are generally located towards the northern boundary while the Stuart land system is present at the southern most boundaries.

Landforms typically encountered within the boundary of the Domgas study area are shown in **Figure 5-3 to 5-5** and include the following:

- Alluvial/Colluvial Plains.
- Claypans and Clay Plains
- Longitudinal Dunes and Interdunal Swales
- Drainage Areas.
- Stony Hills.

Alluvial/colluvial plains (**Plate 5-7**) dominate the landscape along the Domgas study area, commencing along the northern boundary of the Domgas study area, adjacent to Onslow Road extending the length of the Domgas study area. The alluvial/colluvial plains along the northern boundary are characterised by low swales and slopes with soils comprising dark reddish brown sands and sandy loams.

Toward the central and eastern boundaries of the Domgas study area, the alluvial/colluvial plains become broad and flat (**Plate 5-8**) with gradients of 1 in 1000, with micro-relief. They are generally moderately vegetated with Spinifex and low to high shrubs ranging in height between 1 and 2m.

Claypans are intermittently encountered along the northern boundary of the Domgas study area and are typically flat, rounded, depressed surfaces up to 300 m wide; the soils associated with the claypans are reddish brown clay soils with occasional seasonal cracking.

Plate 5-7 Undulating Alluvial/Colluvial Plain

Plate 5-8 Broad Flat Alluvial/Colluvial Plain

Linear inland dunes were identified along the northern to central extent of the Domgas study area comprising of parallel dunes, trending north-south, with the most significant approximately 3km in length and 60 to 80 m wide. Soils are loose dark red sandy soils.

A number of unchannelled drainage areas (**Plate 5-8**) are located centrally of the Domgas study area and west of the Stuart land system. These drainage areas (or floodways) range from flat to a gentle east to west inclination. These areas may receive sheet flow during high rainfall events and range from sparsely to moderately vegetated small to tall shrub (up to 2m in height). Soils of the unchannelled drainage areas comprise of dark reddish brown soils, with loamy surface horizons becoming more clayey with depth.

Plate 5-9 Drainage Areas

Plate 5-10 Stony Hills

A number of low stony hills (**Plate 5-9**), up to 100 to 200 m in width, and rock outcrops are present along the eastern boundary of the Domgas study area, where the Stuart land system commences. The stony hills are characterised by isolated hill tracts and convex slopes. Rock outcrops (intrusion of quartz) were observed with a maximum height of 10m. The stony surfaced outcrops and hills are generally support hummock grasses and occasional tall shrubs.

Adjacent to the stony hills and for the remainder of the Domgas study area, the landscape comprise of broad clayey plains with a stony soil surface. These areas are generally moderately vegetated with hummock grasses. The soils of these are generally red gravelly surface sands sand grading to clay with depth.

Based on the DEC (2009) ASS Risk Map and the landform assessment, the Domgas study area is considered low to no risk for PASS.

5.5 Landform Significance of the Terrestrial Assessment Area

In summary, eleven major landform units have been described within the Terrestrial Assessment area. An assessment of landform significance for the Terrestrial Assessment area was undertaken and was based on the identification of landforms comprising of conservation values significant for the Pilbara Region as discussed in **Section 2.11**. Based on these conservation values, no current landforms of significance were identified within the Terrestrial Assessment area.

Table 5-1 outlines the area of each identified landform that is present in the Terrestrial Assessment area.

5 Landforms and Soils of the SIC, Camp, Construction and Domgas Study Areas

Table 5-1 Landform Unit Significance and Component Occurring in the Terrestrial Assessment Area

Landform Unit	Landforms of Significance	Approximate Area of Landform within Terrestrial Assessment Area (ha)	Components of the Terrestrial Assessment Area (Occurring In This Landform)
Tidal Creeks, Intertidal Flats and Mangrove Swamp	None	326	Ashburton North and surrounds
Supratidal Salt Flat	None	300	Ashburton North and surrounds and Construction study area up gradient of Hooley Creek to the north west, extending as far south to the SIC study area
Saline Flat	None	6	South eastern boundary of SIC adjoining the supratidal salt flats and Construction study area
Samphire Flats	None	439	The west and north of Ashburton North and surrounds and the SIC, Camp and Construction study areas
Claypans and Plains	None	320	Ashburton North and surrounds and within the SIC, Camp and Construction study area. Areas. Claypans are intermittently encountered along the northern boundary of the Domgas study area and as plains where the Stuart landsystem is encountered.
Alluvial/Colluvial Plains	None	798	Throughout the Terrestrial Assessment area, although particularly dominant as broad, flat to gradually undulating throughout the Domgas and Construction study areas
Fringing and Coastal Dunes	None	100	Ashburton North and surrounds
Longitudinal Dunes and Interdunal Swales	None	387	Longitudinal dunes and interdunal swales were typically encountered within the central part of Ashburton North and surrounds and to a lesser extent along the SIC, Construction and Domgas study areas,
Mainland Remnant Dunes	None	141	Ashburton North and surrounds and Construction study area
Stony Hills	None	1	Domgas study area
Drainage Areas	None	13	Domgas study area

5.6 Soils of the Terrestrial Assessment Area

In summary, there are three major identifiable soil groups/types encountered of the shallow soil profile for the Terrestrial Assessment area, and have been summarised below. It should be noted that at the time of writing, intrusive works had not been completed for the Domgas study area and therefore the following summary does not include soil units associated with the stony hills and the drainage areas of the Domgas study area.

Further, while intrusive works were not undertaken for the Construction study area, it is considered that landforms encountered within this study area were typical of landforms encountered within Ashburton North and surrounds and the SIC study area and hence the soil groups/types discussed below are therefore considered generally representative of soils encountered within the Construction study area.

- Red earths: Otherwise known as ‘Ashburton Red Beds’ (Coffey, 2009).
  - These soils include fine to coarse grained, red to red brown SAND/silty SAND with minor clay content, quartz and minor feldspar. These soils are typically encountered within landform units associated with longitudinal dunes and interdunal swales, alluvial/colluvial plains and the fringing and coastal dunes
  - These soils include low to medium plasticity, fine to medium grained, red to red brown clayey SAND/sandy CLAY, with variable shell content. These soils are typically encountered within the landform units associated with the supratidal salt flat, samphire flats, claypans, alluvial/colluvial plains
- Marine/organic deposits: These soils were typically characterised as low to high plasticity CLAY to clayey SAND/SAND, low to high plasticity, brown to dark grey; fine to medium grained, mottling may range from yellow and orange, firm to very soft. These soils are considered to be of marine/organic origin and are generally located within landform units associated with the intertidal flats, tidal creek and mangrove swamp and the samphire flats and supratidal salt flats.
- Calcareous sands/rock: These soils/rock were typically characterised as moderately to very well cemented, fine to coarse grained sands to well cemented rock, pale brown to cream/white, high shell content calcareous SAND/SANDSTONE. This soils/rock were typically located at shallow depths underlying landform units associated with the alluvial/colluvial plains, fringing and coastal dunes and the longitudinal dunes and interdunal swales.

BSQ and PASS Investigation Methodology

6.1 Introduction and Rationale

The following section summarises the field and analytical methodologies completed as part of the BSQ and PASS investigation for Ashburton North and surrounds and the SIC study area. The complete sampling and analysis plan (SAP) and field methodology used in the investigation is attached as **Appendix A**.

Relevant regulatory guidelines require a PASS investigation to complete two samples per hectare to meet relevant guidelines (DEC, 2009b). Given the size of Ashburton North and surrounds and the SIC study area, soil sampling locations were selected based on geological/geomorphological units identified in the desktop assessment of the area. The sampling locations and density was thereby reduced to a total of 37 locations within Ashburton North and surrounds and the SIC study area and is considered representative of these units.

As no construction details were available prior to the completion of these works and based on the proviso that PASS of high to moderate risk is typically encountered within three metres of the natural soil surface (DEC, 2009), the field intrusive works were aimed at investigating to this depth. . Where suspect material was identified at depth, and where sample retention was adequate, the investigation depth was increased accordingly.

The DEC (2009b) required sample collection rate of 0.25 m vertical intervals was reduced to 0.5 m vertical intervals (or less if changes in soil units were reported). The laboratory schedule was further reduced to approximately two samples per location. The rationale for the diverting from the DEC guidelines was based on the input of significant data characterising the various geological/geomorphological units identified within Ashburton North and surrounds and the results of field pH tests (which is further discussed in this Section).

Based on a desktop assessment of the SIC study area, and known information derived from the works completed for Ashburton North and surrounds, the testing frequency was reduced to one sample per borehole for the SIC study area.

A soil erosion assessment was undertaken of soils and landforms encountered within the Terrestrial Assessment area for soil erodibility and dispersion. The criteria used to determine soil erodibility included soil types and landform units encountered. Water and wind erosion hazards were identified as the primary erosion hazards and an assessment of these criteria was completed for the identified erosion hazards.

Field dispersion tests were undertaken in the field on recovered samples for the classification of soils based on behaviour of soil aggregates, when immersed in distilled water, and their coherence in water (Emerson Class Test). Testing was generally undertaken on soils with suitable soil aggregates where a percentage of clay was present. Although sands and gravels are usually unsuitable for the test, slaking was noted for these soils where tested. The field methodology used for field dispersion testing is presented in **Appendix A.**

Soil field tests for pH_f, pH_{fox} and effervescence ‘fizz’ test, and field dispersion tests, were completed on recovered soil samples with the objective of obtaining a preliminary understanding of the soils existing and potential chemical composition. Soil field tests for pH_f, pH_{fox} and an effervescence ‘fizz’ test, were undertaken on the recovered soil cores for each of soil bores completed as part of the investigation at 0.25 m intervals. The results of field tests are presented in **Appendix D.**

6.1.1 Ashburton North and Surrounds

A total of 18 environmental soil bores were drilled at a variety of locations for Ashburton North and surrounds to a maximum depth of 4.6 mbgl using diamond core rotary method between the 27 March and 29 April 2009 (**Figure 7**) (**Table 6.1**). Soil bore logs are presented in **Appendix C**.

A further nine hand auger locations were completed at shallow depths ranging between 0.4 and 1.2 mbgl, between 27 March and 29 April 2009, and 7 July and 9 July 2009. The depth of the hand auger investigation was controlled by depth to groundwater (interception of groundwater resulted in core loss) or the interception of cemented carbonate material resulting in refusal.

Six of the hand auger locations (E034, E038, E040, E041, E042 and E045) were identified as potential areas for PASS during the desktop phase of the investigation. The identified locations, or areas identified as 'high risk' PASS locations based on desktop investigation, were selected based on typical PASS geomorphology profiles using aerial photography (e.g. low lying [below 5 mAHD]) and/or generally waterlogged and the presence of salt tolerant plant species). The remaining three hand auger locations were selected as access to these sites had been restricted for drill rigs due to rainfall events (E036, E037 and E039).

Two of the hand auger locations (E040 and E042) were augered, sampled and analysed during the hand augering programme completed between 27 March and 29 April 2009, and were re-sampled during the hand augering programme completed between 7 July and 9 July 2009. The objective of the duplicate sampling was to illustrate that results could be reproduced, and hence were representative of the Ashburton North and surrounds, at both a field and laboratory level of investigation.

In total, 148 primary samples were collected during the intrusive investigation of which 30 were submitted to ALS laboratory on 15 May 2009 and eight were submitted on 28 July 2009 for analysis of heavy metals including aluminium (Al), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), Copper (Cu), iron (Fe), lead (Pb), mercury (Hg), manganese (Mn), nickel (Ni), vanadium (Va) and zinc (Zn) as part of the BSQ assessment. This suite of 13 heavy metals is considered the standard contaminant assessment suite as recognised by the DEC, with the additional inclusion of iron.

A total of 35 samples were also submitted for the assessment of PASS and ANC using the Chromium suite method on the 15 May 2009 and nine samples were submitted on 28 July 2009.

The total number of samples selected for PASS and ANC testing generally reflects an analytical regime of one sample per shallow borehole. The selection of samples was primarily based on field test results and the soil profiles intercepted, although representation of landform units, typical of the Ashburton North and surrounds, was also considered.

6.1.2 Shared Infrastructure Corridor Study Area

Ten hand auger locations (E046, E047, E048 and E052 and SS01, SS03-SS07) were undertaken between the 19 and 21 October 2009 (Figure 6) as presented in **Table 6.1** and illustrated on **Figure 7**. Soil bore logs are presented in **Appendix C**. The hand auger investigation was driven by depth to groundwater (interception of groundwater resulted in coreloss) or the interception of cemented carbonate material (refusal) and ranged in depths from 1.5 to 1.6 mbgl.

In total, 37 primary samples were collected during the intrusive investigation of which 12 were submitted to ALS laboratory on the 24 November 2009.

The total number of samples selected for PASS and ANC testing generally reflects an analytical regime of one sample per shallow borehole. The selection of samples was primarily based on field test results and the soil profiles intercepted, although representation of landform units, typical of the SIC study area, was also considered.

Table 6-1 Summary of Environmental Bore Completion

Soil Bore Location[1]	Soil Sample ID	Coordinates		Start Date	Completion Date	Total Depth of Environmental Investigation[2]	Static Water Level[3]
		Northing	Easting			mbgl	mbgl
Ashburton North and Surrounds-Environmental Soil Bores							
E002	MB2B	291156	7595091	30/03/2009	30/03/2009	3.0	3.79
E003	MB3A	291105	7595517	30/03/2009	30/03/2009	3.0	4.38
E004	MB4A	291243	7595540	27/03/2009	27/03/2009	3.0	5.93
E005	MB5A	291482	7596954	2/04/2009	2/04/2009	3.2	3.08
E006	MB6A	292538	7598296	5/04/2009	5/04/2009	3.5	1.10
E007	MB7A	292711	7598613	5/04/2009	5/04/2009	3.2	2.12
E008	MB8A	293243	7599460	5/04/2009	5/04/2009	3.0	5.02
E009	MB9A	243256	7599398	5/04/2009	5/04/2009	3.0	4.66
E010	MB10A	293462	7599684	14/04/2009	14/04/2009	3.0	2.29
E011	MB11A	294113	7600691	12/04/2009	12/04/2009	3.1	0.66
E012	MB12A	294958	7600445	21/04/2009	21/04/2009	3.0	0.79
E013	MB13A	295014	7600692	10/04/2009	10/04/2009	3.7	1.0
E015	MB15A	290894	7596347	8/04/2009	8/04/2009	3.0	3.84
E016	MB16A	290313	7596335	4/04/2009	4/04/2009	3.0	3.63
E017	MB17A	290022	7596324	2/04/2009	2/04/2009	4.6	1.07
E018	MB18A	293920	7600287	15/04/2009	15/04/2009	3.0	2.69
E019	MB19A	293685	7600754	29/04/2009	29/04/2009	3.0	2.12
E021	MB21	293984	7600707	21/04/2009	21/04/2009	3.0	1.00
Ashburton North and Surrounds-Environmental Hand Auger Locations							
E034	EB034	294515	7600206	25/04/2009	25/04/2009	1.1	0.47

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[1] URS prefix MB was superseded by Chevron's global use of the prefix E000 for environmental bores at the conclusion of the BSQ and ASS investigation, and therefore laboratory certificates refer to soil samples with the prefixes MB (for monitoring bore).

[2] Refer to URS (2009) Appendix C of Report Baseline Soil Quality and Landforms Assessment (Draft) 28 September 2009 WHST-STU-ET-RPT-0068_Rev D.

[3] Refers to Summary of Groundwater and Environmental Monitoring Bore Installation Sheet (URS, 2009a) Hydrogeological Impact Assessment of Wheatstone Plant Area, Infrastructure Corridor and Accommodation Site (Draft) 42907100 , work in progress (last amended date 15 September 2009) Attached as **Appendix A** of this report. Hand Auger depths were based on field logs of URS (2009) Appendix C of Report Baseline Soil Quality and Landforms Assessment (Draft) 28 September 2009 WHST-STU-ET-RPT-0068_Rev D

Soil Bore Location[1]	Soil Sample ID	Coordinates		Start Date	Completion Date	Total Depth of Environmental Investigation[2]	Static Water Level[3]
E036	E036	294083	7598997	09/07/2009	09/07/2009	0.4	Not intercepted
E037	E037	294330	7598059	09/07/2009	09/07/2009	0.4	Not intercepted
E038	E038	294922	7597474	09/07/2009	09/07/2009	1.0	0.2
E039	E039	294095	7596917	09/07/2009	09/07/2009	0.4	Not intercepted
E040 and E040A	EB040	292978	7599709	25/04/2009 & 07/07/2009	25/04/2009 & 07/07/2009	1.1	0.35 and 0.45
E041	E041	291958	7598163	08/07/2009	08/08/2009	1.0	0.45
E042 and E042A	EB042	290855	7599136	26/04/2009 & 07/07/2009	26/04/2009 & 07/07/2009	1.2 and 1.1	0.5 and 0.45
E045	E045	290687	7597631	07/07/2009	07/07/2009	1.0	Not intercepted
Shared Infrastructure Corridor-Environmental Hand Auger Locations							
E046	E046	293200	7593710	21/10/2009	21/10/2009	1.4	Not intercepted
E047	E047	294209	7592312	20/10/2009	20/10/2009	1.6	2.39[4]
E048	E048	296277	7591591	20/10/2009	20/10/2009	1.6	Not intercepted
E052	E052	300284	7590246	19/10/2009	19/10/2009	1.5	Not intercepted
SS01	SS01	297786	7591155	19/10/2009	19/10/2009	1.25	Not intercepted
SS03	SS03	295408	7591961	20/10/2009	20/10/2009	1.5	Not intercepted
SS04	SS04	293688	7592610	21/10/2009	21/10/2009	1.6	Not intercepted
SS05	SS05	293353	7592933	21/10/2009	21/10/2009	1.6	Not intercepted
SS06	SS06	293078	7594338	21/10/2009	21/10/2009	1.6	0.7
SS07	SS07	293117	7595500	21/10/2009	21/10/2009	1.6	0.7

6.1.3 Geotechnical and Hydrogeological Bore Review for PASS

A review of geotechnical bore logs (completed by Coffey Geotechnics [Coffey] as part of the geotechnical investigation for Ashburton North and surrounds and the SIC study area was also undertaken. The objective of the review was to further delineate the vertical and horizontal extent of PASS through interpretation of the geological profile. Based on this assessment, the PASS Map (discussed in **Section 8**), was amended to account for these findings.

At the time of writing, a review of an additional 107 geotechnical and hydrogeological bores logs and/or core photos been completed. Depths of logs ranged between 10 and 60 m bgl. Information for 34 of the geotechnical bores of Ashburton North and surrounds are yet to be made available.

6.2 Test Methodology

The following section discusses the tests undertaken during the field and/or based on field test results.

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[4] As reported in the corresponding Phase 2 geotechnical logs (attached as **Appendix F**).

6.2.1 Erodibility Assessment

An erodibility assessment was undertaken for landform units of the Terrestrial Assessment area based on soil types and landform units encountered during the field investigation. The assessment was undertaken in general accordance with van Gool *et al* (2005) which provide standard methods for attributing and evaluating conventional land capabilities. Water and wind erosion hazards were identified as the primary erosion hazards associated with the Terrestrial Assessment area.

Wind erosion refers to the inherent susceptibility of the land to the loss of soil as a result of wind movement. The susceptibility of a soil to wind erosion has been assessed from a simple matrix of surface texture and surface condition. The five categories of wind erosion hazard relate to the level of disturbance needed to bring soils to a loss and consequently erodible condition. Category V includes soils that are highly susceptible because they have a loose and consequently erodible condition while Categories I to V have decreasing susceptibility. These soils are less fragile and require some disturbance by machinery to loosen the soil.

Water erosion is the inherent susceptibility of the land to the loss of soil as a result of water movement across the surface, where the susceptibility of landform units to water erosion is based on soil erodibility and slope. Water erosion is highly variable depending on seasonal and climatic factors. For example, a high rainfall event immediately after summer can result in ‘first flush’ of sediment into nearby water ways of the receiving environment.

Susceptibility of landform units are the rating based on a low, moderate, high, very high and extreme ranking outlined in van Gool *et al* (2005)

The field test methodologies used in the assessment of landform susceptibility and soil erodibility are described in detail in **Appendix A**.

6.2.2 Dispersion Tests

Dispersive soils, or sodic soils, collapse or disperse to form dissolved slurry when in contact with fresh water (rain). These soils are highly prone to erosion often leading to tunnel and gully erosion. Unlike other forms of erosion, dispersion result from an imbalance in soil chemistry (Emerson, 1991).Construction activities may increase the risk of the exposure of soils which exhibit dispersive characteristics and therefore result in the erosion of these soils

During construction, the runoff from areas of disturbed dispersive soils, which tend to have a high clay content, may appear cloudy when entering water bodies. It is very difficult to remove this clay from freshwater without the addition of chemicals (e.g. gypsum). If this runoff enters local waterways has the potential to reduce light levels and decrease water quality (Department of Agriculture, 1998).

The identification of dispersive soils is important when identifying potential soils for use in rehabilitation. Many factors affect the success or failure of attempts to stabilise and rehabilitate at closure. Major erosion is often associated with unstable materials prone to tunnelling, such as dispersive spoils. The presence of these materials commonly has the potential to result in the creation of relatively unsafe landforms with widespread tunnels immediately below the soil surface, development of large gullies when tunnels collapse, and instability of rock drains.

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Further, soil aggregates that slake and disperse readily indicate a weak structure that is easily degraded by raindrop impact or mechanical disturbance. This degradation has the potential to reduce infiltration and permeability in loamy and clayey soils, and impede root development and seedling emergence by increasing soil density.

Soil dispersion potential is measured as the Emerson Class number (a simple semi-quantitative dispersion test), which considers soil consistency, depth, and in some cases established soil electro-chemical data. Weathered parent rock substrates can also show dispersive tendencies. Dispersive soils usually contain significant amounts of clay, with at least moderate levels of chemically exchangeable sodium, if they are not buffered by salinity.

The Emerson Aggregate Test assesses how aggregates break down in water and classifies a soil into eight categories. The Emerson Aggregate Test is a simple way of identifying four significant soil groups with respect to their behaviours:

- Soils which are spontaneously dispersive to varying degrees (Class1 and Class 2). Class 1 soils are highly unstable and invariably sodic to highly sodic.
- Soils which are potentially dispersive if remoulded when wet (Class 3).
- Soils which slake but are non-dispersive (Classes 4, 5 and 6).
- Soils which have a high inherent stability (Class 7 and 8).

6.2.3 pH_f and pH_{fox} Tests

Field pH (pH_f) and field peroxide (pH_{fox}) tests were conducted on recovered soil samples at an interval of 0.25 m depth interval in order to assess the potential of the soil to generate acidity. Results of the field tests were conducted in accordance with the *Laboratory Methods Guidelines Acid Sulfate Soils (Version 2.1-June 2004) (Ahern et al, 1998).*

Field pH (pH_f) and field peroxide (pH_{fox}) tests were conducted on recovered soil samples using deionised water and a 30% hydrogen peroxide solution. The pH values were measured using a Hanna pHEP® meter which was calibrated prior to field testing using buffer solutions of pH4 and pH7 +/- 0.01 units.

The complete field methodology used for the completion of these tests is presented in **Appendix A.**

6.2.4 Carbonate 'Fizz' Test

The carbonate 'fizz' test is used to determine the presence of carbonates in soil. The test is normally conducted on samples suspected of containing carbonates such as fine shell, crushed coral or soluble carbonates presence within the soil profile. The field test was conducted in accordance with the *Laboratory Methods Guidelines Acid Sulfate Soils (Version 2.1-June 2004) (Ahern et al, 1998).*

This test is simply an indicator for the presence of carbonate material and detailed analytical tests are required to determine the actual carbonate material available to neutralise *in situ* potential acid generating conditions.

The tests were conducted on recovered soil samples using hydrochloric acid (HCl) solution. Observations were noted as to whether the sample 'fizzed' as 2-3 drops of HCl was applied.

The complete field methodology used for this test is presented in **Appendix A**.

6.3 Assessment Guidelines

6.3.1 Heavy Metals

The Terrestrial Assessment area has had no previous anthropogenic activities that may have adversely altered soil quality; therefore, as the results obtained are considered representative of background concentrations, a comparison against criteria based on future land uses can be useful.

Given the present underdeveloped nature of the Terrestrial Assessment area, soil analytical results were compared with Ecological Investigation Levels (EIL's) as presented in the draft Western Australia DEC (2003) *Contaminated Sites Series Guidelines-Assessment Levels for Soil, Sediment and Water,* which are based on the EIL's provided in the Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC/NHMRC, 1992). The EIL's are generally protective of environmentally sensitive receptors such as mangrove habitats and/or the intertidal environment as located within Ashburton North and surrounds of the Terrestrial Assessment area.

As the proposed future use of Terrestrial Assessment area will result in an operational site, the analytical test results can also be compared to Health Investigation Levels (HIL's), which are primarily based on the Health-based Soil Investigation Levels presented in the National Environmental Protection Measure (NEPM) (NEPC, 1999). Analytical results will be compared against HIL-F trigger values based on the known use of the Terrestrial Assessment area as an industrial site for the process and production of LNG.

An initial comparison of metal concentrations was undertaken utilising studies completed for North west coast deltaic systems of the Pilbara Region (i.e. Oceanica [2005] and URS [2008])

6.4 PASS

The assessment criteria adopted for PASS in Western Australia are the 'Texture Based ASS Action Criteria' developed by Ahern *et al* (1998) and are presented in **Table 6-2.** The criteria act as a guide to determine whether soils will generally require treatment and/or management, based on **Net Acidity** (net acidity = S_{cr} +TAA) as sulfur (% S) or equivalent acidity (mol H^+/tonne).

As clay content tends to influence a soils natural buffering capacity, the action criteria are grouped into three broad texture categories. Classification of the soils encountered during the investigation ranged from medium to fine grained. Based on this generalised classification, and assuming a disturbance of soil (through excavation during the construction of the Terrestrial Infrastructure) of greater than 1 000 tonnes, the selected 'action criteria' for **Net Acidity** is 0.03 %S or the equivalent acidity of 18.7 mol H^+/tonne (as highlighted in **Table 6-2**).

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Table 6-2 Texture Based ASS Action Criteria Matrix

Type of Material		NET ACIDITY ACTION CRITERIA			
		1-1000 tonnes disturbed		>1000 tonnes disturbed	
Texture range McDonald *et al* (1990)	**Approximate Clay Content (%)**	**Equivalent sulfur (%S)**	**Equivalent acidity (mol H^+/tonne)**	**Equivalent sulfur (%S)**	**Equivalent acidity (mol 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**

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

6.4.1 Adopted Laboratory Methodology

The analytical method selected for the analysis of PASS, the Chromium suite, was undertaken in accordance with laboratory methodologies outlined in Ahern *et al* (2004) and is the preferred analytical method adopted by the DEC (DEC, 2009b). The Chromium suite method provides an analytical determination of inorganic sulfur (e.g. iron sulfides) and is not subject to interferences from sulfur, either in organic matter or as sulfate minerals.

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

- **EA033: Chromium Suite for Acid Sulfate Soils**: This method covers the determination of Chromium Reducible Sulfur (S_{CR}); pH_{KCl}; titratable actual acidity (TAA) and acid neutralising capacity by back titration (ANC). The above determinations are reported as % sulfur (S) or the equivalent acidity (mol H^+/tonne) with the exception of ANC which is reported as kg $CaCO_3$/t.

The above determinations can be defined further as the following:

- S_{cr}: A measure of total reduced inorganic sulfide and a measure of a soils potential to generate acidity.
- pH_{KCl}: The determination of pH in a solution of potassium chloride.
- TAA: A measure of total existing acidity. The soluble and exchangeable acidity already present in a soil, often a consequence of previous oxidation of sulfides.
- ANC: A soils inherent ability to buffer acidity and resist the lowering of the pH.

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7.1 Erosion Assessment

The results of the soil erosion assessment is summarised below:

7.1.1 Erodibility Assessment Results

A field landform susceptibility and soil erosion assessment has been completed for the various landform units and associated soil types found within the Terrestrial Assessment area.

The assessment identified three landform units, the fringing and coastal dunes, the longitudinal dunes and the mainland remnant dunes, which have a very high to extreme potential for wind and a high potential for water erosion when disturbed. Results of the assessment are presented in **Table 7.1** and the complete soil erodibility results are presented in **Appendix D.**

Table 7-1 Erodibility Potential for Landform Units of the Terrestrial Assessment Area

Landform Type	Water Erosion Potential[5] (VL, L,M,H, VH, E)	Wind Erosion Potential Class I-V (VL, L,M,H, VH, E)	Assessment Area
Intertidal flats, mangrove communities and tidal creeks [6]	L to M	L	North west of Ashburton North and surrounds and Construction study area
Alluvial / Colluvial	L	L	Ashburton North and surrounds, SIC, Camp, Domgas and Construction study area
Claypans	M	L	Ashburton North and surrounds, SIC, Camp and Construction study area
Fringing and Coastal Dunes	H	VH to E	Ashburton North and surrounds
Drainage Area[6]	L	L	Domgas study area
Stony Hills[6]	L	L	Domgas study area
Longitudinal Dunes and Interdunal Swales	H	VH to E	Ashburton North and surrounds, SIC, Camp Domgas and Construction study area
Mainland Remnant Dunes[6]	H	VH to E	Ashburton North and surrounds and Construction study area
Samphire Flat	L	L to M	Ashburton North and surrounds, SIC, Camp and Construction study area
Supratidal Salt Flat	M	L	Ashburton North and surrounds, SIC and Construction study area
Saline Flats[6]	M	L	SIC study area and Construction study area.

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[5] Erosion potential assessed against *Land evaluation Standards for Land Resource Mapping Third Edition* Dennis van Gool, Peter Tille and Geoff Moore December 2005

[6] Based on desktop assessment of landform erodibility only

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7.1.2 Soil Dispersion Results

Field dispersion tests were conducted on surface and subsurface clayey soil samples for Ashburton North and surrounds and the SIC study area, with the objective of determining soil sodicity across appropriate soil types. A summary of the field test results undertaken during the investigation are presented in **Table 7-2** where clay was intercepted, while the complete field test results are presented in **Appendix D.**

Based on the results of the field dispersion tests, red brown clay and/or clayey soils identified within the Ashburton North and surrounds and the SIC study area generally slake (slightly) but are non dispersive (Class 4, 5 or 6).

Brown to grey CLAY identified within Ashburton North and surrounds was generally identified as potentially dispersive (Class 3). These soils were not identified as dispersive within the SIC study area.

It should be noted that Emerson testing does not account for for high salinity (hyper saline) materials, particularly those of marine origin, and may report a false positive (i.e. non-dispersive soils). If the salt content of a material is very high, then spontaneous dispersion may not occur, even when immersed in excess deionised water.

Overall, the field test suggests that it is unlikely that there is potential for significant erosion, and hence impacts on the environment are considered to be low. However, soils with dispersive tendencies should not be used for rehabilitation, which includes the grey yellow mottled clays of the alluvial/colluvial plains and the brown clays contained within the tidal creeks, mangrove swamps and intertidal flats (refer to **Table 7-2** below).

Table 7-2 Field Dispersion Field Test Results (Clayey Soil)

Landform Unit	Lithological Description	Emerson Class
Longitudinal Dunes and Interdunal Swales	clayey SAND (5% clay), occasional gravel, red/brown	Class 4, 5 or 6
Alluvial/Colluvial Plains	sandy CLAY, red/brown	Class 4, 5 or 6
	CLAY, grey with yellow mottles	Class 3
	sandy CLAY, red/brown	Class 4,5 or 6
	clayey SAND, occasional well cemented Sandstone	Class 4, 5 or 6
	clayey SAND, red/brown	Class 4, 5 or 6
	CLAY, medium to high plasticity, cream/brown	Class 4, 5 or 6
	heavy CLAY, grey, occasional yellow mottles	Class 4, 5 or 6
Tidal Creek, Mangrove Swamp & Intertidal Flat	CLAY, brown, medium plasticity	Class 3
Supratidal Salt Flats	clayey SAND, red brown, fine grained	Class 4, 5 or 6
	clayey SAND, red brown, fine to medium grained	Class 4, 5 or 6
	sandy CLAY, medium plasticity, red brown	Class 4, 5 or 6
	sandy CLAY, mod plasticity, grey some yellow mottling	Class 4, 5 or 6
	Sandy CLAY, mod plasticity, red brown yellow mottling	Class 4, 5 or 6
Samphire Flats	CLAY, moderate to high plasticity, grey red mottles	Class 4, 5 or 6
	CLAY, low to moderate plasticity, grey	Class 4, 5 or 6
	Clayey SAND, low plasticity, red brown	Class 4, 5 or 6

Landform Unit	Lithological Description	Emerson Class
	sandy CLAY, red low plasticity	Class 4, 5 or 6
Claypan	sandy CLAY, moderate plasticity, red brown	Class 4, 5 or 6
	CLAY, red brown high plasticity	Class 4, 5 or 6
	Clayey SAND, low to medium plasticity, red brown	Class 4, 5 or 6
	silty sandy CLAY, red brown low plasticity	Class 4, 5 or 6
	silty CLAY, red brown, low plasticity	Class 4, 5 or 6

7.2 Heavy Metal Assessment

The following section provides a general summary of the analytical testing completed to determine the BSQ for Ashburton North and surrounds and the SIC study area, and a discussion of the results against adopted assessment criteria

Soil analytical results for a suite of heavy metals, including Al, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Ni, Va, Zn. are presented in **Appendix D,** highlighting samples that exceed the adopted EIL and HIL-F trigger values

7.2.1 Ashburton North and Surrounds-Analytical Results

The distribution of metals encountered within Ashburton North and surrounds are presented on **Figure 8-1** and **8-2** and summarised below:

- Reported metal concentrations for all analytes did not exceed HIL-F trigger values for the samples analysed.
- Arsenic concentrations exceeded the EIL trigger value of 20 mg/kg at five locations ranging between 20 mg/kg (E041_0.9-1.0) and 93 mg/kg (E018_2.5). Exceedances were located within the north western to north eastern extent of Ashburton North and surrounds.
- Chromium concentrations exceeded the EIL trigger value of 50 mg/kg at eight locations ranging between 52 mg/kg (E007_0.0) and 108 mg/kg (E018_2.5). These were located within the central to north west to north eastern section of Ashburton North and surrounds.
- Manganese concentrations exceeded the EIL trigger value of 500 mg/kg at two locations (569 mg/kg [E007_0.0] and 1380 mg/kg [E017_1.5-1.75]) within the central part of Ashburton North and surrounds.
- Low manganese concentrations were reported in soils generally associated with PASS or reported generally lower pH values than of the surrounding environment. These included E006__1.0 (66 mg/kg), E011_1.0 (56 mg/kg), E018_2.5 (80 mg/kg), E018_3.0 (55 mg/kg), E019_1.75 (98 mg/kg), E034_0.75-0.85 (95 mg/kg), E040_0.75-0.85 (28 mg/kg) and E040A_1.0-1.1 (26 mg/kg).
- Nickel concentrations exceeded the EIL trigger value of 60 mg/kg at one location, reporting a concentration of 61 mg/kg (E018_3.0) in the north east of Ashburton North and surrounds.

Discussion

No results were reported in exceedance of the adopted HIL-F guideline criteria and hence no risk to human health, with relation to metals, is anticipated.

Elevated arsenic, chromium, manganese and nickel concentrations were detected above the adopted environmental investigation level (EIL) trigger values within the north western and north eastern extent of Ashburton North and surrounds.

Comparison of these results against an assessment of heavy metals completed by Oceanica (2005) and URS (2008) along the Pilbara coastline of similar deltaic systems also reported elevated concentrations of arsenic, chromium and nickel. The elevated metals encountered are comparable suggesting that the high background levels are likely a result of the weathering of terrestrial origin.

These concentrations are therefore considered representative of background conditions given the absence of human induced disturbance within the Terrestrial Assessment area, the distance from the Onslow Salt operations and based on a comparison with other North West coast deltaic systems within the Pilbara Region.

7.2.2 SIC Study Area-Analytical Results

The distribution of metals encountered within the SIC study area are presented on **Figure 8-3** and summarised below:

- Reported metal concentrations for all analytes did not exceed HIL-F trigger values.
- Chromium concentrations exceeded the EIL trigger value of 50 mg/kg at seven locations ranging between 50 mg/kg (E048_0.0-0-0.1) and 70 mg/kg (SS01_0.5-0.6). These exceedances were identified throughout the SIC study area.
- Manganese concentration exceeded the EIL trigger value of 500 mg/kg at five locations ranging between 640 mg/kg (SS01_ 0.5-0.6) and 900 mg/kg (SS01_1.0-1.1). These exceedances were identified throughout the SIC study area where concentrations were generally detected slightly below or above the EIL trigger values
- Low manganese concentrations were reported in soils identified as PASS at SS07_1.5-1.6, which reported concentrations of 26 mg/kg.

Discussion

No results were reported in exceedance of the adopted HIL-F guideline criteria and hence no risk to human health, with relation to metals, is anticipated.

Elevated chromium, manganese and nickel concentrations were detected above the adopted environmental investigation level (EIL) trigger values throughout the SIC study area. However because there have been no historic industrial land use practices within the SIC study area these concentrations are considered representative of background concentrations.

7.3 Potential Acid Sulfate Soils Assessment

The investigation of PASS was undertaken through the completion of field tests and laboratory analysis. The field tests completed were used in conjunction with other field observations to develop a preliminary understanding of the environment. Additional tests were conducted on selected samples using laboratory analyses to provide more detailed information on existing conditions.

Laboratory analytical tests quantitatively assess the amount of existing plus potential acidity present in the soil and hence provide a general measure of the risks of acidic conditions forming if these soils are disturbed. The assessment criteria adopted for the PASS acts as a guide to determine whether soils will generally require treatment and/or management based in the net acidity produced by the soil.

7.3.1 pH_f Field Test Results

The pH_f test measures the existing acidity and is therefore a useful indicator as to whether actual ASS is present. As illustrated in **Table 7-3**, sands and sand dominant soils are generally alkaline to near neutral and are dominant in the landform units associated with the longitudinal dunes and interdunal swales, fringing and coastal dunes and the alluvial/colluvial plains. Mean pH_f values range between 8.93 (calcareous SANDSTONE of the fringing and coastal dunes) and 7.33 pH (red brown gravelly sandy CLAY of the alluvial/colluvial plains)

Sandy soils of the samphire flats and the tidal creek, mangrove swamp and intertidal flats, recorded alkaline to near neutral pH_f values. The high pH_f values are considered most likely a result of high carbonate content reported in the form of shell. Mean pH_f values of these sandy soils range between pH 8.28 and pH 7.76. pH_f values.

Clayey soils of the samphire flats recorded near neutral to slightly acidic with mean pH_f values ranging between pH 7.35 to pH 6.96 (with the minimum pH values reported ranging between pH 4.80 and pH 5.02).

Sandy and clayey soils of the supratidal flats were slightly acidic with mean pH_f values ranging between pH 6.57 to pH 6.31. Claypan soils encountered were typically alkaline to near neutral with mean pH_f values ranging between pH 8.82 to pH 7.05.

In summary, pH_f results indicate soils are generally alkaline and there is no existing acidity in the shallow profile across Ashburton North and surrounds, with the exception of slightly acidic soils which were identified where organic matter and/or marine deposits were identified.

7.3.2 pH_{fox} Field Test Results

The pH_{fox} test (or rapid oxidation) is used to indicate the presence of iron sulfides or PASS. The test involves adding 30% hydrogen peroxide to a sample of soil, thereby replicating what would naturally occur if the soils were exposed to air. Where sulfides are present, a reaction will occur. The reaction can be influenced by the amount of sulfides in the sample and the presence of organic matter where the more vigorous the reaction, the greater potential for acidity (generally). The end pH_{fox}, provides an indication of the potential for a soil to become acidic, whereby the lower the pH the greater the potential acidity.

Based on this assumption, pH_{fox} values remained above neutral, and reactions with the peroxide reactant were generally absent, in red earth soil profiles of the landform units associated with the longitudinal dunes and interdunal swales, and of the fringing and coastal dunes, and alluvial/colluvial plains.

Reactions with claypan soils were generally reported as low to medium with end mean pH_{fox} values ranging from pH 9.08 to pH 6.89 (an increase in pH in some cases).

The most reactive soil profiles were reported in grey to brown clayey soils (with variable mottling) typically encountered within the landform units associated with the intertidal flats, tidal creek and mangrove swamp, samphire flats and supratidal salt flats of the Terrestrial Assessment area. Reactive soils were also detected within marine/organic deposits identified at shallow depths within the alluvial/colluvial plains and fringing and coastal dunes along the north eastern boundary of Ashburton North and surrounds.

These soils have mean pH_{fox} values ranging between pH 5.93 (light brown silty sandy clay of the alluvial/colluvial plains) and pH 0.87 (grey clay of the fringing and coastal dunes) and are considered PASS. In general, soil metals mobilise as soil pH drops below pH 5.5 and therefore, for the purpose of this investigation, this is considered the trigger value for PASS soils with regard to field pH tests.

Table 7-3 pH_f and pH_{fox} Field Test Results for Typical Soil Profiles Encountered within the Terrestrial Assessment Area

Landform Unit	Soil Type	pH(f)	pH(fox)	pH(f)		pH(fox)	
		mean[7]	mean	min	max	min	max
Longitudinal Dunes and Interdunal Swales	light brown to red brown SAND	8.28	7.25	6.34	9.57	5.86	9.28
	SANDSTONE/calcareous SANDSTONE	8.93	8.88	8.72	9.49	7.03	9.31
	silty sandy GRAVEL	7.77	7.33	7.34	8.15	6.57	7.87
	silty SAND	8.34	7.08	6.02	9.70	6.20	8.56
Fringing and Coastal Dunes	calcareous SANDSTONE	8.60	7.52	8.11	9.20	6.59	8.64
	grey CLAY	7.09	0.87	5.50	7.83	0.70	1.05
	silty SAND, SAND some shell	7.84	7.12	7.34	8.33	6.37	7.68
Alluvial/Colluvial Plains	CLAY, brown to grey with yellow mottles	6.72	4.93	5.99	7.36	3.60	6.01
	clayey SAND, red brown	8.25	8.10	6.63	9.00	5.40	8.79
	gravelly SAND, red brown	7.56	7.87	7.00	8.25	7.30	8.20
	gravelly sandy CLAY, red brown	7.33	6.39	7.16	7.75	5.61	7.22
	SAND, brown	7.95	6.40	7.25	8.90	4.33	9.06
	SAND, very fine grained, red brown	7.80	6.38	6.38	1.42	6.38	6.38
	silty CLAY, red/brown, high plasticity	7.91	7.83	7.79	8.22	7.47	8.04
	silty SAND red/brown	7.58	7.17	6.21	9.33	5.06	9.00
	silty sandy CLAY, light brown	7.55	5.93	6.29	8.80	5.02	6.83
	silty sandy CLAY, red brown	7.39	6.84	6.35	8.24	5.10	7.88
Samphire Flats	CLAY, variable plasticity grey, variable mottling	6.64	4.40	4.80	7.36	0.75	7.64
	Clayey SAND, fine grained, red brown	7.35	8.02	7.04	7.61	7.26	8.27
	sandy CLAY to CLAY, variable plasticity, red/brown	6.96	6.31	5.02	7.65	0.92	6.31
	silty SAND, red brown	8.12	7.62	8.12	8.12	7.62	7.62
Intertidal Flats, Tidal Creek and	silty SAND, brown	8.28	5.59	8.15	8.47	2.80	7.20
	CLAY, brown, medium plasticity	6.91	5.06	6.15	7.56	2.09	7.17

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[7] Mean value calculations for pHf and pHfox are presented in detail in Appendix D.

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Landform Unit	Soil Type	pH(f)	pH(fox)	pH(f)		pH(fox)	
		mean[7]	mean	min	max	min	max
Mangrove Swamp	SAND, fine grained, dark grey	7.92	5.32	7.92	7.92	5.32	5.32
	SAND, fine to medium grained, red brown	7.76	6.74	7.37	7.96	6.40	6.97
	sandy CLAY, moderate plasticity, red brown with grey mottling	7.23	7.54	7.12	7.33	7.31	7.76
Supratidal Salt Flats	clayey SAND, fine grained, some black mottles, red/brown	6.57	6.50	6.57	6.57	6.50	6.50
	clayey SAND, low plasticity, light brown	6.37	4.51	5.74	7.21	2.20	7.74
	sandy CLAY, medium plasticity, red brown	6.55	5.33	5.32	6.99	1.94	7.84
	Sandy CLAY, moderate plasticity, grey some yellow mottles	6.31	5.07	5.06	7.62	2.17	5.07
Claypans	CLAY, red brown, high plasticity	7.05	6.89	6.94	7.15	6.63	7.10
	sandy CLAY, red/brown, some large shell fragments	7.58	7.90	7.26	8.01	7.15	8.20
	silty SAND, limestone fragments, red brown	8.82	9.08	8.71	8.97	9.01	9.11
	Silty SAND, very fine to fine grained, light brown	7.68	7.79	7.42	8.15	7.29	8.55
	silty sandy CLAY, low plasticity, red brown	8.15	8.49	7.50	8.80	7.89	9.09

7.3.3 Carbonate ‘Fizz’ Test Results

Using the presence/absence approach, reactions indicative of calcareous material (fizzing), was identified in soil profiles comprising variable amounts of shell fragments and/or sandstone, including red brown sands with silt and clay components. No reaction with HCl was observed in profiles comprising high plasticity, brown to grey clay material.

While there is evidence of carbonate material present in soil profiles across Ashburton North and surrounds, it was generally absent in material suspected of being PASS (clays and silts of marine/mangrove deposits) with the exception of where shell fragments were detected, such as in the shallow soils of profiles located at E018 and E019. The carbonate ‘fizz’ field test results are presented in **Appendix D.**

7.3.4 Ashburton North and Surrounds-Analytical Results

The Chromium suite analytical results are presented in **Appendix D**. **Figure 9** presents the samples that exceed the selected action criteria of 0.03 %S for net acidity. Laboratory certificates are attached as **Appendix E**.

Analytical results for the Chromium suite can be summarised as follows:

- pH_{KCl} values ranged between 5.2 pH (E018_3.0) and 9.9 pH (E003_2.0-2.15 and E019_0.0) across Ashburton North and surrounds indicating soils range between acidic and alkaline.
- Reported pH_{KCl} below 7 pH were generally detected at depth along the north east boundary of Ashburton North and surrounds.
- Reported TAA concentrations (existing acidity), greater than the adopted action criteria, were detected at E018 (MB18A [0.06 %S]) at a depth of 3.0m which is located in the north east extent of Ashburton North and surrounds.
- Calculated net acidity concentrations in exceedance of the action criteria, ranged between 0.11 %S (E010_2.0) and 1.34 %S (E019_1.5), and were generally detected along the north eastern extent of Ashburton North and surrounds.

7 BSQ and PASS Investigation Results

- ANC ranged between 34.7% kg $CaCO_3$/t (E003_2.0-2.15) and 0.11% kg $CaCO_3$/t (E006_1.5) indicating that some soils are present that contain the potential to buffer potential acidity. The most significant being within sands and clays comprising sandstone and limestone of the Dune and Onslow land systems.
- ANC was typically absent in PASS profiles reported within the supratidal salt flats, the samphire flats and the marine deposits underlying the fringing and coastal dunes and the alluvial/colluvial plains. ANC was in excess for PASS profiles reported at two locations only, underlying the intertidal flats, mangrove swamp and tidal creek and the alluvial/colluvial plains. ANC is discussed further in **Section 8.2.**

7.3.5 SIC Study Area-Analytical Results

- pH_{KCl} values ranged between 5.4 pH (QC01 for E007_0.5-0.6)[8] and 9.2 pH (SS05_1.0-1.5) along the SIC study area indicating soils range between acidic and alkaline.
- No TAA concentrations (existing acidity), was detected in exceedance of the adopted trigger value of 0.03 %S.
- Calculated net acidity concentrations in exceedance of the action criteria, was detected at one location only (QC01 for E007_0.5-0.6) within the boundary of the northern extent of the SIC study area of the supratidal salt flats with a concentration of 0.21 %S.
- Corresponding soil profile was sandy CLAY, moderate plasticity, fine to med grained, dark organic matter present, grey with some yellow mottling which was detected to the depth of hand auger (1.5 mbgl).
- ANC ranged between 2.63 % kg $CaCO_3$/t (SS03_0.5-0.6) and 0.51% kg $CaCO_3$/t (SS04_1.0-1.1) indicating that soils encountered within the SIC study area have significantly less potential buffering capacity than Ashburton North and surrounds.
- ANC was typically absent in profiles comprising of PASS material.
- Corresponding soil profiles exhibiting greater capacity for ANC comprise of fine grained red brown clayey SAND. ANC is discussed further in **Section 8.2.**

7.3.6 Geotechnical and Hydrogeological Bores Review for PASS

To further delineate the extent of PASS, a review of available geotechnical bore logs, in the areas of interest, and/or core photos were undertaken. The geotechnical logs and core photos, provided by Coffey, were completed as part of the geotechnical investigation for the Terrestrial Assessment area (Coffey,2010) completed during Phase 1 and Phase 2 field works for Ashburton North and surrounds and the SIC study area. Where Coffey geotechnical bores were not available, URS hydrogeological bores were reviewed.

Appendix F presents the results of the geotechnical bore assessment, including the risk criteria used to derive a risk factor, used in the assessment of PASS for Ashburton North and surrounds and the SIC study area.

Figure 10 and **11** illustrate the locations of the reviewed geotechnical bore locations, and where PASS was identified. **Figure 12** and **Figure 13** illustrates the depth at which PASS was identified and the approximate thickness of these lenses based on the geotechnical bore review. **Table 7-4** presents a summary of the completed geotechnical bores reviewed as part of the PASS assessment.

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[8] Due to elevated RPD values, the field duplicate QC01, which has the higher pH value, is been used for interpretation.

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Table 7-4 Geotechnical Bore Review

Total Bores Reviewed	Total Bores identified with PASS	Total Bores identified with no PASS	Bores with insufficient information
107 bores	31 bores	38 bores	34 Bores

A summary of the review is as follows:

- PASS was identified at a total of 31 bore locations and was generally located toward the north eastern boundary of the Terrestrial Assessment area (**Figure 11**).
- PASS was identified at shallow depths ranging between 0.5 mbgl and 4.4 mbgl (mean 2.25 m bgl) (elevations were not provided on the draft logs).
- PASS was intercepted at depths of less than 1 mbgl generally along the intertidal flats, tidal creek and mangrove swamps. The majority of PASS was intercepted between 1.0 and 3.0 m bgl within the samphire flats, the alluvial colluvial plains and along the fringing and coastal dune network.
- The thickness of the PASS lens ranged between 0.2 and 3.5 m (mean 1.34 m).
- PASS of between 1.0 to 3.0 m in thickness was generally detected below the intertidal flats, tidal creek and mangrove swamps. PASS lenses of less than 1m were reported along the fringing and coastal dunes and alluvial plains.
- PASS was therefore identified within landforms associated with samphire flats, alluvial/colluvial plains, fringing and coastal dunes and intertidal flats. Although PASS is typically not associated with fringing and coastal dunes, it is anticipated underlying marine/organic deposits are associated with the adjacent Ashburton River delta and the Hooley Creek catchment.
- PASS was typically characterised as CLAY to clayey SAND/SAND, low to high plasticity, brown to dark grey; fine to medium grained, mottling may range from yellow and orange, firm to very soft.
- PASS was further identified at depth within the samphire flats located between the longitudinal dune network and the coastal dunes along the western boundary. This area was limited in analytical information only due to accessibility of drill rigs and core loss at shallow depths during hand augering, across the relatively water logged area associated with this landform unit. Based on the geotechnical log review, however, this landform unit will typically comprise of PASS at shallow depths.
- PASS material was not identified along the coastal dunes located between the Ashburton River Delta and the samphire flats/claypans. The geotechnical bores located along this area generally intercepted red earths typically comprising SAND/SAND/sandy GRAVEL, orange to red brown, minor silt, minor clay, fine to medium grained sand, sub rounded, moderately sorted, quartz major with ironstone, sandstone grains.

7.3.7 Acid Sulfate Soils Discussion

The results of the field and analytical investigations and the geotechnical bore review indicate that PASS is present at shallow depths ranging between 0.5 m bgl and 4.5 mbgl with a thickness ranging between 0.2 and 3.5 m, predominantly along the north eastern extent of the Terrestrial Assessment area, although PASS has been identified as far south along the supratidal salt flats to where the SIC study area boundary is located.

Corresponding soil profiles were typically characterised as low to high plasticity CLAY to clayey SAND/SAND, low to high plasticity, brown to dark grey; fine to medium grained, mottling may range from yellow and orange, firm to very soft. These soils are visually identifiable in comparison to the red earths and sandstone pavement typically encountered throughout the Terrestrial Assessment area.

These soils are considered to be of marine/organic origin and are generally located within landform units associated with the intertidal flats, tidal creek and mangrove swamp of the Littoral land system.

PASS was also identified in landforms associated with samphire flats, alluvial/colluvial plains and fringing and coastal dunes. Although PASS is typically not associated with landform units associated with the fringing and coastal dunes, it is believed that shallow marine/organic deposits may be associated with the bordering Ashburton River delta and the Hooley Creek catchment and underlies this network as a chenier formation.

PASS was also identified at shallow depths within the supratidal salt flats which are located along the north eastern boundary of Ashburton North and surrounds and along the northern boundary of the SIC study area. PASS was visually identified as a brown to dark grey CLAY and clayey SAND at depths ~0.5 mbg. Relatively low pH_{fox} results (2.2 to 5.07 pH) and subsequent elevated inorganic sulphide concentrations (0.21 %S) indicate PASS is present. This landform unit also tend to comprise of a surface layer of MBO which is known to generate significant acidity in ‘first flush’ rainfall events, when it is usually disturbed.

Although actual ASS (or existing acidity) was identified at one location only in exceedance of the action criteria, acidic soil conditions was detected at four locations throughout the Terrestrial Assessment area (including the samphire flats, supratidal salt flats and the marine deposits underlying the fringing and coastal dunes) where red and yellow mottling, reported in the soil logs, suggests historical oxidation around the depth of the water table. It was noted also that manganese concentrations were significantly lower in profiles where either actual acidity was present, or acidic pH values were reported. This suggests that manganese has been mobilised through natural processes associated with PASS oxidation.

The ANC of the Terrestrial Assessment area is generally high, however is typically absent in soil profiles identified as PASS. Soils with the highest ANC throughout Ashburton North and surrounds generally comprised of sands and sand clays with shell, limestone and/or sandstone interbedded throughout. ANC of the SIC study area was significantly lower with highest buffering capacity detected in the red clayey sands. Where net acidity concentrations in exceedance of the action criteria were reported, corresponding ANC concentrations were non existent or negligible.

The effectiveness of the ANC in maintaining soil pH at acceptable levels (i.e. pH 6.5 to 9.0 pH or as background levels) depends on the type, amount and particle size of the carbonate

7 BSQ and PASS Investigation Results

present. Shells and carbonate materials often have an insoluble coating which limits ANC availability.

For this reason, and as PASS typically has negligible ANC, any reported ANC needs to be considered in conjunction with the type of ground disturbance proposed and mitigation strategies applied with this in mind. For example, regardless of the ANC of the surrounding environment, PASS that is oxidised in an *in-situ* environment can only utilise the ANC of the immediate profile, and then it must be considered, whether there is sufficient availability of the carbonate material to buffer the potential acidity.

This is discussed further in **Section 8.2.**

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Potential for PASS in Terrestrial Assessment Area

8.1 PASS Identification

A PASS map was produced identifying areas of low, moderate and high risk for PASS for the Terrestrial Assessment area. The PASS map was produced based on the understanding that high to moderate risk for PASS is classified as material within 3 m of natural soil surface that could be disturbed by most land development activities (DEC, 2009).

Soils were then further classified based on strategies provided by Atkinson *et al* (1996) and Ahern *et al* (1998), which and utilising the following site specific inputs:

- Interpretation of aerial photography (e.g. elevation and landforms of less than 5mAHD)
- Landforms identified in the field (e.g. identification of landforms typically associated with PASS.
- Field test results (Relatively low $pH_{(fox)}$ values e.g. <pH5).
- Soil profiles intercepted (clays and sands brown to dark grey). These soils are typically visually identifiable in comparison with the red earths and sandstone pavement typically encountered within the Terrestrial Assessment area.
- Analytical results (elevated chromium reducible sulfur results and/or low pH values)
- Proposed ground disturbance.

The criteria are further outlined in **Table 8.1.**

In developing the PASS map the following assumptions were made:

- As discussed in **Section 6.3.2**, a nominated volume of 1000 tonnes of PASS was assumed to be disturbed at any one time.
- The highest reported net acidity (%S) concentration per landform was used.

Based on these criteria a PASS map was generated for the Terrestrial Assessment area (**Figure 14-1 to 14-5). Appendix F** presents the results of the review and the risk factor applied to each bore (high, moderate and low), based on the trigger criteria outlined above.

In addition to the above, a review of geotechnical bore logs, was undertaken with the objective of further delineating the vertical and horizontal extent of PASS through interpretation of the geological profile. At the time of writing, a review of 107 geotechnical bore logs was undertaken (33 of the bores provided insufficient information for completion of a review). It is anticipated that as geotechnical logs are made available for the remainder of the Terrestrial Assessment area, a review of the PASS map will be undertaken and will be amended.

While **Table 8.1** provides an assessment of the potential for intercepting PASS, it should be noted that the associated risk can be modified and hence reduced, by implementing appropriate management strategies. Further, while the PASS assessment provides a 'worse case scenario' based on field observations, field tests and analytical results, other influences may be critical to the overall assessment. These may include the works to be undertaken, the staging and duration of construction, surface and subsurface hydrology and sensitivity of the surrounding environment.

Based on the results of the PASS assessment, high risk for intercepting PASS is located in the north eastern extent of Ashburton North and surrounds and is typically associated with marine/mangrove deposits. Although PASS is typically not associated with landform units associated with the fringing and coastal dunes and the adjacent alluvial/colluvial plains, it is believed that shallow marine/organic deposits may be associated with the Ashburton River delta and the Hooley Creek catchment which underlie this network. Therefore where PASS has been identified below these landforms, the PASS Map has identified them as high risk.

There is a moderate risk of intercepting PASS (assuming incidental excavation for these areas) for landform units associated with the samphire flats and the supratidal salt flats where PASS typically comprised of dark brown to dark grey SAND/clayey SAND/CLAY at shallow depths. Moderate risk of PASS is also correlated with proximity to mangroves and samphire flats which provide a source of marine/ organic material, are considered low energy environment, and are subject to waterlogging/flooding.

The minor islands located along the north western boundary of the Construction study area, which are bound by the supratidal salt flats, the area immediately south of islands, and the clayey plains south of Ashburton North have been conservatively classified as moderate risk for PASS given that only a desktop study has been undertaken. However, given that the landforms identified at the above locations are typically not associated with PASS, it is unlikely that PASS would be intercepted.

There is considered low to no PASS associated with the longitudinal dune network, where soils are typically of terrestrial origin and contain significant authigenic carbonates (formed *in-situ*) and of the coastal dunes located to the east of the Ashburton River delta.

Table 8-1 PASS Mapping

Classification Criteria	PASS Classification		
	Low to No Risk	Moderate Risk	High Risk
Depth in the Soil Profile	Water table not intercepted or below 3 mbgl	PASS soils (field test identification only) typically at or below water table.	PASS soils typically at or below the water table.
Landform	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation)	Samphire and Supratidal Salt Flats	Intertidal Flats, Tidal Creek, Mangrove Swamp and Chenier formations (and some fringing formations)
Elevation	Above 5 mAHD	Below 5 mAHD	Generally below 5 mAHD unless soils are below Chenier
Volume of Soil to be Excavated	None to incidental (<1000 tonne)	None to Incidental (<1000 tonne)	Large scale (>1000 tonne) excavation/ dredging/dewatering
Field pH Indicators	pH(f)>7.0 pH(fox)>5.5	Generally with a pH(fox) <5.5	Generally with a pH(fox)<4.0
Soil Type	Red earths sands/clays and sandstone/limestone pavement	CLAY/Clayey SAND: Medium to high plasticity, brown to grey	CLAY: medium to high plasticity, brown to grey
Sulfide Content	Non-detect	No inorganic sulfide detected by analysis	Above 0.03 %S

8.2 Acid Neutralising Capacity

ANC is a measure of a soil's inherent ability to buffer acidity and resist the lowering of the soil pH. Acid buffering in the soil may be provided by dissolution of calcium and/or magnesium carbonates (for example shell or limestone), cation exchange reactions, and by reaction with the organic and clay fractions. The effectiveness of these buffering components in maintaining soil pH at acceptable levels (e.g. pH 6.5–9.0) will depend on the types and quantities of clay minerals in the soil, and on the type, amount and particle size of the carbonates or other minerals present.

With regard to the most likely sources of silicate-induced acid neutralisation are clay minerals and chlorite. The other silicate minerals do not contain neutralising cations (quartz, kaolinite) or their dissolution rate is so low, with minor cation exchange capacity, that ANC is negligible (muscovite, albite, orthoclase).

8 Potential for PASS in Terrestrial Assessment Area

Although there is evidence of significant ANC of the surrounding environment of the Terrestrial Assessment area e.g. as reported for soil profiles with significant shell, limestone and/or sandstone, it ranged greatly depending on the composition of the soil profile (e.g. whether it was clay, sand or of marine/mangrove origin).

The current NATA accredited analytical methodology used by ALS, described in **Section 6.3.2,** to determine the ANC of a soil is in accordance with the guidelines, however the DEC (2009a) acknowledge that in addition to this test method, other aspects need to be considered. This is mainly because the net acidity leached to the environment upon disturbance of PASS, depends not only on the amount and rate of acid generation, but also on the amount and reactivity of the neutralising components in the soil. The actual amount of neutralising capacity available under real field conditions is influenced by particle size or fineness of acid neutralising material, armouring and reaction kinetics. For this reason, and as PASS typically has negligible ANC, any reported ANC needs to be considered in conjunction with the type of ground disturbance proposed and mitigation strategies applied.

Conclusions

A BSQ and landforms assessment was completed for in part for the Terrestrial Assessment area, as a desktop study comprising a review of land systems and landforms at a regional scale, followed by a site specific assessment of landforms and BSQ, which was completed between March and October 2009.

The objectives of the investigation were to complete a general regional and site specific assessment of the soils and landforms identified within Ashburton North and surrounds and the SIC study area, identify baseline metal concentrations of the surface and subsurface profile (to approximately 3 mbgl) and identify the general presence or absence of PASS and subsequently derive a PASS map for material encountered within the Terrestrial Assessment area.

A summary of the findings of the works performed are as follows:

- A series of seven land systems were identified within the Terrestrial Assessment area, and include the Littoral, Onslow, Dune, Minderoo, Giralia, Stuart and Uaroo land systems.
- The landforms associated with these land systems include:
    - Littoral land system: intertidal creeks, mangrove, supratidal salt flats and samphire flats
    - Onslow land system: alluvial/colluvial plains, minor claypans and fringing and coastal dunes
    - Dune land system: longitudinal dunes, interdunal swales, alluvial/colluvial plains and claypans.
    - Minderoo land system: alluvial plains and sandy plains.
    - Giralia land system: linear (parallel), sandy and calcrete plains.
    - Stuart land system: undulating plains, minor hills and broad lower plains.
    - Uaroo land system: low hills, low stony rises and pebbly, sandy and calcrete plains.
- Based on the results of the field dispersion tests, clay and/or clayey soils identified within Ashburton North and surrounds and the SIC study area generally slake (slightly) but are non dispersive (Class 4, 5 or 6). PASS was classified as potentially dispersive (Class 3).
- The results of the erodibility assessment indicated landform units of the longitudinal dune network, fringing and coastal dunes and mainland dunes have very high to extreme erosion potential for wind and high erosion potential for water.
- No analytical results for metals were reported in exceedance of the adopted HIL-F guideline criteria and therefore it is considered there is no risk to human health.
- Elevated arsenic, chromium, manganese and nickel concentrations were detected above the adopted EIL trigger values within the north western and north eastern extent of Ashburton North and surrounds and chromium and manganese within the SIC study area
- Because there have been no historic industrial land use practices within the Terrestrial Assessment area and it is not anticipated that adjacent land use practices (Onslow Salt) have negatively impacted these areas.
- Further, a comparison of the these results against an assessment of heavy metals completed by Oceanica (2005) and URS (2008) along the Pilbara coastline of similar deltaic systems, also reported elevated concentrations of arsenic, chromium and nickel. The elevated metals encountered are comparable suggesting that the high background levels are likely a result of the weathering of terrestrial origin.
- The results of the field and analytical investigations and geotechnical bore review indicate that PASS is present at shallow depths ranging between 0.5 mbgl and 4.5 mbgl with a

9 Conclusions

thickness ranging between 0.2 and 3.5 m predominantly along the north eastern extent of Ashburton North and surrounds and along the northern boundary of the SIC study area.

- Corresponding soil profiles were typically characterised as low to high plasticity CLAY to clayey SAND/SAND, low to high plasticity, brown to dark grey; fine to medium grained, mottling may range from yellow and orange, firm to very soft.
- These soils are considered to be of marine/organic origin and are generally located within landform units associated with the intertidal flats, tidal creek and mangrove swamp of the Littoral land system and within the supratidal salt flats and samphire flats where groundwater was intercepted.
- PASS was also identified as a thin underlying lens comprising of marine /organic deposits in landforms associated with the alluvial/colluvial plains and fringing and coastal dunes.
- At the conclusion of the desktop assessment, intrusive works and subsequent analytical testing, a PASS map was produced identifying areas of low, moderate and high risk for intercepting PASS within the Terrestrial Assessment area. There is a high risk of intercepting PASS (assuming excavations >1000 tonne) along the north eastern extent of Ashburton North and surrounds and is typically associated with marine/mangrove deposits, and where PASS was identified as a thin lens underlying the fringing and coastal dunes and alluvial plains between the Ashburton River delta and Hooley Creek.
- There is a moderate risk of intercepting PASS (assuming incidental excavation for these areas) for landform units associated with the samphire flats and the supratidal salt flats where PASS typically comprised of dark brown to dark grey SAND/clayey SAND/CLAY at shallow depths. Moderate risk of PASS is also correlated with proximity to mangroves and samphire flats which provide a source of marine/ organic material, are considered low energy environment, and are subject to waterlogging/flooding.
- The minor islands located along the north western boundary of the Construction study area, the area immediately south of islands, and the clayey plains south of Ashburton North have been conservatively classified as moderate risk for PASS given that only a desktop study has been undertaken. However, given that the landforms identified at the above locations are typically not associated with PASS, it is unlikely that PASS would be intercepted.
- Although there is evidence of significant potential ANC of the soils profiles of the Terrestrial Assessment area (e.g. as reported for soil profiles with significant shell, limestone and/or sandstone), it ranged greatly depending on the composition of the soil profile (e.g. whether it was clay, sand or of marine/mangrove origin).
- There is no to low PASS risk associated with the coastal dunes located to the east of the Ashburton River delta, the longitudinal landform unit and of the landform units identified along the Domgas Study areas.

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10 References

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11

Limitations

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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.

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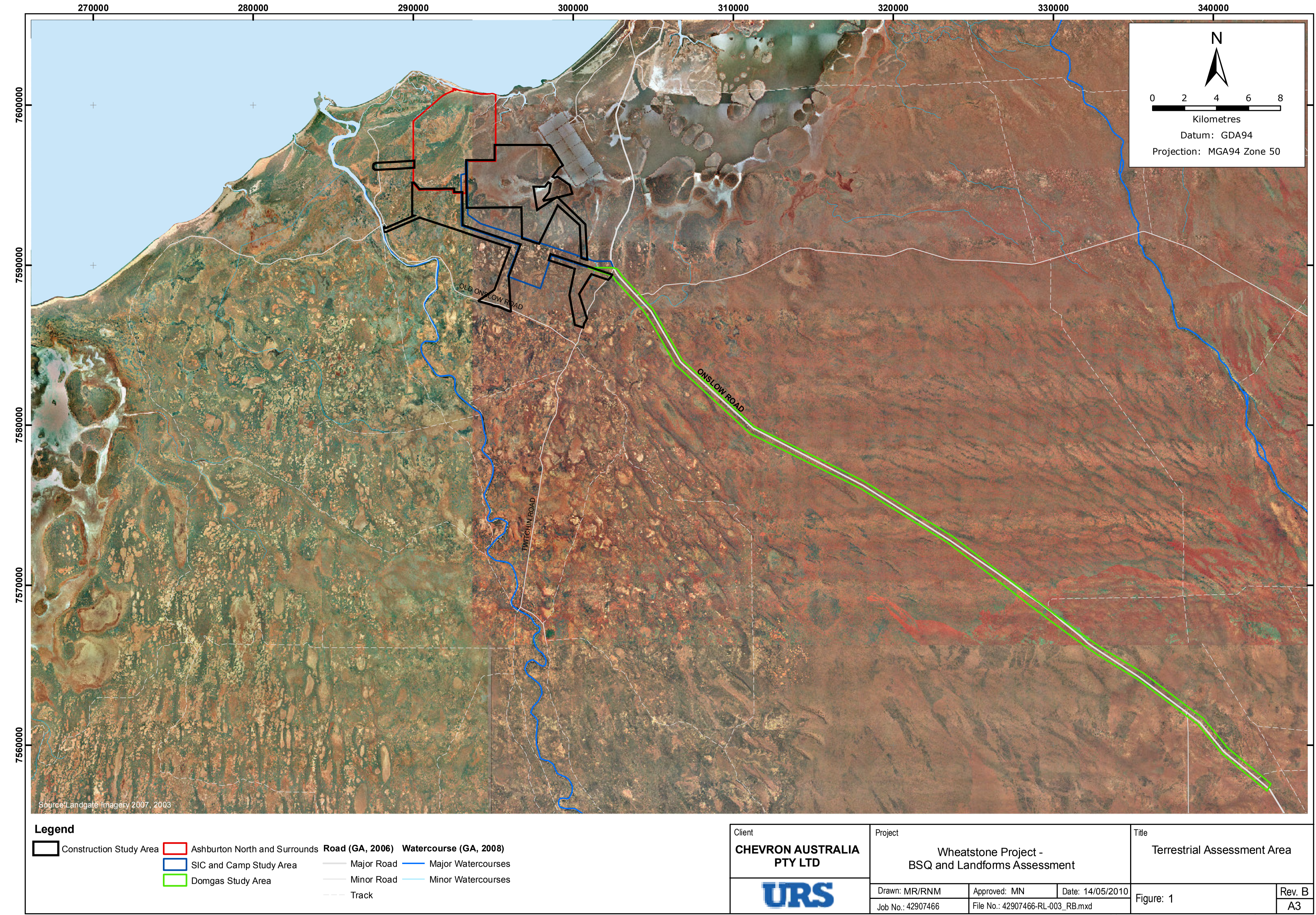
Figures



Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Terrestrial Assessment Area
URS	Drawn: MR/RNM Approved: MN Date: 14/05/2010 Job No.: 42907466 File No.: 42907466-RL-003_RB.mxd	Figure: 1 Rev. B A3

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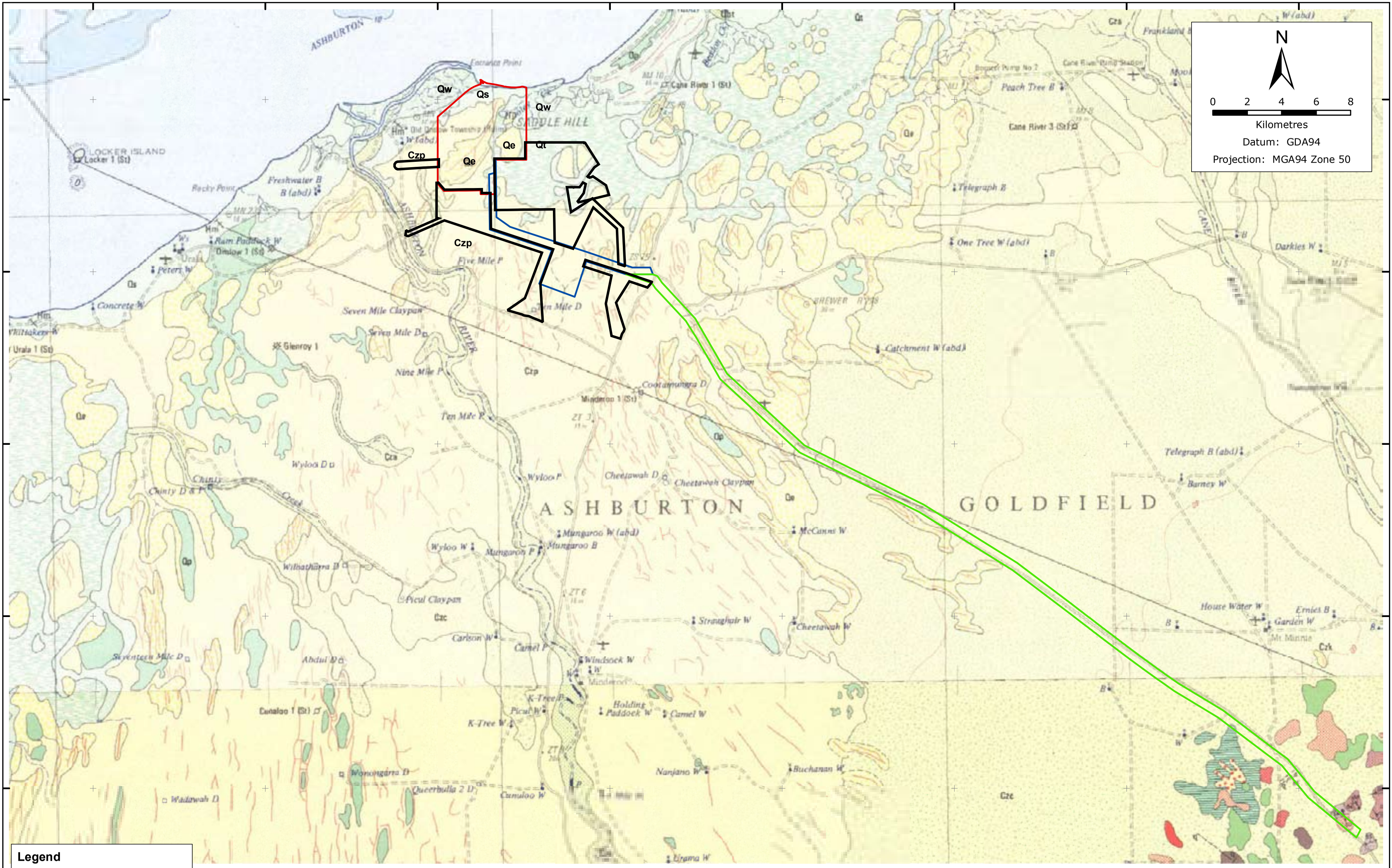

Legend

- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area

Qr Ningaloo Reef - living coralgal reef
Qs Beaches and coastal dunes - light grey, unconsolidated and poorly consolidated quartzose calcarenite
Qw Intertidal flats and mangrove swamps - calcareous clay, silt and sand
Qt Supratidal flats - calcareous clay, silt and sand with authigenic gypsum and superficial algal mats and salt crusts
Qp Claypans - poorly sorted clay, silt, sand and minor pebbles
Qe Longitudinal and network dunes and residual sand plains - reddish-brown to yellowish quartz sand
Czk Calcrete - lumpy to nodular or massive, authigenic limestone, locally silicified
Cza Alluvium - clay, silt, sand and gravel, partly calcreted
Czc Colluvium - poorly sorted clay, silt, sand and gravel; formed on plains and slopes by sheet floodand deflatation; includes minor laterite exposed
Czp Claypan-dominant terrain - claypans with longitudinal and net dunes, and/or flat deflation-lag surfaves; clay, silt, sand and gravel

Source: Landgate Imagery 2007, 2003, Geological Survey of Western Australia

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Regional Surficial Geology
URS	Drawn: MR/RNM Job No.: 42907466	Approved: MN File No.: 42907466-RL-004_RB.mxd
	Date: 14/05/2010	Figure: 2
	Rev. B	A3

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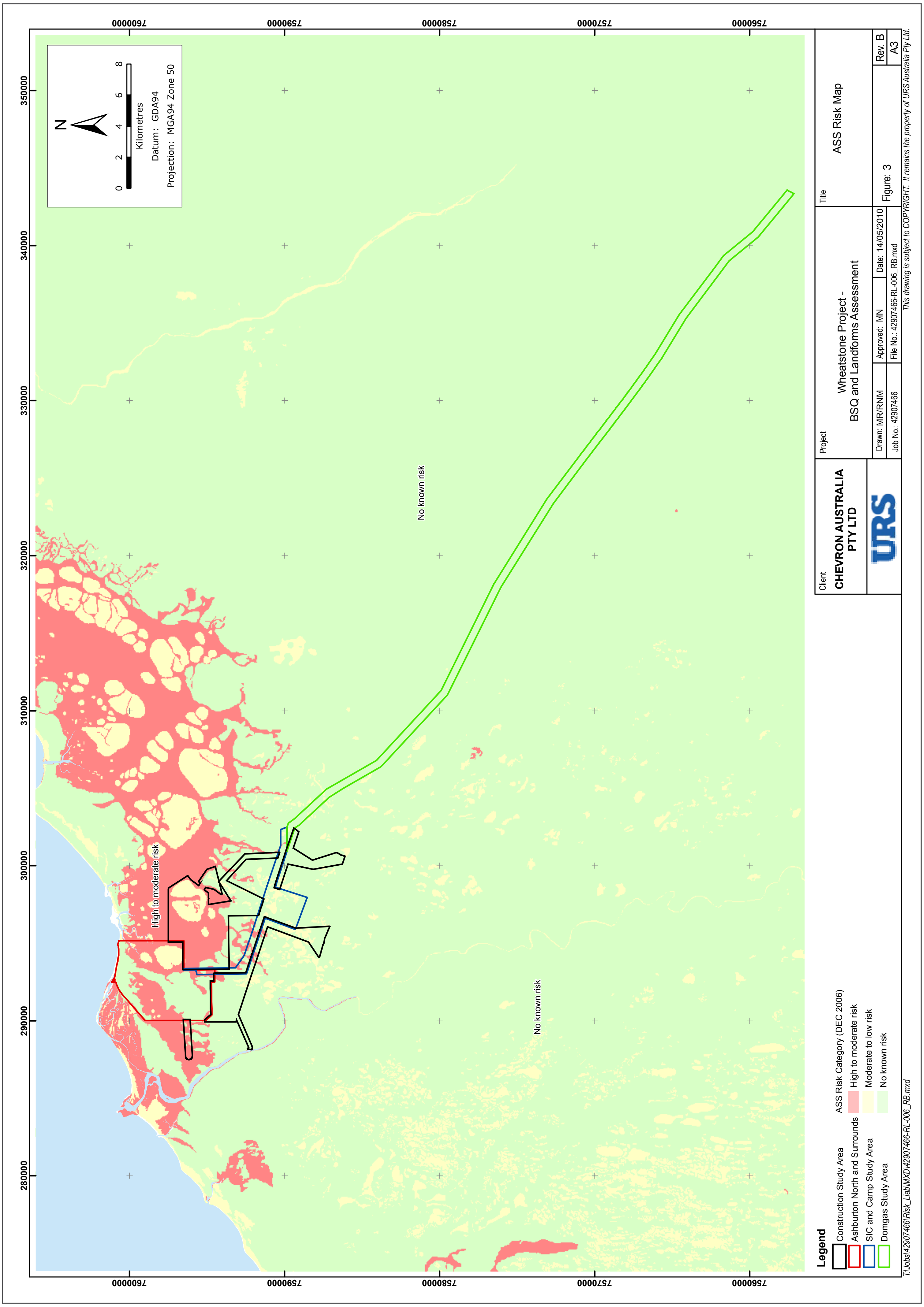
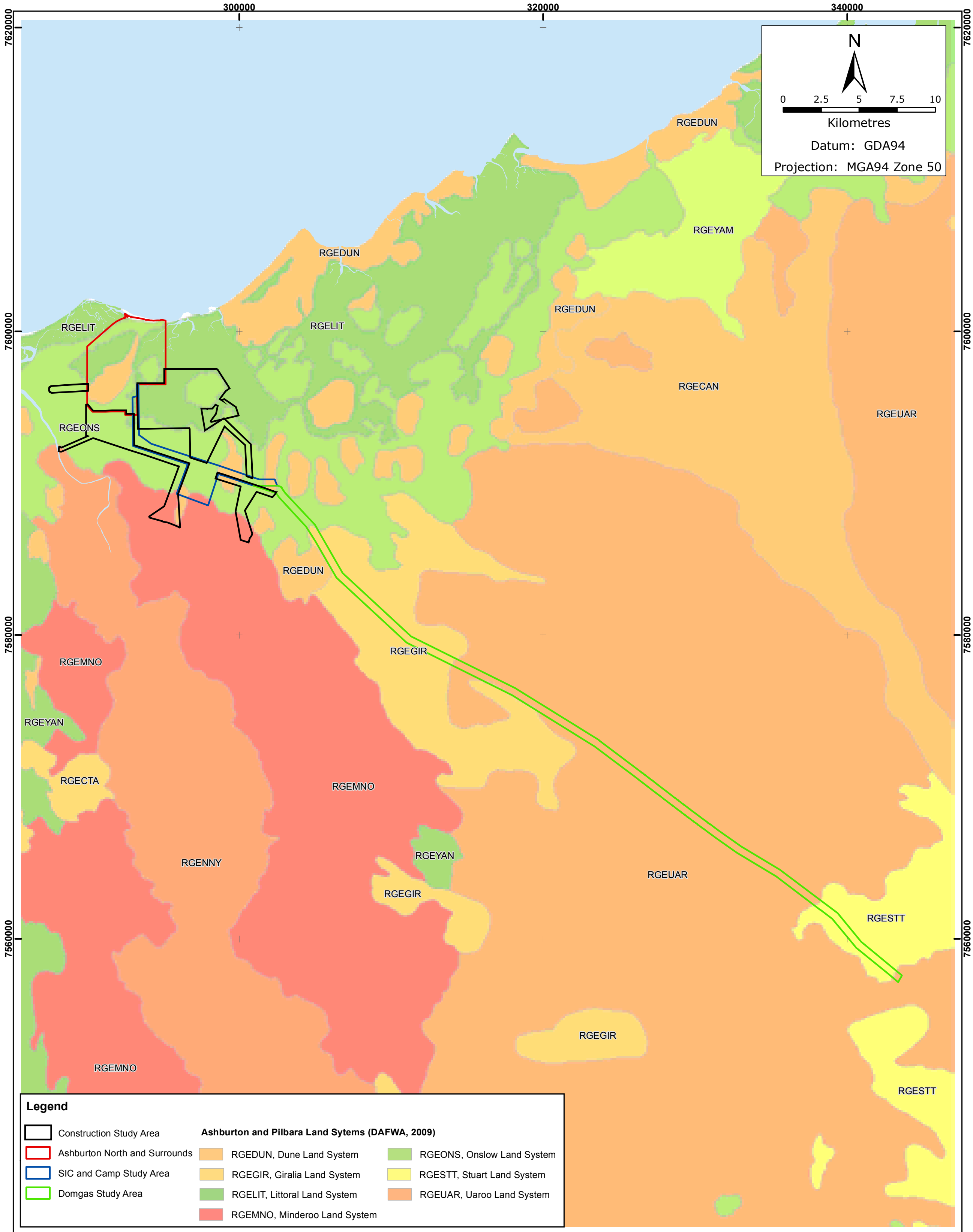


ASS Risk Map

Figure: 3



Client **CHEVRON AUSTRALIA PTY LTD**	Project Wheatstone Project - BSQ and Landforms Assessment		Title Land Systems of the Terrestrial Assessment Area	
URS	Drawn: MR/RNM	Approved: MN Date: 14/05/2010	Figure: 4	Rev. B
	Job No.: 42907466	File No.: 42907466-RL-005_RB.mxd		A3

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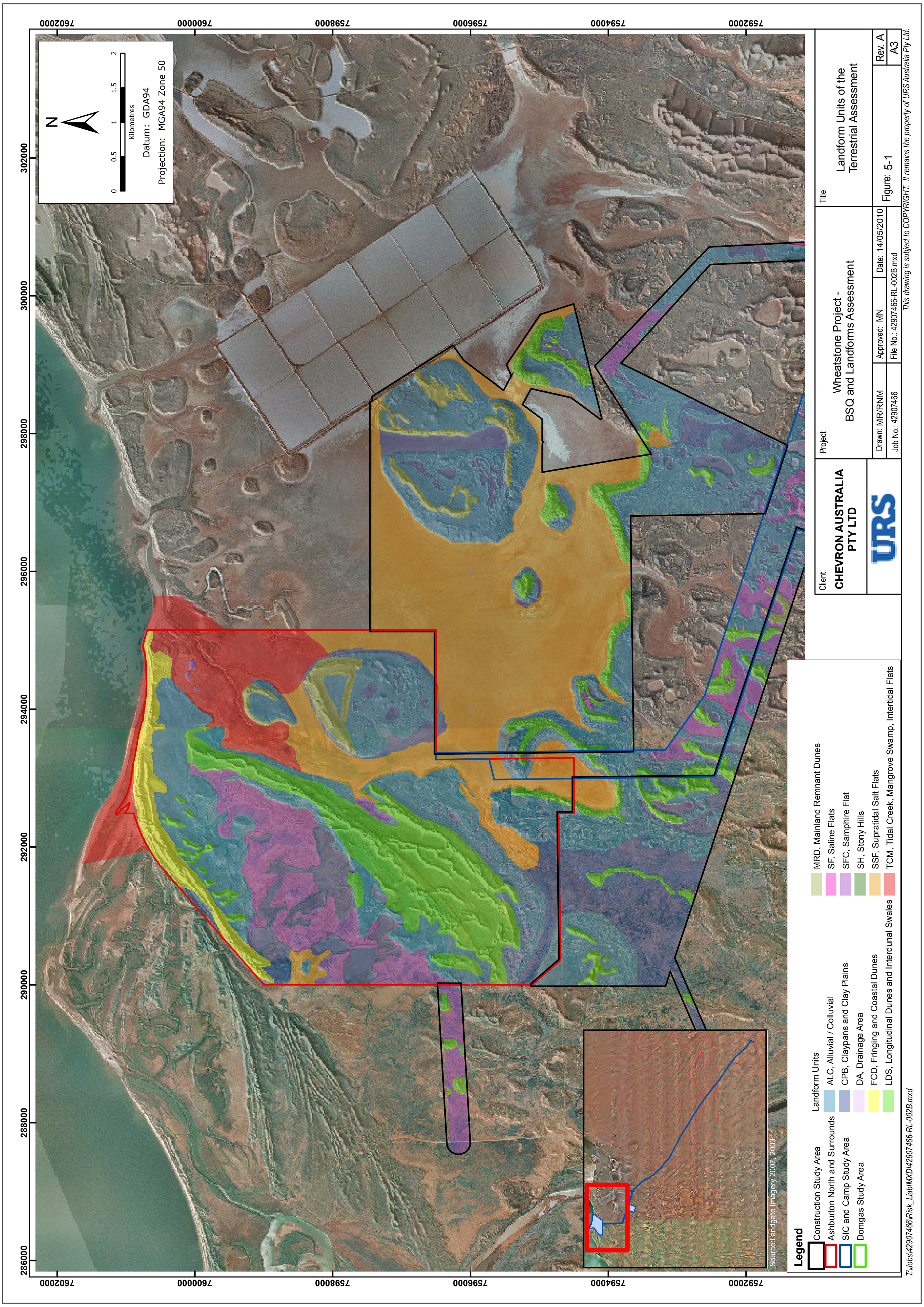
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Projection: MGA94 Zone 50
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7596000
7594000
7592000
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288000
290000
292000
294000
296000
298000
300000
302000
Source:Landgate Imagery 2007, 2003
Legend
Construction Study Area
Ashburton North and Surrounds
SIC and Camp Study Area
Domgas Study Area
Landform Units
ALC, Alluvial / Colluvial
CPB, Claypans and Clay Plains
DA, Drainage Area
FCD, Fringing and Coastal Dunes
LDS, Longitudinal Dunes and Interdunal Swales
MRD, Mainland Remnant Dunes
SF, Saline Flats
SFC, Samphire Flat
SH, Stony Hills
SSF, Supratidal Salt Flats
TCM, Tidal Creek, Mangrove Swamp, Intertidal Flats
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Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project - BSQ and Landforms Assessment
Drawn: MR/RNM
Approved: MN
Date: 14/05/2010
Job No.: 42907466
File No.: 42907466-RL-002B.mxd
Title
Landform Units of the Terrestrial Assessment
Figure: 5-1
Rev. A
A3
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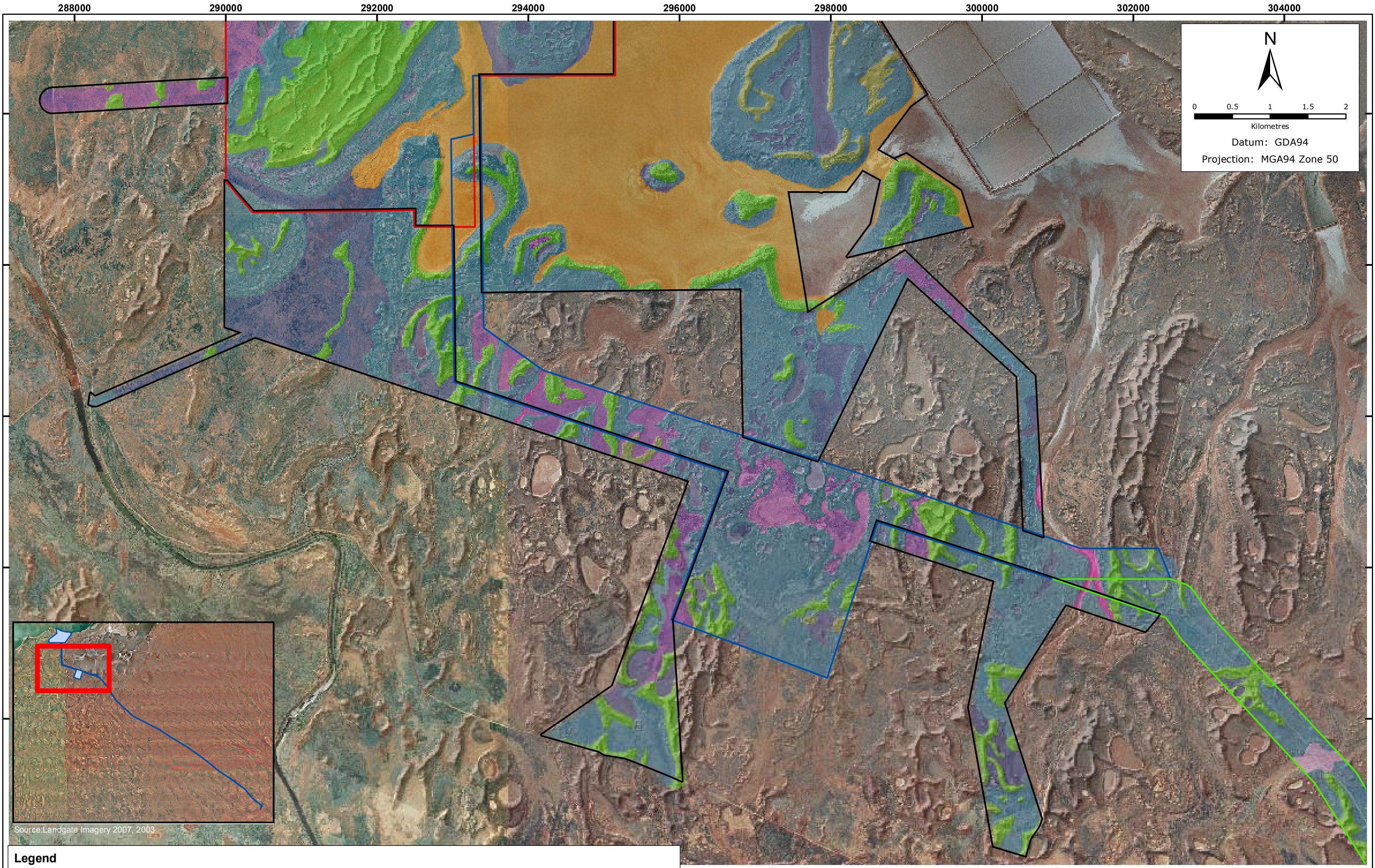

Source:Landgate Imagery 2007, 2003

Legend

⬛	Construction Study Area	Landform Units			
🟥	Ashburton North and Surrounds	▨	ALC, Alluvial / Colluvial	▨	MRD, Mainland Remnant Dunes
🟦	SIC and Camp Study Area	▨	CPB, Claypans and Clay Plains	▨	SF, Saline Flats
🟩	Domgas Study Area	▨	DA, Drainage Area	▨	SFC, Samphire Flat
		▨	FCD, Fringing and Coastal Dunes	▨	SH, Stony Hills
		▨	LDS, Longitudinal Dunes and Interdunal Swales	▨	SSF, Supratidal Salt Flats
				▨	TCM, Tidal Creek, Mangrove Swamp, Intertidal Flats

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Landform Units of the Terrestrial Assessment
URS	Drawn: MR/RNM; Approved: MN; Date: 14/05/2010	Figure: 5-2
	Job No.: 42907466; File No.: 42907466-RL-002_RB.mxd	Rev. B A3

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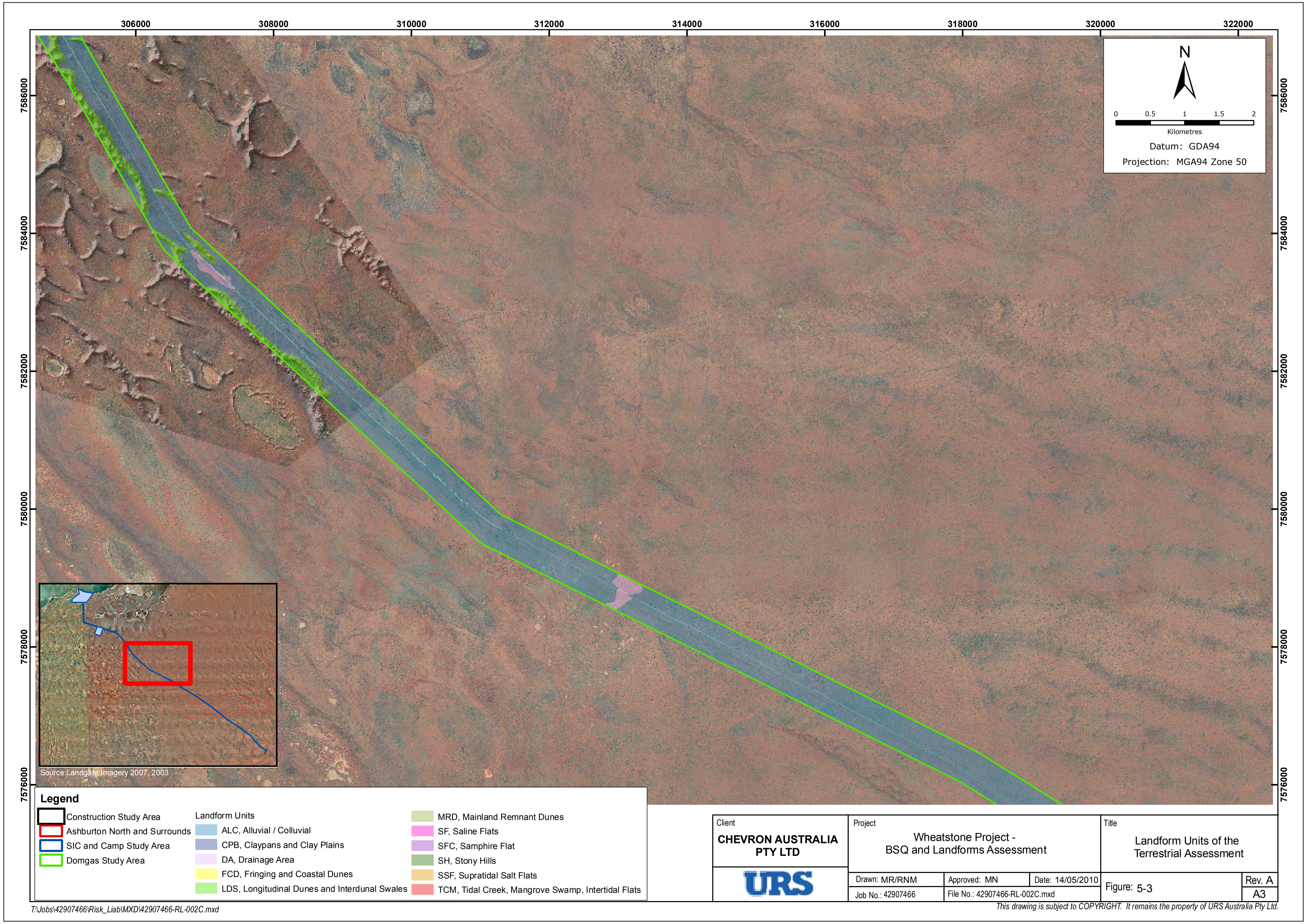
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Kilometres
Datum: GDA94
Projection: MGA94 Zone 50
Source:Landgate Imagery 2007, 2003
Legend
Construction Study Area
Ashburton North and Surrounds
SIC and Camp Study Area
Domgas Study Area
Landform Units
ALC, Alluvial / Colluvial
CPB, Claypans and Clay Plains
DA, Drainage Area
FCD, Fringing and Coastal Dunes
LDS, Longitudinal Dunes and Interdunal Swales
MRD, Mainland Remnant Dunes
SF, Saline Flats
SFC, Samphire Flat
SH, Stony Hills
SSF, Supratidal Salt Flats
TCM, Tidal Creek, Mangrove Swamp, Intertidal Flats
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project - BSQ and Landforms Assessment
Drawn: MR/RNM
Approved: MN
Date: 14/05/2010
Job No.: 42907466
File No.: 42907466-RL-002C.mxd
Title
Landform Units of the Terrestrial Assessment
Figure: 5-3
Rev. A
A3
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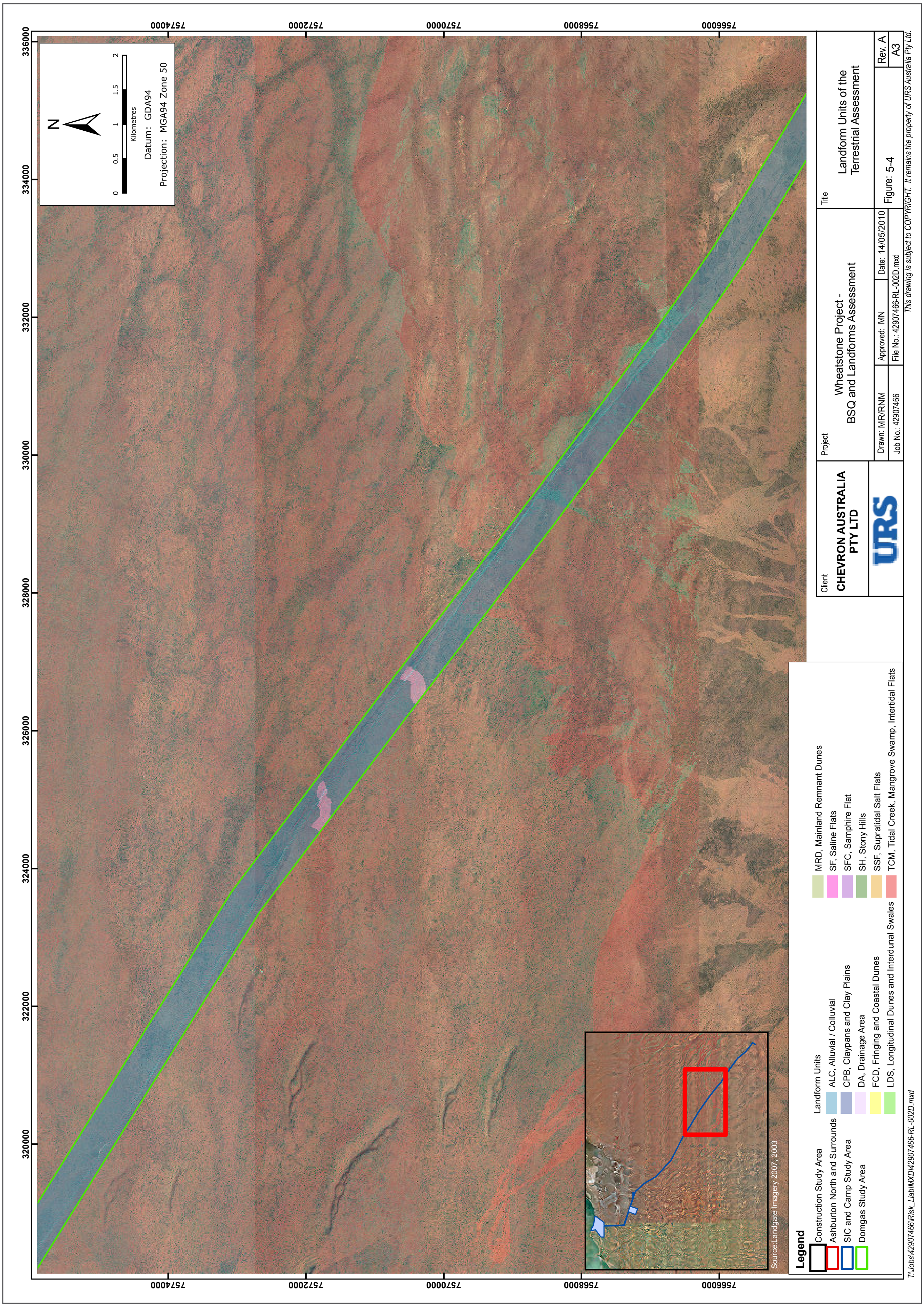
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334000
332000
330000
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324000
322000
320000
Source:Landgate Imagery 2007, 2003
Legend
Construction Study Area
Ashburton North and Surrounds
SIC and Camp Study Area
Domgas Study Area
Landform Units
ALC, Alluvial / Colluvial
CPB, Claypans and Clay Plains
DA, Drainage Area
FCD, Fringing and Coastal Dunes
LDS, Longitudinal Dunes and Interdunal Swales
MRD, Mainland Remnant Dunes
SF, Saline Flats
SFC, Samphire Flat
SH, Stony Hills
SSF, Supratidal Salt Flats
TCM, Tidal Creek, Mangrove Swamp, Intertidal Flats
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project - BSQ and Landforms Assessment
Title
Landform Units of the Terrestrial Assessment
Drawn: MR/RNM
Approved: MN
Date: 14/05/2010
Figure: 5-4
Rev. A
Job No.: 42907466
File No.: 42907466-RL-002D.mxd
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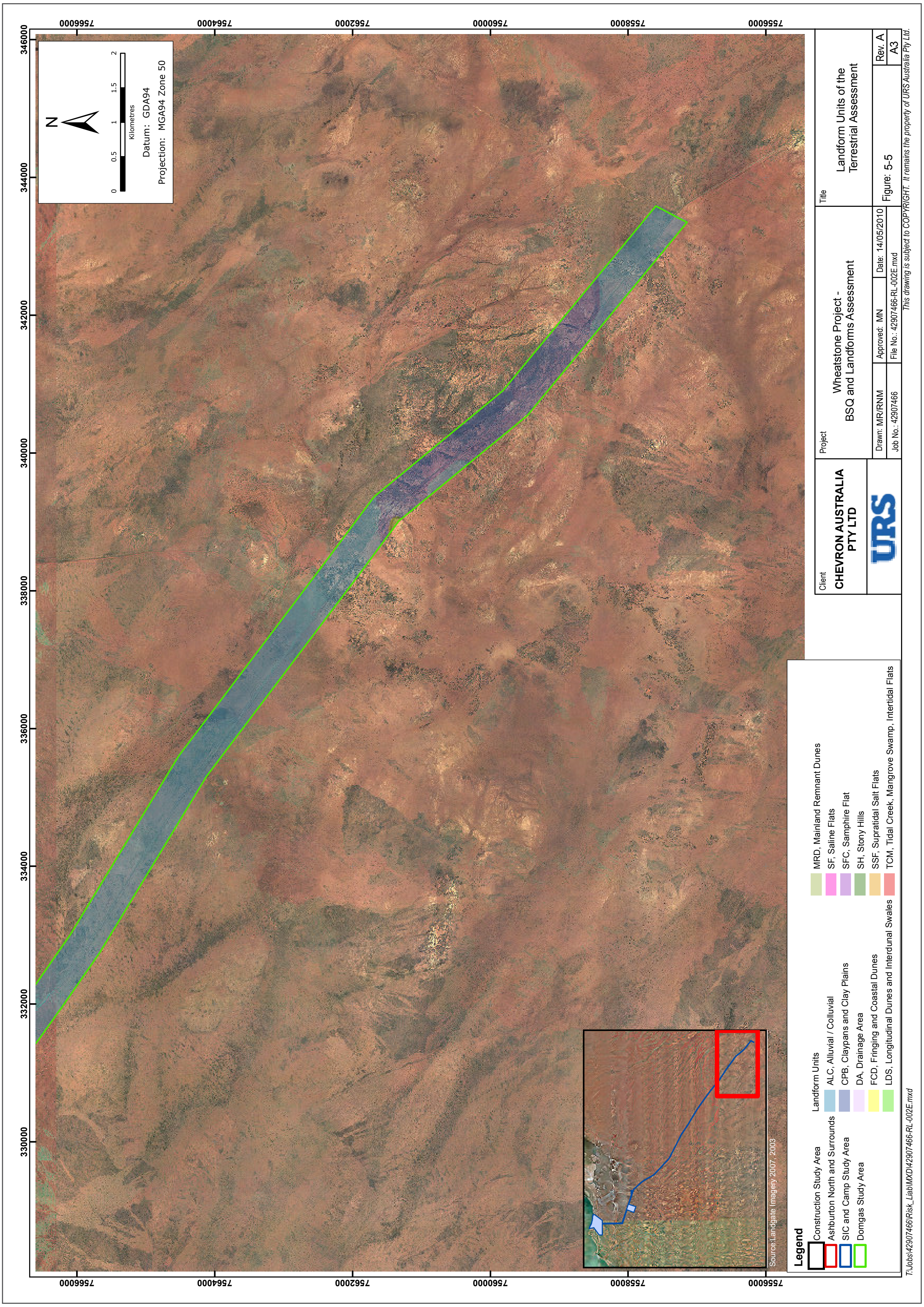
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334000
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Source Landgate Imagery 2007, 2003
Legend
Construction Study Area
Ashburton North and Surrounds
SIC and Camp Study Area
Domgas Study Area
Landform Units
ALC, Alluvial / Colluvial
CPB, Claypans and Clay Plains
DA, Drainage Area
FCD, Fringing and Coastal Dunes
LDS, Longitudinal Dunes and Interdunal Swales
MRD, Mainland Remnant Dunes
SF, Saline Flats
SFC, Samphire Flat
SH, Stony Hills
SSF, Supratidal Salt Flats
TCM, Tidal Creek, Mangrove Swamp, Intertidal Flats
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project - BSQ and Landforms Assessment
Title
Landform Units of the Terrestrial Assessment
Drawn: MR/RNM
Approved: MN
Date: 14/05/2010
Rev. A
Job No.: 42907466
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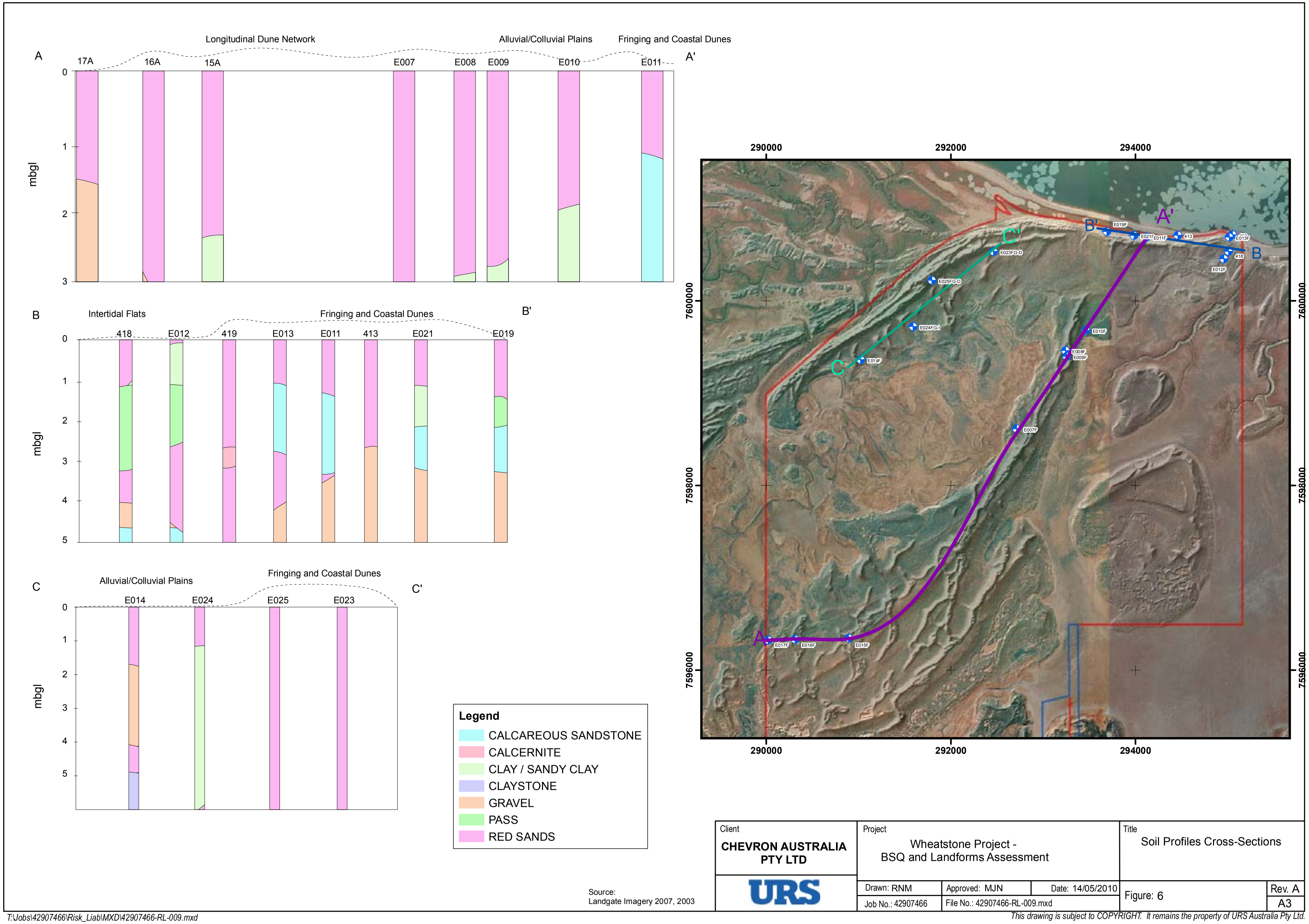

Legend
- 🟦 CALCAREOUS SANDSTONE
- 🟥 CALCERNITE
- 🟩 CLAY / SANDY CLAY
- 🟪 CLAYSTONE
- 🟧 GRAVEL
- 🟩 PASS
- 🟪 RED SANDS

Source:
Landgate Imagery 2007, 2003

Client
CHEVRON AUSTRALIA PTY LTD

URS

Project
Wheatstone Project -
BSQ and Landforms Assessment

Title
Soil Profiles Cross-Sections

Drawn: RNM
Approved: MJN
Date: 14/05/2010
Figure: 6
Rev. A
A3
Job No.: 42907466
File No.: 42907466-RL-009.mxd

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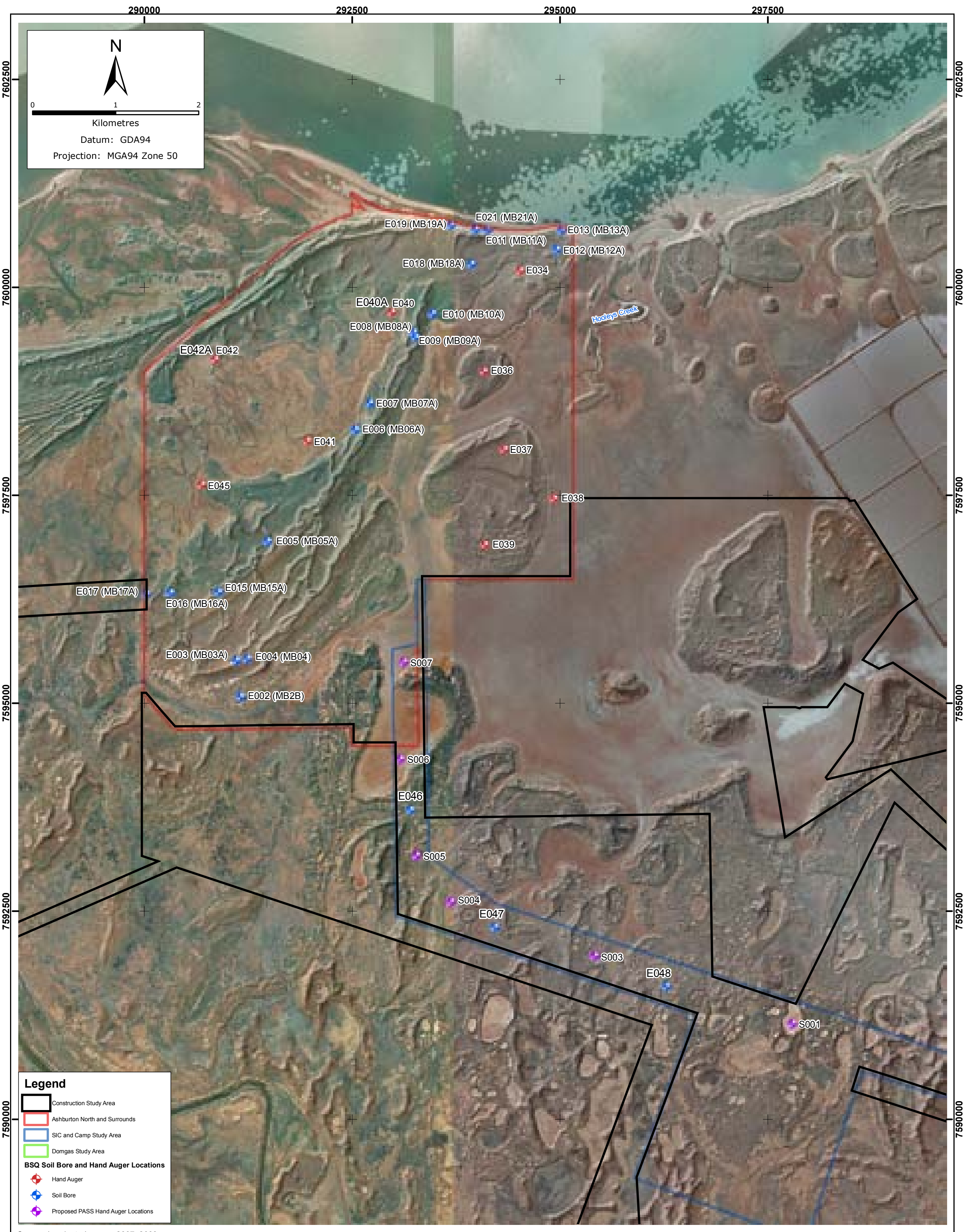

Source: Landgate Imagery 2007, 2003

Client **CHEVRON AUSTRALIA PTY LTD**	Project Wheatstone Project - BSQ and Landforms Assessment	Title Environmental Soil Bore and Hand Auger Locations
URS	Drawn: RNM Job No.: 42907466	Approved: MJN File No.: 42907466-RL-010.mxd
Date: 14/05/2010	Figure: 7	Rev. A A3

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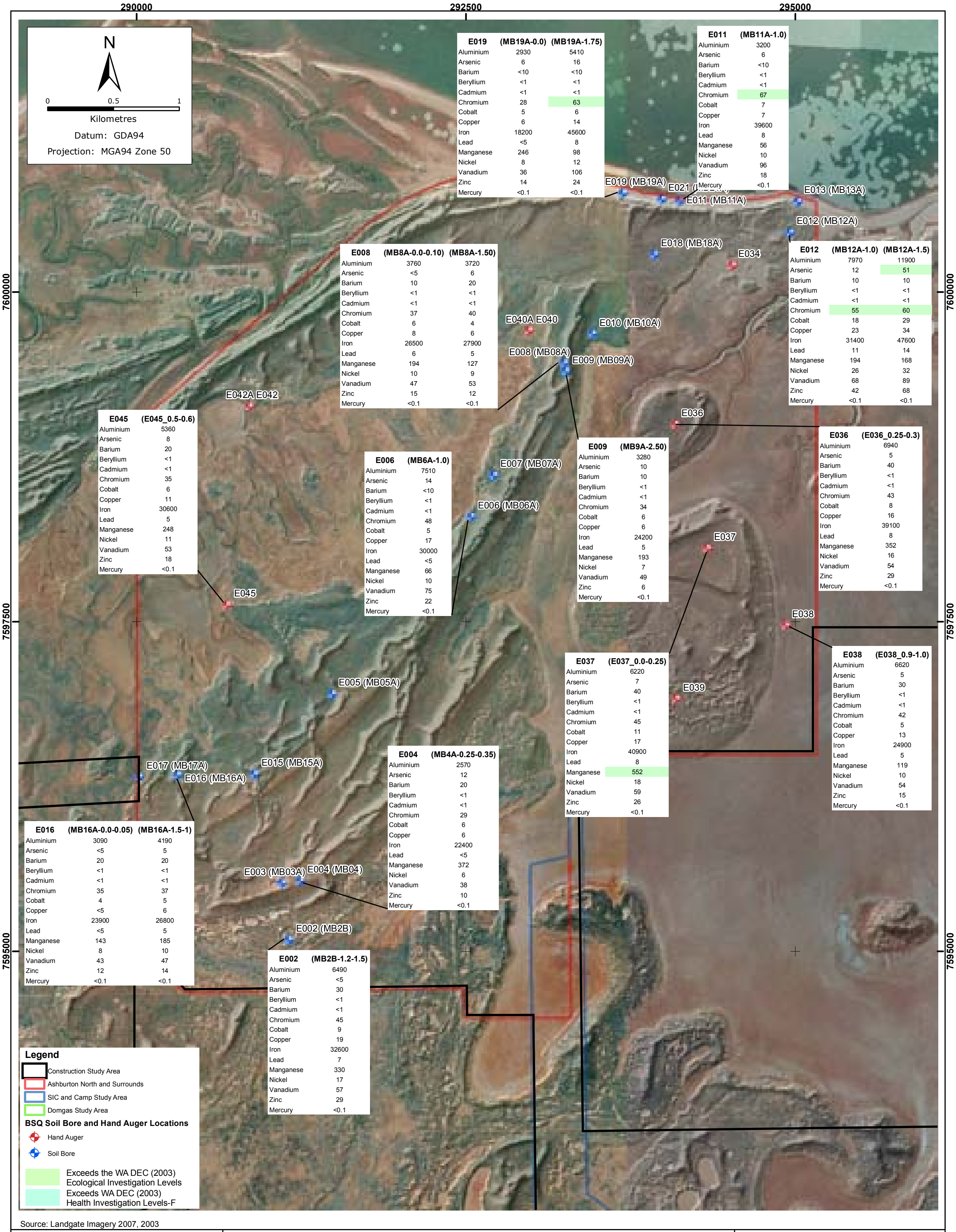

E019	(MB19A-0.0)	(MB19A-1.75)
Aluminium	2930	5410
Arsenic	6	16
Barium	<10	<10
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	28	63
Cobalt	5	6
Copper	6	14
Iron	18200	45600
Lead	<5	8
Manganese	246	98
Nickel	8	12
Vanadium	36	106
Zinc	14	24
Mercury	<0.1	<0.1

E011	(MB11A-1.0)
Aluminium	3200
Arsenic	6
Barium	<10
Beryllium	<1
Cadmium	<1
Chromium	67
Cobalt	7
Copper	7
Iron	39600
Lead	8
Manganese	56
Nickel	10
Vanadium	96
Zinc	18
Mercury	<0.1

E008	(MB8A-0.0-0.10)	(MB8A-1.50)
Aluminium	3760	3720
Arsenic	<5	6
Barium	10	20
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	37	40
Cobalt	6	4
Copper	8	6
Iron	26500	27900
Lead	6	5
Manganese	194	127
Nickel	10	9
Vanadium	47	53
Zinc	15	12
Mercury	<0.1	<0.1

E012	(MB12A-1.0)	(MB12A-1.5)
Aluminium	7970	11900
Arsenic	12	51
Barium	10	10
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	55	60
Cobalt	18	29
Copper	23	34
Iron	31400	47600
Lead	11	14
Manganese	194	168
Nickel	26	32
Vanadium	68	89
Zinc	42	68
Mercury	<0.1	<0.1

E045	(E045_0.5-0.6)
Aluminium	5360
Arsenic	8
Barium	20
Beryllium	<1
Cadmium	<1
Chromium	35
Cobalt	6
Copper	11
Iron	30600
Lead	5
Manganese	248
Nickel	11
Vanadium	53
Zinc	18
Mercury	<0.1

E006	(MB6A-1.0)
Aluminium	7510
Arsenic	14
Barium	<10
Beryllium	<1
Cadmium	<1
Chromium	48
Cobalt	5
Copper	17
Iron	30000
Lead	<5
Manganese	66
Nickel	10
Vanadium	75
Zinc	22
Mercury	<0.1

E009	(MB9A-2.50)
Aluminium	3280
Arsenic	10
Barium	10
Beryllium	<1
Cadmium	<1
Chromium	34
Cobalt	6
Copper	6
Iron	24200
Lead	5
Manganese	193
Nickel	7
Vanadium	49
Zinc	6
Mercury	<0.1

E036	(E036_0.25-0.3)
Aluminium	6940
Arsenic	5
Barium	40
Beryllium	<1
Cadmium	<1
Chromium	43
Cobalt	8
Copper	16
Iron	39100
Lead	8
Manganese	352
Nickel	16
Vanadium	54
Zinc	29
Mercury	<0.1

E037	(E037_0.0-0.25)
Aluminium	6220
Arsenic	7
Barium	40
Beryllium	<1
Cadmium	<1
Chromium	45
Cobalt	11
Copper	17
Iron	40900
Lead	8
Manganese	552
Nickel	18
Vanadium	59
Zinc	26
Mercury	<0.1

E038	(E038_0.9-1.0)
Aluminium	6620
Arsenic	5
Barium	30
Beryllium	<1
Cadmium	<1
Chromium	42
Cobalt	5
Copper	13
Iron	24900
Lead	5
Manganese	119
Nickel	10
Vanadium	54
Zinc	15
Mercury	<0.1

E004	(MB4A-0.25-0.35)
Aluminium	2570
Arsenic	12
Barium	20
Beryllium	<1
Cadmium	<1
Chromium	29
Cobalt	6
Copper	6
Iron	22400
Lead	<5
Manganese	372
Nickel	6
Vanadium	38
Zinc	10
Mercury	<0.1

E016	(MB16A-0.0-0.05)	(MB16A-1.5-1)
Aluminium	3090	4190
Arsenic	<5	5
Barium	20	20
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	35	37
Cobalt	4	5
Copper	<5	6
Iron	23900	26800
Lead	<5	5
Manganese	143	185
Nickel	8	10
Vanadium	43	47
Zinc	12	14
Mercury	<0.1	<0.1

E002	(MB2B-1.2-1.5)
Aluminium	6490
Arsenic	<5
Barium	30
Beryllium	<1
Cadmium	<1
Chromium	45
Cobalt	9
Copper	19
Iron	32600
Lead	7
Manganese	330
Nickel	17
Vanadium	57
Zinc	29
Mercury	<0.1

Source: Landgate Imagery 2007, 2003

Client CHEVRON AUSTRALIA PTY LTD	Project Wheatstone Project - BSQ and Landforms Assessment		Title Analytical Results Metals	
URS	Drawn: RNM	Approved: MN	Date: 14/05/2010	Figure: 8-1	Rev. A
	Job No.: 42907466	File No.: 42907466-RL-011.mxd			A3

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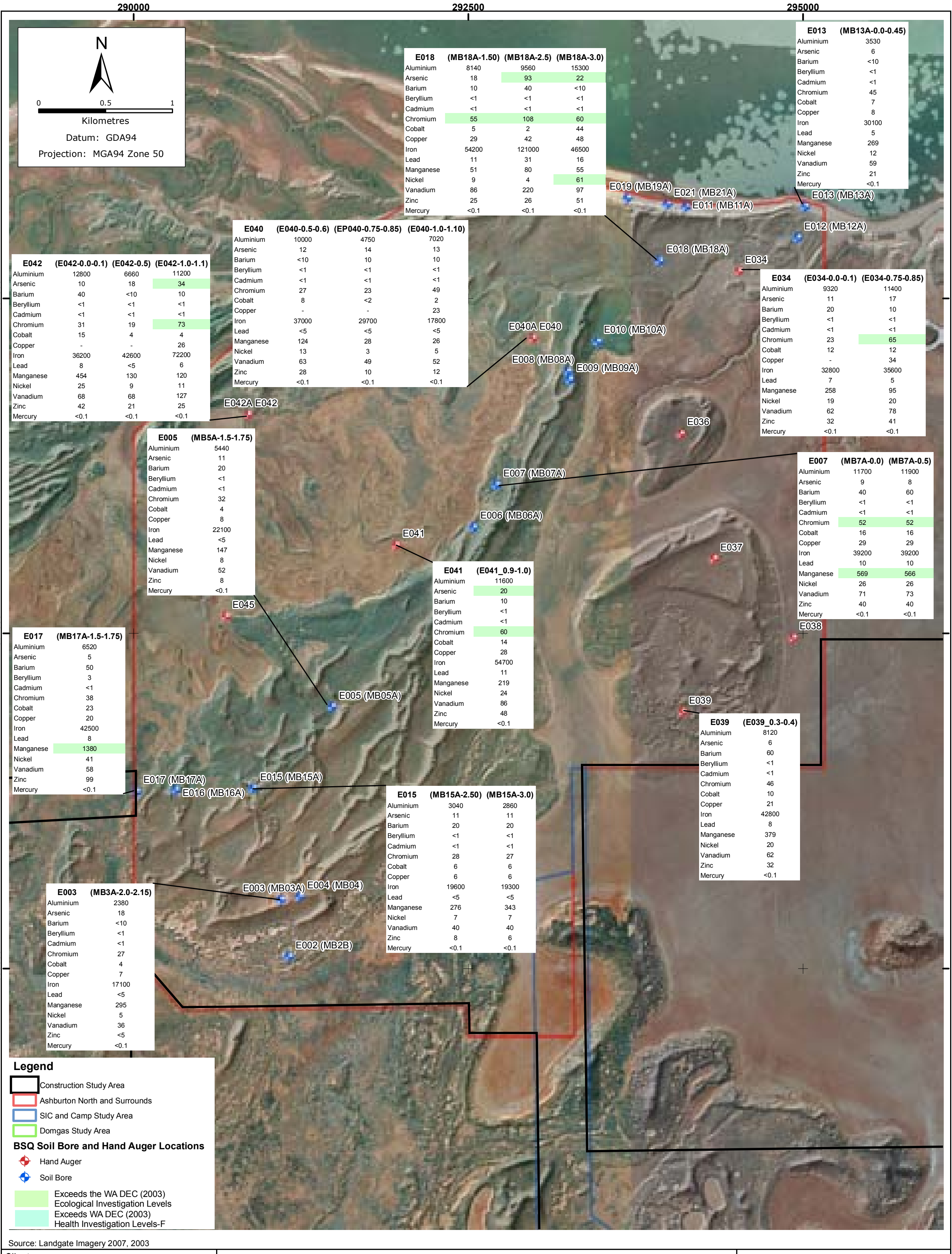

E018	**(MB18A-1.50)**	**(MB18A-2.5)**	**(MB18A-3.0)**
Aluminium	8140	9560	15300
Arsenic	18	93	22
Barium	10	40	<10
Beryllium	<1	<1	<1
Cadmium	<1	<1	<1
Chromium	55	108	60
Cobalt	5	2	44
Copper	29	42	48
Iron	54200	121000	46500
Lead	11	31	16
Manganese	51	80	55
Nickel	9	4	61
Vanadium	86	220	97
Zinc	25	26	51
Mercury	<0.1	<0.1	<0.1

E013	**(MB13A-0.0-0.45)**
Aluminium	3530
Arsenic	6
Barium	<10
Beryllium	<1
Cadmium	<1
Chromium	45
Cobalt	7
Copper	8
Iron	30100
Lead	5
Manganese	269
Nickel	12
Vanadium	59
Zinc	21
Mercury	<0.1

E040	**(E040-0.5-0.6)**	**(EP040-0.75-0.85)**	**(E040-1.0-1.10)**
Aluminium	10000	4750	7020
Arsenic	12	14	13
Barium	<10	10	10
Beryllium	<1	<1	<1
Cadmium	<1	<1	<1
Chromium	27	23	49
Cobalt	8	<2	2
Copper	-	-	23
Iron	37000	29700	17800
Lead	<5	<5	<5
Manganese	124	28	26
Nickel	13	3	5
Vanadium	63	49	52
Zinc	28	10	12
Mercury	<0.1	<0.1	<0.1

E042	**(E042-0.0-0.1)**	**(E042-0.5)**	**(E042-1.0-1.1)**
Aluminium	12800	6660	11200
Arsenic	10	18	34
Barium	40	<10	10
Beryllium	<1	<1	<1
Cadmium	<1	<1	<1
Chromium	31	19	73
Cobalt	15	4	4
Copper	-	-	26
Iron	36200	42600	72200
Lead	8	<5	6
Manganese	454	130	120
Nickel	25	9	11
Vanadium	68	68	127
Zinc	42	21	25
Mercury	<0.1	<0.1	<0.1

E034	**(E034-0.0-0.1)**	**(E034-0.75-0.85)**
Aluminium	9320	11400
Arsenic	11	17
Barium	20	10
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	23	65
Cobalt	12	12
Copper	-	34
Iron	32800	35600
Lead	7	5
Manganese	258	95
Nickel	19	20
Vanadium	62	78
Zinc	32	41
Mercury	<0.1	<0.1

E005	**(MB5A-1.5-1.75)**
Aluminium	5440
Arsenic	11
Barium	20
Beryllium	<1
Cadmium	<1
Chromium	32
Cobalt	4
Copper	8
Iron	22100
Lead	<5
Manganese	147
Nickel	8
Vanadium	52
Zinc	8
Mercury	<0.1

E007	**(MB7A-0.0)**	**(MB7A-0.5)**
Aluminium	11700	11900
Arsenic	9	8
Barium	40	60
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	52	52
Cobalt	16	16
Copper	29	29
Iron	39200	39200
Lead	10	10
Manganese	569	566
Nickel	26	26
Vanadium	71	73
Zinc	40	40
Mercury	<0.1	<0.1

E041	**(E041_0.9-1.0)**
Aluminium	11600
Arsenic	20
Barium	10
Beryllium	<1
Cadmium	<1
Chromium	60
Cobalt	14
Copper	28
Iron	54700
Lead	11
Manganese	219
Nickel	24
Vanadium	86
Zinc	48
Mercury	<0.1

E017	**(MB17A-1.5-1.75)**
Aluminium	6520
Arsenic	5
Barium	50
Beryllium	3
Cadmium	<1
Chromium	38
Cobalt	23
Copper	20
Iron	42500
Lead	8
Manganese	1380
Nickel	41
Vanadium	58
Zinc	99
Mercury	<0.1

E039	**(E039_0.3-0.4)**
Aluminium	8120
Arsenic	6
Barium	60
Beryllium	<1
Cadmium	<1
Chromium	46
Cobalt	10
Copper	21
Iron	42800
Lead	8
Manganese	379
Nickel	20
Vanadium	62
Zinc	32
Mercury	<0.1

E015	**(MB15A-2.50)**	**(MB15A-3.0)**
Aluminium	3040	2860
Arsenic	11	11
Barium	20	20
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	28	27
Cobalt	6	6
Copper	6	6
Iron	19600	19300
Lead	<5	<5
Manganese	276	343
Nickel	7	7
Vanadium	40	40
Zinc	8	6
Mercury	<0.1	<0.1

E003	**(MB3A-2.0-2.15)**
Aluminium	2380
Arsenic	18
Barium	<10
Beryllium	<1
Cadmium	<1
Chromium	27
Cobalt	4
Copper	7
Iron	17100
Lead	<5
Manganese	295
Nickel	5
Vanadium	36
Zinc	<5
Mercury	<0.1

Source: Landgate Imagery 2007, 2003

Client
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Project
Wheatstone Project -
BSQ and Landforms Assessment

Title
Analytical Results
Metals

Drawn: RNM
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Job No.: 42907466
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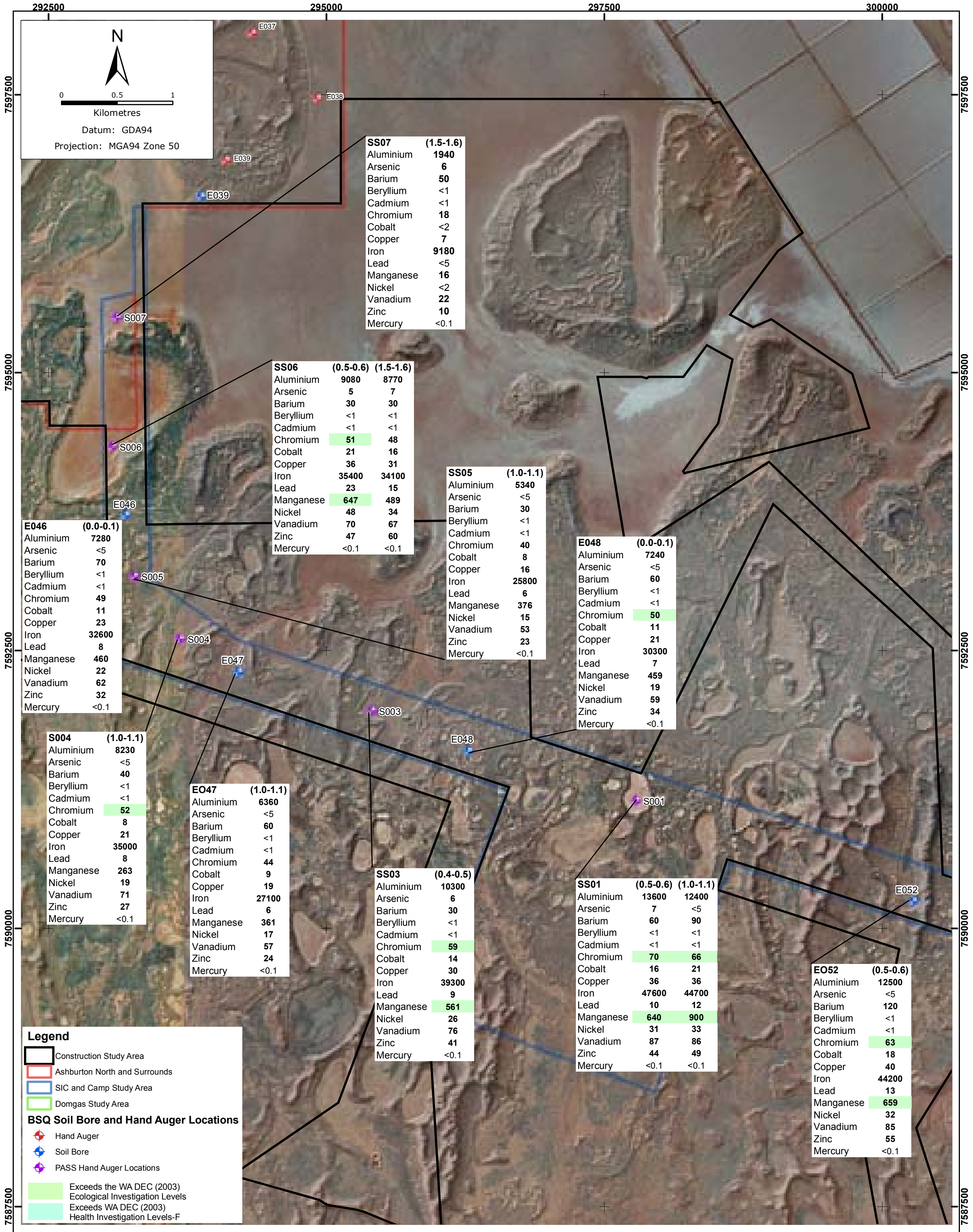

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Aluminium	1940
Arsenic	6
Barium	50
Beryllium	<1
Cadmium	<1
Chromium	18
Cobalt	<2
Copper	7
Iron	9180
Lead	<5
Manganese	16
Nickel	<2
Vanadium	22
Zinc	10
Mercury	<0.1

SS06	(0.5-0.6)	(1.5-1.6)
Aluminium	9080	8770
Arsenic	5	7
Barium	30	30
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	51	48
Cobalt	21	16
Copper	36	31
Iron	35400	34100
Lead	23	15
Manganese	647	489
Nickel	48	34
Vanadium	70	67
Zinc	47	60
Mercury	<0.1	<0.1

SS05	(1.0-1.1)
Aluminium	5340
Arsenic	<5
Barium	30
Beryllium	<1
Cadmium	<1
Chromium	40
Cobalt	8
Copper	16
Iron	25800
Lead	6
Manganese	376
Nickel	15
Vanadium	53
Zinc	23
Mercury	<0.1

E046	(0.0-0.1)
Aluminium	7280
Arsenic	<5
Barium	70
Beryllium	<1
Cadmium	<1
Chromium	49
Cobalt	11
Copper	23
Iron	32600
Lead	8
Manganese	460
Nickel	22
Vanadium	62
Zinc	32
Mercury	<0.1

E048	(0.0-0.1)
Aluminium	7240
Arsenic	<5
Barium	60
Beryllium	<1
Cadmium	<1
Chromium	50
Cobalt	11
Copper	21
Iron	30300
Lead	7
Manganese	459
Nickel	19
Vanadium	59
Zinc	34
Mercury	<0.1

S004	(1.0-1.1)
Aluminium	8230
Arsenic	<5
Barium	40
Beryllium	<1
Cadmium	<1
Chromium	52
Cobalt	8
Copper	21
Iron	35000
Lead	8
Manganese	263
Nickel	19
Vanadium	71
Zinc	27
Mercury	<0.1

EO47	(1.0-1.1)
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Arsenic	<5
Barium	60
Beryllium	<1
Cadmium	<1
Chromium	44
Cobalt	9
Copper	19
Iron	27100
Lead	6
Manganese	361
Nickel	17
Vanadium	57
Zinc	24
Mercury	<0.1

SS03	(0.4-0.5)
Aluminium	10300
Arsenic	6
Barium	30
Beryllium	<1
Cadmium	<1
Chromium	59
Cobalt	14
Copper	30
Iron	39300
Lead	9
Manganese	561
Nickel	26
Vanadium	76
Zinc	41
Mercury	<0.1

SS01	(0.5-0.6)	(1.0-1.1)
Aluminium	13600	12400
Arsenic	7	<5
Barium	60	90
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	70	66
Cobalt	16	21
Copper	36	36
Iron	47600	44700
Lead	10	12
Manganese	640	900
Nickel	31	33
Vanadium	87	86
Zinc	44	49
Mercury	<0.1	<0.1

EO52	(0.5-0.6)
Aluminium	12500
Arsenic	<5
Barium	120
Beryllium	<1
Cadmium	<1
Chromium	63
Cobalt	18
Copper	40
Iron	44200
Lead	13
Manganese	659
Nickel	32
Vanadium	85
Zinc	55
Mercury	<0.1

Source: Landgate Imagery 2007, 2003

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Analytical Results Metals	
URS	Drawn: RNM Job No.: 42907466	Approved: MJN File No.: 42907466-RL-011C.mxd	Date: 14/05/2010 Figure: 8-3	Rev. A A3

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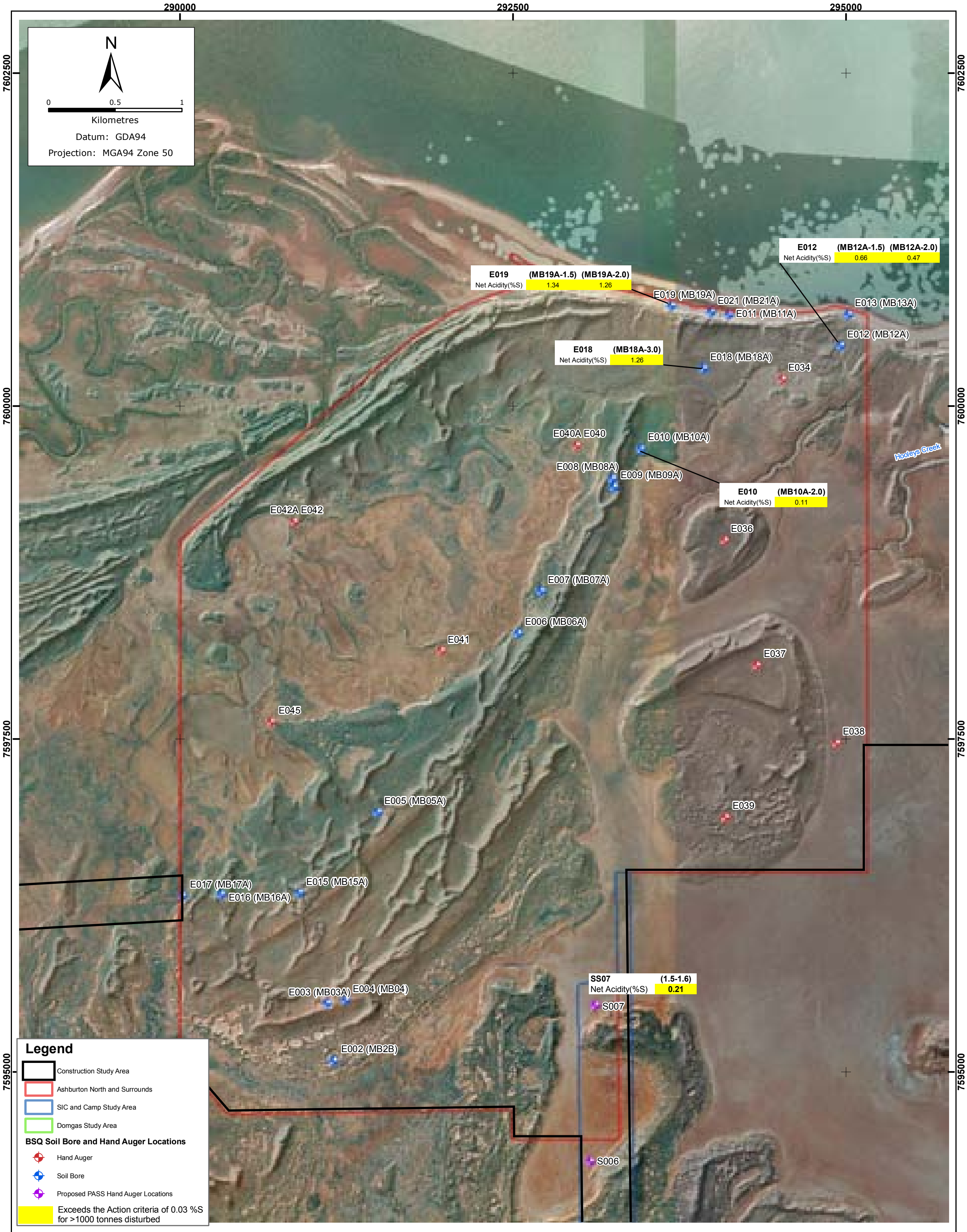

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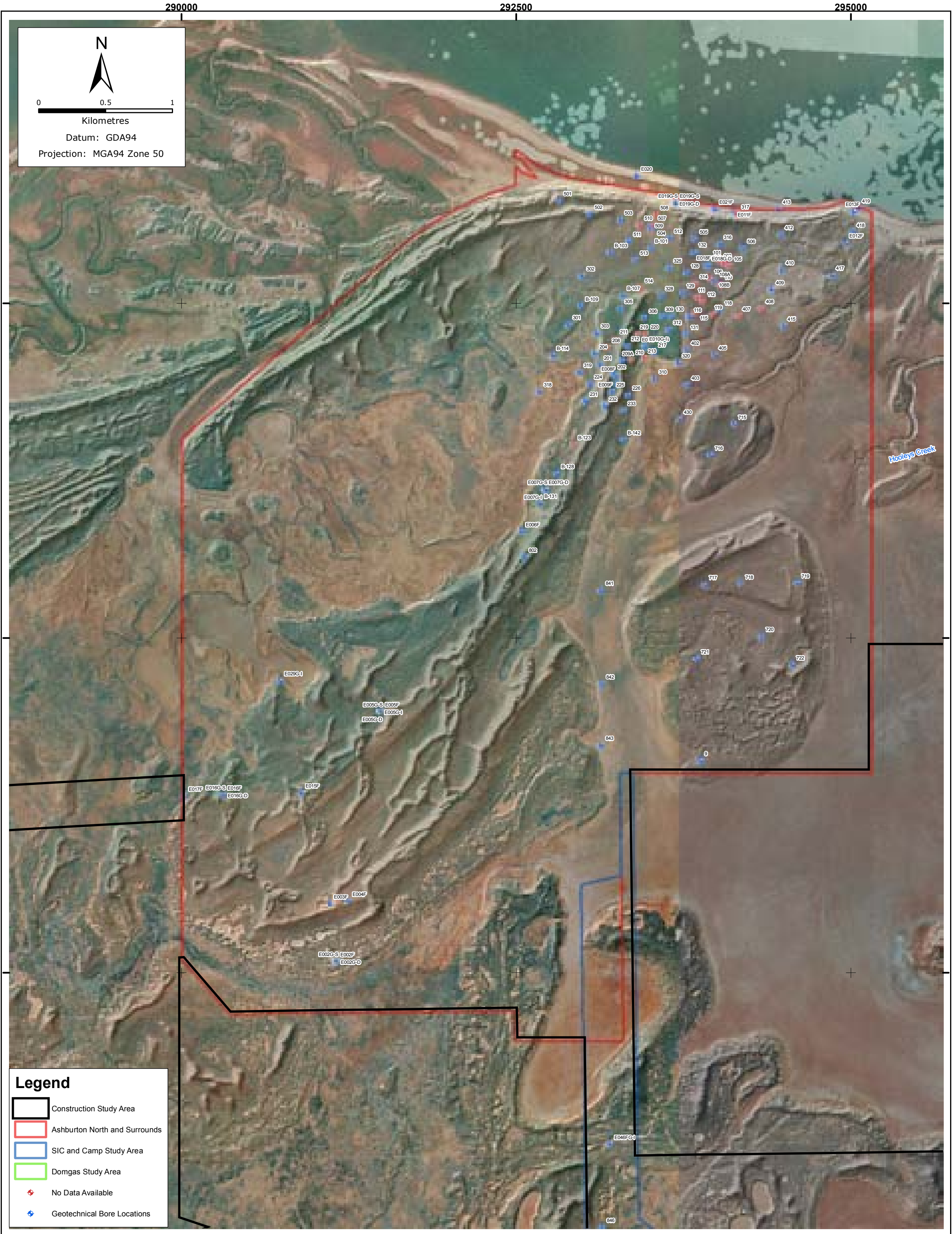

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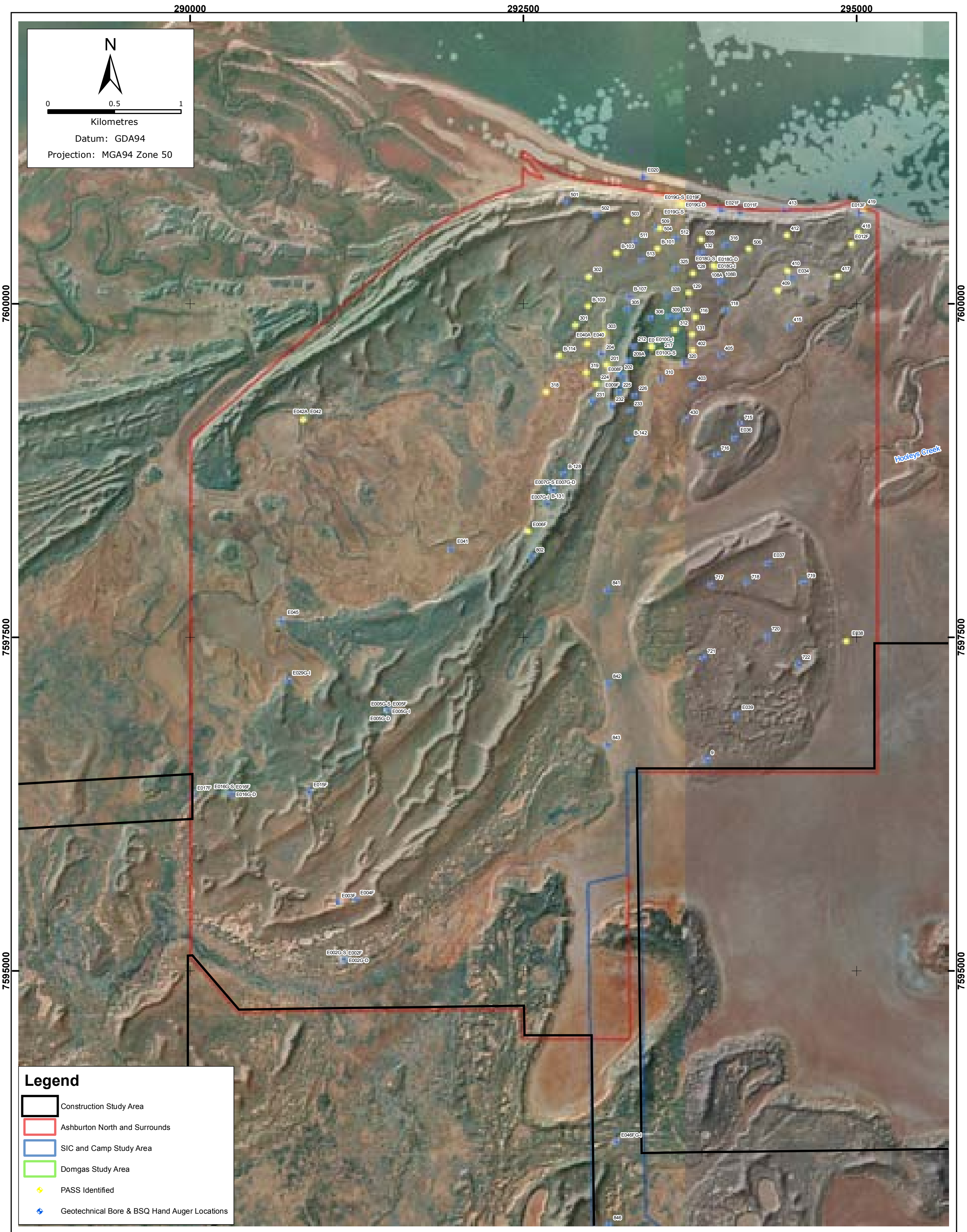

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URS	Drawn: RNM / Approved: MJN / Date: 14/05/2010	Figure: 11	Rev. A
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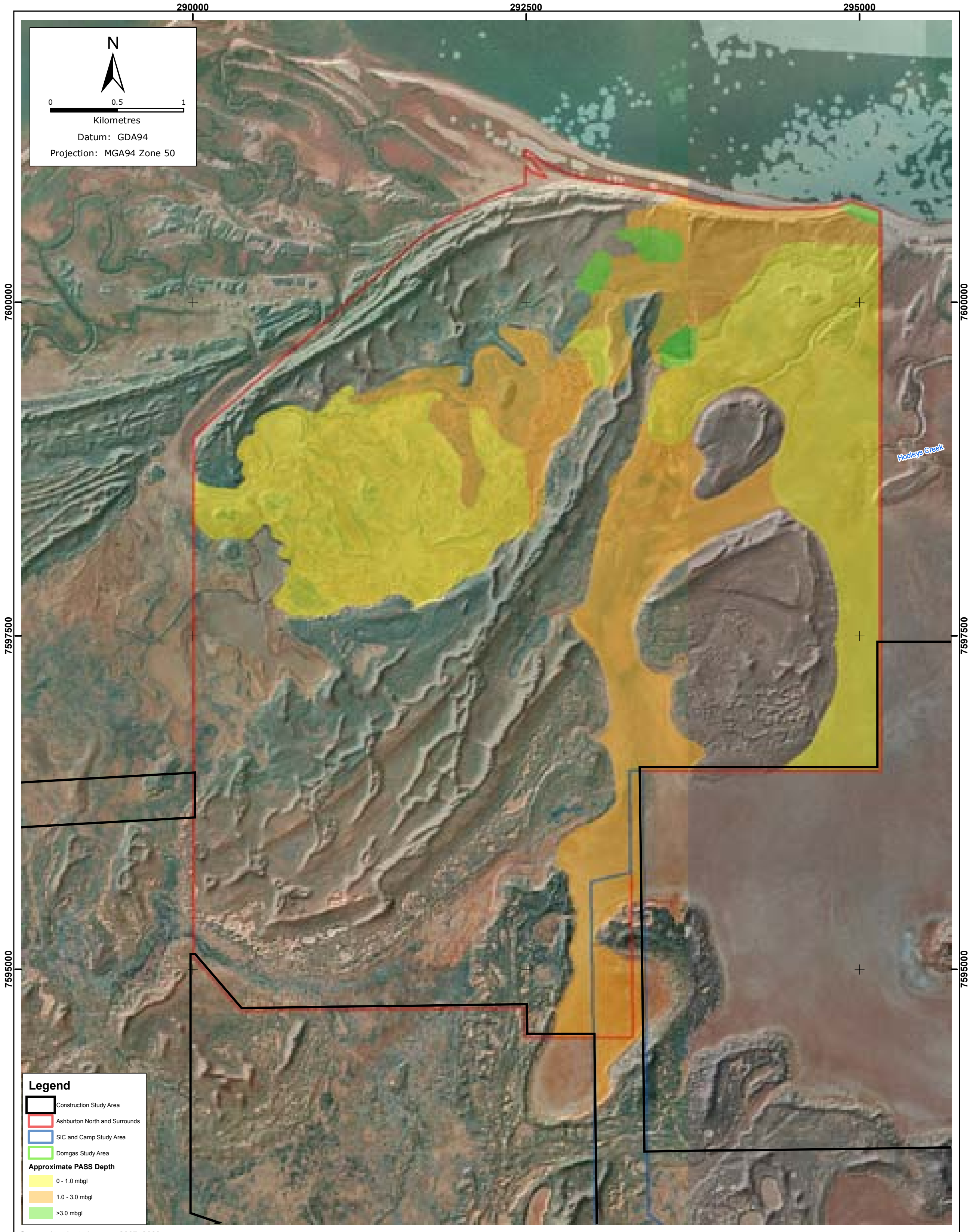

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Wheatstone Project -
BSQ and Landforms Assessment

Title
Bore Review -
Approximate PASS Depth

Drawn: RNM	Approved: MJN	Date: 14/05/2010	Figure: 12	Rev. A
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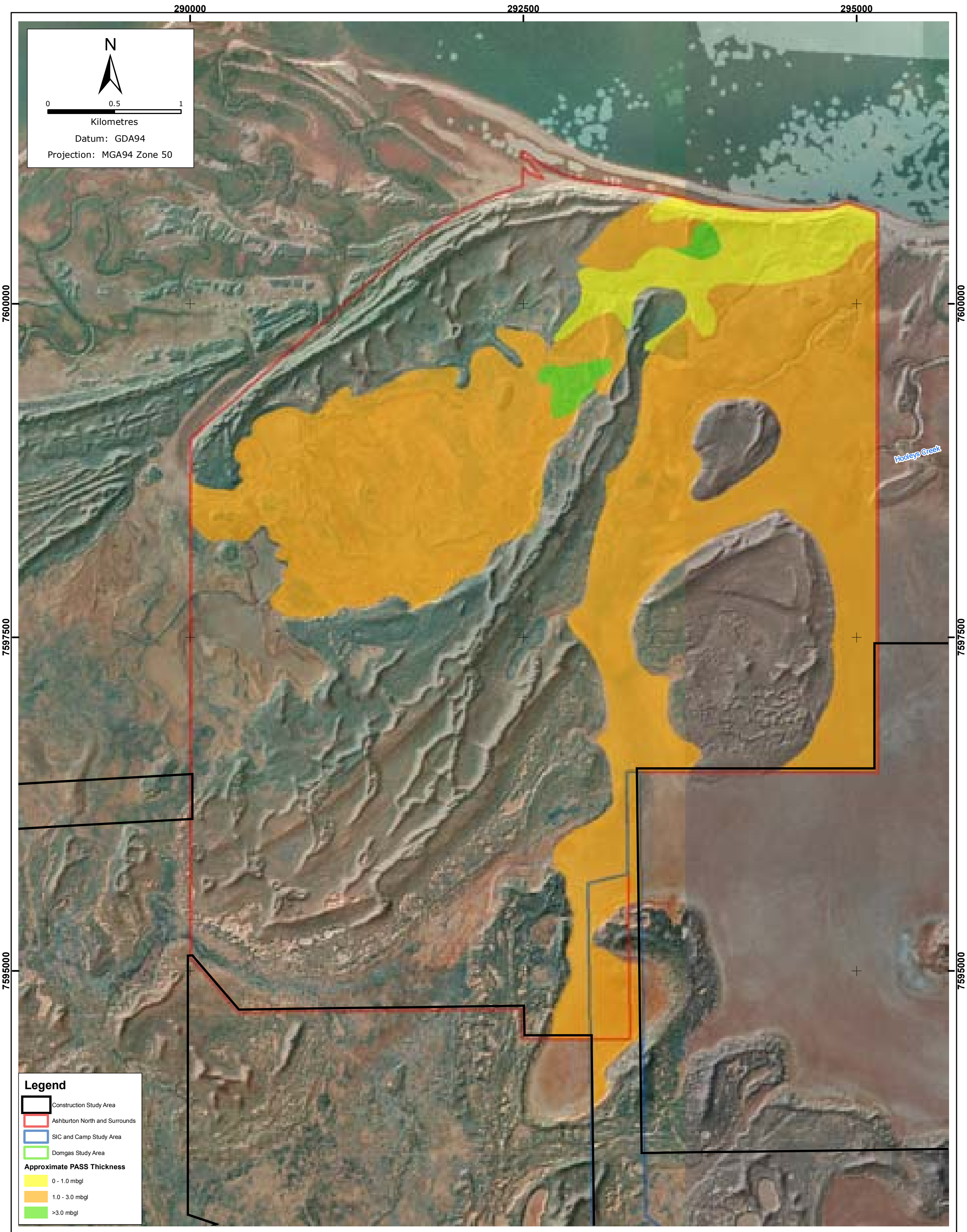

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Client
CHEVRON AUSTRALIA PTY LTD

Project
Wheatstone Project -
BSQ and Landforms Assessment

Title
Bore Review -
Approximate PASS Thickness

Drawn: RNM
Approved: MJN
Date: 14/05/2010
Figure: 13
Rev. A
Job No.: 42907466
File No.: 42907466-RL-016.mxd
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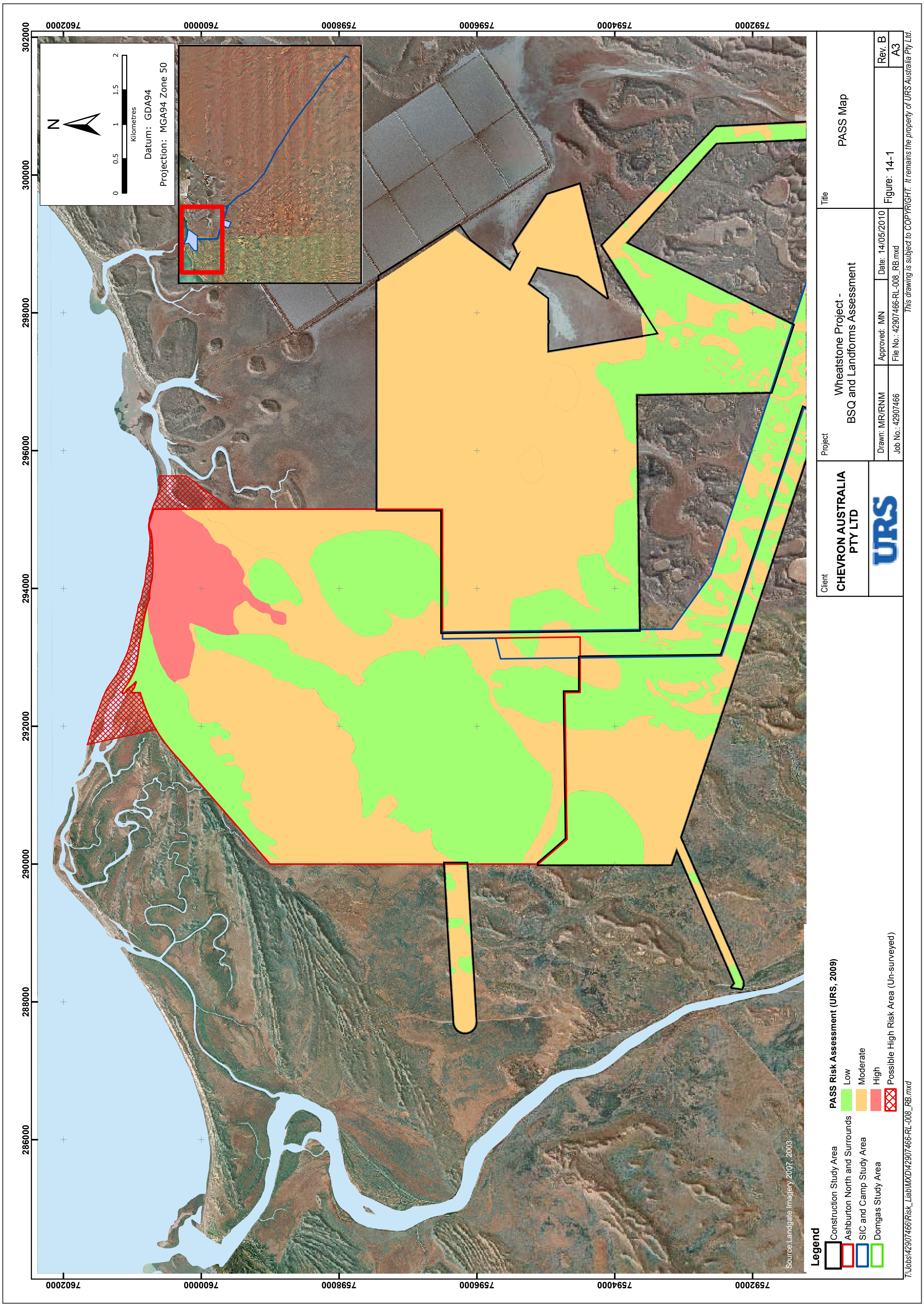

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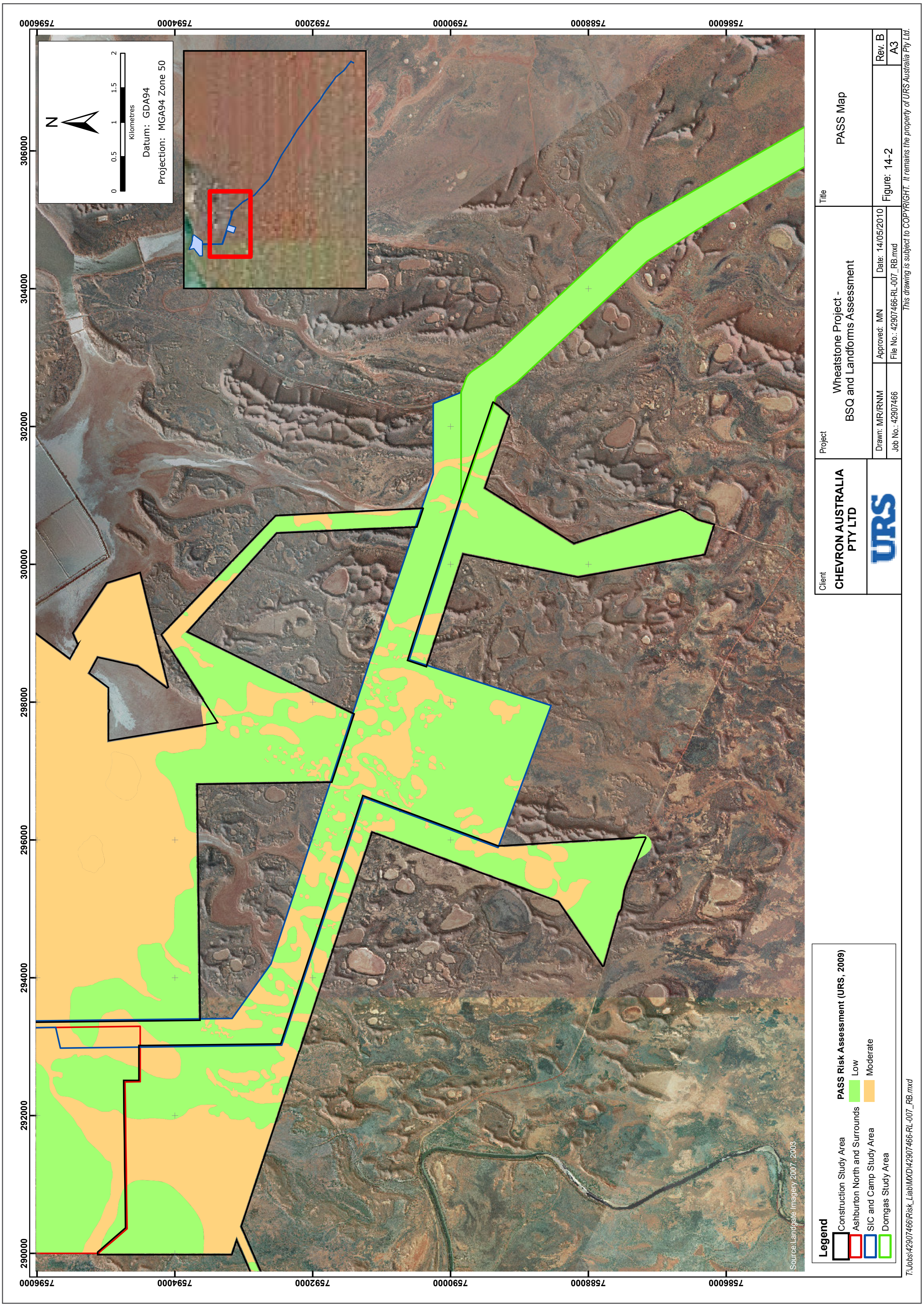

Client
CHEVRON AUSTRALIA PTY LTD

Project
Wheatstone Project -
BSQ and Landforms Assessment

Title
PASS Map

Drawn: MR/RNM
Approved: MN
Date: 14/05/2010
Job No.: 42907466
File No.: 42907466-RL-007_RB.mxd
Figure: 14-2
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A3

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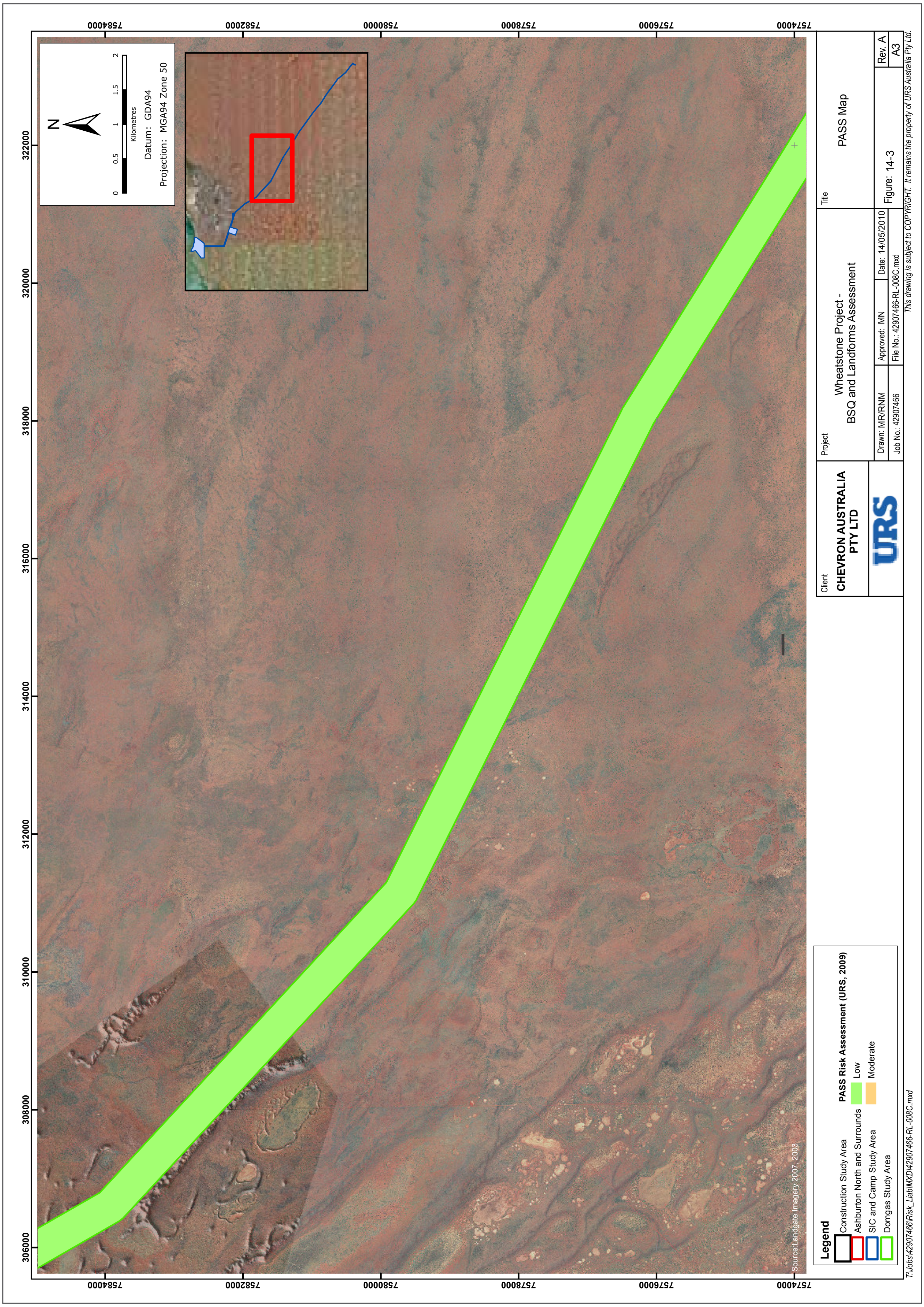
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Projection: MGA94 Zone 50
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320000
322000
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7576000
7574000
Source:Landgate Imagery 2007, 2003
Legend
Construction Study Area
Ashburton North and Surrounds
SIC and Camp Study Area
Domgas Study Area
PASS Risk Assessment (URS, 2009)
Low
Moderate
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project - BSQ and Landforms Assessment
Title
PASS Map
Drawn: MR/RNM
Approved: MN
Date: 14/05/2010
Figure: 14-3
Rev. A
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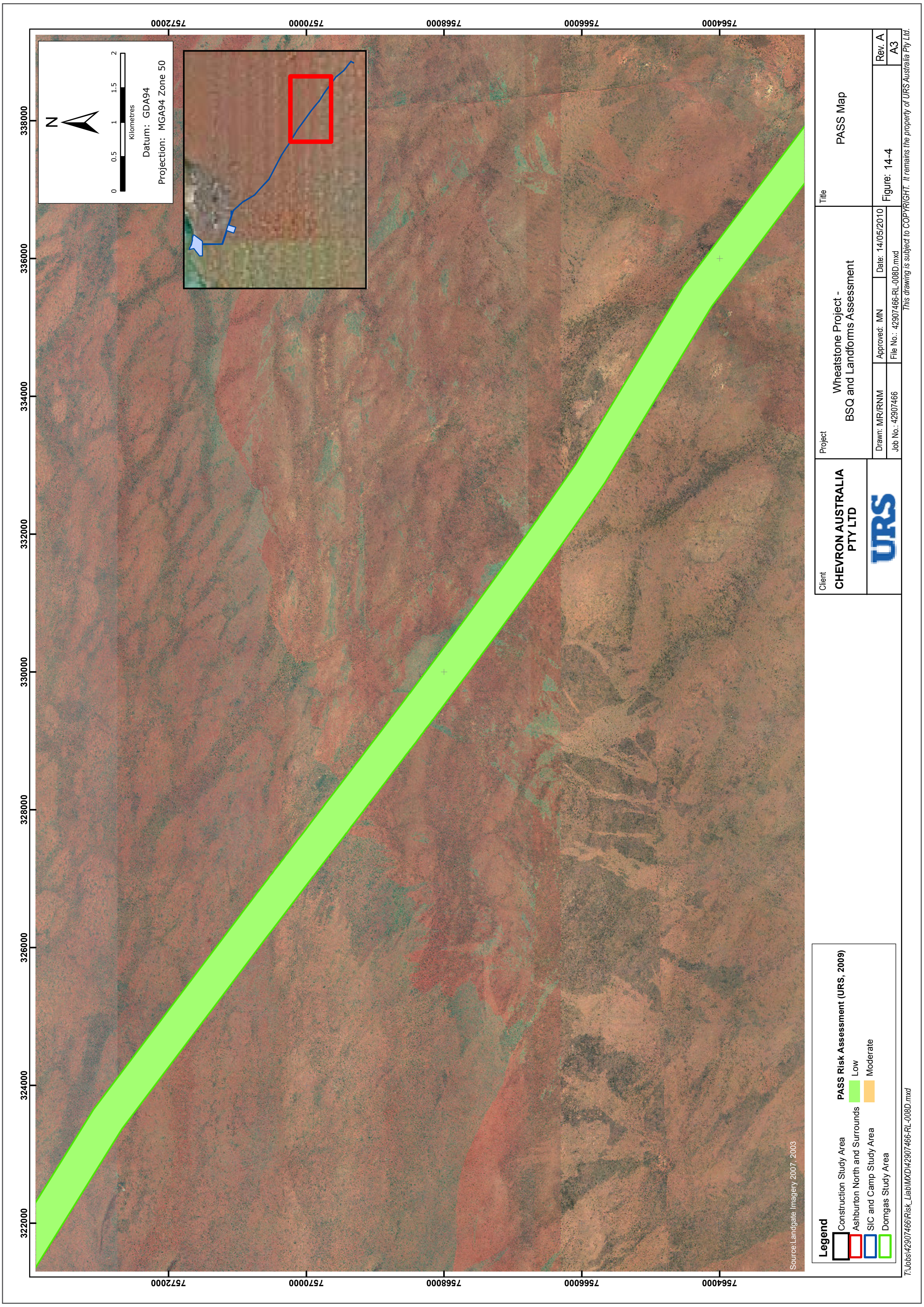
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Kilometres
Datum: GDA94
Projection: MGA94 Zone 50
Source: Landgate Imagery 2007, 2003
Legend
Construction Study Area
Ashburton North and Surrounds
SIC and Camp Study Area
Domgas Study Area
PASS Risk Assessment (URS, 2009)
Low
Moderate
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project - BSQ and Landforms Assessment
Title
PASS Map
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Approved: MN
Date: 14/05/2010
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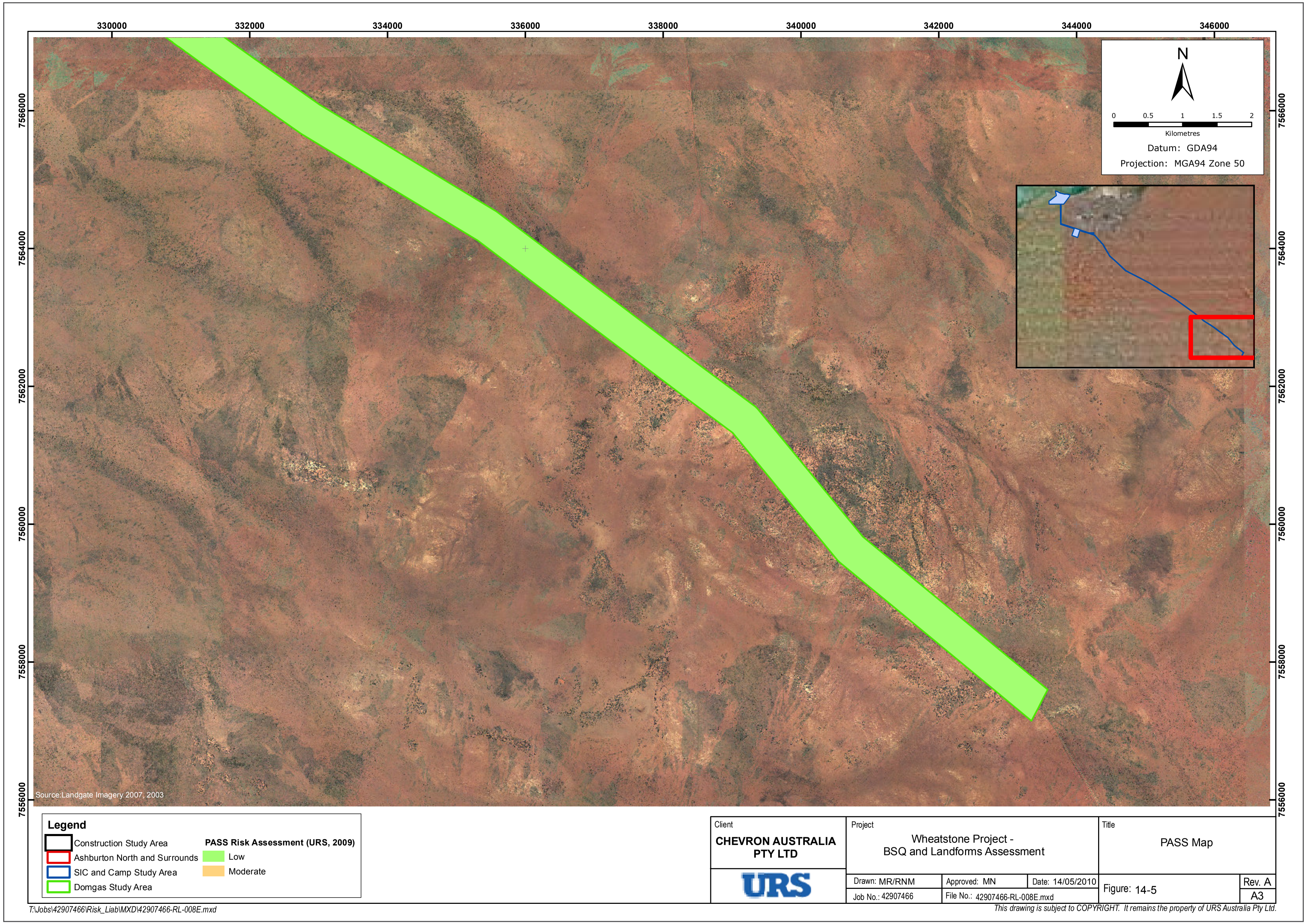

Source:Landgate Imagery 2007, 2003

Client

CHEVRON AUSTRALIA PTY LTD

URS

Project

Wheatstone Project -
BSQ and Landforms Assessment

Title

PASS Map

Drawn: MR/RNM
Approved: MN
Date: 14/05/2010
Job No.: 42907466
File No.: 42907466-RL-008E.mxd

Figure: 14-5

Rev. A

A3

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Appendix A Field Methodology and SAP

Appendix A

Field Methodology and SAP

7 MAY 2010

Prepared for
Chevron

URS-WHST-STU-ET-RPT-0068

Document delivery

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Where an electronic only version is provided to the client, a signed hard copy of this document is held on file by URS and a copy will be provided if requested.

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Appendices

Introduction

1.1 Introduction and Background

URS Australia Pty Ltd (URS) were commissioned by Chevron Australia Pty Ltd (Chevron) to undertake a baseline soil quality and landforms assessment for the proposed Wheatstone Project which includes the Ashburton North and surrounds, the Shared Infrastructure Corridor, the Accommodation Camp and the proposed Domgas Pipeline Route (collectively known as the Wheatstone Study area).

The assessment was completed, in part, as a desktop study comprising a review of land systems and landforms at a regional scale, followed by a site specific assessment of landforms and baseline soil quality (including PASS), which was completed between March and November 2009.

This report outlines the sampling analysis plan (SAP), field methodologies and laboratory analyses used to provide an assessment of landforms and BSQ of the Wheatstone Study area.

1.2 Landforms Assessment

1.2.1 Literature Review

A review of previous work relating to the soils and landforms of the Wheatstone Study area indicated that the available data was coarse and covered only the regional scale rather than the detail of the Wheatstone Study area.

No site specific data was available. The regional physical framework forming the basis for soil development and the potential distribution of profile types and the resultant soil landscapes was derived initially from Van de Graaff *et al* (1982) from the Geological Survey of Western Australia at a scale of 1:250,000 and then land system mapping derived from Department of Agriculture using Payne *et al* (1998) and van Vreeswyk *et al.* (2004).

Where applicable, URS derived site specific information from working documents for the Wheatstone Project. Where information was utilised the material was referenced within the main text of the document.

The following documents were referenced and reviewed for the completion of the landforms assessment component of the investigation:

Biota Environmental Sciences. 2009, A Vegetation and Flora Survey of the Wheatstone Project Area, near Onslow. Prepared for URS Australia on behalf of Chevron Australia, July 2009. WHST-STU-ET-RPT-0083

Coffey (2010) Final Interpretive Report – Onshore Geotechnical Investigation, Ashburton North Site (Rev B 23rd April 10) WS1-0000-GEO-RPT-COF-000-00028-000)(Coffey # GEOTHERD08668AA-DZ

Damara WA Pty Ltd (2009) Coastal Geomorphology of the Ashburton River Delta and Adjacent Areas. Damara Report 82-01 Draft ie-05082009.doc.

Outback Ecology Services (2010) Wheatstone Amendment Area: Flora and Vegetation Assessment, March 2010.

URS (2009) Hydrogeological Impact Assessment of Wheatstone Plant Area, Infrastructure Corridor and Accommodation Site (Draft) 42907100, work in progress (7 May 2010).

1.2.2 Photography Aerial Interpretation

An appraisal of the soil-landscape was completed using stereoscopy and map interpretation. Preliminary, land systems and landforms were identified at the desktop scale which allowed a more detailed investigation design to be implemented. Aerial photography, at a scale of 1:25,000 was used to define the major soil landscapes and morphologic units of the Wheatstone Study Area.

Further, the interpretation of 3m-Hillshade aerial photography was used to further refine landform boundaries. The Fugro Lidar survey data (Fugro, 2008) was interpolated with ArcGIS to create a 1m and 5m resolution DEM for the onshore study area. Hillshade layers were created from the DEM surfaces. The 5m resolution hillshade layer was displayed under a transparent orthophoto (Landgate, August 2007) to produce a shaded relief image. Landform and coastal process control features were delineated from the shaded relief images and digitised with ArcGIS.

1.3 Biota (2009) Landform Assessment

In April 2009, Biota (2009) conducted a flora and vegetation study for the Wheatstone Study area which identified 25 vegetation sub-associations.

Vegetation sub-associations were defined based on dominant vegetation growth form, height, cover and up to five vegetation species for all layers/sub-strata as per the National Vegetation Information System completed by the Executive Steering Committee for Australian Vegetation Information (ESCAVI) (2003).

Biota (2009) further grouped these 25 vegetation sub-associations into nine main landform categories. The landform categories are broadly consistent with the landform units identified by URS during the field component of the landforms assessment for the Wheatstone Study area.

The Biota landforms include the following:

- Tidal mudflats.
- Coastal sand dunes.
- Inland sand dunes.
- Coastal sand plains.
- Claypans.
- Clayey plains.
- Inland sand dunes.
- Stony plains.
- Drainage areas.

Table 1.1 presents the nine landform categories identified by Biota, a description for the landform unit identified by Biota, and the broadly corresponding landform units as identified by URS.

1 Introduction

Table 1-1 Landform Categories and Corresponding Landform Units of the Wheatstone Study Area

Biota Landform Category	Biota (2009) Landform Category Description and Location	Dominant Corresponding Landform Units (URS, 2009)
Tidal Mudflats	Tidal mudflats were located in the northern section of Ashburton North and surrounds and at the westernmost end of the SIC study area and comprised either bare mudflat, with scattered shrubs, or mangal.	Tidal creeks, intertidal flats and mangrove swamp and supratidal salt flats
Coastal Sand Dunes	Occurring behind a narrow beach-front, the foredunes and near-coastal sand dunes were distinct from the more consolidated red sand dunes further inland, having an overstorey dominated by *Acacia coriacea* subsp. *coriacea*. In addition, the coastal foredunes had significant amounts of Beach Spinifex (*Spinifex longifolius*) in the understorey, which was replaced by Soft Spinifex (*Triodia epactia*) further inland.	Fringing and coastal dune
Inland Sand Dunes	Numerous low linear sand dunes within Ashburton North and surrounds, which were relatively consistent in dominant species. Narrow swales between dunes typically featured scattered tall shrubs of the dominant species from the dunes, along with a higher density of *Acacia stellaticeps* low shrubs.	Longitudinal dunes and interdunal swales,
Coastal Sand Plains	The majority of Ashburton North and surrounds, Camp study area and western section of the Domgas study area r comprised of flat to gently undulating sandy inland plains, which were broadly dominated by Soft Spinifex (*Triodia epactia*) hummock grasslands with a varying degree of invasion by introduced perennial grasses.	Alluvial/colluvial plains Mainland dune remnants
Claypans	Claypan areas were scattered throughout Ashburton North and surrounds,, Camp study area and the western quarter of the SIC study area These ranged in size, degree of connectivity with tidal areas (connected and seasonally inundated; or isolated), and apparently in the degree of permeability of the substrate (lending some to hold water for several weeks, while others of similar size were dry).	Samphire flats and Claypans
Clayey Plains	Some broad areas of clayey plain were present, particularly within the Camp study area and western section of the Domgas study area, which supported tussock grasslands of various native species. Other small pockets of clayey substrate formed in drainage depressions, and supported tall shrublands of Mesquite (*Prosopis pallida*) and/or native species over tussock grasslands of native and/or introduced species.	Claypans
Inland Sand Plains	Broad sandy plains were present along the central and eastern sections of the Domgas study area, and these supported very different vegetation species to the sand plains of the more coastal areas.	Alluvial/colluvial plains
Stony Hills	Two stony hills were present towards the eastern end of the Domgas Pipeline study area	Stony Hills (Domgas study area only).
Drainage Areas	Three drainage areas were described, one at the southern end of Ashburton North and surrounds and two along the Onslow Road in the Domgas study area.	Drainage Area (Domgas study area only)

1 Introduction

1.4 Outback Ecology Services (2010) Landform Assessment

In January 2010, Outback Ecology Services (OES) (2010) conducted a flora and vegetation study for the Amendment Area (which comprise of) whereby OES undertook a Level 2 survey (in accordance with the Environmental Protection Authority [EPA]) which includes a desktop review and field investigation (34 quadrats over a 50 x 50 m).

(OES,2010) reports that as part of the broader environmental assessment, six distinct soil-landforms across the Amendment Area including the following:

- Inland sand dunes.
- Sandy Plains
- Clayey plains.
- Salt Pans
- Clay Pans
- Drainage Lines

Table 1.2 presents the six landform categories identified by OES, a description for the landform unit identified by OES, and the broadly corresponding landform units as identified by URS. Landform –soil descriptions were not provided in the OES report.

Table 1-2 OES (2010) Landform Summary-Amendment Area

OES Landform Category	Dominant Corresponding Landform Units (URS, 2010)
Tidal Mudflats	Tidal creeks, intertidal flats and mangrove swamp and supratidal salt flats
Inland Sand Dunes	Longitudinal dunes and interdunal swales,
Coastal Sand Plains	Alluvial/colluvial plains Mainland dune remnants
Claypans	Samphire flats and Claypans
Clayey Plains	Clayplains and alluviall/colluvial plains
Inland Sand Plains	Alluvial/colluvial plains
Drainage Areas	Drainage Area

1.4.1 Geotechnical Bore Review

A review of geotechnical bore logs (completed by Coffey, 2010) as part of the geotechnical investigation for Ashburton North and surrounds) which includes the Phase 2 hydrogeological programme was also undertaken. The objective of the review was to further delineate the vertical and horizontal extent of PASS through interpretation of the geological profile.

At the time of writing, a review of an additional 103 geotechnical and hydrogeological bores logs and/or core photos been completed. Depths of logs ranged between 10 and 60 m bgl. Information for 34 of the geotechnical bores of Ashburton North and surrounds are yet to be made available.

Bore logs and/or core photos identified PASS material, based on the works completed to date, as soils comprising of CLAY to clayey SAND/SAND, low to high plasticity, brown to dark grey; fine to medium grained, mottling may range from yellow and orange, firm to very soft.

The results of the bore assessment were utilised to develop the PASS map, as discussed in **Section 8.1** of the main text.

1.5 Field Inspection

The landforms assessment was completed utilising the environmental bore locations and hand auger locations completed for the BSQ and ASS investigation. The landforms assessment applied to individual sites and was a function of access based on approval. The landform assessment completed of the Domgas study area was undertaken from the road verge of Onslow Road which runs adjacent and parallel to the proposed Domgas Pipeline, as approvals had not been received for this area.

Further, as approvals had not been received for the Accommodation Camp study area, only a desktop landform assessment has been completed.

As a general rule, although depending on the landform, the following was noted:

- Type of landform (landform pattern);
- Location within Terrestrial Assessment area;
- Size of Landform;
- Topography;
- Vegetation;
- Size; and
- Surface Soils.

The results of the landforms assessment is presented in **Appendix D** of the main report (URS-WHST-STU-ET-RPT-0068)

Baseline Soil Quality Field Methodology

2.1 Health, Safety and Environment

Prior to commencing fieldwork, a site specific URS Health, Safety and Environment Plan (HSEP) was prepared for all field works. The plan detailed potential hazards associated with the investigation, the minimisation of those hazards, and plans for implementation of emergency procedures in case of incident or accident involving URS personnel and subcontractors.

Furthermore, all URS staff were trained in Occupational Health and Safety and hazard identification. URS have a behaviour-based safety programme in place known as “4-sight”. This programme requires our staff to be diligent and pro-active.

Lastly, URS field technicians were required to complete a Chevron HAZZID workshop and complete an approved Chevron 4WD training programme prior to approval for access to the Wheatstone Study area.

2.2 Survey locations and Bore Completion

Soil bore locations were while hand augered locations were surveyed using a hand held MGA94 horizontal coordinate system. All location had the appropriate vegetation clearance permit approval. The results for the survey and environmental bore completion are displayed in **Table 2.1.**

Table 2-1 Summary of Environmental Bore Completion

Soil Bore Location[1]	Soil Sample ID	Coordinates		Start Date	Completion Date	Total Depth of Environmental Investigation[2]	Static Water Level[3]
		Northing	Easting			mbgl	mbgl
Ashburton North and Surrounds-Environmental Soil Bores							
E002	MB2B	291156	7595091	30/03/2009	30/03/2009	3.0	3.79
E003	MB3A	291105	7595517	30/03/2009	30/03/2009	3.0	4.38
E004	MB4A	291243	7595540	27/03/2009	27/03/2009	3.0	5.93
E005	MB5A	291482	7596954	2/04/2009	2/04/2009	3.2	3.08
E006	MB6A	292538	7598296	5/04/2009	5/04/2009	3.5	1.10
E007	MB7A	292711	7598613	5/04/2009	5/04/2009	3.2	2.12
E008	MB8A	293243	7599460	5/04/2009	5/04/2009	3.0	5.02
E009	MB9A	243256	7599398	5/04/2009	5/04/2009	3.0	4.66
E010	MB10A	293462	7599684	14/04/2009	14/04/2009	3.0	2.29
E011	MB11A	294113	7600691	12/04/2009	12/04/2009	3.1	0.66
E012	MB12A	294958	7600445	21/04/2009	21/04/2009	3.0	0.79
E013	MB13A	295014	7600692	10/04/2009	10/04/2009	3.7	1.0
E015	MB15A	290894	7596347	8/04/2009	8/04/2009	3.0	3.84

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[1] URS prefix MB was superseded by Chevron’s global use of the prefix E000 for environmental bores at the conclusion of the BSQ and ASS investigation, and therefore laboratory certificates refer to soil samples with the prefixes MB (for monitoring bore).

[2] Refer to URS (2009) Appendix C of Report Baseline Soil Quality and Landforms Assessment (Draft) 28 September 2009 WHST-STU-ET-RPT-0068_Rev D.

[3] Refers to Summary of Groundwater and Environmental Monitoring Bore Installation Sheet (URS, 2009a) Hydrogeological Impact Assessment of Wheatstone Plant Area, Infrastructure Corridor and Accommodation Site (Draft) 42907100 , work in progress (last amended date 15 September 2009) Attached as **Appendix A** of this report. Hand Auger depths were based on field logs of URS (2009) Appendix C of Report Baseline Soil Quality and Landforms Assessment (Draft) 28 September 2009 WHST-STU-ET-RPT-0068_Rev D

Soil Bore Location[1]	Soil Sample ID	Coordinates		Start Date	Completion Date	Total Depth of Environmental Investigation[2]	Static Water Level[3]
E016	MB16A	290313	7596335	4/04/2009	4/04/2009	3.0	3.63
E017	MB17A	290022	7596324	2/04/2009	2/04/2009	4.6	1.07
E018	MB18A	293920	7600287	15/04/2009	15/04/2009	3.0	2.69
E019	MB19A	293685	7600754	29/04/2009	29/04/2009	3.0	2.12
E021	MB21	293984	7600707	21/04/2009	21/04/2009	3.0	1.00
Ashburton North and Surrounds-Environmental Hand Auger Locations							
E034	EB034	294515	7600206	25/04/2009	25/04/2009	1.1	0.47
E036	E036	294083	7598997	09/07/2009	09/07/2009	0.4	Not intercepted
E037	E037	294330	7598059	09/07/2009	09/07/2009	0.4	Not intercepted
E038	E038	294922	7597474	09/07/2009	09/07/2009	1.0	0.2
E039	E039	294095	7596917	09/07/2009	09/07/2009	0.4	Not intercepted
E040 and E040A	EB040	292978	7599709	25/04/2009 & 07/07/2009	25/04/2009 & 07/07/2009	1.1	0.35 and 0.45
E041	E041	291958	7598163	08/07/2009	08/08/2009	1.0	0.45
E042 and E042A	EB042	290855	7599136	26/04/2009 & 07/07/2009	26/04/2009 & 07/07/2009	1.2 and 1.1	0.5 and 0.45
E045	E045	290687	7597631	07/07/2009	07/07/2009	1.0	Not intercepted
Shared Infrastructure Corridor-Environmental Hand Auger Locations							
E046	E046			21/10/2009	21/10/2009	1.4	Not intercepted
E047	E047			20/10/2009	20/10/2009	1.6	1.0
E048	E048			20/10/2009	20/10/2009	1.6	Not intercepted
E052	E052			19/10/2009	19/10/2009	1.5	Not intercepted
SS01	SS01			19/10/2009	19/10/2009	1.25	Not intercepted
SS03	SS03			20/10/2009	20/10/2009	1.5	Not intercepted
SS04	SS04			21/10/2009	21/10/2009	1.6	Not intercepted
SS05	SS05			21/10/2009	21/10/2009	1.6	Not intercepted
SS06	SS06			21/10/2009	21/10/2009	1.6	0.7
SS07	SS07			21/10/2009	21/10/2009	1.6	0.7

2.3 Drilling/Hand Auger Methods

2.3.1 Ashburton North and Surrounds

The Phase 1 Environmental Drilling Programme was undertaken by Hagstrom Drilling between 25 March and 5 May 2009. A total of 20 sites (E001 to E021, excluding E014) comprised the programme, however, ultimately, the programme was constrained to 18 sites. Site E001 was abandoned because of location outside of the approved access zone. Site E020 was drilled but not constructed. The site is within the tidal zone, with limited access.

The Phase 2 Environmental Drilling Programme was undertaken by Hagstrom Drilling between 5 April and 28 September 2009. A total of 29 sites (E014, E022 to E033, E034 to E045 and E053 to E056) comprised the programme within Ashburton North and surrounds.

The BSQ and landforms assessment component of the Phase 1 and Phase 2 Environmental Drilling Programme was completed between the between the 27 March and 29 April 2009 and the 7 July and 9 July 2009 (hand auger locations only).

Two diamond core rotary rigs were used to undertake the drilling, with 122.6 mm (PQ) diameter holes drilled on most sites. Reaming occurred in E011, E018, E018, E019 and enlarging the diameter to 160 mm and enabling monitoring bore construction despite hole sidewall instability.

Core was recovered from all PQ drilling, enabling lithological logging.

Where hand augering was undertaken, the depth of the hand auger investigation was driven by depth to groundwater (interception of groundwater resulted in coreloss) or the interception of cemented carbonate material (refusal).

2.3.2 Shared Infrastructure Corridor

Ten hand auger locations (E046, E047, E048 and E052 and SS01, SS03-SS07) were undertaken between the 19 and 21 October 2009. The hand auger investigation was driven by depth to groundwater (interception of groundwater resulted in coreloss) or the interception of cemented carbonate material (refusal).

2.4 Field Notes

Daily field activities were recorded and handover notes provided to each subsequent field “swing”. Information included within daily field notes includes:

- Project number.
- Date.
- Weather conditions (temperature, wind, cloud cover, rain, snow, etc).
- Personnel on-site.
- Timing of major activities throughout the day.
- Notes for activities undertaken.
- Significant communications with site contractors, site representative, PM, or the client.

2.5 Indicators of Acid Sulfate Soils Material

During field activities, observations were reported with regard to typical indictors of ASS material. These included the following:

2.5.1 Potential ASS Indictors

- Waterlogged soils – blue grey or dark greenish grey mud with a high water content, silty sands or sands (mid to dark grey) or bottom sediments (dark grey to black e.g. iron monosulfides “black oozes”).
- Water pH usually neutral but may be acidic.
- Dominant vegetation is tolerant of salt, acid and/or waterlogging conditions e.g. mangroves, saltcouch, *Phragmites* (a tall acid tolerant grass species).

2.5.2 Actual ASS Indictors

- Presence of corroded shell.
- Sulfurous smell e.g. hydrogen sulfide or ‘rotten egg’ gas.
- Jarositic horizons or substantial iron oxide mottling in surface or where water table fluctuates.

- Water of pH <5.5 (and particularly below 4.5) in surface water bodies.
- Unusually clear or milky blue-green water flowing from or within the area (aluminium released by ASS acts as a flocculating agent).
- Extensive iron stains on any drain or pond surfaces, or iron-stained water and ochre deposits.
- Dead, dying, stunted vegetation.
- Scalded or bare low-lying areas.

2.6 Soil Profiling and Sampling Methodology

The field sampling methodology is summarised as follows:

- All field samples were collected in accordance with standard URS field sampling procedures, which are consistent with the Australian Standards AS4482.1 and AS4482.2 and *Identification and Investigation of Acid Sulfate Soils-ASS Guidelines Series* (DEC, updated 2009) and the *Contaminated Sites Management Series* (DEC,2001-2007).
- Soil samples were collected at approximate intervals of 0.25 m.
- A field description for each soil profile including: soil texture, colour, grain size, roundness, sorting and sphericity using the Australian Soil and Land Survey Field Handbook (McDonald *et al.*, 1990) as a guide.
- Observations of mottling, organic matter, moisture content, watertable level and other diagnostic features (e.g. jarosite, shell).
- Photographs of the soil profile clearly identifying each strata in the soil profile.
- The presence of shell, its location within the profile, size and abundance was recorded on field. It should be noted however, that visible shell or carbonate nodules were removed from the soil sample in the field.
- Disposable nitrile gloves were used during sample collection and samples were placed into laboratory provided sealable bags and/or glass jars with Teflon sealing lids. All samples were labelled in accordance with the bore location and the sample depth interval (eg. MB10A0.5 – 1.0) and then placed in chilled ice coolers.
- Samples for ASS were stored frozen after returning from the field prior to transporting. All samples were transported via cold carrier, Toll Ipec, to a NATA certified laboratory ALS Environmental Pty Ltd (ALS Environmental) for analyses.

2.7 Test Procedures

The following section details the test methodologies employed as part of the landforms and BSQ Assessment.

2.7.1 Landform Susceptibility and Soil Erodibility

Field tests for landform susceptibility and soil erodibility classification was generally undertaken in accordance with guidelines provided by van Gool *et al* (2005) *Land Evaluation Standards for Land Resource Mapping Third Edition Resource Management Technical Report 298.*

The field test methodology is presented below:

2 Baseline Soil Quality Field Methodology

Water Erosion Hazard

Water erosion hazard is the inherent susceptibility of the land to the loss of soil as a result of water movement across the surface. It is a significant problem in WA as it is also an important cause of soil fertility decline as soil nutrients tend to be concentrated near the surface.

The following general assessment is based on the *inherent erodibility* of a soil type and slope. As defined here water erosion hazard does not take into account land management practices (these are assessed in the land capability ratings tables).

Method:

Using **Table 2-2** assign a score for each characteristic, and add up the scores.

If the total score exceeds 10, the soil layer can be considered **highly erodible**.

If the total score is between 5 and 10, the layer can be considered **moderately erodible.**

If the total score is lower than 5, the soil layer can be considered to have **low erodibility**.

- To calculate the soil profile erodibility score, add the erodibility score from all the subsurface layers within the top 80 cm. This will give you a soil profile erodibility score.
- Note: For slaking, dispersion and soil moisture ≤ 30 cm the erodibility rating is doubled because these properties near the surface have a large influence on water erosion.
- Gravel and stones protect the soil surface from erosion. If the surface layer contains more than 50 per cent coarse fragments, reduce the profile erodibility score by 5. If the surface layer contains more than 20-50 per cent coarse fragments, reduce the profile erodibility score by 2.

Table 2-2 Soil Erodibility Scoring

	Soil Erodibility Score			
	0	**1**	**2**	**3**
Organic Carbon%	>2.0	0.8-2.0	<0.8	-
Slaking If soil layer depth </= 30cm erodibility score is 2	Nil	-	Partial	Complete
Dispersion Not applicable for sands If soil layer depth </= 30cm erodibility score is 2	Nil Xx(not applicable)	-	Partial	Complete
Water Repellence For sands (layer 1 only)	N, L	M	H	-
Soil Structure of arrangement of coarse sand	Earthy, poor loose	-	-	-

2 Baseline Soil Quality Field Methodology

	Soil Erodibility Score			
	0	**1**	**2**	**3**
Light sand to clayey sand	-	Earthy, poor	loose	-
Sandy loam to clay loam	-	strong	Earthy, moderate	Loose, poor
Clay	Shrink swell, strong	Earthy, moderate	poor	-
Permeability of latyers within or up to 30cm below the layer being assessed	Moderately rapid to very rapid	moderate	Moderately slow	Slow to very slow
Soil moisture If soil layer depth </= 30cm erodibility score is 2	variable	-	-	Wet, partially wet

- Use **Table 2-3** to convert the soil profile erodibility score into a soil profile erodibility class.
- Using **Table 2-4** estimate the water erosion hazard rating from the soil profile erodibility class and the landform position of the soil. Adjust the rating according the degree of waterlogging experienced by the land unit as instructed in the note below the table.

Table 2-3 Soil Profile Erodibility Classes

	Soil profile erodibility class		
	Low (i)	**Moderate (ii)**	**High (iii)**
Soil profile erodibility score	<15 Bare rock, water	15-30	>30

Table 2-4 Susceptibility of land units to water erosion (based on soil erodibility and slope)

Landform1	Water erosion hazard rating					
	Very low (VL)	**Low (L)**	**Moderate (M)**	**High (H)**	**Very high (VH)**	**Extreme (E)**
A. Flats, Very gentle slopes, Crests (<3%)	(1), (2)2	(3)2		-	-	-
B. Gentle slopes (3-5%), Long slopes, Footslopes, Floodplains	(1)	(2)	(3)	-	-	-
C. Gentle slopes (5-10%), Well drained drainage depressions		(1)	(2)	(3)	-	-
D. Moderate slopes (10-15%), Poorly drained drainage depressions			(1)	(2)	(3)	-
E. Moderate slopes (15-30%), Stream channels			-	(1)	(2)	(3)

F. Steep slopes (>30%)			-	-	(1)	(2), (3)

NOTE: Waterlogging is High or Very high, increase rating by one column (e.g. from High to Very high).

Wind Erosion Hazard

Wind erosion hazard is the inherent susceptibility of the land to the loss of soil as a result of wind movement across the surface. Wind erosion has many adverse effects: sandblasting damage to crops, loss of macro- and micro-nutrients, long-term loss of productivity, and atmospheric pollution. There are also off-site costs to both individuals and the community.

The dust lost from paddocks is rich in nutrients and is carried high into the atmosphere before being deposited, possibly thousands of kilometres downwind. All soils are subject to wind erosion given certain conditions. The key is the level of disturbance by mechanical or animal action required to bring a soil to an erodible condition.

The *susceptibility of a soil* can be assessed from a simple matrix of surface texture and surface condition (**Table 2-5**). The five categories of wind erosion hazard relate to the level of disturbance needed to bring the soil to a loose and consequently erodible condition.

Soils in category (v) are highly susceptible because they have a loose surface and control must rely on the use of windbreaks and/or maintenance of adequate vegetative cover.

Categories (iv) to (i) have decreasing susceptibility. They are less fragile and require some disturbance by machinery or stock to loosen the soil. Gravel both physically protects the surface and increases roughness and this reduces the wind velocity at the soil surface. The surface condition should be assessed when the soil is dry.

The *susceptibility of a land unit* to wind erosion is assessed by combining soil susceptibility (**Table 2.5**) with landform (**Table 2.6**). Landform and location influence wind speed and exposure to high winds. As defined here wind erosion hazard does not take into account land management practices (these are assessed in the land capability ratings tables).

Table 2-5 Susceptibility of Soil

Loose (L)[1]	**Soft, Surface flake (S, X)[1]**	**Firm, Crusting, Cracking, Saline (F, C, K, Z)[1]**	**Hardsetting (H)[1]**	**Self-mulching (M)[1]**	**Wind erodibility rating**
-	-		Coarse sand and sandy loam to clay[2] (KS, SL, L, SCL, CL, C)	Clay[3]	**(1)**
-	-	Coarse sand and sandy loam to Clay (KS, SL, L, SCL, CL, C)	-	Clay[3]	**(2)**
-	Coarse sand and sandy loam to clay (KS, SL, L, SCL, CL, C)	Light sand to clayey sand (SS, S, FS, LS, CS)	Loamy sand to clayey sand (LS, CS)	Clay[3]	**(3)**

2 Baseline Soil Quality Field Methodology

Loose (L)1	Soft, Surface flake (S, X)1	Firm, Crusting, Cracking, Saline (F, C, K, Z)1	Hardsetting (H)1	Self-mulching (M)1	Wind erodibility rating
Coarse sand (KS)	Light sand to clayey sand (KS, SS, S, FS, LS, CS)	-	-	Clay3	**(4)**
Light sand to clay (SS, S, FS, LS, CS, SL, L, SCL, CL, C)	-	-	-		**(5)**

[1] Surface condition – see Table A1.7 of van Gool (2005).

[2] Surface texture – see Table A1.8. of van Gool (2005)

[3] Erodibility of self-mulching clays depends on the size of the particles created when clay mulches. The default value for self-mulching clays is (3).

Table 2-6 Landunit Susceptibility

Landform1		**Wind erosion hazard rating**			
	Low (L)	**Moderate (M)**	**High (H)**	**Very high (VH)**	**Extreme (E)**
A. Foredunes and blowouts	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
B. Crests and rises	**(1), (2)**	**(3)**	**(4)**	**(5)**	-
C. Flats and slopes and larger swamps and salt lakes	**(1), (2), (3)**	**(4)**	**(5)**	-	-
D. Depressions and smaller swamps and salt lakes	**(1), (2), (3), (4)**	**(5)**	-	-	-

2.7.2 Field Dispersion (adapted from Emerson, 1967) Test Procedure

Soil dispersion causes clay particles to block soil pores, resulting in reduced soil permeability. When soil is repeatedly wetted and dried and clay dispersion occurs, it then reforms and solidifies into almost cement-like soil with little or no structure. The main problems caused by sodium-induced dispersion are erosion, reduced infiltration, reduced hydraulic conductivity, and surface crusting

Dispersion is an indicator of sodic soils as it occurs when excessive sodium is present. When water is added, the sodium attaches to the clay and forces the clay particles apart. This results in a cloud of clay forming around the aggregate. The fine clay particles that have dispersed clog up the small pores in the soil and degrade soil structure as well as restricting root growth and water movement.

The following test procedures were followed for the determination of field dispersion:

- An aggregate of approximately 5–10 mm diameter was selected.
- The dry aggregate was immersed in 75 mL of deionised water was placed in a glass beaker container.
- After slaking and dispersion was observed over a time period of 2 hours, the aggregate was remoulded to an approximate 5mm cube and re-immersed in deionised water.
- After two hours, aggregate behaviour for dispersion was assessed again.

The following rating scales were used to aid slaking and dispersion identification:

Slaking test scores
0 No change
1 Aggregate breaks open but remains intact
2 Aggregate breaks down into smaller aggregates
3 Aggregate breaks down completely into sand grains
Dispersion test scores
0 No dispersion.
1 Slight dispersion, recognised by a slight milkiness of the water adjacent to the aggregate and some times a narrow edging of dispersed clay to part of the aggregate
2 Moderate dispersion with obvious milkiness.
3 Strong dispersion with considerable milkiness and about half of the original volume dispersed outwards
4 Complete dispersion leaving only sand grains in a cloud of clay

2.7.3 pH_f/pH_{fox} Field Test Procedure

Field pH (pH_f) and field peroxide (pH_{fox}) tests were conducted on recovered soil samples at an interval of 0.25 m depth interval in order to assess the potential of the soil to generate acidity. Results of the field tests were conducted in accordance with the *Laboratory Methods Guidelines Acid Sulfate Soils (Version 2.1-June 2004)*.

Field pH (pH_f) and field peroxide (pH_{fox}) tests were conducted on recovered soil samples using deionised water and a 30% hydrogen peroxide solution. The pH values were measured using a Hanna pHEP® meter which was calibrated prior to field testing using buffer solutions of pH4 and pH7 +/- 0.01 units.

The field testing procedures are summarised as follows:

- 2 sub-samples were collected from each original sample location at approximately 0.25 m intervals and were placed in separate disposable clear plastic containers, one labelled 'field pH' and the other 'oxidised pH';
- 20 mL of deionised water was added to the container labelled 'field pH'. (soil: water [1:5]). The pH meter was inserted into the soil:water mixture and $pH_{(f)}$ was recorded; and
- 20 mL of hydrogen peroxide was added to the container labelled 'oxidised pH' (soil: water [1:5]). The soil was allowed to react for 15 minutes before reading the pH_{fox} value.

It should also be noted that prior to testing, the hydrogen peroxide pH was raised between 5.0 and 5.5 by adding approximately 0.5 ml of sodium hydroxide to the solution.

2 Baseline Soil Quality Field Methodology

2.7.4 Effervescence “Fizz Test” Field Test Procedure

The carbonate ‘fizz’ test is used to determine the presence of carbonates in soil. The test is normally conducted on samples suspected of containing carbonates such as fine shell, crushed coral or soluble carbonates presence within the soil profile. The field test was conducted in accordance with the Laboratory Methods Guidelines Acid Sulfate Soils (Version 2.1-June 2004) (Ahern *et al*, 1998).

The presence of carbonate material may suggest that there is potential for the soil profile to comprise of some *in situ* neutralising capacity of material against potential acid generating conditions. It should be noted, however, that this test is simply an indicator for the presence of carbonate material. Detailed analytical tests would be required to determine the carbonate material available to neutralise *in situ* potential acid generating conditions.

The field testing procedures are summarised as follows:

- Place 2 or 3 drops of 1 M hydrochloric acid (HCl) onto the soil sample. Soil samples were extracted at 0.25 m depth intervals; and
- For the purpose of this investigation a ‘yes’ or ‘no’ description was deemed applicable in the field as soil samples were submitted for laboratory analysis.

2.8 Interpretation of Field Test Results

2.8.1 Field Dispersion Tests

The Emerson aggregate testing procedures are presented in full as **Appendix B.** It should be noted that no testing for carbonate or gypsum was completed during field works and dispersion has been interpreted to a Class 5 only.

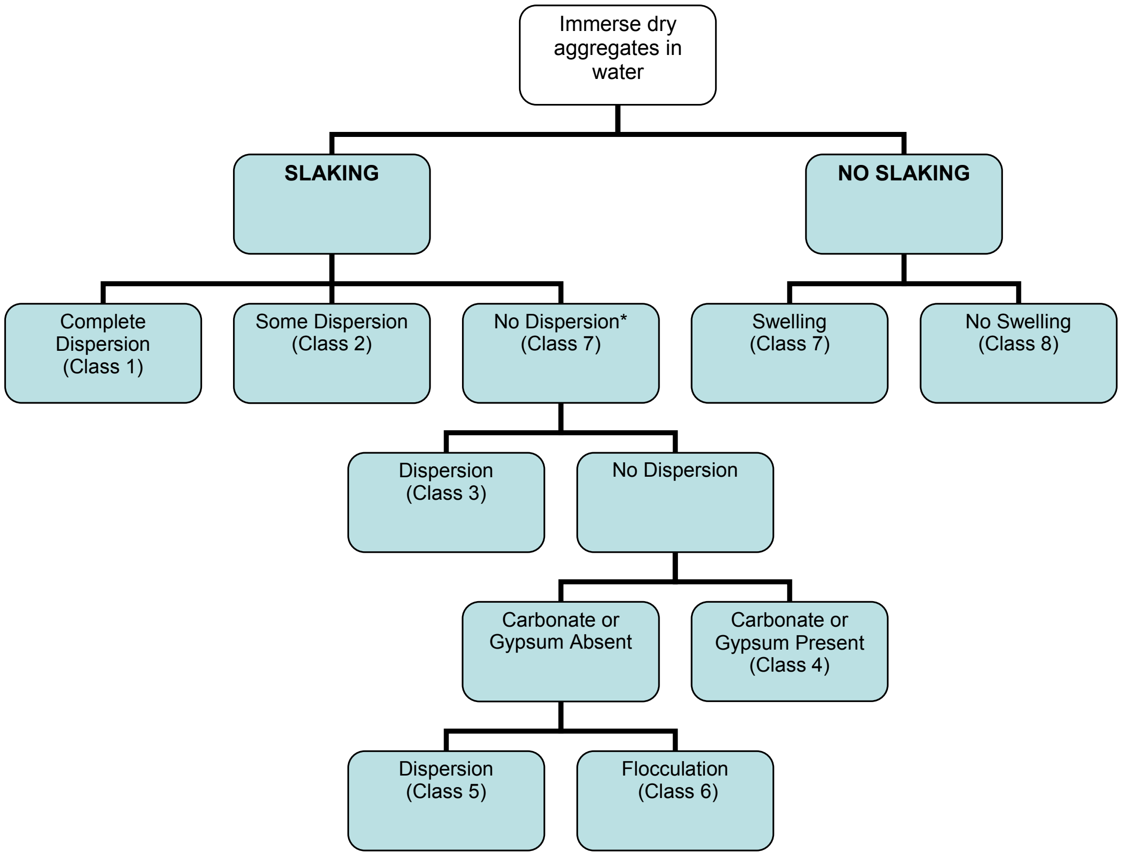
The Emerson aggregate test assesses how aggregates break down in water and classifies a soil into eight categories. The Emerson aggregate test is a simple way of identifying four significant soil groups with respect to their behaviours when cultivated:

- Soils which are spontaneously dispersive to varying degrees (Class1 and Class 2).
- Soils which are potentially dispersive if remoulded when wet (Class 3).
- Soils which slake but are non-dispersive (Classes 4, 5 and 6).
- Soils which have a high inherent stability (Class 7 and 8).

Class 1 soils are highly unstable and invariably sodic to highly sodic

The following chart was used for interpretation:

Determining the Emerson Class Number of Aggregates



*Remould at water content equivalent to field capacity then immerse in water

2.8.2 pH_f/pH_{fox} Field Test

The pH_f test measures the existing acidity and is therefore a useful indicator as to whether actual ASS material is present. The pH_{fox} test (or rapid oxidation) is used to indicate the presence of iron sulfides or potential ASS. The test involves adding 30% hydrogen peroxide to a sample of soil, thereby replicating what would naturally occur if the soils were exposed to air.

A combination of three factors is considered in arriving at a positive identification of sulfides or potential ASS. These include a reaction (strength of) with hydrogen peroxide, the end pH_{fox} value, and the change in pH_{fox} and pH_f values.

If sulfides are present, a reaction will occur. The reaction can be influenced by the amount of sulfides in the sample and the presence of organic matter and the more vigorous the reaction the greater potential for acidity (generally). The lower the final pH_{fox} value and the greater the difference between the pH_f compared to the $pH_{fox,}$ the more indicative the presence of potential ASS.

2.8.3 Effervescence "Fizz Test" Field Test

The carbonate 'fizz' test is used to determine the presence or absence of carbonates in soil. The presence of carbonate material may suggest that there is potential for the soil profile to comprise of some *in situ* neutralising capacity of material against potential acid generating conditions.

This test is simply an indicator for the presence of carbonate material and detailed analytical tests are required to determine the actual carbonate material available to neutralise *in situ* potential acid generating conditions.

2.9 Decontamination Procedures

All down-hole tools (geoprobe tools and hand augers) were decontaminated with a laboratory grade detergent between sampling locations and rinsed with potable water. All sampling equipment (hand spades etc) were decontaminated between sample locations using laboratory grade detergent (Decon 90) mixed with potable water, followed by a potable water rinse. Disposable nitrile gloves were also used during sample handling, with a new pair of gloves used for the collection of each soil sample.

2.10 Sampling and Analysis Plan

2.10.1 Ashburton North and Surrounds

A total of 18 environmental soil bores were drilled at a variety of locations across Ashburton North and surrounds to a maximum depth of 4.6 mbgl using diamond core mud rotary method between the 27 March and 29 April 2009.

A further nine hand auger locations were completed at shallow depths ranging between 0.4 and 1.2 m bgl, between 27 March and 29 April 2009 and 7 July and 9 July 2009.

Six of the hand auger locations (E034, E038, E040, E041, E042 and E045) had been identified as potential areas for PASS material during the desktop phase of the investigation. The identified locations for PASS, or areas identified as 'high risk' based on desktop investigation, were selected based on typical PASS geomorphology profiles using aerial photography (e.g. low lying (below 5 mAHD) and/or generally waterlogged and the presence of salt tolerant plant species).

The remaining three hand auger locations were selected as access to these sites had been restricted by drill rigs due to recent rainfall events along the Onslow coast (E036, E037 and E039).

Two of the hand auger locations (E040 and E042) were augered, sampled and analysed during the hand augering programme completed between 27 March and 29 April 2009, and were re-advanced during the hand augering programme completed between 7 July and 9 July 2009. The objective of the duplicate sampling was to ensure results could be reproduced, and hence were representative of Ashburton North and surrounds, at both a field and laboratory level of investigation.

2.10.2 Shared Infrastructure Corridor

A total of ten hand auger locations (E046, E047, E048 and E052 and SS01, SS03-SS07) were completed between the 19 and 21 October 2009 to a depth ranging between 1.25 and 1.6 mbgl. The hand auger investigation was driven by depth to groundwater (interception of groundwater resulted in coreloss) or the interception of cemented carbonate material (refusal).

The sampling and analysis program for BSQ and ASS investigation has been summarised in **Table 2.2** below.

Table 2-7 Summary of the Completed Sampling and Analysis Programme

Sample Location	Soil Sample ID	Number of Samples Collected	Total samples for Analysis	Field Testing Schedule	Laboratory Schedule and Primary Sample Allocation
Ashburton North and Surrounds-SAP					
E002	MB2B	Samples were collected at approximately every 0.5m interval (depending on core recovery). **A total of 148 samples were collected**.	A sampling intensity of approximately **2 samples per hole was proposed.**	Field tests for pH(f), pH(fox) and 'fizz test' conducted at 0.25m interval and field dispersion tests on select samples.	Chromium reducible (S_{cr}) suite, a suite of heavy metals (inclusive of arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, manganese, nickel, vanadium and zinc), **44 ASS samples and 38 metals samples**
E003	MB3A				
E004	MB4A				
E005	MB5A				
E006	MB6A				
E007	MB7A				
E008	MB8A				
E009	MB9A				
E010	MB10A				
E011	MB11A				
E012	MB12A				
E013	MB13A				
E015	MB15A				
E016	MB16A				
E017	MB17A				
E018	MB18A				
E019	MB19A				
E021	MB21				
E034	E034				
E036	E036				
E037	E037				
E038	E038				
E039	E039				
E040 and E040A	E040 and E040A				
E041	E041				

2 Baseline Soil Quality Field Methodology

Sample Location	Soil Sample ID	Number of Samples Collected	Total samples for Analysis	Field Testing Schedule	Laboratory Schedule and Primary Sample Allocation
E042 and E042A	E042 and E042A				
E045	E045				
Shared Infrastructure Corridor- SAP					
E046	E046	Samples were collected at approximately every 0.5m interval (depending on core recovery). **A total of 37 samples were collected**.	A sampling intensity of approximately **1 sample per hole was proposed.**	Field tests for pH(f), pH(fox) and 'fizz test' conducted at 0.25m interval and field dispersion tests on select samples.	Chromium reducible (S_{cr}) suite, a suite of heavy metals **12 ASS samples and 12 metals samples**
E047	E047				
E048	E048				
E052	E052				
SS01	SS01				
SS03	SS03				
SS04	SS04				
SS05	SS05				
SS06	SS06				
SS07	SS07				

Notes:
pH(f); Field pH value,
pH(fox): Field peroxide value,
'fizz test': Effervescence test conducted on soil samples using hydrochloric acid (HCl)

Analytical Methodology

3.1 Adopted Laboratory Methods

The analytical procedures used by the Environmental Division of Australian Laboratory Services (ALS) have been developed from established internationally recognised 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 adopted laboratory analytical methods and method code are provided below

3.1.1 Laboratory Methodology

Tests chosen for the laboratory analysis of ASS were in accordance with ASS Laboratory Methods Guidelines Version 2.1-June 2004 (Ahern *et al*, 1998). Chemical analysis was conducted at ALS, which is a National Association of Testing Authorities (NATA) accredited laboratory facility for the following analytical methods.

A brief description of the laboratory analytical methods is provided:

- **EA033: Chromium Suite for Acid Sulfate Soils –** This method covers the determination of Chromium Reducible Sulfur (SCR); pHKCl; titratable actual acidity (TAA); acid neutralising capacity by back titration (ANC); and net acid soluble sulfur (SNAS) which incorporates peroxide sulfur. It applies to soils and sediments (including sands) derived from coastal regions. Liming Rate is based on results for samples as submitted and incorporates a minimum safety factor of 1.5
- **EA055-103: Moisture Content -** 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);
- **EG005T: Total Metals by ICP-AES -** (APHA 20th ed., 3120; USEPA SW 846 - 6010) (ICPAES) Metals are determined following an appropriate acid digestion of the soil. The ICPAES technique ionises samples in 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); and
- **EG035T: Total Mercury by FIMS -** AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2) (Cold Vapor generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids is 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).

3.2 Laboratory Schedule

3.2.1 Ashburton North and Surrounds

In total, 148 primary samples were collected during the intrusive investigation of which 30 of the samples were submitted to ALS laboratory on 15 May 2009 and eight were submitted on 28 July 2009 for analysis of heavy metals including aluminium (Al), arsenic(As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co),Copper (Cu), iron (Fe), lead (Pb),

3 Analytical Methodology

mercury (Hg), manganese (Mn), nickel (Ni), vanadium (Va) and zinc (Zn) as part of the BSQ assessment.

A total of 35 samples were also submitted for the assessment of PASS and ANC using the chromium suite methodology on the 15 May 2009 and nine samples were submitted on 28 July 2009.

3.2.2 Shared Infrastructure Corridor

In total, 37 primary samples were collected during the intrusive investigation of which 12 were submitted to ALS laboratory on the 24 November 2009.

Table 3.2 Laboratory Schedule

BSQ and Landforms Assessment			**Laboratory Tests**	
ALS Batch Number	**Chevron site ID**	**URS Sample ID**	**Scr**	**Metals Suite**
Ashburton North and Surrounds				
EP0902640-001	E006	MB06A-1.0		1
EP0902640-002	E006	MB06A-1.5	1	
EP0902640-003	E007	MB07A-0.0	1	1
EP0902640-004	E007F	MB07A-0.5		1
EP0902640-005	E012F	MB12-1.0	1	1
EP0902640-006	E012F	MB12-1.5	1	1
EP0902640-007	E012	MB12-2.0	1	
EP0902640-008	E019	MB19A-0.0	1	1
EP0902640-009	E019	MB19A-1.75		1
EP0902640-010	E034	E034-0.0-0.2	1	
EP0902640-011	E034	E034-0.5-0.6	1	
EP0902640-012	E034	E034-0.75-0.85		1
EP0902640-013	E004	MB4A-0.25-0.35	1	1
EP0902640-014	E003	MB3A-2.0-2.15	1	1
EP0902640-015	E002	MB2B-1.2-1.5	1	1
EP0902640-016	E0017	MB17A-0.0-0.25	1	
EP0902640-017	E0017	MB17A-1.5-1.75	1	1
EP0902640-018	E005	MB5S-0.5-0.75	1	
EP0902640-019	E005	MB5A-1.5-1.75		1
EP0902640-020	E016	MB16A-0.0-0.05		1
EP0902640-021	E016	MB16A-1.5-1	1	1
EP0902640-022	E008	MB8A-0.0-0.10	1	1
EP0902640-023	E008	MB8A-1.0-1.50	1	
EP0902640-024	E008	MB8A-1.50		1
EP0902640-025	E009	MB09A-1.50	1	

3 Analytical Methodology

BSQ and Landforms Assessment			Laboratory Tests	
ALS Batch Number	Chevron site ID	URS Sample ID	Scr	Metals Suite
EP0902640-026	E009	MB09A-2.50		1
EP0902640-027	E009	MB09A-3.0	1	
EP0902640-028	E015	MB15A-2.50	1	1
EP0902640-029	E015	MB15A-3.0	1	1
EP0902640-030	E013	MB13A-0.0-0.45	1	1
EP0902640-031	E011	MB11A-1.0	1	1
EP0902640-032	E018	MB18A-1.50	1	1
EP0902640-033	E018	MB18A-2.5	1	1
EP0902640-034	E018	MB18A-3.0		1
EP0902640-035	E010	MB10A-1.0	1	
EP0902640-036	E010	MB10A-2.0	1	
EP0902640-037	E006	MB06A-0.5	1	
EP0902640-038	E034	EP034-0.0-0.1	1	1
EP0902640-039	E034	EP040-0.5-0.6	1	1
EP0902640-040	E030	EP040-1.0-1.10	1	
EP0902640-041	E040	EP040-0.75-0.85		1
EP0902640-042	E042	EP042-0.0-0.1	1	1
EP0902640-043	E042	EP042-0.5	1	1
EP0902640-044	E019	MB19A-1.5	1	
EP0902640-045	E019	MB19A-2.0	1	
EP0904133-001	E042	E042 0.9-1.0	1	
EP0904133-002	E042	E042 1.0-1.1		1
EP0904133-003	E041	E041 0.9-1.0	1	1
EP0904133-004	E038	E038 0.9-1.0	1	1
EP0904133-005	E040	E040 1.0-1	1	1
EP0904133-006	E039	E039 0.25-0.30	1	
EP0904133-007	E037	E037 0.25-0.30	1	
EP0904133-008	E036	E036 0.25-0.30	1	1
EP0904133-009	E045	E045 0.5-0.6	1	1
EP0904133-012	E039	E039 0.3-0.4		1
EP0904133-013	E037	E037 0.0-0.25		1
EP0904133-014	E038	E038 0.5-0.6	1	
Total Analytical Tests (Primary Samples)			**44**	**38**
Shared Infrastructure Corridor				
EP0906799-001	SS07	SS07 1.5-1.6	1	1
EP0906799-002	SS01	SS01 0.5-0.6	1	1
EP0906799-003	E047	EO47 1.0-1.1	1	1
EP0906799-004	E048	EO48 0.0-0.1	1	1
EP0906799-005	SS04	S004 1.0-1.1	1	1
EP0906799-006	SS01	SS01 1.0-1.1	1	1

BSQ and Landforms Assessment			Laboratory Tests	
ALS Batch Number	**Chevron site ID**	**URS Sample ID**	**Scr**	**Metals Suite**
EP0906799-007	SS05	SS05 1.0-1.1	1	1
EP0906799-008	SS03	SS03 0.4-0.5	1	1
EP0906799-009	E052	EO52 0.5-0.6	1	1
EP0906799-010	SS06	SS06 0.5-0.6	1	1
EP0906799-012	SS06	SS06 1.5-1.6	1	1
EP0906799-013	E046	E046 0.0-0.1	1	1
Total Analytical Tests (Primary Samples)			**12**	**12**

The total number of samples selected generally reflects an analytical regime of one sample per shallow borehole (to a maximum depth of 3.0 mbgl). The samples selected for analysis were primarily based on field test results and soil profiles intercepted, although representation of landform units, typical of the Wheatstone Study area, was also considered.

The objective of the sample selection and the subsequent analytical investigation was to ensure that sufficient information was collected across the shallow soil profile (to a depth of 3.0 mbgl) of the Wheatstone Study area for an assessment of BSQ.

Soil samples that were not submitted for analysis were frozen and stored in the event that further analysis will be required. Further, ALS store all submitted samples for 3 months prior to disposal in the event that retesting of samples may be requested.

3.3 Field and Laboratory QA/QC

Quality assurance and quality control (QA/QC) sampling and analysis was undertaken with general reference to the:

- DEC (2001-2007) Contaminated Sites Management Series.
- DEC (2003-2009) ASS Guideline Series.

3.4 Data Quality Objectives and Methodology

URS requires the analytical testing laboratories and their methodologies to be accredited by NATA. As part of their internal QA/QC, URS requires these laboratories to conduct regular audits on their analyses through the use of reagent blanks, analysis of surrogate spikes, repeat duplicates and verification of recoveries. Results of the laboratory and field QA/QC analyses are presented as part of the laboratory reports and are discussed in **Section 3.5.**

The following field QA/QC procedures were implemented in the field:

- Field duplicate samples are collected in the field to identify any variation in analyte concentrations between samples collected from the same sampling point (duplicates).
- Field QA/QC samples are collected at a frequency of one per 20 samples.

- Rinsate blanks are collected in the field to check the cleanliness of the sampling devices and to confirm the quality of field decontamination procedures.
- Rinsate blanks are collected at a rate of 1 per day.
- Standard URS sampling procedures are applied to ensure sample integrity and quality and are detailed further in **Section 2.6** of this report.
- All primary, duplicate and rinsate blank samples to be analysed by a NATA registered laboratory using NATA accredited methods.
- The relative percent difference (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.

3.5 QA/QC Data Evaluation

Copies of the laboratory reports (including laboratory QA/QC reports) are attached as **Appendix E** of the main document. The following QA/QC interpretation is for ALS work orders EP0902640, EP0904133 and EP0906799.

3.5.1 General Data Quality

The overall data quality is acceptable and is considered to be of sufficient reliability to achieve the objectives of this assessment. Following is a general outline of the data quality:

Laboratory QA/QC

- The limit of reporting between all samples and analysis batches was found to be consistent.
- Laboratory LOR was sufficiently low for comparison with adopted guideline criteria.
- Matrix and surrogate spike recoveries were within the acceptable range.
- Breaches for QC control samples were reported for Duplicate RPD's iron (E042_1.0-1.1) and manganese (E042_1.0-1.1) and (S004_1.0-1.1) where the analyte was not determined in the allocated original sample and hence the RPD exceeded the LOR based limit.
- Breaches for matrix spike recoveries was reported for aluminium and iron for E041_0.9-1.0, MB07A_0.0, MB11A_1.0 and manganese for MB07A_0.0 where the matrix spike was not determined due to background levels been greater that or equal to four times the spike level.
- Samples were received by the laboratory accompanied by chain of custody documentation, chilled, in good order and were analysed within sample holding times. This is with the exception of holding times for moisture content, which were exceeded by 13 to 46 days and for total recoverable mercury by 1 to 26 days.

  These holding time exceedances may have resulted in degradation (evaporative, microbial) of target analytes and reported concentrations may be biased low. Reported concentrations for these analytes should be treated with caution.

3 Analytical Methodology

- All field samples were handled and preserved in accordance with URS and ALS laboratory requirements.
- A review of the analytical results relative to observations made during the site works did not identify any significant anomalous results.

Field QA/QC

- Overall the frequency of duplicate samples analysed per primary sample meets the criteria of one in twenty for all individual soil analytes. This is with the exception of metals where sufficient duplicate samples were collected, however, based on the selection criteria were not analysed.
- RPD values were generally not calculated for field duplicate samples as reported concentrations were below the LOR for samples. Where RPD values could be calculated, the results were within the acceptable limits. It is accepted that the reported results are within the acceptable RPD range (30-50%) indicating the sampling and analysis procedures applied by URS and the laboratory were generally reproducible.
- This is with the exception of QA/QC duplicate QC01_ as analysed on 24/11/2009 (field duplicate for SS07_1.5-1.6). RPD calculations were in exceedance of the acceptable limits for all reproducible analytes. It is suspected that the consistency of which the RPD values were calculated (i.e. ~150%) and after discussions with the laboratory, it is suspected that the sample was relatively heterogeneous (mottling was observed indicating some) and was therefore, in terms of being a field duplicate, was not representative of the primary sample. In this case, it is advised that the higher value (QC01) is used for the interpretation and discussion of analytical results.
- Rinsate blanks were not collected in the field due to the remoteness of the location and the duration of the drilling programme which didn't permit for daily couriering of samples to Perth. Therefore rinsate blank sampling is not in compliance with regulatory guidelines.

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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 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 URS report URS-WHST-STU-ET-RPT-0068.

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 March and 26 September 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.

Appendix A Summary of Groundwater and Environmental Monitoring Bore Installation

Appendix B Emerson Aggregate Test Procedures (1967)

URS

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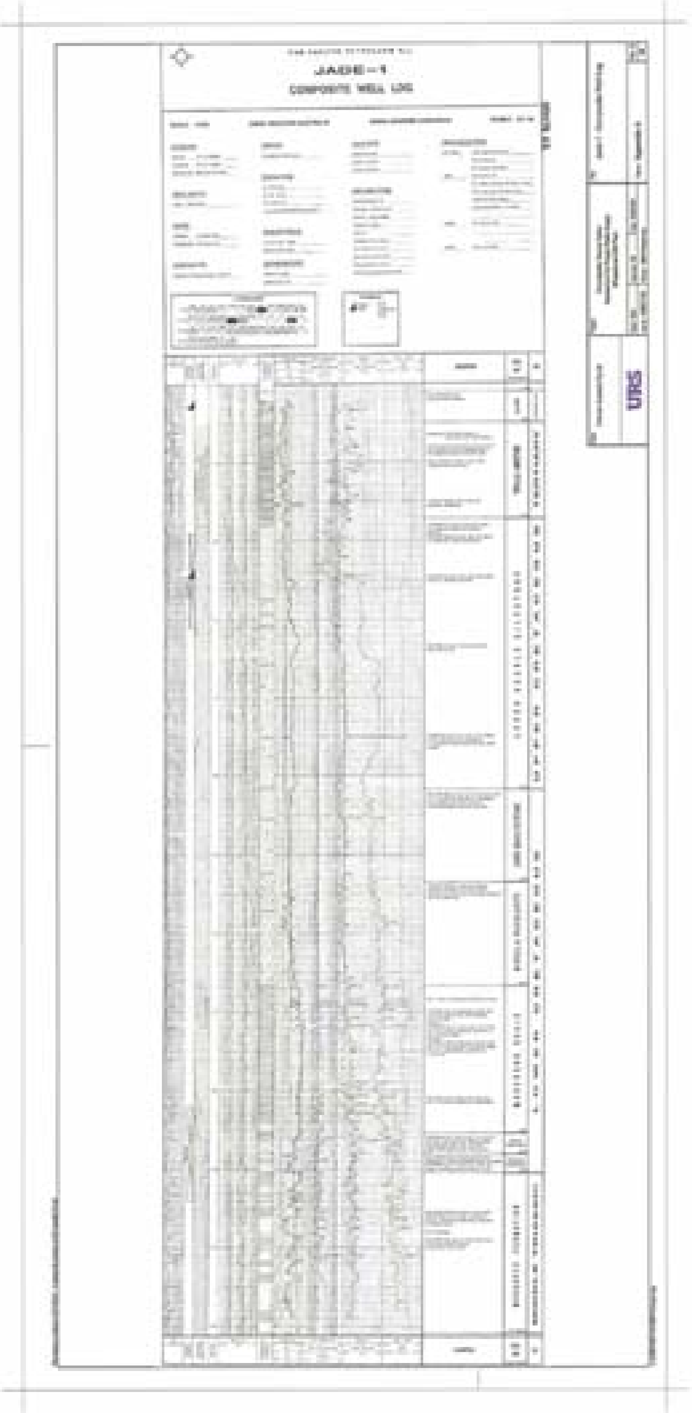
Appendix B Jade 1 - Geological Log (Department of Industry and Resources 1993)



JADE-1

COMPOSITE WELL LOG

C

Appendix C Soil Bore and Hand Auger Logs

URS

Sheet 1 of 1

SOIL BORE E002 (MB2B)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **C. Clark**
Checked By: **MN**
Date Started: **30-3-09**
Date Finished: **30-3-09**

Relative Level: **mRL**
Coordinates: **7595091.00 mN**
291156.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
ASS	0.00	8.79	9.01	MB2B_0.0-0.25			0		silty sandy CLAY, low plasticity, very fine to medium grained quartz, sub angular, red/brown, dry	
	0.25	8.80	9.09	MB2B_0.25-0.45						
									silty CLAY, coarse grained quartz, low plasticity, red/brown, moist	
							1			
A&M	1.20	8.81	9.11	MB2B_1.2-1.5					silty SAND, medium to fine grained quartz, moderately sorted, sub angular, red/brown	
	1.75	8.77	9.08	MB2B_1.75-1.95					silty SAND, limestone fragments, minor bands of cemented clay	
ASS	1.95			MB02B_1.950-2.4			2			
ASS	2.65	8.71	9.01	MB2B_2.65-2.85						
A&M	2.85	8.97	9.10	MB2B_2.85-3.0						
							3		Extent of Investigation @ 3.0 mbgl	
							4			

REMARKS:

Sheet 1 of 1

URS

SOIL BORE E003 (MB03A)

Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landform Assessment**
Drilling Contractor: **HAGSTROM DRILLING**			
Drill Type: **Diamond Core**	Logged By: **C. Clark** Checked By: **MN** Date Started: **30-3-09** Date Finished: **30-3-09**	Relative Level: **mRL** Coordinates: **7595517.00 mN** **291105.00 mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
							0		SAND, moderately sorted, brown/grey, siliceous.	
A&M	0.50	8.89	9.07	MB3A_0.5-0.7					SAND/Calcareous SANDSTONE. Sand is poorly sorted, siliceous, unlithified, brown/grey, with calcareous sand clasts (cemented) to 10mm in size. Approximately 10% limestone clasts and 75% brown sand.	
A&M	1.00	8.77	9.09	MB3A_1.0-1.25			1			
									SAND/Calcareous SANDSTONE. As above but with hard, lithified bands of calcareous sandstone at 1.9m, 2.42, 2.62 and 2.9m. Bands are approximately 3mm wide with shell fragments throughout.	
A&M	1.75	9.01	9.10	MB3A_1.75-1.95						
A&M	2.00	9.00	9.10	MB3A_2.0-2.15			2			
A&M	2.65	8.80	9.01	MB3A_2.65-2.85						
A&M	2.85	8.89	9.11	MB3A_2.85-3.0						
							3		Extent of Investigation @ 3.0 mbgl	
							4			

REMARKS:

Sheet 1 of 1

SOIL BORE E004 (MB04)

Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landform Assessment**
Drilling Contractor: **HAGSTROM DRILLING**			
Drill Type: **Diamond Core**	Logged By: **C. Clark** Checked By: **MN** Date Started: **27-3-09** Date Finished: **27-3-09**	Relative Level: **mRL** Coordinates: **7595540.00 mN** **291243.00 mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
							0	░	SAND, fine to medium grained quartz, loose, some limestone fragments, light brown, dry	
☒ A&M	0.25	8.73	8.86	MB4A_0.25-0.35						
☒ A&M	0.50	9.17	9.28	MB4A_0.5-0.65						
								░	SANDSTONE, fine to medium grained quartz, weak to moderately lithified, some shell fragments to 2mm, sub rounded gravels to 5mm, light brown. Groundwater intercepted at 0.75mbgl.	
							1			
☒ A&M	1.50	8.72	9.09	MB4A_1.5-1.8						
							2			
☒ A&M	2.20	8.83	9.31	MB4A_2.20-2.35						
							3		Extent of Investigation @ 3.0 mbgl	
							4			

REMARKS:

URS

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SOIL BORE E005 (MB05A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **C. Clark**
Checked By: **MN**
Date Started: **2-4-09**
Date Finished: **2-4-09**

Relative Level: **mRL**
Coordinates: **7596954.00 mN**
291482.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)
ASS	0.00	7.03	6.20	MB5A_0.0-0.25			0
		7.68	6.33				
ASS	0.50	7.33	6.42	MB5A_0.5-0.75			
		7.34	6.80				
							1
		7.62	7.06				
Metals	1.50	7.69	6.57	MB5A_1.5-1.75			
		7.74	7.87				
A&M	2.00	7.77	7.70	MB5A_2.0-2.25			2
		8.15	7.53				
Metals	2.50	8.09	7.80	MB05A_2.5			
		8.11	7.63				
A&M	3.00			MB5A_3.0-3.25	SWL = 3.08 m bgl		3
							4

LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
	silty SAND, sub angular to sub rounded, fine to medium grained sand, some rootlets, red/brown, dry	
	gravelly SAND, fine to medium grained sands, some silts, angular gravels, brown	
	sandy GRAVEL, fine grained sands, angular gravels, limestone fragments, some clays, light grey	
	Calcaerous SANDSTONE, fine to medium grained, well cemented, white/grey	
	silty sandy GRAVEL, weathered limestone, angular gravel, shell fragments, large 30 to 40mm angular gravel to towards 1.6mbgl	
	silty sandy GRAVEL, 20 to 30mm weathered limestone, some gravels	
	sandy silty GRAVEL, cemented shell material, gravels of marine origin, light brown	
	clayey silty SAND, shell material slits and clays interbedded to coherent core	
	sandy GRAVEL, rounded to angular to sub angular gravel 10 to 40mm, light brown	
	Extent of Investigation @ 3.2 mbgl	

REMARKS:

URS

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SOIL BORE E006 (MB06A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **C. Clark**
Checked By: **MN**
Date Started: **5-4-09**
Date Finished: **5-4-09**

Relative Level: **mRL**
Coordinates: **7598296.00 mN**
292538.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
ASS	0.00	8.11	7.52	MB06A_0.0			0		silty sandy CLAY, red brown, siliceous, very fine grained, moderately weathered.	
		8.24	7.72							
ASS	0.50	7.89	7.75	MB06A_0.5					SAND, very fine grained sand, red brown. Groundwater intercepted at 0.5mbgl.	
		7.79	6.40							
A&M	1.00	7.80	6.35	MB06A_1.0	SWL = 1.10 m bgl		1			
ASS	1.50	7.68	4.65	MB06A_1.5				CORE LOSS	Core Loss	
ASS	1.95	7.25	4.80	MB06A_1.95-2.2			2		SAND, very fine grained sand, soft, brown, wet	
ASS	2.20	7.71	4.33	MB06A_2.2-2.4						
		7.51	4.90					CORE LOSS	Core Loss	
ASS	3.00			MB06A_3.0-3.45			3		SAND, very fine grained, soft, brown, wet	
ASS				MB06A_3.2					clayey sandy GRAVEL, angular to sub rounded, 2 - 5mm, cemented fine grained quartz, medium grained sands, angular, brown	
									Extent of Investigation @ 3.5 mbgl	
							4			

REMARKS:

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SOIL BORE E007 (MB07A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004
9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **R, Parker**
Checked By: **MN**
Date Started: **5-4-09**
Date Finished: **5-4-09**

Relative Level: **mRL**
Coordinates: **7598613.00 mN**
292711.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒ A&M	0.00	7.88	7.47	MB07A_0.0			0	CORE LOSS	Core Loss	
		7.87	7.60							
☒ Metals	0.50	7.89	7.94	MB07A_0.5						
		7.79	8.00						silty CLAY, moderately weathered, high plasticity, very fine mottles, minor quartz present, red/brown.	
☒ A&M	1.00	7.83	7.92	MB07A_1.0			1			
		8.22	8.04							
☒ A&M	1.50			MB07A_1.5					SANDSTONE, moderately to very well cemented, fine to coarse grained sands, poorly sorted, sub angular to sub rounded, calcareous, pale brown, high shell content, high presence of fossils	
☒ ASS	2.00			MB07A_2.0			2			
					SWL = 2.12 m bgl					
☒ ASS	2.50			MB07A_2.5						
		8.50	8.35							
☒ A&M	3.00			MB07A_3.0			3		Extent of Investigation @ 3.2 mbgl	
☒ Metals	3.10			MB07A_3.2						
							4			

REMARKS:

URS

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SOIL BORE E008 (MB08A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **R, Parker**
Checked By: **MN**
Date Started: **5-4-09**
Date Finished: **5-4-09**

Relative Level: **mRL**
Coordinates: **7599460.00 mN**
293243.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
A&M	0.00	7.72	6.30	MB08A_0.0-0.1			0		SAND, sub angular to sub rounded, poorly sorted, poorly consolidated, quartz, minor silt, red/brown	
		8.39	6.88							
A&M	0.50	8.58	6.33	MB08_0.5						
		8.78	8.85							
A&M	1.00	8.85	6.47	MB08A_1.0-1.5			1			
		8.56	6.50							
Metals	1.50	9.30	6.25	MB08A_1.5						
		9.57	6.36							
							2	ORE LOSS	Core Loss	
Metals	2.50	9.61	6.41	MB08_2.5					silty SAND, sub angular to sub rounded, moderately sorted, well cemented calcareous sandstone, quartz, minor silt, red/brown	
		9.54	6.35							
A&M	2.90	9.48	6.64	MB08_3.0						
							3		Extent of Investigation @ 3.0mbgl	
							4			

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E009 (MB09A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **R, Parker**
Checked By: **MN**
Date Started: **5-4-09**
Date Finished: **5-4-09**

Relative Level: **mRL**
Coordinates: **7599398.00 mN**
243256.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE		SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	A&M	0.00	8.14	6.70	MB09A_0.0			0		silty SAND, sub angular to sub rounded, moderately sorted, poorly consolidated, quartz, red/brown	
			8.16	7.04							
☒	A&M	0.50	8.46	6.87	MB09A_0.5						
			8.47	6.59							
☒	A&M	1.00	8.58	7.12	MB09A_1.0			1			
			9.15	6.33						silty SAND, 50% gravels, well cemented, calcareous sandstone, quartz dominant with feldspar, fine to medium grained, poorly sorted, pale red/brown	
☒	A&M	1.50	9.65	8.33	MB09A_1.5						
			9.47	8.56							
☒	A&M	2.00	9.70	6.71	MB09A_2.0			2		silty SAND, with 30% gravels, well cemented, calcareous sandstone, quartz dominant with feldspar, fine to medium grained, poorly sorted, red/brown	
			9.57	6.43							
☒	Metals	2.50	9.29	6.95	MB09A_2.5						
			9.36	6.66							
☒	A&M	2.90	9.49	7.03	MB09A_3.0					SANDSTONE, moderately hard, ferrous, fossil rich, calcareous cement, shell fragments, minor quartz, pale yellow	
								3		Extent of Investigation @ 3.0 mbgl	
								4			

REMARKS:

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SOIL BORE E010 (MB10A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drilling Contractor: **HAGSTROM DRILLING**

Drill Type: **Diamond Core**

Logged By: **R, Parker**
Checked By: **MN**
Date Started: **14-4-09**
Date Finished: **14-4-09**

Relative Level: **mRL**
Coordinates: **7599684.00 mN**
293462.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒ ASS	0.00	9.32	8.79	MB10A_0.0			0		silty SAND, sub rounded to sub angular, poorly sorted, red/brown	
☒ A&M	0.25	9.33	9.00	MB10A_0.25						
☒ Metals	0.50	9.09	8.10	MB10A_0.5						
		9.00	7.30							
☒ ASS	1.00	8.68	6.92	MB10A_1.0			1			
		8.15	7.50						Silty SAND, red brown, clay weathered, moderately sorted, plastic, moderate stiffness.	
☒ Metals	1.50	7.59	5.06	MB10A_1.5						
		7.25	5.86							
☒ ASS	2.00	7.36	5.90	MB10A_2.0			2		CLAY, moderate plasticity, brown to grey, major shell fragments.	
		7.25	6.04		SWL = 2.29 m bgl					
☒ A&M	2.50	7.16	5.61	MB10A_2.5					gravelly sandy CLAY, moderate plasticity clay, sand is sub angular to sub rounded sands, poorly sorted, micro fossils, angular sandstone gravels 5 to 10mm, red/brown	
		7.28	5.81							
☒ A&M	2.90	7.75	6.19	MB10A_3.0						
							3		Extent of Investigation @ 3.0 mbgl	
							4			

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E011 (MB11A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **R, Parker**
Checked By: **MN**
Date Started: **12-4-09**
Date Finished: **12-4-09**

Relative Level: **mRL**
Coordinates: **7599684.00 mN**
294113.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
							0	CORE LOSS	Core Loss	
					SWL=0.66 m bg					
									calcareous SANDSTONE, fine to medium grained quartz, well cemented and lithified	
									silty SAND, fine grained, well sorted, sub angular to sub rounded quartz, dark minerals, brown	
☒ A&M	1.00	8.33	6.37	MB11A_1.0			1			
		8.23	6.60							
									calcareous SANDSTONE, fine to medium grained, well sorted, sub angular, well sorted, cream/brown	
☒ Metals	1.75			MB11A_1.5						
							2			
☒ ASS	2.75	8.11	6.59	MB11A_2.75						
☒ ASS	3.00	8.11	6.71	MB11A_3.0			3			
									Extent of Investigation @ 3.1 mbgl	
							4			

REMARKS:

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URS

SOIL BORE E012 (MB12A)

Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landform Assessment**
Drilling Contractor: **HAGSTROM DRILLING**			
Drill Type: **Diamond Core**	Logged By: **R, Parker** Checked By: **MN** Date Started: **21-4-09** Date Finished: **21-4-09**	Relative Level: **mRL** Coordinates: **7600445.00 mN** **294958.00 mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
ASS	0.00	7.96	6.86	MB12_0-0.45			0	▨	sandy CLAY, (50% CLAY), fine grained sand, medium plasticity, brown	
Metals	0.50	7.94	6.97	MB12_0.5				▨		
		7.78	5.80		SWL = 0.79 m bgl			▨		
A&M	1.00	7.37	6.40	MB12_1.0			1	▨		
		7.92	5.32					▨	sandy CLAY, (50% CLAY), fine grained sand, medium plasticity, brown with some occasional black mottling	
A&M	1.50	7.19 7.56	2.09 5.07	MB12_1.5				– –	CLAY, tight, high plasticity, occasional black mottling, dark brown	
ASS	2.00	7.55	2.33	MB12_2.0			2	– –		
		8.17	2.80					– –	Grades to silty SAND, fine grained, sub angular to sub rounded, tight, (20% silt) occasional red mottling	
A&M	2.50	8.34	6.60	MB12_2.5				⁘	SAND, coarse grained, angular, loose, brown	
		8.15	5.75					⁘		
ASS	2.90	8.47	7.20	MB12_3.0				⁘		
							3		Extent of Investigation @ 3.0 mbgl	
							4			

REMARKS:

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URS

SOIL BORE E013 (MB13A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004
9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **R, Parker**
Checked By: **MN**
Date Started: **10-4-09**
Date Finished: **10-4-09**

Relative Level: **mRL**
Coordinates: **7600692.00 mN**
295014.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
A&M	0.00	8.90	8.70	MB13A_0-0.45			0	⁙	SAND, fine grained, poor to moderately sorted, sub rounded to sub rounded, shell fragments, loose, brown, dry	
								▥ CORE LOSS	Core Loss	
ASS	1.00	8.85	8.64	MB13A_1.0	SWLI=1.0 m bgl		1	⁙	Calcareous SANDSTONE, moderately well cemented, hard, calcareous, fine to coarse grained, poorly sorted, quartz in silty matrix, some shells, cream/orange	
Metals	1.50	8.75	8.50	MB13A_1.5-1.95						
		9.20	7.18				2	⁙	Calcareous SANDSTONE, fine to medium grained, becoming more calcareous at 2.3m, poorly sorted, very coarse 2mm quartz and feldspar	
ASS	2.25			MB13A_2.25						
ASS	2.85	8.80	7.19	MB13A_2.85-3.0			3	⁙	SAND, poor to moderately cemented, poorly sorted, fine to coarse grained quartz, shell fragments, becomes fine grained from 3.0 to 3.4m, shell rich layer at 3.5 to 3.6m	
							4		Extent of Investigation @ 3.7 mbgl	

REMARKS:

URS

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SOIL BORE E015 (MB15A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004
9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **R, Parker**
Checked By: **MN**
Date Started: **8-4-09**
Date Finished: **8-4-09**

Relative Level: **mRL**
Coordinates: **7596347.00 mN**
290894.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
A&M	0.00	7.62	6.36	MB15A_0-0.2			0		Core Loss	
ASS	0.25	7.68	6.46	MB15A_0.25-0.45						
A&M	0.50	7.68	6.92	MB15A_0.5				CORE LOSS		
ASS	0.60			MB15A_0.5-0.65						
		8.07	7.77							
A&M	1.00	8.39	7.90	MB15A_1.0			1		SAND, fine grained, well sorted, 5% clay content, red/brown	
		8.45	8.46							
A&M	1.50	8.50	7.89	MB15A_1.5-1.75						
ASS	1.75	8.56	8.10	MB15A_1.75-1.95						
Metals	2.08			MB15A_2.08			2			
		8.48	8.21						Grades into fine grained clayey SAND with well cemented sandstone nodules.	
A&M	2.50	8.85	8.12	MB15A_2.5						
		9.00	8.24							
A&M	2.90			MB15A_3.0						
		8.78	8.32				3		Extent of Investigation at 3.0 mbgl	
							4			

REMARKS:

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URS

SOIL BORE E016 (MB16A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **C. Clark**
Checked By: **MN**
Date Started: **4-4-09**
Date Finished: **4-4-09**

Relative Level: **mRL**
Coordinates: **7596335.00 mN**
290313.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
Metals	0.00	6.34	6.30	MB16A_0.0-0.05			0		SAND, fine to medium grained, rounded to sub rounded, some rootlets, red/brown, dry	
		6.56	5.86						silty SAND, fine to medium grained, rounded to sub rounded, red brown/brown, moist	
A&M	0.50			MB16A_0.5						
		6.02	6.57							
A&M	1.00	6.13	6.58	MB16A_1.0			1			
		7.12	7.22							
A&M	1.50	6.88	7.08	MB16A_1.5-1.0					silty SAND, fine to medium grained, traces of fine gravels, rounded to sub rounded, red brown/brown, moist	
		7.85	7.45							
A&M	2.00	7.85	7.26	MB16A_2.0			2			
		7.83	8.08							
A&M	2.50	7.93	8.53	MB16A_2.5						
		8.16	8.19							
ASS	2.90			MB16A_3.0						
		8.02	8.09				3		Extent of Investigation @ 3.0 mbgl	
							4			

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E017 (MB17A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **C. Clark**
Checked By: **MN**
Date Started: **2-4-09**
Date Finished: **2-4-09**

Relative Level: **mRL**
Coordinates: **7596324.00 mN**
290022.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION
ASS	0.00	6.63	5.40	MB17A_0.0-0.25		
ASS	0.25	7.53	6.64	MB17A_0.25-0.5		
ASS	1.10			MB17A_1.1-1.4	SWL = 1.07 m bgl	
		7.27	7.88			
A&M	1.50			MB17A_1.5-1.75		
		6.67	6.65			
Metals				MB17A_1.75		
Metals	2.00	7.17	7.22	MB17A_2-2.25		
ASS	2.25	7.29	7.10	MB17A_2.25-2.45		
ASS	3.50	7.30	7.64	MB17A_3.5-3.75		
		7.17	6.93			
ASS				MB17A_4.2-4.50		

DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
0		clayey SAND, fine to coarse grained, some fine gravels with trace organics, red/brown	
	CORE LOSS	Core Loss	
1		sandy CLAY, medium plasticity, fine to medium grained sand, trace organics, red/brown	
		clayey sandy GRAVEL, fine to coarse grained sand, sub angular to sub rounded gravels, red/brown	
2		sandy clayey GRAVEL, fine to medium grained, black/brown with brown clay	
		sandy clayey GRAVEL, fine to coarse grained, red/brown, with brown clays	
3		silty SAND, fine grained sands, red/brown	
		silty SANDY GRAVEL, limestone fragments, gravels, red/brown	
4		sandy CLAY, fine grained sands, some silts, dense, black	
		clayey sandy GRAVEL, fine to medium grained sand, grey/black	
		Extent of Investigation @4.6 mbgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E018 (MB18A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **R, Parker**
Checked By: **MN**
Date Started: **15-4-09**
Date Finished: **15-4-09**

Relative Level: **mRL**
Coordinates: **7600287.00 mN**
293920.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
A&M	0.00	7.35	7.82	MB18A_0-0.45			0		SAND, fine to medium occasionally coarse grained, moderately sorted, sub angular to sub rounded, quartz, minor feldspar and dark minerals, brown	
		8.66	9.06							
A&M	1.00	7.65	6.13	MB18A_1.0			1			
		8.80	6.83						Grades into silty sand, to silty sandy CLAY, firm, light brown	
A&M	1.50	6.29	5.02	MB18A_1.5						
A&M	2.00	6.77	5.30	MB18A_2.0			2		CLAY, soft, medium to high plasticity, occasional patches of silty SAND becoming harder towards 3.0m, cream/brown with yellow mottles	
		6.90	4.59							
A&M	2.50	6.50	5.22	MB18A_2.5						
		6.29	3.60		SWL = 2.69 m bgl					
A&M	2.90	5.99	9.00	MB18A_3.0						
							3		Extent of Investigation at 3.0 mbgl	
							4			

REMARKS:

Sheet 1 of 1

URS

SOIL BORE E019 (MB19A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004
9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **C. Clark**
Checked By: **MN**
Date Started: **29-4-09**
Date Finished: **29-4-09**

Relative Level: **mRL**
Coordinates: **7600754.00 mN**
293685.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒ A&M	0.00	7.35	7.68	MB19A_0.0			0		SAND, fine to medium grained, well sorted, shell fragments, red/brown, dry	
		7.34	7.63							
☒ ASS	0.50			MB19A_0.5				CORE LOSS	Core Loss	
☒ A&M	1.00	7.96	7.34	MB19A_1.0			1		SAND, fine to medium grained, small to large shell fragments, dark brown/red, wet	
ASS		5.50	1.05						SAND, fine grained, moderately tight, 5% clay content, dark grey, wet	
☒ PASS	1.50	7.59	0.70	MB19A_1.5					CLAY, low plasticity, moderately tight, dark grey, moist to wet	
☒ Metals	1.75	7.83	0.89	MB19A_1.75						
☒ A&M	2.00	7.43	0.85	MB19A_2.0	swl=2.12 m bgl		2		Calcaerous SANDSTONE, weathered, some small shell fragments, cream/white, dry.	
							3		Extent of Investigation @ 3.0 mbgl	
							4			

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E021 (MB21A)

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **HAGSTROM DRILLING**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Diamond Core**

Logged By: **C. Clark**
Checked By: **MN**
Date Started: **21-4-09**
Date Finished: **21-4-09**

Relative Level: **mRL**
Coordinates: **7600707.00 mN**
293984.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
							0	░	SAND, fine to medium grained, poor to moderately sorted, sub angular to sub rounded quartz, brown.	
					swl=1.0 m bgl		1	×	sandy silty CLAY, red brown sand is fine to coarse grained, poorly sorted, some shell fragments.	
							2	⁚	Calcareous SANDSTONE, fine to medium grained, light brown, moderately cemented, minor shell fragments.	
							3		End of Hole at 3.0 mbgl.	
							4			

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E034

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **25-4-09**
Date Finished: **25-4-09**

Relative Level: **mRL**
Coordinates: **7600206.00 mN**
294515.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
ASS	0.00	7.33	7.76	E034_0.0-0.2			0	▨	sandy CLAY, fine to medium grained, moderate plasticity, shell fragments, red/brown with grey mottling, dry to moist	
Metals	0.25	7.12	7.31	EO34_0.25-0.35				▨	sandy CLAY, moderate to high plasticity, fine grained sands, grey, moist to wet	
ASS	0.50	6.68	7.17	E034_0.5-0.6	swl=0.47 m bgl			▨		
Metals	0.75	6.35	7.05	E034_0.75-0.85				– –	CLAY, moderate plasticity, brown, wet	
ASS & Metals	1.00	6.15	6.67	E034_1.0-1.1			1	– –		
									End of hole at 1.1mbgl due to core loss	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E036

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **9-7-09**
Date Finished: **9-7-09**

Relative Level: **mRL**
Coordinates: **7598997.00 mN**
294083.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	6.28	6.60	E036_0.0-0.10			0	▨	silty SAND, very fine to medium grained, tight, dry to moist, red/brown	
☒	0.25	6.21	6.61	E036_0.25-0.30				▨		
									End of Hole @ 0.4 m bgl due to refusal	
							1			

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E037

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **9-7-09**
Date Finished: **9-7-09**

Relative Level: **mRL**
Coordinates: **7598059.00 mN**
294330.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	**DESCRIPTION OF STRATA**	GEOLOGICAL DESCRIPTION
☒	0.00	6.29	6.61	E037_0.0-0.1.0			0		silty SAND, very fine to medium grained, tight, dry to moist, red/brown	
☒	0.25	6.27	6.60	E037_0.25-0.30						
									End of Hole @ 0.4 m bgl due to refusal	
							1			

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E038

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **9-7-09**
Date Finished: **9-7-09**

Relative Level: **mRL**
Coordinates: **7597474.00 mN**
294922.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	6.57	6.50	E038_0.0-0.10			0	▨	clayey SAND, fine grained sand, some black mottling at the surface, red/brown, moist	
					swl=0.2 m bgl					
☒	0.25	6.58	5.39					▨	sandy CLAY, fine to medium grained sand, low plasticity, loose, wet, light brown/cream	
☒	0.50	6.78	4.95	E038_0.50-0.60				▨	clayey SAND, fine to medium grained sand, loose, red/brown, moist	
☒	0.75	5.88	3.77							
☒	0.95	5.74	2.20	E038_0.95-1.0						
							1		End of Hole @ 1.0 m bgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E039

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **9-7-09**
Date Finished: **9-7-09**

Relative Level: **mRL**
Coordinates: **7596917.00 mN**
294095.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	6.65	6.91	E039_0.0-0.1.0			0		silty SAND, very fine to medium grained, tight, dry to moist, red/brown	
☒	0.25	6.71	6.89	E039_0.25-0.30						
									End of Hole @ 0.4 m bgl due to refusal	
							1			

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E040

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **25-4-09**
Date Finished: **25-4-09**

Relative Level: **mRL**
Coordinates: **7599709.00 mN**
292978.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
Metals	0.00	8.12	7.62	EO40_0.0-0.1			0	×	silty SAND, fine grained sand, loose, brown/red, dry	
		6.88	6.55					▨	sandy CLAY, high plasticity, tight, red/brown, dry to moist, very fine grained sands	
					swl=0.35 m bgl					
								–	CLAY, moderate to high plasticity, moderately tight, grey/red, wet	
ASS & Metals	0.50	6.64	6.58	EPO40_0.5-0.6						
								–	CLAY, low to moderate plasticity, grey, wet	
ASS & Metals	0.75	5.17	5.11	EPO40_0.75-0.85						
ASS	1.00	4.80	5.05	EPO40_1.0-1.10			1			
									End oh Hole at 1.1mbgl due to core loss	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E040A

Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landform Assessment**
Drilling Contractor: **None**			
Drill Type: **Hand Auger**	Logged By: **C.Clark** Checked By: **MN** Date Started: **7-7-09** Date Finished: **7-7-09**	Relative Level: **mRL** Coordinates: **7599709.00 mN** **292978.00 mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	7.39	7.72	E040_0.0-0.10			0	▨	sandy CLAY, medium to high plasticity, fine grained, angular sand, red/brown	
☒	0.25	7.25	7.77					▨		
					swl=0.45 m bgl			▧	CLAY, high plasticity, becomes moist to wet, yellow/grey with red mottling, tight	
☒	0.50	7.28	7.23	E040_0.5-0.6				▧		
☒	0.75	7.33	4.95					▧		
☒	1.00	7.28	4.95	E040_1.0-1.10			1	▧		
									End of Hole @ 1.10 m bgl	

REMARKS:

URS		**SOIL BORE E041**	Sheet 1 of 1
Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landform Assessment**
Drilling Contractor: **None**			
Drill Type: **Hand Auger**	Logged By: **C.Clark** Checked By: **MN** Date Started: **8-7-09** Date Finished: **8-7-09**	Relative Level: **mRL** Coordinates: **7598163.00 mN** **291958.00 mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	7.26	7.8	E041_0.0-0.10			0	▨	sandy CLAY, fine to medium grained sand, moderate plasticity, black organic sludge at surface, some large shell fragments, moderately tight, red/brown	
☒	0.25	8.01	7.15							
					swl=0.45 m bgl					
☒	0.50	7.07	6.95	E041_0.5-0.60				▨	CLAY, red/brown, high plasticity, tight, wet	
☒	0.75	7.15	7.1							
☒	0.95	6.94	6.63	E041_0.95-1.0						
							1		End of Hole @ 1.0 m bgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E042

Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landform Assessment**
Drilling Contractor: **None**			
Drill Type: **Hand Auger**	Logged By: **C.Clark** Checked By: **MN** Date Started: **26-4-09** Date Finished: **26-4-09**	Relative Level: **mRL** Coordinates: **7599136.00 mN** **290855.00 mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
ASS & Metals	0.00	5.02	7.70	E042_0.0-0.1			0		sandy CLAY, fine grained sands, low plasticity, red, dry	
		6.05	7.53						CLAY, low to medium plasticity, red, dry to moist	
ASS & Metals	0.50	7.31	7.64	E042_0.5	swl=0.5 m bgl				CLAY, high plasticity, red/brown/grey with some grey/yellow mottling, wet	
		7.13	5.32						CLAY, high plasticity, grey with some yellow mottling, wet	
Metals	1.00	5.85	2.99	E042_1.0			1			
									End of Hole at 1.2mbgl due to wet Core Loss	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E042A

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **7-7-09**
Date Finished: **7-7-09**

Relative Level: **mRL**
Coordinates: **7599136.00 mN**
290855.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	7.31	0.92	E042_0.0-0.10			0	▨	sandy CLAY, medium to high plasticity, fine grained, angular sand, red/brown	
☒	0.25	6.90	1.05					▨		
					0.45 m bgl			▧	CLAY, high plasticity, becomes moist to wet, yellow/grey with red mottling, tight	
☒	0.50	7.00	1.15	E042_0.50-0.60				▧		
☒	0.75	6.62	0.75					▧		
☒ PASS	0.90			E042_0.90-1.0				▧		
☒ Metals	1.00	6.61	0.80	E042_1.0-1.1			1	▧		
									End of Hole @ 1.1 m bgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E045

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landform Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **7-7-09**
Date Finished: **7-7-09**

Relative Level: **mRL**
Coordinates: **7597631.00 mN**
290687.00 mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	7.70	7.68	E045_0.0-0.10			0		gravelly SAND, sub angular to angular gravel to 20mm, 20% gravel 80% sand, fine to medium grained, sub rounded to sub angular sand, red/brown	
☒	0.25	7.0	7.30							
☒	0.50	7.45	8.09	E045_0.50-0.60						
☒	0.75	7.42	8.20						gravel increases to 30% from 0.75 - 0.10 m with occasional shell fragment	
☒	0.90	8.25	8.10	E045_0.9-1.0						
							1		End of Hole @ 1.0 m bgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E046

Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landforms Assessment**
Drilling Contractor: **None**			
Drill Type: **Hand Auger**	Logged By: **C.Clark** Checked By: **MN** Date Started: **21-10-09** Date Finished: **21-10-09**	Relative Level: **mRL** Coordinates: **mN** **mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	8.29	8.76	E046_0.0-0.1			0	▨	clayey SAND, red/brown, fine to medium grained, low plasticity, <10% clays, loose	
☒	0.25	8.54	8.79							
☒	0.50	7.98	7.98	E046_0.5-0.6						
	0.75	7.78	8.40							
☒	1.00	7.89	8.75	E046_1.0-0.1			1			
☒	1.25	8.15	8.67							
☒	1.30	7.87	8.70	SB46_1.3-1.4						
									End of Hole at 1.4 mbgl	

REMARKS:

Sheet 1 of 1

SOIL BORE E047

Level 3, 20 Terrace Road
East Perth, W.A. 6004
9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landforms Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **20-10-09**
Date Finished: **20-10-09**

Relative Level: **mRL**
Coordinates: **mN**
mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	7.20	8.20	E047_0.0-0.1			0		clayey SAND, red/brown, low plasticity, fine grained, moderately tight	
☒	0.25	7.39	8.20							
☒	0.50	7.50	8.57	E047_0.5-0.6						
☒	0.75	7.61	8.17							
☒	1.00	7.45	8.14	E047_1.0-1.1			1		clayey SAND, red/brown, medium grained, less clay content with depth	
									Groundwater intercepted at 1.0 mbgl	
☒	1.25	7.04	8.03							
☒	1.50	7.06	8.00	E047_1.5-1.6						
									End of Hole at 1.6 mbgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E048

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landforms Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **20-10-09**
Date Finished: **20-10-09**

Relative Level: **mRL**
Coordinates: **mN**
mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00			E048_0.0-0.1			0		silty SAND, light brown, very fine grained, loose	
☒	0.50			E048_0.5-0.6					clayey SAND, red/brown, fine to medium grained, low to moderate plasticity, tight	
☒	1.00			E048_1.0-1.1			1			
☒	1.50			E048_1.5-1.6						
									End of Hole at 1.6 mbgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE E052

Level 3, 20 Terrace Road
East Perth, W.A. 6004
9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landforms Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **19-10-09**
Date Finished: **19-10-09**

Relative Level: **mRL**
Coordinates: **mN**
mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	6.90	7.15	SS52_0.0-0.10			0		silty SAND, light brown, very fine grained, < 5% gravels to 5mm, sub angular to sub rounded, loose	
☒	0.25	6.30	7.32							
☒	0.50	6.24	5.11	SS52_0.5-0.6						
☒	0.75	6.35	5.42						sandy CLAY, red/brown, low plasticity, becoming moist with depth, tight	
☒	1.00	7.20	6.69	SS52_1.0-1.1			1			
☒	1.25	6.88	6.58							
☒	1.40	7.21	5.10							
									End of Hole at 1.5 mbgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE SS01

Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landforms Assessment**
Drilling Contractor: **None**			
Drill Type: **Hand Auger**	Logged By: **C.Clark** Checked By: **MN** Date Started: **19-10-09** Date Finished: **19-10-09**	Relative Level: **mRL** Coordinates: **mN** **mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	8.15	8.22	SS01_0.0-0.10			0		silty gravelly SAND,light brown, fine grained, sub angular gravels, <10% gravels, loose	
☒	0.25	7.74	8.55							
☒	0.50	7.74	8.55	SS01_0.5-0.6						
☒	0.75	7.42	7.91						gravelly SAND, light brown, fine to medium grained, <20% gravel	
									silty CLAY, red/brown, tight	
☒	1.00	7.50	7.89	SS01_1.0-1.1			1			
☒	1.15	7.50	7.97							
									End of Hole @ 1.25 m bgl due to core loss	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE SS03

Level 3, 20 Terrace Road East Perth, W.A. 6004	9326 0100 9326 0296	Project No.: **WHST-STU-ET-RPT-0068**	Project Reference: **BSQ and Landforms Assessment**
Drilling Contractor: **None**			
Drill Type: **Hand Auger**	Logged By: **C.Clark** Checked By: **MN** Date Started: **20-10-09** Date Finished: **20-10-09**	Relative Level: **mRL** Coordinates: **mN** **mE** Permit No: **N/A**	Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	6.76	7.89	SS03_0.0-0.10			0		clayey SAND, red/brown, fine grained, low plasticity, moderately tight	
☒	0.25	7.58	7.83							
☒	0.50	7.25	7.98	SS03_0.5-0.60						
☒	0.75	7.55	7.81						sandy CLAY, red/brown, fine grained, low to medium plasticity, some yellow mottling	
☒	0.90	7.65	7.80	SS03_0.9-1.0						
							1			
									Grades to moist at 1.1 mbgl	
☒	1.25	7.58	7.58							
☒	1.40	7.58	8.01	SS03_1.5-1.5						
									End of Hole at 1.5 mbgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE SS04

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landforms Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **21-10-09**
Date Finished: **21-10-09**

Relative Level: **mRL**
Coordinates: **mN**
mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	7.67	8.20	SS04_0.0-0.1			0		sandy CLAY, red/brown, low plasticity, fine grained, tight	
☒	0.25	7.56	8.20							
☒	0.50	7.41	8.20	SS04_0.5-0.6						
☒	0.75	7.53	7.78							
☒	1.00	7.50	7.78	SS04_1.0-1.1			1			
☒	1.25	7.67	8.15						Grades to moist at 1.2 mbgl	
☒	1.50	7.65	8.15	SS04_1.5-1.6						
									End of Hole at 1.6 mbgl	

REMARKS:

Sheet 1 of 1

URS

SOIL BORE SS05

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landforms Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **21-10-09**
Date Finished: **21-10-09**

Relative Level: **mRL**
Coordinates: **mN**
mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	8.57	8.40	SS05_0.0-0.1			0		silty SAND, light brown, very fine grained, loose	
☒	0.25	8.54	8.17							
☒	0.50	8.56	8.10	SS05_0.5-0.6					clayey SAND, red/brown, fine to medium grained, low plasticity	
☒	0.75	8.48	8.27							
☒	1.00	9.00	8.32	SS05_1.0-1.1			1		Grades to moist at 1.0 mbgl	
									clayey SAND, red/brown, fine to medium grained, low plasticity, increased clay content at 1.2 m, moist	
☒	1.25	8.39	8.11							
☒	1.50	8.86	8.12	SS05_1.5-1.6						
									End of Hole at 1.6 mbgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE SS06

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landforms Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **21-10-09**
Date Finished: **21-10-09**

Relative Level: **mRL**
Coordinates: **mN**
mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	7.57	7.65	SS06_0.0-0.1			0		sandy CLAY, brown/red, moderate plasticity, fine to medium grained	
☒	0.25	7.69	7.84						sandy CLAY, dark grey/yellow mottling with black organic matter, fine to medium grained	
☒	0.50	7.62	7.84	SS06_0.5-0.6						
☒	0.75	7.35	7.79						Wet at 0.7 mbgl	
☒	1.00	7.15	7.80	SS06_1.0-1.1			1		clayey SAND, red/brown, yellow mottling, low plasticity, fine to medium grained	
☒	1.25	7.13	7.43							
☒	1.50	7.21	7.43	SS06_1.5-1.6						
									End of Hole at 1.6 mbgl	

REMARKS:

URS

Sheet 1 of 1

SOIL BORE SS07

Level 3, 20 Terrace Road
East Perth, W.A. 6004

9326 0100
9326 0296

Drilling Contractor: **None**

Project No.: **WHST-STU-ET-RPT-0068**

Project Reference: **BSQ and Landforms Assessment**

Drill Type: **Hand Auger**

Logged By: **C.Clark**
Checked By: **MN**
Date Started: **21-10-09**
Date Finished: **21-10-09**

Relative Level: **mRL**
Coordinates: **mN**
mE
Permit No: **N/A**

Client: **Chevron Wheatstone LNG**

SAMPLE TYPE	SAMPLE RUN (m)	Field pH(f) (pH units)	Field pH(fox) (pH units)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	PIEZOMETER CONSTRUCTION	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
☒	0.00	5.32	3.81	SS07_0.0-0.1			0		sandy CLAY, brown/red, moderate plasticity, fine to medium grained	
☒	0.25	5.60	1.94						sandy CLAY, dark grey/yellow mottling with black organic matter, fine to medium grained	
☒	0.50	5.06	2.72	SS07_0.5-0.6						
									Wet at 0.7 mbgl	
☒	0.75	5.15	2.17							
☒	1.00	5.50	2.31	SS07_1.0-1.1			1		clayey SAND, red/brown, yellow mottling, low plasticity, fine to medium grained	
☒	1.25	5.47	2.65							
☒	1.50	6.10	3.31	SS07_1.5-1.6						
									End of Hole at 1.6 mbgl	

REMARKS:

D

Appendix D Field Test and Analytical Result Summary Sheets

APPENDIX D

Soils and Landform Assessment and Field Test Results

										FIELD TESTS				
Start date	**Site ID**	**Site ID2**	**Land system**	**Landform Unit**	**Sources Used**	**Landform Elements**	**From (mbgl)**	**To (mbgl)**	**Lithological Description**	**pH(f)**	**pH(fox)**	**pH (change)**	**Reaction Type**	**HCL Reaction (No/Yes)**
Ashburton North and Surrounds Study Area														
30/03/09	E003	MB03A	Dune	Longitudinal Dunes and Interdunal Swales	Aerial Photography (Landgate,2007)	interdunal swale between dunes.	0.5	0.7	Sand/Calcareous SANDSTONE	8.89	9.07	-0.18	L	Y
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	undulating topography with slopes of 10-15 degrees	1	1.25	Sand/Calcareous SANDSTONE	8.77	9.09	-0.32	L	Y
					Ashburton North Area	moderately vegetated with spinifex and low shrubs	1.75	1.95	Sand/Calcareous SANDSTONE	9.01	9.1	-0.09	L	Y
					Groundtruthing (March-June, 2009)	calcareous cobbles on surface adjacent site	2	2.15	Sand/Calcareous SANDSTONE	9	9.1	-0.1	L	Y
						sparse shell	2.65	2.85	Sand/Calcareous SANDSTONE	8.8	9.01	-0.21	L	Y
							2.85	3	Sand/Calcareous SANDSTONE	8.89	9.11	-0.22	L	Y
27/03/09	E004	MB04A	Dune	Longitudinal Dunes and Interdunal Swales	Aerial Photography (Landgate,2007)	As above	0.25	0.35	SAND, light brown	8.73	8.86	-0.13	L	Y
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)		0.5	0.65	SAND, light brown	9.17	9.28	-0.11	L	Y
					Ashburton North Area		1.5	1.8	SANDSTONE	8.72	9.09	-0.37	L	Y
					Groundtruthing (March-June, 2009)		2.2	2.35	SANDSTONE	8.83	9.31	-0.48	L	Y
2/04/09	E005	MB05A	Dune	Longitudinal Dunes and Interdunal Swales	Aerial Photography (Landgate,2007)	interdunal swale between dunes.	0	0.25	silty SAND, red brown, fine to medium grained	7.03	6.2	0.83	H	-
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	site is marginal to the slope of the ridge, in a basin between two ridges	0.25	0.5	silty SAND, red brown, fine to medium grained	7.68	6.33	1.35	H	-
					Ashburton North Area	adjacent plains to the east	0.5	0.75	gravelly SAND, brown, fine to medium grained	7.33	6.42	0.91	L	-
					Groundtruthing (March-June, 2009)	surface soils is slightly hard set sands.	0.75	1	sandy GRAVEL, light grey, fine to medium grained	7.34	6.8	0.54	M	Y
							1.25	1.5	silty sandy GRAVEL	7.62	7.06	0.56	L	Y
							1.5	1.75	silty sandy GRAVEL	7.69	6.57	1.12	L	Y
							1.75	2	silty sandy GRAVEL	7.74	7.87	-0.13	M	Y
							2	2.25	silty sandy GRAVEL	7.77	7.7	0.07	H	Y
							2.25	2.5	sandy silty GRAVEL	8.15	7.53	0.62	L	Y
							2.5	2.75	sandy silty GRAVEL	8.09	7.8	0.29	L	Y
							2.75	3	clayey silty SAND	8.11	7.63	0.48	L	Y
5/04/09	E008	MB08A	Dune	Longitudinal Dunes and Interdunal Swales	Aerial Photography (Landgate,2007)	marginal edge to longitudinal dunes and alluvial/colluvial plain	0.00	0.05	SAND, red brown	7.72	6.3	1.42	M	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	slope is generally flat to 2 degrees of general surrounds	0.25	0.30	SAND, red brown	8.39	6.88	1.51	M	N
					Ashburton North Area	soil surface is loose, friable incoherent sand.	0.45	0.50	SAND, red brown	8.58	6.33	2.25	M	N
					Groundtruthing (March-June, 2009)	moderately vegetated spinifex. Sparse shrubs	0.70	0.75	SAND, red brown	8.78	8.85	-0.07	M	N
							1.00	1.05	SAND, red brown	8.85	6.47	2.38	M	N
							1.25	1.30	SAND, red brown	8.56	6.5	2.06	L	N
							1.50	1.55	SAND, red brown	9.3	6.25	3.05	L	Y
							1.75	1.80	SAND, red brown	9.57	6.36	3.21	L	Y
							1.95	2.40	CORE LOSS	-	-	-	-	-
							2.50	2.55	silty SAND, red brown	9.61	6.41	3.2	L	Y
							2.75	2.80	silty SAND, red brown	9.54	6.35	3.19	L	Y
							2.95	3.00	silty SAND, red brown	9.48	6.64	2.84	L	Y
5/04/09	E009	MB09A	Dune	Longitudinal Dunes and Interdunal Swales	Aerial Photography (Landgate,2007)	Interdunal swale, marginal to longitudinal dune	0.00	0.05	silty SAND red/brown	8.14	6.7	1.44	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	sand dune within saddle area. Intertidal area to the north west	0.25	0.30	silty SAND red/brown	8.16	7.04	1.12	L	N
					Ashburton North Area	downslope is 3-5 degrees (looking north west)	0.45	0.50	silty SAND red/brown	8.46	6.87	1.59	L	N
					Groundtruthing (March-June, 2009)	surface soils are very fine -fine (silty sand), friable (light finger pressure)	0.70	0.75	silty SAND red/brown	8.47	6.59	1.88	L	N
						sparse vegetation of hummock grasses and weeds. Very sparse shrubs	1.00	1.05	silty SAND red/brown	8.58	7.12	1.46	L	Y
						no organised or incised drainage patterns	1.25	1.30	silty SAND red/brown	9.15	6.33	2.82	L	Y
						Longitudinal dune network ends toward north east	1.50	1.55	silty SAND red/brown	9.65	8.33	1.32	L	Y
							1.75	1.80	silty SAND red/brown	9.47	8.56	0.91	L	Y
							2.00	2.05	silty SAND red/brown	9.7	6.71	2.99	L	Y
							2.25	2.30	silty SAND red/brown	9.57	6.43	3.14	L	Y
							2.50	2.55	silty SAND red/brown	9.29	6.95	2.34	L	Y
							2.75	2.80	silty SAND red/brown	9.36	6.66	2.7	L	Y
							2.95	3.00	SANDSTONE	9.49	7.03	2.46	L	Y
4/04/09	E016	MB16A	Dune	Longitudinal Dunes and Interdunal Swales	Aerial Photography (Landgate,2007)	Interdunal swale, site is in a saddle marginal to longitudinal dunes of 2-3 m in height	0	0.05	SAND, red brown	6.34	6.3	0.04	M	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	moderately vegetated with hummock grasses and low shrubs.	0.25	0.3	SAND, red brown	6.56	5.86	0.7	M	N
					Ashburton North Area	groundwater not intercepted	0.5		SAND, red brown	-	-	-	-	-
					Groundtruthing (March-June, 2009)	surface soils are fine, red sands	0.75	0.8	silty SAND, red brown, fine to medium grained	6.02	6.57	-0.55	L	N
							1	0.05	silty SAND, red brown, fine to medium grained	6.13	6.58	-0.45	L	N
							1.25	1.3	silty SAND, red brown, fine to medium grained	7.12	7.22	-0.1	L	N
							1.5	1.55	silty SAND, red brown, fine to medium grained	6.88	7.08	-0.2	L	Y
							1.75	1.8	silty SAND, red brown, fine to medium grained	7.85	7.45	0.4	L	Y
							2	2.05	silty SAND, red brown, fine to medium grained	7.85	7.26	0.59	L	Y
							2.25	2.3	silty SAND, red brown, fine to medium grained	7.83	8.08	-0.25	L	Y
							2.5	2.55	silty SAND, red brown, fine to medium grained	7.93	8.53	-0.6	L	Y
							2.75	2.8	silty SAND, red brown, fine to medium grained	8.16	8.19	-0.03	L	Y
							3	3.05	silty SAND, red brown, fine to medium grained	8.02	8.09	-0.07	L	Y
8/04/09	E015	MB15A	Dune	Longitudinal Dunes and Interdunal Swales	Aerial Photography (Landgate,2007)	undulating interdunal swale, soil red, saddle between ridges	0.00	0.05	SAND, fine grained, well sorted, red/brown	7.62	6.36	1.26	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	moderately vegetated with spinifex and sparsely with acacia	0.25	0.30	SAND, fine grained, well sorted, red/brown	7.68	6.46	1.22	M	N
					Ashburton North Area	ridges are 6-7 m in height	0.45	0.50	SAND, fine grained, well sorted, red/brown	7.68	6.92	0.76	M	N
					Groundtruthing (March-June, 2009)	drainage is through soil, no discernible drainage lines	0.70	0.75	SAND, fine grained, well sorted, red/brown	8.07	7.77	0.3	L	Y
						sand has no cohesion when disturbed	1.00	1.05	SAND, fine grained, well sorted, red/brown	8.39	7.9	0.49	L	Y
							1.25	1.30	SAND, fine grained, well sorted, red/brown	8.45	8.46	-0.01	L	Y
							1.50	1.55	SAND, fine grained, well sorted, red/brown	8.5	7.89	0.61	L	Y
							1.75	1.80	SAND, fine grained, well sorted, red/brown	8.56	8.1	0.46	L	Y
							2.00	2.05	SAND, fine grained, well sorted, red/brown	-	-	-	-	-
							2.25	2.30	SAND, fine grained, well sorted, red/brown	8.48	8.21	0.27	L	Y
							2.50	2.55	clayey SAND, red brown	8.85	8.12	0.73	L	Y
							2.75	2.80	clayey SAND, red brown	9	8.24	0.76	L	Y
							2.95	3.00	clayey SAND, red brown	8.78	8.32	0.46	L	Y

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APPENDIX D

Soils and Landform Assessment and Field Test Results

Start date	Site ID	Site ID2	Land system	Landform Unit	Sources Used	Landform Elements	From (mbgl)	To (mbgl)	Lithological Description	FIELD TESTS				
										pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)
17/04/09	E006	MB06A	Dune	Alluvial/Colluvial Plains	Aerial Photography (Landgate,2007)	marginal slope to water drainage area on west of dunes area	0.00	0.05	silty sandy CLAY, red brown	8.11	7.57	0.54	M	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	slope of site 5 degrees to base of dune	0.25	0.30	silty sandy CLAY, red brown	8.24	7.72	0.52	H	Y
					Ashburton North Area	site is flat to 1-3% slope to W-SW	0.50	0.55	silty sandy CLAY, red brown	7.89	7.75	0.14	H	Y
					Groundtruthing (March-June, 2009)	adjacent dune ~10-12m in height	0.70	0.75	SAND, very fine grained, red brown	7.79	6.4	1.39	L	N
						moderately vegetated with hummock grasses (spinifex)	1.00	1.05	SAND, very fine grained, red brown	7.8	6.35	1.45	L	N
						soil surface structure amorphous (no structure)	1.50	1.55	SAND, very fine grained, brown	7.68	4.65	3.03	H	N
							1.50	1.95	CORE LOSS	-	-	-	-	-
							1.95	2.20	SAND, very fine grained, brown	7.25	4.8	2.45	H	N
							2.20	2.40	SAND, very fine grained, brown	7.71	4.33	3.38	H	N
							2.40	2.45	SAND, very fine grained, brown	7.51	4.9	2.61	H	N
18/04/09	E007	MB07A	Dune	Alluvial/Colluvial Plains	Aerial Photography (Landgate,2007)	moderately to densely vegetated with spinifex and other shrubs.	0.00	0.05	silty Clay, red/brown, high plasticity	7.88	7.47	0.41	L	Y
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Elevation of ~3m greater than adjacent plains and at base of adjacent dunes	0.25	0.30	silty Clay, red/brown, high plasticity	7.87	7.6	0.27	L	Y
					Ashburton North Area	small dunal ridge (looking south) of ~10m in height	0.50	0.55	silty Clay, red/brown, high plasticity	7.89	7.94	-0.05	L	Y
					Groundtruthing (March-June, 2009)	Marginal slope to former intertidal flood zone	0.70	0.75	silty Clay, red/brown, high plasticity	7.79	8	-0.21	L	Y
						downslope is 3-5 degrees (looking north)	1.00	1.05	silty Clay, red/brown, high plasticity	7.83	7.92	-0.09	L	Y
						some trees 1-3 m in height	1.25	1.30	silty Clay, red/brown, high plasticity	8.22	8.04	0.18	L	Y
						dry, friable, surface soils. Slightly coherent (no harder than finger pressure)	1.50	2.00	CORE LOSS	-	-	-	-	-
							2.00	2.10	CORE LOSS	-	-	-	-	-
							2.1	2.70	Sandstone, well cemented (unable to sample)	-	-	-	-	-
							2.70	3.00	Sandstone, well cemented (unable to sample)	8.5	8.35	0.15	L	Y
17/04/09	E010	MB10A	Onslow	Alluvial/Colluvial Plains	Aerial Photography (Landgate,2007)	Adjacent longitudinal dunes to west and marginal to intertidal flat to east.	0.00	0.05	silty SAND red/brown	9.32	8.79	0.53	L	Y
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	slope is 1-2 degrees.	0.25	0.30	silty SAND red/brown	9.33	9	0.33	L	Y
					Ashburton North Area	soil surface is not hardset, bleached light broad with some coherence.	0.45	0.50	silty SAND red/brown	9.09	8.1	0.99	L	Y
					Groundtruthing (March-June, 2009)		0.70	0.75	silty SAND red/brown	9	7.3	1.7	M	Y
							1.00	1.05	silty SAND red/brown	8.68	6.92	1.76	L	Y
							1.25	1.30	silty SAND red/brown	8.15	7.5	0.65	M	Y
							1.50	1.55	silty SAND red/brown	7.59	5.06	2.53	L	Y
							1.75	1.80	silty SAND red/brown	7.25	5.86	1.39	L	N
							2.00	2.05	CLAY, brown to grey with yellow mottles	7.36	5.9	1.46	H	N
							2.25	2.30	CLAY, brown to grey with yellow mottles	7.25	6.01	1.24	H	N
							2.50	2.55	gravelly sandy CLAY, red brown	7.16	5.61	1.55	H	N
							2.75	2.80	gravelly sandy CLAY, red brown	7.28	5.81	1.47	M	Y
							2.95	3.00	gravelly sandy CLAY, red brown	7.75	6.19	1.56	L	Y
2/04/09	E017	MB17A	Onslow	Alluvial/Colluvial Plains	Aerial Photography (Landgate,2007)	Broad relatively flat plain, slightly undulating (adjacent longitudinal dunes)	0	0.25	clayey SAND, red/brown	6.63	5.4	1.23	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Moderately to densely populated with spinifex and other species	0.25	0.5	clayey SAND, red/brown	7.53	6.64	0.89	L	N
					Ashburton North Area	shallow groundwater encountered.	1.38	1.6	sandy CLAY, red/brown	7.27	7.88	-0.61	L	N
					Groundtruthing (March-June, 2009)		1.6	1.95	clayey sandy GRAVEL	6.67	6.65	0.02	L	N
							1.95	2.25	sandy clayey GRAVEL	7.17	7.22	-0.05	L	N
							2.25	2.45	sandy clayey GRAVEL	7.29	7.1	0.19	L	N
							3.5	3.75	silty SAND	7.3	7.64	-0.34	L	Y
							3.75	4	silty sandy GRAVEL, with limestone	7.17	6.93	0.24	L	Y
15/04/09	E018	MB18A	Onslow	Alluvial/Colluvial Plains	Aerial Photography	South of coastal dunes, low lying broad plains with sandy surface	0.00	0.45	SAND, brown	7.35	7.82	-0.47	L	N
					Aerial Photography (Landgate,2007)	No discernible drainage pattern although slight landform gradient toward the north, i	0.45	0.90	SAND, brown	8.66	9.06	-0.4	M	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	coastal dunes.	1.00	1.05	SAND, brown	7.65	6.13	1.52	L	Y
					Ashburton North Area	moderately vegetated with spinifex	1.25	1.30	silty sandy CLAY, light brown	8.8	6.83	1.97	L	Y
					Groundtruthing (March-June, 2009)		1.50	1.95	silty sandy CLAY, light brown	6.29	5.02	1.27	M	N
							2.00	2.05	CLAY, cream brown with yellow mottles	6.77	5.3	1.47	M	N
							2.25	2.30	CLAY, cream brown with yellow mottles	6.9	4.59	2.31	M	N
							2.50	2.55	CLAY, cream brown with yellow mottles	6.5	5.22	1.28	H	N
							2.75	2.80	CLAY, cream brown with yellow mottles	6.29	3.6	2.69	H	N
							2.95	3.00	CLAY, cream brown with yellow mottles	5.99	3.9	2.09	H	N
09/07/09	E039	E039	Onslow	Alluvial/Colluvial Plains	Aerial Photography (Landgate,2007)	vegetation dense (0.5-1.0 m in height), surface silty sand, with no scalding	0	0.05	silty SAND, red brown, fine to medium grained	6.65	6.91	-0.26	H	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Located on "island" adjacent supratidal salt flats	0.25	0.3	silty SAND, red brown, fine to medium grained	6.71	6.89	-0.18	H	N
07/07/09	E045	E045	Littoral	Alluvial/Colluvial Plains	Ashburton North Area	Bordering samphire flats, very flat, sparsely vegetated, no surface cracking,	0	0.1	gravelly SAND, red brown	7.7	7.68	0.02	M	Y
					Groundtruthing (March-June, 2009)	Broad flat sandy plain, that may occasionally flood with major storm surge and heav	0.25	0.35	gravelly SAND, red brown	7	7.3	-0.3	H	Y
							0.5	0.55	gravelly SAND, red brown	7.45	8.09	-0.64	H	Y
							0.75	0.8	gravelly SAND, red brown	7.42	8.2	-0.78	M	Y
							0.95	1	gravelly SAND, red brown	8.25	8.1	0.15	M	Y
09/07/09	E037	E037	Onslow	Alluvial/Colluvial Plains	Aerial Photography (Landgate,2007)	Base of mainland remnant dunal. Slight gradient of about 5-10 degrees	0	0.05	silty SAND, very fine grained, tight, red/brown	6.29	6.61	-0.32	H	Y
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	vegetation dense (0.5-1.0 m in height), surface silty sand, with no scalding	0.25	0.3	silty SAND, very fine grained, tight, red/brown	6.27	6.6	-0.33	H	Y
09/07/09	E036	E036	Littoral	Alluvial/Colluvial Plains	Ashburton North Area	very flat, broad, moderately to densely vegetated (~0.5m in height) broad sandy plai	0	0.05	silty SAND, very fine grained, tight, red/brown	6.28	6.6	-0.32	M	N
					Groundtruthing (March-June, 2009)	Mainland remnant dunes visible to north, no surface salt scalding	0.25	0.3	silty SAND, very fine grained, tight, red/brown	6.21	6.61	-0.4	M	N
10/04/09	E013	MB13A	Onslow	Fringing and Coastal Dunes	Aerial Photography (Landgate,2007)	Beach location adjacent Hooley Creek	0.00	0.45	SAND, brown, fine grained	8.9	8.7	0.2	-	-
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Beach comprise of very loose, shallow surface sands with significant shell deposition	0.45	1.00	CORE LOSS	-	-	-	-	-
					Ashburton North Area	Gradient toward dunal system is slightly undulating due to	1.00	1.05	Calcareous SANDSTONE	8.85	8.64	0.21	L	Y
					Groundtruthing (March-June, 2009)	mobile nature of sand	1.50	1.95	Calcareous SANDSTONE	8.75	8.5	0.25	L	Y
						No vegetation	2.05	2.25	Calcareous SANDSTONE	9.2	7.18	2.02	L	Y
						Coastal dunes located approximately 200m from waters edge with shrubs of 1-2 m i	2.50	2.55	Calcareous SANDSTONE	-	-	-	-	-
						Sand of coastal dunes are more reddish in colour with a gradient slope of 20-30 deg	2.75	2.80	SAND, fine to coarse grained	-	-	-	-	-
							2.85	3.00	SAND, fine to coarse grained	8.8	7.19	1.61	L	Y

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APPENDIX D

Soils and Landform Assessment and Field Test Results

Start date	Site ID	Site ID2	Land system	Landform Unit	Sources Used	Landform Elements	From (mbgl)	To (mbgl)	Lithological Description	FIELD TESTS				
										pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)
12/04/09	E011	MB11A	Onslow	Fringing and Coastal Dunes	Aerial Photography (Landgate,2007)	fringing dunes and beach, unstable and mobile sand units	0.00	0.45	CORE LOSS	-	-	-	-	-
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Adjacent dunes approximately 3-4 m in height	0.45	0.73	CORE LOSS	-	-	-	-	-
					Ashburton North Area	Beach comprise of very loose, sand with significant shell deposition	0.73	1.00	SAND, fine to coarse grained	-	-	-	-	-
					Groundtruthing (March-June, 2009)		1.00	1.05	silty SAND, occasional shell fragments	8.33	6.37	1.96	L	Y
							1.25	1.30	silty SAND, occasional shell fragments	8.23	6.6	1.63	L	Y
							1.50	2.00	Calcareous SANDSTONE	-	-	-	-	-
							2.00	2.75	Calcareous SANDSTONE	-	-	-	-	-
							2.75	3.00	Calcareous SANDSTONE	8.11	6.59	1.52	L	Y
							3.00	3.10	Calcareous SANDSTONE	8.11	6.71	1.4	L	Y
29/04/09	E019	MB19A	Onslow	Fringing and Coastal Dunes	Aerial Photography (Landgate,2007)	fringing dunes and beach, unstable and mobile sand units	0	0.1	SAND, red/brown	7.35	7.68	-0.33	L	Y
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Significant surface shell deposition	0.25	0.3	SAND, red/brown	7.34	7.63	-0.29	L	Y
					Ashburton North Area	spit located parallel to ocean and moderately vegetated fringing dune.	1	1.1	SAND, red/brown	7.96	7.34	0.62	L	N
					Groundtruthing (March-June, 2009)	Spit look temporary from recent storm surge and heavy rainfall events	1.25	1.3	CLAY, grey	5.5	1.05	4.45	H	N
						Adjacent dunes approximately 3-4 m in height	1.5	2	CLAY, grey	7.59	0.7	6.89	H	N
							1.75	1.8	CLAY, grey	7.83	0.89	6.94	H	N
							1.9	2	CLAY, grey	7.43	0.85	6.58	H	Y
21/04/09	E012	MB12A	Littoral/Onslow Boundary	Intertidal Flats, Tidal Creek and Mangrove Swamps	Aerial Photography (Landgate,2007)	Occasional salt scalding and black algal mottling	0	0.45	SAND, fine to medium grained, red brown	7.96	6.86	1.1	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	moderately vegetated, broad flat flats with alluvial/colluvial plains to north	0.5	0.55	SAND, fine to medium grained, red brown	7.94	6.97	0.97	L	N
					Ashburton North Area	Broad flat mud flats, some surface shell evident	0.75	0.8	CORELOSS	7.78	5.8	1.98	M	N
					Groundtruthing (March-June, 2009)	Tidal creek approximately 80m wide @ low tide, dense mangrove	1	1.05	SAND, fine to medium grained, red brown to brown	7.37	6.4	0.97	M	N
						along eastern side of creek. Light to sparse on western boundary.	1.25	1.3	SAND, fine grained, dark grey	7.92	5.32	2.6	M	N
						Algal mud flat approx. 1km from mouth of tidal creek	1.45	1.5	CLAY, dark brown, high plasticity	7.19	2.09	5.1	H	N
						salt crusting is only a thin veneer (~1mm) over clay rich sand	1.5	1.95	CLAY, dark brown, high plasticity (SPT)	7.56	5.07	2.49	H	N
						Approximately 300m to 1000m in width.	2	2.05	CLAY, dark brown, high plasticity	7.55	2.33	5.22	H	N
							2.25	2.3	CLAY, dark brown, high plasticity	8.17	2.8	5.37	H	N
							2.5	2.55	Silty SAND	8.34	6.6	1.74	M	N
							2.75	2.8	Silty SAND	8.15	5.75	2.4	M	N
							2.95	3	Silty SAND	8.47	7.2	1.27	H	N
25/05/09	E034	E034	Littoral	Intertidal Flats, Tidal Creek and Mangrove Swamps	Aerial Photography (Landgate,2007)	Occasional salt scalding and black algal mottling	0	0.1	sandy CLAY, moderate plasticity, red brown with grey mottling	7.33	7.76	-0.43	H	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	no vegetation, broad flat flats with alluvial/colluvial plains to north	0.25	0.3	sandy CLAY, moderate plasticity, red brown with grey mottling	7.12	7.31	-0.19	M/L	N
					Ashburton North Area	Broad flat mud flats, some surface shell evident	0.5	0.55	CLAY, brown, medium plasticity	6.68	7.17	-0.49	L	N
					Groundtruthing (March-June, 2009)	Intertidal flat	0.75	0.8	CLAY, brown, medium plasticity	6.35	7.05	-0.7	L	N
							1	1.1	CLAY, brown, medium plasticity	6.15	6.67	-0.52	L	N
25/05/09	E040	E040	Littoral	Samphire Flats	Aerial Photography (Landgate,2007)	spinifex and samphire moderately vegetated	0	0.1	silty SAND, fine grained, red brown	8.12	7.62	0.5	H	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	dry, no evidence of recent flooding or rain events	0.25	0.3	sandy CLAY, high plasticity, red brown	6.88	6.55	0.33	L	N
					Ashburton North Area	No MBO detected, broad, low lying continuous flat area	0.5	0.55	CLAY, medium to high plasticity, grey/red mottling	6.64	6.58	0.06	L	N
					Groundtruthing (March-June, 2009)		0.75	0.8	CLAY, low to medium plasticity, grey	5.17	5.11	0.06	M	N
							1	1.05	CLAY, low to medium plasticity, grey	4.8	5.05	-0.25	M	N
26/05/09	E042	E042	Littoral	Samphire Flats	Aerial Photography (Landgate,2007)	Moderately to densely populated with samphire.	0	0.1	sandy CLAY, red, low plasticity	5.02	7.7	-2.68	H	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	some water inundation in adjacent samphire flats	0.25	0.3	CLAY, low to medium plasticity, red	6.05	7.53	-1.48	M/H	N
					Ashburton North Area	adjacent alluvial/colluvial plains	0.5	0.55	CLAY, high plasticity, red/brown/grey some grey/yellow mottling	7.31	7.64	-0.33	L	N
					Groundtruthing (March-June, 2009)	low lying, broad plains, algal blooms and salt crusting on peripheral of flat	0.75	0.8	CLAY, high plasticity, red/brown/grey some grey/yellow mottling	7.13	5.32	1.81	H	N
						MBO detected slightly below surface (decomposed organic matter)	1	1.05	CLAY, high plasticity, grey with some yellow mottling	5.85	2.99	2.86	H	N
07/07/09	E040A	E040A	Littoral	Samphire Flats	Aerial Photography (Landgate,2007)	spinifex and samphire moderately vegetated	0	0.05	sandy CLAY, med to high plasticity, red/brown	7.39	7.72	-0.33	H	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	dry, no evidence of recent flooding or rain events	0.25	0.3	sandy CLAY, med to high plasticity, red/brown	7.25	7.77	-0.52	M	N
					Ashburton North Area	No MBO detected, broad, low lying continuous flat area	0.5	0.55	CLAY, high plasticity, yellow/grey and red mottling	7.28	7.23	0.05	H	N
					Groundtruthing (March-June, 2009)		0.75	0.8	CLAY, high plasticity, yellow/grey and red mottling	7.33	4.95	2.38	H	N
							1	1.05	CLAY, high plasticity, yellow/grey and red mottling	7.28	4.95	2.33	H	N
							1.25	1.3	grades to grey	7.36	4.67	2.69	H	N
07/07/09	E042A	E042A	Littoral	Samphire Flats	Aerial Photography (Landgate,2007)	Moderately to densely populated with samphire.	0	0.05	sandy CLAY, med to high plasticity, red/brown	7.31	0.92	6.39	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	some water inundation in adjacent samphire flats	0.25	0.3	sandy CLAY, med to high plasticity, red/brown	6.9	1.05	5.85	H	N
					Ashburton North Area	adjacent alluvial/colluvial plains	0.5	0.55	CLAY, high plasticity, yellow/grey and red mottling	7	1.15	5.85	H	N
					Groundtruthing (March-June, 2009)	low lying, broad plains	0.75	0.8	CLAY, high plasticity, yellow/grey and red mottling	6.62	0.75	5.87	H	N
						MBO detected slightly below surface (decomposed organic matter)	1	1.05	CLAY, high plasticity, yellow/grey and red mottling	6.61	0.8	5.81	H	N
08/07/09	E041	E041	Littoral	Claypans	Aerial Photography (Landgate,2007)	slight surface salt encrustation, moist to wet due to recent rainfall	0	0.1	sandy CLAY, red/brown, some large shell fragments	7.26	7.8	-0.54	M	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	no surface cracking, some pooling, no vegetation	0.25	0.3	sandy CLAY, red/brown, some large shell fragments	8.01	7.15	0.86	M	N
					Ashburton North Area	broad, low lying adjacent Samphire flats to the north	0.5	0.6	CLAY, red brown, high plasticity	7.07	6.95	0.12	M	N
					Groundtruthing (March-June, 2009)	no discernible drainage lines, 1-2km continuous area	0.75	0.8	CLAY, red brown, high plasticity	7.15	7.1	0.05	M	N
							0.95	1	CLAY, red brown, high plasticity	6.94	6.63	0.31	L	N
30/03/09	E002	MB2B	Dune	Claypans	Aerial Photography (Landgate,2007)	Bare, Claypan, dry, hard cracking -2-5mm	0	0.45	silty sandy CLAY, low plasticity, red brown	8.79	9.01	-0.22	L	Y
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Surrounded by Alluvial/Colluvial-vegetated with spinifex	0.25	0.45	silty sandy CLAY, low plasticity, red brown	8.8	9.09	-0.29	L	Y
					Ashburton North Area	Depressed area	1.2	1.5	silty SAND, red brown	8.81	9.11	-0.3	L	Y
					Groundtruthing (March-June, 2009)	circular, discontinuous, 100-200 m radius	1.75	1.95	silty SAND, limestone fragments	8.77	9.08	-0.31	L	Y
							2.65	2.85	silty SAND, limestone fragments	8.71	9.01	-0.3	L	Y
							2.85	3	silty SAND, limestone fragments	8.97	9.1	-0.13	L	Y
09/07/09	E038	E038	Littoral	Supratidal Salt Flats	Aerial Photography (Landgate,2007)	Salt encrusted, broad, flat area, very low lying	0	0.05	clayey SAND, fine grained, some black mottles, red/brown	6.57	6.5	0.07	H	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	connected to mangroves, no noticeable historical storm surge	0.25	0.3	sandy CLAY, fine grained, low plasticity, light brown	6.58	5.39	1.19	L	N
					Ashburton North Area	Black mottling associated with algal mats and potentially MBO	0.5	0.6	clayey SAND, fine to medium grained, low plasticity, light brown	6.78	4.95	1.83	L	N
					Groundtruthing (March-June, 2009)	No noticeable drainage lines or gradient	0.75	0.8	clayey SAND, fine to medium grained, low plasticity, light brown	5.88	3.77	2.11	L	N

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Soils and Landform Assessment and Field Test Results

										FIELD TESTS				
Start date	Site ID	Site ID2	Land system	Landform Unit	Sources Used	Landform Elements	From (mbgl)	To (mbgl)	Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)
Shared Infrastructure Corridor Study Area														
19/10/09	E052	E052	Dune	Alluvial/Colluvial	Aerial Photography (Landgate,2007)	Adjacent dunes of approximately 5 m in height	0	0.05	silty SAND, very fine grained, some gravels, light brown	6.9	7.15	-0.25	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Broad relatively flat plain, slightly undulating (adjacent longitudinal dunes)	0.25	0.3	silty SAND, very fine grained, some gravels, light brown	6.3	7.32	-1.02	L	N
					SIC study area	Moderately to densely populated with spinifex and other species	0.5	0.6	silty SAND, very fine grained, some gravels, light brown	6.24	5.11	1.13	L	N
					Groundtruthing (October2009)		0.75	0.8	sandy CLAY, low plas, red brown	6.35	5.42	0.93	L	N
							1	1.05	sandy CLAY, low plas, red brown	7.2	6.69	0.51	L	N
							1.25	1.3	sandy CLAY, low plas, red brown	6.88	6.58	0.3	L	N
							1.5	1.5	sandy CLAY, low plas, red brown	7.21	5.1	2.11	L	N
21/10/09	E046	E046	Littoral	Alluvial/Colluvial Plains and Interdunal Swales	Aerial Photography (Landgate,2007)	gentlly slopes toward the SE, surface soils are clayey sand with	0	0.05	clayey SAND, fine to medium grained, low plas, brown/red	8.29	8.76	-0.47	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Surface evidence of erosion, flooding (sheet and draingae lines noted)	0.25	0.3	clayey SAND, fine to medium grained, low plas, brown/red	8.54	8.79	-0.25	L	N
					SIC study area	Vegetation includes sparse hummoack grasses and low shrubs.	0.5	0.6	clayey SAND, fine to medium grained, low plas, brown/red	7.98	7.98	0	L	N
					Groundtruthing (October2009)		0.75	0.8	clayey SAND, fine to medium grained, low plas, brown/red	7.78	8.4	-0.62	L	N
							1	1.05	clayey SAND, fine to medium grained, low plas, brown/red	7.87	8.75	-0.88	L	N
							1.25	1.3	clayey SAND, fine to medium grained, low plas, brown/red	8.15	8.67	-0.52	L	N
							1.5	1.5	clayey SAND, fine to medium grained, low plas, brown/red	7.87	8.7	-0.83	L	N
21/10/09	SS05	SS05	Onslow	Alluvial/Colluvial Plains	Aerial Photography (Landgate,2007)	Flat, adjacent claypan network	0	0.05	silty SAND, very fine grained, loose, light brown	8.57	8.4	0.17	L	Y
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Surface evidence of erosion, flooding (sheet and draingae lines noted)	0.25	0.3	silty SAND, very fine grained, loose, light brown	8.54	8.17	0.37	L	Y
					SIC study area	Spares hummock grassess and low shrubs	0.5	0.6	silty SAND, very fine grained, loose, light brown	8.56	8.1	0.46	L	Y
					Groundtruthing (October2009)		0.75	0.8	clayey SAND, fine to med garined, low plas, red/brown	8.48	8.27	0.21	L	Y
							1	1.05	clayey SAND, fine to med garined, low plas, red/brown	9	8.32	0.68	L	Y
							1.25	1.3	clayey SAND, fine to med garined, low plas, red/brown	8.39	8.11	0.28	L	Y
							1.5	1.5	clayey SAND, fine to med garined, low plas, red/brown	8.86	8.12	0.74	L	Y
20/10/09	SS03	SS03	Onslow	Samphire Flats	Aerial Photography (Landgate,2007)	Moderately to densely populated with samphire.	0	0.05	clayey SAND, fine grained sands, low plas, mod tight, red/brown	6.76	7.89	-1.13	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	adjacent alluvial/colluvial plains	0.25	0.3	clayey SAND, fine grained sands, low plas, mod tight, red/brown	7.58	7.83	-0.25	L	N
					SIC study area	low lying, broad plains	0.5	0.6	clayey SAND, fine grained sands, low plas, mod tight, red/brown	7.25	7.98	-0.73	L	N
					Groundtruthing (October2009)		0.75	0.8	clayey SAND, fine grained sands, low plas, mod tight, red/brown	7.55	7.81	-0.26	L	N
							1	1.05	sandy CLAY, fine grained sands, yellow mottling, red/brown	7.65	7.8	-0.15	L	N
							1.25	1.3	sandy CLAY, fine grained sands, yellow mottling, red/brown	7.58	8.02	-0.44	L	N
							1.5	1.5	sandy CLAY, fine grained sands, yellow mottling, red/brown	7.58	8.01	-0.43	L	N
							1.5	1.5	clayey SAND, fine to med grained, low to med plas, red/brown	7.18	7.26	-0.08	L	N
20/10/09	E047	E047	Onslow	Samphire Flat (edge) Alluvial/Colluvial Plains	Aerial Photography (Landgate,2007)	adjacent samphire flats and claypan network to the west	0	0.05	clayey SAND, fine grained, low plas, mod tight, brown/red	7.2	8.2	-1	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	graduating slope north to south	0.25	0.3	clayey SAND, fine grained, low plas, mod tight, brown/red	7.39	8.2	-0.81	L	N
					SIC study area	runs approximately 800 m N to S and 300 m wide.	0.5	0.6	clayey SAND, fine grained, low plas, mod tight, brown/red	7.5	8.57	-1.07	L	N
					Groundtruthing (October2009)	vegetation comprise of samphire	0.75	0.8	clayey SAND, fine grained, low plas, mod tight, brown/red	7.61	8.17	-0.56	L	N
							1	1.05	clayey SAND, fine grained, low plas, mod tight, brown/red	7.45	8.14	-0.69	L	N
							1.25	1.3	clayey SAND, fine grained, low plas, mod tight, brown/red	7.04	8.03	-0.99	L	N
							1.5	1.5	clayey SAND, fine grained, low plas, mod tight, brown/red	7.06	8	-0.94	L	N
19/10/09	SS01	SS01	Onslow	Claypan	Aerial Photography (Landgate,2007)	Flat, approximately 400 x200m, no vegetation,	0	0.05	silty gravelly SAND, fine, < 10% gravels, loose, Light brown	8.15	8.22	-0.07	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	surface soils are silty gravelly sand	0.25	0.3	silty gravelly SAND, fine, < 10% gravels, loose, Light brown	7.74	8.55	-0.81	L	N
					SIC study area		0.5	0.6	silty gravelly SAND, fine, < 10% gravels, loose, Light brown	7.62	7.98	-0.36	L	N
					Groundtruthing (October2009)		0.75	0.8	SAND, fine to medium grained	7.42	7.91	-0.49	L	N
							1	1.05	silty CLAY, tight, red/brown	7.5	7.89	-0.39	L	N
							1.25	1.3	silty CLAY, tight, red/brown	7.5	7.97	-0.47	L	N
21/10/09	SS04	SS04	Onslow	Claypan	Aerial Photography (Landgate,2007)	Approximately 800m N to S and 300 m wide	0	0.05	sandy CLAY, low plas, red/brown	7.67	8.2	-0.53	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	part of a netwrok of small to moderately sized claypans isolated within	0.25	0.3	sandy CLAY, low plas, red/brown	7.56	8.2	-0.64	L	N
					SIC study area	this region	0.5	0.6	sandy CLAY, low plas, red/brown	7.41	7.9	-0.49	L	N
					Groundtruthing (October2009)		0.75	0.8	sandy CLAY, low plas, red/brown	7.53	7.78	-0.25	L	N
							1	1.05	sandy CLAY, low plas, red/brown	7.5	8.04	-0.54	L	N
							1.25	1.3	sandy CLAY, low plas, red/brown	7.67	7.89	-0.22	L	N
							1.5	1.5	sandy CLAY, low plas, red/brown	7.65	8.15	-0.5	L	N
20/10/09	E048	E048	Onslow	Claypan	Aerial Photography (Landgate,2007)	part of network of small isolated, closed claypans	0	0.05	silty SAND, very fine grained, loose, light brown	7.72	7.31	0.41	L	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Claypan is 150m x 120m in size	0.25	0.3	silty SAND, very fine grained, loose, light brown	7.42	7.38	0.04	L	N
					SIC study area	vegetation coverage is sparse (~10% of hummock grass)	0.5	0.6	silty SAND, very fine grained, loose, light brown	7.45	7.29	0.16	L	N
					Groundtruthing (October2009)	irregualry innundated	0.75	0.8	clayey SAND, fine to med grained, low to med plas, red/brown	7.31	7.42	-0.11	L	N
							1	1.05	clayey SAND, fine to med grained, low to med plas, red/brown	7.38	7.05	0.33	L	N
							1.25	1.3	clayey SAND, fine to med grained, low to med plas, red/brown	7.42	7.23	0.19	L	N
22/10/09	SS07	SS07	Littoral	Supratidal Salt Flats	Aerial Photography (Landgate,2007)	Flat, extends approximately 2 km north to south and 800 from west to east	0	0.05	sandy CLAY, medium plas, fine to med grained, brown/red	5.32	3.81	1.51	H	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	part of the system which adjoins the interidal creeks and mangove swamps	0.25	0.3	sandy CLAY, medium plas, fine to med grained, brown/red	5.6	1.94	3.66	H	N
					SIC study area	of the Ashburton Study area.	0.5	0.6	sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	5.06	2.72	2.34	H	N
					Groundtruthing (October2009)	Surface is clayey and is devoid of vegetation	0.75	0.8	sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	5.15	2.17	2.98	H	N
							1	1.05	sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	5.5	2.31	3.19	H	N
							1.25	1.3	clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	5.47	2.65	2.82	H	N
							1.5	1.5	clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	6.1	3.31	2.79	H	N
22/10/09	SS06	SS06	Littoral	Supratidal Salt Flats	Aerial Photography (Landgate,2007)	gentle slope running NNE to SE, surface is salt encrusted,	0	0.05	sandy CLAY, medium plas, fine to med grained, brown/red	7.57	7.65	-0.08	H	N
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	flat and is devoid of vegetation	0.25	0.3	sandy CLAY, medium plas, fine to med grained, brown/red	7.69	7.84	-0.15	L	N
					SIC study area	surface soils are clayey sand.	0.5	0.6	sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	7.62	7.64	-0.02	L	N
					Groundtruthing (October2009)		0.75	0.8	sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	7.35	7.79	-0.44	L	N
							1	1.05	sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	7.15	7.8	-0.65	L	N
							1.25	1.3	clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	7.13	7.74	-0.61	L	N
							1.5	1.5	clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	7.21	7.43	-0.22	L	N
							0.95	1	clayey SAND, fine to medium grained, low plasticity, light brown	5.74	2.2	3.54	L	N

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APPENDIX D

Soils and Landform Assessment and Field Test Results

										FIELD TESTS				
Start date	**Site ID**	**Site ID2**	**Land system**	**Landform Unit**	**Sources Used**	**Landform Elements**	**From (mbgl)**	**To (mbgl)**	**Lithological Description**	**pH(f)**	**pH(fox)**	**pH (change)**	**Reaction Type**	**HCL Reaction (No/Yes)**
Domgas Pipeline Study Area-no intrusive works completed														
30/10/2009	1	1	Onslow	Alluvial Colluvial Plains	Aerial Photography (Landgate,2007)	Flat, Some low level interdunal swales amongst the plains, spinifex								
30/10/2009	2	2	Onslow	Mainland reminant dune	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	flat to a 35 degree slope of dune, 5 to 8m high, Spinifex grasses with small shrubs top of slope								
30/10/2009	3	3	Giralia	Floodway	Domgas Study Area	Flat, Moderate veg with grasses and small shrubs								
30/10/2009	4	4	Giralia	Agricultural land/colluvial/alluvial plain	Groundtruthing (October2009)	Sparse grassey plains								
30/10/2009	5	5	Giralia	Longitudinal Dune/colluvial/colluvial plains		slight slope N to S , Approx 3km long, dune 60 to 80m wide, Grasses with shrubby vegetation								
30/10/2009	6	6	Giralia	Alluvial Colluvial Plains		Flat, 500m, between longitudinal dune, Eucalyptus trees to 4m, spinifex								
30/10/2009	7	7	Giralia	Alluvial Colluvial Plains		Flat, Shrubs up to 1m hight, dense, grass between dune								
30/10/2009	8	8	Giralia	Alluvial Colluvial Plains		Flat, Increase in size of shrubs to 2m, single eucalypt tree 7m								
30/10/2009	9	9	Giralia	Unchabnneled Drainage Area		Slight slope east to west, vegetation becoming denser (shrubs ground coverage)								
30/10/2009	10	10	Uaroo	Alluvial Colluvial Plains		Flat, shrubs to 2m high, 70% spinifex, 20% shrubs, 10% no veg								
30/10/2009	11	11	Uaroo	Unchanneled Drainag Area		Slight slope east to west, vegetation becoming denser (shrubs ground coverage)								
30/10/2009	12	12	Uaroo	Unchanneled Drainag Area		Slight slope east to west, vegetation becoming denser (shrubs ground coverage)								
30/10/2009	13	13	Uaroo	Alluvial Colluvial Plains		10 to 15% grass, <1% shrubs and trees								
30/10/2009	14	14	Uaroo	Alluvial Colluvial Plains		Single eucalypt to 10m high, shrubs to 2m, 40% coverage between spinifex								
30/10/2009	15	15	Stuart	Hill outcrop		Flat with 10m high hill, Approx 200m by 100m, no vegetation, rock outcrop (intrusion of quartz)								
30/10/2009	16	16	Stuart	Hill outcrop		Flat with 10m high hill, Approx 200m by 100m, None on hill, sparse hummock grass surrounding hill, Conglomeratic outcrop, cemented quartz								

NOTES:

pH(change)

Reaction Type: H=high(reacts vigorously), M=medium(reacts with moderate vigour, may be some 'frothing'), L=low (slight reaction), N=none (no reaction detected).

HCL Reaction: N=no reaction with HCl, Y=reaction with HCl

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Landform Assessment and Field Test Results-Dispersion
BSQ and Landforms Assessment

Date	Chevron Site ID	Location	Landform Unit	Lithological Description	Depth (mbgl)	Slaking Score	Dispersion Score	Dispersion Score (after remoulding-clay only)	Comments	Emerson Class (for clays)
12/04/09	E011	MB11A	Fringing and Coastal Dunes	silty SAND, occasional shell fragments	1.00	1	0	-	slight slaking	
				silty SAND, occasional shell fragments	3.00	1	0	-	slight slaking	
10/04/09	E013	MB13A	Fringing and Coastal Dunes	SAND, coarse, calcareous	0 0.45	1	0	-	slight slaking	
				well cemented Sandstone, occasional shell fragments	1.00	1	1	-	slight slaking	
				very well cemented Sandstone, occasional shell fragments	1.5 - 1.95	1	1	-	slight slaking	
				very well cemented Sandstone, occasional shell fragments	2.25	1	0	-	slight slaking	
				very well cemented Sandstone, occasional shell fragments	2.85 - 3	1	0	-	slight slaking	
5/04/09	E008	MB08A	Longitudinal Dunes and Interdunal Swales	silty SAND (5%silt) red/brown	0 - 0.45	1	0	-	slight slaking	
				silty SAND (5%silt) red/brown	1.00	1	0	-	slight slaking	
				silty SAND (5%silt) red/brown	1.50	1	0	-	slight slaking	
				silty SAND (5%silt) red/brown	2.00	1	0	-	slight slaking	
				sandy CLAY, red/brown	2.50	1	0	0	slight slaking	
				sandy CLAY, red/brown	3.00	1	0	0	slight slaking	
5/04/09	E009	MB09A	Longitudinal Dunes and Interdunal Swales	silty SAND (5%silt) red/brown	0 - 0.05	1	0	-	slight slaking	
				silty SAND (5%silt) red/brown	1.00	1	0	-	slight slaking	
				gravelly, clayey SAND (5% clay) red/brown	1.50	1	0	-	slight slaking	
				clayey SAND (5% clay), occasional gravel, red/brown	2.50	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND (5% clay), occasional gravel, red/brown	3.00	1	0	0	No dispersion, no swelling	Class 5 or 6
17/04/09	E010	MB10A	Alluvial/Colluvial Plains	silty SAND (5%silt) red/brown	0 - 0.25	1	1	-	slight slaking	
				silty SAND (5%silt) red/brown	0.50	1	0	-	No Dispersion	
				silty SAND (5%silt) red/brown	1.00	1	0	0	No Dispersion	
				sandy CLAY, red/brown	1.50	1	1	1	some dispersion	Class 3
				CLAY, grey with yellow mottles	2.00	1	1	1	some dispersion	Class 3
				CLAY, grey with yellow mottles	2.50	1	2	2	some dispersion	Class 3
				sandy CLAY, red/brown	3.00	1	1	1	No dispersion, no swelling	Class 5 or 6
8/04/09	E015	MB15A	Alluvial/Colluvial Plains	clayey SAND, occasional well cemented Sandstone	2.50	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, occasional well cemented Sandstone	3.00	1	0	0	No dispersion, no swelling	Class 5 or 6
15/04/09	E018	MB18A	Alluvial/Colluvial Plains	clayey SAND, red/brown (SPT sample)	0 - 0.45	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, red/brown	1.00	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, red/brown (SPT sample)	1.50	1	0	0	No dispersion, no swelling	Class 5 or 6
				CLAY, medium to high plasticity, cream/brown with yellow mottles	2.00	2	0	0	No dispersion, no swelling	Class 5 or 6
				heavy CLAY, grey, occasional yellow mottles	2.50	2	0	0	No dispersion, no swelling	Class 5 or 6
				heavy CLAY, grey, occasional yellow mottles	3.00	1	0	0	No dispersion, no swelling	Class 5 or 6
19/10/09	E052	E052	Alluvial/Colluvial plains	silty SAND, very fine grained, some gravels, light brown	0	2	0	-		
				silty SAND, very fine grained, some gravels, light brown	0.25	2	0	-		
				silty SAND, very fine grained, some gravels, light brown	0.5	2	0	-		
				sandy CLAY, low plas, red brown	0.75	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red brown	1	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red brown	1.25	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red brown	1.5	1	0	1	slight slaking	Class 5 or 6
21/10/09	E046	E046	Alluvial/Colluvial Plains and Interdunal Swales	clayey SAND, fine to medium grained, low plas, brown/red	0	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to medium grained, low plas, brown/red	0.25	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to medium grained, low plas, brown/red	0.5	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to medium grained, low plas, brown/red	0.75	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to medium grained, low plas, brown/red	1	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to medium grained, low plas, brown/red	1.25	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to medium grained, low plas, brown/red	1.5	1	0	0	No dispersion, no swelling	Class 5 or 6
21/10/09	SS05	SS05	Alluvial/Colluvial Plains	silty SAND, very fine grained, loose, light brown	0	3	0	-		
				silty SAND, very fine grained, loose, light brown	0.25	2	0	-		
				silty SAND, very fine grained, loose, light brown	0.5	2	0	-		
				clayey SAND, fine to med garined, low plas, red/brown	0.75	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to med garined, low plas, red/brown	1	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to med garined, low plas, red/brown	1.25	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to med garined, low plas, red/brown	1.5	2	0	0	No dispersion, no swelling	Class 5 or 6
25/04/09	E034	E034	Tidal Creek, Mangrove Swamp, Intertidal Flats	CLAY, brown, medium plasticity	1.00	1	1	1	some dispersion	Class 3
	E038	E038	Supratidal Salt Flats	clayey SAND, red brown, fine grained	0.00	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, red brown, fine to medium grained	0.50	2	1	1	No dispersion, no swelling	Class 5 or 6
22/10/09	SS06	SS06	Supratidal Salt Flats	sandy CLAY, medium plas, fine to med grained, brown/red	0	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, medium plas, fine to med grained, brown/red	0.25	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	0.5	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	0.75	2	0	1	slight slaking	Class 5 or 6
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	1	2	0	1	slight slaking	Class 5 or 6
				clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	1.25	1	0	1	slight slaking	Class 5 or 6
				clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	1.5	1	0	1	slight slaking	Class 5 or 6

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Landform Assessment and Field Test Results-Dispersion
BSQ and Landforms Assessment

Date	Chevron Site ID	Location	Landform Unit	Lithological Description	Depth (mbgl)	Slaking Score	Dispersion Score	Dispersion Score (after remoulding-clay only)	Comments	Emerson Class (for clays)
22/10/09	SS07	SS07	Supratidal Salt Flats	sandy CLAY, medium plas, fine to med grained, brown/red	0	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, medium plas, fine to med grained, brown/red	0.25	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	0.5	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	0.75	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	1	1	0	1	slight slaking	Class 5 or 6
				clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	1.25	1	0	1	slight slaking	Class 5 or 6
				clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	1.5	1	0	1	slight slaking	Class 5 or 6
25/04/09	E040	E040	Samphire Flats	Silty SAND	0.00	1	0	-	No Dispersion	
				CLAY, moderate to high plasticity, grey red mottles	0.50	2	0	0	No dispersion, no swelling	Class 5 or 6
				CLAY, low to moderate plasticity, grey	0.75	0	0	0	No dispersion, no swelling	Class 5 or 6
26/04/09	E042	E042	Samphire Flat	sandy CLAY, red low plasticity	0.00	2	0	0	No dispersion, no swelling	Class 5 or 6
				CLAY, grey to red brown, high plasticity	0.50	1	0	0	No dispersion, no swelling	Class 5 or 6
20/10/09	SS03	SS03	Samphire Flats	clayey SAND, fine grained sands, low plas, mod tight, red/brown	0	2	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained sands, low plas, mod tight, red/brown	0.25	2	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained sands, low plas, mod tight, red/brown	0.5	2	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained sands, low plas, mod tight, red/brown	0.75	2	0	0	No dispersion, no swelling	Class 5 or 6
				sandy CLAY, fine grained sands, yellow mottling, red/brown	1	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, fine grained sands, yellow mottling, red/brown	1.25	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, fine grained sands, yellow mottling, red/brown	1.5	1	0	1	slight slaking	Class 5 or 6
20/10/09	E047	E047	Samphire Flat (edge) Alluvial/Colluvial Plains	clayey SAND, fine grained, low plas, mod tight, brown/red	0	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained, low plas, mod tight, brown/red	0.25	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained, low plas, mod tight, brown/red	0.5	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained, low plas, mod tight, brown/red	0.75	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained, low plas, mod tight, brown/red	1	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained, low plas, mod tight, brown/red	1.25	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine grained, low plas, mod tight, brown/red	1.5	1	0	0	No dispersion, no swelling	Class 5 or 6
8/07/09	E041	E041	Claypan	sandy CLAY, moderate plasticity	0.00	1	0	0	No dispersion, no swelling	Class 5 or 6
				CLAY, red brown high plasticity	0.50	2	0	0	No dispersion, no swelling	Class 5 or 6
30/3/09	E002	MB2B	Claypan	silty sandy CLAY, red brown low plasticity	1.95	2	0	0	No dispersion, no swelling	Class 5 or 6
				silty CLAY, red brown, low plasticity	2.65	2	0	0	No dispersion, no swelling	Class 5 or 6
19/10/09	SS01	SS01	Claypan	silty gravelly SAND, fine, < 10% gravels, loose, Light brown	0	2	0	-		
				silty gravelly SAND, fine, < 10% gravels, loose, Light brown	0.25	2	0	-		
				silty gravelly SAND, fine, < 10% gravels, loose, Light brown	0.5	2	0	-		
				SAND, fine to medium grained	0.75	2	0	-		
				silty CLAY, tight, red/brown	1	2	0	0	No dispersion, no swelling	Class 5 or 6
				silty CLAY, tight, red/brown	1.25	2	0	0	No dispersion, no swelling	Class 5 or 6
21/10/09	SS04	SS04	Claypan	sandy CLAY, low plas, red/brown	0	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red/brown	0.25	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red/brown	0.5	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red/brown	0.75	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red/brown	1	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red/brown	1.25	1	0	1	slight slaking	Class 5 or 6
				sandy CLAY, low plas, red/brown	1.5	1	0	1	slight slaking	Class 5 or 6
20/10/09	E048	E048	Claypan	silty SAND, very fine grained, loose, light brown	0	2	0	-		
				silty SAND, very fine grained, loose, light brown	0.25	2	0	-		
				silty SAND, very fine grained, loose, light brown	0.5	2	0	-		
				clayey SAND, fine to med grained, low to med plas, red/brown	0.75	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to med grained, low to med plas, red/brown	1	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to med grained, low to med plas, red/brown	1.25	1	0	0	No dispersion, no swelling	Class 5 or 6
				clayey SAND, fine to med grained, low to med plas, red/brown	1.5	1	0	0	No dispersion, no swelling	Class 5 or 6

NOTES

Slaking test scores

0 No change
1 Aggregate breaks open but remains intact-some dispersion
2 Aggregate breaks down into smaller aggregates-some dispersion
3 Aggregate breaks down completely into sand grains-complete dispersion

Emerson Class Definitions

Soils which are spontaneously dispersive to varying degrees (Class1 and Class 2). Class 1 soils are highly unstable and invariably sodic to highly sodic.
Soils which are potentially dispersive if remoulded when wet (Class 3).
Soils which slake but are non-dispersive (Classes 4, 5 and 6).
Soils which have a high inherent stability (Class 7 and 8).

Dispersion test scores

0 No dispersion.
1 Slight dispersion, recognised by a slight milkiness of the water adjacent to the aggregate and some times a narrow edging of dispersed clay to part of the aggregate
2 Moderate dispersion with obvious milkiness.
3 Strong dispersion with considerable milkiness and about half of the original volume dispersed outwards
4 Complete dispersion leaving only sand grains in a cloud of clay
3 Strong dispersion with considerable milkiness and about half of the original volume dispersed outwards
4 Complete dispersion leaving only sand grains in a cloud of clay

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Landform Assessment and Field Test Results-Erodibility Assessment
BSQ and Landforms Assessment

Date	Chevron Site ID	Location	Landform Unit	Lithological Description	Depth (mbgl)	Water Erosion			Wind Erosion	
						Soil Layer Erodibility Score^{1,2}	Soil Profile Erodibility Score	Suscpetibility of land units to water erosion Score	Assessing Susceptibility of Bare Soil	Susceptibility of landform units
10/04/09	E013	MB13A	Fringing and Coastal Dunes	SAND, coarse, calcareous	0 0.45	6	moderate	high	IV to V	VH to E
5/04/09	E008	MB08A	Longitudinal Dunes and Interdunal Swales	silty SAND (5%silt) red/brown	0 - 0.45	6	moderate	high	IV to V	VH to E
5/04/09	E009	MB09A	Longitudinal Dunes and Interdunal Swales	silty SAND (5%silt) red/brown	0 - 0.05	6	moderate	high	IV to V	VH to E
17/04/09	E010	MB10A	Alluvial/Colluvial Plains	silty SAND (5%silt) red/brown	0 - 0.25	7	moderate	Low	I to II	L
15/04/09	E018	MB18A	Alluvial/Colluvial Plains	clayey SAND, red/brown (SPT sample)	0 - 0.45	7	moderate	Low	I to II	L
19/10/09	E052	E052	Alluvial/Colluvial plains	silty SAND, very fine grained, some gravels, light brown	0	6	moderate	Low	I to II	L
				silty SAND, very fine grained, some gravels, light brown	0.25	6				
				silty SAND, very fine grained, some gravels, light brown	0.5	10				
21/10/09	E046	E046	Alluvial/Colluvial Plains and Interdunal Swales	clayey SAND, fine to medium grained, low plas, brown/red	0	6	moderate	Low	I to II	L
				clayey SAND, fine to medium grained, low plas, brown/red	0.25	6				
				clayey SAND, fine to medium grained, low plas, brown/red	0.5	9				
21/10/09	SS05	SS05	Alluvial/Colluvial Plains	silty SAND, very fine grained, loose, light brown	0	6	moderate	Low	I to II	L
				silty SAND, very fine grained, loose, light brown	0.25	6				
				silty SAND, very fine grained, loose, light brown	0.5	10				
	E038	E038	Supratidal Salt Flats	clayey SAND, red brown, fine grained	0.00	11	moderate	Low	I to II	L
				clayey SAND, red brown, fine to medium grained	0.50	11				
22/10/09	SS06	SS06	Supratidal Salt Flats	sandy CLAY, medium plas, fine to med grained, brown/red	0	8	moderate	Low	I to II	L
				sandy CLAY, medium plas, fine to med grained, brown/red	0.25	8				
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	0.5	10				
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	0.75	10				
22/10/09	SS07	SS07	Supratidal Salt Flats	sandy CLAY, medium plas, fine to med grained, brown/red	0	8	High	Moderate	I to II	L
				sandy CLAY, medium plas, fine to med grained, brown/red	0.25	8				
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	0.5	10				
				sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	0.75	10				
25/04/09	E040	E040	Samphire Flats	Silty SAND	0.00	4	moderate	Low	III to IV	L to M
				CLAY, moderate to high plasticity, grey red mottles	0.50	6				
				CLAY, low to moderate plasticity, grey	0.75	6				
26/04/09	E042	E042	Samphire Flat	sandy CLAY, red low plasticity	0.00	6	moderate	Low	III to IV	L to M
				CLAY, grey to red brown, high plasticity	0.50	7				
20/10/09	SS03	SS03	Samphire Flats	clayey SAND, fine grained sands, low plas, mod tight, red/brown	0	7	High	Moderate	III to IV	L to M
				clayey SAND, fine grained sands, low plas, mod tight, red/brown	0.25	7				
				clayey SAND, fine grained sands, low plas, mod tight, red/brown	0.5	10				
				clayey SAND, fine grained sands, low plas, mod tight, red/brown	0.75	10				
20/10/09	E047	E047	Samphire Flat (edge) Alluvial/Colluvial Plains	clayey SAND, fine grained, low plas, mod tight, brown/red	0	11	High	Moderate	III to IV	L to M
				clayey SAND, fine grained, low plas, mod tight, brown/red	0.25	11				
				clayey SAND, fine grained, low plas, mod tight, brown/red	0.5	13				
				clayey SAND, fine grained, low plas, mod tight, brown/red	0.75	13				
8/07/09	E041	E041	Claypan	sandy CLAY, moderate plasticity	0.00	7	Low	very low	I to II	L
				CLAY, red brown high plasticity	0.50	7				
19/10/09	SS01	SS01	Claypan	silty gravelly SAND, fine, < 10% gravels, loose, Light brown	0	8	High	Moderate	I to II	L
				silty gravelly SAND, fine, < 10% gravels, loose, Light brown	0.25	8				
				silty gravelly SAND, fine, < 10% gravels, loose, Light brown	0.5	11				
				SAND, fine to medium grained	0.75	11				
21/10/09	SS04	SS04	Claypan	sandy CLAY, low plas, red/brown	0	7	High	Moderate	I to II	L
				sandy CLAY, low plas, red/brown	0.25	7				
				sandy CLAY, low plas, red/brown	0.5	10				
				sandy CLAY, low plas, red/brown	0.75	10				
20/10/09	E048	E048	Claypan	silty SAND, very fine grained, loose, light brown	0	9	High	Moderate	I to II	L
				silty SAND, very fine grained, loose, light brown	0.25	9				
				silty SAND, very fine grained, loose, light brown	0.5	9				

NOTES

Erosion potential assessed against Land evaluation Standards for Land Resource Mapping Third Edition Dennis van Gool, Peter Tille and Geoff Moore December 2005

Methodologies given in Appendix A of this report

[1] organic carbon (%) and permeability could not be calculated and hence a nominal value of 1 was given.

[2] Water repellence for sands was given a nominal value of 1

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Soils and Field Test Results-Longitudinal Dunes and Interdunal Swales

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
						mean	min	max	mean	min	max
SAND, light brown	8.73	8.86	-0.13	L	Y						
SAND, light brown	9.17	9.28	-0.11	L	Y						
SAND, red brown	7.72	6.3	1.42	M	N						
SAND, red brown	8.39	6.88	1.51	M	N						
SAND, red brown	8.58	6.33	2.25	M	N						
SAND, red brown	8.78	8.85	-0.07	M	N						
SAND, red brown	8.85	6.47	2.38	M	N						
SAND, red brown	8.56	6.5	2.06	L	N						
SAND, red brown	9.3	6.25	3.05	L	Y						
SAND, red brown	9.57	6.36	3.21	L	Y						
SAND, red brown	6.34	6.3	0.04	M	N						
SAND, red brown	6.56	5.86	0.7	M	N						
SAND, red brown	-	-	-	-	-						
SAND, fine grained, well sorted, red/brown	7.62	6.36	1.26	L	N						
SAND, fine grained, well sorted, red/brown	7.68	6.46	1.22	M	N						
SAND, fine grained, well sorted, red/brown	7.68	6.92	0.76	M	N						
SAND, fine grained, well sorted, red/brown	8.07	7.77	0.3	L	Y						
SAND, fine grained, well sorted, red/brown	8.39	7.9	0.49	L	Y						
SAND, fine grained, well sorted, red/brown	8.45	8.46	-0.01	L	Y						
SAND, fine grained, well sorted, red/brown	8.5	7.89	0.61	L	Y						
SAND, fine grained, well sorted, red/brown	8.56	8.1	0.46	L	Y						
SAND, fine grained, well sorted, red/brown	-	-	-	-	-						
SAND, fine grained, well sorted, red/brown	8.48	8.21	0.27	L	Y						
						8.28	**6.34**	**9.57**	**7.25**	**5.86**	**9.28**
Sand/Calcaerous SANDSTONE	8.89	9.07	-0.18	L	Y						
Sand/Calcaerous SANDSTONE	8.77	9.09	-0.32	L	Y						
Sand/Calcaerous SANDSTONE	9.01	9.1	-0.09	L	Y						
Sand/Calcaerous SANDSTONE	9	9.1	-0.1	L	Y						
Sand/Calcaerous SANDSTONE	8.8	9.01	-0.21	L	Y						
Sand/Calcaerous SANDSTONE	8.89	9.11	-0.22	L	Y						
SANDSTONE	9.49	7.03	2.46	L	Y						
SANDSTONE	8.72	9.09	-0.37	L	Y						
SANDSTONE	8.83	9.31	-0.48	L	Y						
						8.93	**8.72**	**9.49**	**8.88**	**7.03**	**9.31**
sandy GRAVEL, light grey, fine to medium grained	7.34	6.8	0.54	M	Y						
sandy silty GRAVEL	8.15	7.53	0.62	L	Y						
sandy silty GRAVEL	8.09	7.8	0.29	L	Y						
silty sandy GRAVEL	7.62	7.06	0.56	L	Y						
silty sandy GRAVEL	7.69	6.57	1.12	L	Y						
silty sandy GRAVEL	7.74	7.87	-0.13	M	Y						
silty sandy GRAVEL	7.77	7.7	0.07	H	Y						
						7.77	**7.34**	**8.15**	**7.33**	**6.57**	**7.87**
silty SAND red/brown	8.14	6.7	1.44	L	N						
silty SAND red/brown	8.16	7.04	1.12	L	N						
silty SAND red/brown	8.46	6.87	1.59	L	N						
silty SAND red/brown	8.47	6.59	1.88	L	N						
silty SAND red/brown	8.58	7.12	1.46	L	Y						
silty SAND red/brown	9.15	6.33	2.82	L	Y						
silty SAND red/brown	9.65	8.33	1.32	L	Y						
silty SAND red/brown	9.47	8.56	0.91	L	Y						
silty SAND red/brown	9.7	6.71	2.99	L	Y						
silty SAND red/brown	9.57	6.43	3.14	L	Y						
silty SAND red/brown	9.29	6.95	2.34	L	Y						
silty SAND red/brown	9.36	6.66	2.7	L	Y						
silty SAND, red brown	9.61	6.41	3.2	L	Y						
silty SAND, red brown	9.54	6.35	3.19	L	Y						
silty SAND, red brown	9.48	6.64	2.84	L	Y						
silty SAND, red brown, fine to medium grained	7.03	6.2	0.83	H	-						
silty SAND, red brown, fine to medium grained	7.68	6.33	1.35	H	-						
silty SAND, red brown, fine to medium grained	6.02	6.57	-0.55	L	N						
silty SAND, red brown, fine to medium grained	6.13	6.58	-0.45	L	N						
silty SAND, red brown, fine to medium grained	7.12	7.22	-0.1	L	N						
silty SAND, red brown, fine to medium grained	6.88	7.08	-0.2	L	Y						
silty SAND, red brown, fine to medium grained	7.85	7.45	0.4	L	Y						
silty SAND, red brown, fine to medium grained	7.85	7.26	0.59	L	Y						
silty SAND, red brown, fine to medium grained	7.83	8.08	-0.25	L	Y						
silty SAND, red brown, fine to medium grained	7.93	8.53	-0.6	L	Y						
silty SAND, red brown, fine to medium grained	8.16	8.19	-0.03	L	Y						
silty SAND, red brown, fine to medium grained	8.02	8.09	-0.07	L	Y	**8.34**	**6.02**	**9.70**	**7.08**	**6.20**	**8.56**

Soils and Field Test Results-Fringing and Coastal Dunes

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
Calcaerous SANDSTONE	-	-	-	-	-	**mean**	**min**	**max**	**mean**	**min**	**max**
Calcaerous SANDSTONE	-	-	-	-	-						
Calcaerous SANDSTONE	8.11	6.59	1.52	L	Y						
Calcaerous SANDSTONE	8.11	6.71	1.4	L	Y						
Calcareous SANDSTONE	8.85	8.64	0.21	L	Y						
Calcareous SANDSTONE	8.75	8.5	0.25	L	Y						
Calcareous SANDSTONE	9.2	7.18	2.02	L	Y						
Calcareous SANDSTONE	-	-	-	-	-						
						8.60	**8.11**	**9.20**	**7.52**	**6.59**	**8.64**
CLAY, grey	5.5	1.05	4.45	H	N						
CLAY, grey	7.59	0.7	6.89	H	N						
CLAY, grey	7.83	0.89	6.94	H	N						
CLAY, grey	7.43	0.85	6.58	H	Y						
						7.09	**5.50**	**7.83**	**0.87**	**0.70**	**1.05**
SAND, red/brown	7.35	7.68	-0.33	L	Y						
SAND, red/brown	7.34	7.63	-0.29	L	Y						
SAND, red/brown	7.96	7.34	0.62	L	N						
silty SAND, occasional shell fragments	8.33	6.37	1.96	L	Y						
silty SAND, occasional shell fragments	8.23	6.6	1.63	L	Y	**7.84**	**7.34**	**8.33**	**7.12**	**6.37**	**7.68**

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Soils and Field Test Results-Alluvial/Colluvial Plains

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
						mean	min	max	mean	min	max
CLAY, brown to grey with yellow mottles	7.36	5.9	-1.46	H	N						
CLAY, brown to grey with yellow mottles	7.25	6.01	-1.24	H	N						
CLAY, cream brown with yellow mottles	6.77	5.3	-1.47	M	N						
CLAY, cream brown with yellow mottles	6.9	4.59	-2.3	M	N						
CLAY, cream brown with yellow mottles	6.5	5.22	-1.28	H	N						
CLAY, cream brown with yellow mottles	6.29	3.6	-2.69	H	N						
CLAY, cream brown with yellow mottles	5.99	3.9	-5.5	H	N						
						6.72	**5.99**	**7.36**	**4.93**	**3.60**	**6.01**
clayey SAND, red brown	8.85	8.12	-0.73	L	Y						
clayey SAND, red brown	9	8.24	-0.76	L	Y						
clayey SAND, red brown	8.78	8.32	0.46	L	Y						
clayey SAND, red/brown	6.63	5.4	1.23	L	N						
clayey SAND, red/brown	7.53	6.64	0.89	L	N						
clayey SAND, fine to med garined, low plas, red/brown	8.48	8.27	0.21	L	Y						
clayey SAND, fine to med garined, low plas, red/brown	9	8.32	0.68	L	Y						
clayey SAND, fine to med garined, low plas, red/brown	8.39	8.11	0.28	L	Y						
clayey SAND, fine to med garined, low plas, red/brown	8.86	8.12	0.74	L	Y						
clayey SAND, fine to medium grained, low plas, brown/red	8.29	8.76	-0.47	L	N						
clayey SAND, fine to medium grained, low plas, brown/red	8.54	8.79	-0.25	L	N						
clayey SAND, fine to medium grained, low plas, brown/red	7.98	7.98	0	L	N						
clayey SAND, fine to medium grained, low plas, brown/red	7.78	8.4	-0.62	L	N						
clayey SAND, fine to medium grained, low plas, brown/red	7.87	8.75	-0.88	L	N						
clayey SAND, fine to medium grained, low plas, brown/red	8.15	8.67	-0.52	L	N						
clayey SAND, fine to medium grained, low plas, brown/red	7.87	8.7	-0.83	L	N						
						8.25	**6.63**	**9.00**	**8.10**	**5.40**	**8.79**
clayey sandy GRAVEL	6.67	6.65	0.02	L	N						
compacted SAND, Qtz major, yellow/brown	8.5	8.35	0.15	L	Y						
						8.18	**6.63**	**9.00**	**8.03**	**5.40**	**8.79**
gravelly SAND, red brown	7.7	7.68	0.02	M	Y						
gravelly SAND, red brown	7	7.3	-0.3	H	Y						
gravelly SAND, red brown	7.45	8.09	-0.64	H	Y						
gravelly SAND, red brown	7.42	8.2	-0.78	M	Y						
gravelly SAND, red brown	8.25	8.1	0.15	M	Y						
gravelly SAND, red brown	7.7	7.68	0.02	M	Y						
gravelly SAND, red brown	7	7.3	-0.3	H	Y						
gravelly SAND, red brown	7.45	8.09	-0.64	H	Y						
gravelly SAND, red brown	7.42	8.2	-0.78	M	Y						
gravelly SAND, red brown	8.25	8.1	0.15	M	Y						
						7.56	**7.00**	**8.25**	**7.87**	**7.30**	**8.20**
gravelly sandy CLAY, red brown	7.16	5.61	1.55	H	N						
gravelly sandy CLAY, red brown	7.28	5.81	1.47	M	Y						
gravelly sandy CLAY, red brown	7.75	6.19	1.56	L	Y						
sandy clayey GRAVEL	7.17	7.22	-0.05	L	N						
sandy clayey GRAVEL	7.29	7.1	0.19	L	N						
						7.33	**7.16**	**7.75**	**6.39**	**5.61**	**7.22**
SAND, brown	7.35	7.82	-0.47	L	N						
SAND, brown	8.66	9.06	-0.4	M	N						
SAND, brown	7.65	6.13	1.52	L	Y						
SAND, brown, fine grained	8.9	8.7	0.2	-	-						
SAND, fine to coarse grained	-	-	-	-	-						
SAND, fine to coarse grained	8.8	7.19	1.61	L	Y						
SAND, very fine grained, brown	7.68	4.65	3.03	H	N						
SAND, fine to coarse grained	7.25	4.8	2.45	H	N						
SAND, fine to coarse grained	7.71	4.33	3.38	H	N						
SAND, fine to coarse grained	7.51	4.9	2.61	H	N						
						7.95	**7.25**	**8.90**	**6.40**	**4.33**	**9.06**
SAND, very fine grained, red brown	7.79	6.4	1.39	L	N						
SAND, very fine grained, red brown	7.8	6.35	1.45	L	N						
						7.80	**6.38**	**1.42**	**6.38**	**6.38**	**6.38**
silty Clay, red/brown, high plasticity	7.88	7.47	0.41	L	Y						
silty Clay, red/brown, high plasticity	7.87	7.6	0.27	L	Y						
silty Clay, red/brown, high plasticity	7.89	7.94	-0.05	L	Y						
silty Clay, red/brown, high plasticity	7.79	8	-0.21	L	Y						
silty Clay, red/brown, high plasticity	7.83	7.92	-0.09	L	Y						
silty Clay, red/brown, high plasticity	8.22	8.04	0.18	L	Y						
						7.91	**7.79**	**8.22**	**7.83**	**7.47**	**8.04**
silty SAND	7.3	7.64	-0.34	L	Y						
silty SAND red/brown	9.32	8.79	0.53	L	Y						
silty SAND red/brown	9.33	9	0.33	L	Y						
silty SAND red/brown	9.09	8.1	0.99	L	Y						
silty SAND red/brown	9	7.3	1.7	M	Y						
silty SAND red/brown	8.68	6.92	1.76	L	Y						
silty SAND red/brown	8.15	7.5	0.65	M	Y						
silty SAND red/brown	7.59	5.06	2.53	L	Y						
silty SAND red/brown	7.25	5.86	1.39	L	N						
silty SAND, red brown, fine to medium grained	6.65	6.91	-0.26	L	N						
silty SAND, red brown, fine to medium grained	6.71	6.89	-0.18	L	N						
silty SAND, very fine grained, tight, red/brown	6.29	6.61	-0.32	L	Y						
silty SAND, very fine grained, tight, red/brown	6.27	6.6	-0.33	L	Y						
silty SAND, very fine grained, tight, red/brown	6.28	6.6	-0.32	L	N						
silty SAND, very fine grained, tight, red/brown	6.21	6.61	-0.4	L	N						
silty SAND, very fine grained, loose, light brown	8.57	8.4	0.17	L	Y						
silty SAND, very fine grained, loose, light brown	8.54	8.17	0.37	L	Y						
silty SAND, very fine grained, loose, light brown	8.56	8.1	0.46	L	Y						
silty SAND, very fine grained, some gravels, light brown	6.9	7.15	-0.25	L	N						
silty SAND, very fine grained, some gravels, light brown	6.3	7.32	-1.02	L	N						
silty SAND, very fine grained, some gravels, light brown	6.24	5.11	1.13	L	N						
						7.58	**6.21**	**9.33**	**7.17**	**5.06**	**9.00**
silty sandy CLAY, light brown	8.8	6.83	1.97	L	Y						
silty sandy CLAY, light brown	6.29	5.02	1.27	M	N						
						7.55	**6.29**	**8.80**	**5.93**	**5.02**	**6.83**
silty sandy CLAY, red brown	8.11	7.57	0.54	M	N						
silty sandy CLAY, red brown	8.24	7.72	0.52	H	Y						
silty sandy CLAY, red brown	7.89	7.75	0.14	H	Y						
sandy CLAY, red/brown	7.27	7.88	-0.61	L	N						

Soils and Field Test Results-Alluvial/Colluvial Plains

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
sandy CLAY, low plas, red brown	6.35	5.42	0.93	H	N						
sandy CLAY, low plas, red brown	7.2	6.69	0.51	H	N						
sandy CLAY, low plas, red brown	6.88	6.58	0.3	H	N						
sandy CLAY, low plas, red brown	7.21	5.1	2.11	H	N						
						7.39	**6.35**	**8.24**	**6.84**	**5.10**	**7.88**
Calcareous SANDSTONE	8.11	6.71	1.4	L	Y	**not calculated**					
silty sandy GRAVEL, with limestone	7.17	6.93	0.24	L	Y	**not calculated**					

Soils and Field Test Results-Samphire Flats

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
CLAY, high plasticity, grey with some yellow mottling	5.85	2.99	2.86	H	N	mean	min	max	mean	min	max
CLAY, high plasticity, red/brown/grey some grey/yellow mottling	7.31	7.64	-0.33	L	N						
CLAY, high plasticity, red/brown/grey some grey/yellow mottling	7.13	5.32	1.81	H	N						
CLAY, high plasticity, yellow/grey and red mottling	7.28	7.23	0.05	H	N						
CLAY, high plasticity, yellow/grey and red mottling	7.33	4.95	2.38	H	N						
CLAY, high plasticity, yellow/grey and red mottling	7.28	4.95	2.33	H	N						
CLAY, high plasticity, yellow/grey and red mottling	7	1.15	5.85	H	N						
CLAY, high plasticity, yellow/grey and red mottling	6.62	0.75	5.87	H	N						
CLAY, high plasticity, yellow/grey and red mottling	6.61	0.8	5.81	H	N						
CLAY, medium to high plasticity, grey/red mottling	6.64	6.58	0.06	H	N						
grades to grey	7.36	4.67	2.69	H	N						
CLAY, low to medium plasticity, grey	5.17	5.11	0.06	M	N						
CLAY, low to medium plasticity, grey	4.8	5.05	-0.25	M	N						
						6.64	**4.80**	**7.36**	**4.40**	**0.75**	**7.64**
clayey SAND, fine grained sands, low plas, mod tight, red/brown	7.58	7.83	-0.25	L	N						
clayey SAND, fine grained sands, low plas, mod tight, red/brown	7.25	7.98	-0.73	L	N						
clayey SAND, fine grained sands, low plas, mod tight, red/brown	7.55	7.81	-0.26	L	N						
clayey SAND, fine grained, low plas, mod tight, brown/red	7.2	8.2	-1	L	N						
clayey SAND, fine grained, low plas, mod tight, brown/red	7.39	8.2	-0.81	L	N						
clayey SAND, fine grained, low plas, mod tight, brown/red	7.5	8.57	-1.07	L	N						
clayey SAND, fine grained, low plas, mod tight, brown/red	7.61	8.17	-0.56	L	N						
clayey SAND, fine grained, low plas, mod tight, brown/red	7.45	8.14	-0.69	L	N						
clayey SAND, fine grained, low plas, mod tight, brown/red	7.04	8.03	-0.99	L	N						
clayey SAND, fine grained, low plas, mod tight, brown/red	7.06	8	-0.94	L	N						
clayey SAND, fine to med grained, low to med plas, red/brown	7.18	7.26	-0.08	L	N						
						7.35	**7.04**	**7.61**	**8.02**	**7.26**	**8.57**
CLAY, low to medium plasticity, red	6.05	7.53	-1.48	M/H	N						
sandy CLAY, high plasticity, red brown	6.88	6.55	0.33	L	N						
sandy CLAY, med to high plasticity, red/brown	7.39	7.72	-0.33	H	N						
sandy CLAY, med to high plasticity, red/brown	7.25	7.77	-0.52	M	N						
sandy CLAY, med to high plasticity, red/brown	7.31	0.92	6.39	L	N						
sandy CLAY, med to high plasticity, red/brown	6.9	1.05	5.85	L	N						
sandy CLAY, red, low plasticity	5.02	7.7	-2.68	H	N						
sandy CLAY, fine grained sands, yellow mottling, red/brown	7.65	7.8	-0.15	H	N						

Soils and Field Test Results-Samphire Flats

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
sandy CLAY, fine grained sands, yellow mottling, red/brown	7.58	8.02	-0.44	H	N						
sandy CLAY, fine grained sands, yellow mottling, red/brown	7.58	8.01	-0.43	H	N						
						6.96	5.02	7.65	6.31	0.92	8.02
silty SAND, fine grained, red brown	8.12	7.62	0.5	H	N						
						8.12	8.12	8.12	7.62	7.62	7.62

Soils and Field Test Results-Intertidal Flats, Tidal Creeks and Mangrove Swamp

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
Silty SAND, brown	8.17	2.8	5.37	H	N	**mean**	**min**	**max**	**mean**	**min**	**max**
Silty SAND, brown	8.34	6.6	1.74	M	N						
Silty SAND, brown	8.15	5.75	2.4	M	N						
Silty SAND, brown	8.47	7.2	1.27	H	N						
						8.28	**8.15**	**8.47**	**5.59**	**2.80**	**7.20**
CLAY, brown, medium plasticity	6.68	7.17	-0.49	L	N						
CLAY, brown, medium plasticity	6.35	7.05	-0.7	L	N						
CLAY, brown, medium plasticity	6.15	6.67	-0.52	L	N						
CLAY, dark brown, high plasticity	7.19	2.09	5.1	H	N						
CLAY, dark brown, high plasticity	7.55	2.33	5.22	H	N						
CLAY, dark brown, high plasticity	7.56	5.07	2.49	H	N						
						6.91	**6.15**	**7.56**	**5.06**	**2.09**	**7.17**
SAND, fine grained, dark grey	7.92	5.32	2.6	M	N						
						7.92	**7.92**	**7.92**	**5.32**	**5.32**	**5.32**
SAND, fine to medium grained, red brown	7.96	6.86	1.1	L	N						
SAND, fine to medium grained, red brown	7.94	6.97	0.97	L	N						
SAND, fine to medium grained, red brown to brown	7.37	6.4	0.97	M	N						
						7.76	**7.37**	**7.96**	**6.74**	**6.40**	**6.97**
sandy CLAY, moderate plasticity, red brown with grey mottling	7.33	7.76	-0.43	H	N						
sandy CLAY, moderate plasticity, red brown with grey mottling	7.12	7.31	-0.19	M/L	N	**7.23**	**7.12**	**7.33**	**7.54**	**7.31**	**7.76**

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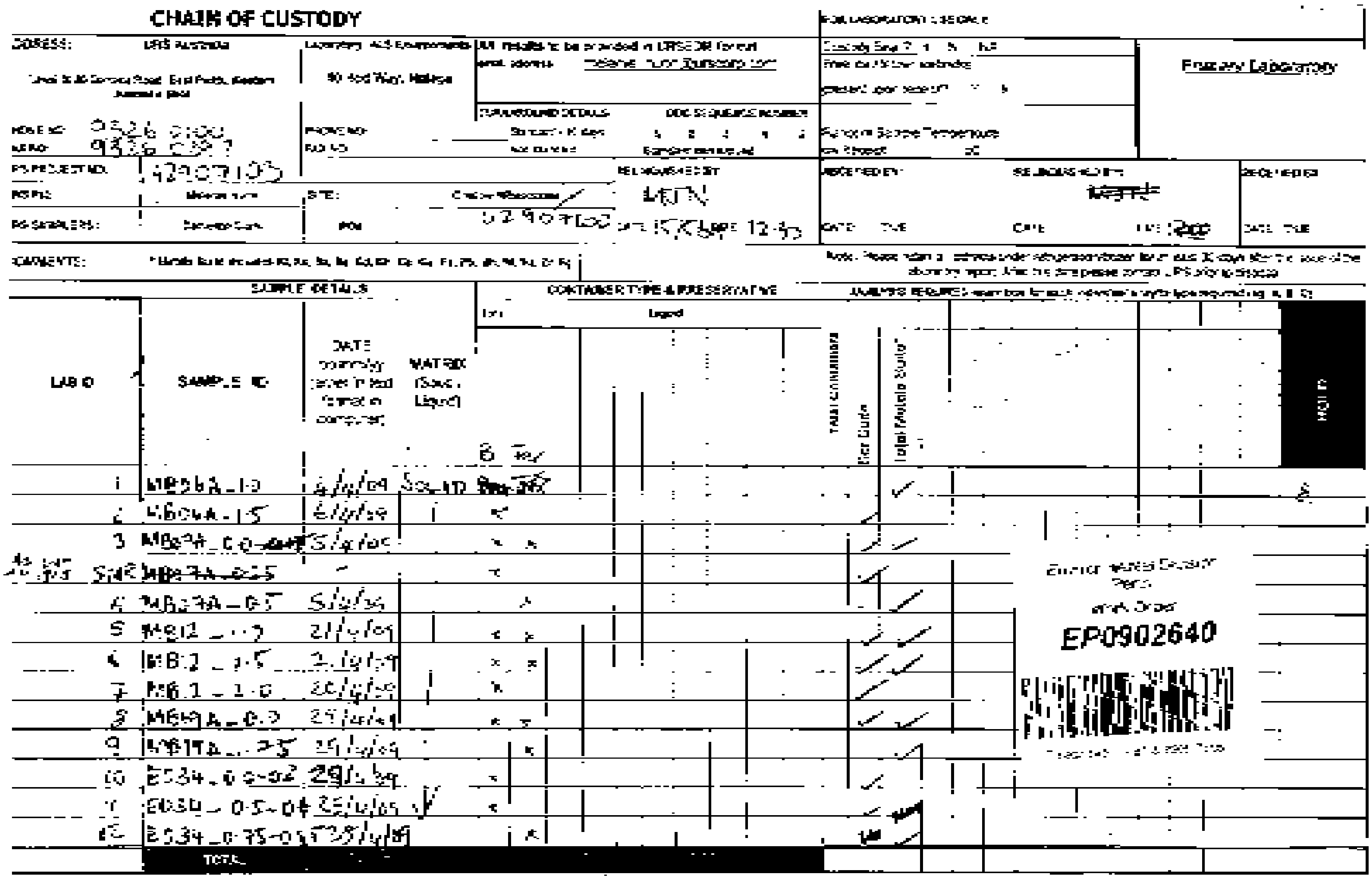
Soils and Field Test Results-Supratidal Flats

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
clayey SAND, fine grained, some black mottles, red/brown	6.57	6.5	0.07	H	N	**mean**	**min**	**max**	**mean**	**min**	**max**
						6.57	**6.57**	**6.57**	**6.50**	**6.50**	**6.50**
clayey SAND, fine to medium grained, low plasticity, light brown	6.78	4.95	1.83	L	N						
clayey SAND, fine to medium grained, low plasticity, light brown	5.88	3.77	2.11	L	N						
clayey SAND, fine to medium grained, low plasticity, light brown	5.74	2.2	3.54	L	N						
clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	6.1	3.31	2.79	H	N						
clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	7.13	7.74	-0.61	L	N						
clayey SAND, fine to med grained, low plas, red/brown with yellow mottling	7.21	7.43	-0.22	L	N						
clayey SAND, fine to medium grained, low plasticity, light brown	5.74	2.2	3.54	L	N						
						6.37	**5.74**	**7.21**	**4.51**	**2.20**	**7.74**
sandy CLAY, fine grained, low plasticity, light brown	6.58	5.39	1.19	L	N						
sandy CLAY, medium plas, fine to med grained, brown/red	5.32	3.81	1.51	L	N						
sandy CLAY, medium plas, fine to med grained, brown/red	5.6	1.94	3.66	H	N						
sandy CLAY, medium plas, fine to med grained, brown/red	7.57	7.65	-0.08	H	N						
sandy CLAY, medium plas, fine to med grained, brown/red	7.69	7.84	-0.15	L	N						
						6.55	**5.32**	**7.69**	**5.33**	**1.94**	**7.84**
sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	5.06	2.72	2.34	H	N						
sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	5.15	2.17	2.98	H	N						
sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	5.5	2.31	3.19	H	N						
sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	7.62	7.64	-0.02	L	N						
sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	7.35	7.79	-0.44	L	N						
sandy CLAY, mod plas, fine to med grained, dk organic matter, grey with some yellow mottling	7.15	7.8	-0.65	L	N						
						6.31	**5.06**	**7.62**	**5.07**	**2.17**	**7.80**

Soils and Field Test Results-Claypans

Lithological Description	pH(f)	pH(fox)	pH (change)	Reaction Type	HCL Reaction (No/Yes)	pH(f)			pH(fox)		
CLAY, red brown, high plasticity	7.07	6.95	0.12	M	N	**mean**	**min**	**max**	**mean**	**min**	**max**
CLAY, red brown, high plasticity	7.15	7.1	0.05	M	N						
CLAY, red brown, high plasticity	6.94	6.63	0.31	L	N						
						7.05	**6.94**	**7.15**	**6.89**	**6.63**	**7.10**
sandy CLAY, red/brown, some large shell fragments	7.26	7.8	-0.54	M	N						
sandy CLAY, red/brown, some large shell fragments	8.01	7.15	0.86	M	N						
sandy CLAY, low plas, red/brown	7.67	8.2	-0.53	H	N						
sandy CLAY, low plas, red/brown	7.56	8.2	-0.64	H	N						
sandy CLAY, low plas, red/brown	7.41	7.9	-0.49	H	N						
sandy CLAY, low plas, red/brown	7.53	7.78	-0.25	H	N						
sandy CLAY, low plas, red/brown	7.5	8.04	-0.54	H	N						
sandy CLAY, low plas, red/brown	7.67	7.89	-0.22	H	N						
sandy CLAY, low plas, red/brown	7.65	8.15	-0.5	H	N						
						7.58	**7.26**	**8.01**	**7.90**	**7.15**	**8.20**
silty SAND, limestone fragments	8.77	9.08	-0.31	L	Y						
silty SAND, limestone fragments	8.71	9.01	-0.3	L	Y						
silty SAND, limestone fragments	8.97	9.1	-0.13	L	Y						
silty SAND, red brown	8.81	9.11	-0.3	L	Y						
						8.82	**8.71**	**8.97**	**9.08**	**9.01**	**9.11**
silty SAND, very fine grained, loose, light brown	7.72	7.31	0.41	H	N						
silty SAND, very fine grained, loose, light brown	7.42	7.38	0.04	H	N						
silty SAND, very fine grained, loose, light brown	7.45	7.29	0.16	H	N						
silty gravelly SAND, fine, < 10% gravels, loose, Light brown	8.15	8.22	-0.07	H	N						
silty gravelly SAND, fine, < 10% gravels, loose, Light brown	7.74	8.55	-0.81	H	N						
silty gravelly SAND, fine, < 10% gravels, loose, Light brown	7.62	7.98	-0.36	H	N						
						7.68	**7.42**	**8.15**	**7.79**	**7.29**	**8.55**
silty sandy CLAY, low plasticity, red brown	8.79	9.01	-0.22	L	Y						
silty sandy CLAY, low plasticity, red brown	8.8	9.09	-0.29	L	Y						
silty CLAY, tight, red/brown	7.5	7.89	-0.39	H	N						
silty CLAY, tight, red/brown	7.5	7.97	-0.47	H	N						
						8.15	**7.50**	**8.80**	**8.49**	**7.89**	**9.09**

Appendix E Laboratory Certificates



CHAIN OF CUSTODY

ADDRESS: URS Australia

Laboratory: ALS Environmental

40 Hod Way, Malaga

PHONE NO: 9326 0100

FAX NO: 9326 0297

URS PROJECT NO: 42907105

SITE: Onslow Wheatstone

ENVIRONMENTAL LABORATORY

Primary Laboratory

RELINQUISHED BY: LEN

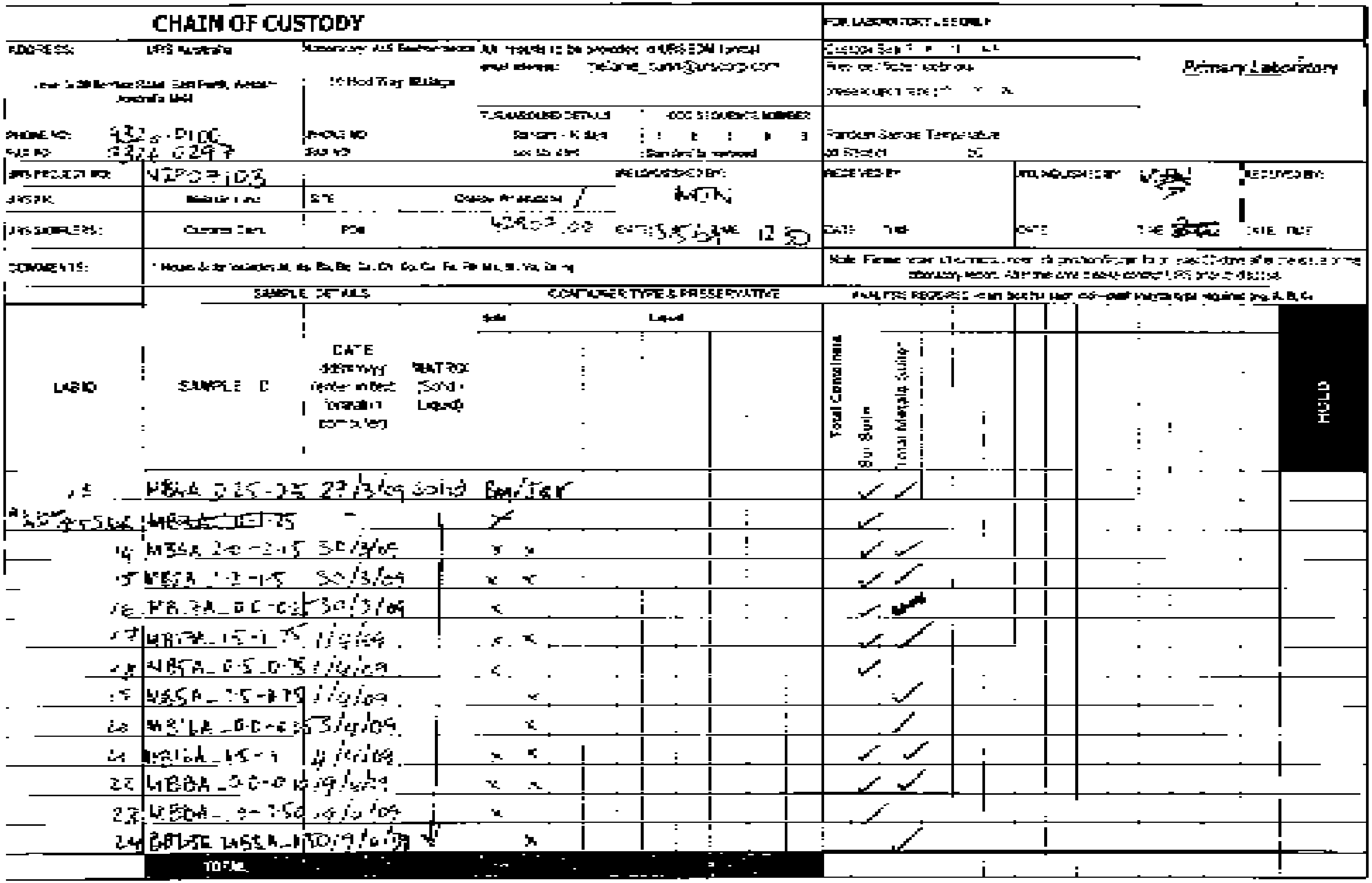
DATE: 15/5/09 TIME: 12:45

Environmental Division Perth

Work Order

EP0902640

LAB ID	SAMPLE ID	DATE	MATRIX
1	MB56A-1.0	6/4/09	SOLID
2	MB64A-1.5	6/4/09	
3	MB34-0.0-0.?	5/4/09	
SWC	~~MB34A-0.25~~		
4	MB23A-0.5	5/4/09	
5	MB12-1.0	21/4/09	
6	MB2-1.5	21/4/09	
7	MB1-1.0	20/4/09	
8	MB9A-0.2	25/4/09	
9	MB17A-0.25	25/4/09	
10	ES34-0.0-0.2	29/4/09	
11	ES34-0.5-0.8	25/4/09	
12	ES34-0.75-0.9	25/4/09	
	TOTAL		



CHAIN OF CUSTODY

ADDRESS: URS Australia

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PHONE NO: 9326 0100

FAX NO: 9326 0297

URS PROJECT NO: [illegible]

RELINQUISHED BY: [illegible]

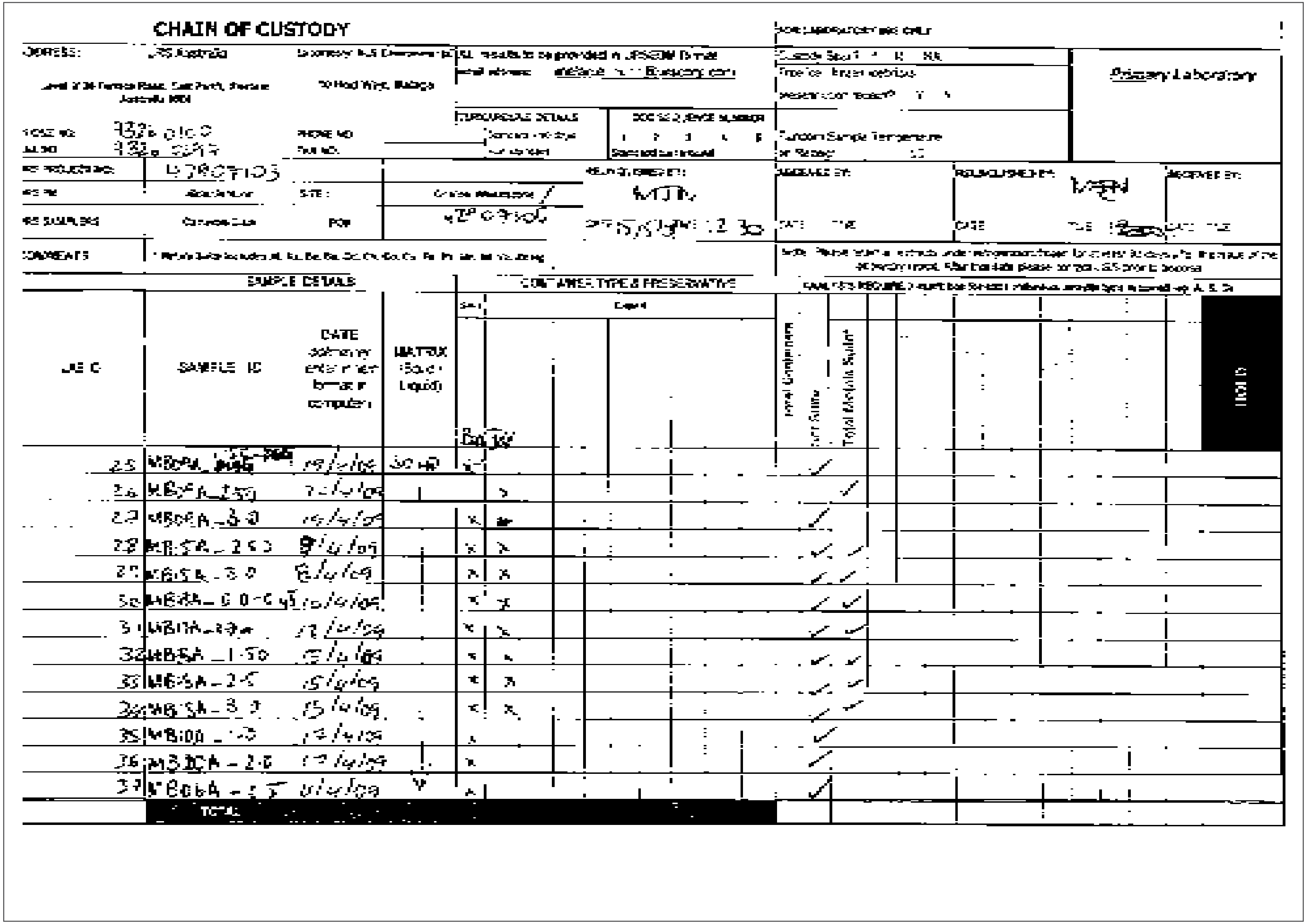
COMMENTS: [illegible]

Primary Laboratory

HOLD

LAB ID	SAMPLE ID	DATE	MATRIX (Solid / Liquid)	Container	Total Conc.	Total Metals
[illegible]	[illegible]	27/3/09	Solid	Bag/Jar	✓	✓
[illegible]	[illegible]			✓	✓	
14	MBAA_2.0-2.5	30/3/09		× ×	✓	✓
15	MBAA_1.0-1.5	30/3/09		× ×	✓	✓
16	[illegible]_0.0-0.2	30/3/09		×	✓	✓
17	[illegible]	1/4/09		× ×	✓	✓
18	[illegible]_0.5_0.75	1/4/09		×	✓	
19	[illegible]	1/4/09		×		✓
20	[illegible]	3/4/09		×		✓
21	[illegible]	[illegible]		× ×	✓	✓
22	[illegible]	[illegible]		× ×	✓	✓
23	[illegible]	[illegible]		×	✓	
24	[illegible]	[illegible]		×		✓

TOTAL



CHAIN OF CUSTODY

ADDRESS: URS Australia

Level 3 The Forrest Centre, 221 St Georges Terrace, Perth, Western Australia 6000

PHONE NO: 9326 0100

FAX NO: 9326 0296

URS PROJECT NO: 42907105

SITE:

PO#

RELINQUISHED BY: MTP

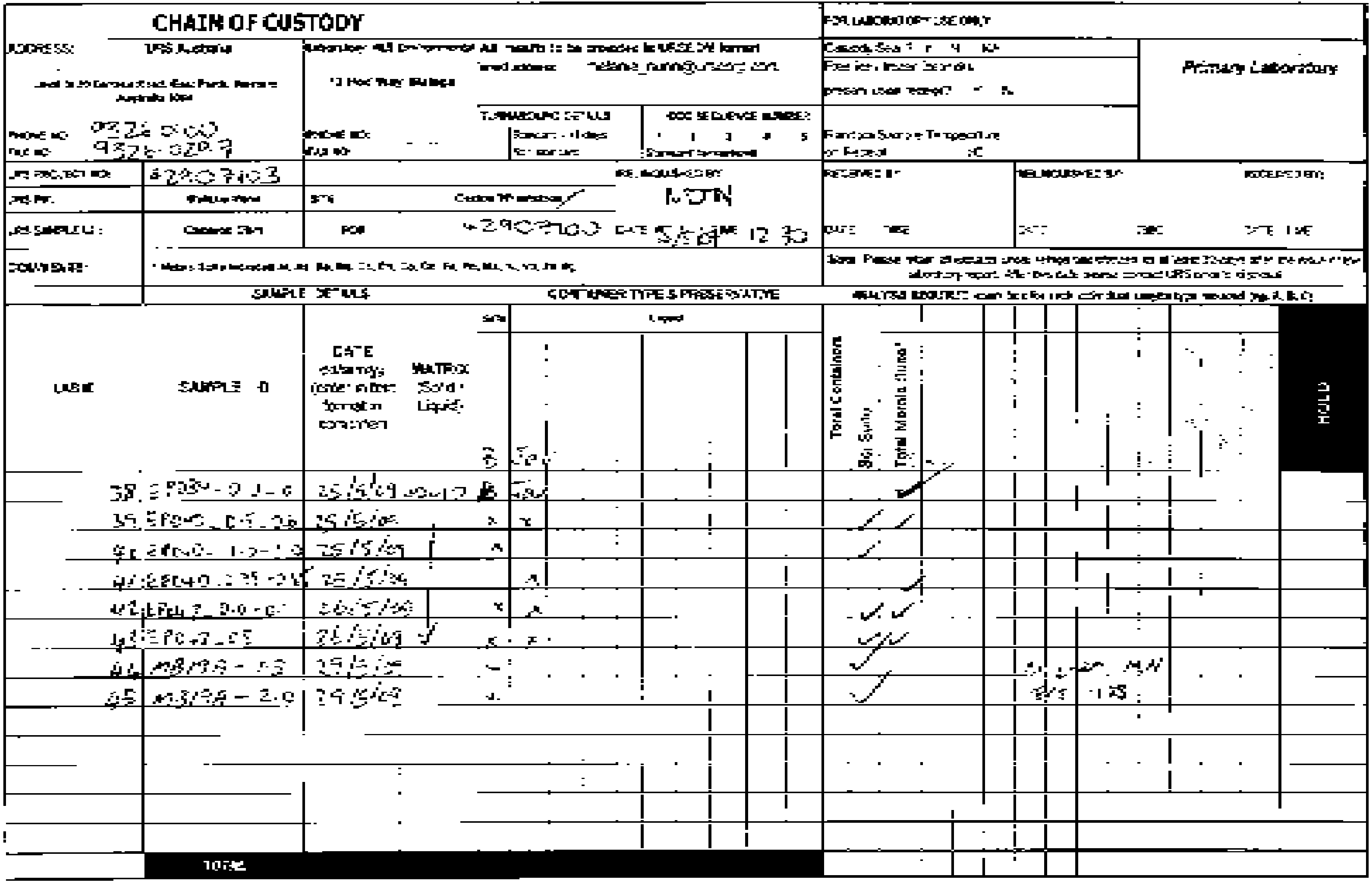
RELINQUISHED BY: [illegible]

RECEIVED BY:

COMMENTS: [illegible]

Primary Laboratory

LAB ID	SAMPLE ID	DATE	MATRIX (Soil / Liquid)	Soil	Liquid	[illegible]	Total Metals Suite
25	MB0?A_[illegible]	15/6/09	SOLID	x		✓	
26	MB0?A_1.50	[illegible]/6/09			x		✓
27	MB0?A_3.0	15/6/09		x	x	✓	
28	MB15A_1.50	9/6/09		x	x	✓	✓
29	MB15A_3.0	6/6/09		x	x	✓	✓
30	MB?A_0.0-0.5	15/6/09		x	x	✓	✓
31	MB1?A_[illegible]	12/6/09		x	x	✓	✓
32	MB?A_1.50	15/6/09		x	x	✓	✓
33	MB?A_2.5	15/6/09		x	x	✓	✓
34	MB?SA_3.0	15/6/09		x	x	✓	✓
35	MB?0A_[illegible]	12/6/09		x		✓	
36	MB?CA_2.0	12/6/09		x		✓	
37	MB?6A_[illegible]	11/6/09		x		✓	
TOTAL							



CHAIN OF CUSTODY

ADDRESS: URS Australia

[illegible] Perth [illegible] Australia [illegible]

PHONE NO: [illegible]

FAX NO: [illegible]

All results to be reported in [illegible] format

Email address: melanie_nunn@urscorp.com

TURNAROUND DETAILS: Standard - 5 days

COC SEQUENCE NUMBER: 1 2 3 4 5

URS PROJECT NO: 42907103

SITE: Onslow Wheatstone ✓

RELINQUISHED BY: MJN

PO#: 42907103 DATE: 5/6/09 TIME: 12:30

COMMENTS: * Metals [illegible] As, Ba, Be, Cd, Co, Cr, Cu, Pb, Mn, Ni, V, Zn, Hg

FOR LABORATORY USE ONLY

Primary Laboratory

SAMPLE DETAILS — CONTAINER TYPE & PRESERVATIVE — ANALYSIS REQUIRED

LAB ID	SAMPLE ID	DATE sampling	MATRIX	Soil	Total Containers	Soil Suite	Total Metals (Suite)*	HOLD
38	[illegible]-0.1-0.6	25/5/09	[illegible]	[illegible]			✓	
39	[illegible]-0.5-2.6	25/5/09				✓	✓	
40	[illegible]-1.5-1.8	25/5/09				✓		
41	[illegible]-0.25-0.35	25/5/09					✓	
42	[illegible]-2.0-2.6	26/5/09				✓	✓	
43	[illegible]-0.5	26/5/09				✓	✓	
44	[illegible]-0.5	25/5/09				✓		
45	[illegible]-2.0	29/5/09				✓		

TOTAL

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

SAMPLE RECEIPT NOTIFICATION (SRN)

Comprehensive Report

Work Order : **EP0902640**

Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MELANIE NUNN	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	: melanie_nunn@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0128	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9221 1639	Facsimile	: +61-8-9209 7600
Project	: 42907103	Page	: 1 of 3
Order number	: 42907100		
C-O-C number	: ----	Quote number	: EP2009URSWA0290 (EN-001-08)
Site	: Onslow Wheatstone		
Sampler	: CAMERON CLARK	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Dates

Date Samples Received	: 15-MAY-2009	Issue Date	: 19-MAY-2009 08:33
Client Requested Due Date	: 22-MAY-2009	Scheduled Reporting Date	: **22-MAY-2009**

Delivery Details

Mode of Delivery	: Carrier	Temperature	: Frozen
No. of coolers/boxes	: 2l	No. of samples received	: 45
Sercurity Seal	: Intact.	No. of samples analysed	: 45

General Comments

- This report contains the following information:
    - Sample Container(s)/Preservation Non-Compliances
    - Summary of Sample(s) and Requested Analysis
    - Requested Deliverables
- Samples received in appropriately pretreated and preserved containers.
- Please see scanned COC for sample discrepencies: extra samples , samples not received etc.
- **Samples received in appropriately pretreated and preserved containers.**
- **Sample(s) have been received within recommended holding times.**
- **pH analysis should be conducted within 6 hours of sampling.**
- Analytical work for this work order will be conducted at ALS Environmental Perth.
- Please direct any turnaround / technical queries to the laboratory contact designated above.
- Please direct any queries related to sample condition / numbering / breakages to Sample Receipt (SamplesPerth@alsenviro.com)
- Sample Disposal - Aqueous (14 days), Solid (90 days) from date of completion of Work Order.

Environmental Division Perth
Part of the ALS Laboratory Group
10 Hod Way Malaga WA Australia 6090
Tel. +61-8-9209 7655 Fax. +61-8-9209 7600 **www.alsglobal.com**
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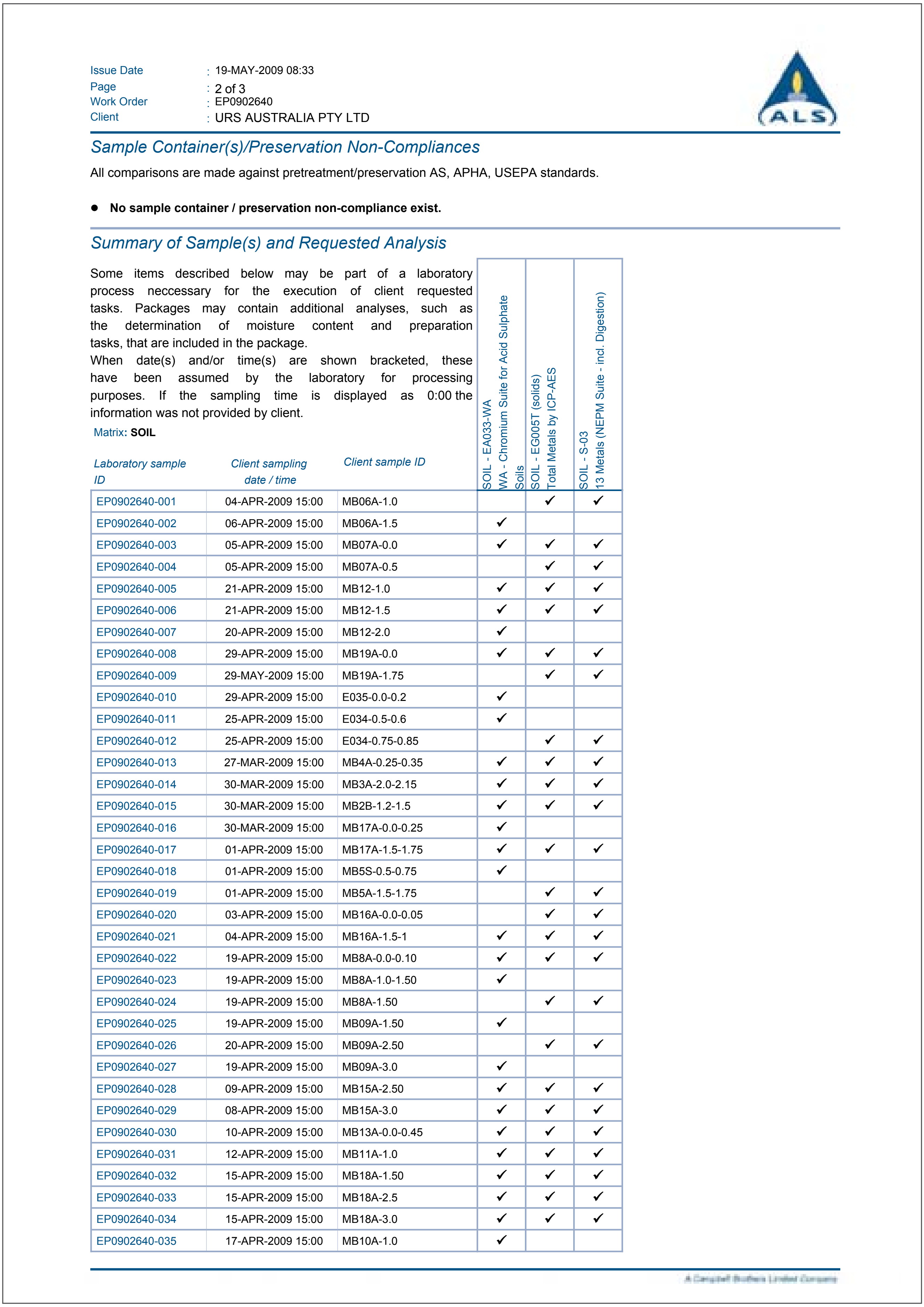


Issue Date : 19-MAY-2009 08:33
Page : 2 of 3
Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exist.**

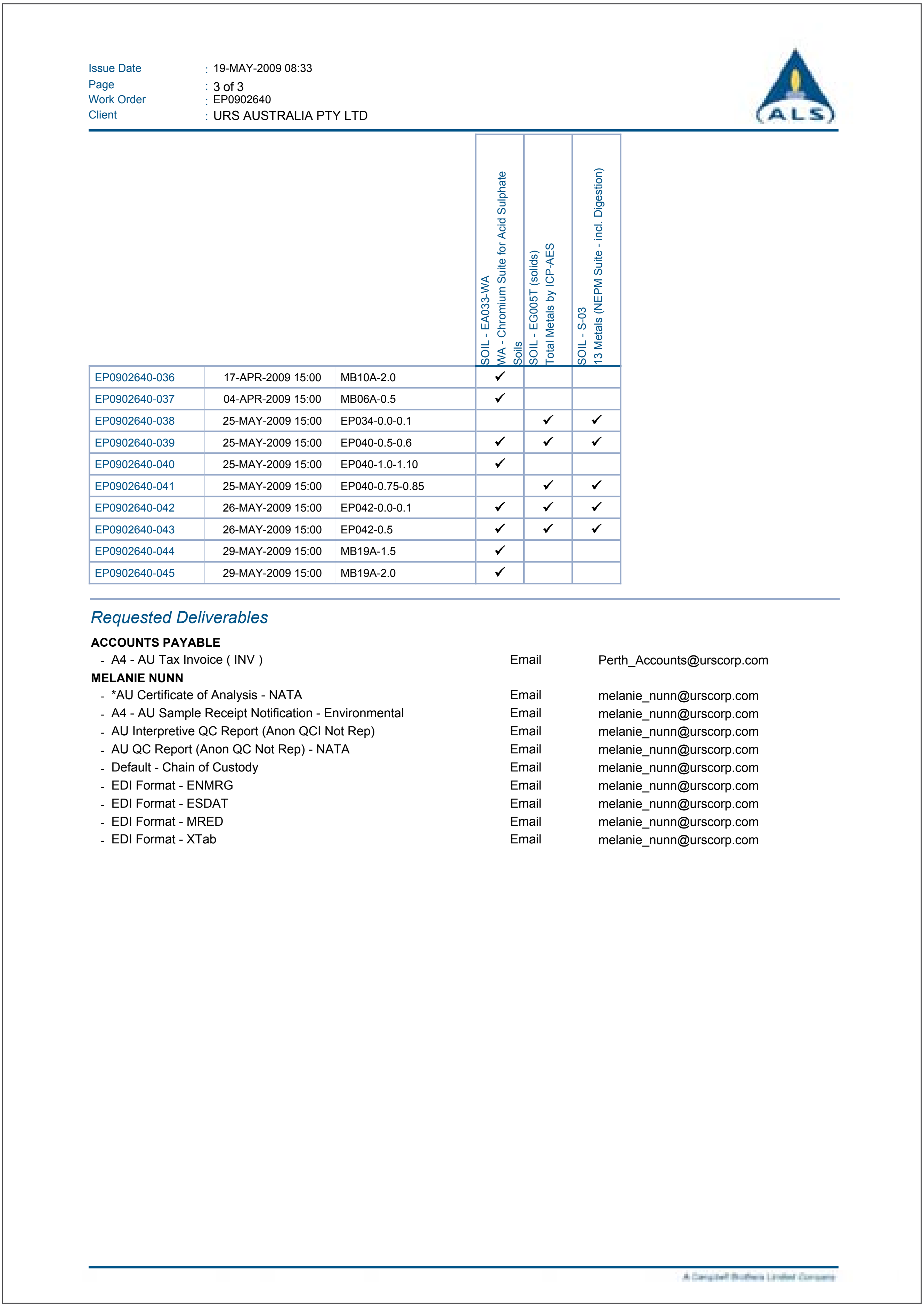
Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process neccessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

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.

Matrix: **SOIL**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	SOIL - EA033-WA WA - Chromium Suite for Acid Sulphate Soils	SOIL - EG005T (solids) Total Metals by ICP-AES	SOIL - S-03 13 Metals (NEPM Suite - incl. Digestion)
EP0902640-001	04-APR-2009 15:00	MB06A-1.0		✓	✓
EP0902640-002	06-APR-2009 15:00	MB06A-1.5	✓		
EP0902640-003	05-APR-2009 15:00	MB07A-0.0	✓	✓	✓
EP0902640-004	05-APR-2009 15:00	MB07A-0.5		✓	✓
EP0902640-005	21-APR-2009 15:00	MB12-1.0	✓	✓	✓
EP0902640-006	21-APR-2009 15:00	MB12-1.5	✓	✓	✓
EP0902640-007	20-APR-2009 15:00	MB12-2.0	✓		
EP0902640-008	29-APR-2009 15:00	MB19A-0.0	✓	✓	✓
EP0902640-009	29-MAY-2009 15:00	MB19A-1.75		✓	✓
EP0902640-010	29-APR-2009 15:00	E035-0.0-0.2	✓		
EP0902640-011	25-APR-2009 15:00	E034-0.5-0.6	✓		
EP0902640-012	25-APR-2009 15:00	E034-0.75-0.85		✓	✓
EP0902640-013	27-MAR-2009 15:00	MB4A-0.25-0.35	✓	✓	✓
EP0902640-014	30-MAR-2009 15:00	MB3A-2.0-2.15	✓	✓	✓
EP0902640-015	30-MAR-2009 15:00	MB2B-1.2-1.5	✓	✓	✓
EP0902640-016	30-MAR-2009 15:00	MB17A-0.0-0.25	✓		
EP0902640-017	01-APR-2009 15:00	MB17A-1.5-1.75	✓	✓	✓
EP0902640-018	01-APR-2009 15:00	MB5S-0.5-0.75	✓		
EP0902640-019	01-APR-2009 15:00	MB5A-1.5-1.75		✓	✓
EP0902640-020	03-APR-2009 15:00	MB16A-0.0-0.05		✓	✓
EP0902640-021	04-APR-2009 15:00	MB16A-1.5-1	✓	✓	✓
EP0902640-022	19-APR-2009 15:00	MB8A-0.0-0.10	✓	✓	✓
EP0902640-023	19-APR-2009 15:00	MB8A-1.0-1.50	✓		
EP0902640-024	19-APR-2009 15:00	MB8A-1.50		✓	✓
EP0902640-025	19-APR-2009 15:00	MB09A-1.50	✓		
EP0902640-026	20-APR-2009 15:00	MB09A-2.50		✓	✓
EP0902640-027	19-APR-2009 15:00	MB09A-3.0	✓		
EP0902640-028	09-APR-2009 15:00	MB15A-2.50	✓	✓	✓
EP0902640-029	08-APR-2009 15:00	MB15A-3.0	✓	✓	✓
EP0902640-030	10-APR-2009 15:00	MB13A-0.0-0.45	✓	✓	✓
EP0902640-031	12-APR-2009 15:00	MB11A-1.0	✓	✓	✓
EP0902640-032	15-APR-2009 15:00	MB18A-1.50	✓	✓	✓
EP0902640-033	15-APR-2009 15:00	MB18A-2.5	✓	✓	✓
EP0902640-034	15-APR-2009 15:00	MB18A-3.0	✓	✓	✓
EP0902640-035	17-APR-2009 15:00	MB10A-1.0	✓		



Issue Date : 19-MAY-2009 08:33
Page : 3 of 3
Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD

			SOIL - EA033-WA WA - Chromium Suite for Acid Sulphate Soils	SOIL - EG005T (solids) Total Metals by ICP-AES	SOIL - S-03 13 Metals (NEPM Suite - incl. Digestion)
EP0902640-036	17-APR-2009 15:00	MB10A-2.0	✓		
EP0902640-037	04-APR-2009 15:00	MB06A-0.5	✓		
EP0902640-038	25-MAY-2009 15:00	EP034-0.0-0.1		✓	✓
EP0902640-039	25-MAY-2009 15:00	EP040-0.5-0.6	✓	✓	✓
EP0902640-040	25-MAY-2009 15:00	EP040-1.0-1.10	✓		
EP0902640-041	25-MAY-2009 15:00	EP040-0.75-0.85		✓	✓
EP0902640-042	26-MAY-2009 15:00	EP042-0.0-0.1	✓	✓	✓
EP0902640-043	26-MAY-2009 15:00	EP042-0.5	✓	✓	✓
EP0902640-044	29-MAY-2009 15:00	MB19A-1.5	✓		
EP0902640-045	29-MAY-2009 15:00	MB19A-2.0	✓		

Requested Deliverables

ACCOUNTS PAYABLE

- A4 - AU Tax Invoice (INV)	Email	Perth_Accounts@urscorp.com

MELANIE NUNN

- *AU Certificate of Analysis - NATA	Email	melanie_nunn@urscorp.com
- A4 - AU Sample Receipt Notification - Environmental	Email	melanie_nunn@urscorp.com
- AU Interpretive QC Report (Anon QCI Not Rep)	Email	melanie_nunn@urscorp.com
- AU QC Report (Anon QC Not Rep) - NATA	Email	melanie_nunn@urscorp.com
- Default - Chain of Custody	Email	melanie_nunn@urscorp.com
- EDI Format - ENMRG	Email	melanie_nunn@urscorp.com
- EDI Format - ESDAT	Email	melanie_nunn@urscorp.com
- EDI Format - MRED	Email	melanie_nunn@urscorp.com
- EDI Format - XTab	Email	melanie_nunn@urscorp.com

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ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0902640**	Page	: 1 of 20
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MELANIE NUNN	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	: melanie_nunn@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0128	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9221 1639	Facsimile	: +61-8-9209 7600
Project	: 42907103	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: 42907100		
C-O-C number	: ----	Date Samples Received	: 15-MAY-2009
Sampler	: CAMERON CLARK	Issue Date	: 25-MAY-2009
Site	: Onslow Wheatstone		
		No. of samples received	: 45
Quote number	: EN-001-08	No. of samples analysed	: 45

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
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

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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**

Page : 3 of 20
Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**MB06A-1.0**	**MB06A-1.5**	**MB07A-0.0**	**MB07A-0.5**	**MB12-1.0**
			Client sampling date / time	04-APR-2009 15:00	06-APR-2009 15:00	05-APR-2009 15:00	05-APR-2009 15:00	21-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-001**	**EP0902640-002**	**EP0902640-003**	**EP0902640-004**	**EP0902640-005**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	----	**6.7**	**9.2**	----	**8.2**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	----	<2	<2	----	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	----	<0.02	<0.02	----	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	----	<0.02	<0.02	----	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	----	<10	<10	----	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	----	**0.11**	**7.48**	----	**1.26**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	----	**23**	**1490**	----	**251**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	----	**0.04**	**2.39**	----	**0.40**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	----	**1.5**	**1.5**	----	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	----	<0.02	<0.02	----	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	----	<10	<10	----	<10
Liming Rate	----	1	kg CaCO3/t	----	<1	<1	----	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	----	<0.02	<0.02	----	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	----	<10	<10	----	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	----	<1	<1	----	<1
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**20.7**	----	**11.3**	**18.9**	**25.3**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**7510**	----	**11700**	**11900**	**7970**
Arsenic	7440-38-2	5	mg/kg	**14**	----	**9**	**8**	**12**
Barium	7440-39-3	10	mg/kg	<10	----	**40**	**60**	**10**
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	**48**	----	**52**	**52**	**55**
Cobalt	7440-48-4	2	mg/kg	**5**	----	**16**	**16**	**18**
Copper	7440-50-8	5	mg/kg	**17**	----	**29**	**29**	**23**
Iron	7439-89-6	50	mg/kg	**30000**	----	**39200**	**39200**	**31400**
Lead	7439-92-1	5	mg/kg	<5	----	**10**	**10**	**11**
Manganese	7439-96-5	5	mg/kg	**66**	----	**569**	**566**	**194**
Nickel	7440-02-0	2	mg/kg	**10**	----	**26**	**26**	**26**
Vanadium	7440-62-2	5	mg/kg	**75**	----	**71**	**73**	**68**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MB06A-1.0**	**MB06A-1.5**	**MB07A-0.0**	**MB07A-0.5**	**MB12-1.0**
			Client sampling date / time	04-APR-2009 15:00	06-APR-2009 15:00	05-APR-2009 15:00	05-APR-2009 15:00	21-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-001**	**EP0902640-002**	**EP0902640-003**	**EP0902640-004**	**EP0902640-005**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	**22**	----	**40**	**40**	**42**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	<0.1	<0.1	<0.1

Page : 5 of 20
Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**MB12-1.5**	**MB12-2.0**	**MB19A-0.0**	**MB19A-1.75**	**E035-0.0-0.2**
			Client sampling date / time	21-APR-2009 15:00	20-APR-2009 15:00	29-APR-2009 15:00	29-MAY-2009 15:00	29-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-006**	**EP0902640-007**	**EP0902640-008**	**EP0902640-009**	**EP0902640-010**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**8.5**	**8.5**	**9.9**	----	**9.4**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	----	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	----	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	**0.66**	**0.47**	<0.02	----	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**410**	**292**	<10	----	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**4.06**	**3.71**	**3.56**	----	**4.72**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**812**	**742**	**711**	----	**944**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.30**	**1.19**	**1.14**	----	**1.51**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	----	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	----	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	----	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	----	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.66**	**0.47**	<0.02	----	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**410**	**292**	<10	----	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	**31**	**22**	<1	----	<1
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**29.5**	----	**15.5**	**23.1**	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**11900**	----	**2930**	**5410**	----
Arsenic	7440-38-2	5	mg/kg	**51**	----	**6**	**16**	----
Barium	7440-39-3	10	mg/kg	**10**	----	<10	<10	----
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	**60**	----	**28**	**63**	----
Cobalt	7440-48-4	2	mg/kg	**29**	----	**5**	**6**	----
Copper	7440-50-8	5	mg/kg	**34**	----	**6**	**14**	----
Iron	7439-89-6	50	mg/kg	**47600**	----	**18200**	**45600**	----
Lead	7439-92-1	5	mg/kg	**14**	----	<5	**8**	----
Manganese	7439-96-5	5	mg/kg	**168**	----	**246**	**98**	----
Nickel	7440-02-0	2	mg/kg	**32**	----	**8**	**12**	----
Vanadium	7440-62-2	5	mg/kg	**89**	----	**36**	**106**	----

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MB12-1.5**	**MB12-2.0**	**MB19A-0.0**	**MB19A-1.75**	**E035-0.0-0.2**
			Client sampling date / time	21-APR-2009 15:00	20-APR-2009 15:00	29-APR-2009 15:00	29-MAY-2009 15:00	29-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-006**	**EP0902640-007**	**EP0902640-008**	**EP0902640-009**	**EP0902640-010**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	**68**	----	**14**	**24**	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	<0.1	<0.1	----

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Sub-Matrix: **SOIL**			*Client sample ID*	**E034-0.5-0.6**	**E034-0.75-0.85**	**MB4A-0.25-0.35**	**MB3A-2.0-2.15**	**MB2B-1.2-1.5**
			Client sampling date / time	25-APR-2009 15:00	25-APR-2009 15:00	27-MAR-2009 15:00	30-MAR-2009 15:00	30-MAR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-011**	**EP0902640-012**	**EP0902640-013**	**EP0902640-014**	**EP0902640-015**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**8.3**	----	**9.8**	**9.9**	**9.1**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<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
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**1.50**	----	**30.2**	**34.7**	**1.51**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**299**	----	**6030**	**6930**	**302**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.48**	----	**9.66**	**11.1**	**0.48**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	----	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	----	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	----	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	----	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	----	<1	<1	<1
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	----	**32.8**	**2.0**	**10.3**	**7.2**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	**11400**	**2570**	**2380**	**6490**
Arsenic	7440-38-2	5	mg/kg	----	**17**	**12**	**18**	<5
Barium	7440-39-3	10	mg/kg	----	**10**	**20**	<10	**30**
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	----	**65**	**29**	**27**	**45**
Cobalt	7440-48-4	2	mg/kg	----	**12**	**6**	**4**	**9**
Copper	7440-50-8	5	mg/kg	----	**34**	**6**	**7**	**19**
Iron	7439-89-6	50	mg/kg	----	**35600**	**22400**	**17100**	**32600**
Lead	7439-92-1	5	mg/kg	----	**5**	<5	<5	**7**
Manganese	7439-96-5	5	mg/kg	----	**95**	**372**	**295**	**330**
Nickel	7440-02-0	2	mg/kg	----	**20**	**6**	**5**	**17**
Vanadium	7440-62-2	5	mg/kg	----	**78**	**38**	**36**	**57**

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Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**E034-0.5-0.6**	**E034-0.75-0.85**	**MB4A-0.25-0.35**	**MB3A-2.0-2.15**	**MB2B-1.2-1.5**
			Client sampling date / time	25-APR-2009 15:00	25-APR-2009 15:00	27-MAR-2009 15:00	30-MAR-2009 15:00	30-MAR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-011**	**EP0902640-012**	**EP0902640-013**	**EP0902640-014**	**EP0902640-015**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	----	**41**	**10**	<5	**29**
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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Sub-Matrix: **SOIL**

			Client sample ID	**MB17A-0.0-0.25**	**MB17A-1.5-1.75**	**MB5S-0.5-0.75**	**MB5A-1.5-1.75**	**MB16A-0.0-0.05**
			Client sampling date / time	30-MAR-2009 15:00	01-APR-2009 15:00	01-APR-2009 15:00	01-APR-2009 15:00	03-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-016**	**EP0902640-017**	**EP0902640-018**	**EP0902640-019**	**EP0902640-020**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**8.7**	**8.0**	**9.6**	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	----	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**1.77**	**1.27**	**4.59**	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**354**	**254**	**917**	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.57**	**0.41**	**1.47**	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	----	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	----	----
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	----	----
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	----	----
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	----	----
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	----	----
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	----	**16.3**	----	**9.6**	**2.0**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	**6520**	----	**5440**	**3090**
Arsenic	7440-38-2	5	mg/kg	----	**5**	----	**11**	<5
Barium	7440-39-3	10	mg/kg	----	**50**	----	**20**	**20**
Beryllium	7440-41-7	1	mg/kg	----	**3**	----	<1	<1
Cadmium	7440-43-9	1	mg/kg	----	<1	----	<1	<1
Chromium	7440-47-3	2	mg/kg	----	**38**	----	**32**	**35**
Cobalt	7440-48-4	2	mg/kg	----	**23**	----	**4**	**4**
Copper	7440-50-8	5	mg/kg	----	**20**	----	**8**	<5
Iron	7439-89-6	50	mg/kg	----	**42500**	----	**22100**	**23900**
Lead	7439-92-1	5	mg/kg	----	**8**	----	<5	<5
Manganese	7439-96-5	5	mg/kg	----	**1380**	----	**147**	**143**
Nickel	7440-02-0	2	mg/kg	----	**41**	----	**8**	**8**
Vanadium	7440-62-2	5	mg/kg	----	**58**	----	**52**	**43**

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Sub-Matrix: **SOIL**

			Client sample ID	**MB17A-0.0-0.25**	**MB17A-1.5-1.75**	**MB5S-0.5-0.75**	**MB5A-1.5-1.75**	**MB16A-0.0-0.05**
			Client sampling date / time	30-MAR-2009 15:00	01-APR-2009 15:00	01-APR-2009 15:00	01-APR-2009 15:00	03-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-016**	**EP0902640-017**	**EP0902640-018**	**EP0902640-019**	**EP0902640-020**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	----	**99**	----	**8**	**12**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	<0.1	----	<0.1	<0.1

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Sub-Matrix: **SOIL**			*Client sample ID*	**MB16A-1.5-1**	**MB8A-0.0-0.10**	**MB8A-1.0-1.50**	**MB8A-1.50**	**MB09A-1.50**
			Client sampling date / time	04-APR-2009 15:00	19-APR-2009 15:00	19-APR-2009 15:00	19-APR-2009 15:00	19-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-021**	**EP0902640-022**	**EP0902640-023**	**EP0902640-024**	**EP0902640-025**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.2**	**7.3**	**9.6**	----	**9.7**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	----	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<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
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	----	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**3.25**	**0.45**	**6.90**	----	**28.0**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**649**	**91**	**1380**	----	**5590**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.04**	**0.14**	**2.21**	----	**8.96**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	----	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	----	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	----	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	----	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	----	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	----	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	----	<1
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**14.3**	**1.8**	----	**11.1**	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**4190**	**3760**	----	**3720**	----
Arsenic	7440-38-2	5	mg/kg	**5**	<5	----	**6**	----
Barium	7440-39-3	10	mg/kg	**20**	**10**	----	**20**	----
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	**37**	**37**	----	**40**	----
Cobalt	7440-48-4	2	mg/kg	**5**	**6**	----	**4**	----
Copper	7440-50-8	5	mg/kg	**6**	**8**	----	**6**	----
Iron	7439-89-6	50	mg/kg	**26800**	**26500**	----	**27900**	----
Lead	7439-92-1	5	mg/kg	**5**	**6**	----	**5**	----
Manganese	7439-96-5	5	mg/kg	**185**	**194**	----	**127**	----
Nickel	7440-02-0	2	mg/kg	**10**	**10**	----	**9**	----
Vanadium	7440-62-2	5	mg/kg	**47**	**47**	----	**53**	----

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MB16A-1.5-1**	**MB8A-0.0-0.10**	**MB8A-1.0-1.50**	**MB8A-1.50**	**MB09A-1.50**
			Client sampling date / time	04-APR-2009 15:00	19-APR-2009 15:00	19-APR-2009 15:00	19-APR-2009 15:00	19-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-021**	**EP0902640-022**	**EP0902640-023**	**EP0902640-024**	**EP0902640-025**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	**14**	**15**	----	**12**	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	----	<0.1	----

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Sub-Matrix: **SOIL**			*Client sample ID*	MB09A-2.50	MB09A-3.0	MB15A-2.50	MB15A-3.0	MB13A-0.0-0.45
			Client sampling date / time	20-APR-2009 15:00	19-APR-2009 15:00	09-APR-2009 15:00	08-APR-2009 15:00	10-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	EP0902640-026	EP0902640-027	EP0902640-028	EP0902640-029	EP0902640-030
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	----	**9.8**	**9.7**	**9.5**	**9.7**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	----	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	----	<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
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	----	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	----	**30.5**	**26.0**	**30.6**	**3.25**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	----	**6090**	**5200**	**6120**	**649**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	----	**9.76**	**8.33**	**9.82**	**1.04**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	----	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	----	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	----	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	----	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	----	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	----	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	----	<1	<1	<1	<1
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**7.2**	----	**9.0**	**14.6**	**1.8**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**3280**	----	**3040**	**2860**	**3530**
Arsenic	7440-38-2	5	mg/kg	**10**	----	**11**	**11**	**6**
Barium	7440-39-3	10	mg/kg	**10**	----	**20**	**20**	<10
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	**34**	----	**28**	**27**	**45**
Cobalt	7440-48-4	2	mg/kg	**6**	----	**6**	**6**	**7**
Copper	7440-50-8	5	mg/kg	**6**	----	**6**	**6**	**8**
Iron	7439-89-6	50	mg/kg	**24200**	----	**19600**	**19300**	**30100**
Lead	7439-92-1	5	mg/kg	**5**	----	<5	<5	**5**
Manganese	7439-96-5	5	mg/kg	**193**	----	**276**	**343**	**269**
Nickel	7440-02-0	2	mg/kg	**7**	----	**7**	**7**	**12**
Vanadium	7440-62-2	5	mg/kg	**49**	----	**40**	**40**	**59**

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Analytical Results

Sub-Matrix: **SOIL**

Compound	CAS Number	LOR	Unit	MB09A-2.50	MB09A-3.0	MB15A-2.50	MB15A-3.0	MB13A-0.0-0.45
			Client sampling date / time	20-APR-2009 15:00	19-APR-2009 15:00	09-APR-2009 15:00	08-APR-2009 15:00	10-APR-2009 15:00
				EP0902640-026	**EP0902640-027**	**EP0902640-028**	**EP0902640-029**	**EP0902640-030**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	**6**	----	**8**	**6**	**21**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**MB11A-1.0**	**MB18A-1.50**	**MB18A-2.5**	**MB18A-3.0**	**MB10A-1.0**
			Client sampling date / time	12-APR-2009 15:00	15-APR-2009 15:00	15-APR-2009 15:00	15-APR-2009 15:00	17-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-031**	**EP0902640-032**	**EP0902640-033**	**EP0902640-034**	**EP0902640-035**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.3**	**7.9**	**8.2**	**5.2**	**9.8**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	**34**	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	**0.06**	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	<0.02	**1.20**	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	**751**	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**5.76**	**1.79**	**1.57**	----	**4.09**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**1150**	**358**	**314**	----	**816**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**1.84**	**0.57**	**0.50**	----	**1.31**
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	**1.26**	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	**786**	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	**59**	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	**1.26**	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	**786**	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	**59**	<1
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**20.0**	**36.2**	**35.3**	**39.3**	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**3200**	**8140**	**9560**	**15300**	----
Arsenic	7440-38-2	5	mg/kg	**6**	**18**	**93**	**22**	----
Barium	7440-39-3	10	mg/kg	<10	**10**	**40**	<10	----
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	**67**	**55**	**108**	**60**	----
Cobalt	7440-48-4	2	mg/kg	**7**	**5**	**2**	**44**	----
Copper	7440-50-8	5	mg/kg	**7**	**29**	**42**	**48**	----
Iron	7439-89-6	50	mg/kg	**39600**	**54200**	**121000**	**46500**	----
Lead	7439-92-1	5	mg/kg	**8**	**11**	**31**	**16**	----
Manganese	7439-96-5	5	mg/kg	**56**	**51**	**80**	**55**	----
Nickel	7440-02-0	2	mg/kg	**10**	**9**	**4**	**61**	----
Vanadium	7440-62-2	5	mg/kg	**96**	**86**	**220**	**97**	----

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MB11A-1.0**	**MB18A-1.50**	**MB18A-2.5**	**MB18A-3.0**	**MB10A-1.0**
			Client sampling date / time	12-APR-2009 15:00	15-APR-2009 15:00	15-APR-2009 15:00	15-APR-2009 15:00	17-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-031**	**EP0902640-032**	**EP0902640-033**	**EP0902640-034**	**EP0902640-035**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	**18**	**25**	**26**	**51**	----
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 : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	MB10A-2.0	MB06A-0.5	EP034-0.0-0.1	EP040-0.5-0.6	EP040-1.0-1.10
			Client sampling date / time	17-APR-2009 15:00	04-APR-2009 15:00	25-MAY-2009 15:00	25-MAY-2009 15:00	25-MAY-2009 15:00
Compound	CAS Number	LOR	Unit	EP0902640-036	EP0902640-037	EP0902640-038	EP0902640-039	EP0902640-040
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	7.7	9.5	----	6.3	6.1
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	----	2	4
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	----	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	0.11	<0.02	----	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	71	<10	----	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	1.18	3.18	----	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	236	635	----	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	0.38	1.02	----	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	----	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	----	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	----	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	----	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.11	<0.02	----	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	71	<10	----	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	5	<1	----	<1	<1
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	----	----	16.2	10.0	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	9320	10000	----
Arsenic	7440-38-2	5	mg/kg	----	----	11	12	----
Barium	7440-39-3	10	mg/kg	----	----	20	<10	----
Beryllium	7440-41-7	1	mg/kg	----	----	<1	<1	----
Cadmium	7440-43-9	1	mg/kg	----	----	<1	<1	----
Chromium	7440-47-3	2	mg/kg	----	----	44	50	----
Cobalt	7440-48-4	2	mg/kg	----	----	12	8	----
Copper	7440-50-8	5	mg/kg	----	----	23	27	----
Iron	7439-89-6	50	mg/kg	----	----	32800	37000	----
Lead	7439-92-1	5	mg/kg	----	----	7	<5	----
Manganese	7439-96-5	5	mg/kg	----	----	258	124	----
Nickel	7440-02-0	2	mg/kg	----	----	19	13	----
Vanadium	7440-62-2	5	mg/kg	----	----	62	63	----

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**MB10A-2.0**	**MB06A-0.5**	**EP034-0.0-0.1**	**EP040-0.5-0.6**	**EP040-1.0-1.10**
			Client sampling date / time	17-APR-2009 15:00	04-APR-2009 15:00	25-MAY-2009 15:00	25-MAY-2009 15:00	25-MAY-2009 15:00
Compound	CAS Number	LOR	Unit	**EP0902640-036**	**EP0902640-037**	**EP0902640-038**	**EP0902640-039**	**EP0902640-040**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	----	----	**32**	**28**	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	----	<0.1	<0.1	----

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	EP040-0.75-0.85	EP042-0.0-0.1	EP042-0.5	MB19A-1.5	MB19A-2.0
			Client sampling date / time	25-MAY-2009 15:00	26-MAY-2009 15:00	26-MAY-2009 15:00	29-MAY-2009 15:00	29-MAY-2009 15:00
Compound	CAS Number	LOR	Unit	EP0902640-041	EP0902640-042	EP0902640-043	EP0902640-044	EP0902640-045
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	----	**8.7**	**7.3**	**5.7**	**6.8**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	----	<2	<2	**7**	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	----	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	----	<0.02	<0.02	**1.32**	**1.26**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	----	<10	<10	**826**	**788**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	----	**6.84**	**0.85**	----	**0.64**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	----	**1370**	**169**	----	**127**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	----	**2.19**	**0.27**	----	**0.20**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	----	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	----	<0.02	<0.02	**1.34**	**1.13**
Net Acidity (acidity units)	----	10	mole H+ / t	----	<10	<10	**833**	**703**
Liming Rate	----	1	kg CaCO3/t	----	<1	<1	**62**	**53**
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	----	<0.02	<0.02	**1.34**	**1.26**
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	----	<10	<10	**833**	**788**
Liming Rate excluding ANC	----	1	kg CaCO3/t	----	<1	<1	**62**	**59**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**7.2**	**4.1**	**5.4**	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**4750**	**12800**	**6660**	----	----
Arsenic	7440-38-2	5	mg/kg	**14**	**10**	**18**	----	----
Barium	7440-39-3	10	mg/kg	**10**	**40**	<10	----	----
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	**44**	**49**	**48**	----	----
Cobalt	7440-48-4	2	mg/kg	<2	**15**	**4**	----	----
Copper	7440-50-8	5	mg/kg	**23**	**31**	**19**	----	----
Iron	7439-89-6	50	mg/kg	**29700**	**36200**	**42600**	----	----
Lead	7439-92-1	5	mg/kg	<5	**8**	<5	----	----
Manganese	7439-96-5	5	mg/kg	**28**	**454**	**130**	----	----
Nickel	7440-02-0	2	mg/kg	**3**	**25**	**9**	----	----
Vanadium	7440-62-2	5	mg/kg	**49**	**68**	**68**	----	----

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Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**EP040-0.75-0.85**	**EP042-0.0-0.1**	**EP042-0.5**	**MB19A-1.5**	**MB19A-2.0**
			Client sampling date / time	25-MAY-2009 15:00	26-MAY-2009 15:00	26-MAY-2009 15:00	29-MAY-2009 15:00	29-MAY-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902640-041**	**EP0902640-042**	**EP0902640-043**	**EP0902640-044**	**EP0902640-045**
EG005T: Total Metals by ICP-AES - Continued								
Zinc	7440-66-6	5	mg/kg	**10**	**42**	**21**	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	----	----

A Campbell Brothers Limited Company

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

QUALITY CONTROL REPORT

Work Order	: **EP0902640**	Page	: 1 of 9
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MELANIE NUNN	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	: melanie_nunn@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0128	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9221 1639	Facsimile	: +61-8-9209 7600
Project	: 42907103	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: Onslow Wheatstone		
C-O-C number	: ----	Date Samples Received	: 15-MAY-2009
Sampler	: CAMERON CLARK	Issue Date	: 25-MAY-2009
Order number	: 42907100		
		No. of samples received	: 45
Quote number	: EN-001-08	No. of samples analysed	: 45

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 Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

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
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

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Work Order	: EP0902640
Client	: URS AUSTRALIA PTY LTD
Project	: 42907103

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.

Key :

Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

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Client : URS AUSTRALIA PTY LTD
Project : 42907103

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR:- No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:- 0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA033-A: Actual Acidity (QC Lot: 982441)									
EP0902640-002	MB06A-1.5	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.0	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.0	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	6.7	6.7	0.0	0% - 20%
EP0902640-015	MB2B-1.2-1.5	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.0	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.0	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	9.1	9.2	0.0	0% - 20%
EA033-A: Actual Acidity (QC Lot: 982442)									
EP0902640-029	MB15A-3.0	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.0	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.0	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	9.5	9.6	0.0	0% - 20%
EP0902640-040	EP040-1.0-1.10	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.0	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	4	4	0.0	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	6.1	6.1	0.0	0% - 20%
EA033-B: Potential Acidity (QC Lot: 982441)									
EP0902640-002	MB06A-1.5	EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EP0902640-015	MB2B-1.2-1.5	EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EA033-B: Potential Acidity (QC Lot: 982442)									
EP0902640-029	MB15A-3.0	EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EP0902640-040	EP040-1.0-1.10	EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EA033-C: Acid Neutralising Capacity (QC Lot: 982441)									
EP0902640-002	MB06A-1.5	EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	0.11	0.12	9.7	0% - 50%
		EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	0.04	0.04	0.0	No Limit
		EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	23	25	9.7	No Limit
EP0902640-015	MB2B-1.2-1.5	EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	1.51	1.49	1.6	0% - 20%
		EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	0.48	0.48	0.0	0% - 20%

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Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA033-C: Acid Neutralising Capacity (QC Lot: 982441) - continued									
EP0902640-015	MB2B-1.2-1.5	EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	302	297	1.6	0% - 20%
EA033-C: Acid Neutralising Capacity (QC Lot: 982442)									
EP0902640-029	MB15A-3.0	EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	30.6	31.2	1.8	0% - 20%
		EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	9.82	10.0	1.8	0% - 20%
		EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	6120	6240	1.8	0% - 20%
EA033-E: Acid Base Accounting (QC Lot: 982441)									
EP0902640-002	MB06A-1.5	EA033: ANC Fineness Factor	----	0.5	-	1.5	1.5	0.0	No Limit
		EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Liming Rate	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
		EA033: Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EP0902640-015	MB2B-1.2-1.5	EA033: ANC Fineness Factor	----	0.5	-	1.5	1.5	0.0	No Limit
		EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Liming Rate	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
		EA033: Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EA033-E: Acid Base Accounting (QC Lot: 982442)									
EP0902640-029	MB15A-3.0	EA033: ANC Fineness Factor	----	0.5	-	1.5	1.5	0.0	No Limit
		EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Liming Rate	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
		EA033: Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EP0902640-040	EP040-1.0-1.10	EA033: ANC Fineness Factor	----	0.5	-	1.5	1.5	0.0	No Limit
		EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Liming Rate	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
		EA033: Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EA055: Moisture Content (QC Lot: 982452)									
EP0902640-001	MB06A-1.0	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	20.7	20.6	0.6	0% - 20%

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Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA055: Moisture Content (QC Lot: 982452) - continued									
EP0902640-015	MB2B-1.2-1.5	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	7.2	7.1	0.0	No Limit
EA055: Moisture Content (QC Lot: 982453)									
EP0902640-031	MB11A-1.0	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	20.0	19.4	3.0	0% - 50%
EA055: Moisture Content (QC Lot: 985054)									
EP0902626-001	Anonymous	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	Anonymous	Anonymous	Anonymous	Anonymous
EP0902647-002	Anonymous	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	Anonymous	Anonymous	Anonymous	Anonymous
EG005T: Total Metals by ICP-AES (QC Lot: 982524)									
EP0902640-001	MB06A-1.0	EG005T: Beryllium	7440-41-7	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Cadmium	7440-43-9	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Barium	7440-39-3	10	mg/kg	<10	<10	0.0	No Limit
		EG005T: Chromium	7440-47-3	2	mg/kg	48	48	0.0	0% - 20%
		EG005T: Cobalt	7440-48-4	2	mg/kg	5	5	0.0	No Limit
		EG005T: Nickel	7440-02-0	2	mg/kg	10	11	0.0	No Limit
		EG005T: Arsenic	7440-38-2	5	mg/kg	14	14	0.0	No Limit
		EG005T: Copper	7440-50-8	5	mg/kg	17	17	0.0	No Limit
		EG005T: Lead	7439-92-1	5	mg/kg	<5	<5	0.0	No Limit
		EG005T: Manganese	7439-96-5	5	mg/kg	66	79	16.8	0% - 50%
		EG005T: Vanadium	7440-62-2	5	mg/kg	75	74	2.3	0% - 50%
		EG005T: Zinc	7440-66-6	5	mg/kg	22	22	0.0	No Limit
		EG005T: Aluminium	7429-90-5	50	mg/kg	7510	7490	0.3	0% - 20%
		EG005T: Iron	7439-89-6	50	mg/kg	30000	31100	3.5	0% - 20%
EP0902640-015	MB2B-1.2-1.5	EG005T: Beryllium	7440-41-7	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Cadmium	7440-43-9	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Barium	7440-39-3	10	mg/kg	30	30	0.0	No Limit
		EG005T: Chromium	7440-47-3	2	mg/kg	45	44	0.0	0% - 20%
		EG005T: Cobalt	7440-48-4	2	mg/kg	9	9	0.0	No Limit
		EG005T: Nickel	7440-02-0	2	mg/kg	17	17	0.0	No Limit
		EG005T: Arsenic	7440-38-2	5	mg/kg	<5	<5	0.0	No Limit
		EG005T: Copper	7440-50-8	5	mg/kg	19	18	0.0	No Limit
		EG005T: Lead	7439-92-1	5	mg/kg	7	7	0.0	No Limit
		EG005T: Manganese	7439-96-5	5	mg/kg	330	333	0.9	0% - 20%
		EG005T: Vanadium	7440-62-2	5	mg/kg	57	56	0.0	0% - 50%
		EG005T: Zinc	7440-66-6	5	mg/kg	29	29	0.0	No Limit
		EG005T: Aluminium	7429-90-5	50	mg/kg	6490	6220	4.2	0% - 20%
		EG005T: Iron	7439-89-6	50	mg/kg	32600	32400	0.7	0% - 20%
EG005T: Total Metals by ICP-AES (QC Lot: 982526)									
EP0902640-030	MB13A-0.0-0.45	EG005T: Beryllium	7440-41-7	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Cadmium	7440-43-9	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Barium	7440-39-3	10	mg/kg	<10	<10	0.0	No Limit
		EG005T: Chromium	7440-47-3	2	mg/kg	45	44	0.0	0% - 20%

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Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG005T: Total Metals by ICP-AES (QC Lot: 982526) - continued									
EP0902640-030	MB13A-0.0-0.45	EG005T: Cobalt	7440-48-4	2	mg/kg	7	7	0.0	No Limit
		EG005T: Nickel	7440-02-0	2	mg/kg	12	11	0.0	No Limit
		EG005T: Arsenic	7440-38-2	5	mg/kg	6	6	0.0	No Limit
		EG005T: Copper	7440-50-8	5	mg/kg	8	8	0.0	No Limit
		EG005T: Lead	7439-92-1	5	mg/kg	5	5	0.0	No Limit
		EG005T: Manganese	7439-96-5	5	mg/kg	269	264	2.0	0% - 20%
		EG005T: Vanadium	7440-62-2	5	mg/kg	59	57	3.6	0% - 50%
		EG005T: Zinc	7440-66-6	5	mg/kg	21	20	0.0	No Limit
		EG005T: Aluminium	7429-90-5	50	mg/kg	3530	3480	1.6	0% - 20%
		EG005T: Iron	7439-89-6	50	mg/kg	30100	29600	1.5	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 982525)									
EP0902640-001	MB06A-1.0	EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	0.0	No Limit
EP0902640-015	MB2B-1.2-1.5	EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	0.0	No Limit
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 982527)									
EP0902640-030	MB13A-0.0-0.45	EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	0.0	No Limit

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Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	*CAS Number*	*LOR*	*Unit*	*Result*	*Concentration*	*LCS*	*Low*	*High*
EA033-A: Actual Acidity (QCLot: 982441)								
EA033: pH KCl (23A)	----	0.1	pH Unit	<0.1	----	----	----	----
EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	----	----	----
EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-A: Actual Acidity (QCLot: 982442)								
EA033: pH KCl (23A)	----	0.1	pH Unit	<0.1	----	----	----	----
EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	----	----	----
EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-B: Potential Acidity (QCLot: 982441)								
EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	----	----	----	----
EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	----	----	----
EA033-B: Potential Acidity (QCLot: 982442)								
EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	----	----	----	----
EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	----	----	----
EA033-C: Acid Neutralising Capacity (QCLot: 982441)								
EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	<0.01	----	----	----	----
EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	<10	----	----	----	----
EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	<0.01	----	----	----	----
EA033-C: Acid Neutralising Capacity (QCLot: 982442)								
EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	<0.01	----	----	----	----
EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	<10	----	----	----	----
EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	<0.01	----	----	----	----
EA033-E: Acid Base Accounting (QCLot: 982441)								
EA033: ANC Fineness Factor	----	0.5		<0.5	----	----	----	----
EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	----	----	----
EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	----	----	----
EA033: Liming Rate	----	1	kg CaCO3/t	<1	----	----	----	----
EA033-E: Acid Base Accounting (QCLot: 982442)								
EA033: ANC Fineness Factor	----	0.5		<0.5	----	----	----	----
EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	----	----	----
EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	----	----	----
EA033: Liming Rate	----	1	kg CaCO3/t	<1	----	----	----	----
EG005T: Total Metals by ICP-AES (QCLot: 982524)								
EG005T: Aluminium	7429-90-5	50	mg/kg	<50	----	----	----	----

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Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	*CAS Number*	*LOR*	*Unit*	*Result*	*Concentration*	*LCS*	*Low*	*High*
EG005T: Total Metals by ICP-AES (QCLot: 982524) - continued								
EG005T: Arsenic	7440-38-2	5	mg/kg	<5	13.75 mg/kg	96.5	85.5	116
EG005T: Barium	7440-39-3	10	mg/kg	<10	143 mg/kg	96.4	87.6	114
EG005T: Beryllium	7440-41-7	1	mg/kg	<1	----	----	----	----
EG005T: Cadmium	7440-43-9	1	mg/kg	<1	2.82 mg/kg	103	82.2	112
EG005T: Chromium	7440-47-3	2	mg/kg	<2	61.6 mg/kg	105	90.6	113
EG005T: Cobalt	7440-48-4	2	mg/kg	<2	----	----	----	----
EG005T: Copper	7440-50-8	5	mg/kg	<5	54.7 mg/kg	105	91.4	115
EG005T: Iron	7439-89-6	50	mg/kg	<50	----	----	----	----
EG005T: Lead	7439-92-1	5	mg/kg	<5	55.5 mg/kg	106	88.8	111
EG005T: Manganese	7439-96-5	5	mg/kg	<5	----	----	----	----
EG005T: Nickel	7440-02-0	2	mg/kg	<2	55.1 mg/kg	104	89.8	116
EG005T: Vanadium	7440-62-2	5	mg/kg	<5	----	----	----	----
EG005T: Zinc	7440-66-6	5	mg/kg	<5	105 mg/kg	105	86.6	113
EG005T: Total Metals by ICP-AES (QCLot: 982526)								
EG005T: Aluminium	7429-90-5	50	mg/kg	<50	----	----	----	----
EG005T: Arsenic	7440-38-2	5	mg/kg	<5	13.75 mg/kg	96.9	85.5	116
EG005T: Barium	7440-39-3	10	mg/kg	<10	143 mg/kg	94.5	87.6	114
EG005T: Beryllium	7440-41-7	1	mg/kg	<1	----	----	----	----
EG005T: Cadmium	7440-43-9	1	mg/kg	<1	2.82 mg/kg	102	82.2	112
EG005T: Chromium	7440-47-3	2	mg/kg	<2	61.6 mg/kg	104	90.6	113
EG005T: Cobalt	7440-48-4	2	mg/kg	<2	----	----	----	----
EG005T: Copper	7440-50-8	5	mg/kg	<5	54.7 mg/kg	106	91.4	115
EG005T: Iron	7439-89-6	50	mg/kg	<50	----	----	----	----
EG005T: Lead	7439-92-1	5	mg/kg	<5	55.5 mg/kg	104	88.8	111
EG005T: Manganese	7439-96-5	5	mg/kg	<5	----	----	----	----
EG005T: Nickel	7440-02-0	2	mg/kg	<2	55.1 mg/kg	104	89.8	116
EG005T: Vanadium	7440-62-2	5	mg/kg	<5	----	----	----	----
EG005T: Zinc	7440-66-6	5	mg/kg	<5	105 mg/kg	106	86.6	113
EG035T: Total Recoverable Mercury by FIMS (QCLot: 982525)								
EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	1.36 mg/kg	87.7	75.4	121
EG035T: Total Recoverable Mercury by FIMS (QCLot: 982527)								
EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	1.36 mg/kg	99.7	75.4	121

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Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

				Matrix Spike (MS) Report			
				Spike	*Spike Recovery (%)*	*Recovery Limits (%)*	
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*Concentration*	*MS*	*Low*	*High*
EG005T: Total Metals by ICP-AES (QCLot: 982524)							
EP0902640-003	MB07A-0.0	EG005T: Aluminium	7429-90-5	50 mg/kg	# Not Determined	70	130
		EG005T: Arsenic	7440-38-2	50 mg/kg	80.6	70	130
		EG005T: Barium	7440-39-3	50 mg/kg	99.2	70	130
		EG005T: Beryllium	7440-41-7	10 mg/kg	112	70	130
		EG005T: Cadmium	7440-43-9	50 mg/kg	99.2	70	130
		EG005T: Chromium	7440-47-3	50 mg/kg	99.4	70	130
		EG005T: Copper	7440-50-8	50 mg/kg	105	70	130
		EG005T: Iron	7439-89-6	50 mg/kg	# Not Determined	70	130
		EG005T: Lead	7439-92-1	50 mg/kg	98.4	70	130
		EG005T: Manganese	7439-96-5	50 mg/kg	# Not Determined	70	130
		EG005T: Nickel	7440-02-0	50 mg/kg	95.6	70	130
		EG005T: Vanadium	7440-62-2	50 mg/kg	91.0	70	130
		EG005T: Zinc	7440-66-6	50 mg/kg	90.9	70	130
EG005T: Total Metals by ICP-AES (QCLot: 982526)							
EP0902640-031	MB11A-1.0	EG005T: Aluminium	7429-90-5	50 mg/kg	# Not Determined	70	130
		EG005T: Arsenic	7440-38-2	50 mg/kg	76.6	70	130
		EG005T: Barium	7440-39-3	50 mg/kg	106	70	130
		EG005T: Beryllium	7440-41-7	10 mg/kg	118	70	130
		EG005T: Cadmium	7440-43-9	50 mg/kg	106	70	130
		EG005T: Chromium	7440-47-3	50 mg/kg	105	70	130
		EG005T: Copper	7440-50-8	50 mg/kg	110	70	130
		EG005T: Iron	7439-89-6	50 mg/kg	# Not Determined	70	130
		EG005T: Lead	7439-92-1	50 mg/kg	106	70	130
		EG005T: Manganese	7439-96-5	50 mg/kg	109	70	130
		EG005T: Nickel	7440-02-0	50 mg/kg	104	70	130
		EG005T: Vanadium	7440-62-2	50 mg/kg	92.0	70	130
		EG005T: Zinc	7440-66-6	50 mg/kg	107	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 982525)							
EP0902640-003	MB07A-0.0	EG035T: Mercury	7439-97-6	10 mg/kg	89.6	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 982527)							
EP0902640-031	MB11A-1.0	EG035T: Mercury	7439-97-6	10 mg/kg	97.4	70	130

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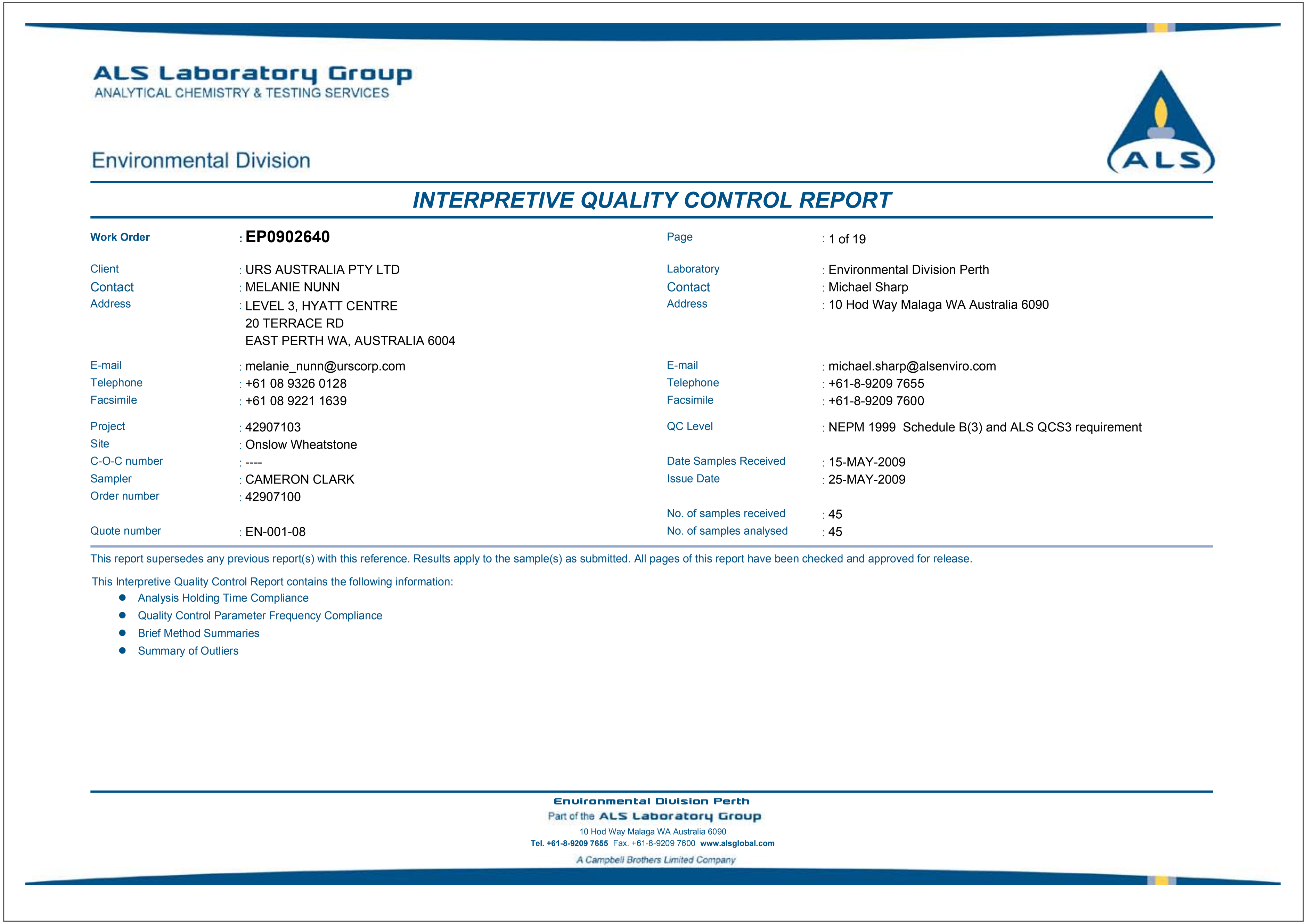

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: **EP0902640**	Page	: 1 of 19
Client	: URS AUSTRALIA PTY LTD	Laboratory	: Environmental Division Perth
Contact	: MELANIE NUNN	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	: melanie_nunn@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0128	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9221 1639	Facsimile	: +61-8-9209 7600
Project	: 42907103	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: Onslow Wheatstone		
C-O-C number	: ----	Date Samples Received	: 15-MAY-2009
Sampler	: CAMERON CLARK	Issue Date	: 25-MAY-2009
Order number	: 42907100		
		No. of samples received	: 45
Quote number	: EN-001-08	No. of samples analysed	: 45

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

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Work Order : EP0902640
Client : URS AUSTRALIA PTY LTD
Project : 42907103

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*
EA033-A: Actual Acidity								
Snap Lock Bag - frozen MB17A-1.5-1.75,	MB5S-0.5-0.75	**01-APR-2009**	**19-MAY-2009**	01-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB16A-1.5-1,	MB06A-0.5	**04-APR-2009**	**19-MAY-2009**	04-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB07A-0.0		**05-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB06A-1.5		**06-APR-2009**	**19-MAY-2009**	06-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-3.0		**08-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-2.50		**09-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB13A-0.0-0.45		**10-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB11A-1.0		**12-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB18A-1.50, MB18A-3.0	MB18A-2.5,	**15-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB10A-1.0,	MB10A-2.0	**17-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB8A-0.0-0.10, MB09A-1.50,	MB8A-1.0-1.50, MB09A-3.0	**19-APR-2009**	**19-MAY-2009**	19-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-2.0		**20-APR-2009**	**19-MAY-2009**	20-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-1.0,	MB12-1.5	**21-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen E034-0.5-0.6		**25-APR-2009**	**19-MAY-2009**	25-APR-2010	✓	**21-MAY-2009**	17-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*
EA033-A: Actual Acidity - Continued								
Snap Lock Bag - frozen EP040-0.5-0.6,	EP040-1.0-1.10	**25-MAY-2009**	**19-MAY-2009**	25-MAY-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP042-0.0-0.1,	EP042-0.5	**26-MAY-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB4A-0.25-0.35		**27-MAR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-0.0,	E035-0.0-0.2	**29-APR-2009**	**19-MAY-2009**	29-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-1.5,	MB19A-2.0	**29-MAY-2009**	**19-MAY-2009**	29-MAY-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB3A-2.0-2.15, MB17A-0.0-0.25	MB2B-1.2-1.5,	**30-MAR-2009**	**19-MAY-2009**	30-MAR-2010	✓	**21-MAY-2009**	17-AUG-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*
EA033-B: Potential Acidity							
Snap Lock Bag - frozen MB17A-1.5-1.75, MB5S-0.5-0.75	**01-APR-2009**	**19-MAY-2009**	01-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB16A-1.5-1, MB06A-0.5	**04-APR-2009**	**19-MAY-2009**	04-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB07A-0.0	**05-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB06A-1.5	**06-APR-2009**	**19-MAY-2009**	06-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-3.0	**08-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-2.50	**09-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB13A-0.0-0.45	**10-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB11A-1.0	**12-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB18A-1.50, MB18A-2.5, MB18A-3.0	**15-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB10A-1.0, MB10A-2.0	**17-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB8A-0.0-0.10, MB8A-1.0-1.50, MB09A-1.50, MB09A-3.0	**19-APR-2009**	**19-MAY-2009**	19-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-2.0	**20-APR-2009**	**19-MAY-2009**	20-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-1.0, MB12-1.5	**21-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen E034-0.5-0.6	**25-APR-2009**	**19-MAY-2009**	25-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP040-0.5-0.6, EP040-1.0-1.10	**25-MAY-2009**	**19-MAY-2009**	25-MAY-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP042-0.0-0.1, EP042-0.5	**26-MAY-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB4A-0.25-0.35	**27-MAR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-0.0, E035-0.0-0.2	**29-APR-2009**	**19-MAY-2009**	29-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-1.5, MB19A-2.0	**29-MAY-2009**	**19-MAY-2009**	29-MAY-2010	✓	**21-MAY-2009**	17-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*
EA033-B: Potential Acidity - Continued							
Snap Lock Bag - frozen MB3A-2.0-2.15, MB2B-1.2-1.5, MB17A-0.0-0.25	**30-MAR-2009**	**19-MAY-2009**	30-MAR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓

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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*
EA033-C: Acid Neutralising Capacity							
Snap Lock Bag - frozen MB17A-1.5-1.75, MB5S-0.5-0.75	**01-APR-2009**	**19-MAY-2009**	01-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB16A-1.5-1, MB06A-0.5	**04-APR-2009**	**19-MAY-2009**	04-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB07A-0.0	**05-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB06A-1.5	**06-APR-2009**	**19-MAY-2009**	06-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-3.0	**08-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-2.50	**09-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB13A-0.0-0.45	**10-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB11A-1.0	**12-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB18A-1.50, MB18A-2.5, MB18A-3.0	**15-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB10A-1.0, MB10A-2.0	**17-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB8A-0.0-0.10, MB8A-1.0-1.50, MB09A-1.50, MB09A-3.0	**19-APR-2009**	**19-MAY-2009**	19-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-2.0	**20-APR-2009**	**19-MAY-2009**	20-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-1.0, MB12-1.5	**21-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen E034-0.5-0.6	**25-APR-2009**	**19-MAY-2009**	25-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP040-0.5-0.6, EP040-1.0-1.10	**25-MAY-2009**	**19-MAY-2009**	25-MAY-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP042-0.0-0.1, EP042-0.5	**26-MAY-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB4A-0.25-0.35	**27-MAR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-0.0, E035-0.0-0.2	**29-APR-2009**	**19-MAY-2009**	29-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-1.5, MB19A-2.0	**29-MAY-2009**	**19-MAY-2009**	29-MAY-2010	✓	**21-MAY-2009**	17-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*
EA033-C: Acid Neutralising Capacity - Continued							
Snap Lock Bag - frozen MB3A-2.0-2.15, MB2B-1.2-1.5, MB17A-0.0-0.25	**30-MAR-2009**	**19-MAY-2009**	30-MAR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓

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Method **Container** / Client Sample ID(s)		**Sample Date**	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	**Date analysed**	Due for analysis	Evaluation
EA033-D: Retained Acidity								
Snap Lock Bag - frozen MB17A-1.5-1.75,	MB5S-0.5-0.75	**01-APR-2009**	**19-MAY-2009**	01-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB16A-1.5-1,	MB06A-0.5	**04-APR-2009**	**19-MAY-2009**	04-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB07A-0.0		**05-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB06A-1.5		**06-APR-2009**	**19-MAY-2009**	06-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-3.0		**08-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-2.50		**09-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB13A-0.0-0.45		**10-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB11A-1.0		**12-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB18A-1.50, MB18A-3.0	MB18A-2.5,	**15-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB10A-1.0,	MB10A-2.0	**17-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB8A-0.0-0.10, MB09A-1.50,	MB8A-1.0-1.50, MB09A-3.0	**19-APR-2009**	**19-MAY-2009**	19-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-2.0		**20-APR-2009**	**19-MAY-2009**	20-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-1.0,	MB12-1.5	**21-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen E034-0.5-0.6		**25-APR-2009**	**19-MAY-2009**	25-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP040-0.5-0.6,	EP040-1.0-1.10	**25-MAY-2009**	**19-MAY-2009**	25-MAY-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP042-0.0-0.1,	EP042-0.5	**26-MAY-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB4A-0.25-0.35		**27-MAR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-0.0,	E035-0.0-0.2	**29-APR-2009**	**19-MAY-2009**	29-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-1.5,	MB19A-2.0	**29-MAY-2009**	**19-MAY-2009**	29-MAY-2010	✓	**21-MAY-2009**	17-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*
EA033-D: Retained Acidity - Continued							
Snap Lock Bag - frozen MB3A-2.0-2.15, MB2B-1.2-1.5, MB17A-0.0-0.25	**30-MAR-2009**	**19-MAY-2009**	30-MAR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓

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Method	**Sample Date**	Extraction / Preparation			Analysis		
Container / Client Sample ID(s)		**Date extracted**	Due for extraction	Evaluation	**Date analysed**	Due for analysis	Evaluation
EA033-E: Acid Base Accounting							
Snap Lock Bag - frozen MB17A-1.5-1.75, MB5S-0.5-0.75	**01-APR-2009**	**19-MAY-2009**	01-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB16A-1.5-1, MB06A-0.5	**04-APR-2009**	**19-MAY-2009**	04-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB07A-0.0	**05-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB06A-1.5	**06-APR-2009**	**19-MAY-2009**	06-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-3.0	**08-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB15A-2.50	**09-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB13A-0.0-0.45	**10-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB11A-1.0	**12-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB18A-1.50, MB18A-2.5, MB18A-3.0	**15-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB10A-1.0, MB10A-2.0	**17-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB8A-0.0-0.10, MB8A-1.0-1.50, MB09A-1.50, MB09A-3.0	**19-APR-2009**	**19-MAY-2009**	19-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-2.0	**20-APR-2009**	**19-MAY-2009**	20-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB12-1.0, MB12-1.5	**21-APR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen E034-0.5-0.6	**25-APR-2009**	**19-MAY-2009**	25-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP040-0.5-0.6, EP040-1.0-1.10	**25-MAY-2009**	**19-MAY-2009**	25-MAY-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen EP042-0.0-0.1, EP042-0.5	**26-MAY-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB4A-0.25-0.35	**27-MAR-2009**	**19-MAY-2009**	---	----	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-0.0, E035-0.0-0.2	**29-APR-2009**	**19-MAY-2009**	29-APR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓
Snap Lock Bag - frozen MB19A-1.5, MB19A-2.0	**29-MAY-2009**	**19-MAY-2009**	29-MAY-2010	✓	**21-MAY-2009**	17-AUG-2009	✓

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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*
EA033-E: Acid Base Accounting - Continued							
Snap Lock Bag - frozen MB3A-2.0-2.15, MB2B-1.2-1.5, MB17A-0.0-0.25	**30-MAR-2009**	**19-MAY-2009**	30-MAR-2010	✓	**21-MAY-2009**	17-AUG-2009	✓

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Evaluation: ✗ = Holding time breach ; ✓ = Within holding time.

Method ***Container** / Client Sample ID(s)*	***Sample Date***	*Extraction / Preparation* ***Date extracted***	 *Due for extraction*	 *Evaluation*	*Analysis* ***Date analysed***	 *Due for analysis*	 *Evaluation*
EA055: Moisture Content							
Snap Lock Bag - frozen MB18A-3.0	**15-APR-2009**	**----**	----	----	**19-MAY-2009**	22-APR-2009	✗
Snap Lock Bag - frozen MB12-1.0, MB12-1.5	**21-APR-2009**	**----**	----	----	**19-MAY-2009**	28-APR-2009	✗
Soil Glass Jar - Unpreserved MB17A-1.5-1.75, MB5A-1.5-1.75	**01-APR-2009**	**----**	----	----	**19-MAY-2009**	08-APR-2009	✗
Soil Glass Jar - Unpreserved MB16A-0.0-0.05	**03-APR-2009**	**----**	----	----	**19-MAY-2009**	10-APR-2009	✗
Soil Glass Jar - Unpreserved MB06A-1.0, MB16A-1.5-1	**04-APR-2009**	**----**	----	----	**19-MAY-2009**	11-APR-2009	✗
Soil Glass Jar - Unpreserved MB07A-0.0, MB07A-0.5	**05-APR-2009**	**----**	----	----	**19-MAY-2009**	12-APR-2009	✗
Soil Glass Jar - Unpreserved MB15A-3.0	**08-APR-2009**	**----**	----	----	**19-MAY-2009**	15-APR-2009	✗
Soil Glass Jar - Unpreserved MB15A-2.50	**09-APR-2009**	**----**	----	----	**19-MAY-2009**	16-APR-2009	✗
Soil Glass Jar - Unpreserved MB13A-0.0-0.45	**10-APR-2009**	**----**	----	----	**19-MAY-2009**	17-APR-2009	✗
Soil Glass Jar - Unpreserved MB11A-1.0	**12-APR-2009**	**----**	----	----	**19-MAY-2009**	19-APR-2009	✗
Soil Glass Jar - Unpreserved MB18A-1.50, MB18A-2.5	**15-APR-2009**	**----**	----	----	**19-MAY-2009**	22-APR-2009	✗
Soil Glass Jar - Unpreserved MB8A-0.0-0.10, MB8A-1.50	**19-APR-2009**	**----**	----	----	**19-MAY-2009**	26-APR-2009	✗
Soil Glass Jar - Unpreserved MB09A-2.50	**20-APR-2009**	**----**	----	----	**19-MAY-2009**	27-APR-2009	✗
Soil Glass Jar - Unpreserved E034-0.75-0.85	**25-APR-2009**	**----**	----	----	**19-MAY-2009**	02-MAY-2009	✗
Soil Glass Jar - Unpreserved EP034-0.0-0.1, EP040-0.5-0.6, EP040-0.75-0.85	**25-MAY-2009**	**----**	----	----	**21-MAY-2009**	01-JUN-2009	✓
Soil Glass Jar - Unpreserved EP042-0.0-0.1, EP042-0.5	**26-MAY-2009**	**----**	----	----	**21-MAY-2009**	02-JUN-2009	✓
Soil Glass Jar - Unpreserved MB4A-0.25-0.35	**27-MAR-2009**	**----**	----	----	**19-MAY-2009**	03-APR-2009	✗
Soil Glass Jar - Unpreserved MB19A-0.0	**29-APR-2009**	**----**	----	----	**19-MAY-2009**	06-MAY-2009	✗
Soil Glass Jar - Unpreserved MB19A-1.75	**29-MAY-2009**	**----**	----	----	**21-MAY-2009**	05-JUN-2009	✓
Soil Glass Jar - Unpreserved MB3A-2.0-2.15, MB2B-1.2-1.5	**30-MAR-2009**	**----**	----	----	**19-MAY-2009**	06-APR-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*
EG005T: Total Metals by ICP-AES								
Snap Lock Bag - frozen MB18A-3.0		**15-APR-2009**	**20-MAY-2009**	12-OCT-2009	✓	**20-MAY-2009**	12-OCT-2009	✓
Snap Lock Bag - frozen MB12-1.0,	MB12-1.5	**21-APR-2009**	**20-MAY-2009**	18-OCT-2009	✓	**20-MAY-2009**	18-OCT-2009	✓
Soil Glass Jar - Unpreserved MB17A-1.5-1.75,	MB5A-1.5-1.75	**01-APR-2009**	**20-MAY-2009**	28-SEP-2009	✓	**20-MAY-2009**	28-SEP-2009	✓
Soil Glass Jar - Unpreserved MB16A-0.0-0.05		**03-APR-2009**	**20-MAY-2009**	30-SEP-2009	✓	**20-MAY-2009**	30-SEP-2009	✓
Soil Glass Jar - Unpreserved MB06A-1.0,	MB16A-1.5-1	**04-APR-2009**	**20-MAY-2009**	01-OCT-2009	✓	**20-MAY-2009**	01-OCT-2009	✓
Soil Glass Jar - Unpreserved MB07A-0.0,	MB07A-0.5	**05-APR-2009**	**20-MAY-2009**	02-OCT-2009	✓	**20-MAY-2009**	02-OCT-2009	✓
Soil Glass Jar - Unpreserved MB15A-3.0		**08-APR-2009**	**20-MAY-2009**	05-OCT-2009	✓	**20-MAY-2009**	05-OCT-2009	✓
Soil Glass Jar - Unpreserved MB15A-2.50		**09-APR-2009**	**20-MAY-2009**	06-OCT-2009	✓	**20-MAY-2009**	06-OCT-2009	✓
Soil Glass Jar - Unpreserved MB13A-0.0-0.45		**10-APR-2009**	**20-MAY-2009**	07-OCT-2009	✓	**20-MAY-2009**	07-OCT-2009	✓
Soil Glass Jar - Unpreserved MB11A-1.0		**12-APR-2009**	**20-MAY-2009**	09-OCT-2009	✓	**20-MAY-2009**	09-OCT-2009	✓
Soil Glass Jar - Unpreserved MB18A-1.50,	MB18A-2.5	**15-APR-2009**	**20-MAY-2009**	12-OCT-2009	✓	**20-MAY-2009**	12-OCT-2009	✓
Soil Glass Jar - Unpreserved MB8A-0.0-0.10,	MB8A-1.50	**19-APR-2009**	**20-MAY-2009**	16-OCT-2009	✓	**20-MAY-2009**	16-OCT-2009	✓
Soil Glass Jar - Unpreserved MB09A-2.50		**20-APR-2009**	**20-MAY-2009**	17-OCT-2009	✓	**20-MAY-2009**	17-OCT-2009	✓
Soil Glass Jar - Unpreserved E034-0.75-0.85		**25-APR-2009**	**20-MAY-2009**	22-OCT-2009	✓	**20-MAY-2009**	22-OCT-2009	✓
Soil Glass Jar - Unpreserved EP034-0.0-0.1, EP040-0.75-0.85	EP040-0.5-0.6,	**25-MAY-2009**	**20-MAY-2009**	21-NOV-2009	✓	**20-MAY-2009**	21-NOV-2009	✓
Soil Glass Jar - Unpreserved EP042-0.0-0.1,	EP042-0.5	**26-MAY-2009**	**20-MAY-2009**	22-NOV-2009	✓	**20-MAY-2009**	22-NOV-2009	✓
Soil Glass Jar - Unpreserved MB4A-0.25-0.35		**27-MAR-2009**	**20-MAY-2009**	23-SEP-2009	✓	**20-MAY-2009**	23-SEP-2009	✓
Soil Glass Jar - Unpreserved MB19A-0.0		**29-APR-2009**	**20-MAY-2009**	26-OCT-2009	✓	**20-MAY-2009**	26-OCT-2009	✓
Soil Glass Jar - Unpreserved MB19A-1.75		**29-MAY-2009**	**20-MAY-2009**	25-NOV-2009	✓	**20-MAY-2009**	25-NOV-2009	✓
Soil Glass Jar - Unpreserved MB3A-2.0-2.15,	MB2B-1.2-1.5	**30-MAR-2009**	**20-MAY-2009**	26-SEP-2009	✓	**20-MAY-2009**	26-SEP-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*
EG035T: Total Recoverable Mercury by FIMS								
Snap Lock Bag - frozen MB18A-3.0		**15-APR-2009**	**20-MAY-2009**	12-OCT-2009	✓	**20-MAY-2009**	13-MAY-2009	✗
Snap Lock Bag - frozen MB12-1.0,	MB12-1.5	**21-APR-2009**	**20-MAY-2009**	18-OCT-2009	✓	**20-MAY-2009**	19-MAY-2009	✗
Soil Glass Jar - Unpreserved MB17A-1.5-1.75,	MB5A-1.5-1.75	**01-APR-2009**	**20-MAY-2009**	28-SEP-2009	✓	**20-MAY-2009**	29-APR-2009	✗
Soil Glass Jar - Unpreserved MB16A-0.0-0.05		**03-APR-2009**	**20-MAY-2009**	30-SEP-2009	✓	**20-MAY-2009**	01-MAY-2009	✗
Soil Glass Jar - Unpreserved MB06A-1.0,	MB16A-1.5-1	**04-APR-2009**	**20-MAY-2009**	01-OCT-2009	✓	**20-MAY-2009**	02-MAY-2009	✗
Soil Glass Jar - Unpreserved MB07A-0.0,	MB07A-0.5	**05-APR-2009**	**20-MAY-2009**	02-OCT-2009	✓	**20-MAY-2009**	03-MAY-2009	✗
Soil Glass Jar - Unpreserved MB15A-3.0		**08-APR-2009**	**20-MAY-2009**	05-OCT-2009	✓	**20-MAY-2009**	06-MAY-2009	✗
Soil Glass Jar - Unpreserved MB15A-2.50		**09-APR-2009**	**20-MAY-2009**	06-OCT-2009	✓	**20-MAY-2009**	07-MAY-2009	✗
Soil Glass Jar - Unpreserved MB13A-0.0-0.45		**10-APR-2009**	**20-MAY-2009**	07-OCT-2009	✓	**20-MAY-2009**	08-MAY-2009	✗
Soil Glass Jar - Unpreserved MB11A-1.0		**12-APR-2009**	**20-MAY-2009**	09-OCT-2009	✓	**20-MAY-2009**	10-MAY-2009	✗
Soil Glass Jar - Unpreserved MB18A-1.50,	MB18A-2.5	**15-APR-2009**	**20-MAY-2009**	12-OCT-2009	✓	**20-MAY-2009**	13-MAY-2009	✗
Soil Glass Jar - Unpreserved MB8A-0.0-0.10,	MB8A-1.50	**19-APR-2009**	**20-MAY-2009**	16-OCT-2009	✓	**20-MAY-2009**	17-MAY-2009	✗
Soil Glass Jar - Unpreserved MB09A-2.50		**20-APR-2009**	**20-MAY-2009**	17-OCT-2009	✓	**20-MAY-2009**	18-MAY-2009	✗
Soil Glass Jar - Unpreserved E034-0.75-0.85		**25-APR-2009**	**20-MAY-2009**	22-OCT-2009	✓	**20-MAY-2009**	23-MAY-2009	✓
Soil Glass Jar - Unpreserved EP034-0.0-0.1, EP040-0.75-0.85	EP040-0.5-0.6,	**25-MAY-2009**	**20-MAY-2009**	21-NOV-2009	✓	**20-MAY-2009**	22-JUN-2009	✓
Soil Glass Jar - Unpreserved EP042-0.0-0.1,	EP042-0.5	**26-MAY-2009**	**20-MAY-2009**	22-NOV-2009	✓	**20-MAY-2009**	23-JUN-2009	✓
Soil Glass Jar - Unpreserved MB4A-0.25-0.35		**27-MAR-2009**	**20-MAY-2009**	23-SEP-2009	✓	**20-MAY-2009**	24-APR-2009	✗
Soil Glass Jar - Unpreserved MB19A-0.0		**29-APR-2009**	**20-MAY-2009**	26-OCT-2009	✓	**20-MAY-2009**	27-MAY-2009	✓
Soil Glass Jar - Unpreserved MB19A-1.75		**29-MAY-2009**	**20-MAY-2009**	25-NOV-2009	✓	**20-MAY-2009**	26-JUN-2009	✓
Soil Glass Jar - Unpreserved MB3A-2.0-2.15,	MB2B-1.2-1.5	**30-MAR-2009**	**20-MAY-2009**	26-SEP-2009	✓	**20-MAY-2009**	27-APR-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)							
Chromium Suite for Acid Sulphate Soils	EA033	4	35	**11.4**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Moisture Content	EA055-103	5	44	**11.4**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	3	30	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	3	30	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Total Mercury by FIMS	EG035T	2	30	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	2	30	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Chromium Suite for Acid Sulphate Soils	EA033	2	35	**5.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	2	30	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	2	30	**6.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Total Mercury by FIMS	EG035T	2	30	**6.7**	**5.0**	✓	ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	2	30	**6.7**	**5.0**	✓	ALS QCS3 requirement

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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*
Chromium Suite for Acid Sulphate Soils	EA033	SOIL	Ahern et al 2004. This method covers the determination of Chromium Reducible Sulfur (SCR); pHKCl; titratable actual acidity (TAA); acid neutralising capacity by back titration (ANC); and net acid soluble sulfur (SNAS) which incorporates peroxide sulfur. It applies to soils and sediments (including sands) derived from coastal regions. Liming Rate is based on results for samples as submitted and incorporates a minimum safety factor of 1.5.
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 Mercury by FIMS	EG035T	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)

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Drying at 85 degrees, bagging and labelling (ASS)	EN020PR	SOIL	In house
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)

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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

Matrix: **SOIL**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Matrix Spike (MS) Recoveries							
EG005T: Total Metals by ICP-AES	EP0902640-003	MB07A-0.0	**Aluminium**	7429-90-5	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**
EG005T: Total Metals by ICP-AES	EP0902640-031	MB11A-1.0	**Aluminium**	7429-90-5	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**
EG005T: Total Metals by ICP-AES	EP0902640-031	MB11A-1.0	**Iron**	7439-89-6	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**
EG005T: Total Metals by ICP-AES	EP0902640-003	MB07A-0.0	**Iron**	7439-89-6	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**
EG005T: Total Metals by ICP-AES	EP0902640-003	MB07A-0.0	**Manganese**	7439-96-5	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Duplicate outliers occur.**
- **For all matrices, no Laboratory Control 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						
Snap Lock Bag - frozen MB18A-3.0	----	----	----	19-MAY-2009	22-APR-2009	**27**

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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 - Analysis Holding Time Compliance						
Snap Lock Bag - frozen MB12-1.0, MB12-1.5	----	----	----	19-MAY-2009	28-APR-2009	**21**
Soil Glass Jar - Unpreserved MB17A-1.5-1.75, MB5A-1.5-1.75	----	----	----	19-MAY-2009	08-APR-2009	**41**
Soil Glass Jar - Unpreserved MB16A-0.0-0.05	----	----	----	19-MAY-2009	10-APR-2009	**39**
Soil Glass Jar - Unpreserved MB06A-1.0, MB16A-1.5-1	----	----	----	19-MAY-2009	11-APR-2009	**38**
Soil Glass Jar - Unpreserved MB07A-0.0, MB07A-0.5	----	----	----	19-MAY-2009	12-APR-2009	**37**
Soil Glass Jar - Unpreserved MB15A-3.0	----	----	----	19-MAY-2009	15-APR-2009	**34**
Soil Glass Jar - Unpreserved MB15A-2.50	----	----	----	19-MAY-2009	16-APR-2009	**33**
Soil Glass Jar - Unpreserved MB13A-0.0-0.45	----	----	----	19-MAY-2009	17-APR-2009	**32**
Soil Glass Jar - Unpreserved MB11A-1.0	----	----	----	19-MAY-2009	19-APR-2009	**30**
Soil Glass Jar - Unpreserved MB18A-1.50, MB18A-2.5	----	----	----	19-MAY-2009	22-APR-2009	**27**
Soil Glass Jar - Unpreserved MB8A-0.0-0.10, MB8A-1.50	----	----	----	19-MAY-2009	26-APR-2009	**23**
Soil Glass Jar - Unpreserved MB09A-2.50	----	----	----	19-MAY-2009	27-APR-2009	**22**
Soil Glass Jar - Unpreserved E034-0.75-0.85	----	----	----	19-MAY-2009	02-MAY-2009	**17**
Soil Glass Jar - Unpreserved MB4A-0.25-0.35	----	----	----	19-MAY-2009	03-APR-2009	**46**
Soil Glass Jar - Unpreserved MB19A-0.0	----	----	----	19-MAY-2009	06-MAY-2009	**13**
Soil Glass Jar - Unpreserved MB3A-2.0-2.15, MB2B-1.2-1.5	----	----	----	19-MAY-2009	06-APR-2009	**43**
EG035T: Total Recoverable Mercury by FIMS						
Snap Lock Bag - frozen MB18A-3.0	----	----	----	20-MAY-2009	13-MAY-2009	**7**
Snap Lock Bag - frozen MB12-1.0, MB12-1.5	----	----	----	20-MAY-2009	19-MAY-2009	**1**
Soil Glass Jar - Unpreserved MB17A-1.5-1.75, MB5A-1.5-1.75	----	----	----	20-MAY-2009	29-APR-2009	**21**

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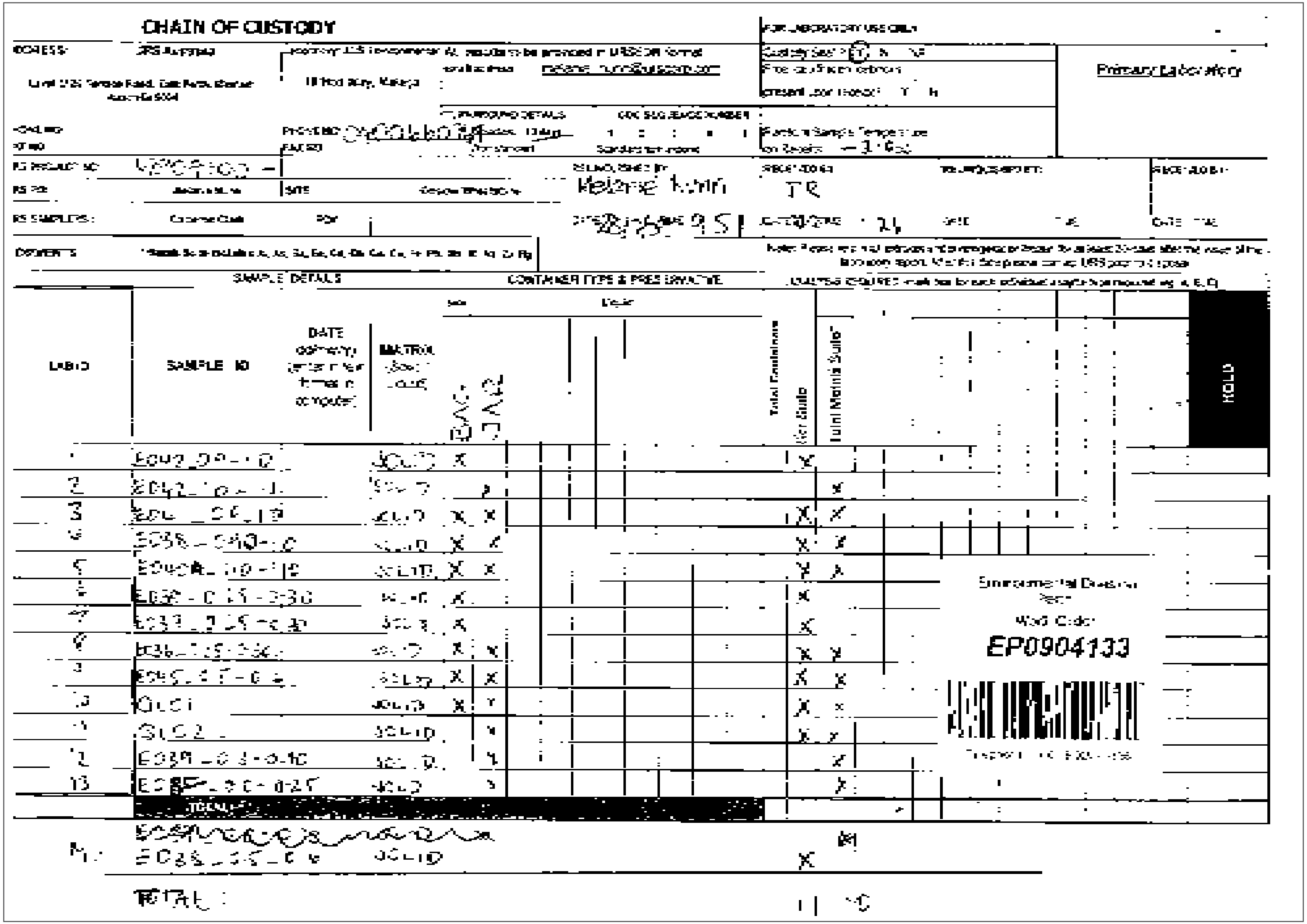
Matrix: **SOIL**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EG035T: Total Recoverable Mercury by FIMS - Analysis Holding Time Compliance						
Soil Glass Jar - Unpreserved MB16A-0.0-0.05	----	----	----	20-MAY-2009	01-MAY-2009	**19**
Soil Glass Jar - Unpreserved MB06A-1.0, MB16A-1.5-1	----	----	----	20-MAY-2009	02-MAY-2009	**18**
Soil Glass Jar - Unpreserved MB07A-0.0, MB07A-0.5	----	----	----	20-MAY-2009	03-MAY-2009	**17**
Soil Glass Jar - Unpreserved MB15A-3.0	----	----	----	20-MAY-2009	06-MAY-2009	**14**
Soil Glass Jar - Unpreserved MB15A-2.50	----	----	----	20-MAY-2009	07-MAY-2009	**13**
Soil Glass Jar - Unpreserved MB13A-0.0-0.45	----	----	----	20-MAY-2009	08-MAY-2009	**12**
Soil Glass Jar - Unpreserved MB11A-1.0	----	----	----	20-MAY-2009	10-MAY-2009	**10**
Soil Glass Jar - Unpreserved MB18A-1.50, MB18A-2.5	----	----	----	20-MAY-2009	13-MAY-2009	**7**
Soil Glass Jar - Unpreserved MB8A-0.0-0.10, MB8A-1.50	----	----	----	20-MAY-2009	17-MAY-2009	**3**
Soil Glass Jar - Unpreserved MB09A-2.50	----	----	----	20-MAY-2009	18-MAY-2009	**2**
Soil Glass Jar - Unpreserved MB4A-0.25-0.35	----	----	----	20-MAY-2009	24-APR-2009	**26**
Soil Glass Jar - Unpreserved MB3A-2.0-2.15, MB2B-1.2-1.5	----	----	----	20-MAY-2009	27-APR-2009	**23**

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.**



CHAIN OF CUSTODY

Primary Laboratory

Melanie Kuhn

SAMPLE DETAILS

CONTAINER TYPE & PRESERVATIVE

LAB ID	SAMPLE ID	DATE	MATRIX			Total Metals Suite	HOLD
1	[illegible]		SOLID	X			
2	[illegible]		SOLID			X	
3	[illegible]		SOLID	X	X	X	
4	[illegible]		SOLID	X	X	X	
5	[illegible]		SOLID	X	X	X	
6	[illegible]		SOLID	X			
7	[illegible]		SOLID	X			
8	[illegible]		SOLID	X	X	X	
9	[illegible]		SOLID	X	X	X	
10	QC01		SOLID	X	X	X	
11	QC02		SOLID		X	X	
12	[illegible]		SOLID		X	X	
13	[illegible]		SOLID		X	X	

TOTAL:

Environmental Division
Perth
Work Order
EP0904133

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

SAMPLE RECEIPT NOTIFICATION (SRN)

Comprehensive Report

Work Order : **EP0904133**

Client : **URS AUSTRALIA PTY LTD**
Contact : MELANIE NUNN
Address : LEVEL 3, HYATT CENTRE
20 TERRACE RD
EAST PERTH WA, AUSTRALIA 6004

E-mail : melanie_nunn@urscorp.com
Telephone : +61 08 9326 0128
Facsimile : +61 08 9221 1639

Project : 42907100
Order number : ----
C-O-C number : ----
Site : Onslow Wheatstone
Sampler : Cameron Clark

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

Page : 1 of 2

Quote number : EP2009URSWA0292 (EN-001-09 BQ)

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Dates

Date Samples Received : 28-JUL-2009
Client Requested Due Date : 04-AUG-2009
Issue Date : 29-JUL-2009 11:19
Scheduled Reporting Date : **04-AUG-2009**

Delivery Details

Mode of Delivery : Carrier
No. of coolers/boxes : 1 large hard
Sercurity Seal : Intact.
Temperature : -2
No. of samples received : 14
No. of samples analysed : 14

General Comments

- This report contains the following information:
    - Sample Container(s)/Preservation Non-Compliances
    - Summary of Sample(s) and Requested Analysis
    - Requested Deliverables
- Samples received in appropriately pretreated and preserved containers.
- Please see scanned COC for sample discrepencies: extra samples , samples not received etc.
- **Samples received in appropriately pretreated and preserved containers.**
- **Sample(s) have been received within recommended holding times.**
- **pH analysis should be conducted within 6 hours of sampling.**
- Analytical work for this work order will be conducted at ALS Environmental Perth.
- Please direct any turnaround / technical queries to the laboratory contact designated above.
- Please direct any queries related to sample condition / numbering / breakages to Sample Receipt (SamplesPerth@alsenviro.com)
- Sample Disposal - Aqueous (14 days), Solid (90 days) from date of completion of Work Order.

Environmental Division Perth
Part of the ALS Laboratory Group
10 Hod Way Malaga WA Australia 6090
Tel. +61-8-9209 7655 Fax. +61-8-9209 7600 **www.alsglobal.com**
A Campbell Brothers Limited Company

Issue Date : 29-JUL-2009 11:19
Page : 2 of 2
Work Order : EP0904133
Client : URS AUSTRALIA PTY LTD

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exist.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process neccessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

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.

Matrix: **SOIL**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	SOIL - EA033-WA WA - Chromium Suite for Acid Sulphate Soils	SOIL - EA055-103 Moisture Content	SOIL - EG005T (solids) Total Metals by ICP-AES	SOIL - EG035T (solids) Total Mercury by FIMS
EP0904133-001	28-JUL-2009 09:51	E042 0.9-1.0	✓			
EP0904133-002	28-JUL-2009 09:51	E042 1.0-1.1		✓	✓	✓
EP0904133-003	28-JUL-2009 09:51	E041 0.9-1.0	✓	✓	✓	✓
EP0904133-004	28-JUL-2009 09:51	E038 0.9-1.0	✓	✓	✓	✓
EP0904133-005	28-JUL-2009 09:51	E040 1.0-1.10	✓	✓	✓	✓
EP0904133-006	28-JUL-2009 09:51	E039 0.25-0.30	✓			
EP0904133-007	28-JUL-2009 09:51	E037 0.25-0.30	✓			
EP0904133-008	28-JUL-2009 09:51	E036 0.25-0.30	✓	✓	✓	✓
EP0904133-009	28-JUL-2009 09:51	E045 0.5-0.6	✓	✓	✓	✓
EP0904133-010	28-JUL-2009 09:51	QC01	✓	✓	✓	✓
EP0904133-011	28-JUL-2009 09:51	QC02	✓	✓	✓	✓
EP0904133-012	28-JUL-2009 09:51	E039 0.3-0.4		✓	✓	✓
EP0904133-013	28-JUL-2009 09:51	E037 0.0-0.25		✓	✓	✓
EP0904133-014	28-JUL-2009 09:51	E038 0.5-0.6	✓			

Requested Deliverables

ACCOUNTS PAYABLE		
- A4 - AU Tax Invoice (INV)	Email	Perth_Accounts@urscorp.com
MELANIE NUNN		
- *AU Certificate of Analysis - NATA (COA)	Email	melanie_nunn@urscorp.com
- A4 - AU Sample Receipt Notification - Environmental (SRN)	Email	melanie_nunn@urscorp.com
- AU Interpretive QC Report (Anon QCI Not Rep) (QCI_NoAnon)	Email	melanie_nunn@urscorp.com
- AU QC Report (Anon QC Not Rep) - NATA (QC_NoAnon)	Email	melanie_nunn@urscorp.com
- Default - Chain of Custody (COC)	Email	melanie_nunn@urscorp.com
- EDI Format - ENMRG (ENMRG)	Email	melanie_nunn@urscorp.com
- EDI Format - ESDAT (ESDAT)	Email	melanie_nunn@urscorp.com
- EDI Format - MRED (MRED)	Email	melanie_nunn@urscorp.com
- EDI Format - XTab (XTAB)	Email	melanie_nunn@urscorp.com

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EP0904133**

Client : **URS AUSTRALIA PTY LTD**
Contact : MELANIE NUNN
Address : LEVEL 3, HYATT CENTRE
20 TERRACE RD
EAST PERTH WA, AUSTRALIA 6004

E-mail : melanie_nunn@urscorp.com
Telephone : +61 08 9326 0128
Facsimile : +61 08 9221 1639

Project : 42907100
Order number : ----
C-O-C number : ----
Sampler : Cameron Clark
Site : Onslow Wheatstone

Quote number : EN-001-09 BQ

Page : 1 of 8

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 : 28-JUL-2009
Issue Date : 05-AUG-2009

No. of samples received : 14
No. of samples analysed : 14

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*
Rassem Ayoubi	Organic Chemist	Perth Inorganics
Scott James	Assistant Laboratory Manager	Perth Inorganics
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

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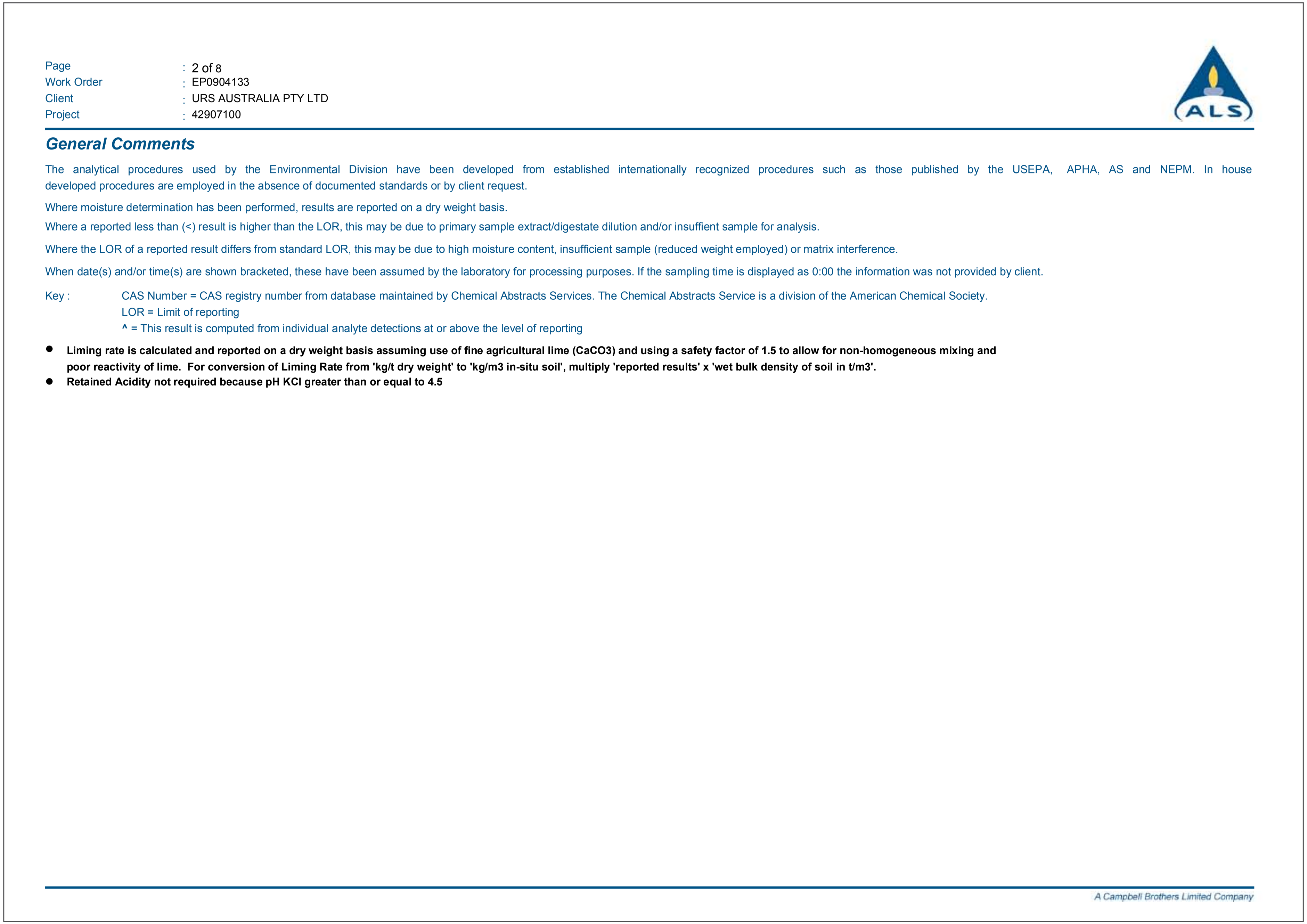

General Comments

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**

Page : 3 of 8
Work Order : EP0904133
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**E042 0.9-1.0**	**E042 1.0-1.1**	**E041 0.9-1.0**	**E038 0.9-1.0**	**E040 1.0-1.10**
			Client sampling date / time	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904133-001**	**EP0904133-002**	**EP0904133-003**	**EP0904133-004**	**EP0904133-005**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**7.3**	----	**8.0**	**6.4**	**5.7**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	<2	<2	**14**
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<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
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**0.95**	----	**1.31**	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**190**	----	**261**	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.30**	----	**0.42**	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	----	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	<0.02	<0.02	**0.03**
Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	<10	<10	**20**
Liming Rate	----	1	kg CaCO3/t	<1	----	<1	<1	**1**
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	----	<0.02	<0.02	**0.03**
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	----	<10	<10	**20**
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	----	<1	<1	**1**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	----	**29.8**	**26.1**	**16.7**	**24.9**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	**11200**	**11600**	**6620**	**7020**
Arsenic	7440-38-2	5	mg/kg	----	**34**	**20**	**5**	**13**
Barium	7440-39-3	10	mg/kg	----	**10**	**10**	**30**	**10**
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	----	**73**	**60**	**42**	**49**
Cobalt	7440-48-4	2	mg/kg	----	**4**	**14**	**5**	**2**
Copper	7440-50-8	5	mg/kg	----	**26**	**28**	**13**	**23**
Iron	7439-89-6	50	mg/kg	----	**72200**	**54700**	**24900**	**17800**
Lead	7439-92-1	5	mg/kg	----	**6**	**11**	**5**	<5
Manganese	7439-96-5	5	mg/kg	----	**120**	**219**	**119**	**26**
Nickel	7440-02-0	2	mg/kg	----	**11**	**24**	**10**	**5**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**E042** **0.9-1.0**	**E042** **1.0-1.1**	**E041** **0.9-1.0**	**E038** **0.9-1.0**	**E040** **1.0-1.10**
			Client sampling date / time	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904133-001**	**EP0904133-002**	**EP0904133-003**	**EP0904133-004**	**EP0904133-005**
EG005T: Total Metals by ICP-AES - Continued								
Vanadium	7440-62-2	5	mg/kg	----	**127**	**86**	**54**	**52**
Zinc	7440-66-6	5	mg/kg	----	**25**	**48**	**15**	**12**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1

Page : 5 of 8
Work Order : EP0904133
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**E039 0.25-0.30**	**E037 0.25-0.30**	**E036 0.25-0.30**	**E045 0.5-0.6**	**QC01**
			Client sampling date / time	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904133-006**	**EP0904133-007**	**EP0904133-008**	**EP0904133-009**	**EP0904133-010**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**7.5**	**6.5**	**8.3**	**9.2**	**6.5**
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	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**0.56**	----	**11.0**	**10.9**	**0.29**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**112**	----	**2210**	**2180**	**58**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.18**	----	**3.54**	**3.49**	**0.09**
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
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	----	----	**5.8**	**7.2**	**18.6**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	**6940**	**5360**	**5630**
Arsenic	7440-38-2	5	mg/kg	----	----	**5**	**8**	**6**
Barium	7440-39-3	10	mg/kg	----	----	**40**	**20**	**40**
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	----	----	**43**	**35**	**43**
Cobalt	7440-48-4	2	mg/kg	----	----	**8**	**6**	**3**
Copper	7440-50-8	5	mg/kg	----	----	**16**	**11**	**10**
Iron	7439-89-6	50	mg/kg	----	----	**39100**	**30600**	**18000**
Lead	7439-92-1	5	mg/kg	----	----	**8**	**5**	<5
Manganese	7439-96-5	5	mg/kg	----	----	**352**	**248**	**43**
Nickel	7440-02-0	2	mg/kg	----	----	**16**	**11**	**7**

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Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**E039 0.25-0.30**	**E037 0.25-0.30**	**E036 0.25-0.30**	**E045 0.5-0.6**	**QC01**
			Client sampling date / time	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904133-006**	**EP0904133-007**	**EP0904133-008**	**EP0904133-009**	**EP0904133-010**
EG005T: Total Metals by ICP-AES - Continued								
Vanadium	7440-62-2	5	mg/kg	----	----	**54**	**53**	**51**
Zinc	7440-66-6	5	mg/kg	----	----	**29**	**18**	**10**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	----	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	QC02	E039 0.3-0.4	E037 0.0-0.25	E038 0.5-0.6	----
			Client sampling date / time	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904133-011**	**EP0904133-012**	**EP0904133-013**	**EP0904133-014**	**----**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**7.0**	----	----	**8.8**	----
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	**0.81**	----	----	**0.88**	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**161**	----	----	**177**	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.26**	----	----	**0.28**	----
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	----
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**17.6**	**5.6**	**3.7**	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**5860**	**8120**	**6220**	----	----
Arsenic	7440-38-2	5	mg/kg	**6**	**6**	**7**	----	----
Barium	7440-39-3	10	mg/kg	**20**	**60**	**40**	----	----
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	**43**	**46**	**45**	----	----
Cobalt	7440-48-4	2	mg/kg	**2**	**10**	**11**	----	----
Copper	7440-50-8	5	mg/kg	**10**	**21**	**17**	----	----
Iron	7439-89-6	50	mg/kg	**19600**	**42800**	**40900**	----	----
Lead	7439-92-1	5	mg/kg	<5	**8**	**8**	----	----
Manganese	7439-96-5	5	mg/kg	**45**	**379**	**552**	----	----
Nickel	7440-02-0	2	mg/kg	**7**	**20**	**18**	----	----

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**QC02**	**E039 0.3-0.4**	**E037 0.0-0.25**	**E038 0.5-0.6**	----
			Client sampling date / time	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	28-JUL-2009 09:51	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904133-011**	**EP0904133-012**	**EP0904133-013**	**EP0904133-014**	**----**
EG005T: Total Metals by ICP-AES - Continued								
Vanadium	7440-62-2	5	mg/kg	**51**	**62**	**59**	----	----
Zinc	7440-66-6	5	mg/kg	**10**	**32**	**26**	----	----
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

QUALITY CONTROL REPORT

Work Order	: **EP0904133**	Page	: 1 of 6
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MELANIE NUNN	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	: melanie_nunn@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0128	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9221 1639	Facsimile	: +61-8-9209 7600
Project	: 42907100	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Site	: Onslow Wheatstone		
C-O-C number	: ----	Date Samples Received	: 28-JUL-2009
Sampler	: Cameron Clark	Issue Date	: 05-AUG-2009
Order number	: ----		
		No. of samples received	: 14
Quote number	: EN-001-09 BQ	No. of samples analysed	: 14

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 Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

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*
Rassem Ayoubi	Organic Chemist	Perth Inorganics
Scott James	Assistant Laboratory Manager	Perth Inorganics
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

A Campbell Brothers Limited Company

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.

Key :

Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

Page : 3 of 6
Work Order : EP0904133
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR:- No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:- 0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA033-A: Actual Acidity (QC Lot: 1053826)									
EP0904133-001	E042 0.9-1.0	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.0	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.0	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	7.3	7.3	0.0	0% - 20%
EP0904133-014	E038 0.5-0.6	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.0	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.0	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	8.8	8.8	0.0	0% - 20%
EA033-B: Potential Acidity (QC Lot: 1053826)									
EP0904133-001	E042 0.9-1.0	EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EP0904133-014	E038 0.5-0.6	EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EA033-C: Acid Neutralising Capacity (QC Lot: 1053826)									
EP0904133-001	E042 0.9-1.0	EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	0.95	0.96	0.0	0% - 20%
		EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	0.30	0.31	0.0	0% - 20%
		EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	190	192	0.8	0% - 50%
EP0904133-014	E038 0.5-0.6	EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	0.88	0.87	1.7	0% - 20%
		EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	0.28	0.28	0.0	0% - 20%
		EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	177	174	1.7	0% - 50%
EA033-E: Acid Base Accounting (QC Lot: 1053826)									
EP0904133-001	E042 0.9-1.0	EA033: ANC Fineness Factor	----	0.5	-	1.5	1.5	0.0	No Limit
		EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Liming Rate	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
		EA033: Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EP0904133-014	E038 0.5-0.6	EA033: ANC Fineness Factor	----	0.5	-	1.5	1.5	0.0	No Limit
		EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	0.0	No Limit
		EA033: Liming Rate	----	1	kg CaCO3/t	<1	<1	0.0	No Limit

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Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA033-E: Acid Base Accounting (QC Lot: 1053826) - continued									
EP0904133-014	E038 0.5-0.6	EA033: Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	0.0	No Limit
		EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
		EA033: Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	0.0	No Limit
EA055: Moisture Content (QC Lot: 1055034)									
EP0904133-012	E039 0.3-0.4	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	5.6	5.3	5.0	No Limit
EP0904133-013	E037 0.0-0.25	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	3.7	3.7	0.0	No Limit
EG005T: Total Metals by ICP-AES (QC Lot: 1053962)									
EP0904133-002	E042 1.0-1.1	EG005T: Beryllium	7440-41-7	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Cadmium	7440-43-9	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Barium	7440-39-3	10	mg/kg	10	<10	0.0	No Limit
		EG005T: Chromium	7440-47-3	2	mg/kg	73	69	5.3	0% - 20%
		EG005T: Cobalt	7440-48-4	2	mg/kg	4	3	28.7	No Limit
		EG005T: Nickel	7440-02-0	2	mg/kg	11	9	19.5	No Limit
		EG005T: Arsenic	7440-38-2	5	mg/kg	34	26	26.5	No Limit
		EG005T: Copper	7440-50-8	5	mg/kg	26	22	12.4	No Limit
		EG005T: Lead	7439-92-1	5	mg/kg	6	<5	0.0	No Limit
		EG005T: Manganese	7439-96-5	5	mg/kg	----	78	# Not Determined	0% - 50%
		EG005T: Vanadium	7440-62-2	5	mg/kg	127	107	17.0	0% - 20%
		EG005T: Zinc	7440-66-6	5	mg/kg	25	21	19.5	No Limit
		EG005T: Aluminium	7429-90-5	50	mg/kg	11200	10200	9.9	0% - 20%
		EG005T: Iron	7439-89-6	50	mg/kg	----	57000	# Not Determined	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 1053963)									
EP0904133-002	E042 1.0-1.1	EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	0.0	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

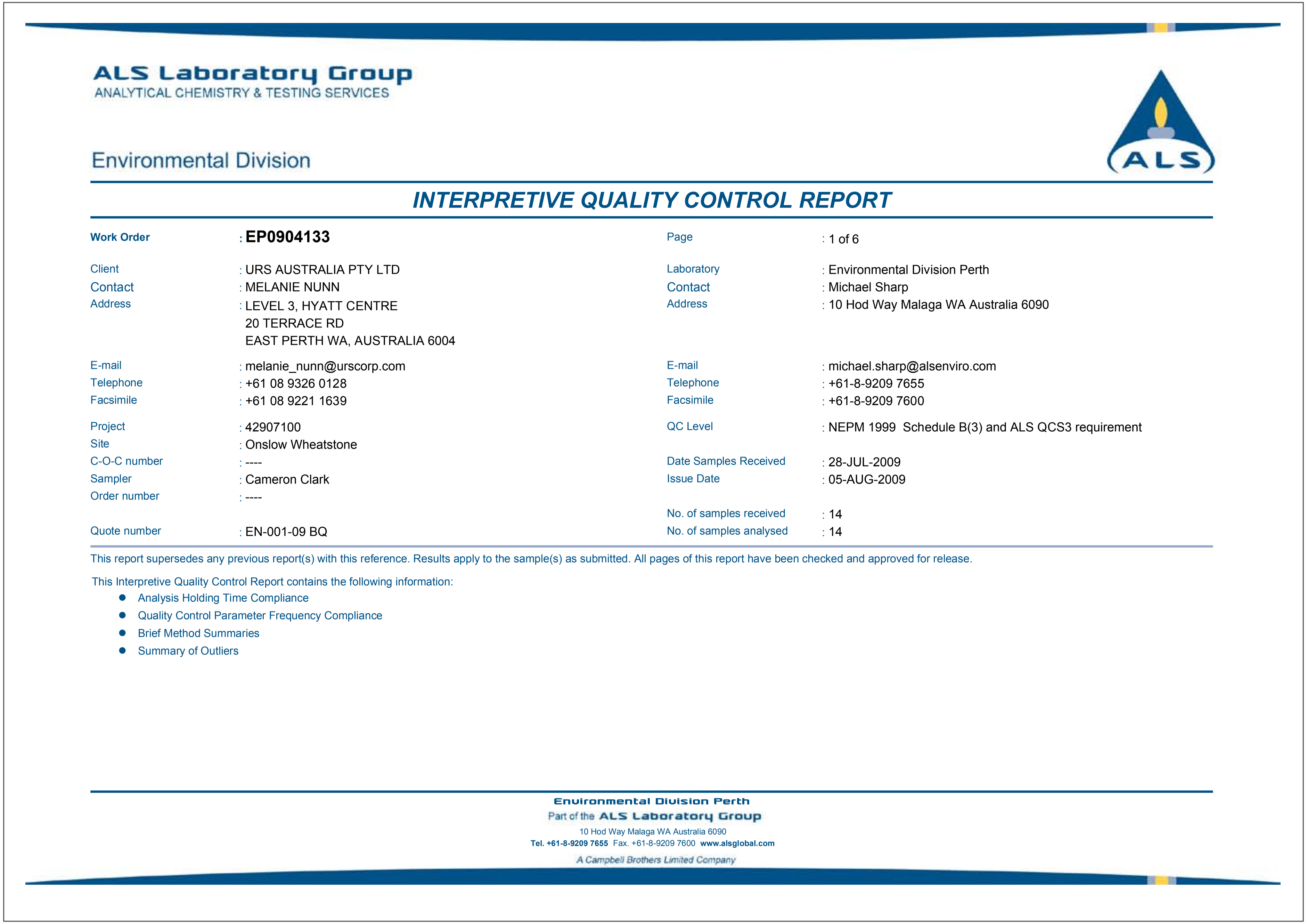
				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA033-A: Actual Acidity (QCLot: 1053826)								
EA033: pH KCl (23A)	----	0.1	pH Unit	<0.1	----	----	----	----
EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	----	----	----
EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-B: Potential Acidity (QCLot: 1053826)								
EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	----	----	----	----
EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	----	----	----
EA033-C: Acid Neutralising Capacity (QCLot: 1053826)								
EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	<0.01	----	----	----	----
EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	<10	----	----	----	----
EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	<0.01	----	----	----	----
EA033-E: Acid Base Accounting (QCLot: 1053826)								
EA033: ANC Fineness Factor	----	0.5		<0.5	----	----	----	----
EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	----	----	----
EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	----	----	----
EA033: Liming Rate	----	1	kg CaCO3/t	<1	----	----	----	----
EG005T: Total Metals by ICP-AES (QCLot: 1053962)								
EG005T: Aluminium	7429-90-5	50	mg/kg	<50	----	----	----	----
EG005T: Arsenic	7440-38-2	5	mg/kg	<5	13.75 mg/kg	105	85.5	116
EG005T: Barium	7440-39-3	10	mg/kg	<10	143 mg/kg	99.6	87.6	114
EG005T: Beryllium	7440-41-7	1	mg/kg	<1	----	----	----	----
EG005T: Cadmium	7440-43-9	1	mg/kg	<1	2.82 mg/kg	93.7	82.2	112
EG005T: Chromium	7440-47-3	2	mg/kg	<2	61.6 mg/kg	98.2	90.6	113
EG005T: Cobalt	7440-48-4	2	mg/kg	<2	----	----	----	----
EG005T: Copper	7440-50-8	5	mg/kg	<5	54.7 mg/kg	97.3	91.4	115
EG005T: Iron	7439-89-6	50	mg/kg	<50	----	----	----	----
EG005T: Lead	7439-92-1	5	mg/kg	<5	55.5 mg/kg	96.6	88.8	111
EG005T: Manganese	7439-96-5	5	mg/kg	<5	----	----	----	----
EG005T: Nickel	7440-02-0	2	mg/kg	<2	55.1 mg/kg	96.4	89.8	116
EG005T: Vanadium	7440-62-2	5	mg/kg	<5	----	----	----	----
EG005T: Zinc	7440-66-6	5	mg/kg	<5	105 mg/kg	95.0	86.6	113
EG035T: Total Recoverable Mercury by FIMS (QCLot: 1053963)								
EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	1.36 mg/kg	92.4	75.4	121

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

				Matrix Spike (MS) Report			
				Spike	Spike Recovery (%)	Recovery Limits (%)	
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*Concentration*	*MS*	*Low*	*High*
EG005T: Total Metals by ICP-AES (QCLot: 1053962)							
EP0904133-003	E041 0.9-1.0	EG005T: Aluminium	7429-90-5	50 mg/kg	# Not Determined	70	130
		EG005T: Arsenic	7440-38-2	50 mg/kg	103	70	130
		EG005T: Barium	7440-39-3	50 mg/kg	104	70	130
		EG005T: Beryllium	7440-41-7	10 mg/kg	105	70	130
		EG005T: Cadmium	7440-43-9	50 mg/kg	101	70	130
		EG005T: Chromium	7440-47-3	50 mg/kg	93.9	70	130
		EG005T: Copper	7440-50-8	50 mg/kg	100	70	130
		EG005T: Iron	7439-89-6	50 mg/kg	# Not Determined	70	130
		EG005T: Lead	7439-92-1	50 mg/kg	95.8	70	130
		EG005T: Manganese	7439-96-5	50 mg/kg	106	70	130
		EG005T: Nickel	7440-02-0	50 mg/kg	92.8	70	130
		EG005T: Vanadium	7440-62-2	50 mg/kg	93.9	70	130
		EG005T: Zinc	7440-66-6	50 mg/kg	91.2	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 1053963)							
EP0904133-003	E041 0.9-1.0	EG035T: Mercury	7439-97-6	10 mg/kg	84.2	70	130



ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

INTERPRETIVE QUALITY CONTROL REPORT

Work Order : **EP0904133**

Client : URS AUSTRALIA PTY LTD
Contact : MELANIE NUNN
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Project : 42907100
Site : Onslow Wheatstone
C-O-C number : ----
Sampler : Cameron Clark
Order number : ----

Quote number : EN-001-09 BQ

Page : 1 of 6

Laboratory : Environmental Division Perth
Contact : Michael Sharp
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Telephone : +61-8-9209 7655
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QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 28-JUL-2009
Issue Date : 05-AUG-2009

No. of samples received : 14
No. of samples analysed : 14

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 6
Work Order : EP0904133
Client : URS AUSTRALIA PTY LTD
Project : 42907100

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*
EA033-A: Actual Acidity							
80* dried soil E042 - 0.9-1.0, E041 - 0.9-1.0, E038 - 0.9-1.0, E040 - 1.0-1.10, E039 - 0.25-0.30, E037 - 0.25-0.30, E036 - 0.25-0.30, E045 - 0.5-0.6, QC01, QC02, E038 - 0.5-0.6	**28-JUL-2009**	**29-JUL-2009**	---	----	**31-JUL-2009**	27-OCT-2009	✓
EA033-B: Potential Acidity							
80* dried soil E042 - 0.9-1.0, E041 - 0.9-1.0, E038 - 0.9-1.0, E040 - 1.0-1.10, E039 - 0.25-0.30, E037 - 0.25-0.30, E036 - 0.25-0.30, E045 - 0.5-0.6, QC01, QC02, E038 - 0.5-0.6	**28-JUL-2009**	**29-JUL-2009**	---	----	**31-JUL-2009**	27-OCT-2009	✓
EA033-C: Acid Neutralising Capacity							
80* dried soil E042 - 0.9-1.0, E041 - 0.9-1.0, E038 - 0.9-1.0, E040 - 1.0-1.10, E039 - 0.25-0.30, E037 - 0.25-0.30, E036 - 0.25-0.30, E045 - 0.5-0.6, QC01, QC02, E038 - 0.5-0.6	**28-JUL-2009**	**29-JUL-2009**	---	----	**31-JUL-2009**	27-OCT-2009	✓

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Page : 3 of 6
Work Order : EP0904133
Client : URS AUSTRALIA PTY LTD
Project : 42907100

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*
EA033-D: Retained Acidity							
80* dried soil E042 - 0.9-1.0, E038 - 0.9-1.0, E039 - 0.25-0.30, E036 - 0.25-0.30, QC01, E038 - 0.5-0.6 E041 - 0.9-1.0, E040 - 1.0-1.10, E037 - 0.25-0.30, E045 - 0.5-0.6, QC02,	**28-JUL-2009**	**29-JUL-2009**	---	----	**31-JUL-2009**	27-OCT-2009	✓
EA033-E: Acid Base Accounting							
80* dried soil E042 - 0.9-1.0, E038 - 0.9-1.0, E039 - 0.25-0.30, E036 - 0.25-0.30, QC01, E038 - 0.5-0.6 E041 - 0.9-1.0, E040 - 1.0-1.10, E037 - 0.25-0.30, E045 - 0.5-0.6, QC02,	**28-JUL-2009**	**29-JUL-2009**	---	----	**31-JUL-2009**	27-OCT-2009	✓
EA055: Moisture Content							
Soil Glass Jar - Unpreserved E042 - 1.0-1.1, E038 - 0.9-1.0, E036 - 0.25-0.30, QC01, E039 - 0.3-0.4, E041 - 0.9-1.0, E040 - 1.0-1.10, E045 - 0.5-0.6, QC02, E037 - 0.0-0.25	**28-JUL-2009**	**----**	----	----	**30-JUL-2009**	04-AUG-2009	✓
EG005T: Total Metals by ICP-AES							
Soil Glass Jar - Unpreserved E042 - 1.0-1.1, E038 - 0.9-1.0, E036 - 0.25-0.30, QC01, E039 - 0.3-0.4, E041 - 0.9-1.0, E040 - 1.0-1.10, E045 - 0.5-0.6, QC02, E037 - 0.0-0.25	**28-JUL-2009**	**29-JUL-2009**	25-AUG-2009	✓	**30-JUL-2009**	24-JAN-2010	✓
EG035T: Total Recoverable Mercury by FIMS							
Soil Glass Jar - Unpreserved E042 - 1.0-1.1, E038 - 0.9-1.0, E036 - 0.25-0.30, QC01, E039 - 0.3-0.4, E041 - 0.9-1.0, E040 - 1.0-1.10, E045 - 0.5-0.6, QC02, E037 - 0.0-0.25	**28-JUL-2009**	**29-JUL-2009**	25-AUG-2009	✓	**30-JUL-2009**	25-AUG-2009	✓

Page : 4 of 6
Work Order : EP0904133
Client : URS AUSTRALIA PTY LTD
Project : 42907100

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*	*Reqular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Chromium Suite for Acid Sulphate Soils	EA033	2	11	**18.2**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Moisture Content	EA055-103	2	12	**16.7**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	10	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	1	10	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Total Mercury by FIMS	EG035T	1	10	**10.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	1	10	**10.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Chromium Suite for Acid Sulphate Soils	EA033	1	11	**9.1**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	10	**10.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	1	10	**10.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Total Mercury by FIMS	EG035T	1	10	**10.0**	**5.0**	✓	ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	1	10	**10.0**	**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*
Chromium Suite for Acid Sulphate Soils	EA033	SOIL	Ahern et al 2004. This method covers the determination of Chromium Reducible Sulfur (SCR); pHKCl; titratable actual acidity (TAA); acid neutralising capacity by back titration (ANC); and net acid soluble sulfur (SNAS) which incorporates peroxide sulfur. It applies to soils and sediments (including sands) derived from coastal regions. Liming Rate is based on results for samples as submitted and incorporates a minimum safety factor of 1.5.
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 Mercury by FIMS	EG035T	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)

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Drying at 85 degrees, bagging and labelling (ASS)	EN020PR	SOIL	In house
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)

Page : 6 of 6
Work Order : EP0904133
Client : URS AUSTRALIA PTY LTD
Project : 42907100

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

Matrix: **SOIL**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Duplicate (DUP) RPDs							
EG005T: Total Metals by ICP-AES	EP0904133-002	E042 1.0-1.1	**Iron**	7439-89-6	Not Determined		**RPD exceeds LOR based limits**
EG005T: Total Metals by ICP-AES	EP0904133-002	E042 1.0-1.1	**Iron**	7439-89-6	Not Determined		**Analyte not determined in allocated original sample.**
EG005T: Total Metals by ICP-AES	EP0904133-002	E042 1.0-1.1	**Manganese**	7439-96-5	Not Determined		**Analyte not determined in allocated original sample.**
EG005T: Total Metals by ICP-AES	EP0904133-002	E042 1.0-1.1	**Manganese**	7439-96-5	Not Determined		**RPD exceeds LOR based limits**
Matrix Spike (MS) Recoveries							
EG005T: Total Metals by ICP-AES	EP0904133-003	E041 0.9-1.0	**Aluminium**	7429-90-5	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**
EG005T: Total Metals by ICP-AES	EP0904133-003	E041 0.9-1.0	**Iron**	7439-89-6	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Laboratory Control 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.

- **No Analysis Holding Time Outliers exist.**

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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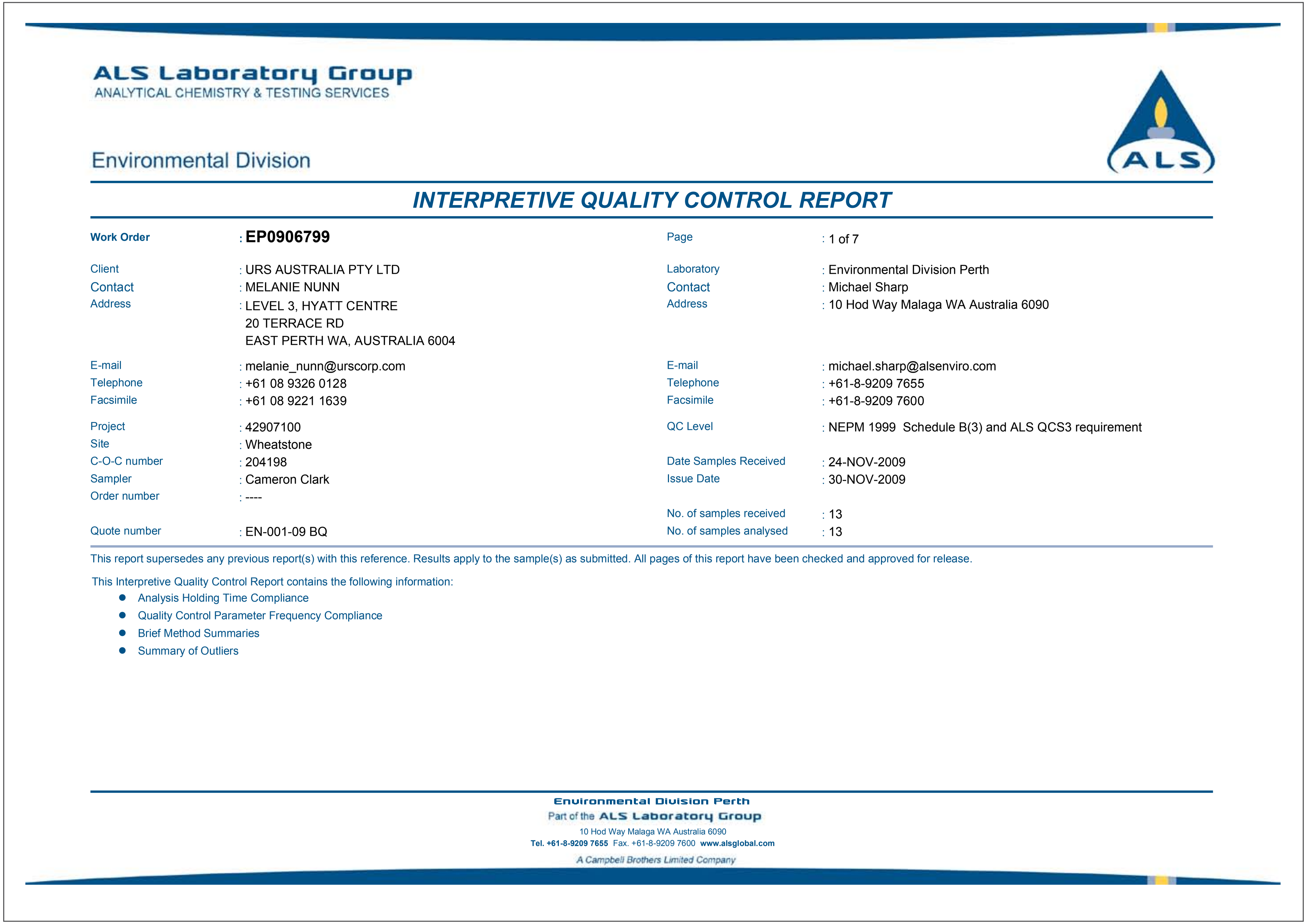

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

INTERPRETIVE QUALITY CONTROL REPORT

Work Order : **EP0906799**
Page : 1 of 7

Client : URS AUSTRALIA PTY LTD
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Facsimile : +61 08 9221 1639
Project : 42907100
Site : Wheatstone
C-O-C number : 204198
Sampler : Cameron Clark
Order number : ----
Quote number : EN-001-09 BQ

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 : 24-NOV-2009
Issue Date : 30-NOV-2009
No. of samples received : 13
No. of samples analysed : 13

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

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*
EA033-A: Actual Acidity							
80* dried soil SS07 - 1.5-1.6, SS01 - 0.5-0.6, EO47 - 1.0-1.1, EO48 - 0.0-0.1, S004 - 1.0-1.1, SS01 - 1.0-1.1, SS05 - 1.0-1.1, SS03 - 0.4-0.5, EO52 - 0.5-0.6, SS06 - 0.5-0.6, QC01, SS06 - 1.5-1.6, E046 - 0.0-0.1	**24-NOV-2009**	**25-NOV-2009**	---	----	**26-NOV-2009**	23-FEB-2010	✓
EA033-B: Potential Acidity							
80* dried soil SS07 - 1.5-1.6, SS01 - 0.5-0.6, EO47 - 1.0-1.1, EO48 - 0.0-0.1, S004 - 1.0-1.1, SS01 - 1.0-1.1, SS05 - 1.0-1.1, SS03 - 0.4-0.5, EO52 - 0.5-0.6, SS06 - 0.5-0.6, QC01, SS06 - 1.5-1.6, E046 - 0.0-0.1	**24-NOV-2009**	**25-NOV-2009**	---	----	**26-NOV-2009**	23-FEB-2010	✓
EA033-C: Acid Neutralising Capacity							
80* dried soil SS07 - 1.5-1.6, SS01 - 0.5-0.6, EO47 - 1.0-1.1, EO48 - 0.0-0.1, S004 - 1.0-1.1, SS01 - 1.0-1.1, SS05 - 1.0-1.1, SS03 - 0.4-0.5, EO52 - 0.5-0.6, SS06 - 0.5-0.6, QC01, SS06 - 1.5-1.6, E046 - 0.0-0.1	**24-NOV-2009**	**25-NOV-2009**	---	----	**26-NOV-2009**	23-FEB-2010	✓

Page : 3 of 7
Work Order : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

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*
EA033-D: Retained Acidity							
80* dried soil SS07 - 1.5-1.6, EO47 - 1.0-1.1, S004 - 1.0-1.1, SS05 - 1.0-1.1, EO52 - 0.5-0.6, QC01, E046 - 0.0-0.1 SS01 - 0.5-0.6, EO48 - 0.0-0.1, SS01 - 1.0-1.1, SS03 - 0.4-0.5, SS06 - 0.5-0.6, SS06 - 1.5-1.6,	**24-NOV-2009**	**25-NOV-2009**	---	----	**26-NOV-2009**	23-FEB-2010	✓
EA033-E: Acid Base Accounting							
80* dried soil SS07 - 1.5-1.6, EO47 - 1.0-1.1, S004 - 1.0-1.1, SS05 - 1.0-1.1, EO52 - 0.5-0.6, QC01, E046 - 0.0-0.1 SS01 - 0.5-0.6, EO48 - 0.0-0.1, SS01 - 1.0-1.1, SS03 - 0.4-0.5, SS06 - 0.5-0.6, SS06 - 1.5-1.6,	**24-NOV-2009**	**25-NOV-2009**	---	----	**26-NOV-2009**	23-FEB-2010	✓
EA055: Moisture Content							
Snap Lock Bag SS01 - 1.0-1.1, SS06 - 0.5-0.6	**24-NOV-2009**	**----**	----	----	**27-NOV-2009**	01-DEC-2009	✓
Soil Glass Jar - Unpreserved SS07 - 1.5-1.6, EO47 - 1.0-1.1, S004 - 1.0-1.1, SS03 - 0.4-0.5, QC01, E046 - 0.0-0.1 SS01 - 0.5-0.6, EO48 - 0.0-0.1, SS05 - 1.0-1.1, EO52 - 0.5-0.6, SS06 - 1.5-1.6,	**24-NOV-2009**	**----**	----	----	**27-NOV-2009**	01-DEC-2009	✓
EG005T: Total Metals by ICP-AES							
Snap Lock Bag SS01 - 1.0-1.1, SS06 - 0.5-0.6	**24-NOV-2009**	**26-NOV-2009**	22-DEC-2009	✓	**26-NOV-2009**	23-MAY-2010	✓
Soil Glass Jar - Unpreserved SS07 - 1.5-1.6, EO47 - 1.0-1.1, S004 - 1.0-1.1, SS03 - 0.4-0.5, QC01, E046 - 0.0-0.1 SS01 - 0.5-0.6, EO48 - 0.0-0.1, SS05 - 1.0-1.1, EO52 - 0.5-0.6, SS06 - 1.5-1.6,	**24-NOV-2009**	**26-NOV-2009**	22-DEC-2009	✓	**26-NOV-2009**	23-MAY-2010	✓

Page	:	4 of 7
Work Order	:	EP0906799
Client	:	URS AUSTRALIA PTY LTD
Project	:	42907100

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*
EG035T: Total Mercury by FIMS							
Snap Lock Bag SS01 - 1.0-1.1, SS06 - 0.5-0.6	**24-NOV-2009**	**26-NOV-2009**	22-DEC-2009	✓	**26-NOV-2009**	22-DEC-2009	✓
Soil Glass Jar - Unpreserved SS07 - 1.5-1.6, SS01 - 0.5-0.6, EO47 - 1.0-1.1, EO48 - 0.0-0.1, S004 - 1.0-1.1, SS05 - 1.0-1.1, SS03 - 0.4-0.5, EO52 - 0.5-0.6, QC01, SS06 - 1.5-1.6, E046 - 0.0-0.1	**24-NOV-2009**	**26-NOV-2009**	22-DEC-2009	✓	**26-NOV-2009**	22-DEC-2009	✓

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)							
Chromium Suite for Acid Sulphate Soils	EA033	2	13	**15.4**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Moisture Content	EA055-103	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	2	20	**10.0**	**10.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Total Mercury by FIMS	EG035T	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Chromium Suite for Acid Sulphate Soils	EA033	1	13	**7.7**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	1	20	**5.0**	**5.0**	✓	NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Total Mercury by FIMS	EG035T	1	20	**5.0**	**5.0**	✓	ALS QCS3 requirement
Total Metals by ICP-AES	EG005T	1	20	**5.0**	**5.0**	✓	ALS QCS3 requirement

Page : 6 of 7
Work Order : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

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*
Chromium Suite for Acid Sulphate Soils	EA033	SOIL	Ahern et al 2004. This method covers the determination of Chromium Reducible Sulfur (SCR); pHKCl; titratable actual acidity (TAA); acid neutralising capacity by back titration (ANC); and net acid soluble sulfur (SNAS) which incorporates peroxide sulfur. It applies to soils and sediments (including sands) derived from coastal regions. Liming Rate is based on results for samples as submitted and incorporates a minimum safety factor of 1.5.
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 Mercury by FIMS	EG035T	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)

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Drying at 85 degrees, bagging and labelling (ASS)	EN020PR	SOIL	In house
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)

Page : 7 of 7
Work Order : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

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

Matrix: **SOIL**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Duplicate (DUP) RPDs							
EG005T: Total Metals by ICP-AES	EP0906799-005	S004 1.0-1.1	**Manganese**	7439-96-5	79.8 %	0-20%	**RPD exceeds LOR based limits**

- **For all matrices, no Method Blank value 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.

- **No Analysis Holding Time Outliers exist.**

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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ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

QUALITY CONTROL REPORT

Work Order : **EP0906799**

Client : **URS AUSTRALIA PTY LTD**
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Project : 42907100
Site : Wheatstone
C-O-C number : 204198
Sampler : Cameron Clark
Order number : ----

Quote number : EN-001-09 BQ

Page : 1 of 6

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 : 24-NOV-2009
Issue Date : 30-NOV-2009

No. of samples received : 13
No. of samples analysed : 13

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 Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance 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
Scott James	Assistant Laboratory Manager	Perth Inorganics
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

A Campbell Brothers Limited Company

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.

Key :
- Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
- 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
- RPD = Relative Percentage Difference
- # = Indicates failed QC

Page : 3 of 6
Work Order : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR:- No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:- 0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA033-A: Actual Acidity (QC Lot: 1173422)									
EP0906799-001	SS07 1.5-1.6	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.0	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.0	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	6.4	6.4	0.0	0% - 20%
EP0906799-011	QC01	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.0	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	8	8	0.0	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	5.4	5.4	0.0	0% - 20%
EA033-B: Potential Acidity (QC Lot: 1173422)									
EP0906799-001	SS07 1.5-1.6	EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	0.06	0.06	0.0	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	39	37	4.6	No Limit
EP0906799-011	QC01	EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	0.20	0.20	0.0	0% - 50%
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	122	124	1.4	0% - 50%
EA033-E: Acid Base Accounting (QC Lot: 1173422)									
EP0906799-001	SS07 1.5-1.6	EA033: ANC Fineness Factor	----	0.5	-	1.5	1.5	0.0	No Limit
		EA033: Net Acidity (sulfur units)	----	0.02	% S	0.06	0.06	0.0	No Limit
		EA033: Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.06	0.06	0.0	No Limit
		EA033: Liming Rate	----	1	kg CaCO3/t	3	3	0.0	No Limit
		EA033: Liming Rate excluding ANC	----	1	kg CaCO3/t	3	3	0.0	No Limit
		EA033: Net Acidity (acidity units)	----	10	mole H+ / t	39	37	4.6	No Limit
		EA033: Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	39	37	4.6	No Limit
EP0906799-011	QC01	EA033: ANC Fineness Factor	----	0.5	-	8.5	9.5	11.1	0% - 50%
		EA033: Net Acidity (sulfur units)	----	0.02	% S	0.21	0.21	0.0	0% - 50%
		EA033: Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.21	0.21	0.0	0% - 50%
		EA033: Liming Rate	----	1	kg CaCO3/t	10	10	0.0	0% - 50%
		EA033: Liming Rate excluding ANC	----	1	kg CaCO3/t	10	10	0.0	0% - 50%
		EA033: Net Acidity (acidity units)	----	10	mole H+ / t	131	132	1.3	0% - 50%
		EA033: Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	131	132	1.3	0% - 50%
EA055: Moisture Content (QC Lot: 1176716)									
EP0906799-001	SS07 1.5-1.6	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	19.7	20.0	1.2	0% - 20%
EP0906799-010	SS06 0.5-0.6	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	25.3	23.6	7.0	0% - 20%
EG005T: Total Metals by ICP-AES (QC Lot: 1175258)									
EP0906768-001	Anonymous	EG005T: Beryllium	7440-41-7	1	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Cadmium	7440-43-9	1	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Barium	7440-39-3	10	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Chromium	7440-47-3	2	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous

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Page : 4 of 6
Work Order : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG005T: Total Metals by ICP-AES (QC Lot: 1175258) - continued									
EP0906768-001	Anonymous	EG005T: Cobalt	7440-48-4	2	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Nickel	7440-02-0	2	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Arsenic	7440-38-2	5	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Copper	7440-50-8	5	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Lead	7439-92-1	5	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Manganese	7439-96-5	5	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Vanadium	7440-62-2	5	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Zinc	7440-66-6	5	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Aluminium	7429-90-5	50	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Iron	7439-89-6	50	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
EP0906799-005	S004 1.0-1.1	EG005T: Beryllium	7440-41-7	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Cadmium	7440-43-9	1	mg/kg	<1	<1	0.0	No Limit
		EG005T: Barium	7440-39-3	10	mg/kg	40	30	31.1	No Limit
		EG005T: Chromium	7440-47-3	2	mg/kg	52	50	3.5	0% - 20%
		EG005T: Cobalt	7440-48-4	2	mg/kg	8	11	34.3	No Limit
		EG005T: Nickel	7440-02-0	2	mg/kg	19	23	20.0	0% - 50%
		EG005T: Arsenic	7440-38-2	5	mg/kg	<5	6	0.0	No Limit
		EG005T: Copper	7440-50-8	5	mg/kg	21	26	19.1	No Limit
		EG005T: Lead	7439-92-1	5	mg/kg	8	9	14.1	No Limit
		EG005T: Manganese	7439-96-5	5	mg/kg	263	611	# 79.8	0% - 20%
		EG005T: Vanadium	7440-62-2	5	mg/kg	71	72	1.4	0% - 50%
		EG005T: Zinc	7440-66-6	5	mg/kg	27	31	12.2	No Limit
		EG005T: Aluminium	7429-90-5	50	mg/kg	8230	9450	13.8	0% - 20%
		EG005T: Iron	7439-89-6	50	mg/kg	35000	35400	1.2	0% - 20%
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 1175259)									
EP0906768-001	Anonymous	EG035T: Mercury	7439-97-6	0.1	mg/kg	Anonymous	Anonymous	Anonymous	Anonymous
EP0906799-005	S004 1.0-1.1	EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	0.0	No Limit

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Work Order : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	*CAS Number*	*LOR*	*Unit*	*Result*	*Concentration*	*LCS*	*Low*	*High*
EA033-A: Actual Acidity (QCLot: 1173422)								
EA033: pH KCl (23A)	----	0.1	pH Unit	<0.1	----	----	----	----
EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	----	----	----
EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-B: Potential Acidity (QCLot: 1173422)								
EA033: Chromium Reducible Sulfur (22B)	----	0.02	% S	<0.02	----	----	----	----
EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	----	----	----
EA033-C: Acid Neutralising Capacity (QCLot: 1173422)								
EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	<0.01	----	----	----	----
EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	<10	----	----	----	----
EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	<0.01	----	----	----	----
EA033-E: Acid Base Accounting (QCLot: 1173422)								
EA033: ANC Fineness Factor	----	0.5		<0.5	----	----	----	----
EA033: Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	----	----	----
EA033: Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	----	----	----
EA033: Liming Rate	----	1	kg CaCO3/t	<1	----	----	----	----
EG005T: Total Metals by ICP-AES (QCLot: 1175258)								
EG005T: Aluminium	7429-90-5	50	mg/kg	<50	----	----	----	----
EG005T: Arsenic	7440-38-2	5	mg/kg	<5	13.75 mg/kg	93.0	85.5	116
EG005T: Barium	7440-39-3	10	mg/kg	<10	143 mg/kg	101	87.6	114
EG005T: Beryllium	7440-41-7	1	mg/kg	<1	----	----	----	----
EG005T: Cadmium	7440-43-9	1	mg/kg	<1	2.82 mg/kg	101	82.2	112
EG005T: Chromium	7440-47-3	2	mg/kg	<2	61.6 mg/kg	99.2	90.6	113
EG005T: Cobalt	7440-48-4	2	mg/kg	<2	----	----	----	----
EG005T: Copper	7440-50-8	5	mg/kg	<5	54.7 mg/kg	101	91.4	115
EG005T: Iron	7439-89-6	50	mg/kg	<50	----	----	----	----
EG005T: Lead	7439-92-1	5	mg/kg	<5	55.5 mg/kg	95.3	88.8	111
EG005T: Manganese	7439-96-5	5	mg/kg	<5	----	----	----	----
EG005T: Nickel	7440-02-0	2	mg/kg	<2	55.1 mg/kg	99.1	89.8	116
EG005T: Vanadium	7440-62-2	5	mg/kg	<5	----	----	----	----
EG005T: Zinc	7440-66-6	5	mg/kg	<5	105 mg/kg	95.6	86.6	113
EG035T: Total Recoverable Mercury by FIMS (QCLot: 1175259)								
EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	1.36 mg/kg	98.9	75.4	121

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

				Matrix Spike (MS) Report			
				Spike	Spike Recovery (%)	Recovery Limits (%)	
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*Concentration*	*MS*	*Low*	*High*
EG005T: Total Metals by ICP-AES (QCLot: 1175258)							
EP0906768-002	Anonymous	EG005T: Aluminium	7429-90-5	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Arsenic	7440-38-2	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Barium	7440-39-3	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Beryllium	7440-41-7	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Cadmium	7440-43-9	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Chromium	7440-47-3	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Copper	7440-50-8	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Iron	7439-89-6	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Lead	7439-92-1	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Manganese	7439-96-5	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Nickel	7440-02-0	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Vanadium	7440-62-2	Anonymous	Anonymous	Anonymous	Anonymous
		EG005T: Zinc	7440-66-6	Anonymous	Anonymous	Anonymous	Anonymous
EG035T: Total Recoverable Mercury by FIMS (QCLot: 1175259)							
EP0906768-002	Anonymous	EG035T: Mercury	7439-97-6	Anonymous	Anonymous	Anonymous	Anonymous

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order : **EP0906799**
Client : **URS AUSTRALIA PTY LTD**
Contact : MELANIE NUNN
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Project : 42907100
Order number : ----
C-O-C number : 204198
Sampler : Cameron Clark
Site : Wheatstone
Quote number : EN-001-09 BQ

Page : 1 of 8
Laboratory : Environmental Division Perth
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Telephone : +61-8-9209 7655
Facsimile : +61-8-9209 7600
QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Date Samples Received : 24-NOV-2009
Issue Date : 30-NOV-2009
No. of samples received : 13
No. of samples analysed : 13

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*
Scott James	Assistant Laboratory Manager	Perth Inorganics
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth ASS

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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'.**
- **Poor metals duplicate precision due to sample heterogeneity.**
- **Retained Acidity not required because pH KCl greater than or equal to 4.5**

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**SS07** **1.5-1.6**	**SS01** **0.5-0.6**	**EO47** **1.0-1.1**	**EO48** **0.0-0.1**	**S004** **1.0-1.1**
			Client sampling date / time	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36
Compound	*CAS Number*	*LOR*	*Unit*	**EP0906799-001**	**EP0906799-002**	**EP0906799-003**	**EP0906799-004**	**EP0906799-005**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**6.4**	**8.5**	**9.1**	**8.4**	**7.9**
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	<0.02	<0.02	<0.02
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**39**	<10	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	----	**1.70**	**1.14**	**0.71**	**0.51**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	----	**339**	**228**	**142**	**102**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	----	**0.54**	**0.37**	**0.23**	**0.16**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**2.5**
Net Acidity (sulfur units)	----	0.02	% S	**0.06**	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	**39**	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	**3**	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.06**	<0.02	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**39**	<10	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	**3**	<1	<1	<1	<1
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**19.7**	**8.1**	**14.1**	**2.6**	**11.4**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**2350**	**13600**	**6360**	**7240**	**8230**
Arsenic	7440-38-2	5	mg/kg	**6**	**7**	<5	<5	<5
Barium	7440-39-3	10	mg/kg	**20**	**60**	**60**	**60**	**40**
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	**28**	**70**	**44**	**50**	**52**
Cobalt	7440-48-4	2	mg/kg	<2	**16**	**9**	**11**	**8**
Copper	7440-50-8	5	mg/kg	**10**	**36**	**19**	**21**	**21**
Iron	7439-89-6	50	mg/kg	**19600**	**47600**	**27100**	**30300**	**35000**
Lead	7439-92-1	5	mg/kg	<5	**10**	**6**	**7**	**8**
Manganese	7439-96-5	5	mg/kg	**26**	**640**	**361**	**459**	**263**
Nickel	7440-02-0	2	mg/kg	**2**	**31**	**17**	**19**	**19**

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**SS07** **1.5-1.6**	**SS01** **0.5-0.6**	**EO47** **1.0-1.1**	**EO48** **0.0-0.1**	**S004** **1.0-1.1**
			Client sampling date / time	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36
Compound	*CAS Number*	*LOR*	*Unit*	**EP0906799-001**	**EP0906799-002**	**EP0906799-003**	**EP0906799-004**	**EP0906799-005**
EG005T: Total Metals by ICP-AES - Continued								
Vanadium	7440-62-2	5	mg/kg	**42**	**87**	**57**	**59**	**71**
Zinc	7440-66-6	5	mg/kg	**7**	**44**	**24**	**34**	**27**
EG035T: Total 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 : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**SS01** **1.0-1.1**	**SS05** **1.0-1.1**	**SS03** **0.4-0.5**	**EO52** **0.5-0.6**	**SS06** **0.5-0.6**
			Client sampling date / time	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36
Compound	*CAS Number*	*LOR*	*Unit*	**EP0906799-006**	**EP0906799-007**	**EP0906799-008**	**EP0906799-009**	**EP0906799-010**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**8.7**	**9.2**	**8.6**	**7.6**	**8.1**
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	<0.02	<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	**1.43**	**2.54**	**2.63**	**0.99**	**0.94**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**285**	**508**	**525**	**198**	**188**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**0.46**	**0.82**	**0.84**	**0.32**	**0.30**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**3.5**	**4.5**	**5.5**	**6.5**	**7.5**
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
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**12.2**	**8.8**	**18.2**	**7.7**	**25.3**
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**12400**	**5340**	**10300**	**12500**	**9080**
Arsenic	7440-38-2	5	mg/kg	<5	<5	**6**	<5	**5**
Barium	7440-39-3	10	mg/kg	**90**	**30**	**30**	**120**	**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	**66**	**40**	**59**	**63**	**51**
Cobalt	7440-48-4	2	mg/kg	**21**	**8**	**14**	**18**	**21**
Copper	7440-50-8	5	mg/kg	**36**	**16**	**30**	**40**	**36**
Iron	7439-89-6	50	mg/kg	**44700**	**25800**	**39300**	**44200**	**35400**
Lead	7439-92-1	5	mg/kg	**12**	**6**	**9**	**13**	**23**
Manganese	7439-96-5	5	mg/kg	**900**	**376**	**561**	**659**	**647**
Nickel	7440-02-0	2	mg/kg	**33**	**15**	**26**	**32**	**48**

A Campbell Brothers Limited Company

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	**SS01 1.0-1.1**	**SS05 1.0-1.1**	**SS03 0.4-0.5**	**EO52 0.5-0.6**	**SS06 0.5-0.6**
			Client sampling date / time	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36
Compound	*CAS Number*	*LOR*	*Unit*	**EP0906799-006**	**EP0906799-007**	**EP0906799-008**	**EP0906799-009**	**EP0906799-010**
EG005T: Total Metals by ICP-AES - Continued								
Vanadium	7440-62-2	5	mg/kg	**86**	**53**	**76**	**85**	**70**
Zinc	7440-66-6	5	mg/kg	**49**	**23**	**41**	**55**	**47**
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Page : 7 of 8
Work Order : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **SOIL**			*Client sample ID*	**QC01**	**SS06** **1.5-1.6**	**E046** **0.0-0.1**	----	----
			Client sampling date / time	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0906799-011**	**EP0906799-012**	**EP0906799-013**	**----**	**----**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**5.4**	**7.6**	**9.0**	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	**8**	<2	<2	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.02	% S	**0.20**	<0.02	<0.02	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**122**	<10	<10	----	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	----	**0.87**	**1.69**	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	----	**173**	**338**	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	----	**0.28**	**0.54**	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**8.5**	**10.5**	**11.5**	----	----
Net Acidity (sulfur units)	----	0.02	% S	**0.21**	<0.02	<0.02	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	**131**	<10	<10	----	----
Liming Rate	----	1	kg CaCO3/t	**10**	<1	<1	----	----
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.21**	<0.02	<0.02	----	----
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**131**	<10	<10	----	----
Liming Rate excluding ANC	----	1	kg CaCO3/t	**10**	<1	<1	----	----
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	**19.0**	**22.6**	**7.2**	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**1940**	**8770**	**7280**	----	----
Arsenic	7440-38-2	5	mg/kg	**6**	**7**	<5	----	----
Barium	7440-39-3	10	mg/kg	**50**	**30**	**70**	----	----
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	**18**	**48**	**49**	----	----
Cobalt	7440-48-4	2	mg/kg	<2	**16**	**11**	----	----
Copper	7440-50-8	5	mg/kg	**7**	**31**	**23**	----	----
Iron	7439-89-6	50	mg/kg	**9180**	**34100**	**32600**	----	----
Lead	7439-92-1	5	mg/kg	<5	**15**	**8**	----	----
Manganese	7439-96-5	5	mg/kg	**16**	**489**	**460**	----	----
Nickel	7440-02-0	2	mg/kg	<2	**34**	**22**	----	----

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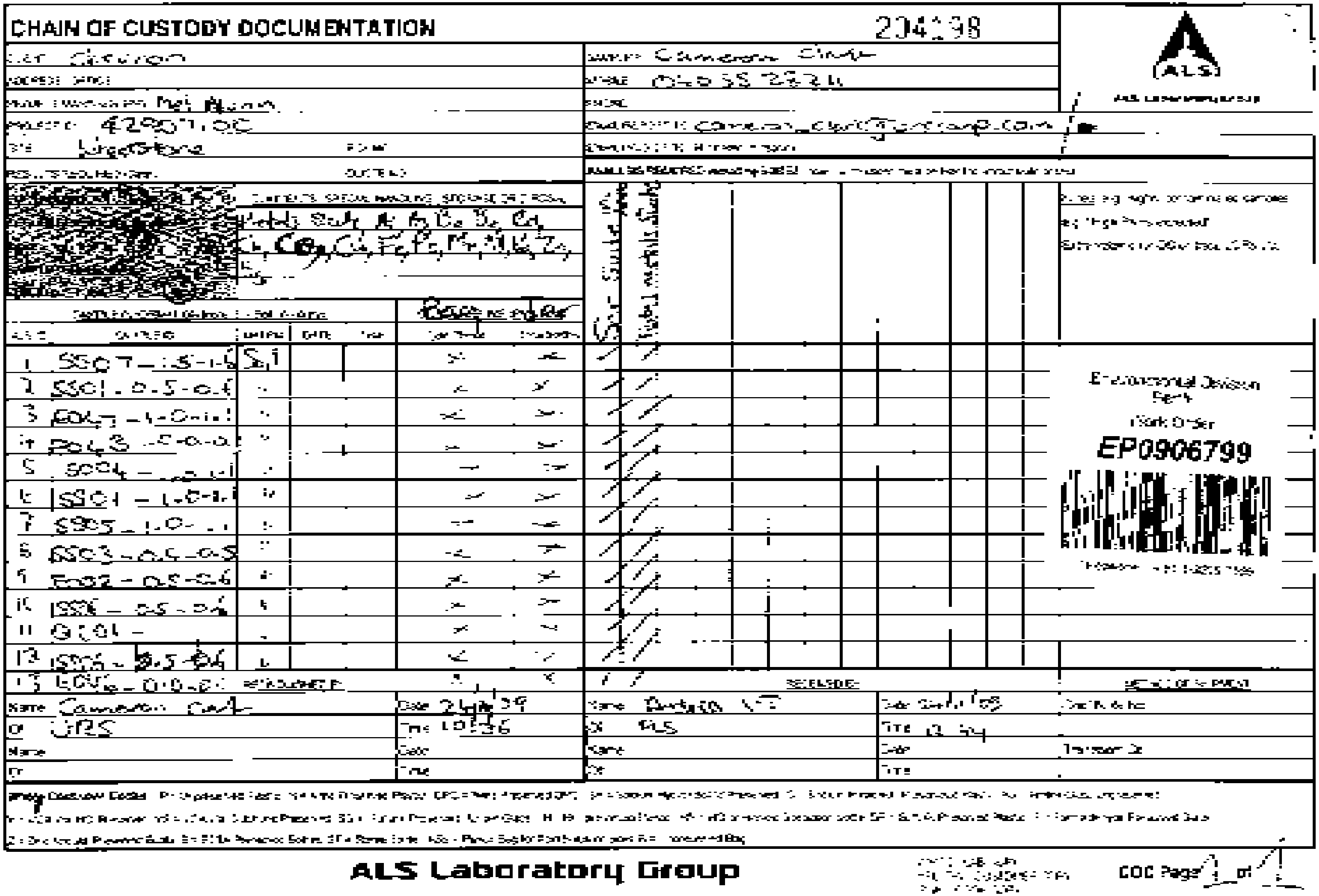
Work Order : EP0906799
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **SOIL**

			Client sample ID	**QC01**	**SS06** **1.5-1.6**	**E046** **0.0-0.1**	----	----
			Client sampling date / time	24-NOV-2009 10:36	24-NOV-2009 10:36	24-NOV-2009 10:36	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0906799-011**	**EP0906799-012**	**EP0906799-013**	**----**	**----**
EG005T: Total Metals by ICP-AES - Continued								
Vanadium	7440-62-2	5	mg/kg	**22**	**67**	**62**	----	----
Zinc	7440-66-6	5	mg/kg	**10**	**60**	**32**	----	----
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	----	----



CHAIN OF CUSTODY DOCUMENTATION

204?98

Client: Chevron

Project Manager: Mel Mann

Project: 42907.06

Site: Wheatstone

Sampler: Cameron Clark

Phone: 0435 528 ...

Email report to: cameron_clark@urscorp.com

ANALYSIS REQUIRED

[redacted]

Metals Soil: Al, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, V, Zn, Hg

Soil Suite ... Metals suite

	SAMPLE ID	MATRIX	DATE	TIME		
1	SS07 - 1.5-1.6	Soil			x	x
2	SS01 - 0.5-0.6				x	x
3	BO47 - 1.0-1.1				x	x
4	BO43 - 0.0-0.1				x	x
5	SS04 -				x	x
6	SS01 - 1.0-1.1				x	x
7	SS05 - 1.0-1.1				x	x
8	SS03 - 0.5-0.5				x	x
9	BO32 - 0.5-0.6				x	x
10	SS06 - 0.5-0.6				x	x
11	GS01 -				x	x
12	SS06 - 0.5-0.6				x	x
13	BO46 - 0.0-0.1				x	x

RELINQUISHED BY

Name: Cameron Clark — Date: 24/06/09

Of: URS — Time: 10:36

Name: — Date:

Of: — Time:

RECEIVED BY

Name: Andrew NT — Date: 24/06/09

Of: ALS — Time: 12:54

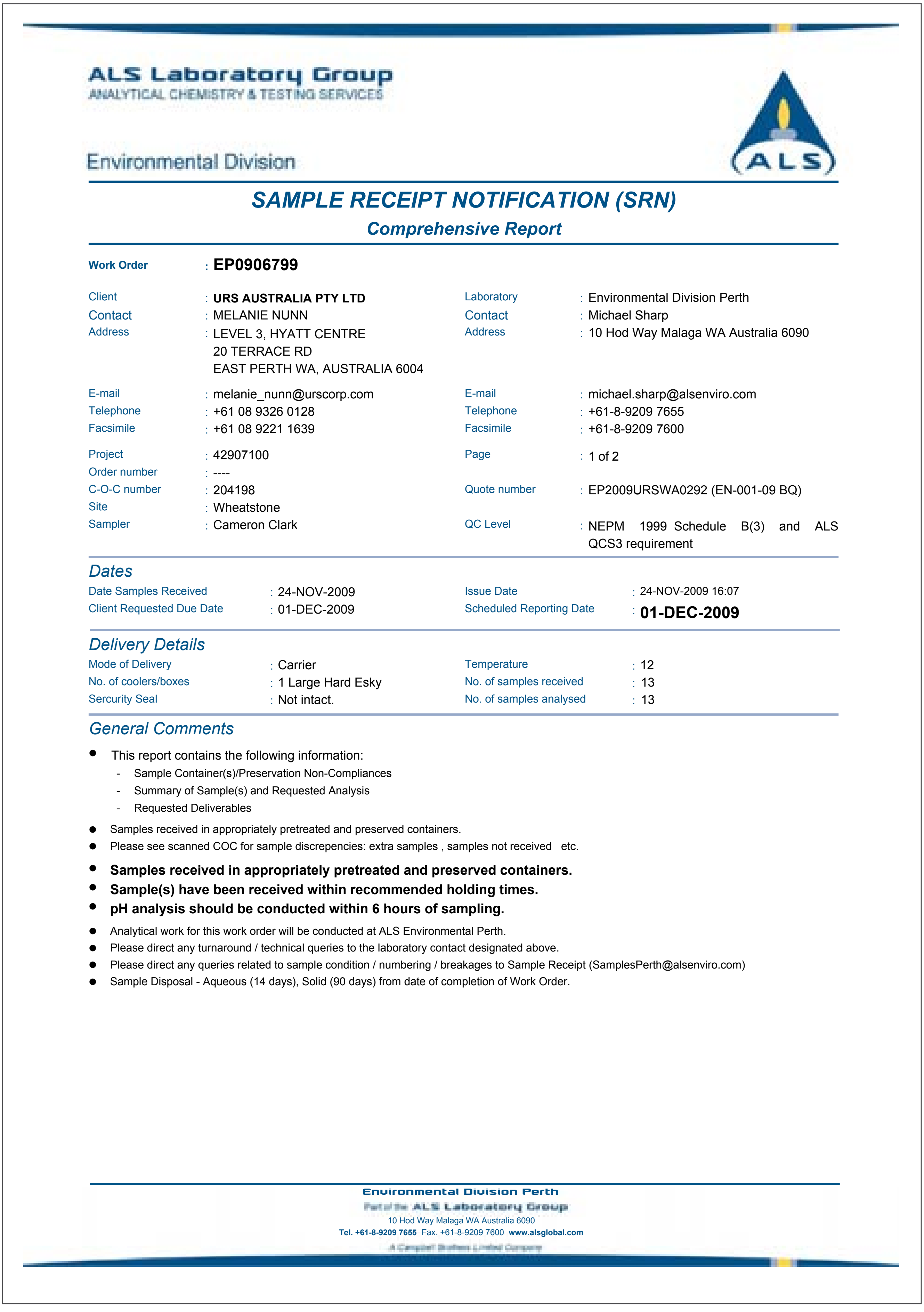
Name: — Date:

Of: — Time:

Environmental Division
Perth
Work Order
EP0906799

ALS Laboratory Group

COC Page 1 of 1



ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

SAMPLE RECEIPT NOTIFICATION (SRN)

Comprehensive Report

Work Order : **EP0906799**

Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MELANIE NUNN	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	: melanie_nunn@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0128	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9221 1639	Facsimile	: +61-8-9209 7600
Project	: 42907100	Page	: 1 of 2
Order number	: ----		
C-O-C number	: 204198	Quote number	: EP2009URSWA0292 (EN-001-09 BQ)
Site	: Wheatstone		
Sampler	: Cameron Clark	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Dates

Date Samples Received	: 24-NOV-2009	Issue Date	: 24-NOV-2009 16:07
Client Requested Due Date	: 01-DEC-2009	Scheduled Reporting Date	: **01-DEC-2009**

Delivery Details

Mode of Delivery	: Carrier	Temperature	: 12
No. of coolers/boxes	: 1 Large Hard Esky	No. of samples received	: 13
Sercurity Seal	: Not intact.	No. of samples analysed	: 13

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Requested Deliverables
- Samples received in appropriately pretreated and preserved containers.
- Please see scanned COC for sample discrepencies: extra samples , samples not received etc.
- **Samples received in appropriately pretreated and preserved containers.**
- **Sample(s) have been received within recommended holding times.**
- **pH analysis should be conducted within 6 hours of sampling.**
- Analytical work for this work order will be conducted at ALS Environmental Perth.
- Please direct any turnaround / technical queries to the laboratory contact designated above.
- Please direct any queries related to sample condition / numbering / breakages to Sample Receipt (SamplesPerth@alsenviro.com)
- Sample Disposal - Aqueous (14 days), Solid (90 days) from date of completion of Work Order.

Environmental Division Perth
Part of the ALS Laboratory Group
10 Hod Way Malaga WA Australia 6090
Tel. +61-8-9209 7655 Fax. +61-8-9209 7600 **www.alsglobal.com**
A Campbell Brothers Limited Company

Issue Date	: 24-NOV-2009 16:07
Page	: 2 of 2
Work Order	: EP0906799
Client	: URS AUSTRALIA PTY LTD

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exist.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process neccessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

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.

Matrix: **SOIL**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	SOIL - EA033-WA WA - Chromium Suite for Acid Sulphate Soils	SOIL - EA055-103 Moisture Content	SOIL - EG005T (solids) Total Metals by ICP-AES	SOIL - EG035T (solids) Total Mercury by FIMS
EP0906799-001	24-NOV-2009 10:36	SS07 1.5-1.6	✓	✓	✓	✓
EP0906799-002	24-NOV-2009 10:36	SS01 0.5-0.6	✓	✓	✓	✓
EP0906799-003	24-NOV-2009 10:36	EO47 1.0-1.1	✓	✓	✓	✓
EP0906799-004	24-NOV-2009 10:36	EO48 0.0-0.1	✓	✓	✓	✓
EP0906799-005	24-NOV-2009 10:36	S004 1.0-1.1	✓	✓	✓	✓
EP0906799-006	24-NOV-2009 10:36	SS01 1.0-1.1	✓	✓	✓	✓
EP0906799-007	24-NOV-2009 10:36	SS05 1.0-1.1	✓	✓	✓	✓
EP0906799-008	24-NOV-2009 10:36	SS03 0.4-0.5	✓	✓	✓	✓
EP0906799-009	24-NOV-2009 10:36	EO52 0.5-0.6	✓	✓	✓	✓
EP0906799-010	24-NOV-2009 10:36	SS06 0.5-0.6	✓	✓	✓	✓
EP0906799-011	24-NOV-2009 10:36	QC01	✓	✓	✓	✓
EP0906799-012	24-NOV-2009 10:36	SS06 1.5-1.6	✓	✓	✓	✓
EP0906799-013	24-NOV-2009 10:36	E046 0.0-0.1	✓	✓	✓	✓

Requested Deliverables

MELANIE NUNN

- *AU Certificate of Analysis - NATA (COA)	Email	melanie_nunn@urscorp.com
- A4 - AU Sample Receipt Notification - Environmental (SRN)	Email	melanie_nunn@urscorp.com
- AU Interpretive QC Report (Anon QCI Not Rep) (QCI_NoAnon)	Email	melanie_nunn@urscorp.com
- AU QC Report (Anon QC Not Rep) - NATA (QC_NoAnon)	Email	melanie_nunn@urscorp.com
- Default - Chain of Custody (COC)	Email	melanie_nunn@urscorp.com
- EDI Format - ENMRG (ENMRG)	Email	melanie_nunn@urscorp.com
- EDI Format - ESDAT (ESDAT)	Email	melanie_nunn@urscorp.com
- EDI Format - MRED (MRED)	Email	melanie_nunn@urscorp.com
- EDI Format - XTab (XTAB)	Email	melanie_nunn@urscorp.com

MR CAMERON CLARK

- *AU Certificate of Analysis - NATA	Email	cameron_clark@urscorp.com
- A4 - AU Sample Receipt Notification - Environmental	Email	cameron_clark@urscorp.com
- AU Interpretive QC Report (Anon QCI Not Rep)	Email	cameron_clark@urscorp.com
- AU QC Report (Anon QC Not Rep) - NATA	Email	cameron_clark@urscorp.com
- Default - Chain of Custody	Email	cameron_clark@urscorp.com
- EDI Format - ENMRG	Email	cameron_clark@urscorp.com
- EDI Format - ESDAT	Email	cameron_clark@urscorp.com
- EDI Format - MRED	Email	cameron_clark@urscorp.com
- EDI Format - XTab	Email	cameron_clark@urscorp.com

THE ACCOUNTS PAYABLE

- A4 - AU Tax Invoice (INV)	Email	Perth_Accounts@urscorp.com

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F

Appendix F Coffey Geotechnical Bore Assessment

PASS Mapping Assessment Criteria

Risk Criteria	Depth in the Soil Profile				Landform		Elevation	Volume of Soil to be Excavated	Field pH Indicators	Soil Type	Sulfide Content
High Risk	Static Water Level mbgl	PASS soils at or below the water table ~1 mbgl			Intertidal Flats, Tidal Creek, Mangrove Swamp and Chenier formations	Description	Generally below 5 mAHD unless soils are below Chenier formation	Large scale (>1000 tonne) excavation/ dredging/dewatering	Generally with a pH(fox)<4.0	CLAY: medium to high plasticity, brown to grey	Above 0.03 %S
Environmental and Hydrogeological Progamme											
site id	swl	depth from	depth to	approximate thickness	Location and type of assessment						
E012	0.79	1.25	2	0.85	Littoral/Onslow Boundary	Occasional salt scalding and black algal mottling	1.46	ASSUMPTION	5.32	SAND, fine grained, dark grey	
					Intertidal Flats, Tidal Creek and Mangrove Swamps	moderately vegetated, broad flat flats with alluvial/colluvial plains to north			2.09	CLAY, dark brown, high plasticity	
					Aerial Photography (Landgate,2007)	Broad flat mud flats, some surface shell evident			2.33	CLAY, dark brown, high plasticity (SPT)	**0.66**
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Tidal creek approximately 80m wide @ low tide, dense mangrove			5.07	CLAY, dark brown, high plasticity	**0.47**
					Ashburton North Area	along eastern side of creek. Light to sparse on western boundary.					
					Groundtruthing (March-June, 2009)	Algal mud flat approx. 1km from mouth of tidal creek					
						salt crusting is only a thin veneer (~1mm) over clay rich sand					
						Approximately 300m to 1000m in width.					
E019	2.12	1.25	1.9	0.65	Onslow	fringing dunes and beach, unstable and mobile sand units	1.34	ASSUMPTION	1.05	CLAY, grey	
					Fringing and Coastal Dunes	Significant surface shell deposition			0.7	CLAY, grey	**1.34**
					Aerial Photography (Landgate,2007)	spit located parallel to ocean and moderately vegetated fringing dune.			0.89	CLAY, grey	
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Spit look temporary from recent storm surge and heavy rainfall events			0.85	CLAY, grey	**1.26**
					Ashburton North Area	Adjacent dunes approximately 3-4 m in height					
					Groundtruthing (March-June, 2009)						
E018	2.69	2.00	2.95	0.95	Onslow	South of coastal dunes, low lying broad plains with sandy surface	2.46	ASSUMPTION	5.3	CLAY, cream brown with yellow mottles	
					Alluvial/Colluvial Plains	No discernible drainge pattern although slight landform gradient toward the north, increasing with proximity to			4.59	CLAY, cream brown with yellow mottles	
					Aerial Photography	coastal dunes.			5.22	CLAY, cream brown with yellow mottles	
					Aerial Photography (Landgate,2007)	moderatley vegetated with spinifex			3.6	CLAY, cream brown with yellow mottles	
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)				3.9	CLAY, cream brown with yellow mottles	**1.26**
					Ashburton North Area						
					Groundtruthing (March-June, 2009)						
E010	2.29	2.00	2.25	0.25	Onslow	Adjacent longitudinal dunes to west and marginal to intertidal flat to east.	2.75	ASSUMPTION	5.9	CLAY, brown to grey	**0.11**
					Alluvial/Colluvial Plains	slope is 1-2 degrees.			6.01	CLAY, brown to grey	
					Aerial Photography (Landgate,2007)	soil surface is not hardset, bleached light brown with some coherence.					
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)						
					Ashburton North Area						
					Groundtruthing (March-June, 2009)						
GEOTECHNICAL BORE REVIEW											
E027	1.9	1.9	2.6	0.7	Bore Log and/or core photo Assessment	Adjacent Supratidal Salt Flats	2.61	ASSUMPTION	not tested	Clay: Yellow - grey. very sticky, soft, mod - high plasticity, minor sand.	not tested
		2.6	3	0.4					not tested	Clayey Sand: Dark grey, fine grained, well sorted, quartz sand, 5 % clay,	not tested
E032	1.56	0.45	1.45	1	Bore Log and/or core photo Assessment	Adjacent Intertidal Flats	2.45	ASSUMPTION	not tested	Sand: Sand - Dark brown. Fine sand with minor silt (1 - 2 %), sub - rounded, well sorted, quartz major, Ironstone minor. Loose - very poorly consolidated. Minor organic content.	not tested
E033	1.96	2.4	4.5	2.1	Bore Log and/or core photo Assessment	Low lying area adjacent samphire flats and coastal dunes	2.59	ASSUMPTION	not tested	CLAY: Dark grey, soft, sticky clay, high plasticity, very high organic conte	not tested
		0.5	1	0.5					not tested	clayey SAND, fine to medium grained sand, loose, brown, moist	not tested
116	not provided	2.9	3.5	0.6	Bore Log and/or core photo Assessment	south of coastal dunes and adjacent intertidal flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, grey (CORE PHOTOS ONLY)	not tested
128	not provided	1.95	2.6	0.65	Bore Log and/or core photo Assessment	south of coastal dunes and adjacent intertidal flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, grey (CORE PHOTOS ONLY)	not tested
129	not provided	1.95	2.2	0.25	Bore Log and/or core photo Assessment	south of coastal dunes and adjacent intertidal flats and samphire flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, grey (CORE PHOTOS ONLY)	not tested
131	not provided	1	2.5	1.5	Bore Log and/or core photo Assessment	adjacent intertidal flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, grey (CORE PHOTOS ONLY)	not tested
217	not provided	3.4	4.5	1.1	Bore Log and/or core photo Assessment	adjacent intertidal flats	2.78	ASSUMPTION	not tested	(CH) SANDY CLAY, high plasticity, grey; with some organic matter, fibrous in pockets; sand is fine; very soft	not tested
302	not provided	4	4.95	0.95	Bore Log and/or core photo Assessment	south of coastal dunes and adjacent samphire flats	not provided	ASSUMPTION	not tested	SILTY CLAY, high plasticity, pale grey; with some gravel, sub-angular to sub-rounded, fine grained; trace of sand; very soft, at 4.20m, becoming dark brown, firm	not tested
312	not provided	1.5	3	1.5	Bore Log and/or core photo Assessment	samphire flats adjacnet intertidal flats		ASSUMPTION	not tested	CLAY/Clayey SAND, dark grey, wet (CORE PHOTOS ONLY)	not tested
402	not provided	0.95	2.2	1.25	Bore Log and/or core photo Assessment	intertidal flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, brown, (CORE PHOTOS ONLY)	not tested
409	not provided	0.95	2.55	1.6	Bore Log and/or core photo Assessment	intertidal flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, brown to dark brown (CORE PHOTOS ONLY)	not tested
410	not provided	0.45	1.3	0.85	Bore Log and/or core photo Assessment	intertidal flats	not provided	ASSUMPTION	not tested	(CL) CLAY, low plasticity, brown; with trace of sand, fine to medium grained, with trace of gravel, fine; very soft	not tested
412	not provided	1.85	2.35	0.55	Bore Log and/or core photo Assessment	fringing coastal dunes adjacent intertidal flats	not provided	ASSUMPTION	not tested	(CL) SANDY CLAY, low to medium plasticity, pale green brown mottled pale blue orange; very stiff, becoming very soft	not tested
		2.35	3.1	0.75					not tested	(SC) CLAYEY SAND, fine to medium grained, green brown; clay is low plasticity, with some gravel, fine to coarse, sub-angular, cemented sand	not tested
		3.1	3.6	0.5					not tested	(CL) SANDY CLAY, low plasticity, dark green / dark brown; sand is fine to medium grained, trace of gravel, fine to medium grained, sub-angular, cemented sand; very soft	not tested
		3.6	3.8	0.2					not tested	(GC) CLAYEY GRAVELLY SAND, fine to medium grained, dark grey; gravel is fine to coarse grained, sub-angular to sub-rounded, cemented sand	not tested
417	not provided	1	1.75	0.75	Bore Log and/or core photo Assessment	adjacent intertidal flats	not provided	ASSUMPTION	not tested	(CL) CLAY, low plasticity, brown mottled dark grey; trace of sand, fine to medium grained, with some silt, trace of organics (roots); very soft to soft	not tested
		1.75	3.35	1.6					not tested	(SC) CLAYEY SAND, fine to medium grained, dark grey mottled brown; with some silt	not tested
		3.35	4	0.65					not tested	CLAYEY SAND, fine to medium grained, dark brown mottled grey	not tested
418	not provided	1.25	1.65	0.4	Bore Log and/or core photo Assessment	adjacent intertidal flats	not provided	ASSUMPTION	not tested	(CL) CLAY, low plasticity, pale blue to pale grey; trace of sand, fine to medium grained; very soft	not tested

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PASS Mapping Assessment Criteria

Risk Criteria	Depth in the Soil Profile				Landform		Elevation	Volume of Soil to be Excavated	Field pH Indicators	Soil Type	Sulfide Content
High Risk	Static Water Level mbgl	PASS soils at or below the water table ~1 mbgl			Intertidal Flats, Tidal Creek, Mangrove Swamp and Chenier formations	Description	Generally below 5 mAHD unless soils are below Chenier formation	Large scale (>1000 tonne) excavation/ dredging/dewatering	Generally with a pH(fox)<4.0	CLAY: medium to high plasticity, brown to grey	Above 0.03 %S
419	not provided	4.4	5	0.5	Bore Log and/or core photo Assessment	Beach adjacent tidal creek	not provided	ASSUMPTION	not tested	(SP) SAND, fine grained, pale grey brown; with trace of gravel, angular, fine shell fragments	not tested
503	not provided	3	4.95	1.95	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	not provided	ASSUMPTION	not tested	(CH) CLAY, high plasticity, grey; organic odour, soft	not tested
504	not provided	2.85	4.5	1.65	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	not provided	ASSUMPTION	not tested	(CH) CLAY, high plasticity, grey; with some sand, fine to medium; firm	not tested
		4.5	5.2	0.7	Bore Log and/or core photo Assessment				not tested	(CH) CLAY, high plasticity, grey brown; with some sand; with some gravel, fine to coarse, sub-angular to sub-rounded, cemented sand; very soft	not tested
505	not provided	2.1	5.5	3.4	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	3.18	ASSUMPTION	not tested	(ML) SILT, blue grey mottled yellow; with some gravel, fine; very soft, gypsum crystals	not tested
506	not provided	2.25	2.7	0.45	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, dark grey (CORE PHOTOS ONLY)	not tested
B-101	not provided	4.2	4.5	0.3	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	not provided	ASSUMPTION	not tested	CLAY, brown (Core Photo Only)	not tested
B-103	not provided	0.45	2	1.55	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	not provided	ASSUMPTION	not tested	CLAY, brown grading black (Core Photo Only)	not tested

PASS Mapping Assessment Criteria

Risk Criteria	**Depth in the Soil Profile**				**Landform**		**Elevation**	**Volume of Soil to be Excavated**	**Field pH Indicators**	**Soil Type**	**Sulfide Content**
Moderate	Static Water Level mbgl	PASS soils (field test identification only) at or below water table ~1 mbgl			Samphire and Supratidal Salt Flats	Description	Below 5 mAHD	None to Incidental (<1000 tonne)	Generally with a pH(fox) <5.5	CLAY/Clayey SAND: Medium to high plasticity, brown to grey	No inorganic sulfide detected by analysis
ENVIRONMENTAL PROGRAMME											
Site ID	swl	depth from	depth to	approximate thickness	Location and type of assessment						
E040	0.35	0.75	1.00	undetermined	Littoral	spinifex and samphire moderately vegetated		ASSUMPTION	5.11	CLAY, low to medium plasticity, grey	non detect
				limit of investigation	Samphire Flats	dry, no evidence of recent flooding or rain events			5.05	CLAY, low to medium plasticity, grey	
				due to coreloss	Aerial Photography (Landgate,2007)	No MBO detected, broad, low lying continuous flat area					
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)						
					Ashburton North Area						
					Groundtruthing (March-June, 2009)						
E040A	0.45	0.75	1.00	undetermined	Littoral	spinifex and samphire moderately vegetated		ASSUMPTION	4.95	CLAY, high plasticity, yellow/grey and red mottling	**non detect**
				limit of investigation	Samphire Flats	dry, no evidence of recent flooding or rain events			4.95	CLAY, high plasticity, yellow/grey and red mottling	
				due to coreloss	Aerial Photography (Landgate,2007)	No MBO detected, broad, low lying continuous flat area				grades to grey	
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)						
					Ashburton North Area						
					Groundtruthing (March-June, 2009)						
E042A	0.45	0.5	1.00	undetermined	Littoral	Moderately to densely populated with samphire.		ASSUMPTION	1.15	CLAY, high plasticity, yellow/grey and red mottling	**non detect**
				limit of investigation	Samphire Flats	some water inundation in adjacent samphire flats			0.75	CLAY, high plasticity, grey with some grey mottling	
				due to coreloss	Aerial Photography (Landgate,2007)	adjacent alluvial/colluvial plains			0.8	CLAY, high plasticity, grey with some grey mottling	
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	low lying, broad plains					
					Ashburton North Area	MBO detected slightly below surface (decomposed organic matter)					
					Groundtruthing (March-June, 2009)						
E042	0.50	0.75	1.00	undetermined	Littoral	Moderately to densely populated with samphire.		ASSUMPTION	5.32	CLAY, high plasticity, red/brown/grey some grey/yellow mottling	**non detect**
				limit of investigation	Samphire Flats	some water inundation in adjacent samphire flats			2.99	CLAY, high plasticity, red/brown/grey some grey/yellow mottling	
				due to coreloss	Aerial Photography (Landgate,2007)	adjacent alluvial/colluvial plains					
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	low lying, broad plains, algal blooms and salt crusting on peripheral of flat					
					Ashburton North Area	MBO detected slightly below surface (decomposed organic matter)					
					Groundtruthing (March-June, 2009)						
E038	0.20	0.25	0.70	undetermined	Littoral	Salt encrusted, broad, flat area, very low lying		ASSUMPTION	5.39	sandy CLAY, fine grained, low plasticity, light brown	**non detect**
				limit of investigation	Supratidal Salt Flats	connected to mangroves, no noticeable historical storm surge			4.95	clayey SAND, fine to medium grained, low plasticity, light brown	
				due to coreloss	Aerial Photography (Landgate,2007)	Black mottling associated with algal mats and potentially MBO			3.77	clayey SAND, fine to medium grained, low plasticity, light brown	
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	No noticeable drainage lines or gradient			2.2	clayey SAND, fine to medium grained, low plasticity, light brown	
					Ashburton North Area						
					Groundtruthing (March-June, 2009)						
E006	1.1	1.50	2.4		Dune	marginal slope to water drainage area on west of dunes area	1.91	ASSUMPTION	4.8	SAND, very fine grained, brown	**non detect**
					Alluvial/Colluvial Plains	slope of site 5 degrees to base of dune			4.33	SAND, very fine grained, brown	
					Aerial Photography (Landgate,2007)	site is flat to 1-3% slope to W-SW			4.9	SAND, very fine grained, brown	
					3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	adjancet dune ~10-12m in height				SAND, very fine grained, brown	
					Ashburton North Area	moderately vegetated with hummock grasses (spinifex)					
					Groundtruthing (March-June, 2009)	soil surface structure amrphous (no structure)					
GEOTECHNICAL BORE REVIEW											
201	not provided	2.85	4	1.15	Bore Log and/or core photo Assessment	samphire flats	2.7	ASSUMPTION	not tested	ORGANIC SAND, fine to medium grained, black; with some fines	not tested
		4	4.5	0.5	Bore Log and/or core photo Assessment				not tested	(CL) CLAY, medium plasticity, grey; with some sand; very soft grading to Clayey SAND	not tested
319	not provided	1	4.5	3.5	Bore Log and/or core photo Assessment	samphire flats	not provided	ASSUMPTION	not tested	Silty CLAY/Clayey SAND, dark grey to black, wet, high organics (CORE PHOTO ONLY)	not tested
224	not provided	2.45	4	1.55	Bore Log and/or core photo Assessment	samphire flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, drak grey grading light grey (CORE PHOTOS ONLY)	not tested
B-109	not provided	2.5	3.5	1	Bore Log and/or core photo Assessment	samphire flats	not provided	ASSUMPTION	not tested	CLAY, dark grey (CORE PHOTOS ONLY)	not tested
B-114	not provided	1.95	3	1.05	Bore Log and/or core photo Assessment	samphire flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, dark brown (CORE PHOTOS ONLY)	not tested
301	not provided	2.75	3	0.25	Bore Log and/or core photo Assessment	samphire flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, dark grey (CORE PHOTOS ONLY)	not tested
303	not provided	2	4	2	Bore Log and/or core photo Assessment	samphire flats	not provided	ASSUMPTION	not tested	CLAY/Clayey SAND, brown, (CORE PHOTOS ONLY)	not tested
318	not provided	2	3	1	Bore Log and/or core photo Assessment	claypan are adjacent samphire flats	not provided	ASSUMPTION	not tested	Silty CLAY/Clayey SAND, dark grey to black, wet, high organics (CORE PHOTO ONLY)	not tested

PASS Mapping Assessment Criteria

Risk Criteria	Depth in the Soil Profile	Landform		Elevation	Volume of Soil to be Excavated	Field pH Indicators		Soil Type	Sulfide Content
Low	Water table not intercepted or below 3 mbgl	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation	Description	Typically above 5 mAHD	None to incidental (<1000 tonne)	pH(f)>7.0	pH(fox)>5.5	Red earths sands/clays	Non-detect
ENVIRONMENTAL PROGRAMME									
Site ID	swl	Landform type and assessment							
E002	not intercepted	Dune	Bare, Claypan, dry, hard cracking -2-5mm	3.76	ASSUMPTION	8.79	9.01	silty sandy CLAY, low plasticity, red brown	non detect
		Claypans	Surrounded by Alluvial/Colluvial-vegetated with spinifex			8.8	9.09	silty sandy CLAY, low plasticity, red brown	
		Aerial Photography (Landgate,2007)	Depressed area			8.81	9.11	silty SAND, red brown	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	circular, discontinuous, 100-200 m radius			8.77	9.08	silty SAND, limestone fragments	
		Ashburton North Area				8.71	9.01	silty SAND, limestone fragments	
		Groundtruthing (March-June, 2009)				8.97	9.1	silty SAND, limestone fragments	
E003	not intercepted	Dune	interdunal swale between dunes.	5.68	ASSUMPTION	8.89	9.07	Sand/Calcaerous SANDSTONE	non detect
		Longitudinal Dunes and Interdunal Swales	undulating topography with slopes of 10-15 degrees			8.77	9.09	Sand/Calcaerous SANDSTONE	
		Aerial Photography (Landgate,2007)	moderately vegetated with spinifex and low shrubs			9.01	9.1	Sand/Calcaerous SANDSTONE	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	calcareous cobbles on surface adjacent site			9	9.1	Sand/Calcaerous SANDSTONE	
		Ashburton North Area	sparse shell			8.8	9.01	Sand/Calcaerous SANDSTONE	
		Groundtruthing (March-June, 2009)				8.89	9.11	Sand/Calcaerous SANDSTONE	
E004	not intercepted	Dune	As above	7.2	ASSUMPTION	8.73	8.86	SAND, light brown	non detect
		Longitudinal Dunes and Interdunal Swales				9.17	9.28	SAND, light brown	
		Aerial Photography (Landgate,2007)				8.72	9.09	SANDSTONE	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)				8.83	9.31	SANDSTONE	
		Ashburton North Area							
		Groundtruthing (March-June, 2009)							
E005	3.08	Dune	interdunal swale between dunes.	3.59	ASSUMPTION	7.03	6.2	silty SAND, red brown, fine to medium grained	non detect
		Longitudinal Dunes and Interdunal Swales	site is marginal to the slope of the ridge, in a basin between two ridges			7.68	6.33	silty SAND, red brown, fine to medium grained	
		Aerial Photography (Landgate,2007)	adjacent plains to the east			7.33	6.42	gravelly SAND, brown, fine to medium grained	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	surface soils is slightly hard set sands.			7.34	6.8	sandy GRAVEL, light grey, fine to medium grained	
		Ashburton North Area				7.62	7.06	silty sandy GRAVEL	
		Groundtruthing (March-June, 2009)				7.69	6.57	silty sandy GRAVEL	
						7.74	7.87	silty sandy GRAVEL	
						7.77	7.7	silty sandy GRAVEL	
						8.15	7.53	sandy silty GRAVEL	
						8.09	7.8	sandy silty GRAVEL	
						8.11	7.63	clayey silty SAND	
E007	2.12	Dune	moderately to densely vegetated with spinifex and other shrubs.	2.68	ASSUMPTION	7.88	7.47	silty Clay, red/brown, high plasticity	non detect
		Alluvial/Colluvial Plains	Elevatation of ~3m greater than adjacent plains and at base of adjacent dunes			7.87	7.6	silty Clay, red/brown, high plasticity	
		Aerial Photography (Landgate,2007)	small dunal ridge (looking south) of ~10m in height			7.89	7.94	silty Clay, red/brown, high plasticity	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Marginal slope to former intertidal flood zone			7.79	8	silty Clay, red/brown, high plasticity	
		Ashburton North Area	downslope is 3-5 degrees (looking north)			7.83	7.92	silty Clay, red/brown, high plasticity	
		Groundtruthing (March-June, 2009)	some trees 1-3 m in height			8.22	8.04	silty Clay, red/brown, high plasticity	
			dry, friable, surface soils. Slightly coherant (no harder than finger pressure)			-	-	Sandstone, well cemented (unable to sample)	
						8.5	8.35	compacted SAND, Qtz major, yellow/brown	
E008	not intercepted	Dune	marginal edge to longitudinal dunes and alluvial/colluvial plain	5.87	ASSUMPTION	7.72	6.3	SAND, red brown	non detect
		Longitudinal Dunes and Interdunal Swales	slope is generally flat to 2 degrees of general surrounds			8.39	6.88	SAND, red brown	
		Aerial Photography (Landgate,2007)	soil surface is loose, fraibel incohernat sand.			8.58	6.33	SAND, red brown	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	moderately vegetated spinifex. Sparse shrubs			8.78	8.85	SAND, red brown	
		Ashburton North Area				8.85	6.47	SAND, red brown	
		Groundtruthing (March-June, 2009)				8.56	6.5	SAND, red brown	
						9.3	6.25	SAND, red brown	
						9.57	6.36	SAND, red brown	
						9.61	6.41	silty SAND, red brown	
						9.54	6.35	silty SAND, red brown	
						9.48	6.64	silty SAND, red brown	
E009	not intercepted	Dune	Interdunal swale, marginal to longitudinal dune	5.89	ASSUMPTION	8.14	6.7	silty SAND red/brown	non detect
		Longitudinal Dunes and Interdunal Swales	sand dune within saddle area. Intertidal area to the north west			8.16	7.04	silty SAND red/brown	
		Aerial Photography (Landgate,2007)	downslope is 3-5 degrees (looking north west)			8.46	6.87	silty SAND red/brown	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	surface soils are very fine -fine (silty sand), friable (light finger pressure)			8.47	6.59	silty SAND red/brown	
		Ashburton North Area	sparse vegetation of hummock grasses and weeds. Very sparse shrubs			8.58	7.12	silty SAND red/brown	
		Groundtruthing (March-June, 2009)	no organised or incised drainage patterns			9.15	6.33	silty SAND red/brown	
			Longitudinal dune network ends toward north east			9.65	8.33	silty SAND red/brown	
						9.47	8.56	silty SAND red/brown	
						9.7	6.71	silty SAND red/brown	
						9.57	6.43	silty SAND red/brown	
						9.29	6.95	silty SAND red/brown	
						9.36	6.66	silty SAND red/brown	
						9.49	7.03	SANDSTONE	
E015	not intercepted	Dune	undulating interdunal swale, soil red, saddle between ridges	4.99	ASSUMPTION	7.62	6.36	SAND, fine grained, well sorted, red/brown	non detect
		Longitudinal Dunes and Interdunal Swales	moderately vegetated with spinifex and saprsely with acacia			7.68	6.46	SAND, fine grained, well sorted, red/brown	
		Aerial Photography (Landgate,2007)	ridges are 6-7 m in height			7.68	6.92	SAND, fine grained, well sorted, red/brown	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	drainge is through soil, no discernible drainage lines			8.07	7.77	SAND, fine grained, well sorted, red/brown	
		Ashburton North Area	sand has no cohesion when disturbed			8.39	7.9	SAND, fine grained, well sorted, red/brown	
		Groundtruthing (March-June, 2009)				8.45	8.46	SAND, fine grained, well sorted, red/brown	
						8.5	7.89	SAND, fine grained, well sorted, red/brown	
						8.56	8.1	SAND, fine grained, well sorted, red/brown	
						-	-	SAND, fine grained, well sorted, red/brown	
						8.48	8.21	SAND, fine grained, well sorted, red/brown	
						8.85	8.12	clayey SAND, red brown	
						9	8.24	clayey SAND, red brown	
						8.78	8.32	clayey SAND, red brown	
E016	not intercepted	Dune	Interdunal swale, site is in a saddle marginal to longitudinal dunes of 2-3 m in h	4.13	ASSUMPTION	6.34	6.3	SAND, red brown	non detect
		Longitudinal Dunes and Interdunal Swales	moderately vegetated with hummock grasses and low shrubs.			6.56	5.86	SAND, red brown	
		Aerial Photography (Landgate,2007)	groundwater not intercepted			-	-	SAND, red brown	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	surface soils are fine, red sands			6.02	6.57	silty SAND, red brown, fine to medium grained	
		Ashburton North Area				6.13	6.58	silty SAND, red brown, fine to medium grained	
		Groundtruthing (March-June, 2009)				7.12	7.22	silty SAND, red brown, fine to medium grained	

PASS Mapping Assessment Criteria

Risk Criteria	Depth in the Soil Profile	Landform		Elevation	Volume of Soil to be Excavated	Field pH Indicators		Soil Type	Sulfide Content
Low	Water table not intercepted or below 3 mbgl	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation	Description	Typically above 5 mAHD	None to incidental (<1000 tonne)	pH(f)>7.0	pH(fox)>5.5	Red earths sands/clays	Non-detect
						6.88	7.08	silty SAND, red brown, fine to medium grained	
						7.85	7.45	silty SAND, red brown, fine to medium grained	
						7.85	7.26	silty SAND, red brown, fine to medium grained	
						7.83	8.08	silty SAND, red brown, fine to medium grained	
						7.93	8.53	silty SAND, red brown, fine to medium grained	
						8.16	8.19	silty SAND, red brown, fine to medium grained	
						8.02	8.09	silty SAND, red brown, fine to medium grained	
E017	1.07	Onslow	Broad relatively flat plain, slightly undulating (adjacent longitudinal dunes)	1.67	ASSUMPTION	6.63	5.4	clayey SAND, red/brown	non detect
		Alluvial/Colluvial Plains	Moderately to densely populated with spinifex and other species			7.53	6.64	clayey SAND, red/brown	
		Aerial Photography (Landgate,2007)	shallow groundwater encountered.			7.27	7.88	sandy CLAY, red/brown	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)				6.67	6.65	clayey sandy GRAVEL	
		Ashburton North Area				7.17	7.22	sandy clayey GRAVEL	
		Groundtruthing (March-June, 2009)				7.29	7.1	sandy clayey GRAVEL	
						7.3	7.64	silty SAND	
E036	not intercepted	Littoral	very flat, broad, moderately to densely vegetated (~0.5m in height) broad sand	not determined	ASSUMPTION	6.28	6.6	silty SAND, very fine grained, tight, red/brown	non detect
		Alluvial/Colluvial Plains	Mainland remnant dunes visible to north, no surface salt scalding			6.21	6.61	silty SAND, very fine grained, tight, red/brown	
		Ashburton North Area							
		Groundtruthing (March-June, 2009)							
E037	not intercepted	Alluvial/Colluvial Plains	Base of mainland remnant dunal. Slight gradient of about 5-10 degrees	not determined	ASSUMPTION	6.29	6.61	silty SAND, very fine grained, tight, red/brown	non detect
		Aerial Photography (Landgate,2007)	vegetation dense (0.5-1.0 m in height), surface silty sand, with no scalding			6.27	6.6	silty SAND, very fine grained, tight, red/brown	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)							
E039	not intercepted	Alluvial/Colluvial Plains	vegetation dense (0.5-1.0 m in height), surface silty sand, with no scalding	not determined	ASSUMPTION	6.65	6.91	silty SAND, red brown, fine to medium grained	non detect
		Aerial Photography (Landgate,2007)	Located on "island" adjacent supratidal salt flats			6.71	6.89	silty SAND, red brown, fine to medium grained	
		3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)							
GEOTECHNICAL BORE REVIEW									
E011	0.86	Bore Log and/or core photo Assessment	Beach	1.5	ASSUMPTION	not tested	not tested		no
E013	1	Bore Log and/or core photo Assessment	Beach	1.79	ASSUMPTION	not tested	not tested		no
E020	not provided	Bore Log and/or core photo Assessment	Beach	not provided	ASSUMPTION	not tested	not tested	SILTY SAND: Light orange brown loose sand with 5% minor silt, fine to medium grained sand, sub rounded, moderately sorted, quartz major with ironstone, sandstone grains, several 3-5mm shell fragments, large (20mm) pieces of dolerite	no
E021	1	Bore Log and/or core photo Assessment	Beach	1.64	ASSUMPTION	not tested	not tested		no
E014	2.73	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta	3.31	ASSUMPTION	not tested	not tested	SAND: Silty, red-brown, well sorted, subrounded, mainly quartz.	no
E022	not provided	Bore Log and/or core photo Assessment	Plant and surrounds	not provided	ASSUMPTION	not tested	not tested		
E023	4.86	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta, West of Bechtel Plot Pl	4.66	ASSUMPTION	not tested	not tested	SAND: Clayey with gravel, some shell fragments, red, brown, soft, well sorted, well rounded, mostly quartz, mica, increasingly compact and filled with more clay content.	no
E024	not provided	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta	not provided	ASSUMPTION	not tested	not tested	GRAVELLY CLAY: Same fine grained sand, 30% gravel ± 20mm. Sun angular to angular, low to moderate plasticity, loose to medium to tight, red, brown.	no
E025	6.75	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta	7.47	ASSUMPTION	not tested	not tested	SAND: Red sand, fine grained, siliceous, well sorted, mature.	no
E026	4.68	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta	4.25	ASSUMPTION	not tested	not tested	SAND: Siliceous, red brown, approximately 90% fine grained sand with minor silt (approximately 10%). Well sorted, sub-rounded quartz grains dominant with minor organic material. Minor gravel at 3 m	no
E028	not provided	Bore Log and/or core photo Assessment	Longitdunal Dune Network	3.95	ASSUMPTION	not tested	not tested	SANDY CLAY: Fine to medium grained, loose, red, brown, low plasticity, loose to moderately tight.	no
E029	not provided	Bore Log and/or core photo Assessment	Longitdunal Dune Network	1.88	ASSUMPTION	not tested	not tested	SAND: Siliceous, red brown, approximately 90% fine grained sand with minor silt (approximately 10%). Well sorted, sub-rounded quartz grains dominant with minor organic material.	no
E030	not provided	Bore Log and/or core photo Assessment	Longitdunal Dune Network	8.8	ASSUMPTION	not tested	not tested	SAND: Red brown, well sorted, fine grained with cemented pebbles.	no
E031	2.06	Bore Log and/or core photo Assessment	Longitdunal Dune Network	2.91	ASSUMPTION	not tested	not tested	SAND: Clayey sand; brown- yellow (around 50 % clay) siliceous. SAND: Siliceous; red - brown, qtz - rich, moderately sorted, medium grained, sub - rounded grains. Minor clay content.	no
130	not provided	Bore Log and/or core photo Assessment	CUCA Condensate Tank	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
202	not provided	Bore Log and/or core photo Assessment	Train 2	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
204	not provided	Bore Log and/or core photo Assessment	Train 2	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
212	not provided	Bore Log and/or core photo Assessment	Train 1	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
225	not provided	Bore Log and/or core photo Assessment	Train2 - CUCA	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
226	not provided	Bore Log and/or core photo Assessment	Train 2 - CUCA	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
231	not provided	Bore Log and/or core photo Assessment	Train 2 - CUCA	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
232	not provided	Bore Log and/or core photo Assessment	Train 2 - CUCA	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
233	not provided	Bore Log and/or core photo Assessment	Train 2 - CUCA	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
305	not provided	Bore Log and/or core photo Assessment	P/R (Marine Flare)	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
306	not provided	Bore Log and/or core photo Assessment	Dom Gas	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
309	not provided	Bore Log and/or core photo Assessment	Dom Gas	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
316	not provided	Bore Log and/or core photo Assessment	P/R (Cryog. Line)	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
320	not provided	Bore Log and/or core photo Assessment	DomGas - CUCA	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
325	not provided	Bore Log and/or core photo Assessment	Slug-Catcher- CUCA	2.7	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
328	not provided	Bore Log and/or core photo Assessment	Slug-Catcher- CUCA	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
413	not provided	Bore Log and/or core photo Assessment	Onshore MOF	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no

PASS Mapping Assessment Criteria

Risk Criteria	Depth in the Soil Profile	Landform		Elevation	Volume of Soil to be Excavated	Field pH Indicators		Soil Type	Sulfide Content
Low	Water table not intercepted or below 3 mbgl	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation	Description	Typically above 5 mAHD	None to incidental (<1000 tonne)	pH(f)>7.0	pH(fox)>5.5	Red earths sands/clays	Non-detect
501	not provided	Bore Log and/or core photo Assessment	Levee @ 400 m (Shoreline Buffer)	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
502	not provided	Bore Log and/or core photo Assessment	Levee @ 400 m (Shoreline Buffer)	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
802	not provided	Bore Log and/or core photo Assessment	Roadway	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
B-107	not provided	Bore Log and/or core photo Assessment	West of Bechtel Plot Plan	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
B-128	not provided	Bore Log and/or core photo Assessment	West of Bechtel Plot Plan	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
B-131	not provided	Bore Log and/or core photo Assessment	West of Bechtel Plot Plan	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no
B-142	not provided	Bore Log and/or core photo Assessment	East of Bechtel Plot Plan	not provided	ASSUMPTION	not tested	not tested	visual interpretation of core logs	no

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No Information Available									**PASS Assessment Criteria**		
OID	**SiteID**	**OldSite**	**Type**	**Depths**	**PropEast**	**PropNorth**	**Chevron Location**	**PASS Detected**	**Log/Core Photo Assessment**	**PASS Field Test Confirmation**	**PASS Detected by Scr**
58	101		Bore Site	40	294013	7600327	LNG Tanks				
59	103		Bore Site	80	294052	7600303	LNG Tanks				
60	105		Bore Site	60	294090	7600280	LNG Tanks				
61	106		Bore Site	40	293946	7600188	LNG Tanks				
62	108		Bore Site	80	293983	7600167	LNG Tanks				
63	110		Bore Site	40	294019	7600146	LNG Tanks				
64	110A		Bore Site	10	294019	7600146	LNG Tanks				
65	111		Bore Site	40	293854	7600048	Condensate Tanks				
66	112		Bore Site	60	293894	7600018	Condensate Tanks				
67	115		Bore Site	40	293841	7599935	Condensate Tanks				
70	119		Bore Site	40	293971	7599918	Condensate Tanks	-		-	-
78	208		Bore Site	30	293188	7599676	Train 2	-	-	-	-
79	209		Bore Site	30	293292	7599579	Train 2	-	-	-	-
80	210		Bore Site	30	293358	7599577	Train 2	-	-	-	-
81	211		Bore Site	30	293242	7599740	Train 1	-	-	-	-
83	213		Bore Site	30	293464	7599597	Train 1	-	-	-	-
85	219		Bore Site	30	293411	7599777	Train 1	-		-	-
86	220		Bore Site	30	293466	7599779	Train 1	-		-	-
99	310		Bore Site	30	293533	7599447	Des. Facility	location not valid	-	-	-
101	314		Bore Site	30	293836	7600152	P/R (Cryog. Line)	-	-	-	-
103	317		Bore Site	40	294135	7600677	P/R (Cryog. Line)	-	-	-	-
107	321		Bore Site	30	293864	7599537	DomGas - CUCA	-	-	-	-
108	322		Bore Site	30	293998	7599481	DomGas - CUCA	-	-	-	-
112	403		Bore Site	20	293775	7599391	Heavy Haul Rd.	-			
113	405		Bore Site	20	293979	7599617	Heavy Haul Rd.	-			
114	407		Bore Site	20	294149	7599900	Heavy Haul Rd.	-			
115	408		Bore Site	35	294311	7599964	Onshore MOF	-			
120	415		Bore Site	35	294528	7599861	Onshore MOF	-			
172	B-123		Bore Site	30	292927.2927	7598948.523	West of Bechtel Plot Plan				
	514		Bore Site								
	506		Bore Site								
	507		Bore Site								
	508		Bore Site								
	510		Bore Site								

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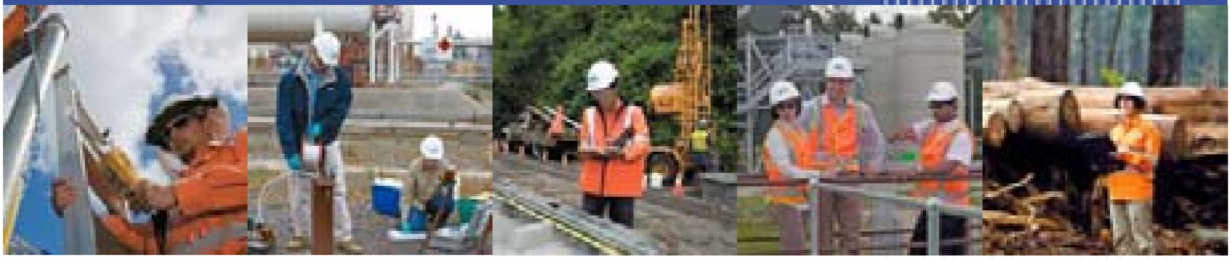

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Appendix I1

A Vegetation and Flora Survey of the Wheatstone Project Area, near Onslow

Tables

Figures

Plates

Plates (cont'd)

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Biota
Environmental
Sciences

A Vegetation and Flora Survey of the Wheatstone Study Area, near Onslow

Prepared for URS Australia Pty Ltd
on behalf of Chevron Australia Pty Ltd

February 2010

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1.0 Summary

1.1 Background to the Study

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and a domestic gas (Domgas) plant 12 km southwest of Onslow on the Pilbara coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future yet-to-be determined gas fields. The project is referred to as the Wheatstone Project and 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). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

This document describes a vegetation and flora survey of the Wheatstone study area, which was conducted by Biota Environmental Sciences Pty Ltd (Biota) in March and April 2009. It also incorporates data from other surveys which overlap the study area, including the northern section of the Wheatstone plant study area (Onshore Environmental Consultants (OEC) 2008, 2009a and 2009b; RPS Environment and Planning (RPS) 2009), the southern section of the Wheatstone plant study area (Astron Environmental Services (Astron) 2009), and the Wheatstone camp and shared infrastructure corridor (SIC) study area (Astron 2009, OEC 2009b, RPS 2009).

1.2 Vegetation of the Wheatstone Study Area

The current survey work combined with the work of OEC (2008 and 2009a) identified 25 vegetation sub-associations[1] as occurring in the Wheatstone study area.

None of the vegetation sub-associations identified are Threatened or Priority Ecological Communities (TECs or PECs) listed by the Western Australian Department of Environment and Conservation (DEC). Although not formally listed, five units of elevated conservation significance were identified for the Wheatstone study area:

- The inland sand dune vegetation sub-associations (**ID1: GsCRcTRzTe** and **ID2: GsCRcHBbTsTe**) were considered to be of High conservation significance, as they potentially support Priority flora (*Eremophila forrestii* subsp. *viridis* and *Triumfetta echinata*), as well as other species of interest (*Aenictophyton* aff. *reconditum*). The dune features would also be particularly susceptible to erosion and weed invasion following disturbance of the soil profile.
- The samphire shrublands (**C3: TECspp**) were of High conservation significance as they may contain a number of poorly recognised samphire species, and it is therefore difficult to determine their distribution in the region. This vegetation also supported the significant flora species *Eleocharis papillosa* (see below) within the Wheatstone pipeline study area.
- The cracking clay grasslands (**CP1: SPmERIbEUa**) were considered to be of Moderate conservation value, being generally in Very Good condition and supporting a suite of species specific to this substrate.
- Mangal is generally recognised as being of conservation significance, particularly along the Pilbara coast where large stands are threatened by mining and other developments.

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[1] Vegetation communities defined by dominant growth form, height, cover and up to 5 species for all layers/sub-strata as per the National Vegetation Information System (NVIS): http://www.environment.gov.au/erin/nvis/publications/avam/pubs/vegetation-attribute-manual-6.pdf.

Mangal was represented by the mangrove scrub along tidal creeks (**T2: AVm**) unit. This vegetation was in Excellent condition, and considered to be of Moderate conservation significance.

The remainder of the vegetation sub-associations were considered relatively representative of those occurring in the locality, or were substantially degraded by invasion of Buffel Grass (**Cenchrus ciliaris*[2]), and were therefore considered to be of Low conservation significance. This is not meant to imply that they have no conservation value, but simply that they are of lower conservation significance than the units highlighted above.

1.3 Flora of the Wheatstone Study Area

A total of 418 taxa of native vascular plants from 162 genera belonging to 58 families has been recorded from the Wheatstone study area through the survey work to date, along with 12 weed species.

One species listed as "Vulnerable" under the Commonwealth *EPBC Act 1999* was recorded from the Wheatstone pipeline study area during the 2009 field surveys:

- Dwarf Desert Spike-rush (*Eleocharis papillosa*) was recorded from a tidal creek, ~800 m southwest of the Peedamulla Station turn-off along the Onslow Road. This record represents a considerable range extension for this species within Western Australia, with the nearest other known population 430 km east-southeast in the Pilbara.

No other species listed under the *EPBC Act 1999* have been previously recorded from the Onslow locality or are expected to occur in the habitats present.

No Declared Rare Flora (DRF) species were recorded from the Wheatstone study area or would be expected to occur.

Five Priority flora species listed by the DEC were recorded:

- *Abutilon uncinatum* ms. (Priority 1) was recorded from a single location towards the western end of the Wheatstone pipeline study area. This prostrate low shrub species is now known to occur over a range of approximately 65 km in the northwestern corner of the Pilbara bioregion, with one other record in the Carnarvon bioregion, 90 km south of the most southern Pilbara record.
- *Atriplex flabelliformis* (Priority 3) was recorded by Astron (2009) from five locations in the southern Wheatstone plant study area, associated with samphire and grassland vegetation on clayey plains (vegetation units TECspp and SPmERIbEUa). This represents a very substantial range extension for this species, with the nearest known population some 430 km east-southeast in the Fortescue Marsh.
- *Eleocharis papillosa* (Priority 3); see discussion above.
- *Eremophila forrestii* subsp. *viridis* (Priority 3) was recorded from three sand dunes located in the northern section of the Wheatstone plant study area, the eastern section of the Wheatstone shared infrastructure corridor (SIC) study area, and the western end of the Wheatstone pipeline study area. This species is known from at least three additional locations within 7 km of the study area. Mr. Andrew Brown (DEC Kensington, pers. comm. 2009) has advised that he suspects this taxon is relatively restricted to the Onslow locality.
- *Triumfetta echinata* (Priority 3) was collected from a single location on a sand dune in the central Wheatstone plant study area by OEC (2009a) and recorded more broadly in the vicinity by OEC (2009b). It was recorded from three additional dunes during the current survey work; one each within the southern section of the Wheatstone camp study area, the

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[2] Note that an asterisk (*) prior to the genus name has been used to denote introduced species throughout this document.

eastern section of the SIC study area, and the western section of the Wheatstone pipeline study area. *T. echinata* has been recorded from a number of other locations in the Onslow area, including west of the Onslow Road at approximately 2.75 km north of the Minderoo Station turnoff (Biota unpublished data), east of the Onslow Road at approximately 6 and 10 km south of the Minderoo Station turnoff (RPS 2009), as well as at additional locations (see OEC 2009a). It appears that this species is relatively widespread through the locality, however t is not common and is restricted to red sand dunes.

While not formally listed, numerous other taxa were considered to be of conservation interest for various reasons (e.g. they represent apparently new (undescribed) taxa, are poorly collected, or the record represents a considerable range extension; see Section 6.2.5). These included:

- The undescribed pea *Aenictophyton* aff. *reconditum* appears to be restricted to sand dune habitats in the Onslow locality. This taxon was recorded by OEC (2009a) from a dune in the northern Wheatstone plant study area, and was recorded during the current surveys from two dunes at the eastern end of the Wheatstone SIC study area and the western end of the Wheatstone pipeline study area. It is known from at least eight additional locations within 10 km of the study area.
- Another undescribed pea, *Vigna* sp. Hamersley clay (A.A. Mitchell PRP 113), was recorded from numerous locations on the sandy coastal plains of the Wheatstone plant study area. This taxon appears to have a broad distribution through the Pilbara.
- Other species of interest, including potentially new taxa in the genera *Tecticornia, Abutilon* and *Bonamia*.

Twelve introduced (weed) species were recorded from the Wheatstone study area, three of which (Parkinsonia and two species of Mesquite) are Declared Plants under the *Agriculture and Related Resources Protection Act 1976* (see Table 1.1).

Table 1.1: Weed species recorded from the Wheatstone study area.

Family	Species	Broad Distribution in the Study Area
Caesalpiniaceae	**Parkinsonia aculeata* (Parkinsonia)	Uncommon; two records from creekline near southern boundary of Wheatstone plant study area
Mimosaceae	**Prosopis pallida* / **P. glandulosa* (Mesquite)	Widespread; particularly common through the Wheatstone camp and SIC study area, but also scattered through the Wheatstone plant study area
	**Vachellia farnesiana* (Mimosa Bush)	Widespread; particularly common through the Wheatstone camp and SIC study area, but also scattered through the Wheatstone plant study area
Poaceae	**Cenchrus ciliaris* (Buffel Grass)	Widespread; particularly abundant within the Wheatstone camp and SIC study area, and along disturbed areas and sand dunes within the Wheatstone plant study area; scattered through the Wheatstone pipeline study area, mainly along road verges
	**Cenchrus setiger* (Birdwood Grass)	Widespread; distributed through the same areas as *C. *ciliaris*, but much less abundant
	**Setaria verticillata* (Whorled Pigeon Grass)	Uncommon; two records from the northern Wheatstone plant study area
Amaranthaceae	**Aerva javanica* (Kapok Bush)	Uncommon; recorded from a Telstra Radio Station facility along the Wheatstone pipeline study area; described as present in "disturbed habitats" in the Wheatstone plant study area by OEC (2008), but only one location provided
Cucurbitaceae	**Cucumis melo* subsp. *agrestis* (Ulcardo melon)	Infrequent; recorded from clayey substrates in the Wheatstone camp and SIC study area

Family	**Species**	**Broad Distribution in the Study Area**
Malvaceae	**Malvastrum americanum* (Spiked Malvastrum)	Infrequent; recorded mainly from clayey substrates in the Wheatstone camp study area, with one record from the southern Wheatstone plant study area; described as a "minor component of the flora" of the Wheatstone plant study area by OEC (2008), but no coordinates provided
Passifloraceae	**Passiflora foetida* var. *hispida* (Stinking Passion Flower)	Uncommon; two records in creek system in southern section of the Wheatstone plant study area
Portulacaceae	**Portulaca oleracea* (Purslane)	Widespread; scattered through the southern Wheatstone plant study area, Wheatstone camp study area and Wheatstone pipeline study area (particularly at the eastern end)

2.0 Background to the Study

2.1 Description of the Wheatstone Project

Chevron proposes to construct and operate a multi-train LNG and Domgas plant 12 km southwest 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 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 MTPA of LNG.

The Wheatstone Project has been referred to the State EPA and the Commonwealth DEWHA. The investigations outlined in this report have been conducted to support the environmental impact assessment process.

2.2 The Biological Study Area

Biota was commissioned to carry out a biological survey of the Wheatstone study area in April 2009 (the fauna survey is reported on in Biota (2009)). The site in question is situated in a Pilbara coastal setting, between the Onslow Solar Salt Field and the mouth of the Ashburton River. The study area, henceforth referred to as the Wheatstone study area, has three components (see Figure 2.1):

1. an area to encompass the LNG and Domgas plant site, located on the coastal plain ("the Wheatstone plant study area"; approximately 3,885 ha);
2. an area for a proposed accommodation camp, along with an associated shared infrastructure corridor (SIC) extending from the Wheatstone plant study area, along the northern edge of the camp area to the Onslow Road ("the Wheatstone camp and SIC study area"; approximately 1,685 ha); and
3. a corridor for a gas pipeline, extending from the eastern end of the shared infrastructure corridor and paralleling the Onslow Road inland for 53 km to the southeast ("the Wheatstone pipeline study area"; approximately 4,224 ha).

Note that only a portion of the area of each of these study components will be required for the actual development footprint. The remainder of the study areas is to allow for flexibility in siting of the infrastructure and to provide regional context information.

2.3 Scope and Objectives of this Study

The botanical survey of the Wheatstone study area was planned and implemented as far as practicable[3] according to the Environmental Protection Authority (EPA) Position Statement No. 3 "Terrestrial Biological Surveys as an Element of Biodiversity Protection" (EPA 2002) and Guidance Statement No. 51 "Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia" (EPA 2004).

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[3] No seasonal sampling of the southern section of the Wheatstone plant study area, nor of the Wheatstone camp and pipeline study areas, was possible in the timeframe.

The scope of the botanical survey was to:

- describe and map the vegetation types occurring within the study area at the association level or lower (as defined by the NVIS); go to http://www.environment.gov.au/erin/nvis/publications/avam/pubs/vegetation-attribute-manual-6.pdf);
- identify any vegetation types of particular conservation significance;
- document the suite of flora species occurring within the study area; and
- identify any species of particular conservation significance, including DRF, Priority flora and other flora of interest.

This report describes the methodology employed for this study and documents the findings of the field surveys. It is intended for use as a supporting document to the Environmental Review and Management Programme (ERMP) to be prepared for the proposed project. The survey itself and this document are subject to certain limitations, as outlined in Section 3.9.

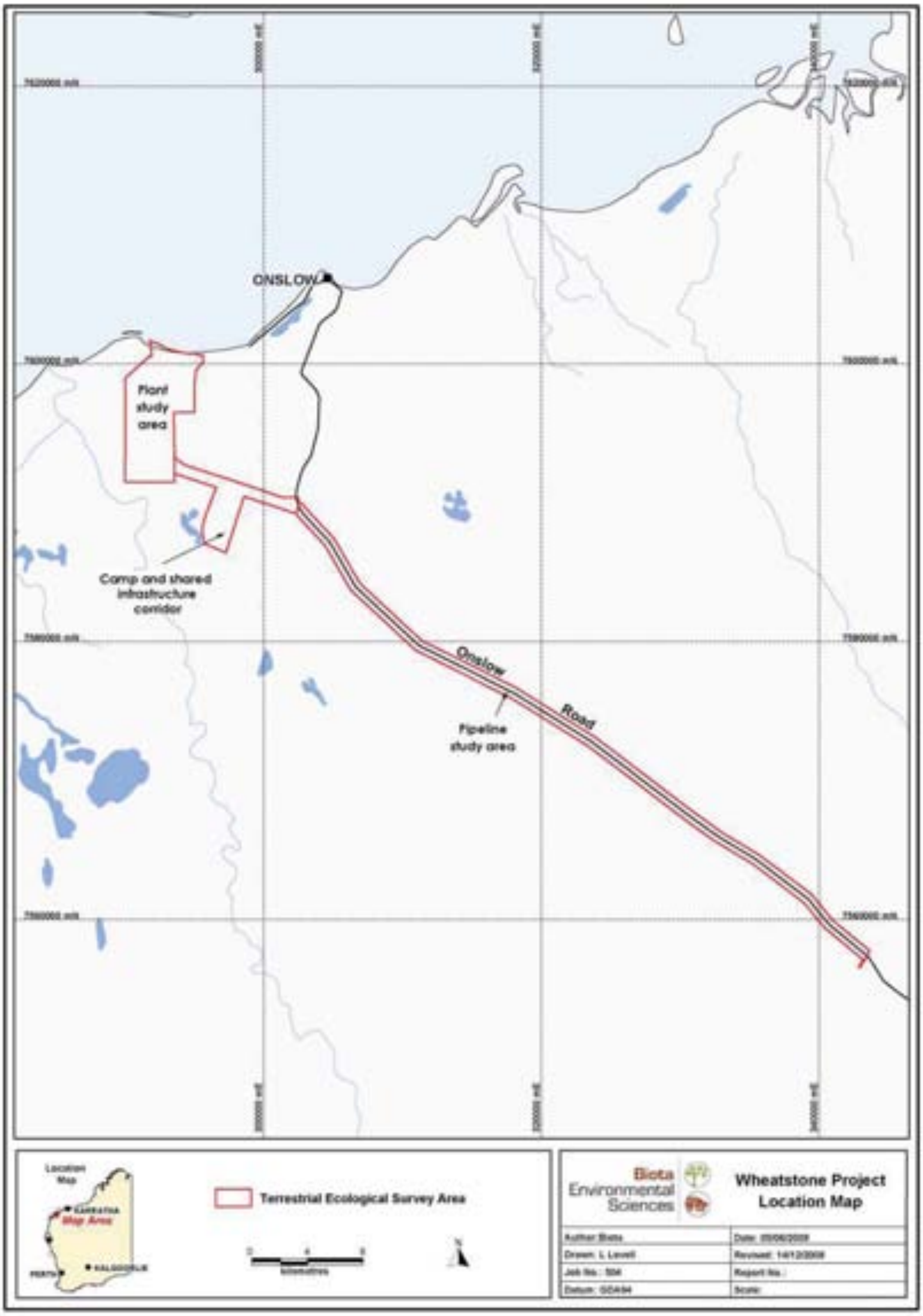

Figure 2.1: **Location and components of the Wheatstone study area.**

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3.0 Methodology

3.1 Desktop Assessment and Review

3.1.1 Database Searches

The database of matters of national environmental significance (NES) protected under the Commonwealth *EPBC Act 1999* was searched using the "Protected Matters Search Tool" on the 12th of May 2009. The search area comprised a broad (approximately 150 km^2 area) surrounding Onslow.

Listed matters of NES relevant to the current study essentially comprise listed threatened species and communities. The results of the Protected Matters search are discussed in the appropriate subsections of Sections 4.5 and 4.6.

Searches of the Western Australian DEC and Western Australian Herbarium rare flora databases had been undertaken by OEC in 2008 and were therefore not requested again for the current study. The species identified by this search (as stated in OEC (2009a)) were reviewed against the habitats present in the Wheatstone study area to indicate species likely to occur in the area (see Sections 4.6.2 and 4.6.3).

3.1.2 Review of Published and Unpublished Information

3.1.2.1 Previous Sampling within the Wheatstone Study Area

Botanists from OEC conducted an initial flora and vegetation survey of a 460 ha area encompassing the northernmost section of the Wheatstone plant study area in July 2008 (OEC 2008). This was followed by a 10 day survey of a 2,200 ha area encompassing adjacent areas to the south, which was completed by three botanists from OEC (including Mr Darren Brearley and Mr Jerome Bull) between the 12th and 21st of November 2008 (OEC 2009a). This survey work included:

- description and mapping of 18 vegetation sub-associations within three broad landform groups (coastal fringe, undulating inland plain and saline flats);
- assessment of 280 standard 50 m by 50 m floristic survey quadrats, which were regularly spaced at ~300 m intervals throughout the study area; and
- extensive systematic foot traverses through the area to ground-truth vegetation unit boundaries and to search for flora of conservation significance.

Additional targeted rare flora searches were conducted by OEC (2009b) for a geotechnical test drilling programme, including proposed tracks and drill pads within the northern Wheatstone plant study area and the Wheatstone camp and SIC study area.

In November 2008, botanists from RPS described and mapped vegetation types and assessed standard floristic survey quadrats along an alternate pipeline corridor (the "Ashburton North Pipeline Route Option 3"), extending from within the Wheatstone plant study area to broadly parallel the Onslow Road (see RPS 2009). Four of the quadrats assessed lie within the Wheatstone study area; two within the northern section of the Wheatstone plant study area (P301 and P303) and two within the Wheatstone SIC study area (P304 and P319).

In August and November 2008, botanists from Astron surveyed a proposed rail corridor to Onslow on behalf of API Management Pty Ltd (see Astron 2009). The westernmost section of this corridor overlapped the current study area, with nine standard floristic survey quadrats assessed within the southern section of the Wheatstone plant study area (4API01-4API04, 4API06 and Q43-Q46), and seven quadrats assessed inside (or within 50 m of) the Wheatstone SIC study area (4API05, 4API07, 4API15, Q42 and Q47-Q54).

The flora species documented in OEC (2008, 2009a and 2009b), along with the data from the 20 additional quadrats assessed in the study area through other survey work (i.e. the four quadrats in RPS (2009) and the 16 quadrats in Astron (2009)), were imported into the Biota Vegetation Database (see Section 3.6). The species lists were reviewed and updated as necessary to reflect current nomenclature as advised by the WA Herbarium.

3.1.2.2 Previous Sampling in the Locality

Various botanical surveys have been completed in the broader Onslow locality. Apart from the surveys mentioned in Section 3.1.2.1 which extended beyond the immediate Wheatstone study area (i.e. Astron 2009 and RPS 2009), the studies listed below comprised the main comparative references used to place the vegetation and flora values of the Wheatstone study area in a regional context:

- a vegetation and flora survey of two previously considered sites for the Chevron Domgas plant, and a pipeline corridor linking them (the southern end of this study area being approximately 2 km north of the Wheatstone study area; Validus Group (Validus) 2008);
- a two-phase flora and vegetation survey of the BHP Scarborough LNG Development (on the coast approximately 6 km east of Wheatstone; Biota unpublished data);
- a flora and vegetation survey of the Onslow Industrial Area single-phase (adjoining the BHP Scarborough LNG Development on the inland edge; Biota 2006a); and
- a two-phase flora and vegetation survey of the Yannarie Salt Project (on the eastern side of the Exmouth Gulf, approximately 70 km southwest of Wheatstone; Biota 2005).

3.1.2.3 Regional-scale Information

Various regional-scale reports and datasets were reviewed to indicate botanical factors of relevance to the current study area, including features of the Interim Biogeographic Regionalisation for Australia (IBRA) bioregions and subregions (see May and McKenzie 2003; Section 4.1), land systems (van Vreeswyk et al. 2004; Payne et al. 1987, 1988; Section 4.3), Beard's vegetation mapping (Section 4.4), and Threatened and Priority Ecological Communities (Section 4.5).

3.2 Botanical Survey Team and Field Survey Timing

The first sampling phase of the main study area[4], focussing on the Wheatstone camp study area and Wheatstone pipeline study area, was completed between the 2nd and 9th of April 2009 by five botanists from Biota (Ms Jeni Alford, Ms Rachel Butler, Ms Preeti Chukowry, Mr Justin Fairhead and Ms Michi Maier). Ms Judith Hughes and Ms Roslyn Davidson (traditional owners from the Thalanyji group) assisted in the survey work between the 3rd and 7th of April.

The second sampling phase focussed on the Wheatstone plant study area, and was completed between the 15th and 24th of April 2009 by Ms Rachel Butler, Ms Preeti Chukowry, Mr Justin Fairhead and Mr Paul Hoffman from Biota. Ms Anne Hayes, Ms Karen Hayes, Mr Rodney Hicks, Mr Meachum Kelly and Mr Joshua Hicks of the Thalanyji group each participated at some time over this period.

In addition, a four day site visit by two botanists from Biota (Mr Justin Fairhead and Ms Rachel Butler) was conducted between the 23rd and 26th of March 2009 to search for flora of conservation significance within 17 small (generally 60 m by 60 m) areas associated with proposed geotechnical test drilling sites. This was completed as part of a Native Vegetation Clearing Permit condition. This information was incorporated as additional "relevés" (unbounded flora survey sites) conducted within the Wheatstone study area (see Section 3.4). These relevés were labelled WSB-02 to WSB-18 (WSB-11 not used), WSB access and WSB laydown), and were scattered through the northern half of the Wheatstone plant study area (see Appendix 3).

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[4] Work conducted previously by OEC (2008) is discussed in Section 3.1.2.1.

The closest official meteorological recording station to the Wheatstone study area is at Onslow, approximately 12 km northeast of the Wheatstone plant study area. Data from this station indicate that considerable rain fell over the January-February 2009 period, and that this followed an extended period of very low rainfall (Figure 3.1). The January-February 2009 rainfall was well above the long-term average for Onslow (based on data from 1886-2009), and conditions at the time of the current field surveys were favourable for the collection of annual and cryptic perennial species.

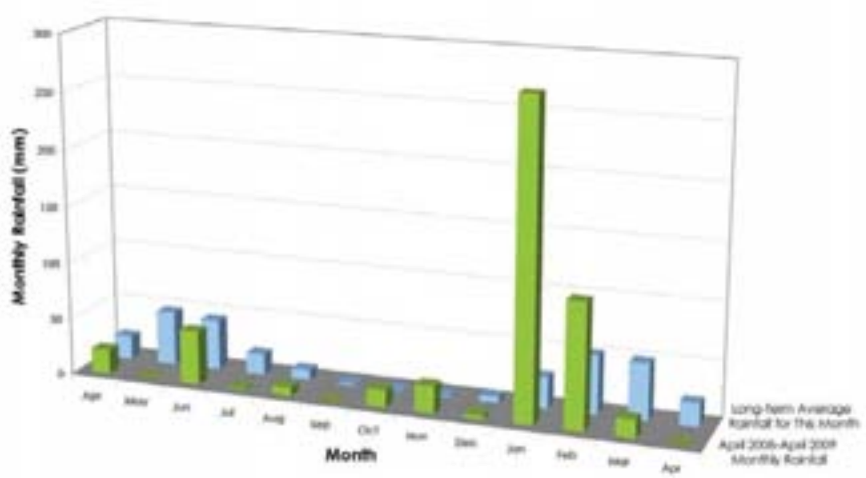

Figure 3.1: **Monthly rainfall for the Onslow recording station for the year preceding the current field surveys in March and April 2009, together with long-term averages.**
Data from the WA Bureau of Meteorology website (http://www.bom.gov.au/), accessed 12/05/09.

3.3 Vegetation Description and Mapping

Vegetation descriptions were based on the height and estimated cover of dominant species using Aplin's (1979) modification of the vegetation classification of Specht (1970) to include a hummock grassland category (see Appendix 2). Descriptions were made at each of the floristic survey quadrats and also at relevés (unbounded flora survey sites) (see Section 3.4). Additional brief vegetation descriptions were made and vegetation boundaries were ground-truthed during foot traverses through representative areas.

The vegetation descriptions were then grouped to arrive at vegetation units that were defined on the basis of a shared suite of perennial species with a similar range of cover values. These were generally defined at the level of vegetation sub-association, as per Level VI of the NVIS classification framework, and have been listed under the main landform/habitat types in which they were found to occur (see Section 5.2).

The vegetation boundaries were subsequently digitised on-screen using the ArcView 3.2 package. The resulting shapefiles were "tagged" to provide each polygon with the vegetation sub-association code. The coding system for the vegetation sub-associations incorporated the dominant flora species for the type, organised from tallest strata to lowest strata. Species names were abbreviated to capital letter/s for genus, followed by lower case letter/s for species, with multiple letters used where necessary to avoid confusion (e.g. GsCRcTRzTe = dominant species *Grevillea stenobotrya, Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* and *Triodia epactia*). Although this can result in some relatively unwieldy codes, it is considered the most appropriate method to code the digital mapping, allowing for subsequent studies to be more easily rationalised. For ease of use, a "unit code" was also assigned (e.g. "ID1" for vegetation sub-association GsCRcTRzTe) and has been used to refer to the sub-associations through this document.

Other point source datasets, such as locations of quadrats, weeds and flora of conservation significance, were generated into spatial data using MapInfo. These datasets were subsequently saved as separate MapInfo shapefiles. These datasets, in conjunction with other data supplied from other organisations, were used in the production of the vegetation maps contained in this report (Appendix 3). All maps were produced using the MapInfo package.

3.4 Assessment of Floristic Quadrats and Relevés

The locations of the 61 detailed flora recording quadrats assessed during the current study were chosen to represent the main vegetation sub-associations occurring within the Wheatstone study area. The quadrats were uniquely numbered, from WH01 to WH68 (some numbers in the sequence were not used). Twenty-six relevés (unbounded flora survey sites comprising a similar area to a standard quadrat) were also sampled, including those from the initial rare flora searches of the geotechnical test drilling sites (see Section 3.2). Relevés were labelled WSB-02 to WSB-25 (again, some numbers in the sequence were not used), WSB access, WSB laydown, WH-MA to WH-MB, WH-JFA to WH-JFD, WH-RB1 to WH-RB4.

All quadrats were established and assessed using the following methodology.

Quadrats were typically 50 m x 50 m, as this size gives an adequate sample of flora presence in northern Western Australia. It also gives an adequate indication of the shrub and grass layer vegetation structure for most vegetation types that occur in 'uniform' habitats (e.g. on plains, where vegetation stands are typically greater than this quadrat size). Quadrat shape and/or size were adjusted as necessary to fit smaller or oddly shaped habitats (e.g. sand dunes and drainage lines).

Most quadrats were permanently marked using steel fence droppers at three to four corners of the quadrat. An optical square and measuring tapes were used to ensure that the quadrat sides were correctly positioned.

The following parameters were recorded for each quadrat (see Appendix 4):

1. **Location**: AMG coordinates recorded in WGS84 datum (within 1-2 m of GDA94) using a hand-held Global Positioning System (GPS), to an accuracy usually within 5 m; readings taken for all four corners of the quadrat;
2. **Vegetation Description**: Broad description based on the height and estimated cover of dominant species after Aplin's (1979) modification of the vegetation classification system of Specht (1970) (see Appendix 2);
3. **Habitat**: Description of landform and habitat;
4. **Soil**: Broad description of soil type and stony surface mantle;
5. **Disturbance Details**: Condition ranked according to the scale developed by Trudgen (1988) as shown in Appendix 2, considering evidence of grazing, physical disturbance, weed invasion, frequent fires etc. Note that fire effects are only considered as a negative impact if they are caused by repeated burning (such as that done for pastoral purposes). Fire is a natural and frequent process in the Pilbara to which the vegetation has adapted, and to class areas as being in poor condition simply because they have been recently burnt is misleading; and
6. **Percentage Foliar Cover**: Cover was estimated visually for each species. Estimates were made to the nearest percent where possible, or a range (e.g. 5-10%) was used. '+' was used where only occasional individuals were present, providing a cover of less than 1%.

Colour photographs of the vegetation at each site were taken using a digital camera.

3.5 Searches for Rare Flora and Weeds

Botanists from OEC walked systematic traverses through the entire northern section of the Wheatstone plant study area to search for rare flora in July and November 2008 (OEC 2008 and 2009a; see Section 3.1.2.1). The July 2008 survey timing followed below-average autumn rainfall (although there was slightly above-average rainfall in June 2008), and the November 2008 survey timing followed an extended period of low rainfall (see Figure 3.1). Annual flora are therefore unlikely to have been abundant within the study area. However, as a number of relatively inconspicuous ephemeral species (including annual daisies) were recorded, it appears that the OEC survey work was relatively thorough.

Given the extent of the current Wheatstone study area, the entire area could not be systematically searched for rare flora over the period of the 2009 field surveys. Instead, representative foot traverses were walked through the main habitats to search for rare species and to indicate the level of weed invasion. Particular habitats which are known to frequently support rare or habitat-restricted flora (e.g. sand dunes, cracking clay plains, claypans and drainage lines) were specifically targeted.

Any locations of rare flora were recorded using a GPS (WGS84 datum), together with an indication of the number of individuals present, the habitat and associated plant species. Voucher specimens were also collected for lodgement with the Western Australian Herbarium. Rare Flora Report Forms will be lodged with DEC for all flora of conservation significance found within the Wheatstone study area.

Introduced flora were also recorded as part of this exercise, although not all of the locations could be recorded for particularly widespread species (e.g. **Cenchrus ciliaris, *Prosopis pallida* and **Vachellia farnesiana*, all of which were common within the Wheatstone plant and camp study areas in particular). Any additional native flora species that had not been previously recorded in the area by the survey team were also noted during these traverses.

All records of rare flora and the less common weed species are displayed on the vegetation mapping in Appendix 3.

3.6 Specimen Identification, Nomenclature and Data Entry

Common species that were well known to the survey botanists were identified in the field. Voucher specimens of all other species were collected and assigned a unique number to facilitate tracking of data. These were pressed in the field, and dried in a drying oven.

These vouchers were then identified by keying out, reference to appropriate publications, use of voucher reference collections and comparison to the collections held at the Western Australian Herbarium. Most specimens were identified by botanists from Biota. Various other specialists were consulted as required, and are gratefully acknowledged for their assistance with this study: these included Mr Malcolm Trudgen of M.E. Trudgen and Associates (for various difficult plant groups including the family Malvaceae and the genus *Tephrosia*), Ms Kelly Shepherd of the WA Herbarium (samphires) and Mr Andrew Brown of DEC Kensington (*Eremophila*). Mr Jerome Bull and Mr Darren Brearley of OEC provided assistance with resolving the identity of the undescribed *Vigna* taxon in the Wheatstone study area. The assistance of Mr Greg Guerin (South Australian Department of Environment and Heritage) is also appreciated for providing information regarding undescribed *Vigna* species in the Pilbara, while Dr Stephen van Leeuwen (DEC Woodvale) kindly allowed access to *Vigna* specimens in his collection and assisted with enquiries about *Eleocharis papillosa.*

Nomenclature was checked against the current listing of scientific names recognised by the Western Australian Herbarium and updated as necessary. The only outdated nomenclature retained was that relating to *Cassia*. This genus is currently recognised as *Senna* (see Randell

1989), however the older *Cassia* classification (Symon 1966) was perceived to be a more realistic level of separation of the taxa (e.g. with taxa such as '*glutinosa*' and '*pruinosa*' recognised at specific rather than subspecific level). A more detailed discussion is contained in Trudgen and Casson (1998), while a comparison of the nomenclature under the two classifications is presented in Appendix 5.

All data was entered into an Access Vegetation Database structure held internally at Biota, which was developed by Mr Ted Griffin (private consultant) at the request of Mr Malcolm Trudgen (M.E. Trudgen and Associates).

Specimens will be lodged with the Western Australian Herbarium for all taxa representing flora of conservation significance, undescribed taxa, range extensions or gaps in the known taxa, provided that adequate material is available. Ms Ryonen Butcher of the Western Australian Herbarium is also acknowledged for expediting the lodgement of *Vigna* specimens with the Herbarium, and their subsequent transfer to researchers in Queensland reviewing this genus (specifically Ms Ailsa Holland).

3.7 Floristic Analysis

Analysis of the flora quadrat data from the Wheatstone study area and other coastal study areas extending from the Exmouth Gulf to Port Hedland was undertaken to explore similarities or dissimilarities in the vegetation types sampled by the quadrats. PRIMER v6 multivariate statistical software (Clarke and Gorley 2006) was used to conduct these analyses.

The dataset used for the analysis comprised a total of 546 quadrats and relevés, including sites from seven studies in the immediate vicinity of Onslow:

- the 61 quadrats and numerous well-sampled relevés from the current survey work by Biota;
- 21 quadrats assessed by Astron (2009) for the West Pilbara Project Onslow Rail Route on behalf of API Management Pty Ltd, including 16 within the Wheatstone study area;
- 47 quadrats from the Chevron Domgas Project pipeline corridor surveyed by Validus (2008), along with 44 quadrats from another study (Biota unpubl. data), both of which extended to the coast from just north of the eastern end of the Wheatstone shared infrastructure corridor; and
- 46 quadrats from three surveys approximately 9 km north of the camp and shared infrastructure corridor (Biota unpubl. data)[5].

The dataset also included sites from several other study areas along the northern Carnarvon and Pilbara coast and near-coastal areas:

- 37 quadrats and one relevé from Giralia Station, 102-140 km southwest of the Wheatstone plant site (DEC and Biota, unpubl. data);
- 57 quadrats from the Yannarie Solar Salt Project study area, 27-96 km southwest of the Wheatstone plant site on the eastern side of Exmouth Gulf (Biota 2005, 2008a);
- 45 quadrats from the vicinity of Mesa A, Mesa G and Warramboo, near Pannawonica (Biota 2006b and unpubl. data); 70-120 km east of Wheatstone;
- 47 quadrats from Cape Preston, 130-160 km northeast of Wheatstone (Halpern Glick Maunsell, Biota and Trudgen 2001);
- 27 quadrats from the Dampier Salt Saltfield Expansion, 200 km northeast of Wheatstone (Biota 2008b);

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[5] Note that the quadrats assessed by RPS (2009) for the Ashburton North Pipeline Route Option 3 survey were not included, as cover values for each species were not provided in the report.

- 11 quadrats from a survey east of Dampier, ranging between 200-250 km northeast of Wheatstone (Biota unpubl. data);
- 24 quadrats from Cape Lambert, 250 km northeast of Wheatstone (Biota 2008c);
- 24 quadrats and one relevé from the Cape Lambert to Emu Siding rail corridor (Biota 2008d), extending over 60 km south from the coast;
- one quadrat near Boodarie, 390 km northeast of Wheatstone (Biota unpubl. data); and
- 16 quadrats from the Port Hedland Solar Saltfield Expansion, 410 km northeast of Wheatstone (Biota 2006c).

Given the size of the dataset, Non-metric Multidimensional Scaling (MDS) could not be used to display patterns in species occurrence (ordination). The collected data were used in the computation of triangular similarity matrices based on the Bray-Curtis similarity measure, and results were instead displayed as dendrograms reflecting site similarity. SIMPROF analyses were also run, to indicate "true" clusters within the dataset.

Almost all ecological datasets benefit from some level of transformation, particularly in the case of the Bray-Curtis resemblance measure as it does not contain any form of scaling (Clarke and Gorley 2006). However, transformations beyond cube root move towards presence/absence data (McCune and James 2002), and even cubed root transformations down-weight abundant species to a high degree. A conservative approach was therefore taken with this data and a square-root transformation was applied to the percent cover data prior to the computation of the similarity matrices.

3.8 Vegetation Conservation Significance Assessment

The assessment of vegetation conservation significance for this study attempted to integrate the following information:

1. the land system/s with which the vegetation sub-associations were most strongly associated. In doing this, the distribution of the land systems through the north-west of WA was gauged as being either widespread or restricted. The occurrence of the land system within the study area in relation to the distribution of that land system as a whole was also taken into account. The strong regionalisation in floristic composition, as shown in floristic analyses to date, suggests that outlying occurrences of a land system can be expected to support floristic types that are not typical of the overall unit. This information was used to indicate the likely representation in the region of vegetation types linked strongly to particular land systems.
2. other features of the vegetation units defined for the study, including their areal extent within the study area, occurrence on restricted habitats, capacity to support rare or restricted flora, species richness and condition (health); and
3. reservation priorities of ecosystems as identified by DEC (Kendrick and Mau 2002).

The features, and the scores ascribed to each, are described in Table 3.1. As the DEC ecosystem reservation priorities are assigned on the basis of Beard's mapping units, these could not always be linked to a specific vegetation sub-association. These priorities were therefore used in a more general sense to increase the conservation ranking of selected units.

Table 3.1: Explanation of features and codes used in the vegetation conservation assessment.

Regional Representation of Land System/s		**Score**
R,O	Restricted, and outlier - Land system is restricted to a particular section of the bioregion, and the study area occurs within an outlying occurrence of the land system or at one end of the mapped distribution of the land system	4
R	Restricted - Land system is restricted to a particular section of the bioregion	3
W,O	Widespread, but outlier - Land system is widespread in the bioregion, but the study area occurs within an outlying occurrence of the land system or at one end of the mapped distribution of the land system	2
W	Widespread - Land system occurs broadly across the bioregion	1
Other Key Attributes Increasing Conservation Value		**Score**
C	Significant physical feature (moderate-sized or larger creeklines or other drainage features, gorges, sand dunes) – likely to be at the level of land units within a land system	1
F	Known or probable habitat for restricted flora comprising: DRF / EPBC Act 1999 listed species Priority flora species Other flora of interest	 3 2 1
A	Small area of extent, for example due to occurrence on a minor habitat (e.g. dunes)	1
S	High species richness	1
H	Very Good to Excellent condition stand of this vegetation	1
Other Key Attributes Decreasing Conservation Value		**Score**
D	Substantially degraded (eg. by weed invasion, dieback, clearing, heavy grazing)	-3

3.9 Limitations

The survey work completed to date within the Wheatstone study area, including sampling of the northern section of the Wheatstone plant study area during three different surveys, is believed to give a thorough indication of the vegetation sub-associations and flora species occurring in the area. However, the following limitations must be taken into account when reviewing the results of the field surveys and the subsequent conservation assessments:

- Fungi and nonvascular flora (e.g. algae, mosses and liverworts) were not specifically sampled by this study. Surveys for algae have been commissioned by Chevron under other scopes of works for the Wheatstone Project.
- Although the timing of the 2009 surveys was appropriate to detect most annual flora species, groups such as the daisies (family Asteraceae) which germinate mainly after winter rainfall are under-represented on the vascular flora list. In addition, the entire study area was not systematically searched for rare flora. Some of the 2008 field survey work was also done during dry periods (see OEC 2008, 2009a). The species lists recorded for the individual sampling sites, as well as the overall study area, should therefore be taken as comprehensive but not necessarily exhaustive.
- The vegetation sub-associations for this study were defined based on interpretation of aerial photography signatures combined with the site data and field mapping notes recorded during the field surveys. As it was not possible to map areas outside the Wheatstone study area in this way, the distribution of these units outside the study area can only be inferred by their correlation with land systems mapping prepared by the Department of Agriculture and reference to other studies completed in the locality. This means that there is a level of uncertainty regarding the assessment of distribution of these vegetation sub-associations outside the current study area.

- The floristic analysis is limited by the availability of site data for the locality and broader region. Such data is typically clustered in particular areas, typically associated with resource developments, and would not represent the full range of variation in vegetation over the region.
- This report does not include any discussion of potential impacts arising from the development nor management recommendations. Detailed identification of impacts of the Wheatstone Project and appropriate management measures will be addressed within the ERMP and do not form part of the scope of this study.

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4.0 Existing Environment

4.1 IBRA Bioregions and Subregions

The IBRA[6] currently recognises 85 bioregions and 403 biological subregions for Australia. The Wheatstone study area is located at the junction between two of the IBRA bioregions, Carnarvon and the Pilbara. The majority of the Wheatstone study area (over 80%; comprising the Wheatstone plant study area, camp and infrastructure study area, and the western two-thirds of the pipeline study area) lies at the northeastern edge of the Carnarvon bioregion, while the remaining area (comprising the easternmost 20 km section of the Wheatstone pipeline study area) lies at the northwestern edge of the Pilbara region.

4.1.1 Carnarvon (CAR)

There are two biological subregions within the Carnarvon bioregion (Environment Australia 2000):

1. Cape Range: Rugged tertiary limestone ranges and extensive areas of red Aeolian dunefields, quaternary coastal dunes and mud flats. *Acacia* shrublands (*Acacia stuartii* or *A. bivenosa*) over *Triodia* on limestone and red dune fields. *Triodia* hummock grassland with sparse *Eucalyptus* trees and shrubs on the Cape Range. The Exmouth Gulf supports extensive mangroves in tidal mudflats and sheltered embayments, while the hinterland area supports a mosaic of samphire and saltbush low shrublands in saline alluvial plains.
2. Wooramel: Alluvial plains associated with downstream sections and deltas of the Gascoyne, Minilya and Wooramel rivers. *Acacia* shrublands (Mulga, Bowgada and *A. coriacea*) over bunch grasses on red sandy ridges and plains. Mangroves confined to small areas near Lake MacLeod and Carnarvon. Samphire and saltbush low shrublands on saline alluvial plains in near-coastal areas.

The parts of the Wheatstone study area lying within the Carnarvon bioregion are all located within the Cape Range subregion. For further discussion of this subregion, see Kendrick and Mau (2002).

4.1.2 Pilbara (PIL)

There are four biological subregions within the Pilbara bioregion (Environment Australia 2000):

1. Hamersley: Mountainous area of Proterozoic sedimentary ranges and plateaux with Mulga (*Acacia aneura*) low woodland over bunch grasses on fine textured soils and Snappy Gum (*Eucalyptus leucophloia*) over *Triodia brizoides* on skeletal sandy soils of the ranges.
2. The Fortescue Plains: Alluvial plains and river frontages. Salt marsh, mulga-bunch grass, and short grass communities on alluvial plains. River Gum (*Eucalyptus camaldulensis*) woodlands fringe the drainage lines. This is the northern limit of Mulga (*Acacia aneura*).
3. Chichester: Archaean granite and basalt plains supporting shrub steppe characterised by *Acacia pyrifolia* over *Triodia pungens* hummock grasses. Snappy Gum tree steppes occur on ranges.
4. Roebourne: Quaternary alluvial plains with a grass savanna of mixed bunch and hummock grasses, and dwarf shrub steppe of *Acacia translucens* over *Triodia pungens*. Samphire, *Sporobolus* and Mangal occur on marine alluvial flats. Arid tropical with summer rain.

The parts of the Wheatstone study area lying within the Pilbara bioregion are all located within the Roebourne subregion. For further discussion of this subregion, see Kendrick and Stanley (2001).

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[6] http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html

4.2 Conservation Reserves in the Locality

The closest gazetted conservation reserve to the Wheatstone study area is the C-class Cane River Conservation Park, approximately 4.5 km to the east of the eastern end of the Wheatstone pipeline study area. The Cane River Conservation Park, about 100 km southeast of Onslow, extends over 148,000 ha and includes several landforms and vegetation types of particular significance not found in other conservation reserves in the Pilbara[7].

The Pilbara bioregion is listed as a medium priority for funding for land purchase under the National Reserves System Co-operative Program due to the limited representation of the area in conservation reserves. Portions of various pastoral leases in the region have been nominated for exclusion for public purposes in 2015, when the leases come up for renewal. Many of the submissions are from the DEC, with the intention of adding these areas to the existing conservation estate in order to provide a comprehensive, adequate and representative reserve system.

The National Reserves System Co-operative Program's current proposals include extensions to the Cane River Conservation Park to include the Mt Minnie Pastoral Lease, Ashburton (110,921 ha), and part of the Nanutarra Pastoral Lease, Ashburton (70,030 ha)[8]. Once this extension of the Cane River Conservation Park is implemented, the eastern 44 km section of the Wheatstone pipeline study area will be located within the Park.

A number of other reserves occur in the broader locality (e.g. the Cape Range National Park, Ningaloo Marine Park, Barrow Island Nature Reserve, etc; see Kendrick and Mau 2002), however these are all sufficiently distant to be of no direct relevance to the current proposal.

4.3 Land Systems in the Study Area

Land systems (Rangeland) mapping covering the Wheatstone study area has been prepared by the Western Australian Department of Agriculture (Payne et al. 1987 and van Vreeswyk et al. 2004). Land systems are comprised of repeating patterns of topography, soils, and vegetation (Christian and Stewart 1953) (i.e. a series of "land units" that occur on characteristic physiographic types within the land systems).

The Wheatstone study area intersects seven land systems (Table 4.1). The study area contains just over 4% of the total area of the Onslow land system mapped for the State, along with 2% of the Dune land systems; the remaining land systems are represented by less than 0.5% of their total area (Table 4.2).

Table 4.1: Land systems in the Wheatstone study area (from van Vreeswyk et al. 2004, Payne et al. 1987).

Land System	Description
Dune	Dunefields supporting soft spinifex grasslands; vegetation mostly in very good condition; occurs in the northern section of the development area including portions of the Wheatstone plant study area, the Wheatstone camp study area and a small section of the Wheatstone pipeline study area.
Giralia	Linear dunes and broad sandy plains supporting hard and soft spinifex grasslands; vegetation mostly in very good condition; occurs in the central section of the Wheatstone pipeline study area.
Littoral	Bare coastal mudflats with mangroves of seaward fringes, *Tecticornia* (samphire) flats, sandy islands, coastal dunes and beaches; vegetation mostly in good to very good condition; occurs in the northern section of the Wheatstone plant study area.
Minderoo	Alluvial plains supporting tall shrublands and tussock grasslands, and sandy plains supporting hummock grasslands; vegetation mostly in good condition; occurs in the southern section of the Wheatstone camp study area.

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[7] http://www.dec.wa.gov.au/news/minister-for-the-environment/new-conservation-park-for-the-pilbara.html

[8] http://www.dec.wa.gov.au/news/minister-for-the-environment/new-conservation-park-for-the-pilbara.html

Land System	Description
Onslow	Sandplains, dunes and claypans supporting soft spinifex grasslands and minor tussock grasslands; vegetation mostly in good to very good condition; occurs in the northern section of the study area, including over half of the Wheatstone plant and camp study areas and a section of the Wheatstone pipeline study area.
Stuart	Gently undulating stony plains supporting hard and soft spinifex grasslands and snakewood shrublands; vegetation mostly in very good condition; occurs at the eastern end of the Wheatstone pipeline study area.
Uaroo	Broad sandy plains supporting shrubby hard and soft spinifex grasslands; vegetation mostly in good to very good condition; occurs along a large section of the central Wheatstone pipeline study area, together with a small section at the easternmost tip.

Land units occurring within each land system are described in the following sections.

4.3.1 Dune Land System

The Dune land system has four land units:

1. Linear and reticulate dunes (55% of this land system): typically supporting hummock grasslands of *Triodia schinzii* or *T. pungens* (Soft Spinifex) with numerous low and mid-height shrubs. Occasionally **Cenchrus ciliaris* is dominant.
2. Swales and sandplains (32% of this land system): typically supporting hummock grasslands of *Triodia pungens* (Soft Spinifex) and some *T. lanigera* (Hard Spinifex) with sparse low shrubs such as *Acacia stellaticeps*.
3. Swamps and depressions (8% of this land system): typically supporting scattered low woodlands of *Eucalyptus victrix* with *Muehlenbeckia florulenta* and tussock grasses such as *Sporobolus mitchellii* and *Eriachne benthamii*.
4. Claypans (5% of this land system): typically bare unvegetated areas.

All of these landform units occur in the Wheatstone study area, however the swamps and depressions generally lack the *Eucalyptus victrix* overstorey layer described above.

4.3.2 Giralia Land System

The Giralia land system has five land units, three of which occur in the Wheatstone study area:

1. Sand dunes (10% of this land system): typically supporting hummock grasslands of *Triodia schinzii* (Soft Spinifex) with an overstorey of *Grevillea gordoniana*, *Pityrodia* and *Tephrosia* spp. and numerous annuals after fire.
2. Plains with thin sand cover (70% of this land system): typically supporting hummock grasslands of *Triodia lanigera* (Hard Spinifex) and some *T. pungens* (Soft Spinifex) with an overstorey of *Acacia inaequilatera*, *A. stellaticeps*, *A. victoriae*, *Hakea lorea* and numerous annuals after fire.
3. Broad through-flow zones (10% of this land system): typically supporting hummock grasslands of *Triodia pungens*, sparse tussock grasses, low shrubs, forbs and annual grasses. Also tall shrublands of *Acacia inaequilatera*, *A. sclerosperma*, *A. victoriae* or trees of *Eucalyptus victrix*, with hummock grass understorey.

4.3.3 Littoral Land System

The Littoral land system has nine land units, all of which occur in the Wheatstone plant study area:

1. Beaches (<1% of this land system): typically devoid of vegetation.

2. Coastal dunes (3% of this land system): typically supporting hummock grasslands of *Triodia pungens* or *T. epactia* (Soft Spinifex) and scattered shrubs such as *Acacia coriacea*, **Aerva javanica* and *Threlkeldia diffusa.*
3. Limestone ridges (<1% of this land system): typically supporting mixed grasslands of *Triodia pungens* and **Cenchrus ciliaris* with isolated shrubs.
4. Tidal flats (70% of this land system): typically supporting no vegetation. Occasional patches of very scattered low shrublands of *Tecticornia* spp.
5. Mangrove outer margins (5% of this land system): typically supporting closed woodlands with *Avicennia marina* and *Rhizophora stylosa*.
6. Tidal channels (4% of this land system): typically narrow fringing communities of mangroves and samphire.
7. Samphire flats (10% of this land system): typically supporting scattered to moderately close low shrublands or grassy shrublands of *Tecticornia* spp. and *Sporobolus virginicus*
8. Alluvial plains (2% of this land system): typically supporting tussock grasslands of **Cenchrus ciliaris* or mixed perennial grasses such as *Chrysopogon fallax*, *Eragrostis xerophila* and *Sporobolus virginicus*; also *Triodia pungens*.
9. Sandy plains and islands (5% of this land system): typically supporting hummock grasslands of *Triodia pungens*, *T. epactia* (Soft Spinifex) with isolated shrubs; less frequently with other *Triodia* spp.

4.3.4 Minderoo Land System

The Minderoo land system has seven land units, four of which occur in the Wheatstone study area:

1. Sand dunes (10% of this land system): typically supporting hummock grasslands of *Triodia schinzii* with an overstorey of *Acacia murrayana, A. stellaticeps*, *Corchorus walcottii*, and *Grevillea gordoniana* and the grass **Cenchrus ciliaris*, and annual grasses.
2. Sand plains (15% of this land system): typically supporting hummock grasslands of *Triodia schinzii* and *Triodia pungens* with an overstorey of *Acacia sclerosperma*, *A. tetragonophylla, A. victoriae, Eremophila forrestii, Eucalyptus victrix* and *Rhagodia eremaea.*
3. Gilgai plains (15% of this land system): typically supporting variable open tussock grasslands of *Astrebla elymoides*, *Chrysopogon fallax* or *Eragrostis xerophila* or *Eriachne benthamii* or *Sporobolus virginicus* with an open tall shrub overstorey of *Acacia tetragonophylla* and *A. victoriae*.
4. Claypans (5% of this land system): typically bare but occasionally supports *Eriachne gardneri*.

4.3.5 Onslow Land System

The Onslow land system has seven land units, five of which occur in the Wheatstone study area:

1. Sandplains (40% of this land system): typically supporting hummock grasslands of *Triodia pungens* (Soft Spinifex) with isolated *Acacia* spp. shrubs; also patches of **Cenchrus ciliaris*.
2. Dunes (5% of this land system): typically supporting hummock grasslands of *Triodia pungens* with isolated to very scattered shrubs such as *Crotalaria cunninghamii*; also patches of **Cenchrus ciliaris*.
3. Saline flats (12% of this land system): typically supporting very scattered low shrublands of *Tecticornia* spp. and/or *Frankenia* spp. with variable amounts of *Sporobolus virginicus* grass. Some highly saline parts with no vegetation.
4. Depressions (1% of this land system): typically supporting variable tussock grasslands, mostly *Sporobolus virginicus* and *Eriachne benthamii* with fringing margins or *Eucalyptus victrix* trees.
5. Claypans (2% of this land system): typically supporting no vegetation.

4.3.6 Stuart Land System

The Stuart land system has four land units, three of which occur in the Wheatstone study area:

1. Low hills (3% of this land system): typically supporting hummock grasslands of *Triodia wiseana* (Hard Spinifex) with isolated or very scattered shrubs such as *Acacia atkinsiana* and *A. bivenosa*.
2. Stony plains (42% of this land system): typically supporting hummock grasslands of *Triodia wiseana*, *T. lanigera*, *T. brizoides* (Hard Spinifex) with isolated to scattered *Acacia* spp. and other shrubs. Less frequently *Triodia pungens* (Soft Spinifex).
3. Lower plains (40% of this land system): typically supporting very scattered to scattered tall shrublands of *Acacia xiphophylla* with numerous low shrubs including *Enchylaena tomentosa, Maireana* and *Cassia* spp. and hummock grasses such as *Triodia longiceps* or *T. pungens* (Soft Spinifex). Also hummock grasslands of *T. longiceps* or *T. pungens* with very few shrubs.

4.3.7 Uaroo Land System

The Uaroo land system has six land units, of which one is dominant in the Wheatstone study area:

1. Sandy/loamy plains (82% of this land system): typically supporting hummock grasslands or shrubby hummock grasslands of *Triodia pungens*, *T. epactia*, *T. schinzii* (Soft Spinifex) or *T. lanigera, T.* spp. (Hard Spinifex) with isolated to scattered (occasionally moderately close) shrubs particularly *Acacia stellaticeps*, *A. inaequilatera*, *A. tumida* and occasional eucalypts and other trees.

Table 4.2: **Distribution of land systems within the Wheatstone study area, and in the State** (data from Payne et al. 1987, 1988 and van Vreeswyk et al. 2004).

Land System	Total Area in the State (ha)	General Distribution through the State	Area within Wheatstone Study Area †	
			Hectares	% of total in State
Dune	49,302	Distributed through near-coastal areas over a range of ~170 km, from the eastern side of the Exmouth Gulf to east of Onslow; predominantly in the Carnarvon bioregion, extending into the westernmost Pilbara bioregion	931	1.9%
Giralia	362,631	Distributed over a range of >200 km from inland of Lake MacLeod to Onslow; several very large areas in the Carnarvon bioregion and numerous smaller areas within the Pilbara bioregion	1117	0.3%
Littoral	337,551	Widespread over 650 km of coastline, stretching from the base of the Exmouth Gulf to east of Port Hedland; predominantly in the Carnarvon and Pilbara bioregions	1276	0.4%
Minderoo	144,436	Localised to an area of ~90 km by 40 m within the northern section of the Carnarvon bioregion, but well represented within this area	463	0.3%
Onslow	74,022	Widespread towards the coast in both the Carnarvon and Pilbara bioregions, extending from the eastern side of the Exmouth Gulf to the Fortescue River	3136	4.2%
Stuart	276,685	Localised but well represented within the western section of the Pilbara bioregion, with occasional occurrences in the adjacent Gascoyne bioregion	560	0.2%
Uaroo	1,412,819	Widespread in the northwest region from inland of Lake MacLeod to the eastern Pilbara; occurrences in the Carnarvon, Gascoyne and Pilbara bioregions	2262	0.2%
State Total	**2,657,446**			

† NB. An additional 49 ha of the study area was off the coast and therefore not covered by the land systems mapping.

4.4 Beard's Vegetation Mapping

Beard (1975) mapped the vegetation of the Pilbara at a scale of 1:1,000,000. The extent of this map sheet also covered the northern Carnarvon Basin region. The Wheatstone study area lies across portions of both the Carnarvon Botanical District and the Fortescue Botanical District of the Eremaean Botanical Province as defined by Beard.

The majority of the Wheatstone study area (the area within the Carnarvon bioregion; see Section 4.1) is located in the Carnarvon Botanical District and, more specifically, falls within the Cape Yannarie Coastal Plain (CYCP) as delineated by Beard (1975).

Three topographic/soils units were recognised from the Yannarie Coastal Plain:

- Pediplains and hills on siltstones and other marine rocks. Chief soils are hard alkaline red soils.
- Extensive plains with some occasional rocky hills in the inland parts, claypans in the coastal parts, and considerable sandy stretches with parallel sand dune formations. Chief soils of the dunes are red sands and the soils of the plains are acid, neutral and alkaline red earths, with non-cracking clays in the claypans.
- Salt flats, tidal swamps and coastal sand dunes on the seaward fringe. Chief soils are saline loams with shelly sands and small areas of calcareous and/or siliceous sands on coastal dunes. Saline clays or muds on slopes and flats submerged at high tide occur in the mangrove zone.

Due to the inaccessibility of the coastline of the Yannarie Coastal Plain during the Beard (1975) vegetation survey, the area was not visited and the vegetation community types identified at this time were interpreted from aerial photography.

Beard's (1975) survey described three broad vegetation complexes in this area:

- Mangrove vegetation on the coastline and covering the intertidal zone, with *Avicennia marina* as the principal species and some *Rhizophora stylosa*.
- Behind the intertidal zone is a belt of bare hypersaline mud, which sometimes floods with spring tides. This zone is quite devoid of any vegetation, but some samphire communities occur locally (*Tecticornia* species).
- Behind the saline tidal mud flats area is a zone mapped as shrub steppe on sandhills with numerous small claypans. The shrub steppe is typically dominated by *Triodia* species (*T. epactia/pungens*) with *Acacia bivenosa, A. synchronicia, A. tetragonophylla* and *A. xiphophylla* the most common shrub species present.

The remaining section of the Wheatstone study area (the area within the Pilbara bioregion; see Section 4.1) is located in the Fortescue Botanical District and, more specifically, falls within the Onslow Coastal Plain (OCP) as delineated by Beard (1975).

Three topographic/soil units are recognised from the Onslow Coastal Plain:

- Extensive plains dominated by neutral and alkaline earths with areas of acid and alkaline red earths, frequently with a cover of surface gravels.
- Plains dominated by hard alkaline red soils with some areas of both cracking and non-cracking clay soils.
- Coastal fringes of salt flats, tidal swamps and coastal sand dunes, chief soils being saline loams with shelly sands.
- Areas of calcareous earths and shallow loams are associated with marls.

Beard (1975) mapped seven finer-scale units within the Wheatstone study area:

- CYCP 98: *Acacia pyrifolia* open shrubland over *Triodia pungens, T. basedowii* open hummock grassland (a_2Sr.$t_{1,2}$Hi); assigned a Low reservation priority by DEC (Kendrick and Mau 2002);

- CYCP 117: *Triodia pungens* open hummock grassland (t_1Hi); assigned a Medium reservation priority by DEC (Kendrick and Mau 2002);
- CYCP 127: Mud flats (fl); assigned a Low reservation priority by DEC (Kendrick and Mau 2002);
- CYCP 589: Mixed bunch grassland/*Triodia pungens* open hummock grassland (xGc/t_1Hi); assigned a High reservation priority by DEC (Kendrick and Mau 2002);
- CYCP 670: Mixed open shrubland over *Triodia basedowii* open hummock grassland (xSr.t_2Hi); assigned a Low reservation priority by DEC (Kendrick and Mau 2002);
- CYCP 676: *Tecticornia* spp. low shrubland (k_3Ci); assigned a High reservation priority by DEC (Kendrick and Mau 2002); and
- OCP 585: *Acacia victoriae, A. xiphophylla* shrubland/*Acacia pyrifolia* open shrubland over *Triodia pungens, T. basedowii* open hummock grassland ($a_{10,11}$Si/a_2Sr $t_{1,2}$Hi); assigned a Medium reservation priority by DEC (Kendrick and Mau 2002).

Given the broad nature of Beard's mapping, these units are only broadly applicable to the vegetation occurring on site (see Section 5.0).

4.5 Vegetation of Conservation Significance Known from the Locality

Vegetation communities of the highest conservation concern are listed as TECs by the Western Australian DEC. While some TECs for WA are also listed under the Commonwealth *EPBC Act 1999*, this does not apply to any currently described from the Pilbara or Carnarvon bioregions. Other communities of conservation significance are listed as Priority Ecological Communities (PECs). While these communities do not have any legislative protection, it is best practice environmental management to avoid disturbance to these areas. The framework for ranking communities of conservation significance is presented in Appendix 1.

4.5.1 Threatened Ecological Communities in the Vicinity of the Study Area

The search of the broad (~150 km^2) area around Onslow using the *EPBC Act 1999* Protected Matters Search Tool yielded no listed TECs as known from or likely to occur in the locality.

Although a small number of TECs have been defined for the Pilbara and Carnarvon bioregions by the DEC, none of these are known to occur in the vicinity of Onslow (DEC 2006).

4.5.2 Priority Ecological Communities in the Vicinity of the Study Area

A number of PECs are listed for the Pilbara bioregion, however none of these are known to occur in the Onslow locality. There are no PECs listed for the Carnarvon bioregion (DEC 2008).

4.6 Flora of Conservation Significance Known from the Locality

While all native flora are protected under the Western Australian *Wildlife Conservation Act 1950-1979,* a number of plant species are assigned an additional level of conservation significance based on the limited number of known populations and the perceived threats to these populations. Species of the highest conservation concern are listed as DRF under the State listing prepared by the DEC (Atkins 2008). The two DRF in the Pilbara and the single DRF in the Carnarvon bioregion are also listed as Threatened species under the Commonwealth *EPBC Act 1999*. Species that appear to be rare or threatened, but for which there is insufficient information to properly evaluate their conservation significance, are assigned to one of four Priority flora categories by DEC (see Atkins 2008). This is an administrative (rather than legislated) level of protection. The framework for ranking flora species of conservation significance is presented in Appendix 1.

4.6.1 Listed Species under the *EPBC Act 1999* Occurring in the Locality

The search of the broad (~150 km^2) area around Onslow using the *EPBC Act 1999* Protected Matters Search Tool yielded no listed flora species as known from or likely to occur in the locality.

4.6.2 Declared Rare Flora Occurring in the Locality

There are currently only two DRF species for the Pilbara bioregion, and neither species would occur in the Wheatstone study area based on their distribution and preferred habitats:

- Mountain Thryptomene (*Thryptomene wittweri*) is restricted to high-altitude mountain tops (>1000 m), and the nearest known populations are in the southern Pilbara.
- Hamersley Lepidium (*Lepidium catapycnon*) occurs on shaly hills, scree slopes and stony plains, and the nearest known populations are in the central Pilbara.

Only one DRF species is currently recorded for the Carnarvon bioregion, and this would be highly unlikely to occur in the Wheatstone study area based on its distribution:

- Beard's Mallee (*Eucalyptus beardiana*) occurs on red or yellow sand ridges, and the nearest known populations are at the southernmost end of the Carnarvon bioregion, over 500 km south of the Wheatstone study area.

4.6.3 Priority Flora Known from the Locality

Based on the searches of the DEC and WA Herbarium databases conducted for OEC (2008 and 2009a) (see Section 3.1.1), a number of Priority flora species are known to occur in the locality:

- *Abutilon uncinatum* ms.[9] (Priority 1) is known from two locations approximately 40 km apart in the northwestern corner of the Pilbara bioregion, with the westernmost of these being 22 km east-southeast of Onslow. There is one other known location, 113 km south of Onslow in the Carnarvon bioregion. This species is recorded as occurring on red sandplains and could potentially occur within the Wheatstone study area.
- *Helichrysum oligochaetum* (Priority 1) has a relatively broad distribution through the Pilbara and northern Gascoyne bioregions. This annual daisy could potentially occur on the clayey plains habitats of the Wheatstone study area, although it has not been recorded from the Onslow locality to date.
- *Carpobrotus* sp. Thevenard Island (M. White 050) (Priority 2) is only currently known from white sand dunes on islands off the Pilbara coast. This species is unlikely to occur in the Wheatstone study area.

In addition to these species, *Triumfetta echinata* (Priority 3) is known from populations in the Onslow locality, from west (within the Wheatstone plant study area; OEC 2009a) to approximately 20 km southeast of Onslow. There is another outlying population some 115 km south of Onslow, on Uaroo Station in the northwestern corner of the Gascoyne bioregion.

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[9] "ms." denotes a manuscript name which has not yet been published.

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5.0 Vegetation of the Wheatstone Study Area

5.1 Overview of Vegetation

The current survey work combined with the work of OEC (2008 and 2009) identified 25 vegetation sub-associations as occurring in the Wheatstone study area. These are described individually in Section 5.2, grouped within the main landform categories present within the Wheatstone study area.

The sub-associations fall into nine broad groups based on their occurrence on landform units (see overview map in Appendix 3):

- Tidal mudflats supported scattered low shrubs of *Tecticornia* spp.[10] (samphire), while tidal creeks supported mangal (vegetation dominated by mangroves; at this location principally *Avicennia marina*).
- Pale coastal sand dunes supported *Acacia coriacea* subsp. *coriacea* (Wirewood) tall shrublands, with an understorey of *Spinifex longifolius* (Beach Spinifex) on coastal foredunes and *Triodia epactia* (Soft Spinifex) on near-coastal dunes.
- The red sand dunes occurring further inland supported tall open shrublands dominated by *Grevillea stenobotrya*, *Crotalaria cunninghamii* (Green Birdflower) and *Trichodesma zeylanicum* var. *grandiflorum* (Camel Bush) over *Triodia epactia* and/or *T. schinzii;* shrublands of *Acacia stellaticeps* over *Triodia epactia* occurred in the dune swales.
- Coastal sand plains supported a general cover of *Triodia epactia* hummock grasslands with scattered shrubs, mainly *Acacia tetragonophylla* (Kurara), **Prosopis pallida* (Mesquite) and **Vachellia farnesiana* (Mimosa Bush); these areas were variably invaded by **Cenchrus ciliaris* (Buffel Grass). Small areas of outcropping calcrete supported characteristic shrubs including *Scaevola pulchella* and *Indigofera monophylla*.
- Claypans ranged from being virtually bare of vegetation, to supporting open tussock grasslands of *Eriachne* aff. *benthamii* or low open shrublands of samphire.
- Clayey plains in the coastal section of the study area supported mixed closed tussock grasslands dominated by species such as *Sporobolus mitchellii, Eriachne benthamii, Eragrostis xerophila* and *Eulalia aurea* with a variable shrub cover. Clayey plains along the Onslow Road in the Wheatstone pipeline study area supported *Acacia xiphophylla* (Snakewood) tall shrublands over various spinifex species.
- Inland sand plains supported *Triodia lanigera* hummock grasslands with a variable shrub cover dominated by wattles (*Acacia* spp.).
- Two small rocky hills along the Onslow Road supported *Triodia lanigera, T. brizoides* open hummock grasslands with scattered shrubs of *Acacia inaequilatera* (Baderi).
- There were few defined drainage areas within the study area. The single moderate-sized creekline, at the southern boundary of the Wheatstone plant study area, supported *Eucalyptus victrix* (Coolibah) open forest over a tussock grassland of *Eulalia aurea* and Buffel Grass. A broad drainage area in the western section of the Wheatstone pipeline study area supported scattered Coolibahs over a shrubland of *Acacia synchronicia* and *A. bivenosa* and a hummock grassland of *Triodia epactia*. Another broad, poorly-defined drainage plain at the eastern end of the Wheatstone pipeline study area supported scattered mallees of *Corymbia hamersleyana* (Bloodwoods) over a tall open shrubland dominated by *Acacia tumida* and *Grevillea wickhamii* and an open hummock grassland of *Triodia epactia* and *T. lanigera*.

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[10] "spp." is used to denote multiple species in the same genus.

5.2 Description of Vegetation Sub-Associations

The sub-associations within the Wheatstone plant study area were generally consistent with those identified by OEC (2008 and 2009a) for the area, however some of the OEC units were merged for this study as the differences between them could not be evaluated by the current survey work. The correlation between the units identified by the current survey work and those of OEC (2008 and 2009a) is presented in Table 5.1.

5.2.1 Vegetation of Tidal Mudflats and Tidal Creeks

Tidal mudflats in the northern section of the Wheatstone plant study area and at the western end of the Wheatstone SIC study area comprised either "bare" mudflat, with only very scattered shrubs, or tidal creeks supporting mangal.

Unit Code	Description	Sub-association Code
T1:	***Tecticornia* spp. scattered low shrubs**	**mf**
Areas of coastal mudflat are regularly inundated by tidal movements, and hence feature only very scattered shrubs, mainly of samphires (*Tecticornia* spp.) but occasionally of White Mangrove (*Avicennia marina*). This unit was in Excellent condition.		
T2:	***Avicennia marina* open scrub**	**AVm**
Areas of mangal (mangrove vegetation) dominated by White Mangrove (*Avicennia marina*) were mapped along the coastal section of the Wheatstone plant study area by OEC (2008 and 2009a). Other species identified in OEC (2009a) as associated with the mangal included Spurred Mangrove (*Ceriops tagal*), and low halophytic shrubs such as *Muellerolimon salicorniaceum, Suaeda arbusculoides* and *Tecticornia halocnemoides* subsp. *tenuis*. Most of these areas were not able to be accessed during the current study as the intervening tidal mudflats were under water. This unit would be expected to be in Excellent condition, as weeds are typically unable to invade such harsh habitats.		

5.2.2 Vegetation of Coastal Sand Dunes

Occurring behind a narrow beach-front, the foredunes and near-coastal sand dunes were distinct from the more consolidated red sand dunes further inland, having an overstorey dominated by *Acacia coriacea* subsp. *coriacea*. In addition, the coastal foredunes had significant amounts of Beach Spinifex (*Spinifex longifolius*) in the understorey, which was replaced by Soft Spinifex (*Triodia epactia*) further inland.

Unit Code	Description	Sub-association Code
CD1:	***Acacia coriacea* subsp. *coriacea*, *Crotalaria cunninghamii* tall shrubland over *Spinifex longifolius*, (*Cenchrus ciliaris) open tussock grassland**	**AcCRcSXlCEc**
This vegetation occurred on the pale tan sands of the coastal foredunes (Plate 5.1 and Plate 5.2). Depending on the location, scattered hummocks of *Triodia epactia* were also sometimes present. Other species typically associated with this unit included *Adriana tomentosa* var. *tomentosa, Corynotheca pungens, Eriachne gardneri, Euphorbia myrtoides, Ipomoea costata, Salsola tragus, Scaevola spinescens, Sporobolus virginicus, Threlkeldia diffusa, Tribulus occidentalis* and *Trichodesma zeylanicum* var. *grandiflorum*. This vegetation was typically in Very Good to Good condition, with usually only scattered individuals of Buffel Grass (**Cenchrus ciliaris*).		

Unit Code	Description	Sub-association Code
CD2:	**Acacia coriacea subsp. coriacea tall shrubland over Crotalaria cunninghamii, Trichodesma zeylanicum var. grandiflorum open shrubland over Triodia epactia open hummock grassland with *Cenchrus ciliaris open tussock grassland**	**AcCRcTRzTeCEc**
This vegetation occurred on the near-coastal dunes behind the foredunes (Plate 5.3). Other species typically associated with this vegetation sub-association included *Adriana tomentosa* var. *tomentosa, Cassytha capillaris, Corynotheca pungens, Euphorbia myrtoides, Indigofera colutea, Olearia dampieri* subsp. *dampieri, Pityrodia loxocarpa, Rhagodia eremaea, Rhynchosia minima, Salsola tragus, Scaevola sericophylla, Sida rohlenae* subsp. *rohlenae, Solanum lasiophyllum, Threlkeldia diffusa* and *Tribulus occidentalis*. This vegetation was typically only in Good to Poor condition, often being invaded by **Cenchrus ciliaris*.		

Plate 5.1: **Unit CD1 on coastal foredune (quadrat WH46).**

Plate 5.2: **Unit CD1 on coastal foredune (quadrat WH49).**

Plate 5.3: **Unit CD2 on near-coastal dune (quadrat WH41).**

5.2.3 Vegetation of Inland Sand Dunes

There were numerous low linear sand dunes within the Wheatstone study area, which were relatively consistent in dominant species. Two vegetation sub-associations have been identified, discriminated broadly by the dominance of *Triodia epactia* versus *Triodia schinzii* in the hummock grassland understorey. Narrow swales between these dunes typically featured scattered tall shrubs of the dominant species from the dunes, along with a higher density of *Acacia stellaticeps* low shrubs.

A number of the plant species recorded from the inland sand dunes are essentially restricted to sandy substrates: these include the Priority 3 shrubs *Eremophila forrestii* subsp. *viridis* and *Triumfetta echinata*, and the undescribed taxon *Aenictophyton* aff. *reconditum*. All of these species were recorded from a small number of dunes within the Wheatstone study area, including both of the inland dune vegetation sub-associations, and were not noted in any other habitat (see Section 6.2).

Unit Code	Description	Sub-association Code
ID1:	**Grevillea stenobotrya tall open shrubland over Crotalaria cunninghamii, Trichodesma zeylanicum var. grandiflorum open shrubland over Triodia epactia open hummock grassland**	**GsCRcTRzTe**
This vegetation sub-association was recorded from consolidated linear red sand dunes within the Wheatstone plant study area, occurring broadly over the dune crests, slopes and in less prominent swales (cf. unit AstTe) (Plate 5.4 and Plate 5.5). Although the description above includes the principal dominant species, depending on the location, other species such as *Acacia stellaticeps* were sometimes co-dominant. Although such habitat would be highly susceptible to weed invasion (by Buffel Grass and Kapok), most of the dunes were still in Very Good to Good condition, typically with less than 10% cover of **Cenchrus ciliaris* noted. Other associated species included *Acacia coriacea* subsp. *coriacea, Aristida holathera* var. *holathera, Bonamia* aff. *linearis, B. rosea, Cassytha capillaris, Corchorus sidoides* var. *vermicularis*, occasionally *Corymbia zygophylla, Corynotheca pungens, Desmodium filiforme, Euphorbia myrtoides, Evolvulus alsinoides* var. *decumbens, Grevillea eriostachya, Hakea stenophylla* subsp. *stenophylla, Indigofera colutea, Ipomoea muelleri, I. polymorpha, Olearia dampieri* subsp. *dampieri, Pityrodia loxocarpa, P. paniculata, Rhagodia eremaea, Rhynchosia minima, Scaevola sericophylla, Sida rohlenae* subsp. *rohlenae, Solanum diversiflorum, S. lasiophyllum, Tephrosia rosea* var. *clementii, T. gardneri, Urochloa holosericea* subsp. *velutina* and *Verticordia forrestii.*		
ID2:	**Grevillea stenobotrya tall open shrubland over Crotalaria cunninghamii, Hibiscus brachychlaenus open shrubland over Triodia schinzii, (T. epactia) open hummock grassland**	**GsCRcHBbTsTe**
This vegetation sub-association was recorded from consolidated linear red sand dunes within the Wheatstone camp and pipeline study areas, occurring broadly over the dune crests, slopes and in less prominent swales (Plate 5.6 and Plate 5.7). Although the unit title includes the principal dominant shrub species, other species such as *Acacia stellaticeps, Adriana tomentosa* var. *tomentosa* and *Stylobasium spathulatum* were sometimes co-dominant depending on the location. Although such habitat would be highly susceptible to weed invasion (by Buffel Grass and Kapok), most of the dunes were in Very Good condition, with only scattered individuals of **Cenchrus ciliaris* noted. Exceptions were those dunes in close proximity to stock-watering points (e.g. in the southern section of the Wheatstone camp study area; quadrat WH29), which were obviously more frequently traversed by cattle and supported a higher density of weeds; these were considered to be in Good to Poor condition. Other associated species included *Acacia coriacea* subsp. *coriacea*, *Aristida holathera* var. *holathera, Bonamia linearis, B. rosea, Bulbostylis barbata, Cassytha capillaris, Corchorus sidoides* var. *vermicularis*, *Cucumis maderaspatanus, Cullen martinii, Desmodium filiforme, Eriachne gardneri, Grevillea eriostachya, Ptilotus arthrolasius, Scaevola sericophylla, Sida rohlenae* subsp. *rohlenae, Solanum lasiophyllum, Tephrosia gardneri, Trianthema pilosa, Tribulus occidentalis, Trichodesma zeylanicum* var. *grandiflorum* and *Urochloa holosericea* subsp. *velutina.*		
ID3:	**Acacia stellaticeps shrubland over Triodia epactia hummock grassland**	**AstTe**
This vegetation occurred in more well-defined swales between the above dunes, as well as on sloping sand sheets adjacent to some of the larger dunes (Plate 5.8 and Plate 5.9). Other associated species included *Acacia coriacea* subsp. *coriacea*, *A. tetragonophylla, Bonamia rosea, Cassytha capillaris, Diplopeltis eriocarpa, Grevillea eriostachya, Indigofera boviperda* subsp. *boviperda, I. colutea, Petalostylis cassioides, Pityrodia loxocarpa, Solanum lasiophyllum* and *Verticordia forrestii*. This vegetation sub-association was generally in Very Good condition.		

Plate 5.4: Unit ID1 on red sand dune (within the Wheatstone camp study area).

Plate 5.5: Unit ID1 on red sand dune (relevé WSB-15).

Plate 5.6: Unit ID2 on red sand dune (WH10).

Plate 5.7: Unit ID2 on red sand dune (WH13).

Plate 5.8: Unit ID3 in dune swale (relevé WSB-16).

Plate 5.9: Unit ID3 in dune swale (relevé WSB-25).

5.2.4 Vegetation of Coastal Sand Plains

The majority of the Wheatstone plant and camp study areas and the western section of the Wheatstone pipeline study area comprised flat to gently undulating sandy inland plains, which were broadly dominated by Soft Spinifex (*Triodia epactia*) hummock grasslands with a varying degree of invasion by introduced perennial grasses (**Cenchrus* species).

<table>
<tr><th>Unit Code</th><th>Description</th><th>Sub-association Code</th></tr>
<tr><td>CS1:</td><td>**Acacia tetragonophylla scattered shrubs over Triodia epactia hummock grassland**</td><td>**AteTe**</td></tr>
<tr><td colspan="3">This vegetation sub-association broadly dominated the undulating sandy plains of the southern half of the Wheatstone plant and camp study areas and the western section of the Wheatstone pipeline study area. It occurred on the orange-brown sands to sandy loams between the low-lying claypan/clayey plain habitats and the more elevated red sand dune systems (Plate 5.10 and Plate 5.11). Small patches of Buffel Grass (**Cenchrus ciliaris*) and occasional shrubs of Mesquite (**Prosopis pallida*) and Mimosa Bush (**Vachellia farnesiana*) were recorded, but did not dominate the landscape; this unit was considered to be in Very Good to Excellent condition overall. Other associated species included *Acacia synchronicia, Bonamia* aff. *linearis, Bulbostylis barbata, Crotalaria medicaginea* var. *neglecta, C. ramosissima, Desmodium filiforme, Evolvulus alsinoides* var. *decumbens* and var. *villosicalyx, Fimbristylis dichotoma, Goodenia forrestii, Indigofera colutea, I. linifolia, Ipomoea polymorpha, Pluchea dunlopii, Polygala* aff. *isingii, Rhynchosia minima, Scaevola spinescens* (both the typical narrow leaved taxon and the broad-leafed form), *Solanum lasiophyllum, Trichodesma zeylanicum* var. *grandiflorum* and **Vachellia farnesiana*.</td></tr>
<tr><td>CS2:</td><td>**Acacia tetragonophylla scattered shrubs over Triodia epactia hummock grassland with *Cenchrus ciliaris open tussock grassland**</td><td>**AteTeCEc**</td></tr>
<tr><td colspan="3">This vegetation sub-association is essentially unit AteTe in Poor condition through invasion by Buffel Grass (**Cenchrus ciliaris*; see Plate 5.12 and Plate 5.13). Occasional shrubs of Mesquite (**Prosopis pallida*) and Mimosa Bush (**Vachellia farnesiana*) were also typically present. It was not always possible to map this unit separately, as it typically occurred throughout the same areas as AteTe (although more common through the northern section of the Wheatstone plant study area) on substrates which had been physically disturbed (e.g. at the junction between claypans and the more elevated sandy plain, where the substrate was loose and unstable and prone to wind erosion; and along the edges of vehicle tracks); or on substrates which were in lower-lying, more mesic areas. Such substrates favoured the occurrence of a number of coloniser species or species more typical of clayey areas which were less common or absent from the more general AteTe vegetation sub-association. Associated species included *Acacia synchronicia, Atriplex bunburyana, Bulbostylis barbata, Cassytha capillaris, Chrysopogon fallax, Crotalaria medicaginea* var. *neglecta, Cyperus bulbosus, Dactyloctenium radulans, Eulalia aurea, Evolvulus alsinoides* var. *villosicalyx, Fimbristylis dichotoma, Indigofera colutea, I. linifolia, I. linnaei, I. trita, Ipomoea polymorpha, Lawrencia viridigrisea, Neobassia astrocarpa, Polygala* aff. *isingii, Rhynchosia minima, Sclerolaena uniflora, Solanum lasiophyllum, Stemodia* sp. Onslow (A.A. Mitchell 76/148), *Trianthema turgidifolia, Trichodesma zeylanicum* var. *grandiflorum,* **Vachellia farnesiana* and *Vigna* sp. Hamersley clay (A.A. Mitchell PRP 113).</td></tr>
</table>

Plate 5.10: **Unit CS1 (quadrat WH56).**

Plate 5.11: **Unit CS1 (Wheatstone plant study area).**

Plate 5.12: **Unit CS2 (quadrat WH03).**

Plate 5.13: **Unit CS2 (quadrat WH63).**

Unit Code	Description	Sub-association Code
CS3:	**Acacia tetragonophylla scattered shrubs over Scaevola pulchella, Indigofera monophylla low open shrubland over Triodia epactia hummock grassland**	**AtSCpImTe**
Small patches within the Wheatstone plant study area showed outcropping calcrete patches or surface scatters of calcrete pebbles (Plate 5.14 and Plate 5.15). These were very similar to AteTe, but included some key indicator species such as *Heliotropium pachyphyllum, Indigofera monophylla* (Burrup form), *Maireana lanosa* and *Scaevola pulchella*. *Acacia bivenosa* was apparently dominant in the overstorey in some areas (OEC 2009a), however these were not able to be accessed during the 2009 survey. Other associated species included *Bonamia* aff. *linearis, Cassytha capillaris, Crotalaria medicaginea* var. *neglecta, Diplopeltis eriocarpa, Evolvulus alsinoides* var. *villosicalyx, Ptilotus exaltatus* var. *exaltatus, Rhynchosia minima, Solanum diversiflorum* and *S. lasiophyllum*. This vegetation was in Very Good to Good condition, with varying amounts of invasion by Buffel Grass (*Cenchrus ciliaris*).		
CS4:	***Prosopis pallida, Acacia tetragonophylla, A. synchronicia scattered tall shrubs over Triodia epactia very open hummock grassland and *Cenchrus ciliaris open tussock grassland**	**PRpAteAsyTeCEc**
This vegetation occurred on orange-brown loamy sands in "wind scalded" areas fringing claypans (Plate 5.16 and Plate 5.17). Shrubs of *Atriplex bunburyana* commonly provided a sparse to open cover, and annual herbs and grasses contributed a relatively high cover. Associated species included *Atriplex codonocarpa, Boerhavia* spp., *Chrysopogon fallax, Crotalaria medicaginea* var. *neglecta, Cullen cinereum, Dactyloctenium radulans, Dichanthium sericeum* subsp. *humilius, Eragrostis xerophila, Eulalia aurea, Flaveria australasica, Indigofera colutea, I. linifolia, I. trita, Lawrencia viridigrisea, Neobassia astrocarpa, Polygala* aff. *isingii, *Portulaca oleracea, Rhynchosia minima, Sclerolaena uniflora* and *Trianthema triquetra*. This vegetation was considered to be in Poor condition due to invasion by Buffel Grass (*Cenchrus ciliaris*).		

Plate 5.14: Unit CS3 (quadrat WH48).

Plate 5.15: Unit CS3 (quadrat WH51).

Plate 5.16: Unit CS4 in a scalded area (Wheatstone camp study area).

Plate 5.17: Unit CS4 in a scalded area (quadrat WH44).

5.2.5 Vegetation of Claypans

Claypan areas were scattered throughout the Wheatstone plant and camp study areas and the western quarter of the Wheatstone pipeline study area. These ranged in size, degree of connectivity with tidal areas (connected and seasonally inundated; or isolated), and apparently in the degree of permeability of the substrate (lending some to hold water for several weeks, while others of similar size were dry). The degree of vegetative cover on these claypans varied as described below, but most were fringed by a narrow band of ephemeral grasses, sedges and herbs, including species such as *Calotis plumulifera, Centipeda minima* subsp. *macrocephala, Dysphania platycarpa* and *Eragrostis leptocarpa*.

Unit Code	**Description**	**Sub-association Code**
C1:	**Bare claypan**	**cp**
There were numerous "bare" claypans (Plate 5.18) and small scalded areas (Plate 5.19) within the Wheatstone study area, which typically had only very sporadic perennial shrubs, and otherwise supported scattered plants of annual species (either as a fringing band or as a more general, scattered cover). Commonly recorded species included the grasses *Dactyloctenium radulans* and *Eragrostis pergracilis*, and the herbs *Atriplex codonocarpa, A. semilunaris, Ptilotus murrayi, Swainsona pterostylis* and *Trianthema triquetra*. Other associated species included *Calandrinia ptychosperma, Corchorus tridens, Dysphania rhadinostachya, Fimbristylis dichotoma, Indigofera linifolia, Marsilea hirsuta, Polygala* aff. *isingii* and *Synaptantha tillaeacea* var. *tillaeacea*. This unit was considered to be in Excellent to Very Good condition.		

Unit Code	Description	Sub-association Code
C2:	**Eriachne aff. benthamii open tussock grassland**	**ERIb**
Open tussock grasslands of *Eriachne* aff. *benthamii* dominated some of the wetter and less saline claypan areas, and occurred in patches fringing otherwise "bare" claypans (see Plate 5.20). Other associated species were few, but included *Cressa australis, Eulalia aurea, Gomphrena sordida, Goodenia lamprosperma* and *Sporobolus mitchellii*. This vegetation sub-association was in Excellent condition.		
C3:	**Tecticornia spp.[11] low shrubland**	**TECspp**
Low open shrublands to low shrublands dominated by samphires were common on or fringing saline claypans with some degree of connectivity with tidal areas. The cover of annual herbs and grasses varied depending on the frequency of inundation and the salinity of the site, and bunch grasslands dominated by *Eragrostis pergracilis* were a conspicuous feature of infrequently inundated claypans (see Plate 5.21 to Plate 5.24). *Frankenia ambita* was often dominant along the upper edges of this habitat, occurring with open tussock grasslands of Marine Couch (*Sporobolus virginicus*) and with *Lawrencia viridigrisea, Neobassia astrocarpa* and *Trianthema turgidifolia*. Other associated species included *Alternanthera nodiflora, Chloris pumilio, Crotalaria medicaginea* var. *neglecta, Cullen cinereum, Cyperus bulbosus, C. rigidellus, C. squarrosus, Dysphania plantaginella, Flaveria australasica, Lawrencia viridigrisea, Marsilea hirsuta, Mimulus gracilis, Muellerolimon salicorniaceum, Neobassia astrocarpa, Pluchea rubelliflora, Ptilotus murrayi, Sesbania cannabina, Sporobolus mitchellii* and *Streptoglossa bubakii*. This vegetation was generally in Excellent condition.		

Plate 5.18: **Small bare claypan at western end of Wheatstone pipeline study area (note fringing annual species).**

Plate 5.19: **"Scald" supporting scattered annual flora species.**

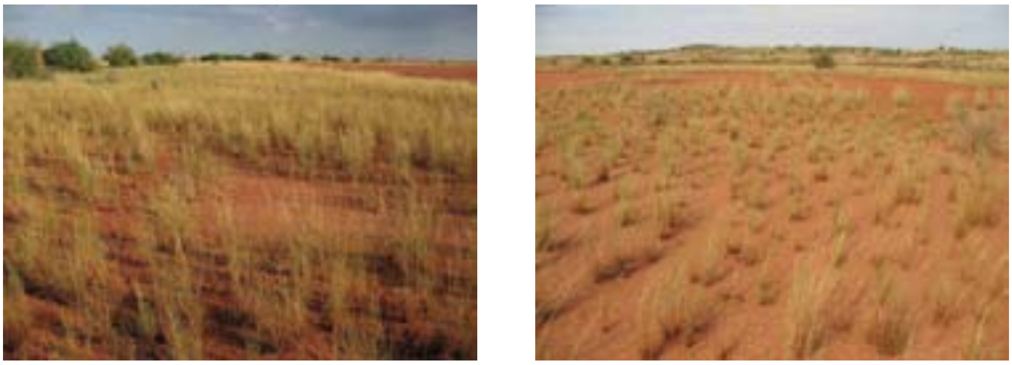

Plate 5.20: **Unit C2 within claypans.**

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[11] Numerous specimens of *Tecticornia* were collected from the Wheatstone study area, and a number of different taxa were identified, however many of the specimens were sterile and could not be identified to species level. Given this, it is considered most appropriate to define vegetation units dominated by samphires only as containing "*Tecticornia* spp.", to indicate that various species may be present.

Plate 5.21: **Unit C3 (Tecticornia spp. low open shrubland in tidal claypan; quadrat WH40).**

Plate 5.22: **Unit C3 (Tecticornia spp. low open shrubland over Eragrostis pergracilis annual bunch grassland in claypan; quadrat WH22).**

Plate 5.23: **Unit C3 (Tecticornia spp. low open shrubland over Eragrostis pergracilis open annual bunch grassland dominating tidal claypan in western section of Wheatstone pipeline study area).**

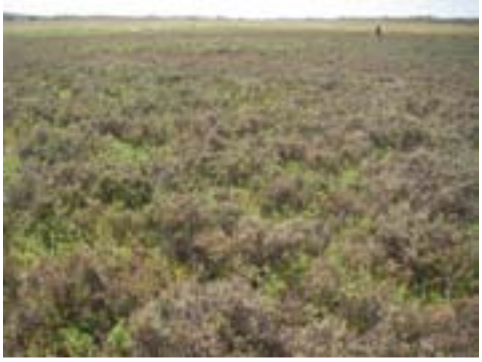

Plate 5.24: **Unit C3 (Tecticornia spp. low open shrubland over Cullen cinereum herbs in saline drainage area; quadrat WH55).**

5.2.6 Vegetation of Clayey Plains

Some broad areas of clayey plain were present, particularly within the Wheatstone camp study area and western section of the Wheatstone pipeline study area, which supported tussock grasslands of various native species. Other small pockets of clayey substrate formed in drainage depressions, and supported tall shrublands of Mesquite (**Prosopis pallida*) and/or native species over tussock grasslands of native and/or introduced species. Areas of clayey plain along the eastern section of the Wheatstone pipeline study area supported Snakewood (*Acacia xiphophylla*) tall shrublands over various spinifex species.

Unit Code	Description	Sub-association Code
CP1:	**Sporobolus mitchellii, Eriachne aff. benthamii, E. benthamii, Eulalia aurea tussock grassland**	**SPmERIbEUa**
This vegetation sub-association occurred on heavy clay plains in low-lying areas within the Wheatstone plant and camp study areas and northern half of the Wheatstone pipeline study area. Depending on the location, Marine Couch (*Sporobolus virginicus*) or Knotty-butt Neverfail (*Eragrostis xerophila*) were sometimes co-dominant in the grass layer. The swathe of this vegetation along the Onslow Road had scattered low trees of Coolibahs (*Eucalyptus victrix*). Scattered tall shrubs of Mesquite (**Prosopis pallida*) and Mimosa Bush (**Vachellia farnesiana*) were often present in the Wheatstone camp study area, but did not dominate this habitat. Other associated species included very scattered shrubs of *Acacia synchronicia, A.*		

<table>
<tr><td colspan="3"><i>tetragonophylla, Atriplex bunburyana</i> and <i>Scaevola spinescens</i>; annual sedges such as <i>Cyperus iria, C. rigidellus, C. squarrosus</i> and <i>Schoenoplectus dissachanthus</i>; grasses including <i>Brachyachne convergens, Chloris pumilio, Dactyloctenium radulans, Dichanthium sericeum</i> subsp. <i>humilius, Eragrostis pergracilis, Leptochloa fusca</i> subsp. <i>muelleri, Panicum decompositum</i> and <i>P. laevinode</i>; and the herbs <i>Aeschynomene indica, Alternanthera nodiflora, Alysicarpus muelleri, Centipeda minima</i> subsp. <i>macrocephala, Crotalaria medicaginea</i> var. <i>neglecta, Cucumis maderaspatanus, Cullen cinereum, Ipomoea coptica, Marsilea hirsuta, Neptunia dimorphantha, Pluchea rubelliflora, Ptilotus murrayi, Rostellularia adscendens</i> var. <i>clementii, Sesbania cannabina</i> and <i>Streptoglossa bubakii</i>. This vegetation was generally in Very Good condition, occasionally Excellent.</td></tr>
<tr><td>CP2:</td><td>*Prosopis pallida scattered tall shrubs to tall open shrubland over Acacia tetragonophylla, *Vachellia farnesiana shrubland over Eulalia aurea, Chrysopogon fallax, Sporobolus mitchellii tussock grassland</td><td>PRpAteVfEUaCHfSPm</td></tr>
<tr><td colspan="3">This vegetation developed on clayey plains in drainage depressions within the more general tussock grassland vegetation (Plate 5.27 and Plate 5.28). Generally these areas had surprisingly minimal amounts of the weeds Mesquite (*<i>Prosopis pallida</i>) and Buffel Grass (*<i>Cenchrus ciliaris</i>), with the exception being areas in close proximity to stock-watering points. Other associated species included scattered shrubs of <i>Acacia sclerosperma, A. synchronicia</i> and <i>Scaevola spinescens</i>; annual sedges including <i>Cyperus rigidellus</i>; grasses such as <i>Eriachne benthamii</i> and <i>Panicum decompositum</i>; herbs including <i>Aeschynomene indica, Alternanthera nodiflora, Alysicarpus muelleri, Cucumis maderaspatanus, Cullen cinereum, Indigofera colutea, I. linifolia, Ipomoea coptica, I. muelleri, Marsilea hirsuta, M. drummondii, Pluchea rubelliflora, Rhynchosia minima</i> and <i>Sesbania cannabina</i>. This vegetation was in Good to Very Good condition.</td></tr>
</table>

Plate 5.25: **Unit CP1 (quadrat WH50).**

Plate 5.26: **Unit CP1 (quadrat WH64).**

Plate 5.27: **Unit CP2 within drainage depression (Wheatstone camp study area).**

Plate 5.28: **Unit CP2 within drainage depression (quadrat WH54).**

Unit Code	Description	Sub-association Code
CP3:	**Acacia xiphophylla tall shrubland over Triodia epactia open hummock grassland**	**AxTe**
This vegetation occurred on areas of clayey plain along the eastern section of the Wheatstone pipeline study area (Plate 5.29). Other associated species included *Brachyachne prostrata* and *Dactyloctenium radulans*. This vegetation was in Very Good condition, with some invasion by Buffel Grass (**Cenchrus ciliaris*).		
CP4:	**Acacia xiphophylla tall shrubland over Triodia lanigera open hummock grassland**	**AxTla**
This vegetation occurred on more elevated areas of clayey plain along the eastern section of the Wheatstone pipeline study area (Plate 5.30 and Plate 5.31). Other associated species included *Abutilon fraseri, Acacia synchronicia, Aristida contorta, Brachyachne prostrata, Cassia luerssenii, C.* aff. *oligophylla* (thinly sericeous) x *helmsii, Cucumis maderaspatanus, Dactyloctenium radulans, Dichanthium sericeum* subsp. *humilius, Enneapogon caerulescens, Eriachne pulchella* subsp. *dominii, Evolvulus alsinoides* var. *villosicalyx, Iseilema dolichotrichum, Maireana planifolia, Rhagodia eremaea, Salsola tragus, Solanum lasiophyllum, Sporobolus australasicus* and *Tripogon loliiformis*. This vegetation was in Very Good to Excellent condition.		
CP5:	**Acacia xiphophylla tall open shrubland over Triodia brizoides very open hummock grassland**	**AxTbr**
This vegetation occurred on more elevated areas of plain with a somewhat clayey substrate along the eastern section of the Wheatstone pipeline study area, particularly those with a surface layer of calcareous/quartz pebbles (Plate 5.32, Plate 5.33). This habitat was relatively arid and species poor, with the few other species noted comprising *Abutilon fraseri, Acacia synchronicia, Brachyachne prostrata, Bulbostylis barbata, Dichanthium sericeum* subsp. *humilius, Enneapogon caerulescens, Enteropogon ramosus, Eriachne pulchella* subsp. *dominii, Evolvulus alsinoides* var. *villosicalyx, Iseilema dolichotrichum, Rhagodia eremaea, Solanum ellipticum, Sporobolus australasicus* and *Trianthema triquetra*. This vegetation was in Excellent condition.		

Plate 5.29: **Unit CP3 (Wheatstone pipeline study area).**

Plate 5.30: **Unit CP4 (quadrat WH32).**

Plate 5.31: **Unit CP4 (Wheatstone pipeline study area).**

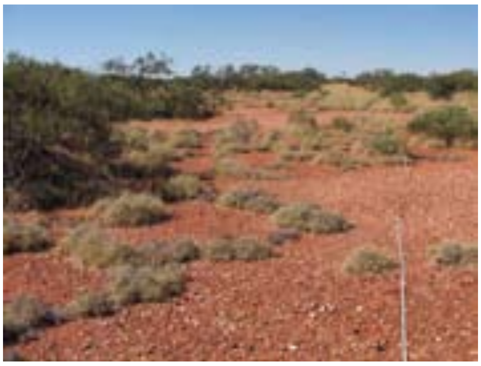

Plate 5.32: **Unit CP5 (quadrat WH35).**

Plate 5.33: **Unit CP5 (Wheatstone pipeline study area).**

5.2.7 Vegetation of Inland Sand Plains

Broad sandy plains were present along the central and eastern sections of the Wheatstone pipeline study area, and these supported very different species to the sand plains of the more coastal sections of the Wheatstone study area. Two vegetation sub-associations were described.

Unit Code	Description	Sub-association Code
IS1:	**Corymbia hamersleyana scattered low mallees over Acacia ancistrocarpa, A. bivenosa shrubland over Triodia lanigera hummock grassland**	ChAaAbTla
This vegetation occurred broadly over the general sandy plain in the central and eastern sections of the Wheatstone pipeline study area (Plate 5.34 and Plate 5.35). While Coolibahs (*Eucalyptus victrix*) are more typically located in drainage areas in the Pilbara, this species occurred occasionally within this vegetation unit and appeared to be more broadly distributed over the general plains in the Onslow area. The trees were generally in mallee form (atypical for these species), presumably arising from coppicing as the result of frequent fires through the area. Along the western section of the Wheatstone pipeline study area, there was typically a variable cover of the shrub *Acacia stellaticeps*, ranging from a low shrubland to only scattered shrubs. There was often an admixture of *Triodia schinzii* in the hummock grassland stratum, with *Triodia epactia* occurring in low-lying areas. Other associated species included *Acacia inaequilatera, A. synchronicia, Aristida contorta, A. holathera* var. *holathera, Bonamia rosea, Bulbostylis barbata, Cleome uncifera, Corymbia candida, C. zygophylla, Cucumis maderaspatanus, Dicrastylis cordifolia, Eragrostis eriopoda, Eriachne aristidea, E. pulchella* subsp. *dominii, Eucalyptus xerothermica, Euphorbia australis, Goodenia microptera, Grevillea eriostachya, Hakea lorea* subsp. *lorea, Indigofera boviperda* subsp. *boviperda, Isotropis atropurpurea, Mollugo molluginea, Polycarpaea corymbosa* var. *corymbosa, Polygala* aff. *isingii, Ptilotus astrolasius* var. *astrolasius, P. axillaris, P. fusiformis* var. *fusiformis, Scaevola parvifolia* subsp. *pilbarae, S. spinescens, Stemodia* sp. Onslow (A.A. Mitchell 76/148), *Triumfetta* aff. *chaetocarpa* (H123-10) and *Yakirra australiensis* var. *australiensis*. This vegetation was typically in Excellent condition, with only scattered weeds observed, mainly along road verges.		
IS2:	**Acacia inaequilatera tall open shrubland over A. ancistrocarpa open shrubland over Triodia lanigera open hummock grassland**	AiAaTla
This vegetation occurred on slightly elevated areas within the more general stony plain dominated by unit ChAaAbTla (Plate 5.36 and Plate 5.37). Other associated species included *Acacia synchronicia, Aristida contorta, A. holathera* var. *holathera, Bonamia* aff. *linearis, Bulbostylis barbata, Cleome uncifera, Corymbia hamersleyana, Eriachne aristidea, E. pulchella* subsp. *dominii, Euphorbia australis* (mid-green form), *Goodenia microptera, Mollugo molluginea, Ptilotus astrolasius* var. *astrolasius, P. axillaris, P. fusiformis, Triumfetta* aff. *chaetocarpa* (H123-10) and *Yakirra australiensis* var. *australiensis*. This vegetation was considered to be in Very Good to Excellent condition.		

Plate 5.34: **Unit IS1 (quadrat WH16).**

Plate 5.35: **Unit IS1 (Wheatstone pipeline study area).**

Plate 5.36: **Unit IS2 (Wheatstone pipeline study area).**

Plate 5.37: **Unit IS2 (quadrat WH20).**

5.2.8 Vegetation of Stony Hills

Stony hills were present towards the eastern end of the Wheatstone pipeline study area and these supported a single vegetation sub-association.

Unit Code	Description	Sub-association Code
H1:	**Acacia inaequilatera tall open shrubland over Triodia lanigera, T. brizoides open hummock grassland**	**AiTlaTbr**
This vegetation occurred on two stony hills within the Wheatstone pipeline study area, both of which had a substrate of quartz stones and rocks (Plate 5.38). Other associated species included very scattered shrubs of *Acacia ancistrocarpa, A. bivenosa* and *A. synchronicia*, together with scattered *Aristida holathera* var. *holathera, Bonamia rosea, Bulbostylis barbata, Cassia* spp., *Enneapogon caerulescens, Eriachne pulchella* subsp. *dominii, Evolvulus alsinoides* var. *villosicalyx, Fimbristylis dichotoma, Hybanthus aurantiacus, Indigofera boviperda* subsp. *boviperda, Mollugo molluginea, Paraneurachne muelleri, Portulaca pilosa, Sida echinocarpa, S. rohlenae* subsp. *rohlenae* and *Sporobolus australasicus*. This vegetation was in Excellent condition.		

Plate 5.38: **Unit H1 (quadrat WH27).**

5.2.9 Vegetation of Drainage Areas

Apart from the drainage features associated with the coastal section of the Wheatstone study area, there were few conspicuous drainages within the study area. Only three drainage units were described, one at the southern end of the Wheatstone plant study area and two along the Onslow Road in the Wheatstone pipeline study area.

Unit Code	Description	Sub-association Code
D1:	**Eucalyptus victrix open forest over Eulalia aurea, *Cenchrus ciliaris tussock grassland**	**EvEUaCEc**
This vegetation sub-association was recorded in a tributary of the Ashburton River at the southern boundary of the Wheatstone plant study area (Plate 5.39). Other associated species included *Alternanthera nodiflora, Cucumis maderaspatanus, Leptochloa digitata, *Malvastrum americanum, *Parkinsonia aculeata, *Passiflora foetida* var. *hispida, Rhynchosia minima, Sesbania formosa, Setaria dielsii, *Vachellia farnesiana* and *Vigna lanceolata*. This Vegetation was in Poor condition, containing substantial infestations of weeds.		
D2:	**Eucalyptus victrix scattered low trees over Acacia synchronicia, A. bivenosa shrubland over Triodia epactia hummock grassland**	**EvAsyAbTe**
This vegetation occurred on a broad area of clayey plain in the western section of the Wheatstone pipeline study area (Plate 5.40). Other associated species included *Acacia ancistrocarpa, A. sclerosperma, A. tetragonophylla, Chrysopogon fallax, Cyperus iria, Dactyloctenium radulans, Gossypium australe* (Burrup Peninsula form), *Ipomoea muelleri, *Portulaca oleracea, Ptilotus exaltatus* var. *exaltatus, Sida arsiniata, Sporobolus australasicus, Stemodia* sp. Onslow (A.A. Mitchell 76/148), *Trianthema triquetra* and *T. turgidifolia*. This vegetation was in Very Good to Excellent condition.		

Plate 5.39: **Unit D1 (southern Wheatstone plant study area).**

Plate 5.40: **Unit D2 (quadrat WH11).**

Unit Code	Description	Sub-association Code
D3:	**Corymbia hamersleyana scattered low mallees over Acacia tumida var. pilbarensis, Grevillea wickhamii subsp. hispidula tall open shrubland over A. ancistrocarpa open shrubland over Triodia epactia, T. lanigera open hummock grassland**	**ChAtuGwAaTeTla**
This vegetation occurred in another broad, poorly defined drainage area at the eastern end of the Wheatstone pipeline study area (Plate 5.41 and Plate 5.42). Other associated species included *Acacia pyrifolia, Aristida holathera* var. *holathera, Boerhavia coccinea, Bonamia* aff. *linearis, B. rosea, Cucumis maderaspatanus, Eriachne pulchella* subsp. *dominii, Goodenia microptera, Hakea chordophylla, Indigofera colutea, Isotropis atropurpurea, Mollugo molluginea, Phyllanthus erwinii, Polycarpaea corymbosa* var. *corymbosa, Polygala* aff. *isingii, Ptilotus fusiformis Solanum lasiophyllum* and *S. sturtianum*. This vegetation was considered to be in Very Good to Excellent condition.		

Plate 5.41: Unit D3 (Wheatstone pipeline study area).

Plate 5.42: Unit D3 (quadrat WH30).

5.3 Floristic Analysis

Following is a discussion of the main patterns indicated by the PRIMER clustering analysis performed on the site data (see Section 3.7). Due to the size of the dataset used, there has been no attempt to present the dendrograms arising from the PRIMER analysis, however these are available for inspection if required.

Some suites of species are widespread in the region, while others appear to be more restricted in distribution (it should be noted that these patterns are based on a dataset highly clustered in its spatial distribution):

- Quadrats from the Snakewood (*Acacia xiphophylla*) vegetation units CP3, CP4 and CP5 clustered out separately within the dendrogram, occurring with other sites from over 100 km southwest and over 200 km northeast. The units were defined based on the different dominant spinifex species in the hummock grassland stratum (*T. epactia, T. lanigera* and *T. brizoides* for CP3, CP4 and CP5 respectively), and such clusters were supported by the SIMPROF analysis.
- Quadrats from the *Triodia lanigera* dominated vegetation types from the dry inland sandy plains and stony hills along the Wheatstone pipeline corridor (units IS1, IS2 and H1) clustered together with other inland sites from up to 132 southwest and 66 km northwest of Wheatstone.
- The primary coastal dunes without significant *Cenchrus ciliaris* invasion (unit CD1) clustered out with other sites from the Onslow locality, as well as sites from Cape Preston and Cape Lambert (150 km and 250 km northeast respectively). The secondary red sand dunes with *Triodia epactia* as the dominant spinifex (unit ID1) occurring within the Wheatstone study area also occurred in other study areas in the Onslow locality, and were represented as far as

the eastern side of the Exmouth Gulf, some 75 km southwest. A mixture of primary and secondary dune vegetation types (units CD2, ID1 and ID2) from the Onslow locality grouped out separately, and were quite distinct from dune habitats to the west. It appears that the presence of **Cenchrus ciliaris* in several of these quadrats may be at least partly responsible for this latter cluster.

- Sites from the Onslow locality on coastal sand plain with substantial amounts of **Cenchrus ciliaris* (unit CS2) clustered in the same broad section of the dendrogram, along with several sites up to 80 km southwest and a single site from Cape Preston, 150 km northwest. There was distinct patterning within this group of sites, with eight separate clusters supported by the SIMPROF analysis; it is not clear at this stage which species are driving this finer level variation. Sites from the Onslow locality on coastal sand plain in relatively good condition (i.e. with minimal **Cenchrus ciliaris*; unit CS1) generally clustered together in a single group, in association with sites from up to 125 km southwest.
- Quadrats within samphire vegetation (unit C3) at Wheatstone occurred in three main clusters in the dendrogram. One of these, the cluster containing relevé WH-MB, included sites distributed as far east as Port Hedland (over 400 km). The second cluster, containing quadrat WH40, included sites distributed as far west as the base of the Exmouth Gulf (116 km). The third cluster, containing quadrats WH22, WH52 and WH62, included sites from the Onslow locality only. In addition, quadrats WH08, WH28 and WH55 contained relatively large amounts of herb and grass species typically associated with the grasslands on clays (unit CP1); these sites were intermingled in clusters containing quadrats from the latter vegetation unit. There is clearly considerable variation between the samphire quadrats in terms of floristic composition.
- Quadrats located within grasslands on clayey plains (unit CP1) fell into two main clusters, which included only sites from the Onslow locality. Quadrats within drainage depressions in the same plains (unit CP2) also fell into two clusters, largely associated with sites from the Onslow locality, along with a single site from over 200 km northeast.
- The single quadrat in the drainage vegetation unit D3 grouped out with two others 60-80 km northeast.
- The single quadrat in the drainage vegetation unit D2 did not group with any other sites.

Based on the data sourced for the above analysis, it would be premature to describe any of the units which currently appear to be known only from the Onslow locality as genuinely rare. This is particularly true with respect to the samphire vegetation, bearing in mind the poor state of taxonomy of many of the taxa collected, and the limited number of regional samphire sites available for comparison (only 18 outside of the Onslow locality). It is suggested that further survey work in the northern Carnarvon and coastal Pilbara region should seek to address some of the gaps in distribution of flora sampling sites, particularly for habitats such as sand dunes, samphire and areas of clay.

5.4 Conservation Significance of the Vegetation Sub-Associations

5.4.1 Summary of Vegetation Condition

Overall, the vegetation of the majority of the Wheatstone pipeline study area (i.e. from the Onslow Road intersection to the east) was in Very Good to Excellent condition. Only scattered shrubs of Mesquite (**Prosopis pallida*) were noted within clayey plains habitats towards the northern end of this section, and Buffel Grass (**Cenchrus ciliaris*) was predominantly limited to the verges of the Onslow Road.

For the remainder of the Wheatstone study area (comprising the Wheatstone plant and camp study areas and the section of the Wheatstone pipeline study area west of the Onslow Road), the vegetation was largely in Very Good to Excellent condition (particularly the claypan areas and spinifex plains). However, a number of vegetation units were heavily infested with Buffel Grass (*Cenchrus ciliaris*) and/or Mesquite (*Prosopis pallida*); particularly units CD2, CS2 and CS4. Birdwood Grass (*Cenchrus setiger*) and Mimosa Bush (*Vachellia farnesiana*) were also recorded through these areas. Weed infestations were particularly prevalent in proximity to stock watering points, such as the dam in the southern section of the Wheatstone camp study area.

Fire effects were noted in a range of habitats throughout the study area, with only the claypan areas appearing largely untouched. In particular, the spinifex-dominated vegetation along the Onslow Road within the Wheatstone pipeline study area appeared to have been frequently burnt, with most of the Eucalypts showing evidence of coppicing after fires. These fire-effects were not considered to reduce the vegetation condition overall, with all areas appearing to regenerate well from the current fire regime.

5.4.2 Threatened Ecological Communities

No communities listed as TECs under the Commonwealth *EPBC Act 1999* or Western Australian *Wildlife Conservation Act 1950* occur in the Wheatstone study area. Although a small number of TECs have been defined for the Pilbara and Carnarvon bioregions by the Western Australian DEC, none of these are known to occur in the vicinity of Onslow (see DEC 2006).

5.4.3 Priority Ecological Communities

None of the vegetation sub-associations identified for the Wheatstone study area are PECs listed by the Western Australian DEC (see DEC 2008).

5.4.4 Groundwater-Dependent Communities

Of the vegetation sub-associations identified for the Wheatstone study area, none are likely to comprise ecosystems dependent entirely on groundwater. Most of the species recorded are xerophytic, sourcing their water requirements from the unsaturated zone of the soil profile. The only truly phreatophytic[12] species in the area comprised *Eucalyptus camaldulensis* (River Red Gum) and *Melaleuca argentea* (Silver Cadjeput), and these were recorded only as very occasional individuals in areas of ponding water adjacent to the Onslow Road. *Eucalyptus victrix* (Coolibah) was present as a dominant species in units D1 and D2, and was also scattered through the sandy plains along the Onslow Road. This species is generally believed to be vadophytic[13], particularly when occurring as small trees, however larger trees may behave as phreatophytes (see Biota 2002). Most of the trees in the Wheatstone study area were small stunted individuals, typically less than 5 m tall. Trees greater than 10 m in height were observed within unit EvEUaCEc, and this would represent the only potential groundwater-dependent vegetation in the Wheatstone study area.

5.4.5 Vegetation Sub-Associations of Local Conservation Significance

The methodology used for the conservation significance assessment is presented in Section 3.8, and the resulting matrix is presented in Appendix 6.

Although not formally listed as TECs or PECs, three vegetation sub-associations of High conservation significance and two units of Moderate significance were identified for the Wheatstone study area. The remainder of the vegetation sub-associations are considered to be relatively representative of the locality and of Low conservation significance. The relative

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[12] Phreatophytes are plants that are primarily or totally reliant on the saturated zone below the watertable to meet their physiological water requirements.

[13] Vadophytes are plants that source their water requirements from the vadose zone of the soil profile above the water table; their water is usually derived from surface flows or direct rainfall inflitrating the soil profile.

conservation significance of the various vegetation sub-associations is summarised in Table 5.1, along with the equivalent units from OEC (2009a).

High Significance

- The inland sand dune vegetation sub-associations (**ID1: GsCRcTRzTe** and **ID2: GsCRcHBbTsTe**) support Priority flora (*Eremophila forrestii* subsp. *viridis* and *Triumfetta echinata*), as well as other species of interest (*Aenictophyton* aff. *reconditum*) (see Sections 6.2.3 and 6.2.5.1). The dune features would also be particularly susceptible to erosion and weed invasion following disturbance of the soil profile.
- The samphire shrublands (**C3: TECspp**) contain a number of poorly recognised species (see Section 6.2.5.1), and it is difficult to determine their distribution in the region. This vegetation also supports the significant flora species *Eleocharis papillosa* (listed as Vulnerable under the *EPBC Act 1999*) within the Wheatstone pipeline study area (see Section 6.2.1).

Moderate Significance

- The cracking clay grasslands (**CP1: SPmERIbEUa**) are considered to be of Moderate conservation value, being generally in Very Good condition and supporting a suite of species specific to this substrate.
- Mangal is generally recognised as being of conservation significance, and is represented by the mangrove scrub along tidal creeks (**T2: AVm**) unit. Mangrove communities elsewhere along the Pilbara coast that are threatened by mining and other developments are considered to be “ecosystems at risk” by DEC (Kendrick and Stanley 2001).

Low Significance

- The remainder of the vegetation sub-associations are considered relatively representative of those occurring in the locality, or are substantially degraded by invasion of Buffel Grass (**Cenchrus ciliaris*), and are therefore considered to be of Low conservation significance. This is not meant to imply that they have no conservation value, but simply that they are of lower conservation significance than the units highlighted above.

Summary maps showing the vegetation units grouped by their significance levels are presented in Appendix 6.

Table 5.1: **Summary of vegetation sub-associations identified in the Wheatstone study area through this study, their relative conservation significance and the equivalent vegetation units from OEC (2009a).**

This Study				**Equivalent from OEC (2009a)**	
Landform	**Unit Code, Vegetation Sub-Association and Habitat**	**Sampling Sites**	**Conservation Status**	**Landform**	**Habitat / Vegetation Sub-Association**
Tidal Mudflats and Tidal Creeks	**T1:** *Tecticornia* spp. scattered low shrubs on mudflats (mf)	–	Low	Coastal Fringe	**1a: Intertidal Mud Flats** – *Avicennia marina* scattered tall shrubs over *Tecticornia halocnemoides* subsp. *tenuis* low scattered shrubs
	T2: *Avicennia marina* open scrub along tidal creeks (AVm)	WH-RB4	Moderate	Coastal Fringe	**1b: Tidal Swamp** – *Avicennia marina, Ceriops tagal* open scrub over *Tecticornia halocnemoides* subsp. *tenuis, Muellerolimon salicorniaceum* low shrubland
Coastal Sand Dunes	**CD1**: *Acacia coriacea* subsp. *coriacea, Crotalaria cunninghamii* tall shrubland over *Spinifex longifolius, (*Cenchrus ciliaris)* open tussock grassland on foredunes (AcCRcSXlCEc)	WH46, WH49	Low	Coastal Fringe	**1c: Foredune:** *Acacia coriacea* subsp. *pendens, Adriana tomentosa* var. *tomentosa* open shrubland over *Crotalaria cunninghamii, Trichodesma zeylanicum, Tephrosia gardneri, Euphorbia myrtoides* low open shrubland over *Spinifex longifolius* curly spinifex grassland over **Cenchrus ciliaris, Eriachne gardneri* very open tussock grassland
	CD2: *Acacia coriacea* subsp. *coriacea* tall shrubland over *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland on near-coastal dunes (AcCRcTRzTeCEc)	WH41, WH47, WSB-23	Low	Coastal Fringe	**1d: Coastal Dune:** *Acacia coriacea* subsp. *pendens* scattered tall shrubs over *Acacia coriacea* subsp. *pendens, Adriana tomentosa* var. *tomentosa* open shrubland over *Crotalaria cunninghamii, Trichodesma zeylanicum, Tribulus hystrix, Euphorbia myrtoides, Indigofera colutea* low open shrubland over *Triodia epactia* open hummock grassland over **Cenchrus ciliaris* open tussock grassland over *Bulbostylis barbata* very open sedgeland
Inland Sand Dunes	**ID1:** *Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland on red sand dunes (GsCRcTRzTe)	WH04, WH23, WH42, WH45, WSB-05, WSB-15	High	Undulating Inland Plain	**2c: Inland Dune:** *Acacia coriacea* subsp. *pendens, Grevillea stenobotrya* scattered tall shrubs over *Acacia coriacea* subsp. *pendens, Grevillea stenobotrya, Verticordia forrestii* subsp. *forrestii* open shrubland over *Scaevola sericophylla, Acacia stellaticeps, Bonamia rosea, Diplopeltis eriocarpa* low open shrubland over *Triodia epactia* hummock grassland over **Cenchrus ciliaris* very open tussock grassland
	ID2: *Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii, Hibiscus brachychlaenus* open shrubland over *Triodia schinzii, (T. epactia)* open hummock grassland on red sand dunes (GsCRcHBbTsTe)	WH09, WH10, WH13, WH29	High	Not present in OEC study area	

This Study				Equivalent from OEC (2009a)	
Landform	**Unit Code, Vegetation Sub-Association and Habitat**	**Sampling Sites**	**Conservation Status**	**Landform**	**Habitat / Vegetation Sub-Association**
Inland Sand Dunes (continued)	**ID3:** *Acacia stellaticeps* shrubland over *Triodia epactia* hummock grassland in swales (AstTe)	WSB-16, WSB-25	Low	Undulating Inland Plain	**2d: Interdunal Swale A**: *Grevillea stenobotrya, Hakea stenophylla* subsp. *stenophylla* open shrubland over *Hakea stenophylla* subsp. *stenophylla, Acacia stellaticeps, Bonamia rosea, Diplopeltis eriocarpa* low open shrubland over *Triodia epactia* hummock grassland over **Cenchrus ciliaris* very open tussock grassland **2e: Interdunal Swale B**: *Scaevola cunninghamii, Acacia stellaticeps* low shrubland over *Triodia epactia* hummock grassland over *Eriachne helmsii* very open tussock grassland
Coastal Sand Plains	**CS1:** *Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland occurring broadly over sandy plains (AteTe)	WH02, WH06, WH19, WH21, WH24, WH56, WH58, WH-MA, WH-RB2, WSB access, WSB set down, WSB-03, WSB-04	Low	Undulating Inland Plain	**2a: Plain**: *Indigofera linifolia, Vigna* sp. Hamersley clay, *Indigofera colutea* low open shrubland over *Triodia epactia* hummock grassland over **Cenchrus ciliaris, Sporobolus virginicus* open tussock grassland
	CS2: *Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland occurring on sandy plains, particularly fringing claypans (AteTeCEc)	WH01, WH03, WH43, WH57, WH60, WH63, WH66, WSB-08, WSB-09, WSB-10, WSB-12 (mosaic with unit SPmERIbEUa), WSB-14, WSB-17, WSB-18, WSB-24, WH-JFA, WH-JFC	Low	Undulating Inland Plain	**2b: Degraded Plain**: **Prosopis pallida* scattered tall shrubs over *Acacia tetragonophylla, A. synchronicia* scattered shrubs over *Atriplex bunburyana* low open shrubland over **Cenchrus ciliaris* tussock grassland over *Triodia epactia* open hummock grassland

This Study				**Equivalent from OEC (2009a)**	
Landform	**Unit Code, Vegetation Sub-Association and Habitat**	**Sampling Sites**	**Conservation Status**	**Landform**	**Habitat / Vegetation Sub-Association**
Coastal Sand Plains (continued)	**CS3:** *Acacia tetragonophylla* scattered shrubs over *Scaevola pulchella, Indigofera monophylla* low open shrubland over *Triodia epactia* hummock grassland on areas of calcrete (AtSCpImTe)	WH48, WH51	Low	Undulating Inland Plain	**2f: Calcrete Platform A**: *Acacia tetragonophylla, A. synchronicia, A. coriacea* subsp. *pendens* open shrubland over *Indigofera monophylla, Hibiscus sturtii* subsp. *platychlamys, Solanum lasiophyllum* low open shrubland over *Triodia epactia* hummock grassland over **Cenchrus ciliaris, Enneapogon caerulescens* open tussock grassland over *Ptilotus exaltatus* var. *exaltatus* very open herbland **2g: Calcrete Platform B**: *Acacia bivenosa, A. sclerosperma* subsp. *sclerosperma, A. tetragonophylla, A. sclerosperma* subsp. *sclerosperma* x *bivenosa* hybrid, *Rhagodia eremaea* shrubland over *Indigofera monophylla, Hibiscus sturtii* var. *platychlamys, Scaevola spinescens, Heliotropium pachyphyllum* low open shrubland over *Triodia epactia* open hummock grassland over **Cenchrus ciliaris* open tussock grassland
	CS4: **Prosopis pallida, Acacia tetragonophylla, A. synchronicia* scattered tall shrubs over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* open tussock grassland in scalded areas (PRpAteAsyTeCEc)	WH44, WSB-06, WSB-07	Low	Saline Flats	**3d: Saline Plains**: *Tecticornia halocnemoides* subsp. *tenuis, T. indica* subsp. aff. *bidens, Lawrencia viridigrisea, Frankenia ambita, Hemichroa diandra, Neobassia astrocarpa* low shrubland over *Cullen cinereum, Angianthus milnei, Swainsona pterostylis, Lotus cruentus* open herbland over *Sporobolus virginicus, *Cenchrus ciliaris* open tussock grassland over *Cyperus bulbosus* very open sedgeland **3e: Fringing Claypan Scalds**: *Atriplex bunburyana, Sclerolaena uniflora, Lawrencia viridigrisea* low shrubland over *Triodia epactia* very open hummock grassland over **Cenchrus ciliaris* open tussock grassland
Claypans	**C1:** Bare claypan (cp)	WSB-02	Low	Saline Flats	**3a: Claypan A** (Bare areas)
	C2: *Eriachne* aff. *benthamii* open tussock grassland in claypans (ERIb)	–	Low	Not described from OEC study area	
	C3: *Tecticornia* spp. low shrubland in saline claypans (TECspp)	WH08, WH22, WH28 (mosaic with SPmERIbEUa), WH40, WH52, WH55, WH62, WH67, WH-JFB, WH-MB, WH-RB3	Moderate	Saline Flats	**3b: Claypan B** (Regularly Inundated): *Tecticornia halocnemoides* subsp. *tenuis, T. indica* subsp. *leiostachya, T. pergranulata* subsp. *pergranulata, T. pergranulata* subsp. *elongata, Muellerolimon salicorniaceum* low open shrubland over *Eragrostis pergracilis* scattered grasses 3c: Claypan C (Irregularly inundated): *Tecticornia auriculata* low shrubland over *Nicotiana occidentalis* subsp. *occidentalis* very open herbland over *Eragrostis pergracilis* tussock grassland

This Study				Equivalent from OEC (2009a)	
Landform	**Unit Code, Vegetation Sub-Association and Habitat**	**Sampling Sites**	**Conservation Status**	**Landform**	**Habitat / Vegetation Sub-Association**
Clayey Plains	**CP1:** *Sporobolus mitchellii, Eriachne* aff. *benthamii, E. benthamii, Eulalia aurea* tussock grassland on low-lying clayey plains (SPmERIbEUa)	WH07, WH26, WH28 (mosaic with TECspp), WH50, WH53, WH59, WH61, WH64, WH65, WH68, WSB-12 (mosaic with unit AteTeCEc), WH-JFD, WH-RB1	Moderate	Undulating Inland Plain	Some similarity to **2h: Drainage Foci**: *Pluchea rubelliflora, Vigna* sp. Hamersley clay, *Indigofera colutea, Lawrencia viridigrisea* low open shrubland over *Sporobolus virginicus, *Cenchrus ciliaris, Sporobolus mitchellii* tussock grassland over *Cullen cinereum, Mimulus gracilis, Marsilea hirsuta, Angianthus milnei* very open herbland
	CP2: **Prosopis pallida* scattered tall shrubs to tall open shrubland over *Acacia tetragonophylla, *Vachellia farnesiana* shrubland over *Eulalia aurea, Chrysopogon fallax, Sporobolus mitchellii* tussock grassland within drainage depressions in low-lying clayey plains (PRpAteVfEUaCHfSPm)	WH05, WH17, WH54	Low	Undulating Inland Plain	Some similarity to **2i: Unincised Drainage Line**: **Prosopis pallida* scattered tall shrubs over *Acacia tetragonophylla, A. victoriae* shrubland over *Indigofera monophylla, Stemodia* sp. Onslow, *Frankenia ambita, Tecticornia indica* subsp. *leiostachya* low open shrubland over *Eriachne gardneri, Sporobolus mitchellii* closed tussock grassland
	CP3: *Acacia xiphophylla* tall shrubland over *Triodia epactia* open hummock grassland on clayey plains (AxTe)	–	Low	Habitat absent from OEC study area	
	CP4: *Acacia xiphophylla* tall shrubland over *Triodia lanigera* open hummock grassland on elevated areas of clayey plains (AxTla)	WH32	Low	Habitat absent from OEC study area	
	CP5: *Acacia xiphophylla* tall open scrub over *Triodia brizoides* open hummock grassland on elevated areas of clayey plains, particularly where the substrate was calcareous (AxTbr)	WH35	Low	Habitat absent from OEC study area	
Inland Sand Plains	**IS1:** *Corymbia hamersleyana* scattered low mallees over *Acacia ancistrocarpa, A. bivenosa* shrubland over *Triodia lanigera* hummock grassland occurring broadly over inland sandy plains (ChAaAbTla)	WH12, WH14, WH15, WH16, WH18, WH34	Low	Habitat absent from OEC study area	
	IS2: *Acacia inaequilatera* tall open shrubland over *A. ancistrocarpa* open shrubland over *Triodia lanigera* open hummock grassland on slightly elevated areas of inland sandy plains (AiAaTla)	WH20	Low	Habitat absent from OEC study area	

This Study				**Equivalent from OEC (2009a)**	
Landform	**Unit Code, Vegetation Sub-Association and Habitat**	**Sampling Sites**	**Conservation Status**	**Landform**	**Habitat / Vegetation Sub-Association**
Stony Hills	**H1:** *Acacia inaequilatera* tall open shrubland over *Triodia lanigera, T. brizoides* open hummock grassland on stony hills (AiTlaTbr)	WH27	Low	Habitat absent from OEC study area	
Drainage Areas	**D1:** *Eucalyptus victrix* open forest over *Eulalia aurea, *Cenchrus ciliaris* tussock grassland in tributary of Ashburton River (EvEUaCEc)	–	Low	Habitat absent from OEC study area	
	D2: *Eucalyptus victrix* scattered low trees over *Acacia synchronicia, A. bivenosa* shrubland over *Triodia epactia* hummock grassland in broad ill-defined drainage through clayey plain (EvAsyAbTe)	WH11	Low	Habitat absent from OEC study area	
	D3: *Corymbia hamersleyana* scattered low mallees over *Acacia tumida* var. *pilbarensis, Grevillea wickhamii* subsp. *hispidula* tall open shrubland over *A. ancistrocarpa* open shrubland over *Triodia epactia, T. lanigera* open hummock grassland (ChAtuGwAaTeTla)	WH30	Low	Habitat absent from OEC study area	

6.0 Flora of the Wheatstone Study Area

6.1 Overview of the Flora

A total of 418 taxa of native vascular plants from 162 genera belonging to 58 families has been recorded from the Wheatstone study area through the survey work to date, along with 12 weed species (Appendix 5). These numbers represent an amalgamation of:

- 336 native taxa from 144 genera and 54 families and 11 weed species recorded during the survey work by Biota to date;
- 235 native taxa from 132 genera and 50 families and six weed species recorded from the northern section of the Wheatstone plant study area by OEC (2008 and 2009a) and from the camp and SIC study area by OEC (2009b). This number included 51 taxa not recorded through any of the other survey work conducted in the area:
    - Over 55% of these additional taxa were annual or weakly perennial species; including 10 daisy species (family Asteraceae), which would not have been present at the time of the 2009 field surveys but would be expected to be recorded following winter rainfall.
    - The remainder of the species were perennial shrubs, which are probably sporadically distributed in the locality, and would not necessarily have been encountered during the largely spot-sampling work of the other studies.
- 106 native taxa from 64 genera and 24 families and five weed species recorded from 16 quadrats assessed in the area by Astron (2009). This number included 19 taxa not recorded for the area by any of the other studies, 74% of which were annual species.
- 67 native taxa from 46 genera and 21 families and one weed species recorded from four quadrats assessed in the area by RPS (2009). This number included three taxa of weakly perennial low shrubs not recorded by any of the other studies.

The dominant native plant families and genera are summarised in Table 6.1. While the majority of the species recorded are typical of near-coastal and inland areas in this locality, some are quite uncommon and represent significant range extensions; these are discussed within Section 6.2.

Table 6.1: Plant families and genera with the highest species richness in the Wheatstone study area.

Family	**No. of Native Taxa**
Poaceae (grass family)	66
Chenopodiaceae (saltbush family)	44
Papilionaceae (pea family)	42
Asteraceae (daisy family)	28
Malvaceae (hibiscus family)	26
Mimosaceae (wattle family)	22
Amaranthaceae (mulla-mulla family)	21
Genus	**No. of Native Taxa**
Acacia (wattles)	21
Tecticornia (samphires)	19
Ptilotus (mulla-mullas)	14
Abutilon (lantern-flowers)	11
Cassia (cassias, sennas)	10
Eragrostis (lovegrasses)	10
Euphorbia (spurges)	10
Eriachne (wanderrie grasses)	9
Cullen (scurf-pea, verbine)	8
Indigofera (indigo peas)	8
Tephrosia (peas)	8

6.2 Flora of Conservation Significance

The framework for assessing the conservation significance of flora species is presented in Appendix 1.

6.2.1 Threatened Flora Listed under the *EPBC Act 1999* Occurring in the Study Area

One species (*Eleocharis papillosa*) listed as a Threatened Flora species under the Commonwealth *EPBC Act 1999* was recorded from the Wheatstone pipeline study area during the 2009 field surveys. No other species listed under the *EPBC Act 1999* have been previously recorded from the Onslow locality or are expected to occur in the habitats present.

- **Eleocharis papillosa** **Vulnerable (EPBC Act 1999)**
  This tiny sedge, known as Dwarf Desert Spike-rush, is listed as Vulnerable under the *EPBC Act 1999*, meaning that it is not considered to be critically endangered or endangered, but is facing a high risk of extinction in the wild in the medium-term future. Curiously, this species was not listed on the most recent Declared Rare and Priority Flora listing for Western Australia (Atkins 2008). Discussion with Dr Stephen van Leeuwen (DEC Woodvale, pers. comm.) indicated that this was probably an oversight, and the species has since been assigned Priority 3 status (see the DEC FloraBase website).

  E. papillosa appears to have been listed under the *EPBC Act 1999* on the basis that it was then known from only eight populations in the Northern Territory (see Figure 6.1); some of these locations were under threat from weed invasion, and it was considered that the area and extent of habitat for this species had declined. However, the most current records of this species[14] indicate that *E. papillosa* actually has a considerably broader distribution, extending from the north of the Northern Territory through to northern South Australia and into the west of Western Australia (see Figure 6.2). It is likely that this species has been poorly collected in the past due to its small size and ephemeral nature, although it certainly does not appear to be common in Western Australia. This view is supported by the fact that the regional Pilbara Biological Survey completed recently by the Western Australian DEC yielded only a single record of *Eleocharis papillosa*, from the Fortescue Marsh area in the eastern Pilbara, some 430 km east-southeast of Onslow (Dr Stephen van Leeuwen, DEC, pers. comm. 2009).

  E. papillosa was recorded from a single location within the Wheatstone pipeline study area, from samphire shrubland vegetation within a tidally influenced creek along the Onslow Road, southeast of the main Peedamulla Station turnoff (Table 6.2; Appendix 3, Map 2). Subsequent attempts to better define this population have failed to locate any individuals, as conditions have been too dry. This sedge was not recorded by RPS (2009) from the alternate pipeline route, which traversed the same tidal creek some 300 m to the east, however it is not clear whether any sampling work was conducted within this area specifically (the seasonal conditions in November 2008 would probably have been unsuitable for observing this species in any case). Although there was only a single record of this species during the current survey work, given its small stature (growing to under 10 cm in height), this sedge should be considered likely to occur throughout this particular creek habitat, and could potentially be more widespread within the remainder of the Wheatstone study area.

  The record of *E. papillosa* from the Wheatstone study area represents a considerable range extension for this species within Western Australia, with the nearest other known population 430 km east-southeast in the Pilbara.

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[14] Based on voucher specimens lodged at all main Herbaria in Australia, as displayed on Australia's Virtual Herbarium (AVH) website; http://www.anbg.gov.au/avh. It should be noted that this map may include specimens with affinities to *E. papillosa*, as the AVH search function does not discriminate to this level.

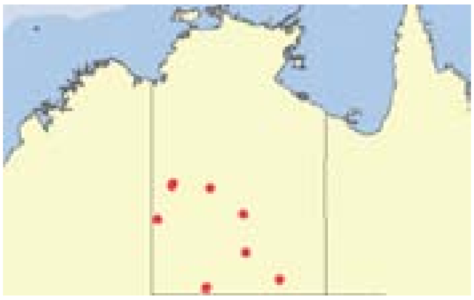

Figure 6.1: **Indicative distribution map of Eleocharis papillosa in Species Profile and Threats Database of the EPBC Act 1999.** (Source: Department of the Environment, Water, Heritage and the Arts, Canberra. Available from: http://www.environment.gov.au/sprat. Accessed 2009-05-11@12:49:05.)

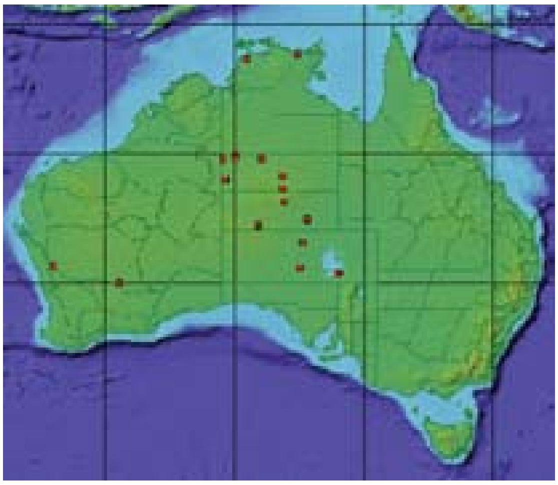

Figure 6.2: **Distribution map of Eleocharis papillosa obtained from Australia's Virtual Herbarium database.** (Available from http://www.anbg.gov.au/avh. Accessed 11/05/2009.)

Table 6.2: **Record of Eleocharis papillosa from the Wheatstone pipeline study area.**

Broad Location	Easting (mE)	Northing (mN)	No. of Individuals
Tidal creek within Wheatstone pipeline study area, ~800 m southwest of Peedamulla Station turn-off along Onslow Road	304538	7587447	Not recorded (scattered individuals; <1% cover)

6.2.2 Probability of Declared Rare Flora Occurring in the Study Area

No species listed as DRF by the DEC under the Western Australian *Wildlife Conservation Act 1950* were recorded from the Wheatstone study area during the 2008 or 2009 field surveys, or have previously been recorded from the locality. No DRF would be expected to occur in the habitats present in the Wheatstone study area (see Section 4.6.2).

6.2.3 Priority Flora Recorded from the Study Area

Five Priority species, *Abutilon uncinatum* ms., *Atriplex flabelliformis, Eleocharis papillosa, Eremophila forrestii* subsp. *viridis* and *Triumfetta echinata*, have been recorded from the Wheatstone study area to date:

- **Abutilon uncinatum ms.** **Priority 1**
  This prostrate low shrub species was previously known from only two records east of Onslow in the Pilbara bioregion, and one record 113 km south of Onslow in the Carnarvon bioregion (see Section 4.6.3). During the current survey work by Biota, this species was recorded from a single location within the Wheatstone pipeline study area (Table 6.3), approximately 24 km southwest of the closest known population. This location comprised a loamy plain supporting a shrubland of *Acacia synchronicia and A bivenosa* over an open hummock grassland of *Triodia epactia*. Although the distribution of *A. uncinatum* covers almost 140 km, and three of the four known locations are within 60 km of Onslow, this species does not appear to be common: it was not recorded by any of the other recent surveys in the Onslow locality.

Table 6.3: Record of Abutilon uncinatum ms. from the Wheatstone pipeline study area.

Broad Location	Easting (mE)	Northing (mN)	No. of Individuals
Wheatstone pipeline study area; 10.7 km southeast of the Peedamulla Station turn-off along the Onslow Road	310677	7579899	Not recorded (<1% cover)

- **Atriplex flabelliformis** **Priority 3**
  This straggling perennial herb species has only been recorded from a small number of locations, but has a broad range extending from the Pilbara to the Great Sandy Desert and Tanami bioregions. The associated habitats comprise saline flats or marshes with clay-loam or loamy soils. This species was recorded by Astron (2009) from three locations in the southern section of the Wheatstone plant study area (providing 45% cover at one of these sites) and two locations at the western end of the shared infrastructure corridor, generally in samphire shrublands (vegetation unit TECspp) or grasslands (unit SPmERIbEUa) on clayey substrates. These records represent a very large range extension from the previously known westernmost populations, some 430 km east-southeast in the Fortescue Marsh.

Table 6.4: Records of Atriplex flabelliformis from the Wheatstone study area.

Broad Location	Easting (mE)	Northing (mN)	No. of Individuals
Wheatstone plant study area, southern section (recorded by Astron 2009)	291348	7594647	Not recorded (45% cover)
	291562	7593426	Not recorded (<2% cover)
	291762	7593050	Not recorded (<2% cover)
Wheatstone camp and SIC study area; western section of SIC (recorded by Astron 2009)	293838	7592051	Not recorded (<2% cover)
	295779	7591696	Not recorded (<2% cover)

- **Eleocharis papillosa** **Priority 3**
  See discussion in Section 6.2.1.

- **Eremophila forrestii subsp. viridis** **Priority 3**
  The specimens of this taxon from the 2009 survey work were confirmed by Mr Andrew Brown (DEC Kensington). Based on the vouchered specimens displayed on FloraBase, this shrub species appears to have a broad distribution through Western Australia, occurring near Onslow in the northern Carnarvon bioregion, at two locations in the central Pilbara and another near the southern border of the Great Sandy Desert bioregion. However, Andrew Brown has advised that none of the specimens that he has determined from outside the Onslow locality have been referrable to subspecies *viridis*, and he suspects this taxon is actually relatively restricted to the Onslow locality (pers. comm. 2009). During the 2009 survey work, this species was recorded from single dunes within the northern section of the Wheatstone plant study area, the eastern section of the shared infrastructure corridor, and the Wheatstone pipeline study area (see Table 6.5). This taxon was also on the list of species recorded by OEC (2008) from the northern Wheatstone plant study area, however no coordinates were provided therein. *E. forrestii* subsp. *viridis* has been recorded in the broader Onslow locality from two additional locations approximately 3 km north of the Minderoo Station turnoff (Biota unpublished data), and a location 7 km east-northeast of the same turnoff (Astron 2009).

Table 6.5: Records of *Eremophila forrestii* subsp. *viridis* from the Wheatstone study area.

Broad Location	Easting (mE)	Northing (mN)	No. of Individuals
Wheatstone plant study area, northern section	293303	7599680	Not recorded (<1% cover)
Wheatstone SIC study area, eastern section (recorded by OEC 2009b)	299447	7590439	Not recorded (described as being a minor component of the vegetation)
Wheatstone pipeline study area, 10.9 km southeast of the Peedamulla Station turn-off along the Onslow Road	311072	7580063	Not recorded (<1% cover)

- ***Triumfetta echinata*** **Priority 3**

  This low shrub species has a distribution concentrated on the area surrounding Onslow, at the junction of the northern Carnarvon and western Pilbara bioregions, with an outlying population some 115 km south in the Gascoyne bioregion (see Section 4.6.3). *T. echinata* was originally recorded on a single dune within the central Wheatstone plant study area by OEC (2009a), and was recollected in 2009 this general area (OEC 2009b; Table 6.6). During the survey work by Biota, this species was recorded from three separate sand dunes; one each within the southern section of the Wheatstone camp study area, the eastern section of the SIC study area and the western section of the Wheatstone pipeline study area (see Table 6.6). *T. echinata* has been recorded from a number of other locations in the Onslow area, including west of the Onslow Road at approximately 2.75 km north of the Minderoo Station turnoff (Biota unpublished data), east of the Onslow Road at approximately 6 and 10 km south of the Minderoo Station turnoff (RPS 2009), as well as at additional locations (see OEC 2009a). It appears that this species is relatively widespread through the locality, however it is not common and it is restricted to red sand dunes.

Table 6.6: Records of *Triumfetta echinata* from the Wheatstone study area.

Broad Location	Easting (mE)	Northing (mN)	No. of Individuals
Wheatstone plant study area, central area (recorded by OEC 2009a)	292741	7598352	Not recorded (<1% cover)
(recorded by OEC 2009b)	292372	7597797	Not recorded
	292609	7598163	Not recorded
	292665	7598271	Not recorded
	292692	7598307	Not recorded
	292701	7598342	Not recorded
	292763	7598411	Not recorded
Southern section of Wheatstone camp study area	296008	7588460	1
	296002	7588451	1
	296002	7588422	1
	295899	7588283	1
	295862	7588262	5
	295845	7588255	5
	295862	7588243	5
	295868	7588034	5
	295861	7588017	1
	295934	7587828	5
	295943	7587818	9
	295925	7587815	8
	296074	7587583	1

Broad Location	Easting (mE)	Northing (mN)	No. of Individuals
Dune in Wheatstone SIC study area, 3 km west-northwest of the Minderoo Station turnoff from the Onslow Road (recorded by OEC 2009b)	299417	7590229	3
	299550	7590470	only fruit present
	299596	7590476	only fruit present
Dune in Wheatstone SIC study area, 750 m west-northwest of the Minderoo Station turnoff from the Onslow Road	301759	7589980	11
Dune in Wheatstone pipeline study area, ~4 km south-southeast of the Peedamulla Station turnoff from the Onslow Road	305887	7585030	1
	305984	7584875	7
	305998	7584856	2
	306045	7584802	4
	306131	7584522	1

Plate 6.1: Triumfetta echinata: low-growing shrub habit, leaves and distinctive fruit with long spines.

6.2.4 Probability of Other Priority Flora Occurring in the Study Area

Other Priority flora identified through DEC searches include:

- *Helichrysum oligochaetum* (Priority 1) has a relatively broad distribution through the Pilbara and northern Gascoyne bioregions, occurring on clayey plains habitats. Although suitable habitat is present within the Wheatstone study area, this species is considered unlikely to occur, given that it has not been recorded for the area by OEC (2008 and 2009a) or RPS (2009), nor has it been vouchered from Onslow to date from the various other surveys conducted in the locality. This species would not have been visible at the time of the 2009 survey work, if present.
- *Carpobrotus* sp. Thevenard Island (M. White 050) (Priority 2) is only currently known from white sand dunes on islands off the Pilbara coast. This species is unlikely to occur in the Wheatstone study area.

6.2.5 Other Flora of Conservation Interest

While not formally listed as DRF or Priority flora, other species may be considered to be of conservation interest for various reasons (e.g. if they represent apparently new (undescribed) taxa, are poorly collected, or if the record represents a considerable range extension).

6.2.5.1 Undescribed Taxa

- **Aenictophyton aff. reconditum (Onslow)**
  The Papilionaceae (pea) family contains numerous taxa in the Pilbara which appear to be new, some of which have been assigned phrase-names and are awaiting description. Mr.

Malcolm Trudgen (M.E. Trudgen & Associates) has indicated that this taxon is a new entity which should be considered to be poorly known and geographically restricted to the Onslow locality (see OEC 2009a). Five plants of this species were recorded within the Wheatstone plant study area by OEC (2009a), from a single location on a sand dune (Table 6.7). During the current surveys, this species was recorded from two dunes; one at the eastern end of the Wheatstone SIC study area and one at the western end of the Wheatstone pipeline study area, 4.1 km southeast of the Minderoo Station turnoff (Table 6.7). It is known from an additional six locations between 2.1 km and 3.3 km north of the Minderoo Station turnoff from the Onslow Road (Validus 2008 and Biota unpublished data), and was also recorded from two quadrats on the east side of Onslow Road approximately 6 km and 10 km south of the Minderoo Station turnoff (RPS 2009). It has also been recorded at other locations in similar habitat near Onslow, and at Yannarie Station (between Onslow and Karratha; see OEC 2009a). It appears that this taxon is not common in the area and is restricted to dune habitats.

Table 6.7: Records of Aenictophyton aff. reconditum from the Wheatstone study area.

Broad Location	Easting (mE)	Northing (mN)	No. of Individuals
Wheatstone plant study area, southwestern corner (recorded by OEC 2009a)	290436	7595702	5
Wheatstone pipeline study area, ~750 m west-northwest of the Minderoo Station turnoff from the Onslow Road	301759	7589980	Not recorded (<1% cover)
Wheatstone pipeline study area, ~1.8 km southeast of the Peedamulla Station turnoff from the Onslow Road	305225	7586790	Not recorded (<1% cover)

- **Vigna sp. Hamersley clay (A.A. Mitchell PRP 113)**
  A broad-leafed *Vigna* taxon was recorded from numerous locations on the sandy coastal plains of the Wheatstone plant study area. This was found to match the type of the undescribed *Vigna* sp. Hamersley clay (A.A. Mitchell PRP 113). This taxon was also recorded numerous times by OEC (2008, 2009a[15] and 2009b). *Vigna* sp. Hamersley clay (A.A. Mitchell PRP 113) appears to be widespread through the Pilbara, with records from the vicinity of Onslow, Tom Price, and several locations along a rail corridor extending from Cape Lambert to Marandoo (Biota unpubl. data). Several specimens from the Wheatstone study area have been sent to a *Vigna* specialist (Ms Ailsa Holland) in order to further investigate the status of this taxon.

- **Tecticornia spp.**
  Samphires (*Tecticornia* spp.) are notoriously problematic to identify and have a tendency to be under-collected, as many appear superficially similar in the field. Samphire specimens from the 2009 surveys of the Wheatstone study area were identified as far as possible by Ms Kelly Shepherd of the WA Herbarium. She has indicated that as many as nine different taxa may be represented within the sterile material collected, although some may be referrable to existing named taxa or to each other. This includes two specimens of undescribed taxa, which unfortunately lacked sufficient material to allow them to be circumscribed and allocated a phrase name (Table 6.8): both of these appear to be within the species complex designated *T. halocnemoides* sens. lat. 'large seed aggregate', and are probably different from each other (K. Shepherd, WA Herbarium, pers. comm. 2009). Additional samphire taxa were also recorded by OEC (2008 and 2009a).

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[15] This entity was listed in the two former reports as "*Vigna lanceolata*".

Table 6.8: Records of undescribed Tecticornia taxa from the Wheatstone study area.

Species	Broad Location	Easting (mE)	Northing (mN)
Tecticornia sp. (WH40-04) (within the *T. halocnemoides* sens. lat. 'large seed aggregate', and probably different from *T.* sp. (WHPH-15))	Northwestern section of the Wheatstone plant study area	290032	7598556
Tecticornia sp. (WHPH-15) (within the *T. halocnemoides* sens. lat. 'large seed aggregate', and probably different from *T.* sp. (WH40-04))	Northern section of the Wheatstone plant study area	293404	7599453

- **Other Groups**
  Numerous plant groups in the Pilbara are poorly resolved and urgently require revision; these include the genera *Abutilon, Bonamia, Eriachne, Euphorbia, Polygala, Sida* and *Triumfetta*. Most of the undescribed taxa recorded during the Wheatstone study have been recorded more widely in the Pilbara. Possible exceptions include a single *Abutilon* species, which could only be matched to one other indeterminate specimen at the WA Herbarium (also from near Onslow); and the *Bonamia* aff. *linearis* taxon (which has winged seeds, supposedly not a character of *B. linearis* in the typical sense; Jessop 1981).

6.2.5.2 Range Extensions

Numerous species recorded from the Wheatstone study area have not been previously recorded from either the northern section of the Carnarvon bioregion or the northwestern section of the Pilbara bioregion. Note that this information is based purely on the records of vouchered specimens presented on FloraBase, and that species may be more generally recognised as occurring in the area but simply not have been vouchered. Species representing range extensions include:

- *Abutilon oxycarpum* subsp. *prostratum*: a large extension north within the Carnarvon bioregion.
- *Acacia chartacea*: a substantial range extension north from the Lake MacLeod locality, north of Carnarvon; recorded along the old tram line in the northern plant study area by OEC (2009b).
- *Acacia sphaerostachya:* first record for the Carnarvon bioregion, although only a slight range extension from the known populations in the Pilbara.
- *Aeschynomene indica:* substantial extension north within the Carnarvon bioregion.
- *Alysicarpus muelleri:* first record for the Carnarvon bioregion (no specimen was collected).
- *Aristida holathera* var. *latifolia:* first record for the Carnarvon bioregion; based on FloraBase, this would appear to be a substantial range extension from the Kimberley region, however this taxon has been collected on other recent surveys in the Pilbara (Ms Denise True, Western Botanical, pers. comm. 2009).
- *Astrebla pectinata:* substantial extension north within the Carnarvon bioregion (no specimen was collected).
- *Bergia pedicellaris:* first record for the Carnarvon bioregion; substantial extension west from the vouchered Pilbara populations.
- *Bergia perennis* subsp. *perennis:* first record for the Carnarvon bioregion; substantial extension west from the vouchered Pilbara populations.
- *Blumea tenella:* first record for the Carnarvon bioregion; substantial extension west from the vouchered Pilbara populations.
- *Brachyachne convergens:* first record for the Carnarvon bioregion (no specimen was collected).
- *Convolvulus angustissimus* subsp. *angustissimus:* extension north within the Carnarvon bioregion (recorded by OEC (2008)).

- *Corchorus tridens:* first record for the Carnarvon bioregion (no specimen collected).
- *Crotalaria ramosissima*: first record for the northern Carnarvon bioregion, although recorded to the south on the western boundary of the Pilbara bioregion.
- **Cucumis melo* subsp. *agrestis:* first record for the Carnarvon bioregion.
- *Cullen graveolens:* extension north within the Carnarvon bioregion.
- *Desmodium filiforme:* first record for the Carnarvon bioregion.
- *Dysphania platycarpa*: substantial extension north within the Carnarvon bioregion.
- *Eleocharis papillosa*: very large range extension (see Section 6.2.1).
- *Fimbristylis dichotoma*: first record for the Carnarvon bioregion, and a range extension west within the Pilbara bioregion.
- *Gomphrena sordida*: first record for the Carnarvon bioregion.
- *Heliotropium diversifolium*: first record for the Carnarvon bioregion, and a very large range extension west from the nearest known populations in the eastern Pilbara bioregion.
- *Indigofera georgei*: a substantial extension north within the Carnarvon bioregion (but only a small extension west from populations in the Pilbara bioregion).
- *Ipomoea coptica*: first record for the Carnarvon bioregion.
- *Leptochloa fusca subsp. muelleri*: extension north within the Carnarvon bioregion.
- *Maireana georgei*: extension north within the Carnarvon bioregion
- *Maireana lanosa*: extension north within the Carnarvon bioregion.
- *Marsilea drummondii*: large extension north within the Carnarvon bioregion (but only a small distance west from populations in the Pilbara bioregion).
- *Polycarpaea corymbosa* var. corymbosa: range extension within the Pilbara bioregion for this variety (although specimens undetermined for infraspecies have been recorded from the western Pilbara and probably represent this taxon), and the first record for the Carnarvon bioregion.
- *Ptilotus fusiformis*: first record for the Carnarvon bioregion, but only a slight range extension from populations in the Pilbara bioregion (no specimens were collected).
- *Rostellularia adscendens* var. *clementii*: first specimens of this genus lodged from the Carnarvon bioregion; substantial range extension from nearest populations in the Pilbara bioregion.
- *Rotala diandra:* large range extension north within the Carnarvon bioregion (recorded by OEC (2008)).
- *Sida arsiniata:* first record for the Carnarvon bioregion, but only a slight range extension from populations in the Pilbara bioregion.
- *Solanum horridum:* first record for the Carnarvon bioregion, but only a slight range extension from populations in the Pilbara bioregion (recorded by OEC (2008)).
- *Tinospora smilacina*: slight range extension west in the Pilbara bioregion.
- *Triodia brizoides*: a very large range extension from the central Pilbara. This material is not typical for *T. brizoides* and would warrant further investigation; specimens lodged with the WA Herbarium should be incorporated into the next review of *Triodia* undertaken for the State.
- *Tripogon loliiformis*: substantial range extension west within the Pilbara bioregion.
- *Vigna* sp. Hamersley clay (A.A. Mitchell PRP 113): first record for the Carnarvon bioregion; substantial range extension from nearest vouchered populations in the Pilbara bioregion.
- *Zornia albiflora:* first record for the Carnarvon bioregion.

6.2.5.3 Species at the Limits of Distribution

Many of the species recorded from the Wheatstone study area are at the western ends of their known distribution (including *Acacia tumida* var. *pilbarensis, Gomphrena cunninghamii, Grevillea wickhamii* subsp. h*ispidula, Portulaca pilosa, Ptilotus fusiformis, Schoenoplectus dissachanthus, Tephrosia* sp. B Kimberley Flora (C.A. Gardner 7300), *Urochloa holosericea* subsp. *velutina, Verticordia forrestii, Vigna* sp. Hamersley clay (A.A. Mitchell PRP 113), *Whiteochloa airoides* and *Zornia albiflora*). Several other species are at the northern end of their distribution (e.g. *Acacia chartacea, Hakea stenophylla* subsp. *stenophylla, Maireana lanosa, Pityrodia loxocarpa, P. paniculata, Samolus* sp. Shark Bay (M.E. Trudgen 7410), *Scaevola pulchella, Tecticornia doleiformis, Trachymene pilbarensis* and *Triumfetta echinata*). This is a reflection of the location of the Wheatstone study area at the boundary between the northern end of the Carnarvon and western end of the Pilbara bioregions.

6.3 Introduced Flora

Twelve introduced flora species have been recorded from the Wheatstone study area, three of which (Parkinsonia and two species of Mesquite) are Declared Plants under the *Agriculture and Related Resources Protection Act 1976* (see Table 6.9). It should be noted that no attempt was made to record individual locations of the **Cenchrus* species or of Mesquite and Mimosa Bush, as all of these species were widespread through the Wheatstone plant, camp and SIC study areas. Mesquite, Mimosa Bush, Buffel Grass, Whorled Pigeon Grass, Kapok Bush and Spiked Malvastrum were all recorded for the Wheatstone plant study area by OEC (2008 and 2009a).

Table 6.9: Weed species recorded from the Wheatstone study area.

Family	Species	Broad Distribution in the Study Area
Caesalpiniaceae	**Parkinsonia aculeata* (Parkinsonia)	Uncommon; two records from creekline near southern boundary of Wheatstone plant study area
Mimosaceae	**Prosopis pallida* / **P. glandulosa* (Mesquite)	Widespread; particularly common through the Wheatstone camp and SIC study area, but also scattered through the Wheatstone plant study area
	**Vachellia farnesiana* (Mimosa Bush)	Widespread; particularly common through the Wheatstone camp and SIC study area, but also scattered through the Wheatstone plant study area
Poaceae	**Cenchrus ciliaris* (Buffel Grass)	Widespread; particularly abundant within the Wheatstone camp and SIC study area, and along disturbed areas and sand dunes within the Wheatstone plant study area; scattered through the Wheatstone pipeline study area, mainly along road verges
	**Cenchrus setiger* (Birdwood Grass)	Widespread; distributed through the same areas as **C. ciliaris*, but much less abundant
	**Setaria verticillata* (Whorled Pigeon Grass)	Uncommon; two records from the northern Wheatstone plant study area
Amaranthaceae	**Aerva javanica* (Kapok Bush)	Uncommon; recorded from a Telstra Radio Station facility along the Wheatstone pipeline study area; described as present in "disturbed habitats" in the Wheatstone plant study area by OEC (2008), but only one location provided
Cucurbitaceae	**Cucumis melo* subsp. *agrestis* (Ulcardo melon)	Infrequent; recorded from clayey substrates in the Wheatstone camp and SIC study area
Malvaceae	**Malvastrum americanum* (Spiked Malvastrum)	Infrequent; recorded mainly from clayey substrates in the Wheatstone camp study area, with one record from the southern Wheatstone plant study area; described as a "minor component of the flora" of the Wheatstone plant study area by OEC (2008), but no coordinates provided

Family	Species	Broad Distribution in the Study Area
Passifloraceae	**Passiflora foetida* var. *hispida* (Stinking Passion Flower)	Uncommon; two records in creek system in southern section of the Wheatstone plant study area
Portulacaceae	**Portulaca oleracea* (Purslane)	Widespread; scattered through the southern Wheatstone plant study area, the Wheatstone camp study area and the Wheatstone pipeline study area (particularly at the eastern end)

A brief description of each species is provided in the following:

- **Parkinsonia (*Parkinsonia aculeata)** was recorded at two locations (40 m apart) in a single creekline near the southern boundary of the Wheatstone plant study area (Appendix 3, Map 1; Appendix 7). This species was also noted where this creekline joins the Ashburton River at the "Five Mile Creek" rest stop, just over 1 km to the south. Parkinsonia is a Declared Plant for Western Australia under the *Agriculture and Related Resources Protection Act 1976*, being listed as P1 (movement of plants or their seeds prohibited) for the State, and P2 (eradicate infestation to destroy and prevent propagation each year until no plants remain) for the Carnarvon and Exmouth districts. Parkinsonia is also listed as a "Weed of National Significance" by Thorp and Lynch (2000).

- **Mesquite (*Prosopis pallida, *P. glandulosa and various hybrids)** is an erect, thorny thicket-forming tall shrub or tree. All **Prosopis* species are Declared Plants under the Western Australian *Agriculture and Related Resources Protection Act 1976,* being listed as P1 and P2 for the Onslow locality (see discussion above for Parkinsonia). **Prosopis* is also listed as a "Weed of National Significance" by Thorp and Lynch (2000). Mesquite was widespread over the sandy plains and clayey plains habitats of the Wheatstone plant and camp study areas and the section of the Wheatstone pipeline study area west of the Onslow Road. Although the current survey work recorded only **Prosopis pallida, *P. glandulosa* was also recorded for the area by Astron (2009). While Mesquite generally occurred as scattered individuals, some denser thickets were present within drainage depressions. Some of the shrubs on Minderoo Station (particularly near the boundary with Urala Station) were dead and appeared to have been targeted for chemical spraying.

Plate 6.2: Mesquite (*Prosopis pallida): tall shrub habit, bipinnate leaves, and smooth stems with large paired spines.

- **Mimosa Bush (*Vachellia farnesiana)** is a common but scattered shrubby weed of drainage areas and clayey plains in the Pilbara, but is sometimes abundant in areas subject to heavy grazing (e.g. near stock watering-points). This species looks superficially similar to Mesquite, but can be distinguished by the presence of lenticels (looking like white dots) on the reddish stems (Mesquite has smooth stems; see Plate 6.2). Mimosa Bush was scattered throughout the Wheatstone plant study area and the Wheatstone camp and SIC study area.

- **Buffel Grass (*Cenchrus ciliaris)** and the less common **Birdwood Grass (*C. setiger)** are tufted perennial grasses which were introduced to the Pilbara as fodder species (Plate 6.3). **Cenchrus ciliaris* has demonstrated allelopathic capacities, whereby it releases chemicals that inhibit the growth of other plants, and it is an aggressive and effective competitor with native flora species. This perennial grass forms dense tussock grasslands, particularly along creeklines, floodplains and in sandy coastal areas of the Pilbara. **C. setiger* tends to be less abundant but is often found intermixed with **C. ciliaris* through the same areas.

  Buffel Grass was widespread through the Wheatstone camp and SIC study area and also through the Wheatstone plant study area, often forming dense infestations, particularly in wind-eroded habitats (see Plate 6.5). It was also scattered through the Wheatstone pipeline study area, particularly along the verges of Onslow Road.

Plate 6.3: Comparison of flower spikes of *Cenchrus ciliaris (left) and *C. setiger (right).

Plate 6.4: Dense patches of Buffel Grass growing in a scalded area.

- **Whorled Pigeon Grass (*Setaria verticillata)** was recorded as scattered individuals from two locations along tracks in the northern section of the Wheatstone plant study area (Appendix 3, Map 1; Appendix 7). Whorled Pigeon Grass is a common weed of clayey substrates and drainage areas in the Pilbara, but rarely contributes much cover.

- **Kapok (*Aerva javanica)** was recorded from a coastal dune in the northern Wheatstone plant study area by OEC (2008). During the 2009 surveys, this species was only noted in the immediate vicinity of a Telstra radio station facility within the Wheatstone pipeline study area (Plate 6.5; Appendix 3, Map 3; Appendix 7). Kapok can be a significant weed of loose sandy substrates in coastal areas, and it is encouraging that this species is not abundant within the Wheatstone plant study area in particular, given the prevalence of susceptible habitats through this area.

Plate 6.5: Kapok plants within the enclosure around the Telstra facility.

- The cucurbid creeper **Ulcardo Melon (*Cucumis melo subsp. agrestis)** was recorded as scattered individuals from several locations on clayey substrates, mainly within the Wheatstone camp study area (Appendix 3, Maps 1 and 2; Appendix 7). This species is a common weed of clayey habitats in the Pilbara, but is rarely recorded in large numbers.

- **Spiked Malvastrum (*Malvastrum americanum)** was described as being "a minor component of the flora" of the northern Wheatstone plant study area by OEC (2008), however no location coordinates were provided in that report. This species was recorded as scattered individuals from several locations on clayey substrates during the 2009 surveys, mainly within the Wheatstone camp study area, with a single record in the southern Wheatstone plant study area (Appendix 3, Maps 1 and 2; Appendix 7). Spiked Malvastrum is a common weed of Mulga vegetation and clayey habitats in the Pilbara, but does not appear to aggressively compete with native species.

- **Stinking Passion Flower (*Passiflora foetida var. hispida)** was recorded as scattered individuals from two locations (approximately 1 km apart) within a creek system in the southern section of the Wheatstone plant study area (Appendix 3, Map 1; Appendix 7). Stinking Passion Flower is a common woody vine in the Kimberley region, and occurs occasionally in creeklines through the northern Pilbara.

- **Purslane (*Portulaca oleracea)** was recorded as scattered individuals from numerous locations on clayey substrates, particularly associated with "scalds" in the Wheatstone plant and camp study areas, but also present within apparently undisturbed native vegetation along the eastern end of the Wheatstone pipeline study area (Appendix 3, Maps 1 to 4; Appendix 7). Purslane is a very common weed of clayey and stony plains in the Pilbara, but does not appear to compete with native species.

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Appendix 1

Framework for Listing the Conservation Status of Species and Communities in Western Australia

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A. Definitions, Categories and Criteria for Threatened and Priority Ecological Communities

1. General Definitions

Ecological Community
A naturally occurring biological assemblage that occurs in a particular type of habitat.

Note: The scale at which ecological communities are defined will often depend on the level of detail in the information source, therefore no particular scale is specified.

A **threatened ecological community** (TEC) is one which is found to fit into one of the following categories; “presumed totally destroyed”, “critically endangered”, “endangered” or “vulnerable”.

Possible threatened ecological communities that do not meet survey criteria are added to DEC’s Priority Ecological Community Lists under Priorities 1, 2 and 3. Ecological Communities that are adequately known, are rare but not threatened, or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5.

An **assemblage** is a defined group of biological entities.

Habitat is defined as the areas in which an organism and/or assemblage of organisms lives. It includes the abiotic factors (e.g. substrate and topography), and the biotic factors.

Occurrence: a discrete example of an ecological community, separated from other examples of the same community by more than 20 metres of a different ecological community, an artificial surface or a totally destroyed community.

By ensuring that every discrete occurrence is recognised and recorded future changes in status can be readily monitored.

Adequately Surveyed is defined as follows:
“An ecological community that has been searched for thoroughly in most likely habitats, by relevant experts.”

Community structure is defined as follows:
“The spatial organisation, construction and arrangement of the biological elements comprising a biological assemblage” (e.g. *Eucalyptus salmonophloia* woodland over scattered small shrubs over dense herbs; structure in a faunal assemblage could refer to trophic structure, e.g. dominance by feeders on detritus as distinct from feeders on live plants).

Definitions of **Modification** and **Destruction** of an ecological community:

Modification: “changes to some or all of ecological processes (including abiotic processes such as hydrology), species composition and community structure as a direct or indirect result of human activities. The level of damage involved could be ameliorated naturally or by human intervention.”

Destruction: “modification such that reestablishment of ecological processes, species composition and community structure within the range of variability exhibited by the original community is unlikely within the foreseeable future even with positive human intervention.”

Note: Modification and destruction are difficult concepts to quantify, and their application will be determined by scientific judgement. Examples of modification and total destruction are cited below:

<u>Modification of ecological processes:</u> The hydrology of Toolibin Lake has been altered by clearing of the catchment such that death of some of the original flora has occurred due to dependence on fresh water. The system may be bought back to a semblance of the original state by redirecting saline runoff and pumping waters of the rising underground watertable away to restore the hydrological balance. Total destruction of downstream lakes has occurred due to hydrology being altered to the point that few of the original flora or fauna species are able to tolerate the level of salinity and/or water logging.

<u>Modification of structure:</u> The understorey of a plant community may be altered by weed invasion due to nutrient enrichment by addition of fertiliser. Should the additional nutrients be removed from the system the balance may be restored, and the original plant species better able to compete. Total destruction may occur if additional nutrients continue to be added to the system causing the understorey to be completely replaced by weed species, and death of overstorey species due to inability to tolerate high nutrient levels.

Modification of species composition: Pollution may cause alteration of the invertebrate species present in a freshwater lake. Removal of pollutants may allow the return of the original inhabitant species. Addition of residual highly toxic substances may cause permanent changes to water quality, and total destruction of the community.

Threatening processes are defined as follows:
"Any process or activity that threatens to destroy or significantly modify the ecological community and/or affect the continuing evolutionary processes within any ecological community."

Examples of some of the continuing threatening processes in Western Australia include: general pollution; competition, predation and change induced in ecological communities as a result of introduced animals; competition and displacement of native plants by introduced species; hydrological changes; inappropriate fire regimes; diseases resulting from introduced micro-organisms; direct human exploitation and disturbance of ecological communities.

Restoration is defined as returning an ecological community to its pre-disturbance or natural state in terms of abiotic conditions, community structure and species composition.

Rehabilitation is defined as the re-establishment of ecological attributes in a damaged ecological community although the community will remain modified.

2. Definitions and Criteria for Presumed Totally Destroyed, Critically Endangered, Endangered and Vulnerable Ecological Communities

ECOLOGICAL COMMUNITIES

Presumed Totally Destroyed (PD)

An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future.

An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies (A or B):

A) Records within the last 50 years have not been confirmed despite thorough searches of known or likely habitats or

B) All occurrences recorded within the last 50 years have since been destroyed

Critically Endangered (CR)

An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated.

An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C):

A) The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and either or both of the following apply (i or ii):

    i) geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 10 years);

    ii) modification throughout its range is continuing such that in the immediate future (within approximately 10 years) the community is unlikely to be capable of being substantially rehabilitated.

B) Current distribution is limited, and one or more of the following apply (i, ii or iii):

    i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 10 years);

    ii) there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes;
    iii) there may be many occurrences but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes.

C) The ecological community exists only as highly modified occurrences that may be capable of being rehabilitated if such work begins in the immediate future (within approximately 10 years).

Endangered (EN)
An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future.

An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B, or C):

A) The geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlement and either or both of the following apply (i or ii):
    i) the estimated geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short term future (within approximately 20 years);
    ii) modification throughout its range is continuing such that in the short term future (within approximately 20 years) the community is unlikely to be capable of being substantially restored or rehabilitated.

B) Current distribution is limited, and one or more of the following apply (i, ii or iii):
    i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years);
    ii) there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes;
    iii) there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes.

C) The ecological community exists only as very modified occurrences that may be capable of being substantially restored or rehabilitated if such work begins in the short-term future (within approximately 20 years).

Vulnerable (VU)
An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range.

An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction or significant modification in the medium to long-term future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B or C):

A) The ecological community exists largely as modified occurrences that are likely to be capable of being substantially restored or rehabilitated.

B) The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations.

C) The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long term future because of existing or impending threatening processes.

3. Definitions and Criteria for Priority Ecological Communities

PRIORITY ECOLOGICAL COMMUNITY LIST
Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the Priority Ecological Community Lists under Priorities 1, 2 and 3. These three categories are ranked in order of priority for survey and/or definition of the community, and evaluation of conservation status, so that consideration can be given to their declaration as threatened ecological communities. Ecological Communities that are adequately known, and are rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5.

Priority One: Poorly-known ecological communities
Ecological communities with apparently few, small occurrences, all or most not actively managed for conservation (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) and for which current threats exist. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.

Priority Two: Poorly-known ecological communities
Communities that are known from few small occurrences, all or most of which are actively managed for conservation (e.g. within national parks, conservation parks, nature reserves, State forest, unallocated Crown land, water reserves, etc.) and not under imminent threat of destruction or degradation. Communities may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under threat from known threatening processes.

Priority Three: Poorly known ecological communities

(i) Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or:

(ii) communities known from a few widespread occurrences, which are either large or within significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat, or;

(iii) communities made up of large, and/or widespread occurrences, that may or not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes.

Communities may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and/or are not well defined, and known threatening processes exist that could affect them.

Priority Four: Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list. These communities require regular monitoring.

(a) Rare. Ecological communities known from few occurrences that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These communities are usually represented on conservation lands.

(b) Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.

(c) Ecological communities that have been removed from the list of threatened communities during the past five years.

Priority Five: Conservation Dependent ecological communities
Ecological communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

Reference: Department of Environment and Conservation 2007.

B. Threatened Flora Statutory Framework

In Western Australia, all native flora species are protected under the *Wildlife Conservation Act 1950-1979,* making it an offence to remove or harm native flora species without approval. In addition to this basic level of statutory protection, a number of plant species are assigned an additional level of conservation significance based on the fact that there are a limited number of known populations, some of which may be under threat.

Species of the highest conservation significance are designated Declared Rare Flora (DRF), either extant or presumed extinct:

- **X: Declared Rare Flora - Presumed Extinct**: taxa which have not been collected, or otherwise verified, over the past 50 years despite thorough searching, or of which all known wild populations have been destroyed more recently, and have been gazetted as such, following approval by the Minister for the Environment, after recommendation by the State's Endangered Flora Consultative Committee;
- **R: Declared Rare Flora - Extant**: taxa which have been adequately searched for, and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such, following approval by the Minister for the Environment, after recommendation by the State's Endangered Flora Consultative Committee (Atkins 2008). *(= Threatened Flora = Endangered + Vulnerable)*

Species that appear to be rare or threatened, but for which there is insufficient information to properly evaluate their conservation significance, are assigned to one of four Priority flora categories:

- **P1: Priority One - Poorly Known**: taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat, e.g. road verges, urban areas, farmland, active mineral leases, etc., or the plants are under threat, e.g. from disease, grazing by feral animals, etc. May include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.
- **P2: Priority Two - Poorly Known**: taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.
- **P3: Priority Three - Poorly Known**: taxa which are known from several populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in need of further survey.
- **P4: Priority Four - Rare**: taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5–10 years.

Note that of the above classifications, only 'Declared Rare Flora' has statutory standing. The Priority Flora classifications are employed by the Department of Environment and Conservation to manage and classify their database of species considered potentially rare or at risk, but these categories have no legislative status. Note also that proposals that appear likely to affect DRF require formal written approval from the Minister for the Environment under Section 23(f) of the *Wildlife Conservation Act 1950-1979* in addition to the requirements of the *Environmental Protection (Native Vegetation Clearing) Regulations 2004*.

References:

Atkins, K.J. (2008). Declared Rare and Priority Flora List for Western Australia. Prepared by the Department of Environment and Conservation, 6 October 2008.

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Appendix 2

Vegetation Structural Classification and Condition Ranking Scale

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Vegetation Structural Classes*

Stratum	Canopy Cover (%)				
	70-100%	**30-70%**	**10-30%**	**2-10%**	**<2%**
Trees over 30 m	Tall closed forest	Tall open forest	Tall woodland	Tall open woodland	Scattered tall trees
Trees 10-30 m	Closed forest	Open forest	Woodland	Open woodland	Scattered trees
Trees under 10 m	Low closed forest	Low open forest	Low woodland	Low open woodland	Scattered low trees
Shrubs over 2 m	Tall closed scrub	Tall open scrub	Tall shrubland	Tall open shrubland	Scattered tall shrubs
Shrubs 1-2 m	Closed heath	Open heath	Shrubland	Open shrubland	Scattered shrubs
Shrubs under 1 m	Low closed heath	Low open heath	Low shrubland	Low open shrubland	Scattered low shrubs
Hummock grasses	Closed hummock grassland	Hummock grassland	Open hummock grassland	Very open hummock grassland	Scattered hummock grasses
Grasses, Sedges, Herbs	Closed tussock grassland / bunch grassland / sedgeland / herbland	Tussock grassland / bunch grassland / sedgeland / herbland	Open tussock grassland / bunch grassland / sedgeland / herbland	Very open tussock grassland / bunch grassland / sedgeland / herbland	Scattered tussock grasses / bunch grasses / sedges / herbs

* Based on Muir (1977), and Aplin's (1979) modification of the vegetation classification system of Specht (1970): Aplin T.E.H. (1979). The Flora. Chapter 3 *In* O'Brien, B.J. (ed.) (1979). *Environment and Science.* University of Western Australia Press; Muir B.G. (1977). Biological Survey of the Western Australian Wheatbelt. Part II: Vegetation and habitat of Bendering Reserve. *Records of the Western Australian Museum, Suppl*. No. 3; Specht R.L. (1970). Vegetation. *In The Australian Environment.* 4th edn (Ed. G.W. Leeper). Melbourne.

Vegetation Condition Scale*

E = Excellent (=Pristine of BushForever)
Pristine or nearly so; no obvious signs of damage caused by the activities of European man.

VG = Very Good (= Excellent of BushForever)
Some relatively slight signs of damage caused by the activities of European man. For example, some signs of damage to tree trunks caused by repeated fire, the presence of some relatively non-aggressive weeds such as **Ursinia anthemoides* or **Briza* spp., or occasional vehicle tracks.

G = Good (= Very Good of BushForever)
More obvious signs of damage caused by the activities of European man, including some obvious impact on the vegetation structure such as that caused by low levels of grazing or by selective logging. Weeds as above, possibly plus some more aggressive ones such as **Ehrharta* spp.

P = Poor (= Good of BushForever)
Still retains basic vegetation structure or ability to regenerate to it after very obvious impacts of activities of European man, such as grazing, partial clearing (chaining) or frequent fires. Weeds as above, probably plus some more aggressive ones such as **Ehrharta* spp.

VP = Very Poor (= Degraded of BushForever)
Severely impacted by grazing, very frequent fires, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species including very aggressive species.

D = Completely Degraded (= Completely Degraded of BushForever)
Areas that are completely or almost completely without native species in the structure of their vegetation; i.e. areas that are cleared or 'parkland cleared' with their flora comprising weed or crop species with isolated native trees or shrubs.

* Based on Trudgen M.E. (1988). A Report on the Flora and Vegetation of the Port Kennedy Area. Unpublished report prepared for Bowman Bishaw and Associates, West Perth.

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Appendix 3

Vegetation Mapping for the Wheatstone Study Area, including Land Systems, Priority Species and Less Common Weeds

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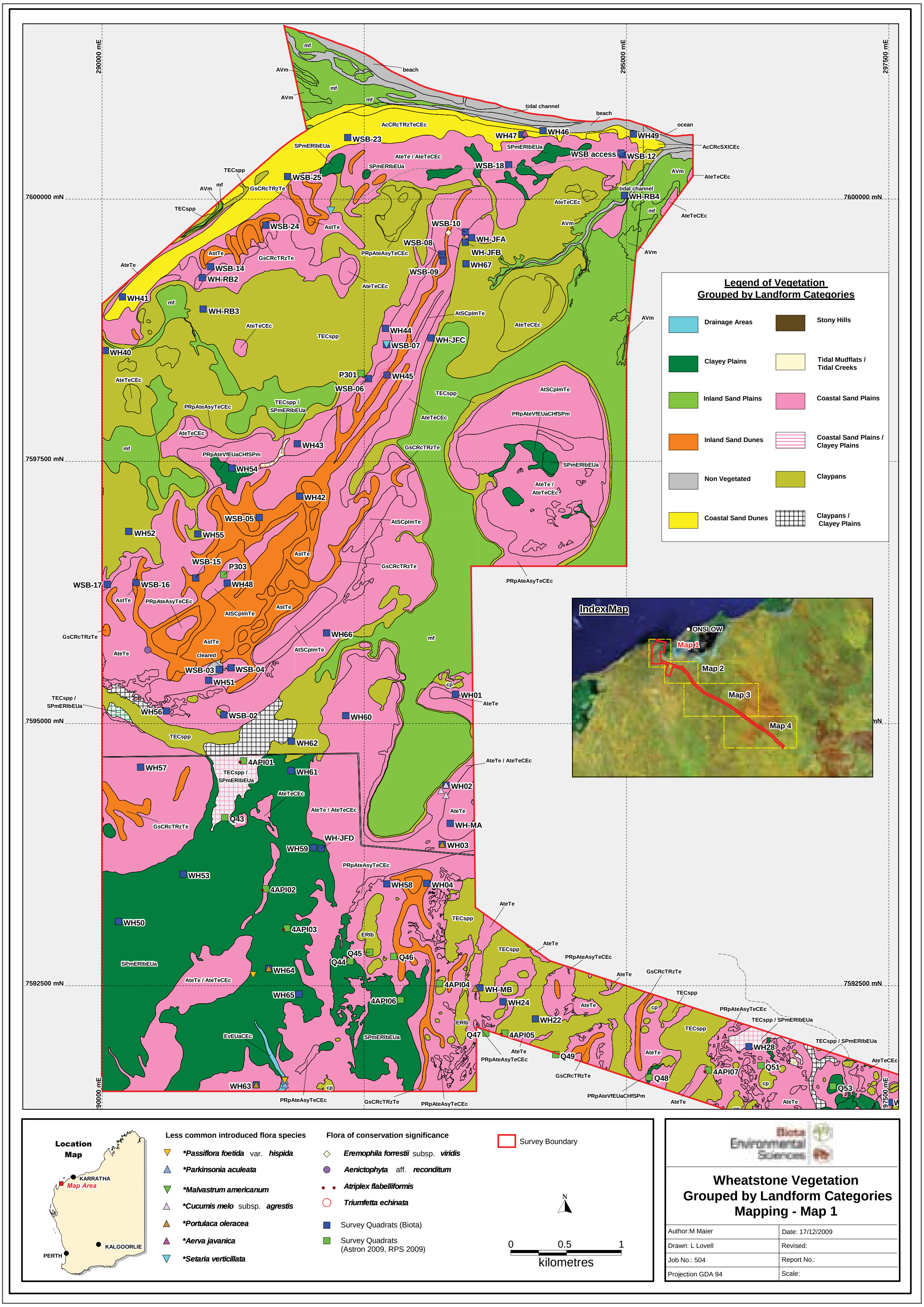
Legend of Vegetation Grouped by Landform Categories
Drainage Areas
Stony Hills
Clayey Plains
Tidal Mudflats / Tidal Creeks
Inland Sand Plains
Coastal Sand Plains
Inland Sand Dunes
Coastal Sand Plains / Clayey Plains
Non Vegetated
Claypans
Coastal Sand Dunes
Claypans / Clayey Plains
Index Map
ONSLOW
Map 1
Map 2
Map 3
Map 4
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH
Less common introduced flora species
*Passiflora foetida var. hispida
*Parkinsonia aculeata
*Malvastrum americanum
*Cucumis melo subsp. agrestis
*Portulaca oleracea
*Aerva javanica
*Setaria verticillata
Flora of conservation significance
Eremophila forrestii subsp. viridis
Aenictophyta aff. reconditum
Atriplex flabelliformis
Triumfetta echinata
Survey Quadrats (Biota)
Survey Quadrats (Astron 2009, RPS 2009)
Survey Boundary
N
0 0.5 1
kilometres
Biota Environmental Sciences
Wheatstone Vegetation Grouped by Landform Categories Mapping - Map 1
Author:M Maier
Date: 17/12/2009
Drawn: L Lovell
Revised:
Job No.: 504
Report No.:
Projection GDA 94
Scale:
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295000 mE
297500 mE
7600000 mN
7597500 mN
7595000 mN
7592500 mN
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tidal channel
ocean
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AteTeCEc
AVm
mf
AcCRcTRzTeCEc
SPmERlbEUa
TECspp
GsCRcTRzTe
AstTe
PRpAteAsyTeCEc
AtSCplmTe
PRpAteVfEUaCHfSPm
AteTe / AteTeCEc
TECspp / SPmERlbEUa
cleared
cp
ERlb
EvEUaCEc
WSB-23
WH47
WH46
WH49
WSB access
WSB-12
WSB-18
WSB-25
WH-RB4
WSB-24
WSB-10
WH-JFA
WSB-08
WH-JFB
WSB-14
WH67
WH-RB2
WSB-09
WH41
WH-RB3
WH44
WSB-07
WH-JFC
WH40
P301
WH45
WSB-06
WH43
WH54
WH42
WSB-05
WH52
WH55
WSB-15
P303
WSB-17
WSB-16
WH48
WH66
WSB-03
WSB-04
WH51
WH01
WH56
WSB-02
WH60
WH62
4API01
WH57
WH61
WH02
Q43
WH-MA
WH-JFD
WH03
WH59
WH53
WH58
WH04
4API02
WH50
4API03
Q45
Q46
Q44
WH64
4API04
WH-MB
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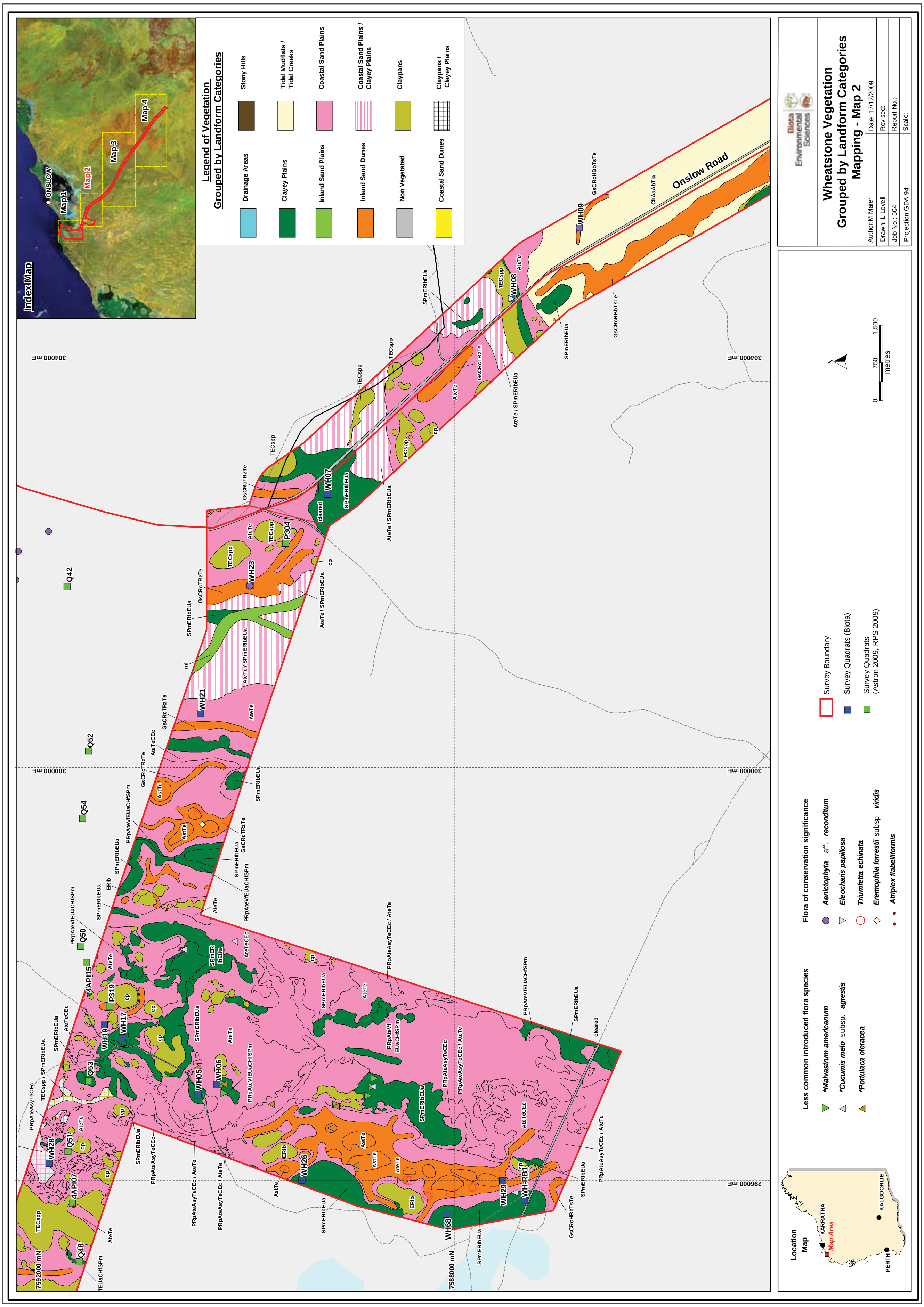
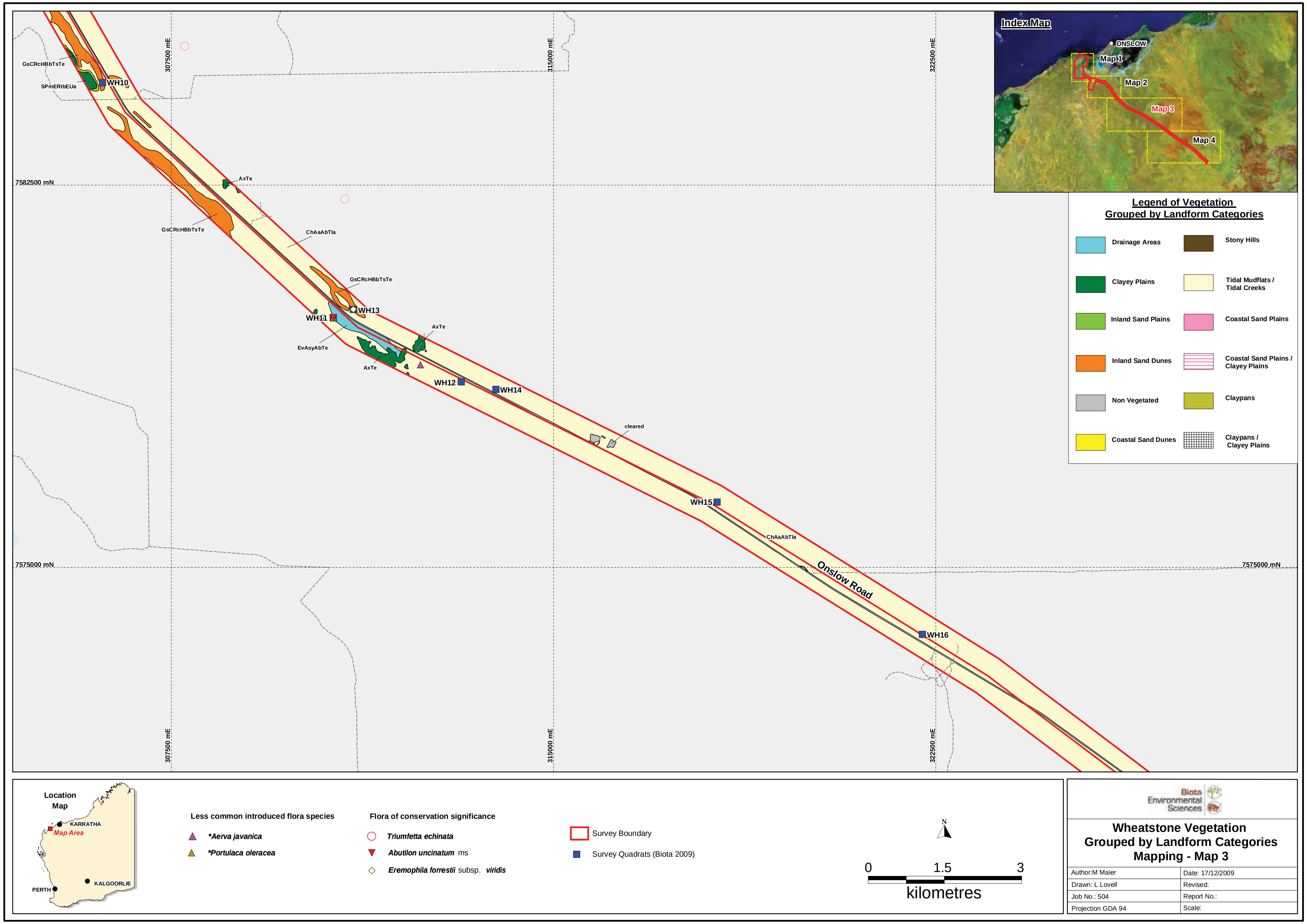
Q48
Q53
WH63


Index Map
ONSLOW
Map 1
Map 2
Map 3
Map 4
Legend of Vegetation Grouped by Landform Categories
Drainage Areas
Stony Hills
Clayey Plains
Tidal Mudflats / Tidal Creeks
Inland Sand Plains
Coastal Sand Plains
Inland Sand Dunes
Coastal Sand Plains / Clayey Plains
Non Vegetated
Claypans
Coastal Sand Dunes
Claypans / Clayey Plains
Onslow Road
304000 mE
300000 mE
296000 mE
7592000 mN
7588000 mN
WH09
WH08
WH07
WH23
WH21
WH19
WH17
WH05
WH06
WH28
WH26
WH29
WH-RB1
WH68
P304
P319
Q42
Q52
Q54
Q50
Q53
Q51
Q48
4API15
4API07
TECspp
cp
cleared
mf
AteTe
AstTe
ERlb
SPmERlbEUa
GsCRcTRzTe
GsCRcHBbTsTe
ChAaAbTla
AteTe / SPmERlbEUa
AteTeCEc
PRpAteVfEUaCHfSPm
PRpAteAsyTeCEc
PRpAteAsyTeCEc / AteTe
TECspp / SPmERlbEUa
EUaCHfSPm
Less common introduced flora species
*Malvastrum americanum
*Cucumis melo subsp. agrestis
*Portulaca oleracea
Flora of conservation significance
Aenictophyta aff. reconditum
Eleocharis papillosa
Triumfetta echinata
Eremophila forrestii subsp. viridis
Atriplex flabelliformis
Survey Boundary
Survey Quadrats (Biota)
Survey Quadrats (Astron 2009, RPS 2009)
N
0
750
1,500
metres
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH
Biota Environmental Sciences
Wheatstone Vegetation Grouped by Landform Categories Mapping - Map 2
Author:M Maier
Date: 17/12/2009
Drawn: L Lovell
Revised:
Job No.: 504
Report No.:
Projection GDA 94
Scale: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Coastal Sand Plains
Inland Sand Dunes
Coastal Sand Plains / Clayey Plains
Non Vegetated
Claypans
Coastal Sand Dunes
Claypans / Clayey Plains
307500 mE
315000 mE
322500 mE
7582500 mN
7575000 mN
GsCRcHBbTsTe
SPmERlbEUa
WH10
AxTe
GsCRcHBbTsTe
ChAaAbTla
GsCRcHBbTsTe
WH11
WH13
EvAsyAbTe
AxTe
AxTe
WH12
WH14
cleared
WH15
ChAaAbTla
Onslow Road
WH16
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH
Less common introduced flora species
*Aerva javanica
*Portulaca oleracea
Flora of conservation significance
Triumfetta echinata
Abutilon uncinatum ms
Eremophila forrestii subsp. viridis
Survey Boundary
Survey Quadrats (Biota 2009)
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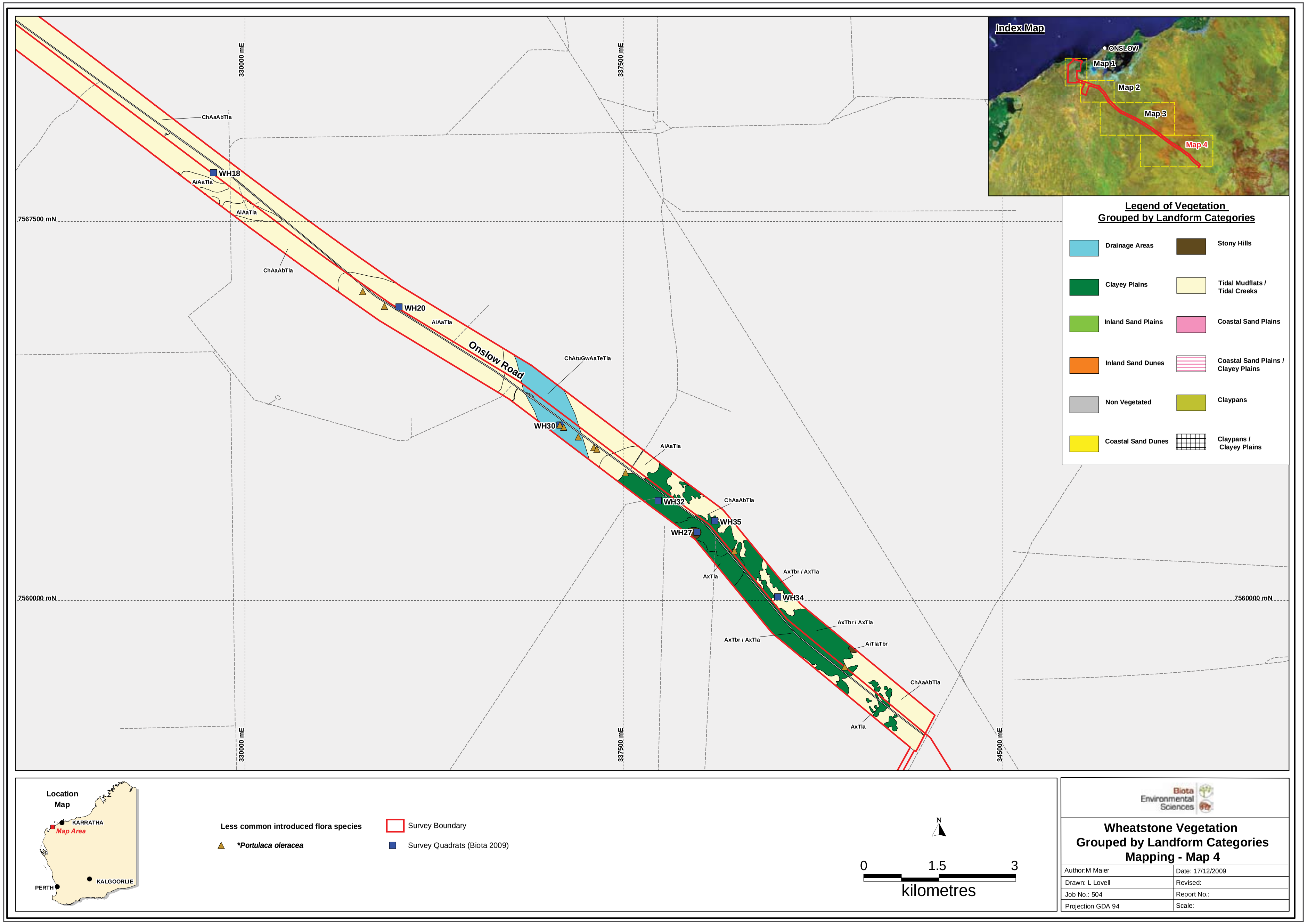
3
kilometres
Biota Environmental Sciences
Wheatstone Vegetation Grouped by Landform Categories Mapping - Map 3
Author:M Maier
Date: 17/12/2009
Drawn: L Lovell
Revised:
Job No.: 504
Report No.:
Projection GDA 94
Scale:


Index Map
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Drainage Areas
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Inland Sand Plains
Coastal Sand Plains
Inland Sand Dunes
Coastal Sand Plains / Clayey Plains
Non Vegetated
Claypans
Coastal Sand Dunes
Claypans / Clayey Plains
ChAaAbTla
WH18
AiAaTla
AiAaTla
7567500 mN
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WH20
AiAaTla
Onslow Road
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WH32
ChAaAbTla
WH35
WH27
AxTbr / AxTla
AxTla
WH34
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7560000 mN
AxTbr / AxTla
AxTbr / AxTla
AiTlaTbr
ChAaAbTla
AxTla
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337500 mE
345000 mE
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH
Less common introduced flora species
*Portulaca oleracea
Survey Boundary
Survey Quadrats (Biota 2009)
N
0
1.5
3
kilometres
Biota Environmental Sciences
Wheatstone Vegetation Grouped by Landform Categories Mapping - Map 4
Author:M Maier
Date: 17/12/2009
Drawn: L Lovell
Revised:
Job No.: 504
Report No.:
Projection GDA 94
Scale:

Vegetation of Wheatstone Study Area

Vegetation of Tidal Mudflats

🟫	**mf**	***Tecticornia*** spp. scattered low shrubs
🟨	**AVm**	***Avicennia marina*** open scrub

Vegetation of Coastal Sand Dunes

⬜	**AcCRcSXlCEc**	***Acacia coriacea*** subsp. ***coriacea, Crotalaria cunninghamii*** tall shrubland over ***Spinifex longifolius, (*Cenchrus ciliaris)*** open tussock grassland
🟩	**AcCRcTRzTeCEc**	***Acacia coriacea*** subsp. ***coriacea*** tall shrubland over ***Crotalaria cunninghamii, Trichodesma zeylanicum*** var. ***grandiflorum*** open shrubland over ***Triodia epactia*** open hummock grassland with ****Cenchrus ciliaris*** open tussock grassland

Vegetation of Inland Sand Dunes

🟧	**GsCRcTRzTe**	***Grevillea stenobotrya*** stenobotrya tall open shrubland over ***Crotalaria cunninghamii, Trichodesma zeylanicum*** var. ***grandiflorum*** open shrubland over ***Triodia epactia*** open hummock grassland
🟨	**GsCRcHBbTsTe**	***Grevillea stenobotrya*** tall open shrubland over ***Crotalaria cunninghamii, Hibiscus brachychlaenus*** open shrubland over ***Triodia schinzii, (T. epactia)*** open hummock grassland
🟧	**AstTe**	***Acacia stellaticeps*** shrubland over ***Triodia epactia*** hummock grassland

Vegetation of Coastal Sand Plains

🟧	**AteTe**	***Acacia tetragonophylla*** scattered shrubs over ***Triodia epactia*** hummock grassland
▨	**AteTe / AteTeCEc**	
▤	**AteTe / SPmERlbEUa**	
⬜	**AteTeCEc**	***Acacia tetragonophylla*** scattered shrubs over ***Triodia epactia*** hummock grassland with ****Cenchrus ciliaris*** open tussock grassland
🟧	**AtSCplmTe**	***Acacia tetragonophylla*** scattered shrubs over ***Scaevola pulchella, Indigofera monophylla*** low open shrubland over***Triodia epactia*** hummock grassland
🟫	**PRpAteAsyTeCEc**	****Prosopis pallida, Acacia tetragonophylla, A. synchronicia*** scattered tall shrubs over ***Triodia epactia*** very open hummock grassland and ****Cenchrus ciliaris*** open hummock grassland
▤	**PRpAteAsyTeCEc / AteTe**	

Vegetation of Claypans

🟪	**cp**	Bare claypan
🟥	**ERlb**	***Eriachne*** aff. ***benthamii*** open tussock grassland
🟥	**TECspp**	***Tecticornia*** spp. low shrubland
▦	**TECspp / SPmERlbEUa**	

Vegetation Community Types Descriptions for Wheatstone Study Area Vegetation Map

Legend Sheet 1 of 2

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Vegetation of Wheatstone Study Area

Vegetation of Clayey Plains

🟧	**SPmERIbEUa**	***Sporobolus mitchellii, Eriachne*** aff. ***benthamii, E. benthamii, Eulalia aurea*** tussock grassland
🟩	**PRpAteVfEUaCHfSPm**	****Prosopis pallida*** scattered tall shrubs to tall open shrubland over ***Acacia tetragonophylla, *Vachellia farnesiana*** shrubland over ***Eulalia aurea, Chrysopogon fallax, Sporobolus mitchellii*** tussock grassland
🟧	**AxTe**	***Acacia xiphophylla*** tall shrubland over ***Triodia epactia*** open hummock grassland
🟥	**AxTla**	***Acacia xiphophylla*** tall shrubland over ***Triodia lanigera*** open hummock grassland
	AxTbr	***Acacia xiphophylla*** tall open shrubland over ***Triodia brizoides*** very open hummock grassland
▨	**AxTbr / AxTla**	

Vegetation of Inland Sand Plains

🟨	**ChAaAbTla**	***Corymbia hamersleyana*** tall open shrubland over scattered low mallees over ***Acacia ancistrocarpa, A. bivenosa*** shrubland over ***Triodia lanigera*** hummock grassland
🟩	**AiAaTla**	***Acacia inaequilatera*** tall open shrubland over ***A. ancistrocarpa*** open shrubland over ***Triodia lanigera*** open hummock grassland

Vegetation of Stony Hills

🟩	**AiTlaTbr**	***Acacia inaequilatera*** tall open shrubland over ***Triodia lanigera, T. brizoides*** open hummock grassland

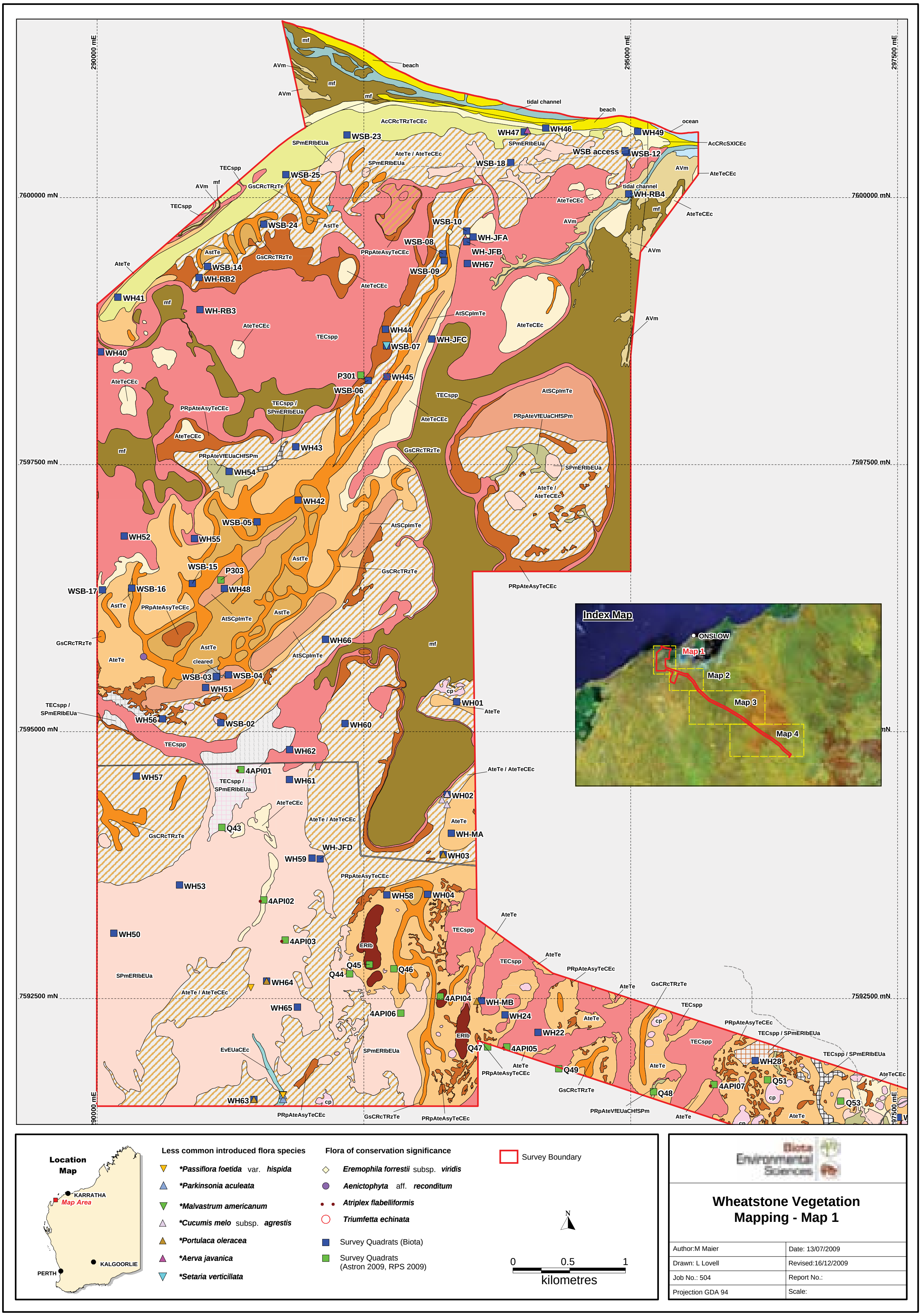
Vegetation of Drainage Areas

🟦	**EvEUaCEc**	***Eucalyptus victrix*** open forest over ***Eulalia aurea, *Cenchrus ciliaris*** tussock grassland
🟦	**EvAsyAbTe**	***Eucalyptus victrix*** scattered low trees over ***Acacia synchronicia, A. bivenosa*** shrubland over ***Triodia epactia*** hummock grassland
🟪	**ChAtuGwAaTeTla**	***Corymbia hamersleyana*** scattered low mallees over ***Acacia tumida*** var. ***pilbarensis, Grevillea wickhamii*** subsp. ***hispidula*** tall open shrubland over ***A. ancistrocarpa*** open shrubland over ***Triodia epactia, T. lanigera*** open hummock grassland

⬜	**cleared**	Areas that have been previously cleared of most of their native vegetation.
🟨	**beach**	
🟦	**ocean**	
🟦	**tidal channel**	

Vegetation Community Types Descriptions for
Wheatstone Study Area Vegetation Map
Legend Sheet 2 of 2

Biota Environmental Sciences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mf
beach
AVm
tidal channel
ocean
AcCRcTRzTeCEc
AcCRcSXICEc
WSB-23
WH47
WH46
WH49
SPmERIbEUa
AteTe / AteTeCEc
WSB access
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WSB-18
TECspp
WSB-25
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WH-JFC
WSB-07
AtSCpImTe
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WSB-06
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WH65
4API06
WH22
4API05
Q47
EvEUaCEc
Q49
WH28
4API07
Q51
Q48
Q53
WH63
cp
Index Map
ONSLOW
Map 1
Map 2
Map 3
Map 4
Location Map
KARRATHA
Map Area
PERTH
KALGOORLIE
Less common introduced flora species
*Passiflora foetida var. hispida
*Parkinsonia aculeata
*Malvastrum americanum
*Cucumis melo subsp. agrestis
*Portulaca oleracea
*Aerva javanica
*Setaria verticillata
Flora of conservation significance
Eremophila forrestii subsp. viridis
Aenictophyta aff. reconditum
Atriplex flabelliformis
Triumfetta echinata
Survey Quadrats (Biota)
Survey Quadrats (Astron 2009, RPS 2009)
Survey Boundary
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0.5
1
kilometres
Biota Environmental Sciences
Wheatstone Vegetation Mapping - Map 1
Author:M Maier
Date: 13/07/2009
Drawn: L Lovell
Revised:16/12/2009
Job No.: 504
Report No.:
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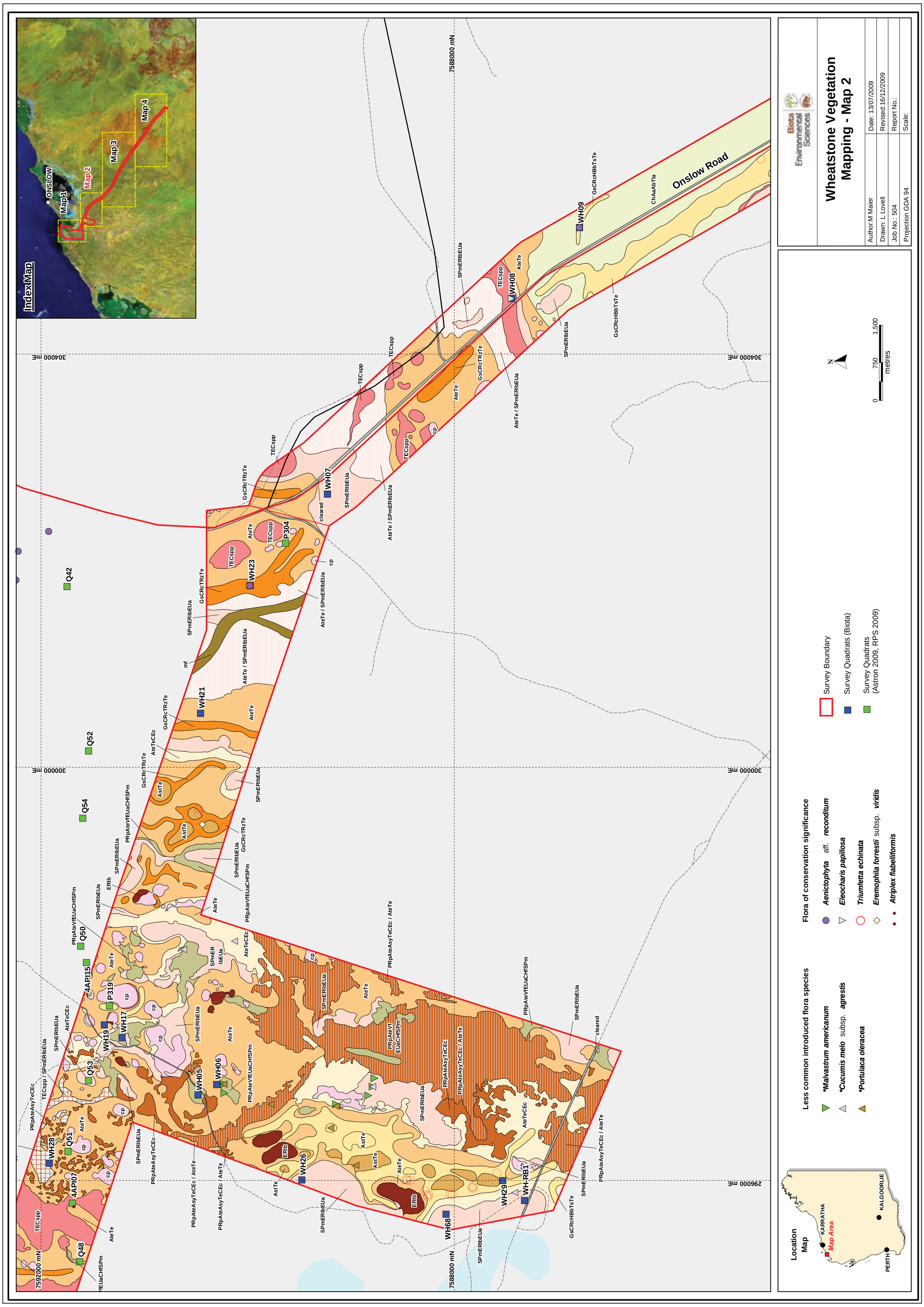
Scale: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Biota Environmental Sciences
Author: M Maier
Drawn: L Lovell
Job No.: 504
Projection GDA 94
Date: 13/07/2009
Revised: 16/12/2009
Report No.:
Scale:
Index Map
ONSLOW
Map 1
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Map 3
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Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH
Less common introduced flora species
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Aenictophyta aff. reconditum
Eleocharis papillosa
Triumfetta echinata
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Atriplex flabelliformis
Survey Boundary
Survey Quadrats (Biota)
Survey Quadrats (Astron 2009, RPS 2009)
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1,500
metres
Onslow Road
7592000 mN
7588000 mN
304000 mE
300000 mE
296000 mE
Q42
Q52
Q54
Q50
Q53
Q51
Q48
4APl15
4APl07
P319
P304
WH05
WH06
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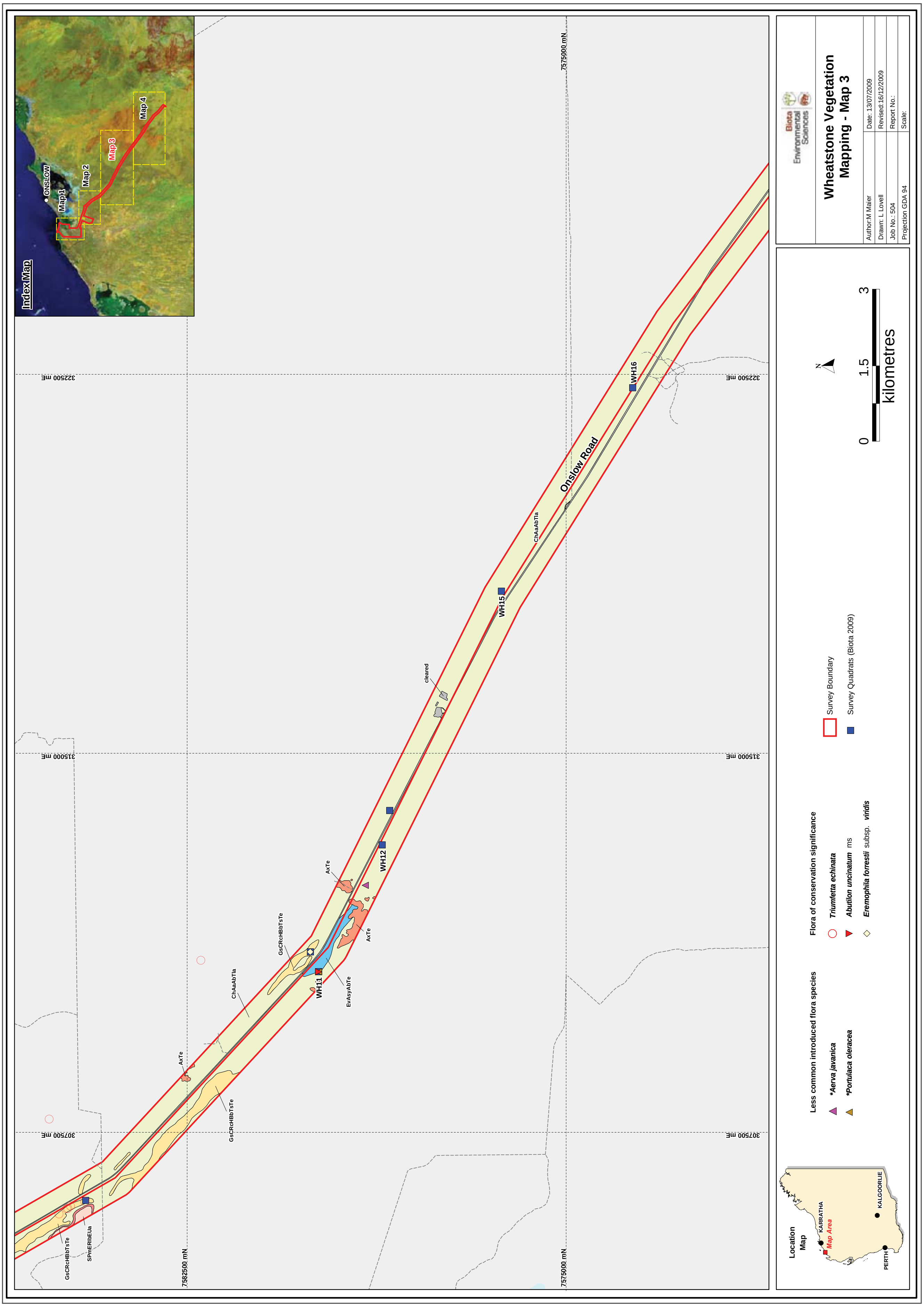
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Map 1
Map 2
Map 3
Map 4
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Onslow Road
WH11
WH12
WH15
WH16
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GsCRcHBbTsTe
ChAaAbTla
EvAsyAbTe
SPmERiEUa
cleared
Biota Environmental Sciences
Wheatstone Vegetation Mapping - Map 3
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Drawn: L Lovell
Job No.: 504
Projection GDA 94
Date: 13/07/2009
Revised:16/12/2009
Report No.:
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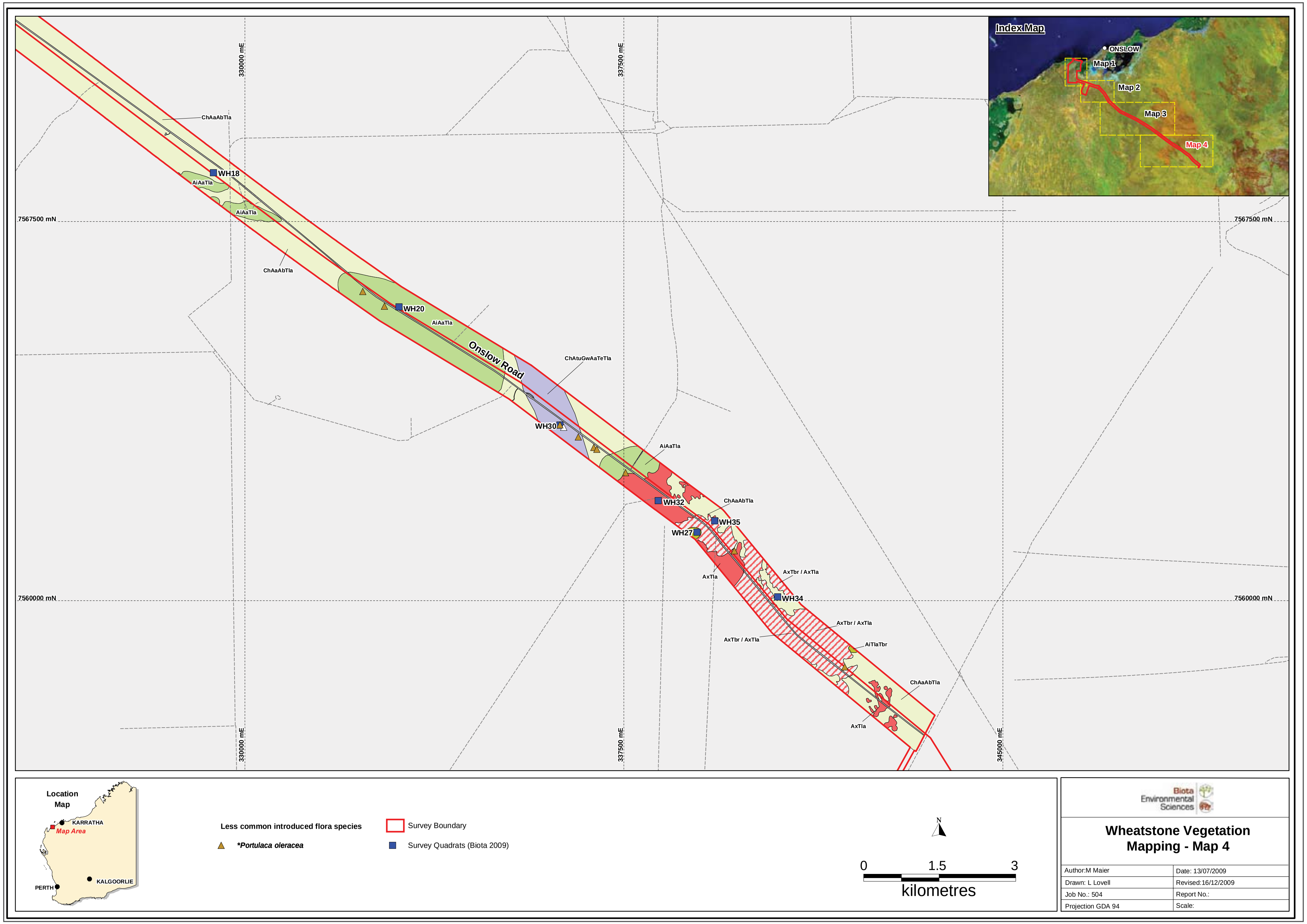
kilometres
Survey Boundary
Survey Quadrats (Biota 2009)
Flora of conservation significance
Triumfetta echinata
Abutilon uncinatum ms
Eremophila forrestii subsp. viridis
Less common introduced flora species
*Aerva javanica
*Portulaca oleracea
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH


Index Map
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Map 3
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AiAaTla
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WH20
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Onslow Road
ChAtuGwAaTeTla
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AxTbr / AxTla
WH34
AxTbr / AxTla
AxTbr / AxTla
AiTlaTbr
ChAaAbTla
AxTla
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH
Less common introduced flora species
*Portulaca oleracea
Survey Boundary
Survey Quadrats (Biota 2009)
N
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1.5
3
kilometres
Biota Environmental Sciences
Wheatstone Vegetation Mapping - Map 4
Author:M Maier
Date: 13/07/2009
Drawn: L Lovell
Revised:16/12/2009
Job No.: 504
Report No.:
Projection GDA 94
Scale:

Appendix 4

Raw Data from Quadrats and Relevés Assessed in the Wheatstone Study Area in 2009

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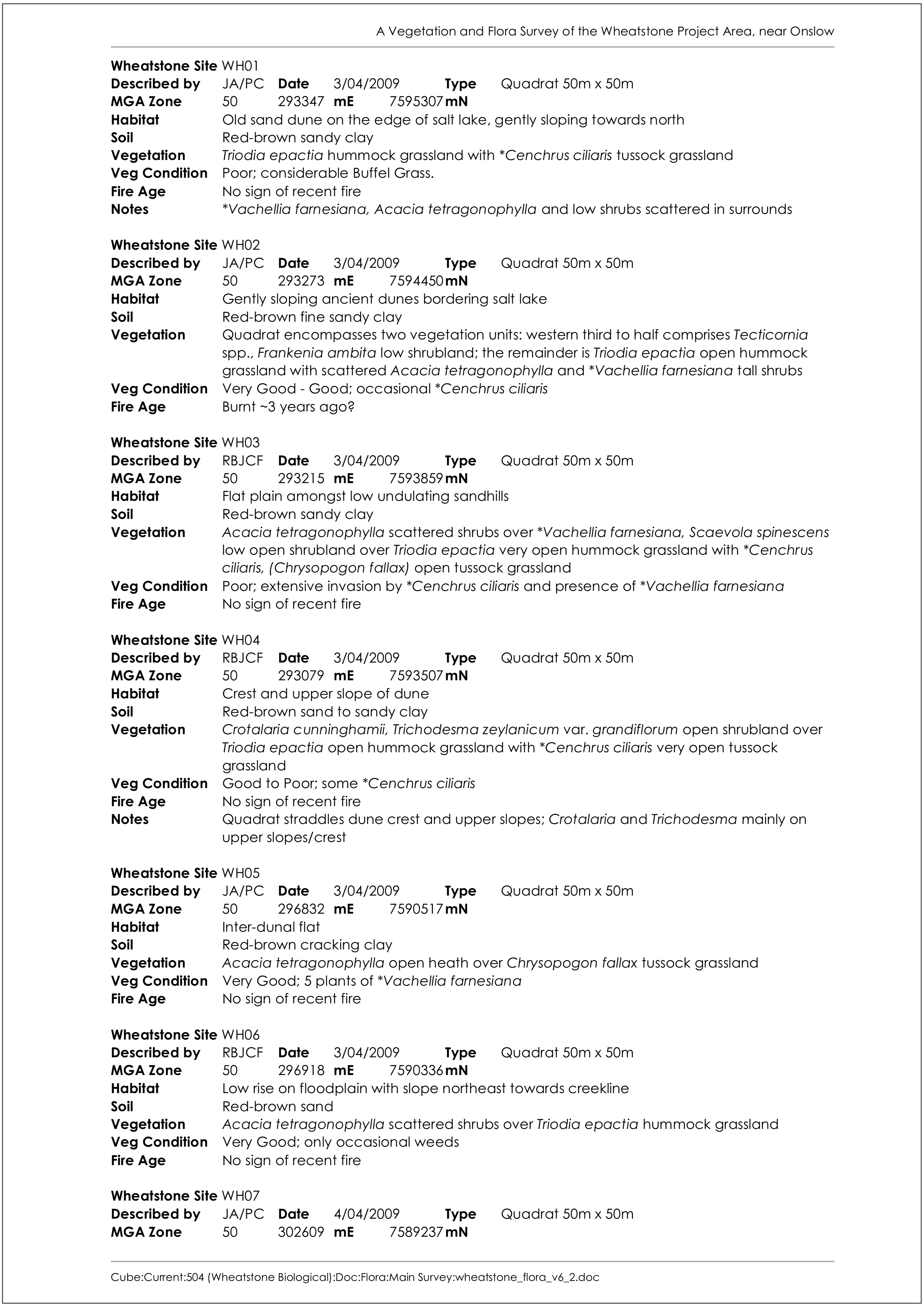

Wheatstone Site WH01
Described by JA/PC **Date** 3/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 293347 **mE** 7595307 **mN**
Habitat Old sand dune on the edge of salt lake, gently sloping towards north
Soil Red-brown sandy clay
Vegetation *Triodia epactia* hummock grassland with **Cenchrus ciliaris* tussock grassland
Veg Condition Poor; considerable Buffel Grass.
Fire Age No sign of recent fire
Notes **Vachellia farnesiana, Acacia tetragonophylla* and low shrubs scattered in surrounds

Wheatstone Site WH02
Described by JA/PC **Date** 3/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 293273 **mE** 7594450 **mN**
Habitat Gently sloping ancient dunes bordering salt lake
Soil Red-brown fine sandy clay
Vegetation Quadrat encompasses two vegetation units: western third to half comprises *Tecticornia* spp., *Frankenia ambita* low shrubland; the remainder is *Triodia epactia* open hummock grassland with scattered *Acacia tetragonophylla* and **Vachellia farnesiana* tall shrubs
Veg Condition Very Good - Good; occasional **Cenchrus ciliaris*
Fire Age Burnt ~3 years ago?

Wheatstone Site WH03
Described by RBJCF **Date** 3/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 293215 **mE** 7593859 **mN**
Habitat Flat plain amongst low undulating sandhills
Soil Red-brown sandy clay
Vegetation *Acacia tetragonophylla* scattered shrubs over **Vachellia farnesiana, Scaevola spinescens* low open shrubland over *Triodia epactia* very open hummock grassland with **Cenchrus ciliaris, (Chrysopogon fallax)* open tussock grassland
Veg Condition Poor; extensive invasion by **Cenchrus ciliaris* and presence of **Vachellia farnesiana*
Fire Age No sign of recent fire

Wheatstone Site WH04
Described by RBJCF **Date** 3/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 293079 **mE** 7593507 **mN**
Habitat Crest and upper slope of dune
Soil Red-brown sand to sandy clay
Vegetation *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* very open tussock grassland
Veg Condition Good to Poor; some **Cenchrus ciliaris*
Fire Age No sign of recent fire
Notes Quadrat straddles dune crest and upper slopes; *Crotalaria* and *Trichodesma* mainly on upper slopes/crest

Wheatstone Site WH05
Described by JA/PC **Date** 3/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 296832 **mE** 7590517 **mN**
Habitat Inter-dunal flat
Soil Red-brown cracking clay
Vegetation *Acacia tetragonophylla* open heath over *Chrysopogon fallax* tussock grassland
Veg Condition Very Good; 5 plants of **Vachellia farnesiana*
Fire Age No sign of recent fire

Wheatstone Site WH06
Described by RBJCF **Date** 3/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 296918 **mE** 7590336 **mN**
Habitat Low rise on floodplain with slope northeast towards creekline
Soil Red-brown sand
Vegetation *Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland
Veg Condition Very Good; only occasional weeds
Fire Age No sign of recent fire

Wheatstone Site WH07
Described by JA/PC **Date** 4/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 302609 **mE** 7589237 **mN**

Habitat Broad plain (seasonally inundated)
Soil cracking clay
Vegetation *Eriachne benthamii, Sporobolus mitchellii* tussock grassland with *Marsilea hirsuta* herbland
Veg Condition Very Good; occasional **Vachellia farnesiana* only
Fire Age No sign of recent fire

Wheatstone Site WH08
Described by RBJCF **Date** 4/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 304511 **mE** 7587457 **mN**
Habitat Broad saline drainage area
Soil Red-brown clay
Vegetation *Tecticornia indica* subsp. *leiostachya, Tecticornia* sp. low open shrubland over *Sporobolus mitchellii* scattered tussock grasses
Veg Condition Good; 10+ **Cenchrus ciliaris* individuals
Fire Age No sign of recent fire

Wheatstone Site WH09
Described by JA/PC **Date** 4/04/2009 **Type** Quadrat 30m x 70m
MGA Zone 50 305191 **mE** 7586807 **mN**
Habitat Low dune
Soil Red-brown fine grained sand
Vegetation *Grevillea stenobotrya* scattered tall shrubs over *Acacia stellaticeps* shrubland over *Triodia schinzii, (T. epactia)* hummock grassland
Veg Condition Very Good; very occasional weeds
Fire Age No sign of recent fire
Notes Quadrat size 30m x 70m to capture dune community

Wheatstone Site WH10
Described by RBJCF **Date** 4/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 306128 **mE** 7584534 **mN**
Habitat Crest and slope of sand dune
Soil Red sand
Vegetation *Grevillea stenobotrya* scattered tall shrubs over *Adriana tomentosa* var. *tomentosa, Crotalaria cunninghamii, Acacia coriacea* open shrubland over *Triodia schinzii, (T. epactia)* open hummock grassland with **Cenchrus ciliaris* scattered tussock grasses
Veg Condition Very good; only scattered weeds
Fire Age No sign of recent fire

Wheatstone Site WH11
Described by JA/PC **Date** 4/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 310642 **mE** 7579903 **mN**
Habitat Broad flat between distant aeolian dunes
Soil Patchy; clay and loam
Vegetation *Acacia synchronicia, A bivenosa* shrubland over *Triodia epactia* open hummock grassland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH12
Described by RBJCF **Date** 4/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 313180 **mE** 7578675 **mN**
Habitat Flat plain
Soil Red sandy clay
Vegetation *Eucalyptus victrix* scattered low trees over *Acacia ancistrocarpa, Grevillea eriostachya* tall open shrubland over *Acacia stellaticeps* shrubland over *Triodia lanigera* hummock grassland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH13
Described by JA/PC **Date** 4/04/2009 **Type** Quadrat 30m x 70m
MGA Zone 50 311037 **mE** 7580072 **mN**
Habitat Dune crest sloping west
Soil Red-brown fine sand
Vegetation *Grevillea stenobotrya* tall open scrub over *Pityrodia loxocarpa, (Acacia stellaticeps, Bonamia rosea)* low shrubland over *Triodia schinzii* open hummock grassland

Veg Condition Very Good
Fire Age No sign of recent fire
Notes Quadrat sized to 30m x 70m to capture dune community

Wheatstone Site WH14
Described by RB/PC **Date** 5/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 313870 **mE** 7578528 **mN**
Habitat Broad flat plain
Soil Red-brown loamy sand
Vegetation *Acacia bivenosa, (A. ancistrocarpa, A. synchronicia)* open heath over *Triodia lanigera, (Triodia epactia)* hummock grassland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH15
Described by JAJCF **Date** 5/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 318172 **mE** 7576282 **mN**
Habitat Flat sandy plain
Soil Red-brown sandy clay
Vegetation *Corymbia hamersleyana* scattered low trees over *Acacia ancistrocarpa* scattered shrubs over *Triodia schinzii, T. lanigera* open hummock grassland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH16
Described by RB/PC **Date** 5/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 322226 **mE** 7573719 **mN**
Habitat Flat plain
Soil Red-brown loamy sand
Vegetation *Corymbia hamersleyana* low open woodland over *Acacia bivenosa, A. ancistrocarpa, A. coriacea* subsp. *coriacea, A. sericophylla, Grevillea eriostachya* tall open shrubland over *Triodia lanigera* hummock grassland
Veg Condition Excellent
Fire Age No sign of recent fire
Notes *Corymbia hamersleyana* trees are in mallee form

Wheatstone Site WH17
Described by JAJCF **Date** 5/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 297361 **mE** 7591244 **mN**
Habitat Plain between Aeolian dunes, seasonally inundated
Soil Brown cracking clay
Vegetation **Prosopis pallida* tall shrubland over **Vachellia farnesiana, (Acacia tetragonophylla)* open shrubland over *Sporobolus mitchellii* tussock grassland
Veg Condition Poor to Good; moderate cover of weedy shrubs
Fire Age No sign of recent fire

Wheatstone Site WH18
Described by RB/PC **Date** 5/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 329386 **mE** 7568503 **mN**
Habitat Broad flat plain
Soil Red-brown loamy sand
Vegetation *Corymbia hamersleyana* low open woodland over *Acacia ancistrocarpa, A. bivenosa, A. coriacea* tall open shrubland to scattered tall shrubs over *Triodia lanigera* hummock grassland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH19
Described by JAJCF **Date** 6/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 297484 **mE** 7591416 **mN**
Habitat Low flat rise between claypans
Soil Brown clay loam, cracking in places
Vegetation **Vachellia farnesiana, Acacia synchronicia* scattered low shrubs over *Triodia epactia* hummock grassland
Veg Condition Very Good; small patch of Buffel Grass <2 m^2, and scattered **Vachellia*
Fire Age No sign of recent fire

Wheatstone Site WH20
Described by MPR **Date** 5/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 333045 **mE** 7565842 **mN**
Habitat Flat plain
Soil Red-brown loamy sand with surface gravel and a few pebbles of ironstone and quartz
Vegetation *Acacia inaequilatera* tall open shrubland over *A. ancistrocarpa* scattered shrubs over *Triodia lanigera* open hummock grassland
Veg Condition Excellent
Fire Age Burnt ?3 years ago

Wheatstone Site WH21
Described by JA/RB **Date** 7/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 300498 **mE** 7590480 **mN**
Habitat Broad undulating plain bordered by steep hills to the west and salt lakes to the east
Soil Red-brown loamy sand
Vegetation *Acacia stellaticeps* open shrubland over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* very open tussock grassland
Veg Condition Good to Very Good; 20+ individuals of **Cenchrus ciliaris*
Fire Age Burnt >3 yrs ago?

Wheatstone Site WH22
Described by RB/PC **Date** 6/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 294122 **mE** 7592216 **mN**
Habitat Plain surrounded by dunes and claypans
Soil Red-brown loamy clay
Vegetation *Tecticornia auriculata* low shrubland over *Eragrostis pergracilis* bunch grassland
Veg Condition Very Good; only a few scattered plants of **Cenchrus ciliaris* and **Vachellia farnesiana*
Fire Age No sign of recent fire

Wheatstone Site WH23
Described by JA/RB **Date** 7/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 301750 **mE** 7590011 **mN**
Habitat Crest and upper slopes of large (tall and wide) dune
Soil Red loamy sand
Vegetation *Crotalaria cunninghamii, Grevillea stenobotrya, Trichodesma zeylanicum* var. *grandiflorum* shrubland over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* very open tussock grassland
Veg Condition Good; some patches of **Cenchrus*
Fire Age No sign of recent fire
Notes 11 individuals of *Triumfetta echinata*; all seem healthy

Wheatstone Site WH24
Described by RB/PC **Date** 6/04/2009 **Type** Quadrat 40m x 60m
MGA Zone 50 293805 **mE** 7592376 **mN**
Habitat Gently undulating plain with saline drainage areas
Soil Red-brown sandy loam
Vegetation *Triodia epactia* closed hummock grassland with **Cenchrus ciliaris* very open tussock grassland
Veg Condition Good; presence of **Cenchrus ciliaris*
Fire Age No sign of recent fire
Notes Quadrat located in *Triodia epactia* plain habitat; 40m x 60m quadrat to avoid drainage lines.

Wheatstone Site WH26
Described by RB/PC **Date** 6/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 295986 **mE** 7589503 **mN**
Habitat broad, flat cracking clay plain surrounded by dunes
Soil red brown cracking clay
Vegetation *Eriachne benthamii, Sporobolus mitchellii, Eragrostis xerophila* tussock grassland
Veg Condition Very Good; a few scattered juvenile **Vachellia farnesiana*
Fire Age No sign of recent fire

Wheatstone Site WH27
Described by JA/PC **Date** 8/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 338914 **mE** 7561370 **mN**
Habitat Moderate slope (~35 degrees) on rocky quartz hill, facing northeast

Soil Red-brown skeletal loam amongst rocks; little soil apparent on surface
Rock Type White quartz rocks and pebbles, some scattered large boulders
Vegetation *Acacia inaequilatera* scattered tall shrubs over *Triodia lanigera* open hummock grassland
Veg Condition Excellent
Fire Age No sign of recent fire
Notes Very old track / machine disturbance on east edge of quadrat; no impact on the species recorded

Wheatstone Site WH28
Described by JF/PC **Date** 7/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 296136 **mE** 7591935 **mN**
Habitat Claypan
Soil Red-brown cracking clay
Vegetation **Prosopis pallida, Acacia tetragonophylla* tall open shrubland over *Tecticornia indica* subsp. *leiostachya* scattered low shrubs over *Sporobolus mitchellii* very open tussock grassland
Veg Condition Good; scattered shrubby weeds and **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WH29
Described by RBJCF **Date** 9/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 295968 **mE** 7587536 **mN**
Habitat Crest and upper slope of dune
Soil Red-brown sand
Vegetation *Stylobasium spathulatum* tall open shrubland over *Acacia stellaticeps, Adriana tomentosa* var. *tomentosa, Crotalaria cunninghamii* open shrubland over *Triodia schinzii, T. epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Poor; extensive invasion of **Cenchrus ciliaris* and some presence of **Cenchrus setiger* (5+).
Fire Age No sign of recent fire

Wheatstone Site WH30
Described by JF/PC **Date** 7/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 336233 **mE** 7563514 **mN**
Habitat Broad flat plain alongside drainage channel
Soil Red-brown clayey loam
Vegetation *Grevillea wickhamii* subsp. *hispidula, Acacia ancistrocarpa* tall open scrub over *Triodia epactia* open hummock grassland
Veg Condition Very Good; only a few scattered **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WH32
Described by RBJCF **Date** 8/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 338157 **mE** 7562011 **mN**
Habitat Broad flat plain
Soil Red-brown clay loam with ironstone / quartz pebbles on surface
Vegetation *Acacia xiphophylla* tall shrubland over *Triodia lanigera* open hummock grassland
Veg Condition Very good to Excellent; some signs of human activity (wood harvested from *A. xiphophylla*)
Fire Age No sign of recent fire

Wheatstone Site WH34
Described by RBJCF **Date** 8/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 340518 **mE** 7560074 **mN**
Habitat Broad flat plain
Soil Red-brown sandy loam
Vegetation *Acacia bivenosa (A. ancistrocarpa)* tall shrubland over *Triodia lanigera* closed hummock grassland
Veg Condition Very Good; 5+ individuals of **Cenchrus setiger* present
Fire Age No sign of recent fire

Wheatstone Site WH35
Described by JA/PC **Date** 8/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 339263 **mE** 7561588 **mN**
Habitat Broad flat plain
Soil Red-brown loamy sand with ironstone and quartz gravel and pebbles on surface
Vegetation *Acacia xiphophylla* tall open shrubland over *Triodia brizoides* very open hummock

Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH40
Described by RB/PC **Date** 16/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290008 **mE** 7598583 **mN**
Habitat Mud flat surrounded by *Triodia epactia* plains and dunes
Soil Red-brown clay
Vegetation *Tecticornia* spp. low shrubland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH41
Described by MMJCF **Date** 16/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290182 **mE** 7599109 **mN**
Habitat Shallow depression on crest of low (~5m) sand dune; gentle slope, mainly to southeast
Soil Brown sand
Vegetation *Acacia coriacea* subsp. *coriacea* tall shrubland over *Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* very open tussock grassland
Veg Condition Good; some Buffel Grass, mainly under *Acacia coriacea* shrubs
Fire Age No sign of recent fire

Wheatstone Site WH42
Described by RB/PC **Date** 16/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291869 **mE** 7597199 **mN**
Habitat Crest and swale in low dunes
Soil Red-brown loamy sand
Vegetation *Grevillea stenobotrya, Abutilon* sp., *Crotalaria cunninghamii* open shrubland over *Acacia stellaticeps* low open shrubland over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Good; some invasion by **Cenchrus ciliaris*
Fire Age Burnt >3 years ago?

Wheatstone Site WH43
Described by MMJCF **Date** 16/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291830 **mE** 7597688 **mN**
Habitat Broad open sandy plain
Soil Red-brown clay loam
Vegetation *Acacia tetragonophylla* scattered shrubs over *Triodia epactia* open hummock grassland and **Cenchrus ciliaris* tussock grassland
Veg Condition Poor; invaded by **Cenchrus ciliaris*
Fire Age No sign of recent fire
Notes Consistent with other areas of *Acacia tetragonophylla* over *Triodia epactia*, but with some small wash-out areas

Wheatstone Site WH44
Described by RB/PC **Date** 16/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 292678 **mE** 7598791 **mN**
Habitat Gently undulating plain bordering dry lake
Soil Red-brown clay
Vegetation *Atriplex bunburyana* low open shrubland over *Triodia epactia* very open hummock grassland with **Cenchrus ciliaris* tussock grassland
Veg Condition Poor; invaded by Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WH45
Described by MMJCF **Date** 16/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 292709 **mE** 7598357 **mN**
Habitat Slopes and crest of low (~5 - 6m) sand dune
Soil Orange-brown sand
Vegetation *Grevillea stenobotrya* tall open shrubland over *Acacia coriacea* subsp. *coriacea, Trichodesma zeylanicum* var. *grandiflorum, Tephrosia rosea* var. *clementii* open shrubland over *Pityrodia loxocarpa* low open shrubland over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* very open tussock grassland
Veg Condition Good; presence of Buffel Grass

Fire Age No sigh of recent fire

Wheatstone Site WH46
Described by JRPA **Date** 17/04/2009 **Type** Quadrat 25m x 100m
MGA Zone 50 294156 **mE** 7600669 **mN**
Habitat Coastal foredune
Soil Red-brown sand
Rock Type Limestone surface expression
Vegetation *Crotalaria cunninghamii* tall shrubland over *Trichodesma zeylanicum* var. *grandiflorum, Scaevola spinescens, Tephrosia gardneri* low open shrubland over *Spinifex longifolius (Eriachne gardneri)* very open tussock grassland
Veg Condition Very Good; only 10+ individuals of **Cenchrus ciliaris* observed
Fire Age No sign of recent fire
Notes 100x25m quadrat to fit foredune vegetation

Wheatstone Site WH47
Described by JRP **Date** 17/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 293979 **mE** 7600641 **mN**
Habitat Crest and upper slope (south-facing) of primary beach dune
Soil Red-brown sand
Vegetation *Acacia coriacea* subsp. *coriacea* scattered tall shrubs over *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* tussock grassland
Veg Condition Poor; invaded by Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WH48
Described by RB/PC **Date** 18/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291176 **mE** 7596373 **mN**
Habitat Gentle slope (southeast facing) of low calcrete ridge
Soil Red-brown loamy sand
Rock Type Limestone/calcrete surface expression
Vegetation *Acacia stellaticeps, Scaevola pulchella, Diplopeltis eriocarpa* low open shrubland over Triodia *epactia* hummock grassland
Veg Condition Very Good; only 5+ individuals of **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WH49
Described by PH/J **Date** 18/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 295031 **mE** 7600616 **mN**
Habitat Primary dune area
Soil Yellow-brown sand
Vegetation *Crotalaria cunninghamii (Acacia coriacea* subsp. *coriacea)* open heath over *Triodia epactia* very open hummock grassland with *Spinifex longifolius, *Cenchrus ciliaris* open tussock grassland
Veg Condition Very Good; some Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WH50
Described by RB/PC **Date** 18/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290126 **mE** 7593134 **mN**
Habitat Broad, flat plain
Soil Red-brown cracking clay
Vegetation *Eriachne benthamii, Sporobolus mitchellii* closed tussock grassland over *Marsilea hirsuta* open herbland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH51
Described by JCF **Date** 18/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290985 **mE** 7595433 **mN**
Habitat Slope of calcrete outcrop (sloping away to the south)
Soil Red-brown clayey loam
Rock Type Calcrete
Vegetation *Triodia epactia* open hummock grassland
Veg Condition Very Good; only occasional individuals of Buffel Grass

Fire Age No sign of recent fire

Wheatstone Site WH52
Described by PRJR **Date** 19/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290245 **mE** 7596861 **mN**
Habitat Claypan
Soil Red-brown clayey loam
Vegetation *Tecticornia ?auriculata, T. halocnemoides* subsp. *tenuis* low open shrubland over *Eragrostis pergracilis* open bunch grassland
Veg Condition Very Good; 3+ individuals of **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WH53
Described by JCF **Date** 18/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290747 **mE** 7593594 **mN**
Habitat Open floodplain
Soil Red-brown cracking clay
Vegetation *Eriachne benthamii, Sporobolus virginicus* closed tussock grassland
Veg Condition Very Good; only occasional weed species
Fire Age No sign of recent fire

Wheatstone Site WH54
Described by RB/R **Date** 19/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291197 **mE** 7597442 **mN**
Habitat Drainage area within loamy plain
Soil Red-brown clayey sand
Vegetation **Prosopis pallida* scattered tall shrubs over *Acacia tetragonophylla (*Vachellia farnesiana)* shrubland over *Eulalia aurea, Sporobolus mitchellii* tussock grassland with *Marsilea drummondii, M. hirsuta* very open herbland
Veg Condition Good; several established **Prosopis* and **Vachellia* shrubs
Fire Age No sign of recent fire

Wheatstone Site WH55
Described by JFPCJ **Date** 19/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290904 **mE** 7596851 **mN**
Habitat Drainage area surrounded by low-lying dunes
Soil Red-brown loamy clay
Vegetation *Tecticornia indica* subsp. ? low shrubland over *Cullen cinereum, Bergia trimera* very open herbland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH56
Described by PHRBR **Date** 19/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290603 **mE** 7595155 **mN**
Habitat Flat plain "mosaiced" with scalded (erosional) patches; dunes to northwest
Soil Red-brown loamy sand
Vegetation *Triodia epactia* hummock grassland
Veg Condition Very Good; some **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WH57
Described by JFPCJ **Date** 19/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 290340 **mE** 7594606 **mN**
Habitat Broad, gently undulating plain with dunes to south and east
Soil Red-brown loam with calcrete pebbles and gravel on surface
Vegetation *Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Good; some **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WH58
Described by PH/RB **Date** 20/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 292681 **mE** 7593480 **mN**
Habitat Gently undulating plain
Soil Red-brown loamy sand

Vegetation *Triodia epactia* hummock grassland
Veg Condition Very Good to Good; 10+ individuals of **Cenchrus ciliaris*
Fire Age Burnt >4 years ago

Wheatstone Site WH59
Described by JFPCJ **Date** 20/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291985 **mE** 7593835 **mN**
Habitat Broad, flat drainage plain
Soil Red-brown cracking clay
Vegetation *Tecticornia indica* subsp. ? scattered low shrubs over *Sporobolus mitchellii* open tussock grassland over *Ptilotus murrayi* scattered herbs
Veg Condition Excellent
Fire Age No sign of recent fire
Notes Historical **Prosopis pallida* spraying evident

Wheatstone Site WH60
Described by PH/RB **Date** 20/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 292304 **mE** 7595108 **mN**
Habitat Open plain
Soil Red sandy loam
Vegetation *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Good; fair amount of **Cenchrus ciliaris*
Fire Age No sign of recent fire
Notes Mature Mesquite right next to quadrat: x 50 individuals

Wheatstone Site WH61
Described by JFPCJ **Date** 20/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291774 **mE** 7594568 **mN**
Habitat Broad plain
Soil Red-brown loamy clay
Vegetation *Scaevola spinescens, Tecticornia indica* subsp. ? scattered low shrubs over *Sporobolus mitchellii, (Eriochloa pseudoacrotricha, Iseilema macratherum)* closed tussock grassland
Veg Condition Very Good
Fire Age No sign of recent fire

Wheatstone Site WH62
Described by PH/RB **Date** 20/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291781 **mE** 7594858 **mN**
Habitat Flat plain
Soil Red-brown clayey sand
Vegetation *Tecticornia auriculata, T. ? halocnemoides* subsp. *tenuis* low open shrubland over *Eragrostis pergracilis* bunch grassland with *Cyperus bulbosus* very open sedgeland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH63
Described by JF/PC **Date** 20/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291437 **mE** 7591579 **mN**
Habitat Gently undulating plain next to creek
Soil Red-brown sandy loam
Vegetation *Acacia sclerosperma, A. tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* tussock grassland
Veg Condition Very Poor; dominated by **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WH64
Described by PH/PC **Date** 21/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291586 **mE** 7592702 **mN**
Habitat Wide plain
Soil Red-brown cracking clay
Vegetation *Sporobolus mitchellii, Brachyachne convergens, Eriochloa pseudoacrotricha* closed tussock grassland
Veg Condition Excellent to Very Good; very scattered **Portulaca oleracea*
Fire Age No sign of recent fire

Wheatstone Site WH65
Described by JFRBJ **Date** 21/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 291853 **mE** 7592445 **mN**
Habitat Broad, open plain with small clay pan (bare) areas
Soil Red-brown clay
Vegetation *Sporobolus mitchellii, Eriochloa pseudoacrotricha* closed tussock grassland
Veg Condition Very Good; minor intrusions of Buffel Grass (3+ individuals)
Fire Age No sign of recent fire

Wheatstone Site WH66
Described by PH/PC **Date** 21/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 292126 **mE** 7595903 **mN**
Habitat Plain between saline drainage to east and low dunes to west
Soil Red-brown sand
Vegetation *Triodia epactia* hummock grassland with *Cenchrus ciliaris* open tussock grassland
Veg Condition Good to Poor; considerable Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WH67
Described by RBJFJ **Date** 22/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 293444 **mE** 7599413 **mN**
Habitat Mud flats adjacent to creek (Mangrove system)
Soil Red-brown clay
Vegetation *Tecticornia* sp. low shrubland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH68
Described by PH/PC **Date** 22/04/2009 **Type** Quadrat 50m x 50m
MGA Zone 50 295641 **mE** 7588097 **mN**
Habitat Flat plain on western side of dune
Soil Red-brown cracking clay
Vegetation *Acacia synchronicia* scattered tall shrubs over **Vachellia farnesiana* scattered shrubs over *Eriachne benthamii, Sporobolus mitchellii* tussock grassland
Veg Condition Very Good; only scattered weeds
Fire Age No sign of recent fire

Wheatstone Site WSB-02
Described by RBJCF **Date** 23/03/2009 **Type** Relevé 12-18m x 30m
MGA Zone 50 291168 **mE** 7595097 **mN**
Habitat Claypan
Soil Red-brown clay
Vegetation *Eriachne* aff. *benthamii* scattered grasses
Veg Condition Excellent
Fire Age No sign of recent fire
Notes Only one individual of *Eriachne* aff. *benthamii* within the pegged area. Area is ~12-18 m by 30 m to fit within unvegetated claypan.

Wheatstone Site WSB-03
Described by RBJCF **Date** 23/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 291095 **mE** 7595522 **mN**
Habitat Old quarry site in flat plain landscape
Soil Red-brown sand
Rock Type Ironstone, quartz
Vegetation *Indigofera monophylla* scattered low shrubs over *Triodia epactia* very open hummock grassland with **Cenchrus ciliaris* scattered tussock grasses
Veg Condition "Poor/Disturbed" in quarry site; "Good" outside, with presence of some **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WSB-04
Described by RBJCF **Date** 23/03/2009 **Type** Relevé 150m x 80m
MGA Zone 50 291197 **mE** 7595540 **mN**
Habitat Old quarry site (~150m x 80m) in flat plain landscape
Soil Red-brown clay loam
Rock Type Ironstone
Vegetation *Acacia coriacea* subsp. *coriacea* scattered tall shrubs over *A. stellaticeps* low open

shrubland over *Triodia epactia* very open hummock grassland with **Cenchrus ciliaris* scattered tussock grasses
Veg Condition Poor; located in an old quarry site
Fire Age No sign of recent fire

Wheatstone Site WSB-05
Described by RBJCF **Date** 24/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 291461 **mE** 7596986 **mN**
Habitat Low sandy hill/dune
Soil Red-brown sand
Vegetation *Acacia stellaticeps, Hakea lorea* subsp. *lorea, Grevillea stenobotrya* very open shrubland over *Triodia epactia* hummock grassland
Veg Condition Good; some **Cenchrus ciliaris*
Fire Age No sign of recent fire

Wheatstone Site WSB-06
Described by RBJCF **Date** 24/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 292499 **mE** 7598288 **mN**
Habitat Flat sandy plain adjacent to clay pan on west and low rise to east
Soil Red-brown sand
Vegetation *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* tussock grassland
Veg Condition Poor; presence of two invasive weeds (Buffel Grass and Mesquite)
Fire Age No sign of recent fire

Wheatstone Site WSB-07
Described by RBJCF **Date** 24/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 292670 **mE** 7598608 **mN**
Habitat Sandy plain with gentle rise to west eventually forming low hills. Claypan adjacent to east.
Soil Red-brown sand
Vegetation *Acacia tetragonophylla, *Vachellia farnesiana* very open shrubland over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* closed tussock grassland
Veg Condition Poor; extensive **Cenchrus ciliaris* and **Vachellia*
Fire Age No sign of recent fire

Wheatstone Site WSB-08
Described by RBJCF **Date** 25/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 293201 **mE** 7599497 **mN**
Habitat Southeast facing slope of low rise
Soil Red-brown sand
Vegetation *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Poor; area invaded by Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WSB-09
Described by RBJCF **Date** 24/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 293232 **mE** 7599447 **mN**
Habitat Sandy plain sloping up towards the east to form low hills
Soil Red-brown sand
Vegetation *Diplopeltis eriocarpa, Bonamia rosea* scattered low shrubs over *Triodia epactia* very open hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Poor; invaded by Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WSB-10
Described by RBJCF **Date** 25/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 293457 **mE** 7599735 **mN**
Habitat Flat plain; bordered by low hills
Soil Red-brown sand
Vegetation *Triodia epactia* hummock grassland with **Cenchrus ciliaris* tussock grassland
Veg Condition Poor; extensive invasion by Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WSB-12
Described by RBJCF **Date** 25/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 294930 **mE** 7600448 **mN**
Habitat Flat plain sloping towards the west; wet depression at base of slope

Soil Red-brown sand
Vegetation *Tecticornia pruinosa, Frankenia ambita* scattered low shrubs over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris, Sporobolus virginicus* open tussock grassland
Veg Condition Poor; invaded by Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WSB-14
Described by RBJCF **Date** 25/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 291000 **mE** 7599384 **mN**
Habitat Flat plain with gentle rise to the northwest; claypan area ~200m to the south
Soil Red-brown sand
Vegetation *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Poor; invaded by Buffel Grass
Fire Age No sign of recent fire
Notes Very close to (but outside) boundary of European heritage area (southern border of cleared area aligns with boundary).

Wheatstone Site WSB-15
Described by RBJCF **Date** 23/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 290859 **mE** 7596413 **mN**
Habitat Undulating red sandy plain (dunes)
Soil Red-brown sand
Vegetation *Crotalaria cunninghamii, Grevillea stenobotrya, Acacia sclerosperma* subsp. *sclerosperma* tall shrubland over *Trichodesma zeylanicum* var. *grandiflorum, A. stellaticeps* open shrubland over *Verticordia forrestii* low open shrubland over *Triodia epactia* very open hummock grassland
Veg Condition Good to Very Good; occasional individuals of Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WSB-16
Described by RBJCF **Date** 26/03/2009 **Type** Relevé 50m x 60m
MGA Zone 50 290301 **mE** 7596374 **mN**
Habitat Depression/swale between two low dunes
Soil Red-brown sand
Vegetation *Verticordia forrestii, Acacia stellaticeps* low open heath over *Triodia epactia* open hummock grassland
Veg Condition Good to Very Good; occasional individuals of Buffel Grass and some track disturbance
Fire Age No sign of recent fire
Notes Pegged area restricted to 50m width to avoid dune crests

Wheatstone Site WSB-17
Described by RBJCF **Date** 26/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 290018 **mE** 7596359 **mN**
Habitat Undulating sandy plain sloping up towards the east
Soil Red-brown sand, to clayey loam in some areas
Vegetation *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Poor to Good; invaded by Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WSB-18
Described by RBJCF **Date** 25/03/2009 **Type** Relevé 60m x 60m
MGA Zone 50 293851 **mE** 7600358 **mN**
Habitat Flat plain
Soil Red-brown sand
Vegetation *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland
Veg Condition Poor; invaded by Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WSB-23
Described by PH/PC **Date** 21/04/2009 **Type** Relevé 60m x 60m
MGA Zone 50 292301 **mE** 7600595 **mN**
Habitat Dune
Soil Red-brown sand
Vegetation *Adriana tomentosa* var. *tomentosa, Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* low shrubland over *Triodia epactia* open hummock grassland and **Cenchrus ciliaris* open tussock grassland

Wheatstone Site WSB-24
Described by RBJCF **Date** 21/04/2009 **Type** Relevé 60m x 60m
MGA Zone 50 291562 **mE** 7599753 **mN**
Habitat Open plain adjacent to low dune system
Soil Red-brown clayey loam
Vegetation *Triodia epactia* open hummock grassland with *Cenchrus ciliaris* open tussock grassland
Fire Age No sign of recent fire

Wheatstone Site WSB-25
Described by RBJCF **Date** 20/04/2009 **Type** Relevé 60m x 60m
MGA Zone 50 291769 **mE** 7600216 **mN**
Habitat Southeast facing (gentle slope) dune swale
Soil Red-brown sand
Vegetation *Acacia stellaticeps* open shrubland over *Triodia epactia* hummock grassland with *Cenchrus ciliaris* very open tussock grassland
Veg Condition Good; *Cenchrus ciliaris* scattered extensively through vegetation
Fire Age No sign of recent fire

Wheatstone Site WSB access
Described by RBJCF **Date** 24/03/2009 **Type** Relevé ~100m x 10m
MGA Zone 50 294900 **mE** 7600432 **mN**
Habitat Sandy plain
Soil Red-brown sand to loam
Vegetation *Triodia epactia* hummock grassland with *Cenchrus ciliaris* very open tussock grassland
Veg Condition Good; some Buffel Grass
Fire Age No sign of recent fire
Notes Access track runs on plain around northern side of claypan

Wheatstone Site WSB setdown
Described by RBJCF **Date** 23/03/2009 **Type** Relevé ~30m x 30m
MGA Zone Setdown area is near Drillhole 04; no coordinates recorded but area pegged
Habitat Sandy plain
Soil Red-brown sand to loam
Vegetation *Triodia epactia* open hummock grassland
Veg Condition Good to Very Good; very occasional individuals of Buffel Grass
Fire Age No sign of recent fire

Wheatstone Site WH-JFA
Described by JF/PC **Date** 24/04/2009 **Type** Relevé 60x60
MGA Zone 50 293496 **mE** 7599667 **mN**
Vegetation *Acacia tetragonophylla* scattered shrubs over *Triodia epactia* closed hummock grassland with *Cenchrus ciliaris* tussock grassland
Fire Age Burnt >5 years ago
Notes Completed as part of *Vigna* search. Chevron reference for this site is B217, part of the Phase two drilling program. Area not staked; flagged only.

Wheatstone Site WH-JFB
Described by JF/PC **Date** 24/04/2009 **Type** Relevé 60x60
MGA Zone 50 293457 **mE** 7599634 **mN**
Soil Brown clay
Vegetation *Tecticornia* sp. low open shrubland
Veg Condition Excellent
Fire Age No sign of fire
Notes Completed as part of *Vigna* search. Chevron reference for this site is B213, part of the Phase two drilling program. Area not staked; flagged only.

Wheatstone Site WH-JFC
Described by JF/PC **Date** 24/04/2009 **Type** Relevé 60x60
MGA Zone 50 293117 **mE** 7598714 **mN**
Habitat Flat plain on the edge of a bare claypan area.
Vegetation *Cenchrus ciliaris* tussock grassland with *Triodia epactia* open hummock grassland
Veg Condition Poor to Good
Fire Age No signs of fire
Notes Completed as part of *Vigna* search. Chevron reference for this site is E027, part of the Environmental drilling program. Area not staked; flagged only.

Wheatstone Site WH-JFD
Described by JF/PC **Date** 20/04/2009 **Type** Relevé
MGA Zone 50 292090 **mE** 7593811 **mN**
Habitat Undulating plain
Vegetation *Acacia tetragonophylla* scattered shrubs over *Eulalia aurea, *Cenchrus ciliaris* tussock grassland
Veg Condition Poor
Fire Age Burnt > 5 years ago
Notes Grassland area between quadrat location WH59 and bare blow-out areas

Wheatstone Site WH-MA
Described by MM **Date** 3/04/2009 **Type** Relevé
MGA Zone 50 293319 **mE** 7594051 **mN**
Habitat Upper slope of low dune; gentle slope with southwest aspect
Soil Orange-brown sand with surface crust
Vegetation *Acacia tetragonophylla* scattered tall shrubs over *Triodia epactia* closed hummock grassland
Veg Condition Very Good; only occasional weeds
Fire Age No sign of recent fire

Wheatstone Site WH-MB
Described by MM **Date** 6/04/2009 **Type** Relevé
MGA Zone 50 293602 **mE** 7592481 **mN**
Habitat Saline claypan within broad sandplain
Soil Orange-brown clay loam
Vegetation *Tecticornia indica* subsp. *leiostachya* low shrubland over *Eragrostis pergracilis* very open bunch grassland
Veg Condition Excellent
Fire Age No sign of recent fire

Wheatstone Site WH-RB1
Described by RBJCF **Date** 9/04/2009 **Type** Relevé
MGA Zone 50 295806 **mE** 7587322 **mN**
Habitat Flat plain
Vegetation *Eriachne benthamii, Sporobolus mitchellii* tussock grassland with *Marsilea drummondii* herbland
Veg Condition Good; presence of *Prosopis pallida*

Wheatstone Site WH-RB2
Described by RB/PC **Date** 17/04/2009 **Type** Relevé
MGA Zone 50 290955 **mE** 7599255 **mN**
Habitat Flat plain
Vegetation *Triodia epactia* closed hummock grassland with **Cenchrus ciliaris* scattered tussock grasses
Veg Condition Good; presence of **Cenchrus ciliaris*.

Wheatstone Site WH-RB3
Described by RB/PC **Date** 18/04/2009 **Type** Relevé
MGA Zone 50 290964 **mE** 7598952 **mN**
Habitat Claypan
Vegetation *Tecticornia doleiformis, T. auriculata* low open shrubland
Veg Condition Excellent

Wheatstone Site WH-RB4
Described by RB/PC **Date** 18/04/2009 **Type** Relevé
MGA Zone 50 294981 **mE** 7600039 **mN**
Habitat Mangrove tidal mud-flats.
Vegetation *Avicennia marina* open shrubland.
Veg Condition Excellent

Species	**WH01**	**WH02**	**WH03**	**WH04**	**WH05**	**WH06**	**WH07**	**WH08**	**WH09**	**WH10**	**WH11**	**WH12**	**WH13**	**WH14**	**WH15**	**WH16**	**WH17**	**WH18**	**WH19**	**WH20**	**WH21**	**WH22**	**WH23**	**WH24**	**WH26**	**WH27**	**WH28**
Abutilon fraseri																											
Abutilon aff. *lepidum* (4)																											
Abutilon otocarpum																<1%											
Abutilon oxycarpum subsp. *prostratum*			<1%																								
Abutilon uncinatum											<1%																
Abutilon sp.									<1%	<1%			<1%								<1%		1%				
Acacia ancistrocarpa												4%		1%	1%	1%		4%		<1%						<1%	
Acacia bivenosa											2%	<1%		30%	<1%	2%		1%		<1%						<1%	
Acacia coriacea subsp. *coriacea*										1%					<1%	1%		1%									
Acacia inaequilatera																				2-3%						2%	
Acacia pyrifolia																											
Acacia sclerosperma subsp. *sclerosperma*										<1%																	
Acacia sericophylla																1%											
Acacia stellaticeps									30%			15%	1		<1%	<1%					5%		<1%				
Acacia synchronicia					<1%		<1%	<1%			20%			1%			<1%		1-2%	<1%	<1%			<1%	<1%	<1%	
Acacia tetragonophylla		1%	1%	<1%	40-50%	1%	<1%										<1%				<1%			<1%	<1%		1%
Acacia trachycarpa																		<1%									
Acacia tumida var. *pilbarensis*																				<1%							
Acacia wanyu																											
Acacia xiphophylla																											
Adriana urticoides var. *urticoides*										3%																	
Aenictophyton aff. *reconditum*									<1%																		
Aeschynomene indica					<1%		<1%																				
Alternanthera nodiflora							<1%	<1%									<1%					<1%			<1%		
Alysicarpus muelleri						<1%																					
Aristida contorta															<1%					<1%							
Aristida holathera var. *holathera*									<1%	<1%				<1%		<1%				<1%						<1%	
Aristida holathera var. *latifolia*													<1%														
Atriplex bunburyana			<1%																								<1%
Atriplex codonocarpa		<1%	<1%																		<1%						
Atriplex semilunaris			<1%					<1%																			
Avicennia marina subsp. *marina*																											
Bergia trimera																											
Blumea tenella																											
Boerhavia burbidgeana			<1%																								
Boerhavia coccinea													<1%														
Bonamia aff. *linearis*															<1%	<1%				<1%	<1%						
Bonamia rosea				<1%					1%	<1%		<1%	1%	<1%		<1%		<1%					<1%			<1%	
Brachyachne convergens																											
Brachyachne prostrata											<1%																
Bulbostylis barbata			<1%			<1%			<1%		<1%		<1%	<1%					<1%	<1%	<1%		<1%	<1%		<1%	<1%
Calandrinia ptychosperma			<1%																		<1%						<1%
Calotis plumulifera			<1%																								
Cassia glutinosa																											
Cassia glutinosa x *luerssenii*																											
Cassia luerssenii																							<1%			<1%	
Cassia notabilis													<1%							<1%						<1%	
Cassia oligophylla																											
Cassia oligophylla (thinly sericeous MET 15,035)																											
Cassia oligophylla x *helmsii*																											
Cassia oligophylla (thinly sericeous) x *helmsii*																											
Cassia pruinosa																										<1%	

Species	WH01	WH02	WH03	WH04	WH05	WH06	WH07	WH08	WH09	WH10	WH11	WH12	WH13	WH14	WH15	WH16	WH17	WH18	WH19	WH20	WH21	WH22	WH23	WH24	WH26	WH27	WH28
Cassytha capillaris									<1%	<1%			<1%						<1%		<1%		<1%				
Centaurium spicatum																											
Centipeda minima subsp. *macrocephala*							<1%										<1%								<1%		
Chloris pectinata																									<1%		<1%
Chloris pumilio								<1%													<1%	<1%					
Chrysopogon fallax			1%		50-60%	<1%					<1%																
Cleome uncifera subsp. *uncifera*																		<1%		<1%							
Corchorus aff. *laniflorus*																										<1%	
Corchorus sidoides subsp. *vermicularis*									<1%					<1%													
Corymbia hamersleyana															2%	5%		5-7%									
Corynotheca pungens										<1%																	
Cressa australis								<1%																			
Crotalaria cunninghamii				3%					<1%	1%			<1%										7%				
Crotalaria medicaginea var. *neglecta*	<1%	<1%				<1%		<1%											<1%			<1%		<1%	<1%		<1%
Crotalaria ramosissima				<1%															<1%								
Crotalaria sp.																											
Cucumis maderaspatanus					<1%	<1%			<1%	<1%						<1%		<1%				<1%	<1%				
Cullen cinereum		<1%			<1%		<1%	<1%									5%					<1%			<1%		2%
Cullen graveolens																	<1%										
Cullen lachnostachys																											
Cullen leucanthum																											<1%
Cullen leucochaites																											
Cullen martinii	<1%								<1%				1%								<1%		<1%				
Cullen pogonocarpum																											
Cymbopogon procerus																											
Cyperus bulbosus		<1%	<1%					<1%														<1%					<1%
Cyperus iria							<1%																				
Cyperus rigidellus					<1%			<1%									<1%								<1%		<1%
Cyperus squarrosus			<1%																		<1%	<1%					
Dactyloctenium radulans		<1%	<1%								<1%										<1%	<1%					<1%
Desmodium filiforme				<1%		<1%			<1%										<1%		<1%		<1%	<1%			
Dichanthium sericeum subsp. *humilius*																									<1%		
Dicrastylis cordifolia															<1%												
Digitaria brownii																											
Diplopeltis eriocarpa																											
Dysphania plantaginella								<1%														<1%					
Eleocharis papillosa								<1%																			
Enchylaena tomentosa var. *tomentosa*																					<1%						
Enneapogon caerulescens																										<1%	
Enteropogon ramosus																											
Eragrostis cumingii								<1%																			
Eragrostis eriopoda													<1%														
Eragrostis falcata		<1%																									
Eragrostis aff. *falcata*																											<1%
Eragrostis leptocarpa																											
Eragrostis pergracilis								<1%														70%					<1%
Eragrostis aff. *setifolia*																									<1%		
Eragrostis xerophila																									10%		
Eremophila forrestii subsp. *viridis*													<1%														
Eriachne aristidea								<1%							<1%	<1%				<1%							
Eriachne benthamii					<1%		70%										2%								45%		
Eriachne aff. *benthamii*																											<1%

Species	**WH01**	**WH02**	**WH03**	**WH04**	**WH05**	**WH06**	**WH07**	**WH08**	**WH09**	**WH10**	**WH11**	**WH12**	**WH13**	**WH14**	**WH15**	**WH16**	**WH17**	**WH18**	**WH19**	**WH20**	**WH21**	**WH22**	**WH23**	**WH24**	**WH26**	**WH27**	**WH28**
Eriachne gardneri									<1%				<1%														
Eriachne obtusa																											
Eriachne pulchella subsp. *dominii*																				<1%						<1%	
Eriochloa pseudoacrotricha					<1%												<1%								<1%		
Eucalyptus victrix											<1%	1%															
Eulalia aurea					1%		<1%										1%				<1%				<1%		
Euphorbia australis																											
Euphorbia australis (mid-green form)																				<1%							
Euphorbia biconvexa																											
Euphorbia boophthona			<1%																								
Euphorbia aff. *coghlanii*																											
Euphorbia myrtoides				<1%					<1%	<1%													<1%				
Euphorbia tannensis subsp. *eremophila*	<1%																										
Evolvulus alsinoides var. *decumbens*				<1%																			<1%				
Evolvulus alsinoides var. *villosicalyx*			<1%			<1%													<1%		<1%			<1%		<1%	
Fimbristylis dichotoma			<1%																		<1%			<1%		<1%	
Flaveria australasica		<1%																									
Frankenia ambita		15%																									
Gomphrena cunninghamii																											
Gomphrena sordida			<1%																								
Goodenia forrestii	<1%					<1%													<1%		<1%						
Goodenia microptera														<1%	<1%	<1%				<1%							
Gossypium australe (Burrup Peninsula form)											<1%																
Grevillea eriostachya				<1%					<1%			1%			<1%	1%											
Grevillea stenobotrya									1-2%	2%			40%								<1%		2%				
Grevillea wickhamii subsp. *hispidula*																											
Hakea lorea subsp. *lorea*															<1%			<1%									
Hakea stenophylla subsp. *stenophylla*																											
Heliotropium curassavicum								<1%																			
Heliotropium inexplicitum																<1%				<1%							
Heliotropium pachyphyllum																											
Hibiscus brachychlaenus									<1%	<1%			<1%							<1%	<1%		<1%				
Hibiscus sturtii var. *campylochlamys*																											
Hibiscus sturtii var. *platychlamys*				<1%					<1%																		
Hybanthus aurantiacus																										<1%	
Indigofera boviperda subsp. *boviperda*											<1%			<1%	<1%	<1%		<1%		<1%	<1%					<1%	
Indigofera colutea	1%		<1%	<1%		<1%													<1%		<1%		<1%	<1%			
Indigofera georgei																											
Indigofera linifolia		<1%	<1%	<1%		<1%													<1%		<1%			<1%			
Indigofera linnaei	<1%		<1%			<1%																					
Indigofera monophylla (Burrup form)																											
Indigofera trita																											
Ipomoea coptica			<1%																			<1%		<1%			
Ipomoea costata																											
Ipomoea muelleri								<1%															<1%				
Ipomoea polymorpha	<1%			<1%																			<1%	<1%			
Iseilema dolichotrichum																											
Iseilema macratherum																									<1%		<1%
Isotropis atropurpurea																		<1%									
Lawrencia viridigrisea		<1%																				<1%					<1%
Lepidium platypetalum																											
Leptochloa fusca subsp. *muelleri*																											<1%

Species	WH01	WH02	WH03	WH04	WH05	WH06	WH07	WH08	WH09	WH10	WH11	WH12	WH13	WH14	WH15	WH16	WH17	WH18	WH19	WH20	WH21	WH22	WH23	WH24	WH26	WH27	WH28
Maireana georgei			<1%								<1%			<1%													
Maireana lanosa																											
Maireana planifolia																											
Maireana sp.																											
Marsilea drummondii																											
Marsilea hirsuta			<1%		<1%		25%	<1%									10%					<1%			<1%		<1%
Melhania oblongifolia																											
Mimulus gracilis																	<1%								<1%		
Mollugo molluginea																		<1%		<1%						<1%	
Muellerolimon salicorniaceum																											
Neobassia astrocarpa		1%																				<1%					<1%
Neptunia dimorphantha																											
Nicotiana rosulata subsp. *rosulata*																						1%					
Olearia dampieri subsp. *dampieri*																											
Panicum decompositum								<1%									<1%								<1%		
Panicum laevinode																									<1%		
Paraneurachne muelleri																										<1%	
Paspalidium clementii																										<1%	
Petalostylis cassioides													<1%														
Phyllanthus erwinii			<1%																								
Phyllanthus maderaspatensis																											
Pimelea ammocharis																											
Pityrodia loxocarpa													20%														
Pityrodia paniculata										<1%				<1%													
Pluchea dunlopii																				<1%	<1%						
Pluchea rubelliflora			<1%					<1%									<1%							<1%			<1%
Polycarpaea corymbosa var. *corymbosa*														<1%					<1%		<1%						
Polygala aff. *isingii*	<1%	<1%	<1%											<1%		<1%			<1%		<1%			<1%			<1%
Portulaca pilosa																										<1%	
Pterocaulon sphaeranthoides			<1%																	<1%	<1%		<1%			<1%	
Ptilotus appendiculatus var. *appendiculatus*																											
Ptilotus arthrolasius									<1%	<1%																	
Ptilotus astrolasius var. *astrolasius*															<1%	<1%				<1%							
Ptilotus axillaris														<1%						<1%							
Ptilotus exaltatus var. *exaltatus*											<1%																
Ptilotus fusiformis												<1%				<1%		<1%		<1%							
Ptilotus murrayi																									<1%		<1%
Rhagodia eremaea					<1%																						
Rhagodia preissii subsp. *obovata*																											
Rhynchosia minima		<1%	<1%		<1%																						
Rostellularia adscendens var. *clementii*																											
Salsola tragus																											
Sarcostemma viminale subsp. *australe*																											
Scaevola parvifolia subsp. *pilbarae*												<1%			<1%	<1%		<1%									
Scaevola pulchella																											
Scaevola sericophylla									<1%	<1%																	
Scaevola spinescens					<1%												1%	<1%	<1%		<1%						<1%
Scaevola spinescens (broad form)			1%			<1%													<1%								
Schoenoplectus dissachanthus																											
Sclerolaena recurvicuspis																											
Sclerolaena uniflora																											
Sesbania cannabina								<1%									<1%					<1%		<1%	<1%		<1%

Species	**WH01**	**WH02**	**WH03**	**WH04**	**WH05**	**WH06**	**WH07**	**WH08**	**WH09**	**WH10**	**WH11**	**WH12**	**WH13**	**WH14**	**WH15**	**WH16**	**WH17**	**WH18**	**WH19**	**WH20**	**WH21**	**WH22**	**WH23**	**WH24**	**WH26**	**WH27**	**WH28**
Setaria dielsii																											
Sida arsiniata											<1%																
Sida echinocarpa																										<1%	
Sida aff. *fibulifera* (B64-13B)			<1%																								
Sida aff. *fibulifera* (M69.12)				<1%																	<1%						
Sida pilbarensis (ferruginous form)																				<1%						<1%	
Sida rohlenae subsp. *rohlenae*				<1%									<1%										<1%			<1%	
Solanum diversiflorum																											
Solanum ellipticum																										<1%	
Solanum lasiophyllum				<1%					<1%		<1%		<1%								<1%		<1%				
Solanum sturtianum																											
Spinifex longifolius																											
Sporobolus australasicus																										<1%	
Sporobolus mitchellii							30%	1-2%									30%								10%		2%
Sporobolus virginicus																											
Stemodia sp. Onslow (A.A. Mitchell 76/148)			<1%								<1%	<1%		<1%	<1%	<1%											
Streptoglossa bubakii																				<1%		<1%			<1%		<1%
Streptoglossa decurrens																				<1%							
Streptoglossa macrocephala														<1%							<1%						
Streptoglossa odora																	<1%										
Streptoglossa sp.								<1%																			
Stylobasium spathulatum																					<1%						
Suaeda arbusculoides																											
Swainsona kingii subsp. *kingii*																											
Swainsona pterostylis		<1%						<1%																			
Synaptantha tillaeacea var. *tillaeacea*			<1%																	<1%				<1%			
Tecticornia auriculata		10%																				30%					<1%
Tecticornia ? auriculata																											
Tecticornia doleiformis																											
Tecticornia halocnemoides subsp. *tenuis*																											
Tecticornia ? halocnemoides subsp. *tenuis*																											
Tecticornia indica subsp. ? (intergrade between *leiostachya/bidens/julacea)*																											
Tecticornia indica subsp. *leiostachya*								2%																			2%
Tecticornia pergranulata																											
Tecticornia pruinosa																											
Tecticornia pterygosperma subsp. *denticulata*		2%																									
Tecticornia ? sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)																											
Tecticornia sp. nov. 1 (?*T. halocnemoides* complex)																											
Tecticornia sp.								2%																			
Tephrosia gardneri									<1%	<1%			<1%														
Tephrosia rosea var. *clementii*									<1%																		
Tephrosia aff. *supina* (HD133-20)																				<1%						<1%	
Tephrosia aff. *supina* (MET 12,357)																											
Tephrosia sp. B Kimberley Flora (C.A. Gardner 7300)																			<1%								
Threlkeldia diffusa																											<1%
Tinospora smilacina																		<1%									
Trachymene pilbarensis			<1%																		<1%						
Trianthema pilosa									<1%	<1%			<1%										<1%				
Trianthema triquetra			<1%								<1%											<1%					
Trianthema turgidifolia											<1%										<1%						<1%
Tribulus astrocarpus																											
Tribulus macrocarpus																				<1%							

Species	**WH01**	**WH02**	**WH03**	**WH04**	**WH05**	**WH06**	**WH07**	**WH08**	**WH09**	**WH10**	**WH11**	**WH12**	**WH13**	**WH14**	**WH15**	**WH16**	**WH17**	**WH18**	**WH19**	**WH20**	**WH21**	**WH22**	**WH23**	**WH24**	**WH26**	**WH27**	**WH28**
Tribulus occidentalis										<1%																	
Trichodesma zeylanicum var. *grandiflorum*	<1%			2%					<1%												<1%		20%				
Triodia brizoides																											
Triodia epactia	60%	30%	5-10%	30%		40%			<1%	<1%	30%			10%					30-70%		30%		35%	75%			<1%
Triodia lanigera												60%		50%	10%	55%		60%		30%						25%	
Triodia schinzii									50-60%	30%			20%		20%	<1%		<1%									
Tripogon loliiformis																											
Triumfetta aff. *chaetocarpa* (H123-10)																		<1%		<1%							
Triumfetta aff. *chaetocarpa* (PAN3/4)																											
Triumfetta clementii																											
Triumfetta echinata										<1%													<1%				
Urochloa holosericea subsp. *velutina*				<1%																	<1%						
Verticordia forrestii													<1%														
Vigna sp. Hamersley Clay (A.A. Mitchell PRP 113)																											
Waltheria indica																<1%											
Whiteochloa airoides					<1%																						
Yakirra australiensis var. *australiensis*													<1%	<1%						<1%							
Introduced Species																											
**Cenchrus ciliaris*	30-40%	2%	15%	5%		<1%		<1%	<1%	1%			5%			<1%		<1%	<1%		5%	<1%	5%	5%			2%
**Cenchrus setiger*																											
**Cucumis melo* subsp. *agrestis*		<1%																									
**Portulaca oleracea*			<1%								<1%																
**Prosopis pallida*																	20%										2%
**Setaria verticillata*																											
**Vachellia farnesiana*		<1%	2%		<1%		<1%										20%		1-2%			<1%			<1%		

Species	**WH29**	**WH30**	**WH32**	**WH34**	**WH35**	**WH40**	**WH41**	**WH42**	**WH43**	**WH44**	**WH45**	**WH46**	**WH47**	**WH48**	**WH49**	**WH50**	**WH51**	**WH52**	**WH53**	**WH54**	**WH55**	**WH56**	**WH57**	**WH58**	**WH59**	**WH60**	**WH61**	**WH62**
Abutilon fraseri			<1%		<1%																							
Abutilon aff. *lepidum* (4)														<1%														
Abutilon otocarpum																												
Abutilon oxycarpum subsp. *prostratum*																												
Abutilon uncinatum																												
Abutilon sp.	<1%						<1%	1%			<1%		<1%															
Acacia ancistrocarpa		30%		1%																								
Acacia bivenosa				20%																								
Acacia coriacea subsp. *coriacea*	<1%						15-20%	<1%			1-2%	<1%	3%	<1%	1%					<1%								
Acacia inaequilatera																												
Acacia pyrifolia		<1%																										
Acacia sclerosperma subsp. *sclerosperma*																												
Acacia sericophylla																												
Acacia stellaticeps	3%							2%						3%														
Acacia synchronicia			<1%	<1%	<1%					<1%										<1%		<1%	<1%	<1%		<1%		
Acacia tetragonophylla									1%	<1%				<1%			<1%			25%		<1%	1%	<1%				
Acacia trachycarpa																												
Acacia tumida var. *pilbarensis*		1%																										
Acacia wanyu				<1%																								
Acacia xiphophylla			20%		5%																							
Adriana urticoides var. *urticoides*	1%						<1%					<1%	<1%															
Aenictophyton aff. *reconditum*																												
Aeschynomene indica																<1%												
Alternanthera nodiflora																<1%				<1%	<1%				<1%		<1%	<1%
Alysicarpus muelleri																												
Aristida contorta			<1%	<1%																								
Aristida holathera var. *holathera*	<1%	<1%		<1%				<1%																				
Aristida holathera var. *latifolia*																												
Atriplex bunburyana									<1%	3%												<1%	<1%					
Atriplex codonocarpa																									<1%			
Atriplex semilunaris																												
Avicennia marina subsp. *marina*																												
Bergia trimera																					2%							
Blumea tenella																												
Boerhavia burbidgeana																												
Boerhavia coccinea		<1%																										
Bonamia aff. *linearis*		<1%						<1%						<1%			<1%											
Bonamia rosea	<1%	<1%		<1%				<1%			<1%																	
Brachyachne convergens																									<1%		<1%	
Brachyachne prostrata			<1%		<1%																							
Bulbostylis barbata	<1%			<1%	<1%																			<1%		<1%		
Calandrinia ptychosperma																				<1%								
Calotis plumulifera																												
Cassia glutinosa								<1%						<1%														
Cassia glutinosa x *luerssenii*																												
Cassia luerssenii			<1%																									
Cassia notabilis		<1%																										
Cassia oligophylla														<1%														
Cassia oligophylla (thinly sericeous MET 15,035)																												
Cassia oligophylla x *helmsii*																												
Cassia oligophylla (thinly sericeous) x *helmsii*			<1%																									
Cassia pruinosa																												

Species	WH29	WH30	WH32	WH34	WH35	WH40	WH41	WH42	WH43	WH44	WH45	WH46	WH47	WH48	WH49	WH50	WH51	WH52	WH53	WH54	WH55	WH56	WH57	WH58	WH59	WH60	WH61	WH62
Cassytha capillaris							<1%	<1%	<1%		1%		<1%	<1%			<1%			<1%			<1%					
Centaurium spicatum																		<1%										
Centipeda minima subsp. *macrocephala*																<1%					<1%							
Chloris pectinata																												
Chloris pumilio																		<1%	<1%	<1%	<1%						<1%	<1%
Chrysopogon fallax									<1%	<1%													<1%					
Cleome uncifera subsp. *uncifera*																												
Corchorus aff. *laniflorus*				<1%																								
Corchorus sidoides subsp. *vermicularis*														<1%														
Corymbia hamersleyana		1%																										
Corynotheca pungens												<1%	<1%															
Cressa australis																						<1%						
Crotalaria cunninghamii	1%						<1%	1%			<1%	20%	1%		70%													
Crotalaria medicaginea var. *neglecta*									<1%	<1%				<1%			<1%	<1%				<1%	<1%			<1%		<1%
Crotalaria ramosissima																								<1%				
Crotalaria sp.												<1%																
Cucumis maderaspatanus	<1%	<1%		<1%												<1%									<1%		<1%	
Cullen cinereum										<1%								<1%		<1%	2%		<1%		<1%		<1%	<1%
Cullen graveolens																											<1%	
Cullen lachnostachys																												
Cullen leucanthum																												
Cullen leucochaites		<1%																										
Cullen martinii	<1%											<1%												<1%				
Cullen pogonocarpum									<1%																			
Cymbopogon procerus				<1%																								
Cyperus bulbosus																		<1%			<1%						<1%	4
Cyperus iria																<1%			<1%									
Cyperus rigidellus																				<1%	<1%				<1%		<1%	
Cyperus squarrosus																<1%				<1%		<1%					<1%	
Dactyloctenium radulans			<1%						<1%	<1%						<1%		<1%				<1%					<1%	<1%
Desmodium filiforme	<1%																							<1%				
Dichanthium sericeum subsp. *humilius*				<1%						<1%																		
Dicrastylis cordifolia																												
Digitaria brownii				<1%																								
Diplopeltis eriocarpa								<1%						1%														
Dysphania plantaginella																		<1%										
Eleocharis papillosa																												
Enchylaena tomentosa var. *tomentosa*				<1%																				<1%				
Enneapogon caerulescens			<1%											<1%														
Enteropogon ramosus					<1%																							
Eragrostis cumingii																												
Eragrostis eriopoda																												
Eragrostis falcata																												
Eragrostis aff. *falcata*																												
Eragrostis leptocarpa																											<1%	<1%
Eragrostis pergracilis						<1%												20%			<1%				<1%		<1%	50%
Eragrostis aff. *setifolia*									<1%	<1%												<1%						
Eragrostis xerophila										<1%																		
Eremophila forrestii subsp. *viridis*																												
Eriachne aristidea																												
Eriachne benthamii																35%			60%						<1%		<1%	
Eriachne aff. *benthamii*																												

Species	**WH29**	**WH30**	**WH32**	**WH34**	**WH35**	**WH40**	**WH41**	**WH42**	**WH43**	**WH44**	**WH45**	**WH46**	**WH47**	**WH48**	**WH49**	**WH50**	**WH51**	**WH52**	**WH53**	**WH54**	**WH55**	**WH56**	**WH57**	**WH58**	**WH59**	**WH60**	**WH61**	**WH62**
Eriachne gardneri												1%																
Eriachne obtusa																												
Eriachne pulchella subsp. *dominii*		<1%	<1%		<1%																							
Eriochloa pseudoacrotricha																				<1%	<1%				<1%		1%	<1%
Eucalyptus victrix																												
Eulalia aurea									<1%	<1%						<1%				25%		<1%	<1%				<1%	
Euphorbia australis																												
Euphorbia australis (mid-green form)		<1%	<1%																									
Euphorbia biconvexa				<1%																								
Euphorbia boophthona																												
Euphorbia aff. *coghlanii*										<1%																		
Euphorbia myrtoides	<1%						<1%	<1%				<1%	<1%		<1%													
Euphorbia tannensis subsp. *eremophila*																								<1%				
Evolvulus alsinoides var. *decumbens*	<1%							<1%									<1%							<1%				
Evolvulus alsinoides var. *villosicalyx*				<1%				<1%	<1%	<1%				<1%			<1%							<1%		<1%		
Fimbristylis dichotoma																						<1%				<1%		
Flaveria australasica										<1%																		<1%
Frankenia ambita																		<1%	<1%									
Gomphrena cunninghamii				<1%																								
Gomphrena sordida																												
Goodenia forrestii				<1%					<1%														<1%	<1%				
Goodenia microptera		<1%							<1%					<1%														
Gossypium australe (Burrup Peninsula form)																												
Grevillea eriostachya								<1%																				
Grevillea stenobotrya								5%			3%																	
Grevillea wickhamii subsp. *hispidula*		20%																										
Hakea lorea subsp. *lorea*		<1%												<1%														
Hakea stenophylla subsp. *stenophylla*											<1%																	
Heliotropium curassavicum																												
Heliotropium inexplicitum																												
Heliotropium pachyphyllum														<1%			<1%											
Hibiscus brachychlaenus								<1%			<1%																	
Hibiscus sturtii var. *campylochlamys*				<1%																								
Hibiscus sturtii var. *platychlamys*									<1%					<1%			<1%											
Hybanthus aurantiacus																												
Indigofera boviperda subsp. *boviperda*		<1%		<1%					<1%														<1%			<1%		
Indigofera colutea	<1%						<1%			<1%			<1%									<1%	<1%	<1%		<1%		
Indigofera georgei							<1%																					
Indigofera linifolia									<1%	<1%												<1%		<1%				
Indigofera linnaei																							<1%	<1%		<1%		
Indigofera monophylla (Burrup form)														<1%			<1%											
Indigofera trita									<1%	<1%																<1%		
Ipomoea coptica																<1%											<1%	
Ipomoea costata															<1%													
Ipomoea muelleri	<1%										<1%																	
Ipomoea polymorpha	<1%																							<1%				
Iseilema dolichotrichum			<1%	<1%														<1%										
Iseilema macratherum																				<1%					<1%		2%	
Isotropis atropurpurea		<1%		<1%																								
Lawrencia viridigrisea										<1%								<1%				<1%	<1%					
Lepidium platypetalum																						<1%						
Leptochloa fusca subsp. *muelleri*																<1%			<1%						<1%			

Species	**WH29**	**WH30**	**WH32**	**WH34**	**WH35**	**WH40**	**WH41**	**WH42**	**WH43**	**WH44**	**WH45**	**WH46**	**WH47**	**WH48**	**WH49**	**WH50**	**WH51**	**WH52**	**WH53**	**WH54**	**WH55**	**WH56**	**WH57**	**WH58**	**WH59**	**WH60**	**WH61**	**WH62**
Maireana georgei																												
Maireana lanosa														<1%			<1%											
Maireana planifolia			<1%																									
Maireana sp.																												
Marsilea drummondii																				2.5%								
Marsilea hirsuta																10%			<1%	2.5%	<1%				<1%		<1%	<1%
Melhania oblongifolia														<1%														
Mimulus gracilis																					<1%							
Mollugo molluginea		<1%																										
Muellerolimon salicorniaceum						<1%																						
Neobassia astrocarpa										<1%								<1%										
Neptunia dimorphantha																											<1%	
Nicotiana rosulata subsp. *rosulata*																		<1%			<1%							<1%
Olearia dampieri subsp. *dampieri*								<1%			<1%		<1%															
Panicum decompositum				<1%										<1%		<1%			<1%	<1%					<1%		<1%	
Panicum laevinode																												
Paraneurachne muelleri																												
Paspalidium clementii				<1%	<1%																							
Petalostylis cassioides																												
Phyllanthus erwinii		<1%		<1%																								
Phyllanthus maderaspatensis																												
Pimelea ammocharis																												
Pityrodia loxocarpa							<1%	<1%			3-4%		<1%															
Pityrodia paniculata																												
Pluchea dunlopii		<1%		<1%																								
Pluchea rubelliflora									<1%							<1%			<1%	<1%	<1%							
Polycarpaea corymbosa var. *corymbosa*		<1%																										
Polygala aff. *isingii*		<1%							<1%	<1%				<1%								<1%	<1%	<1%		<1%		
Portulaca pilosa																												
Pterocaulon sphaeranthoides		<1%		<1%										<1%	<1%								<1%					
Ptilotus appendiculatus var. *appendiculatus*				<1%																								
Ptilotus arthrolasius																												
Ptilotus astrolasius var. *astrolasius*																												
Ptilotus axillaris										<1%				<1%														
Ptilotus exaltatus var. *exaltatus*									<1%					<1%			<1%											
Ptilotus fusiformis		<1%		<1%																								
Ptilotus murrayi																									1%			
Rhagodia eremaea							<1%	<1%			<1%		<1%	<1%										<1%				
Rhagodia preissii subsp. *obovata*							<1%																					
Rhynchosia minima							<1%	<1%	<1%	<1%	<1%			<1%			<1%						<1%			<1%		
Rostellularia adscendens var. *clementii*																												
Salsola tragus			<1%				<1%					<1%																
Sarcostemma viminale subsp. *australe*									<1%																			
Scaevola parvifolia subsp. *pilbarae*																												
Scaevola pulchella														1%			<1%											
Scaevola sericophylla	<1%							<1%			<1%		<1%										<1%					
Scaevola spinescens	<1%			<1%					<1%			1%								<1%		<1%	<1%	<1%	<1%	<1%	1%	
Scaevola spinescens (broad form)									<1%								<1%											
Schoenoplectus dissachanthus																<1%												
Sclerolaena recurvicuspis									<1%																			
Sclerolaena uniflora									<1%	<1%													<1%					
Sesbania cannabina																			<1%							<1%		<1%

Species	**WH29**	**WH30**	**WH32**	**WH34**	**WH35**	**WH40**	**WH41**	**WH42**	**WH43**	**WH44**	**WH45**	**WH46**	**WH47**	**WH48**	**WH49**	**WH50**	**WH51**	**WH52**	**WH53**	**WH54**	**WH55**	**WH56**	**WH57**	**WH58**	**WH59**	**WH60**	**WH61**	**WH62**
Setaria dielsii																												
Sida arsiniata														<1%														
Sida echinocarpa																												
Sida aff. *fibulifera* (B64-13B)																							<1%					
Sida aff. *fibulifera* (M69.12)	<1%																											
Sida pilbarensis (ferruginous form)																												
Sida rohlenae subsp. *rohlenae*	<1%			<1%				<1%			<1%		<1%															
Solanum diversiflorum								<1%	<1%					<1%			<1%											
Solanum ellipticum									<1%																			
Solanum lasiophyllum	<1%	<1%	<1%				<1%	<1%	<1%		<1%	<1%	<1%	<1%			<1%					<1%	<1%	<1%				
Solanum sturtianum		<1%																										
Spinifex longifolius												5%			10%													
Sporobolus australasicus		<1%	<1%	<1%	<1%																							
Sporobolus mitchellii																35%		<1%		10%	<1%	<1%			30%		80%	<1%
Sporobolus virginicus									2%						<1%				30%									
Stemodia sp. Onslow (A.A. Mitchell 76/148)									<1%											<1%								
Streptoglossa bubakii		<1%																<1%			<1%		<1%		<1%		<1%	<1%
Streptoglossa decurrens				<1%																								
Streptoglossa macrocephala		<1%																										
Streptoglossa odora																												
Streptoglossa sp.																						<1%						
Stylobasium spathulatum	5%																<1%											
Suaeda arbusculoides																												
Swainsona kingii subsp. *kingii*										<1%																		<1%
Swainsona pterostylis										<1%						<1%		<1%				<1%			<1%		<1%	
Synaptantha tillaeacea var. *tillaeacea*		<1%																										
Tecticornia auriculata						5%																						20%
Tecticornia ? auriculata																		6%										
Tecticornia doleiformis																												
Tecticornia halocnemoides subsp. *tenuis*						3%												4%										
Tecticornia ? halocnemoides subsp. *tenuis*																					<1%						<1%	5%
Tecticornia indica subsp. ? (intergrade between *leiostachya/bider*																			<1%		25%				1%		1%	
Tecticornia indica subsp. *leiostachya*																												
Tecticornia pergranulata																<1%												
Tecticornia pruinosa																												
Tecticornia pterygosperma subsp. *denticulata*																												
Tecticornia ? sp. Dennys Crossing (K.A. Shepherd & J. English KS 55:						<1%																						
Tecticornia sp. nov. 1 (*?T. halocnemoides* complex)						7%																						
Tecticornia sp.																												
Tephrosia gardneri							<1%	<1%				1%	<1%		<1%		<1%											
Tephrosia rosea var. *clementii*											1%																	
Tephrosia aff. *supina* (HD133-20)																												
Tephrosia aff. *supina* (MET 12,357)									<1%																			
Tephrosia sp. B Kimberley Flora (C.A. Gardner 7300)																												
Threlkeldia diffusa							<1%								<1%													
Tinospora smilacina																												
Trachymene pilbarensis																												
Trianthema pilosa	<1%																											
Trianthema triquetra																												
Trianthema turgidifolia									<1%																			
Tribulus astrocarpus																												
Tribulus macrocarpus																												

Species	**WH29**	**WH30**	**WH32**	**WH34**	**WH35**	**WH40**	**WH41**	**WH42**	**WH43**	**WH44**	**WH45**	**WH46**	**WH47**	**WH48**	**WH49**	**WH50**	**WH51**	**WH52**	**WH53**	**WH54**	**WH55**	**WH56**	**WH57**	**WH58**	**WH59**	**WH60**	**WH61**	**WH62**
Tribulus occidentalis	<1%						<1%					<1%	<1%															
Trichodesma zeylanicum var. *grandiflorum*	<1%						5-8%	<1%			1%	1%	2%		<1%									<1%				
Triodia brizoides					10%																							
Triodia epactia	10%	20%					15-20%	20%	30%	2-5%	35%		30%	35%	3%		30%			<1%		55%	50%	65%		40%		
Triodia lanigera			20%	75%																								
Triodia schinzii	20%																											
Tripogon loliiformis			<1%																									
Triumfetta aff. *chaetocarpa* (H123-10)				<1%																								
Triumfetta aff. *chaetocarpa* (PAN3/4)											<1%																	
Triumfetta clementii				<1%																								
Triumfetta echinata																												
Urochloa holosericea subsp. *velutina*																												
Verticordia forrestii								<1%																				
Vigna sp. Hamersley Clay (A.A. Mitchell PRP 113)																												
Waltheria indica																												
Whiteochloa airoides																												
Yakirra australiensis var. *australiensis*																								<1%				
Introduced Species																												
**Cenchrus ciliaris*	30%	<1%					5%	10%	40%	60%	5-8%	<1%	30%	<1%	3%		1%	<1%	<1%			<1%	10%	<1%		20%		
**Cenchrus setiger*	<1%			<1%																								
**Cucumis melo* subsp. *agrestis*																												
**Portulaca oleracea*		<1%																										
**Prosopis pallida*																				1%					<1%			
**Setaria verticillata*																												
**Vachellia farnesiana*									<1%										<1%	1%		<1%	<1%				<1%	

Species	**WH63**	**WH64**	**WH65**	**WH66**	**WH67**	**WH68**	**WH-JFA**	**WH-JFB**	**WH-JFC**	**WH-JFD**	**WH-MA**	**WH-MB**	**WH-RB1**	**WH-RB2**	**WH-RB3**	**WH-RB4**	**WSB-02**	**WSB-03**	**WSB-04**	**WSB-05**	**WSB-06**	**WSB-07**	**WSB-08**	**WSB-09**
Abutilon fraseri																								
Abutilon aff. *lepidum* (4)																								
Abutilon otocarpum																								
Abutilon oxycarpum subsp. *prostratum*	<1%																							
Abutilon uncinatum																								
Abutilon sp.																								
Acacia ancistrocarpa																								
Acacia bivenosa																								
Acacia coriacea subsp. *coriacea*														nc				<1%	1%				<1%	
Acacia inaequilatera																								
Acacia pyrifolia																								
Acacia sclerosperma subsp. *sclerosperma*	1%																						<1%	<1%
Acacia sericophylla																								
Acacia stellaticeps																			2%	2%				<1%
Acacia synchronicia	<1%					1%			nc										<1%			<1%		
Acacia tetragonophylla	1%			<1%			1%		nc	1%	1-2			nc				<1%	<1%	<1%		2%		
Acacia trachycarpa																								
Acacia tumida var. *pilbarensis*																								
Acacia wanyu																								
Acacia xiphophylla																								
Adriana urticoides var. *urticoides*																								
Aenictophyton aff. *reconditum*																								
Aeschynomene indica																								
Alternanthera nodiflora		<1%	<1%									<1%												
Alysicarpus muelleri																								
Aristida contorta																								
Aristida holathera var. *holathera*																				<1%				
Aristida holathera var. *latifolia*																								
Atriplex bunburyana		<1%	<1%	<1%																	<1%	2%		
Atriplex codonocarpa																								
Atriplex semilunaris			<1%																					
Avicennia marina subsp. *marina*																nc								
Bergia trimera																								
Blumea tenella		<1%																						
Boerhavia burbidgeana																								
Boerhavia coccinea	<1%																							
Bonamia aff. *linearis*																								
Bonamia rosea																				1%			<1%	1%
Brachyachne convergens		20	<1%																					
Brachyachne prostrata																								
Bulbostylis barbata				<1%						<1%	<1%			nc										
Calandrinia ptychosperma																								
Calotis plumulifera	<1%																							
Cassia glutinosa																								
Cassia glutinosa x *luerssenii*																								
Cassia luerssenii																								
Cassia notabilis																								
Cassia oligophylla																								
Cassia oligophylla (thinly sericeous MET 15,035)	<1%																							
Cassia oligophylla x *helmsii*																			<1%					
Cassia oligophylla (thinly sericeous) x *helmsii*																								
Cassia pruinosa																								

Species	WH63	WH64	WH65	WH66	WH67	WH68	WH-JFA	WH-JFB	WH-JFC	WH-JFD	WH-MA	WH-MB	WH-RB1	WH-RB2	WH-RB3	WH-RB4	WSB-02	WSB-03	WSB-04	WSB-05	WSB-06	WSB-07	WSB-08	WSB-09
Cassytha capillaris																				<1%			<1%	<1%
Centaurium spicatum																								
Centipeda minima subsp. *macrocephala*		<1%																						
Chloris pectinata																								
Chloris pumilio			<1%																					
Chrysopogon fallax	<1%					<1%																		
Cleome uncifera subsp. *uncifera*																								
Corchorus aff. *laniflorus*																								
Corchorus sidoides subsp. *vermicularis*																								
Corymbia hamersleyana																								
Corynotheca pungens																								
Cressa australis																								
Crotalaria cunninghamii																				<1%			<1%	<1%
Crotalaria medicaginea var. *neglecta*	<1%		<1%	<1%						<1%	<1%										<1%	<1%	<1%	
Crotalaria ramosissima											<1%													
Crotalaria sp.																								
Cucumis maderaspatanus	<1%	<1%	<1%																					
Cullen cinereum	<1%	<1%	<1%			<1%						<1%									<1%	<1%		
Cullen graveolens			<1%																					
Cullen lachnostachys				<1%																				
Cullen leucanthum																								
Cullen leucochaites																								
Cullen martinii																								
Cullen pogonocarpum																								
Cymbopogon procerus																								
Cyperus bulbosus																					<1%	<1%		
Cyperus iria		<1%	<1%																					
Cyperus rigidellus		<1%	<1%			<1%						<1%												
Cyperus squarrosus																								
Dactyloctenium radulans	<1%		<1%	<1%					nc													<1%		
Desmodium filiforme	<1%										<1%													
Dichanthium sericeum subsp. *humilius*			<1%																					
Dicrastylis cordifolia																								
Digitaria brownii																								
Diplopeltis eriocarpa																							<1%	1%
Dysphania plantaginella												<1%												
Eleocharis papillosa																								
Enchylaena tomentosa var. *tomentosa*																								
Enneapogon caerulescens																		<1%						
Enteropogon ramosus																								
Eragrostis cumingii																								
Eragrostis eriopoda																							<1%	
Eragrostis falcata																					<1%			
Eragrostis aff. *falcata*																								
Eragrostis leptocarpa																								
Eragrostis pergracilis		<1%	<1%				<1%					10%												
Eragrostis aff. *setifolia*																								
Eragrostis xerophila																								
Eremophila forrestii subsp. *viridis*																								
Eriachne aristidea																								
Eriachne benthamii		<1%	<1%			40%							nc											
Eriachne aff. *benthamii*																	<1%							

Species	**WH63**	**WH64**	**WH65**	**WH66**	**WH67**	**WH68**	**WH-JFA**	**WH-JFB**	**WH-JFC**	**WH-JFD**	**WH-MA**	**WH-MB**	**WH-RB1**	**WH-RB2**	**WH-RB3**	**WH-RB4**	**WSB-02**	**WSB-03**	**WSB-04**	**WSB-05**	**WSB-06**	**WSB-07**	**WSB-08**	**WSB-09**
Eriachne gardneri																								
Eriachne obtusa																								
Eriachne pulchella subsp. *dominii*																								
Eriochloa pseudoacrotricha		5%	35%																					
Eucalyptus victrix										<1%														
Eulalia aurea	<1%		<1%			<1%				1%				nc								<1%		
Euphorbia australis																			<1%					
Euphorbia australis (mid-green form)																								
Euphorbia biconvexa																								
Euphorbia boophthona																								
Euphorbia aff. *coghlanii*																								
Euphorbia myrtoides											<1%									<1%				<1%
Euphorbia tannensis subsp. *eremophila*																								
Evolvulus alsinoides var. *decumbens*											<1%													
Evolvulus alsinoides var. *villosicalyx*	<1%			<1%															<1%					
Fimbristylis dichotoma				<1%																				
Flaveria australasica							<1%														<1%	<1%		
Frankenia ambita							<1%		nc												<1%			
Gomphrena cunninghamii																								
Gomphrena sordida																								
Goodenia forrestii																								
Goodenia microptera																			<1%					
Gossypium australe (Burrup Peninsula form)																								
Grevillea eriostachya																				<1%			<1%	
Grevillea stenobotrya																				1%				
Grevillea wickhamii subsp. *hispidula*																								
Hakea lorea subsp. *lorea*																				1%				
Hakea stenophylla subsp. *stenophylla*																				<1%				
Heliotropium curassavicum																								
Heliotropium inexplicitum																								
Heliotropium pachyphyllum																								
Hibiscus brachychlaenus																								
Hibiscus sturtii var. *campylochlamys*																								
Hibiscus sturtii var. *platychlamys*																								
Hybanthus aurantiacus																								
Indigofera boviperda subsp. *boviperda*																								
Indigofera colutea	<1%			<1%					nc		<1%			nc							<1%	<1%		
Indigofera georgei																								
Indigofera linifolia				<1%					nc		<1%													
Indigofera linnaei	<1%								nc	<1%														
Indigofera monophylla (Burrup form)																		1-2	<1%					<1%
Indigofera trita									nc					nc							<1%	<1%		<1%
Ipomoea coptica		<1%	<1%							<1%														
Ipomoea costata																								
Ipomoea muelleri																								
Ipomoea polymorpha											<1%													
Iseilema dolichotrichum																								
Iseilema macratherum		<1%	<1%																					
Isotropis atropurpurea																								
Lawrencia viridigrisea							<1%		nc												<1%	<1%		
Lepidium platypetalum																								
Leptochloa fusca subsp. *muelleri*		<1%										<1%												

Species	**WH63**	**WH64**	**WH65**	**WH66**	**WH67**	**WH68**	**WH-JFA**	**WH-JFB**	**WH-JFC**	**WH-JFD**	**WH-MA**	**WH-MB**	**WH-RB1**	**WH-RB2**	**WH-RB3**	**WH-RB4**	**WSB-02**	**WSB-03**	**WSB-04**	**WSB-05**	**WSB-06**	**WSB-07**	**WSB-08**	**WSB-09**
Maireana georgei																								
Maireana lanosa																								
Maireana planifolia																								
Maireana sp.	<1%						<1%		nc															
Marsilea drummondii						1%							nc											
Marsilea hirsuta		<1%	<1%			<1%						1%												
Melhania oblongifolia																								
Mimulus gracilis						<1%						<1%												
Mollugo molluginea																								
Muellerolimon salicorniaceum																								
Neobassia astrocarpa							<1%		nc															
Neptunia dimorphantha				<1%																				
Nicotiana rosulata subsp. *rosulata*																								
Olearia dampieri subsp. *dampieri*																				<1%			<1%	<1%
Panicum decompositum		<1%	<1%							<1%														
Panicum laevinode						<1%																		
Paraneurachne muelleri																								
Paspalidium clementii																								
Petalostylis cassioides																								
Phyllanthus erwinii																								
Phyllanthus maderaspatensis		<1%	<1%																					
Pimelea ammocharis																							<1%	
Pityrodia loxocarpa																							<1%	
Pityrodia paniculata																								
Pluchea dunlopii																								
Pluchea rubelliflora		<1%							nc	<1%														
Polycarpaea corymbosa var. *corymbosa*				<1%																				
Polygala aff. *isingii*	<1%			<1%			<1%		nc		<1%			nc							<1%	<1%		
Portulaca pilosa																								
Pterocaulon sphaeranthoides										<1%														
Ptilotus appendiculatus var. *appendiculatus*																								
Ptilotus arthrolasius																								
Ptilotus astrolasius var. *astrolasius*																								
Ptilotus axillaris																								
Ptilotus exaltatus var. *exaltatus*									nc															
Ptilotus fusiformis																								
Ptilotus murrayi		<1%										<1%												
Rhagodia eremaea																							<1%	
Rhagodia preissii subsp. *obovata*																								
Rhynchosia minima	<1%		<1%						nc		<1%			nc					<1%			<1%	<1%	
Rostellularia adscendens var. *clementii*		<1%	<1%																					
Salsola tragus																								
Sarcostemma viminale subsp. *australe*																								
Scaevola parvifolia subsp. *pilbarae*																								
Scaevola pulchella																								
Scaevola sericophylla																				<1%			<1%	<1%
Scaevola spinescens						<1%				<1%								<1%	<1%					
Scaevola spinescens (broad form)	<1%			<1%							<1%													
Schoenoplectus dissachanthus																								
Sclerolaena recurvicuspis																								
Sclerolaena uniflora																								
Sesbania cannabina		<1%	<1%			<1%								nc										

Species	WH63	WH64	WH65	WH66	WH67	WH68	WH-JFA	WH-JFB	WH-JFC	WH-JFD	WH-MA	WH-MB	WH-RB1	WH-RB2	WH-RB3	WH-RB4	WSB-02	WSB-03	WSB-04	WSB-05	WSB-06	WSB-07	WSB-08	WSB-09
Setaria dielsii			<1%																					
Sida arsiniata																								
Sida echinocarpa																								
Sida aff. *fibulifera* (B64-13B)																								
Sida aff. *fibulifera* (M69.12)																								
Sida pilbarensis (ferruginous form)																								
Sida rohlenae subsp. *rohlenae*																								
Solanum diversiflorum				<1%															<1%	<1%				
Solanum ellipticum																								
Solanum lasiophyllum											<1%			nc					<1%				<1%	<1%
Solanum sturtianum																								
Spinifex longifolius																								
Sporobolus australasicus	<1%																							
Sporobolus mitchellii		50%	50%			20%						<1%	nc											
Sporobolus virginicus														nc										
Stemodia sp. Onslow (A.A. Mitchell 76/148)																								
Streptoglossa bubakii			<1%																					
Streptoglossa decurrens																								
Streptoglossa macrocephala																								
Streptoglossa odora																								
Streptoglossa sp.																								
Stylobasium spathulatum																								
Suaeda arbusculoides																nc								
Swainsona kingii subsp. *kingii*																								
Swainsona pterostylis	<1%																							
Synaptantha tillaeacea var. *tillaeacea*																								
Tecticornia auriculata															nc									
Tecticornia ? auriculata																								
Tecticornia doleiformis															nc									
Tecticornia halocnemoides subsp. *tenuis*																								
Tecticornia ? halocnemoides subsp. *tenuis*																								
Tecticornia indica subsp. ? (intergrade between *leiostachya/bider*																								
Tecticornia indica subsp. *leiostachya*												20%									<1%			
Tecticornia pergranulata																								
Tecticornia pruinosa																								
Tecticornia pterygosperma subsp. *denticulata*																								
Tecticornia ? sp. Dennys Crossing (K.A. Shepherd & J. English KS 55																nc								
Tecticornia sp. nov. 1 (?*T. halocnemoides* complex)																								
Tecticornia sp.			<1%		15%		<1%	nc								nc								
Tephrosia gardneri																								
Tephrosia rosea var. *clementii*																				<1%	<1%			
Tephrosia aff. *supina* (HD133-20)																								
Tephrosia aff. *supina* (MET 12,357)																								
Tephrosia sp. B Kimberley Flora (C.A. Gardner 7300)											<1%													
Threlkeldia diffusa	<1%																							
Tinospora smilacina																								
Trachymene pilbarensis																								
Trianthema pilosa																								
Trianthema triquetra		<1%																						
Trianthema turgidifolia				<1%																	<1%			
Tribulus astrocarpus																								
Tribulus macrocarpus																								

Species	**WH63**	**WH64**	**WH65**	**WH66**	**WH67**	**WH68**	**WH-JFA**	**WH-JFB**	**WH-JFC**	**WH-JFD**	**WH-MA**	**WH-MB**	**WH-RB1**	**WH-RB2**	**WH-RB3**	**WH-RB4**	**WSB-02**	**WSB-03**	**WSB-04**	**WSB-05**	**WSB-06**	**WSB-07**	**WSB-08**	**WSB-09**
Tribulus occidentalis																								
Trichodesma zeylanicum var. *grandiflorum*																		<1%		<1%			<1%	<1%
Triodia brizoides																								
Triodia epactia	40%			30%			75%		nc		85			nc				3	3%	35%	15%	5%	30%	7%
Triodia lanigera																								
Triodia schinzii																								
Tripogon loliiformis																								
Triumfetta aff. *chaetocarpa* (H123-10)																								
Triumfetta aff. *chaetocarpa* (PAN3/4)																								
Triumfetta clementii																								
Triumfetta echinata																								
Urochloa holosericea subsp. *velutina*																								
Verticordia forrestii																				<1%				
Vigna sp. Hamersley Clay (A.A. Mitchell PRP 113)				<1%																				
Waltheria indica																								
Whiteochloa airoides																								
Yakirra australiensis var. *australiensis*																								
Introduced Species																								
**Cenchrus ciliaris*	50%		<1%	25%			30%		nc	35%	1-2			nc				1	1%	<1%	45%	70%	15%	30%
**Cenchrus setiger*																								
**Cucumis melo* subsp. *agrestis*																								
**Portulaca oleracea*	<1%	<1%																						
**Prosopis pallida*			<1%										nc								<1%			
**Setaria verticillata*																						<1%		
**Vachellia farnesiana*	<1%		<1%			1%				<1%												1%		

Species	WSB-10	WSB-12	WSB-14	WSB-15	WSB-16	WSB-17	WSB-18	WSB-23	WSB-24	WSB-25	WSB access	WSB setdown
Abutilon fraseri												
Abutilon aff. *lepidum* (4)												
Abutilon otocarpum												
Abutilon oxycarpum subsp. *prostratum*												
Abutilon uncinatum												
Abutilon sp.								<1%				
Acacia ancistrocarpa												
Acacia bivenosa												
Acacia coriacea subsp. *coriacea*					<1%			<1%		<1%		
Acacia inaequilatera												
Acacia pyrifolia												
Acacia sclerosperma subsp. *sclerosperma*				3%							<1%	
Acacia sericophylla												
Acacia stellaticeps			<1%	5%	25%					15%		
Acacia synchronicia	<1%		<1%			<1%			<1%			
Acacia tetragonophylla			<1%		<1%	<1%						<1%
Acacia trachycarpa												
Acacia tumida var. *pilbarensis*												
Acacia wanyu												
Acacia xiphophylla												
Adriana urticoides var. *urticoides*								5-10%		<1%		
Aenictophyton aff. *reconditum*												
Aeschynomene indica												
Alternanthera nodiflora												
Alysicarpus muelleri												
Aristida contorta												
Aristida holathera var. *holathera*				<1%								
Aristida holathera var. *latifolia*												
Atriplex bunburyana			<1%					<1%				
Atriplex codonocarpa												
Atriplex semilunaris												
Avicennia marina subsp. *marina*												
Bergia trimera												
Blumea tenella												
Boerhavia burbidgeana												
Boerhavia coccinea												
Bonamia aff. *linearis*												
Bonamia rosea										<1%		
Brachyachne convergens												
Brachyachne prostrata												
Bulbostylis barbata		<1%				<1%	<1%					
Calandrinia ptychosperma												
Calotis plumulifera												
Cassia glutinosa												
Cassia glutinosa x *luerssenii*					<1%							
Cassia luerssenii												
Cassia notabilis												
Cassia oligophylla												
Cassia oligophylla (thinly sericeous MET 15,035)												
Cassia oligophylla x *helmsii*												
Cassia oligophylla (thinly sericeous) x *helmsii*												
Cassia pruinosa												

Species	WSB-10	WSB-12	WSB-14	WSB-15	WSB-16	WSB-17	WSB-18	WSB-23	WSB-24	WSB-25	WSB access	WSB setdown
Cassytha capillaris	<1%		<1%		<1%		<1%					
Centaurium spicatum												
Centipeda minima subsp. *macrocephala*												
Chloris pectinata						<1%						
Chloris pumilio												
Chrysopogon fallax												
Cleome uncifera subsp. *uncifera*												
Corchorus aff. *laniflorus*												
Corchorus sidoides subsp. *vermicularis*												
Corymbia hamersleyana												
Corynotheca pungens												
Cressa australis												
Crotalaria cunninghamii				10%	<1%			5-10%		<1%	<1%	
Crotalaria medicaginea var. *neglecta*			<1%				<1%		<1%			
Crotalaria ramosissima												
Crotalaria sp.												
Cucumis maderaspatanus												
Cullen cinereum						<1%						
Cullen graveolens												
Cullen lachnostachys												
Cullen leucanthum												
Cullen leucochaites												
Cullen martinii												
Cullen pogonocarpum												
Cymbopogon procerus												
Cyperus bulbosus		<1%				<1%						
Cyperus iria												
Cyperus rigidellus												
Cyperus squarrosus												
Dactyloctenium radulans	<1%	<1%				<1%			<1%			
Desmodium filiforme												
Dichanthium sericeum subsp. *humilius*												
Dicrastylis cordifolia												
Digitaria brownii												
Diplopeltis eriocarpa												
Dysphania plantaginella						<1%						
Eleocharis papillosa												
Enchylaena tomentosa var. *tomentosa*												
Enneapogon caerulescens												
Enteropogon ramosus												
Eragrostis cumingii												
Eragrostis eriopoda			<1%									
Eragrostis falcata		1				<1%						
Eragrostis aff. *falcata*												
Eragrostis leptocarpa												
Eragrostis pergracilis												
Eragrostis aff. *setifolia*									<1%			
Eragrostis xerophila												
Eremophila forrestii subsp. *viridis*												
Eriachne aristidea												
Eriachne benthamii												
Eriachne aff. *benthamii*												

Species	**WSB-10**	**WSB-12**	**WSB-14**	**WSB-15**	**WSB-16**	**WSB-17**	**WSB-18**	**WSB-23**	**WSB-24**	**WSB-25**	**WSB acces**	**WSB setdow**
Eriachne gardneri												
Eriachne obtusa							<1%					
Eriachne pulchella subsp. *dominii*												
Eriochloa pseudoacrotricha												
Eucalyptus victrix												
Eulalia aurea												
Euphorbia australis												
Euphorbia australis (mid-green form)												
Euphorbia biconvexa												
Euphorbia boophthona												
Euphorbia aff. *coghlanii*												
Euphorbia myrtoides								<1%				
Euphorbia tannensis subsp. *eremophila*												
Evolvulus alsinoides var. *decumbens*												
Evolvulus alsinoides var. *villosicalyx*												
Fimbristylis dichotoma												
Flaveria australasica												
Frankenia ambita	<1%	<1%										
Gomphrena cunninghamii												
Gomphrena sordida												
Goodenia forrestii												
Goodenia microptera			<1%						<1%			
Gossypium australe (Burrup Peninsula form)												
Grevillea eriostachya												
Grevillea stenobotrya				5%								
Grevillea wickhamii subsp. *hispidula*												
Hakea lorea subsp. *lorea*												
Hakea stenophylla subsp. *stenophylla*									<1%			
Heliotropium curassavicum												
Heliotropium inexplicitum												
Heliotropium pachyphyllum												
Hibiscus brachychlaenus												
Hibiscus sturtii var. *campylochlamys*				<1%								
Hibiscus sturtii var. *platychlamys*												
Hybanthus aurantiacus												
Indigofera boviperda subsp. *boviperda*												
Indigofera colutea	<1%	<1%	<1%			<1%	<1%	<1%	<1%	<1%		
Indigofera georgei												
Indigofera linifolia	<1%	<1%				<1%	<1%					
Indigofera linnaei												
Indigofera monophylla (Burrup form)												
Indigofera trita	<1%	<1%	<1%						<1%			
Ipomoea coptica									<1%			
Ipomoea costata												
Ipomoea muelleri												
Ipomoea polymorpha												
Iseilema dolichotrichum												
Iseilema macratherum												
Isotropis atropurpurea												
Lawrencia viridigrisea	<1%	<1%				<1%						
Lepidium platypetalum												
Leptochloa fusca subsp. *muelleri*												

Species	**WSB-10**	**WSB-12**	**WSB-14**	**WSB-15**	**WSB-16**	**WSB-17**	**WSB-18**	**WSB-23**	**WSB-24**	**WSB-25**	**WSB access**	**WSB setdown**
Maireana georgei												
Maireana lanosa												
Maireana planifolia												
Maireana sp.												
Marsilea drummondii												
Marsilea hirsuta												
Melhania oblongifolia												
Mimulus gracilis												
Mollugo molluginea												
Muellerolimon salicorniaceum												
Neobassia astrocarpa	<1%	<1%				<1%						
Neptunia dimorphantha												
Nicotiana rosulata subsp. *rosulata*		<1%				<1%						
Olearia dampieri subsp. *dampieri*				<1%								
Panicum decompositum						<1%						
Panicum laevinode												
Paraneurachne muelleri												
Paspalidium clementii												
Petalostylis cassioides												
Phyllanthus erwinii												
Phyllanthus maderaspatensis												
Pimelea ammocharis												
Pityrodia loxocarpa					<1%			<1%		<1%		
Pityrodia paniculata												
Pluchea dunlopii												
Pluchea rubelliflora		<1%										
Polycarpaea corymbosa var. *corymbosa*												
Polygala aff. *isingii*									<1%			
Portulaca pilosa												
Pterocaulon sphaeranthoides												
Ptilotus appendiculatus var. *appendiculatus*												
Ptilotus arthrolasius												
Ptilotus astrolasius var. *astrolasius*												
Ptilotus axillaris												
Ptilotus exaltatus var. *exaltatus*												
Ptilotus fusiformis												
Ptilotus murrayi												
Rhagodia eremaea	<1%					<1%				<1%		
Rhagodia preissii subsp. *obovata*												
Rhynchosia minima	<1%	<1%	<1%						<1%		<1%	
Rostellularia adscendens var. *clementii*												
Salsola tragus												
Sarcostemma viminale subsp. *australe*												
Scaevola parvifolia subsp. *pilbarae*												
Scaevola pulchella								<1%				
Scaevola sericophylla			<1%									
Scaevola spinescens									<1%		<1%	
Scaevola spinescens (broad form)												
Schoenoplectus dissachanthus												
Sclerolaena recurvicuspis												
Sclerolaena uniflora	<1%		<1%						<1%			
Sesbania cannabina												

Species	**WSB-10**	**WSB-12**	**WSB-14**	**WSB-15**	**WSB-16**	**WSB-17**	**WSB-18**	**WSB-23**	**WSB-24**	**WSB-25**	**WSB access**	**WSB setdowr**
Setaria dielsii												
Sida arsiniata												
Sida echinocarpa												
Sida aff. *fibulifera* (B64-13B)												
Sida aff. *fibulifera* (M69.12)												
Sida pilbarensis (ferruginous form)												
Sida rohlenae subsp. *rohlenae*								<1%				
Solanum diversiflorum			<1%		<1%							
Solanum ellipticum												
Solanum lasiophyllum			<1%	<1%	<1%		<1%		<1%	<1%	<1%	<1%
Solanum sturtianum												
Spinifex longifolius												
Sporobolus australasicus												
Sporobolus mitchellii												
Sporobolus virginicus	<1%	5-10%	<1%						<1%			
Stemodia sp. Onslow (A.A. Mitchell 76/148)									<1%			
Streptoglossa bubakii												
Streptoglossa decurrens												
Streptoglossa macrocephala												
Streptoglossa odora												
Streptoglossa sp.												
Stylobasium spathulatum												
Suaeda arbusculoides												
Swainsona kingii subsp. *kingii*												
Swainsona pterostylis		<1%				<1%						
Synaptantha tillaeacea var. *tillaeacea*												
Tecticornia auriculata									<1%			
Tecticornia ? auriculata												
Tecticornia doleiformis												
Tecticornia halocnemoides subsp. *tenuis*						<1%						
Tecticornia ? halocnemoides subsp. *tenuis*												
Tecticornia indica subsp. ? (intergrade between *leiostachya/bider*												
Tecticornia indica subsp. *leiostachya*												
Tecticornia pergranulata												
Tecticornia pruinosa		<1%										
Tecticornia pterygosperma subsp. *denticulata*												
Tecticornia ? sp. Dennys Crossing (K.A. Shepherd & J. English KS 55												
Tecticornia sp. nov. 1 (*?T. halocnemoides* complex)												
Tecticornia sp.						<1%						
Tephrosia gardneri												
Tephrosia rosea var. *clementii*												
Tephrosia aff. *supina* (HD133-20)												
Tephrosia aff. *supina* (MET 12,357)												
Tephrosia sp. B Kimberley Flora (C.A. Gardner 7300)												
Threlkeldia diffusa						<1%						
Tinospora smilacina												
Trachymene pilbarensis												
Trianthema pilosa												
Trianthema triquetra												
Trianthema turgidifolia						<1%						
Tribulus astrocarpus								<1%				
Tribulus macrocarpus												

Species	**WSB-10**	**WSB-12**	**WSB-14**	**WSB-15**	**WSB-16**	**WSB-17**	**WSB-18**	**WSB-23**	**WSB-24**	**WSB-25**	**WSB access**	**WSB setdow**
Tribulus occidentalis												
Trichodesma zeylanicum var. *grandiflorum*				7%				5-10%	<1%	<1%		
Triodia brizoides												
Triodia epactia	35%	15-20%	30%	5%	25%	15%	35%	10-30%	30%	55%	50	15
Triodia lanigera												
Triodia schinzii												
Tripogon loliiformis												
Triumfetta aff. *chaetocarpa* (H123-10)												
Triumfetta aff. *chaetocarpa* (PAN3/4)												
Triumfetta clementii												
Triumfetta echinata												
Urochloa holosericea subsp. *velutina*												
Verticordia forrestii				2%	25%							
Vigna sp. Hamersley Clay (A.A. Mitchell PRP 113)							<1%		<1%			
Waltheria indica												
Whiteochloa airoides												
Yakirra australiensis var. *australiensis*												
Introduced Species												
**Cenchrus ciliaris*	35%	20%	20%	1%	<1%	12%	25%	<1%	10%	10%	5	<1%
**Cenchrus setiger*												
**Cucumis melo* subsp. *agrestis*												
**Portulaca oleracea*												
**Prosopis pallida*						<1%					<1%	
**Setaria verticillata*												
**Vachellia farnesiana*												

Appendix 5

List of Flora Species Recorded from the Wheatstone Study Area

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NB. * denotes introduced species

Comparison of *Cassia* vs. *Senna* nomenclature:

Cassia artemisioides = *Senna artemisioides*
Cassia glutinosa = *Senna glutinosa* subsp. *glutinosa*
Cassia luerssenii = *Senna glutinosa* subsp. x *luerssenii*
Cassia notabilis = *Senna notabilis*
Cassia oligophylla = *Senna artemisioides* subsp. *oligophylla*
Cassia helmsii = *Senna artemisioides* subsp. *helmsii*
Cassia pruinosa = *Senna glutinosa* subsp. *pruinosa*

Family	**Species**	**This study**	**OEC (2008/9)**	**RPS (2009)**
Acanthaceae	*Rostellularia adscendens* var. *clementii*	√		
Aizoaceae	*Trianthema pilosa*	√		√
	Trianthema triquetra	√	√	
	Trianthema turgidifolia	√	√	
Amaranthaceae	**Aerva javanica*	√	√	
	Alternanthera nodiflora	√	√	
	Amaranthus mitchellii		√	
	Gomphrena affinis subsp. *pilbarensis*	√		
	Gomphrena cunninghamii	√		
	Gomphrena sordida	√		
	Hemichroa diandra	√	√	
	Ptilotus appendiculatus var. *appendiculatus*	√		
	Ptilotus arthrolasius	√		
	Ptilotus astrolasius var. *astrolasius*	√		
	Ptilotus axillaris	√	√	√
	Ptilotus exaltatus var. *exaltatus*	√	√	√
	Ptilotus fusiformis	√		
	Ptilotus gomphrenoides var. *conglomeratus*		√	
	Ptilotus latifolius		√	
	Ptilotus macrocephalus	√		
	Ptilotus murrayi	√	√	
	Ptilotus obovatus		√	
	Ptilotus polystachyus var. *polystachyus*	√	√	√
	Ptilotus villosiflorus		√	
Anthericaceae	*Corynotheca flexuosissima*		√	
	Corynotheca pungens	√	√	
	Murchisonia volubilis		√	
Apiaceae	*Trachymene pilbarensis*	√	√	√
Asclepiadaceae	*Sarcostemma viminale* subsp. *australe*	√	√	
Asteraceae	*Angianthus milnei*		√	√
	Blumea tenella	√		
	Brachyscome ciliocarpa		√	
	Calotis plumulifera	√	√	
	Centipeda minima subsp. *macrocephala*	√	√	
	Decazesia hecatocephala		√	
	Flaveria australasica	√	√	√
	Minuria cunninghamii		√	
	Olearia dampieri subsp. *dampieri*	√	√	
	Pluchea dunlopii	√	√	
	Pluchea ferdinandi-muelleri	√	√	
	Pluchea rubelliflora	√	√	
	Pluchea sp. B Kimberley Flora (K.F. Kenneally 9526A)		√	
	Pterocaulon sphaeranthoides	√	√	
	Rhodanthe floribunda		√	
	Rhodanthe humboldtiana		√	
	Rhodanthe stricta		√	
	Streptoglossa adscendens		√	
	Streptoglossa bubakii	√		

Family	**Species**	**This study**	**OEC (2008/9)**	**RPS (2009)**
Asteraceae (cont.)	*Streptoglossa decurrens*	√	√	
	Streptoglossa liatroides		√	
	Streptoglossa macrocephala	√	√	
	Streptoglossa odora	√		
	Streptoglossa sp.	√		
Avicenniaceae	*Avicennia marina* subsp. *marina*	√	√	
Boraginaceae	*Heliotropium crispatum*	√		
	Heliotropium curassavicum	√		
	Heliotropium diversifolium	√		
	Heliotropium inexplicitum	√		
	Heliotropium ovalifolium			√
	Heliotropium pachyphyllum	√	√	
	Heliotropium sp.			√
	Trichodesma zeylanicum var. *grandiflorum*	√	√	√
	Trichodesma zeylanicum var. *zeylanicum*		√	
Brassicaceae	*Lepidium pholidogynum*		√	
	Lepidium platypetalum	√	√	
Caesalpiniaceae	*Cassia artemisioides*		√	
	Cassia glutinosa	√	√	
	Cassia glutinosa x *luerssenii*	√		√
	Cassia luerssenii	√	√	
	Cassia notabilis	√		√
	Cassia oligophylla	√	√	√
	Cassia oligophylla (thinly sericeous MET 15,035)	√		
	Cassia oligophylla x *helmsii*	√		
	Cassia oligophylla (thinly sericeous) x helmsii	√		
	Cassia pruinosa	√		
	**Parkinsonia aculeata*	√		
	Petalostylis cassioides	√		
Campanulaceae	*Wahlenbergia tumidifructa*		√	
Capparaceae	*Cleome uncifera* subsp. *uncifera*	√		
	Cleome viscosa		√	
Caryophyllaceae	*Polycarpaea corymbosa* var. *corymbosa*	√		
Celastraceae	*Stackhousia muricata*		√	
Chenopodiaceae	*Atriplex bunburyana*	√	√	
	Atriplex codonocarpa	√	√	
	Atriplex semilunaris	√	√	
	Dissocarpus paradoxus		√	
	Dysphania kalpari		√	
	Dysphania plantaginella	√		
	Dysphania platycarpa	√		
	Dysphania rhadinostachya	√	√	
	Enchylaena tomentosa var. *tomentosa*	√	√	√
	Maireana georgei	√		
	Maireana lanosa	√		
	Maireana planifolia	√	√	√
	Maireana tomentosa	√	√	
	Maireana sp.	√		
	Neobassia astrocarpa	√	√	√
	Rhagodia eremaea	√	√	√
	Rhagodia preissii subsp. *obovata*	√	√	
	Salsola tragus	√	√	√
	Sclerolaena costata		√	
	Sclerolaena recurvicuspis	√	√	
	Sclerolaena uniflora	√	√	
	Suaeda arbusculoides	√		
	Tecticornia auriculata	√	√	√
	Tecticornia ? auriculata	√		

Family	**Species**	**This study**	**OEC (2008/9)**	**RPS (2009)**
Chenopodiaceae (cont.)	*Tecticornia doleiformis*	√	√	
	Tecticornia halocnemoides		√	
	Tecticornia halocnemoides subsp. *tenuis*	√	√	
	Tecticornia ? halocnemoides subsp. *tenuis*	√		√
	Tecticornia indica subsp. *bidens*		√	
	Tecticornia indica subsp. aff. *bidens*		√	
	Tecticornia indica subsp. *leiostachya*	√	√	
	Tecticornia indica subsp. ? (intergrade between subspecies *leiostachya/bidens/julacea*)	√		
	Tecticornia pergranulata (insufficient material for further id)	√		
	Tecticornia pergranulata subsp. *elongata*		√	
	Tecticornia pergranulata subsp. *pergranulata*		√	
	Tecticornia pruinosa	√	√	
	Tecticornia pterygosperma subsp. *denticulata*	√	√	
	Tecticornia ? sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	√		
	Tecticornia sp. (WH40-04) (a potentially new taxon within the *T. halocnemoides* sens. lat. 'large seed aggregate', probably different from *T.* sp. (WHPH-15))	√		
	Tecticornia sp. (WHPH-15) (a potentially new taxon within the *T. halocnemoides* sens. lat. 'large seed aggregate', probably different from *T.* sp. (WH40-04))	√		
	Tecticornia sp. (insufficient material for further id)	√		
	Threlkeldia diffusa	√	√	
Convolvulaceae	*Bonamia erecta*		√	
	Bonamia linearis		√	√
	Bonamia aff. *linearis*	√		
	Bonamia rosea	√	√	√
	Convolvulus angustissimus subsp. *angustissimus*		√	
	Cressa australis	√	√	
	Evolvulus alsinoides var. *decumbens*	√	√	√
	Evolvulus alsinoides var. *villosicalyx*	√		√
	Ipomoea coptica	√		
	Ipomoea costata	√		
	Ipomoea muelleri	√	√	
	Ipomoea polymorpha	√	√	√
Cucurbitaceae	*Cucumis maderaspatanus*	√		
	**Cucumis melo* subsp. *agrestis*	√		
Cyperaceae	*Bulbostylis barbata*	√	√	√
	Cyperus bulbosus	√	√	
	Cyperus iria	√		
	Cyperus rigidellus	√		
	Cyperus squarrosus	√	√	
	Eleocharis papillosa	√		
	Fimbristylis dichotoma	√		
	Fimbristylis rara		√	
	Schoenoplectus dissachanthus	√		
Elatinaceae	*Bergia pedicellaris*	√		
	Bergia perennis subsp. *exigua*	√	√	
	Bergia perennis subsp. *perennis*	√		
	Bergia trimera	√		
Euphorbiaceae	*Adriana tomentosa* var. *tomentosa*	√	√	
	Euphorbia australis	√	√	
	Euphorbia australis (mid-green form)	√		
	Euphorbia biconvexa	√	√	
	Euphorbia boophthona	√		
	Euphorbia coghlanii	√		
	Euphorbia aff. *coghlanii*	√		

Family	**Species**	**This study**	**OEC (2008/9)**	**RPS (2009)**
Euphorbiaceae (cont.)	*Euphorbia drummondii* subsp. *drummondii*		√	
	Euphorbia myrtoides	√	√	√
	Euphorbia tannensis subsp. *eremophila*	√	√	√
	Phyllanthus erwinii	√		
	Phyllanthus maderaspatensis	√		
Frankeniaceae	*Frankenia ambita*	√	√	√
Gentianaceae	*Centaurium clementii*		√	
	Centaurium spicatum	√		
Geraniaceae	*Erodium cygnorum*		√	
Goodeniaceae	*Goodenia forrestii*	√	√	√
	Goodenia lamprosperma	√		
	Goodenia microptera	√	√	
	Scaevola cunninghamii		√	
	Scaevola parvifolia subsp. *pilbarae*	√		
	Scaevola pulchella	√	√	√
	Scaevola sericophylla	√	√	√
	Scaevola spinescens	√	√	√
	Scaevola spinescens (broad form)	√	√	
Gyrostemonaceae	*Codonocarpus cotinifolius*	√	√	
	Gyrostemon ramulosus		√	
Haloragaceae	*Haloragis gossei* var. *gossei*	√	√	
	Haloragis gossei var. *inflata*		√	
Lamiaceae	*Dicrastylis cordifolia*	√		
	Pityrodia loxocarpa	√	√	
	Pityrodia paniculata	√	√	√
Lauraceae	*Cassytha aurea* var. *aurea*		√	
	Cassytha capillaris	√	√	√
Lythraceae	*Rotala diandra*		√	
Malvaceae	*Abutilon cunninghamii*	√	√	
	Abutilon fraseri	√		
	Abutilon dioicum			√
	Abutilon lepidum		√	
	Abutilon aff. *lepidum* (1) (MET 15 352)	√		
	Abutilon aff. *lepidum* (4)	√		
	Abutilon otocarpum	√		
	Abutilon otocarpum (acute leaf form)	√		
	Abutilon oxycarpum subsp. *prostratum*	√	√	
	Abutilon uncinatum	√		
	Abutilon sp.	√		
	Alyogyne pinoniana	√		
	Gossypium australe (Burrup Peninsula form)	√	√	
	Hibiscus brachychlaenus	√	√	√
	Hibiscus brachysiphonius	√		
	Hibiscus leptocladus	√		
	Hibiscus sturtii var. *campylochlamys*	√		
	Hibiscus sturtii var. *platychlamys*	√	√	√
	Lawrencia viridigrisea	√	√	√
	**Malvastrum americanum*	√	√	
	Sida arsiniata	√	√	
	Sida echinocarpa	√		
	Sida aff. *fibulifera*		√	√
	Sida aff. *fibulifera* (B64-13B)	√		
	Sida aff. *fibulifera* (M69.12)	√		
	Sida pilbarensis (ferruginous form) (may = *Sida* sp. Pilbara (A.A. Mitchell PRP 154)).	√		
	Sida rohlenae subsp. *rohlenae*	√	√	√
Marsileaceae	*Marsilea drummondii*	√		
	Marsilea hirsuta	√	√	

Family	**Species**	**This study**	**OEC (2008/9)**	**RPS (2009)**
Meliaceae	*Owenia reticulata*	√		
Menispermaceae	*Tinospora smilacina*	√		
Mimosaceae	*Acacia ancistrocarpa*	√		
	Acacia bivenosa	√	√	
	Acacia colei var. *colei*	√		
	Acacia coriacea subsp. *coriacea*	√	√	√
	Acacia coriacea subsp. *pendens*		√	
	Acacia inaequilatera	√		
	Acacia pyrifolia	√	√	
	Acacia sclerosperma subsp. *sclerosperma*	√	√	√
	Acacia sclerosperma hybrid		√	
	Acacia sericophylla	√		
	Acacia sphaerostachya	√		
	Acacia stellaticeps	√	√	√
	Acacia synchronicia	√	√	
	Acacia tetragonophylla	√	√	√
	Acacia trachycarpa	√		
	Acacia trudgeniana	√		
	Acacia tumida var. *pilbarensis*	√		
	Acacia victoriae		√	
	Acacia wanyu	√		
	Acacia xiphophylla	√		
	Neptunia dimorphantha	√	√	
	*Prosopis pallida	√	√	
	*Vachellia farnesiana	√	√	
Molluginaceae	*Mollugo molluginea*	√		
Myoporaceae	*Eremophila cuneifolia*	√		
	Eremophila forrestii subsp. *forrestii*		√	
	Eremophila forrestii subsp. *viridis*	√	√	
	Eremophila longifolia	√		
	Myoporum montanum		√	
Myrtaceae	*Corymbia candida*	√		
	Corymbia hamersleyana	√		
	Corymbia zygophylla	√	√	
	Eucalyptus camaldulensis var. *obtusa*	√		
	Eucalyptus victrix	√	√	
	Eucalyptus xerothermica	√		
	Melaleuca argentea	√		
	Melaleuca glomerata		√	
	Verticordia forrestii	√	√	
Nyctaginaceae	*Boerhavia burbidgeana*	√		
	Boerhavia coccinea	√	√	
Papilionaceae	*Aenictophyton* aff. *reconditum*	√	√	
	Aeschynomene indica	√		
	Alysicarpus muelleri	√		
	Canavalia rosea		√	
	Crotalaria cunninghamii subsp. *sturtii*	√	√	√
	Crotalaria medicaginea var. *neglecta*	√	√	
	Crotalaria ramosissima	√		√
	Crotalaria sp. (insufficient material)	√		
	Cullen cinereum	√	√	
	Cullen graveolens	√		
	Cullen lachnostachys	√		
	Cullen leucanthum	√	√	
	Cullen leucochaites	√	√	
	Cullen martinii	√		
	Cullen pogonocarpum	√	√	
	Desmodium filiforme	√	√	√

Family	**Species**	**This study**	**OEC (2008/9)**	**RPS (2009)**
Papilionaceae (cont.)	*Indigofera boviperda* subsp. *boviperda*	√	√	√
	Indigofera colutea	√	√	√
	Indigofera georgei	√	√	
	Indigofera linifolia	√	√	?
	Indigofera linnaei	√		
	Indigofera monophylla		√	√
	Indigofera monophylla (Burrup form)	√		
	Indigofera trita	√	√	
	Isotropis atropurpurea	√		
	Lotus cruentus		√	√
	Rhynchosia minima	√	√	√
	Sesbania cannabina	√	√	
	Swainsona kingii subsp. *kingii*	√	√	
	Swainsona pterostylis	√	√	√
	Tephrosia gardneri	√	√	
	Tephrosia remotiflora		√	
	Tephrosia rosea var. *clementii*	√	√	√
	Tephrosia supina		√	
	Tephrosia aff. *supina* (HD133-20)	√		
	Tephrosia aff. *supina* (MET 12,357)	√		
	Tephrosia uniovulata	√		
	Tephrosia sp. B Kimberley Flora (C.A. Gardner 7300)	√		
	Vigna sp. Hamersley Clay (A.A. Mitchell PRP 113)	√	√	
	Zornia albiflora	√		
Passifloraceae	**Passiflora foetida* var. *hispida*	√		
Plumbaginaceae	*Muellerolimon salicorniaceum*	√	√	
Poaceae	*Aristida contorta*	√	√	
	Aristida holathera var. *holathera*	√	√	
	Aristida holathera var. *latifolia*	√		
	Astrebla elymoides	√		
	Astrebla pectinata	√		
	Brachyachne convergens	√		
	Brachyachne prostrata	√		
	**Cenchrus ciliaris*	√	√	√
	**Cenchrus setiger*	√		
	Chloris pectinata	√	√	
	Chloris pumilio	√		
	Chrysopogon fallax	√	√	
	Cymbopogon ambiguus	√		
	Cymbopogon obtectus	√	√	√
	Cymbopogon procerus	√		
	Dactyloctenium radulans	√	√	
	Dichanthium sericeum subsp. *humilius*	√	√	
	Digitaria brownii	√	√	
	Enneapogon caerulescens	√	√	
	Enneapogon polyphyllus	√		
	Enteropogon ramosus	√	√	
	Eragrostis cumingii	√	√	
	Eragrostis eriopoda	√	√	
	Eragrostis falcata	√	√	√
	Eragrostis aff. *falcata*	√		
	Eragrostis leptocarpa	√		
	Eragrostis pergracilis	√	√	
	Eragrostis aff. *setifolia*	√		
	Eragrostis tenellula	√		
	Eragrostis xerophila	√	√	
	Eriachne aristidea	√	√	
	Eriachne benthamii	√	√	
	Eriachne aff. *benthamii*	√		

Family	**Species**	**This study**	**OEC (2008/9)**	**RPS (2009)**
Poaceae (cont.)	*Eriachne gardneri*	√	√	√
	Eriachne helmsii		√	
	Eriachne mucronata	√		
	Eriachne obtusa	√	√	
	Eriachne pulchella subsp. *dominii*	√		
	Eriochloa pseudoacrotricha	√	√	
	Eulalia aurea	√	√	
	Iseilema dolichotrichum	√		
	Iseilema eremaeum		√	
	Iseilema macratherum	√		
	Iseilema membranaceum	√		
	Leptochloa digitata	√		
	Leptochloa fusca subsp. *muelleri*	√	√	
	Panicum decompositum	√	√	
	Panicum laevinode	√		
	Paraneurachne muelleri	√	√	
	Paspalidium clementii	√		
	Setaria dielsii	√		
	**Setaria verticillata*	√	√	
	Sorghum plumosum	√	√	
	Spinifex longifolius	√	√	
	Sporobolus australasicus	√		
	Sporobolus mitchellii	√	√	
	Sporobolus virginicus	√	√	
	Triodia brizoides	√		
	Triodia epactia	√	√	√
	Triodia lanigera	√		
	Triodia schinzii	√	√	
	Tripogon loliiformis	√		
	Triraphis mollis		√	
	Urochloa holosericea subsp. *velutina*	√		
	Whiteochloa airoides	√	√	
	Yakirra australiensis var. *australiensis*	√	√	√
Polygalaceae	*Polygala aff. isingii*	√	√	
Portulacaceae	*Calandrinia ptychosperma*	√	√	
	**Portulaca oleracea*	√		
	Portulaca pilosa	√		
Primulaceae	*Samolus* sp. Millstream (M.I.H. Brooker 2076)		√	
	Samolus sp. Shark Bay (M.E. Trudgen 7410)	√		
Proteaceae	*Grevillea eriostachya*	√	√	
	Grevillea stenobotrya	√	√	√
	Grevillea wickhamii subsp. *hispidula*	√		
	Hakea lorea subsp. *lorea*	√	√	
	Hakea stenophylla subsp. *stenophylla*	√	√	√
Rhizophoraceae	*Ceriops tagal*		√	
Rubiaceae	*Synaptantha tillaeacea* var. *tillaeacea*	√		
Santalaceae	*Santalum lanceolatum*	√	√	
Sapindaceae	*Diplopeltis eriocarpa*	√	√	
Scrophulariaceae	*Mimulus gracilis*	√	√	
	Mimulus uvedaliae		√	
	Stemodia sp. Onslow (A.A. Mitchell 76/148)	√	√	
Solanaceae	*Nicotiana occidentalis* subsp. *occidentalis*		√	√
	Nicotiana rosulata subsp. *rosulata*	√		
	Solanum diversiflorum	√	√	√
	Solanum ellipticum	√	√	
	Solanum horridum		√	
	Solanum lasiophyllum	√	√	√
	Solanum phlomoides	√		

Family	**Species**	**This study**	**OEC (2008/9)**	**RPS (2009)**
Solanaceae (cont)	*Solanum sturtianum*	√		
Sterculiaceae	*Melhania oblongifolia*	√	√	
	Waltheria indica	√		
Surianaceae	*Stylobasium spathulatum*	√	√	
Thymelaeaceae	*Pimelea ammocharis*	√	√	
Tiliaceae	*Corchorus* aff. *laniflorus*	√		
	Corchorus sidoides subsp. *vermicularis*	√	√	
	Corchorus tridens	√		
	Triumfetta aff. *chaetocarpa* (H123-10)	√		
	Triumfetta aff. *chaetocarpa* (PAN3/4)	√		
	Triumfetta clementii	√		
	Triumfetta echinata	√	√	
Violaceae	*Hybanthus aurantiacus*	√		
Zygophyllaceae	*Tribulus astrocarpus*	√		
	Tribulus hirsutus	√		√
	Tribulus hystrix		√	
	Tribulus macrocarpus	√		
	Tribulus occidentalis	√	√	

Appendix 6

Matrix Assessing Conservation Significance of Vegetation Sub-Associations

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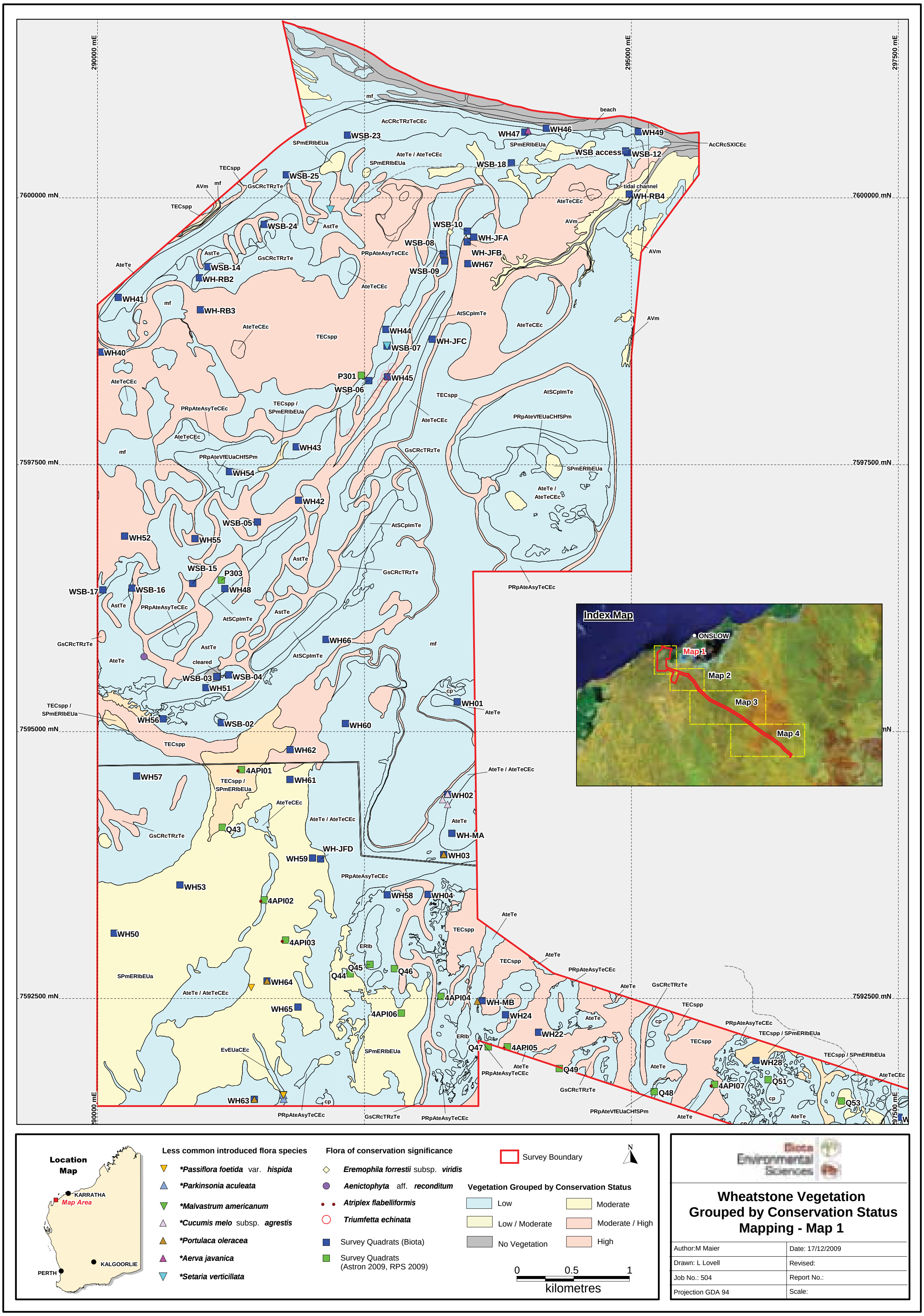
For explanation of factors and codes, see Section 3.8.

Veg Code	Associated Land System/s (regional representation symbol)	Other Key Attributes Increasing Conservation Value	Other Key Attributes Decreasing Conservation Value	Score based on distribution of land system/s	Score from other attributes that increase conservation value	Score from other attributes that decrease conservation value	Overall Score	Perceived Relative Significance †
Maximum Possible Score for this Assessment				**4**	**7**	**0**	**11**	Very High
Minimum Possible Score for this Assessment				**1**	**0**	**-3**	**-2**	None
Tidal Mudflats and Tidal Creeks								
T1 (mf)	Littoral (W)	H (+1)		1	1		2	Low
T2 (AVm)	Littoral (W)	A (+1), H (+1)		1	2		3	Moderate*
Coastal Sand Dunes								
CD1 (AcCRcSXICEc)	Onslow(R)	C (+1)		3	1		4	Low
CD2 (AcCRcTRzTeCEc)	Onslow(R)	C (+1)	D (-3)	3	1	-3	1	Low
Inland Sand Dunes								
ID1 (GsCRcTRzTe)	Dune (R), Onslow (R)	C (+1), F (+2,+1), H (+1)		3	5		8	High
ID2 (GsCRcHBbTsTe)	Dune (R), Giralia (W,O)	C (+1), F (+2,+1), H (+1)		2.5	5		7.5	High*
ID3 (AstTe)	Dune (R)	A (+1), H (+1)		3	2		5	Low
Coastal Sand Plains								
CS1 (AteTe)	Dune (R), Onslow (R)	S (+1), H (+1)		3	2		5	Low
CS2 (AteTeCEc)	Dune (R), Onslow (R)	S (+1)	D (-3)	3	1	-3	1	Low
CS3 (AtSCplmTe)	Dune (R), Onslow (R)	S (+1), H (+1)		3	2		5	Low
CS4 (PRpAteAsyTeCEc)	Littoral (W), Minderoo (R), Onslow (R)		D (-3)	3		-3	0	Low
Claypans								
C1 (cp)	Minderoo (R), Onslow (R)	H (+1)		3	1		4	Low
C2 (ERlb)	Dune (R), Minderoo (R), Onslow (R)	H (+1)		3	1		4	Low
C3 (TECspp)	Littoral (W), Onslow (R)	F (+3,+1), S (+1), H (+1)		2	6		8	High
Clayey Plains								
CP1 (SPmERlbEUa)	Minderoo (R)	F (+1), S (+1), H (+1)		3	3		6	Moderate
CP2 (PRpAteVfEUaCHfSPm)	Dune (R), Onslow (R)			3			3	Low
CP3 (AxTe)	Giralia (W,O)	H (+1)		2	1		3	Low
CP4 (AxTla)	Stuart (W)	H (+1)		1	1		2	Low
CP5 (AxTbr)	Stuart (W)	F (+1), H (+1)		1	2		3	Low
Inland Sand Plains								
IS1 (ChAaAbTla)	Giralia (W,O), Uaroo (W)	S (+1), H (+1)		1.5	2		3.5	Low
IS2 (AiAaTla)	Uaroo (W)	S (+1), H (+1)		1	2		3	Low
Stony Hills								
H1 (AiTlaTbr)	Stuart (W)	F (+1), A (+1), H (+1)		1	3		4	Low
Drainage Areas								
D1 (EvEUaCEc)	Minderoo (R), Onslow (R)	C (+1), A (+1)	D (-3)	3	2	-3	2	Low
D2 (EvAsyAbTe)	Giralia (W,O)	F (+1), H (+1)		2	2		4	Low
D3 (ChAtuGwAaTeTla)	Uaroo (W)	S (+1), H (+1)		1	2		3	Low

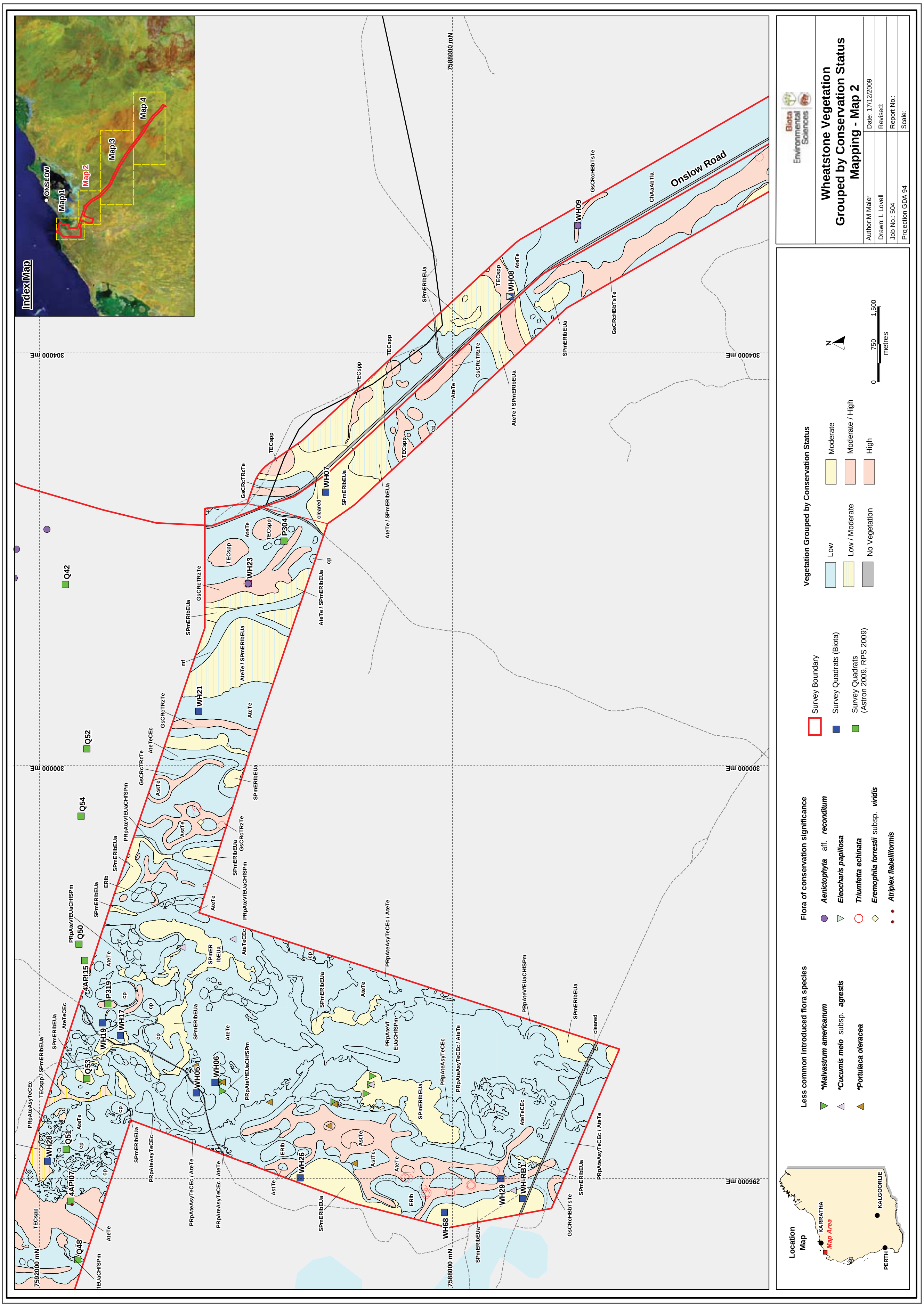
† **Very High**: overall score 10-11; **High**: overall score 8-9; **Moderate**: overall score 6-7; **Low**: overall score 0-5; **No signfiicance**: overall score <0.

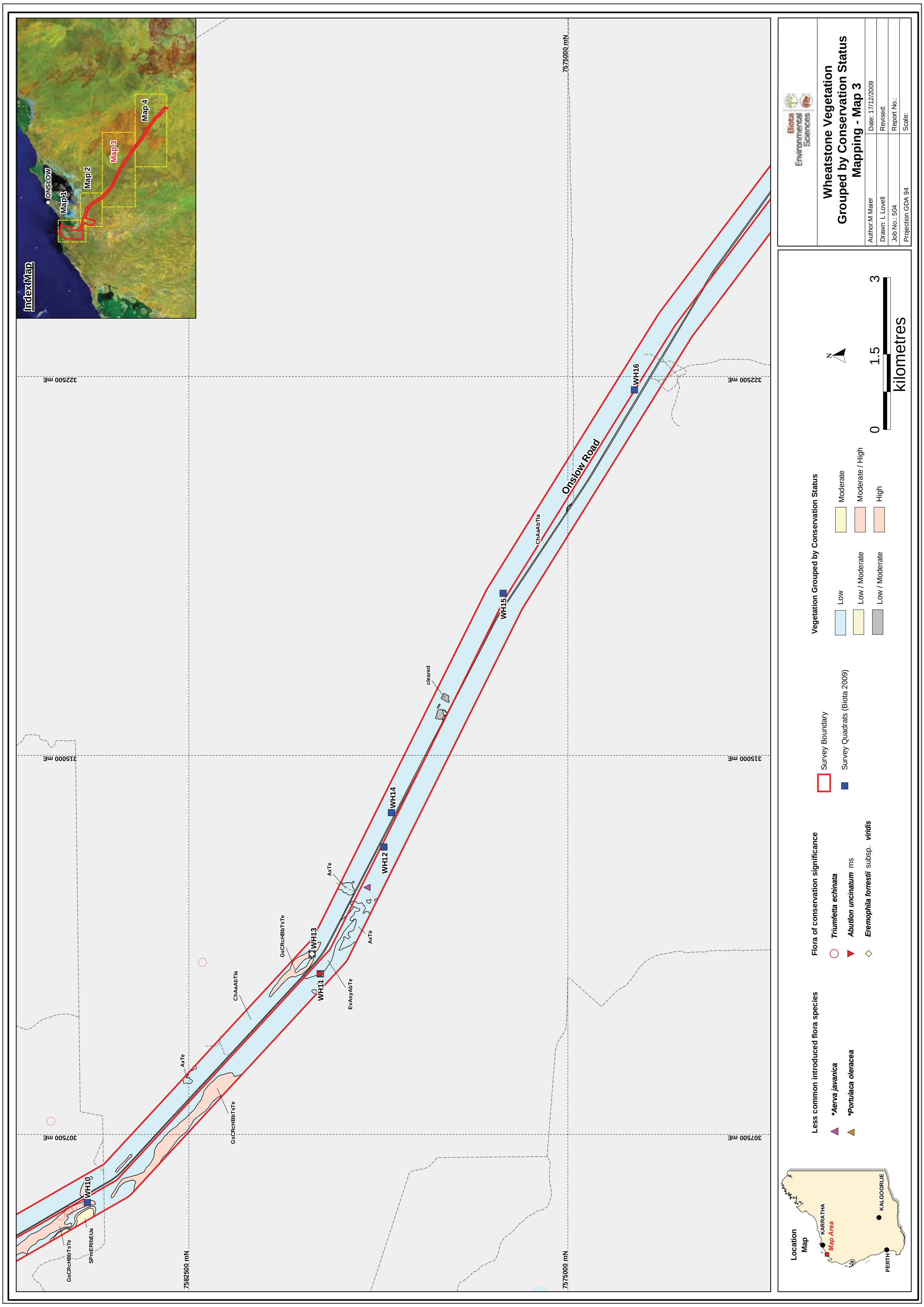
* Ranking increased on the basis of ecosystem reservation priority assigned by DEC (see Section 4.4).

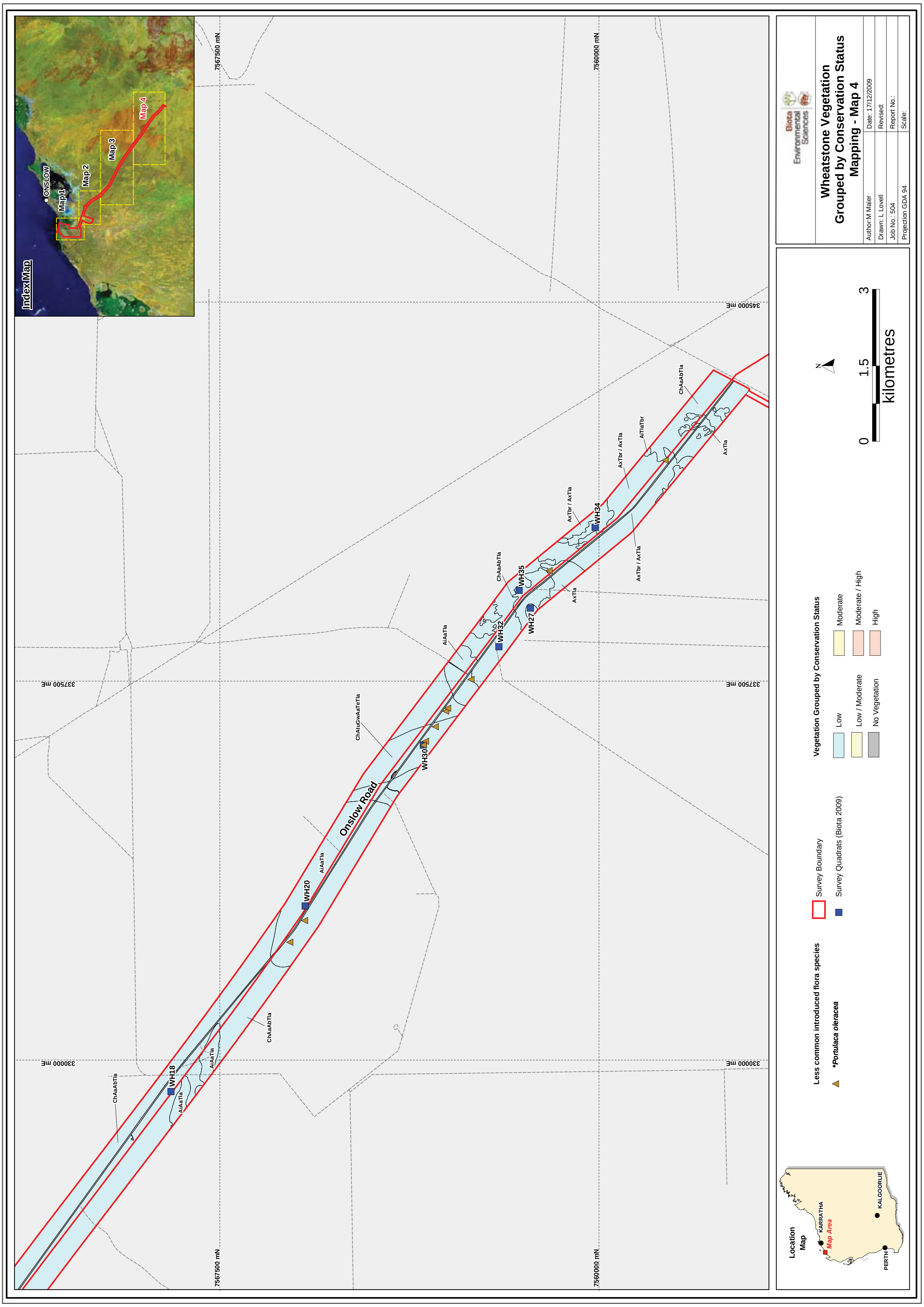


Wheatstone Vegetation Grouped by Conservation Status Mapping - Map 1

Author:M Maier	Date: 17/12/2009
Drawn: L Lovell	Revised:
Job No.: 504	Report No.:
Projection GDA 94	Scale:


Wheatstone Vegetation
Grouped by Conservation Status
Mapping - Map 2
Biota Environmental Sciences
Author:M Maier
Drawn: L Lovell
Job No.: 504
Projection GDA 94
Date: 17/12/2009
Revised:
Report No.:
Scale:
Index Map
ONSLOW
Map 1
Map 2
Map 3
Map 4
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH
Less common introduced flora species
*Malvastrum americanum
*Cucumis melo subsp. agrestis
*Portulaca oleracea
Flora of conservation significance
Aenictophyta aff. reconditum
Eleocharis papillosa
Triumfetta echinata
Eremophila forrestii subsp. viridis
Atriplex flabelliformis
Survey Boundary
Survey Quadrats (Biota)
Survey Quadrats (Astron 2009, RPS 2009)
Vegetation Grouped by Conservation Status
Low
Low / Moderate
No Vegetation
Moderate
Moderate / High
High
N
0
750
1,500
metres
Onslow Road
7592000 mN
7588000 mN
296000 mE
300000 mE
304000 mE
WH07
WH08
WH09
WH17
WH19
WH21
WH23
WH26
WH28
WH29
WH05
WH06
WH68
WH-RB1
P304
P319
Q42
Q48
Q50
Q51
Q52
Q53
Q54
4API07
4API15
SPmERIbEUa
AteTe
AteTe / SPmERIbEUa
GsCRcTRzTe
GsCRcHBbTsTe
TECspp
AteTeCEc
AstTe
PRpAteVfEUaCHfSPm
PRpAteAsyTeCEc
PRpAteAsyTeCEc / AteTe
ChAaAbTla
ERIb
cp
cleared
mf


Wheatstone Vegetation Grouped by Conservation Status Mapping - Map 3
Biota Environmental Sciences
Author: M Maier
Drawn: L Lovell
Job No.: 504
Projection GDA 94
Date: 17/12/2009
Revised:
Report No.:
Scale:
Index Map
ONSLOW
Map 1
Map 2
Map 3
Map 4
Onslow Road
WH10
WH11
WH12
WH13
WH14
WH15
WH16
GsCRcHBbTsTe
SPmERbEUa
AxTe
ChAaAbTla
EvAsyAbTe
cleared
7582500 mN
7575000 mN
307500 mE
315000 mE
322500 mE
Less common introduced flora species
*Aerva javanica
*Portulaca oleracea
Flora of conservation significance
Triumfetta echinata
Abutilon uncinatum ms
Eremophila forrestii subsp. viridis
Survey Boundary
Survey Quadrats (Biota 2009)
Vegetation Grouped by Conservation Status
Low
Low / Moderate
Low / Moderate
Moderate
Moderate / High
High
N
0
1.5
3
kilometres
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH


Index Map
ONSLOW
Map 1
Map 2
Map 3
Map 4
7567500 mN
7560000 mN
345000 mE
337500 mE
330000 mE
Onslow Road
WH18
WH20
WH30
WH32
WH27
WH35
WH34
ChAaAbTla
AlAaTla
ChAtuGwAaTeTla
AxTla
AxTbr / AxTla
AlTlaTbr
Less common introduced flora species
*Portulaca oleracea
Survey Boundary
Survey Quadrats (Biota 2009)
Vegetation Grouped by Conservation Status
Low
Low / Moderate
No Vegetation
Moderate
Moderate / High
High
N
0
1.5
3
kilometres
Location Map
KARRATHA
Map Area
KALGOORLIE
PERTH
Biota Environmental Sciences
Wheatstone Vegetation Grouped by Conservation Status Mapping - Map 4
Author: M Maier
Drawn: L Lovell
Job No.: 504
Projection GDA 94
Date: 17/12/2009
Revised:
Report No.:
Scale:

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Appendix 7

Records of Less Common Weed Species in the Wheatstone Study Area

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NB. **Cenchrus ciliaris, *C. setiger, *Prosopis pallida* and **Vachellia farnesiana* were all widespread and relatively common through the Wheatstone plant and camp study areas; no attempt was made to record individual locations.

Records of *Parkinsonia aculeata in the Wheatstone plant study area.

Broad Location	Easting (mE)	Northing (mN)	Density
Wheatstone plant study area, just above southern boundary	291742	7591595	scattered
Wheatstone plant study area, just above southern boundary	291744	7591559	scattered

Records of *Setaria verticillata in the Wheatstone plant study area.

Broad Location	Easting (mE)	Northing (mN)	Density
Wheatstone plant study area, northern section (OEC 2008)	292182	7599888	scattered
Wheatstone plant study area, northern section	292712	7598612	scattered

Records of *Aerva javanica in the Wheatstone study area.

Broad Location	Easting (mE)	Northing (mN)	Density
Wheatstone plant study area, northern section (OEC 2008)	294033	7600631	scattered (<1% cover)
Wheatstone pipeline study area, 12.5 km southeast of the Peedamulla Station turnoff on the Onslow Road; localised to vicinity of Telstra radio station	312387	7578975	scattered (<20 individuals)

Records of *Cucumis melo subsp. agrestis in the Wheatstone study area.

Broad Location	Easting (mE)	Northing (mN)	Density
Wheatstone pipeline study area, western section	293279	7594415	scattered
Wheatstone pipeline study area, western section	293232	7594363	scattered
Wheatstone pipeline study area, western section	293279	7594318	scattered
Wheatstone camp study area	298237	7590620	x8
Wheatstone camp study area	296933	7590230	scattered
Wheatstone camp study area	298317	7590127	x5
Wheatstone camp study area	296909	7588791	scattered
Wheatstone camp study area	295884	7587415	scattered

Records of *Malvastrum americanum in the Wheatstone study area.

Broad Location	Easting (mE)	Northing (mN)	Density
Wheatstone plant study area, southern section	291742	7591595	scattered
Wheatstone camp study area	296933	7590230	scattered
Wheatstone camp study area	296846	7590225	scattered
Wheatstone camp study area	296738	7589144	x1
Wheatstone camp study area	296822	7588832	scattered
Wheatstone camp study area	296909	7588791	scattered
Wheatstone camp study area	296990	7588773	scattered

Records of *Passiflora foetida var. hispida in the Wheatstone plant study area.

Broad Location	Easting (mE)	Northing (mN)	Density
Wheatstone plant study area, southern section	291441	7592603	scattered
Wheatstone plant study area, southern section	291742	7591595	scattered

Records of *Portulaca oleracea in the Wheatstone study area.

Broad Location	Easting (mE)	Northing (mN)	Density
Wheatstone plant study area, southern section	291588	7592666	scattered
Wheatstone plant study area, southern section	291469	7591557	scattered
Wheatstone pipeline study area, western section	293243	7593850	scattered
Wheatstone pipeline study area, western section	293557	7592475	scattered
Wheatstone camp study area	297088	7590492	scattered
Wheatstone camp study area	296933	7590230	scattered
Wheatstone camp study area	296738	7589774	scattered
Wheatstone camp study area	296508	7589197	scattered
Wheatstone camp study area	296720	7589144	x1
Wheatstone camp study area	296146	7588953	scattered
Wheatstone pipeline study area, central section	310677	7579899	scattered
Wheatstone pipeline study area, eastern section	332333	7566116	scattered
Wheatstone pipeline study area, eastern section	332761	7565826	scattered
Wheatstone pipeline study area, eastern section	336233	7563478	scattered
Wheatstone pipeline study area, eastern section	336308	7563431	scattered
Wheatstone pipeline study area, eastern section	336597	7563239	scattered
Wheatstone pipeline study area, eastern section	336903	7563030	scattered
Wheatstone pipeline study area, eastern section	336965	7562994	scattered on old drill pad
Wheatstone pipeline study area, eastern section	337532	7562532	scattered
Wheatstone pipeline study area, eastern section	339686	7560987	scattered
Wheatstone pipeline study area, eastern section	341870	7558689	scattered

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Appendix I2

Vegetation of the Wheatstone Addendum Area

Tables

Figures

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Biota Environmental Sciences

Wheatstone Project Flora and Fauna Assessment Addendum

Prepared for URS Australia Pty Ltd
on behalf of Chevron Australia Pty Ltd

May 2010

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Project No.:	579
Prepared by:	Justin Fairhead, Garth Humphreys
Checked by:	Michi Maier
Approved for Issue:	Garth Humphreys

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1.0 Introduction

1.1 Project Background

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) and a domestic gas (Domgas) plant 12 km southwest of Onslow on the Pilbara coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin, followed in the future by yet-to-be determined gas fields. The project is referred to as the Wheatstone Project and 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.

Comprehensive Level 2 flora and fauna assessments were conducted by Biota Environmental Sciences (Biota) to support the formal environmental assessment of the Wheatstone Project. These included surveys of terrestrial flora and vegetation (Biota 2010a), terrestrial fauna (Biota 2010b), subterranean fauna (Biota 2010c) and the fauna of ephemeral claypan systems (Biota 2010d).

With improved engineering definition, materials sourcing areas and infrastructure necessary for the construction of the Wheatstone Project have now been identified. These areas (hereafter referred to as the Wheatstone Materials Sourcing (WMS) areas) consist of four borrow sites and five construction access roads. The majority of these areas are either covered by the work completed by Biota (2010a, 2010b, 2010c and 2010d), or were included within adjoining areas that were subsequently surveyed for vegetation and flora by Outback Ecology (2010).

To facilitate assessment of the WMS areas, Biota was commissioned to complete a desktop assessment of the biological values of five areas adjacent to the original Wheatstone study area reported on in Biota (2010a, 2010b, 2010c and 2010d). These areas total 2,772 ha, the majority of which was covered by the work of Outback Ecology (2010). For the purpose of this report, these areas have been collectively referred to as the Wheatstone addendum area (Figure 1.1).

1.2 Scope and Role of this Report

This report comprises a review of significant vegetation, flora and fauna values of the Wheatstone addendum area at the desktop level, and has been completed such that it is suitable for use for assessments under the:

- Environmental Protection Authority's (EPA) Position Statement No. 3, *Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA 2002);
- EPA Guidance Statement No. 51, *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004a); and
- EPA Guidance Statement No. 56, *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004b).

The report is subject to a number of limitations, which are discussed in Section 2.3.

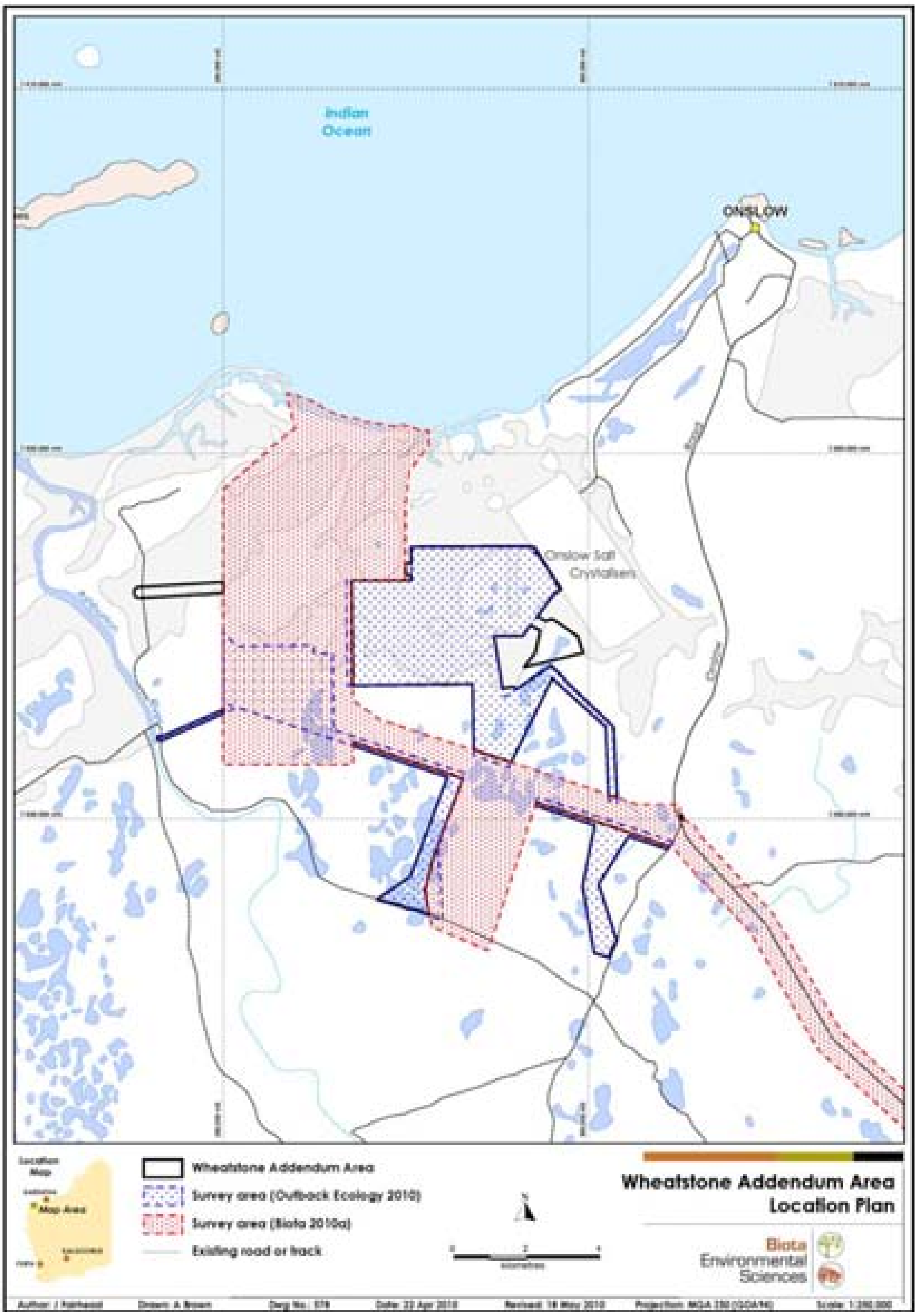

Figure 1.1: Location of the Wheatstone addendum area in relation to previous biological survey areas.

2.0 Methodology of the Desktop Review

2.1 Review of Existing Data

2.1.1 Previous Sampling Within the Wheatstone Addendum Area

Approximately 92% of the 2,772 ha of land encompassed by the Wheatstone addendum area has previously been surveyed for vegetation and flora by Outback Ecology (2010):

- In January 2010, Outback Ecology was commissioned to survey an area adjoining the Biota (2010a) survey area. This encompassed three of the borrow sites (including the only available comprehensive survey of Horseshoe island) and several large sections of the intended construction roads (Outback Ecology 2010) (see Figure 1.1). No fauna sampling was conducted as part of this survey.

2.1.2 Previous Sampling in the Locality

2.1.2.1 Flora and Vegetation

A number of other botanical surveys have been conducted in the Wheatstone locality, which provide additional contextual data for assessment of the Wheatstone addendum area. The studies listed below comprised the main comparative references used to place the vegetation and flora values of the Wheatstone addendum area into regional context:

- In July 2008, botanists from Onshore Environmental Consulting (OEC) conducted a flora and vegetation survey of a 460 ha area encompassing the two northern WMS borrow sites and several of the intended construction roads (OEC 2008).
- In March and April 2009, Biota conducted a flora and vegetation survey of a large area that included the two northern borrow sites and encompassed the majority of the proposed construction roads (Biota 2010a). This survey assessed the locations for the Wheatstone plant site, camp site and shared infrastructure corridor (SIC) as proposed at the time.
- In November 2008, RPS conducted a vegetation and flora survey along an alternate pipeline corridor (the “Ashburton North Pipeline Route Option 3”) (RPS 2009);
- In August and November 2008, Astron Environmental Services (Astron) completed a survey of a proposed rail corridor to Onslow for API Management Pty Ltd (see Astron 2009); and
- In May 2008, Validus Group (Validus) conducted a vegetation and flora survey of two previously considered sites for the Chevron Domgas plant, and a pipeline corridor linking them (the southern end of this study area being approximately 2 km north of the Wheatstone addendum area; Validus 2008).

2.1.2.2 Fauna

While no systematic fauna survey work has been undertaken in the Wheatstone addendum area, a systematic fauna survey has previously been conducted in a large area adjoining this as part of the survey work for the main Wheatstone Project. This survey is considered to provide adequate information for the purpose of a desktop assessment of the faunal values of the Wheatstone addendum area:

- A single-phase systematic fauna survey was conducted by Biota from the 14th to 23rd of April 2009. This included systematic censusing of terrestrial fauna assemblages, including avifauna, mammals and herpetofauna (reptiles and frogs), at 16 trapping sites (Biota 2010b). This study overlapped a section of the WMS area, specifically the two northern borrow sites and the majority of the proposed construction roads.

A number of other terrestrial fauna surveys have previously been completed in the locality as summarised by Biota (2010b). These include the:

- Onslow Solar Saltfield three-phase terrestrial fauna survey (1996, 2000 and 2005) (Biota 2005a);
- WA Museum terrestrial fauna survey at Tubridgi Point 2005 (WA Museum database 2009);
- Department of Environment and Conservation (DEC) Cane River Conservation Park fauna surveys at Tubridgi Point 2004 (WA Museum database 2009);
- Yannarie Salt Project fauna survey (Biota 2005b);
- Chevron Domgas Project Onslow fauna assessment (Validus 2008); and
- API Management Onslow Rail Corridor Terrestrial Fauna Survey (Biota 2009) (which passed adjacent to the southernmost end of the Wheatstone addendum area).

Although conducted under different seasonal conditions, including additional habitats, and with somewhat differential sampling effort, these studies still provide useful contextual information for the current assessment.

2.1.3 Database Searches

The database of matters of National Environmental Significance (NES) protected under the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* was searched using the "Protected Matters Search Tool" on the 12th of May 2009. The search area comprised a broad (approximately 150 km^2 area) surrounding Onslow.

Listed matters of NES relevant to the current study essentially comprise listed threatened species and communities. The results of the Protected Matters search are discussed in the appropriate subsections of Sections 3.0, 4.0 and 5.0.

Searches of the Western Australian DEC and Western Australian Herbarium rare flora databases had been undertaken by OEC in 2008 and were not requested again for the current study. The species identified by this search (as stated in OEC (2009)) were reviewed against the habitats present in the Wheatstone addendum area to indicate species likely to occur.

2.1.4 Regional-scale Information

Various other regional-scale reports and datasets were reviewed to assess other biological factors of relevance to the current study area, including features of the Interim Biogeographic Regionalisation for Australia (IBRA) bioregions and subregions (see May and McKenzie 2003; Section 3.1), Land Systems (van Vreeswyk et al. 2004; Payne et al. 1987, 1988 (Section 3.2)), and Beard's vegetation mapping (Section 3.3).

2.2 Extension of Vegetation Mapping for Unsurveyed Areas

For the majority of the Wheatstone addendum area, which was mapped by Outback Ecology (2010), vegetation descriptions were based on the height and estimated cover of dominant species using Aplin's (1979) modification of the vegetation classification of Specht (1970) to include a hummock grassland category (see Appendix 1). The vegetation mapping units were generally defined at the level of vegetation sub-association as per the National Vegetation Information System[1], and were kept consistent where possible with those identified in Biota (2010a) for the adjoining Wheatstone plant, camp and SIC study areas.

The coding system for the vegetation sub-associations incorporated the dominant flora species for the vegetation type, organised from tallest strata to lowest strata. Species names were abbreviated to capital letter(s) for genus, followed by lower case letter/s for species, with multiple letters used where necessary to avoid confusion (e.g. GsCRcTRzTe = dominant species *Grevillea*

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[1] See http://www.environment.gov.au/erin/nvis/publications/avam/section-2-1.html#hierarchy

stenobotrya, Crotalaria cunninghamii, Trichodesma zeylanicum var. *grandiflorum* and *Triodia epactia*).

Other point source datasets, such as locations of quadrats, weeds and flora of conservation significance, were generated into spatial data using MapInfo Professional Geographical Information System (GIS) v9 (MapInfo). These datasets were subsequently saved as separate MapInfo tables. These datasets, in conjunction with other data supplied from other organisations, were used in the production of the vegetation maps contained in this report (Appendix 2). All maps were produced using MapInfo.

For sections of the Wheatstone addendum area that lay outside the mapping coverage from Outback Ecology (2010), the vegetation sub-associations were extended based on interpretation of aerial photography signatures combined with site data and vegetation mapping for comparable adjacent areas. The units were then coded following the same protocol described above.

2.3 Limitations

While the majority (approximately 92%) of the Wheatstone addendum area has been previously surveyed for vegetation and flora by Outback Ecology (2010), approximately 8% of the current area has not been evaluated in the field. The following limitations therefore apply to this study:

- The boundaries of the vegetation units mapped in the extrapolated areas, and their attributed vegetation code, have not been ground-truthed.
- Vegetation descriptions were based on associations recorded from comparable habitats during previous surveys in the broader locality.
- Sampling of terrestrial fauna, claypan fauna and subterranean fauna has only been conducted in areas adjoining the Wheatstone addendum area (Biota 2010b, 2010c and 2010d). This sampling was, however, representative of the range of habitats present in the Wheatstone addendum area, and the available fauna data are therefore considered appropriate to provide a suitable desktop assessment.

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3.0 Vegetation

3.1 IBRA Bioregions and Subregions

The IBRA[2] currently recognises 85 bioregions and 403 biological subregions for Australia. The Wheatstone addendum area is located in the Carnarvon IBRA bioregion.

There are two biological subregions within the Carnarvon bioregion (Environment Australia 2000):

1. Cape Range: Rugged tertiary limestone ranges and extensive areas of red Aeolian dunefields, quaternary coastal dunes and mud flats. *Acacia* shrublands (*Acacia stuartii* or *A. bivenosa*) over *Triodia* on limestone and red dune fields. *Triodia* hummock grassland with sparse *Eucalyptus* trees and shrubs on the Cape Range. The Exmouth Gulf supports extensive mangroves in tidal mudflats and sheltered embayments, while the hinterland area supports a mosaic of samphire and saltbush low shrublands in saline alluvial plains.
2. Wooramel: Alluvial plains associated with downstream sections and deltas of the Gascoyne, Minilya and Wooramel rivers. *Acacia* shrublands (Mulga, Bowgada and *A. coriacea*) over bunch grasses on red sandy ridges and plains. Mangroves confined to small areas near Lake MacLeod and Carnarvon. Samphire and saltbush low shrublands on saline alluvial plains in near-coastal areas.

The Wheatstone addendum area lies within the Cape Range subregion. For further discussion of this subregion, see Kendrick and Mau (2002).

3.2 Land Systems

Land Systems (Rangeland) mapping covering the Wheatstone addendum area has been prepared by the Western Australian Department of Agriculture (Payne et al. 1987). Land Systems are comprised of repeating patterns of topography, soils, and vegetation (Christian and Stewart 1953) (i.e. a series of “land units” that occur on characteristic physiographic types within the land systems).

The Wheatstone addendum area intersects five Land Systems: Dune, Littoral, Minderoo, Nanyarra and Onslow. The Wheatstone addendum area contains 1.8% of the total area of the Onslow land system mapped for the State; the remaining land systems are represented by less than 0.4% of their total area.

3.2.1 Dune Land System

This Land System comprises dunefields supporting soft spinifex grasslands, mostly in very good condition. The Dune Land System is distributed through near-coastal areas over a range of ~170 km, from the eastern side of the Exmouth Gulf to east of Onslow; predominantly in the Carnarvon bioregion, extending into the westernmost Pilbara bioregion.

3.2.2 Littoral Land System

This Land System comprises bare coastal mudflats with mangroves of seaward fringes, *Tecticornia* (samphire) flats, sandy islands, coastal dunes and beaches. The vegetation of this Land System is mostly in good to very good condition. The Littoral Land System is widespread over 650 km of coastline, stretching from the base of the Exmouth Gulf to east of Port Hedland; predominantly in the Carnarvon and Pilbara bioregions.

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[2] http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html

Table 3.1: Distribution of Land Systems within the Wheatstone addendum area, and in the State (data from Payne et al. 1987).

Land System	Total Area in the State (ha)	General Distribution through the State	Area within Wheatstone Addendum Area	
			Hectares	% of total in State
Dune	49,302	Distributed through near-coastal areas over a range of ~170 km, from the eastern side of the Exmouth Gulf to east of Onslow; predominantly in the Carnarvon bioregion, extending into the westernmost Pilbara bioregion	13.0	0.03
Littoral	337,551	Widespread over 650 km of coastline, stretching from the base of the Exmouth Gulf to east of Port Hedland; predominantly in the Carnarvon and Pilbara bioregions	1,182.6	0.35
Minderoo	144,436	Localised to an area of ~90 km by 40 km within the northern section of the Carnarvon bioregion, but well represented within this area	233.0	0.16
Nanyarra	38,627	Localised to a single area of ~65 km by 10 km in the northeastern section of the Carnarvon bioregion, extending south from near the southern edge of the Wheatstone plant study area	3.3	0.01
Onslow	74,022	Widespread towards the coast in both the Carnarvon and Pilbara bioregions, extending from the eastern side of the Exmouth Gulf to the Fortescue River	1,339.3	1.81
State Total	575,311			

3.2.3 Minderoo Land System

This Land System comprises alluvial plains supporting tall shrublands and tussock grasslands, and sandy plains supporting hummock grasslands; the vegetation is mostly in good condition. The Minderoo Land System is localised to an area of ~90 km by 40 km in the northern section of the Carnarvon bioregion, but is well represented within this area.

3.2.4 Nanyarra Land System

This Land System comprises alluvial plains supporting tall shrublands and low woodlands with prominent tussock grasses; the vegetation is mostly in good condition. The Nanyarra Land System is localised to a single area of ~65 km by 10 km in the northeastern section of the Carnarvon bioregion.

3.2.5 Onslow Land System

This Land System comprises sandplains, dunes and claypans supporting soft spinifex grasslands and minor tussock grasslands; the vegetation is mostly in good to very good condition. The Onslow Land System is widespread towards the coast in both the Carnarvon and Pilbara bioregions, extending from the eastern side of the Exmouth Gulf to the Fortescue River.

3.3 Beard’s Vegetation Units

Beard (1975) mapped the vegetation of the Pilbara at a scale of 1:1,000,000. The extent of this map sheet also covered the northern Carnarvon Basin region. The Wheatstone addendum area lies within the Carnarvon Botanical District of the Eremaean Botanical Province as defined by Beard and, more specifically, falls within the Cape Yannarie Coastal Plain (CYCP) as delineated by Beard (1975).

Three topographic/soils units were recognised from the Cape Yannarie Coastal Plain:

- Pediplains and hills on siltstones and other marine rocks. Chief soils are hard alkaline red soils.
- Extensive plains with some occasional rocky hills in the inland parts, claypans in the coastal parts, and considerable sandy stretches with parallel sand dune formations. Chief soils of the dunes are red sands and the soils of the plains are acid, neutral and alkaline red earths, with non-cracking clays in the claypans.
- Salt flats, tidal swamps and coastal sand dunes on the seaward fringe. Chief soils are saline loams with shelly sands and small areas of calcareous and/or siliceous sands on coastal dunes. Saline clays or muds on slopes and flats submerged at high tide occur in the mangrove zone.

Due to the inaccessibility of the coastline of the Yannarie Coastal Plain during the Beard (1975) vegetation survey, the area was not visited and the vegetation community types identified at this time were interpreted from aerial photography.

Beard’s (1975) survey described three broad vegetation complexes in this area:

- Mangrove vegetation on the coastline and covering the intertidal zone, with *Avicennia marina* as the principal species and some *Rhizophora stylosa.*
- Behind the intertidal zone is a belt of bare hypersaline mud, which sometimes floods with spring tides. This zone is quite devoid of any vegetation, but some samphire communities occur locally (*Tecticornia* species).
- Behind the saline tidal mud flats area is a zone mapped as shrub steppe on sandhills with numerous small claypans. The shrub steppe is typically dominated by *Triodia* species (*T. epactia/pungens*) with *Acacia bivenosa, A. synchronicia, A. tetragonophylla* and *A. xiphophylla* the most common shrub species present.

Beard (1975) mapped five finer-scale units within the Wheatstone addendum area:

- CYCP 117: *Triodia pungens* open hummock grassland (t_1Hi); assigned a Medium reservation priority by DEC (Kendrick and Mau 2002);
- CYCP 127: Mud flats (fl); assigned a Low reservation priority by DEC (Kendrick and Mau 2002);
- CYCP 589: Mixed bunch grassland/*Triodia pungens* open hummock grassland (xGc/t_1Hi); assigned a High reservation priority by DEC (Kendrick and Mau 2002);
- CYCP 670: Mixed open shrubland over *Triodia basedowii* open hummock grassland (xSr.t_2Hi); assigned a Low reservation priority by DEC (Kendrick and Mau 2002); and
- CYCP 676: *Tecticornia* spp. low shrubland (k_3Ci); assigned a High reservation priority by DEC (Kendrick and Mau 2002).

Given the broad nature of Beard's mapping, these units are only broadly applicable to the vegetation occurring within the Wheatstone addendum area (see Section 3.4).

3.4 Vegetation of the Wheatstone Addendum Area

Approximately 34.71 ha of the Wheatstone addendum area has been cleared. The remainder of the addendum area intersects 19 vegetation sub-associations. These included 14 of the 27 vegetation sub-associations identified as occurring in the broader Wheatstone study area, along with five new vegetation units (full descriptions of these can be found in Outback Ecology (2010)).

Brief descriptions of each of the 19 vegetation sub-associations found in the Wheatstone addendum area are presented below. All descriptions were originally from Biota (2010a) unless otherwise specified. The area of extent of each of the vegetation units within the Wheatstone addendum area is summarised in Table 3.2, and displayed on the mapping in Appendix 2.

3.4.1 Vegetation of Tidal Mudflats

Tidal mudflats identified within the Wheatstone addendum area were virtually "bare", with only very scattered shrubs of samphires.

Unit Code	Description	Sub-association Code	Conservation Significance
T1	*Tecticornia* spp. scattered low shrubs	mf	Low

3.4.2 Vegetation of Coastal Sand Dunes

Occurring behind a narrow beach-front and coastal foredunes, the near-coastal sand dunes were distinct from the more consolidated red sand dunes further inland, having an overstorey dominated by *Acacia coriacea* subsp. *coriacea*.

Unit Code	Description	Sub-association Code	Conservation Significance
CD2	*Acacia coriacea* subsp. *coriacea* tall shrubland over *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland	AcCRcTRzTeCEc	Low

3.4.3 Vegetation of Inland Sand Dunes

There were several low linear sand dunes within the Wheatstone addendum area, which were relatively consistent in dominant species. Three vegetation sub-associations have been identified, discriminated broadly by the dominance of *Triodia epactia* versus *Triodia schinzii* in the hummock grassland understorey and the degree of invasion by **Cenchrus ciliaris*. Narrow swales between these dunes typically featured scattered tall shrubs of the dominant species from the dunes, along with a higher density of *Acacia stellaticeps* low shrubs.

A number of the plant species recorded from the inland sand dunes are essentially restricted to sandy substrates: these include the Priority 3 shrubs *Eremophila forrestii* subsp. *viridis* and *Triumfetta echinata*, and the undescribed taxon *Aenictophyton* aff. *reconditum*. All of these species were recorded from sand dunes in the Wheatstone locality (Biota 2010a), including both of the inland dune vegetation sub-associations, and were not noted in any other habitat.

Unit Code	Description	Sub-association Code	Conservation Significance
ID1	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii*, *Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland	GsCRcTRzTe	High
ID2	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii*, *Hibiscus brachychlaenus* open shrubland over *Triodia schinzii*, *(T. epactia)* open hummock grassland	GsCRcHBbTsTe	High
ID3	*Acacia stellaticeps* shrubland over *Triodia epactia* hummock grassland	AstTe	Low
ID4	*Grevillea stenobotrya*, *Acacia stellaticeps* shrubland over *Triodia epactia* hummock grassland and **Cenchrus ciliaris* tussock grassland	GsAstTeCEc †	High

† This unit was described by Outback Ecology (2010).

3.4.4 Vegetation of Coastal Sand Plains

Large sections of the Wheatstone addendum area consisted of flat to gently undulating sandy inland plains, which were broadly dominated by Soft Spinifex (*Triodia epactia*) hummock grasslands with a varying degree of invasion by introduced perennial grasses (**Cenchrus* species).

Unit Code	Description	Sub-association Code	Conservation Significance
CS1	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland	AteTe	Low
CS2	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland	AteTeCEc	Low
CS4	**Prosopis pallida*, *Acacia tetragonophylla*, *A. synchronicia* scattered tall shrubs over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* open tussock grassland	PRpAteAsyTeCEc	Low
CS5	**Prosopis pallida*, *Acacia sclerosperma subsp. sclerosperma*, *A. tetragonophylla* scattered tall shrubs over *Triodia epactia* open hummock grassland and **Cenchrus ciliaris* open tussock grassland	PRpAssAteTeCEc †	Low
CS6	**Prosopis pallida* scattered tall shrubs to tall open shrubland over *Acacia tetragonophylla*, *Atriplex bunburyana* shrubs over *Triodia epactia* open hummock grassland and **Cenchrus ciliaris* open tussock grassland	PRpAteATbTeCEc †	Low

† These units were described by Outback Ecology (2010).

3.4.5 Vegetation of Claypans

Claypan areas were scattered throughout the Wheatstone addendum area and supported four vegetation types. The claypans varied in size, degree of connectivity with tidal areas (connected and seasonally inundated; or isolated), and degree of permeability of the substrate (leading some to hold water for several weeks, while others of similar size were dry). The degree of vegetative cover on the claypans themselves consequently varied from virtually bare (only scattered individuals of mainly annual flora) to up to 30% foliar cover of grasses or low shrubs (see below). Most claypans were fringed by a narrow band of ephemeral grasses, sedges and herbs, including species such as *Calotis plumulifera, Centipeda minima* subsp. *macrocephala, Dysphania platycarpa* and *Eragrostis leptocarpa*.

Unit Code	Description	Sub-association Code	Conservation Significance
C1	Bare claypan	cp	Low
C2	*Eriachne* aff. *benthamii* open tussock grassland	ERIb	Low
C3	*Tecticornia* spp.[3] low shrubland	TECspp	High
C4	**Prosopis pallida, Atriplex bunburyana* open shrubland over *Triodia epactia* open hummock grassland and **Cenchrus ciliaris* open tussock grassland	PRpATbTeCEc †	Low

† This unit was described by Outback Ecology (2010).

3.4.6 Vegetation of Clayey Plains

Two distinct forms of clayey plains occurred within the Wheatstone addendum area: large areas which supported tussock grasslands of various native species; and other small pockets of clayey substrate formed in drainage depressions, supporting tall shrublands of Mesquite (**Prosopis pallida*) and/or native species over tussock grasslands of native and/or introduced species.

Unit Code	Description	Sub-association Code	Conservation Significance
CP1	*Sporobolus mitchellii, Eriachne* aff. *benthamii, E. benthamii, Eulalia aurea* tussock grassland	SPmERIbEUa	Moderate
CP2	**Prosopis pallida* scattered tall shrubs to tall open shrubland over *Acacia tetragonophylla, *Vachellia farnesiana* shrubland over *Eulalia aurea, Chrysopogon fallax, Sporobolus mitchellii* tussock grassland	PRpAteVfEUaCHfSPm	Low

3.4.7 Vegetation of Drainage Lines

There were few conspicuous drainage features in the Wheatstone locality. Two drainage units were mapped within the Wheatstone addendum area.

Unit Code	Description	Sub-association Code	Conservation Significance
D2	*Eucalyptus victrix* scattered low trees over *Acacia synchronicia, A. bivenosa* shrubland over *Triodia epactia* hummock grassland	EvAsyAbTe	Low
D4	*Eucalyptus victrix* low trees over *Acacia tetragonophylla, A. synchronicia* tall shrubland over *Hibiscus brachychlaenus* shrubland over **Cenchrus ciliaris* tussock grassland	EvAteAsyHbrCEc †	Low

† This unit was described by Outback Ecology (2010).

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[3] Numerous specimens of *Tecticornia* were collected from the Wheatstone study area by Biota (2010), and a number of different taxa were identified, however many of the specimens were sterile and could not be identified to species level. Given this, it was considered most appropriate to define vegetation units dominated by samphires only as containing "*Tecticornia* spp.", to indicate that various species may be present.

3.5 Conservation Significance of the Vegetation Sub-associations

Three vegetation sub-associations of High conservation significance and one of Moderate significance were identified as being locally significant for the Wheatstone addendum area. These, except for GsAstTeCEc, were based on Biota's (2010a) assessment of vegetation conservation significance. The vegetation sub-associations (denoted by † in the tables above) described by Outback Ecology (2010) were assessed during this review and based upon the suite of species present, vegetation condition and weed invasion or other disturbance.

High Significance

- The inland sand dune vegetation sub-associations (ID1, ID2 and ID4) support Priority flora (*Eremophila forrestii* subsp. *viridis* and *Triumfetta echinata*), as well as other species of interest (*Aenictophyton* aff. *reconditum*), while the dune landform is particularly susceptible to erosion and weed invasion following soil profile disturbance (Biota 2010a).
- The samphire shrublands (C3) contain a number of poorly recognised *Tecticornia* species whose distributions in the region are also difficult to determine. This vegetation unit also contains the significant flora species *Eleocharis papillosa*, which is listed as Vulnerable under the *EPBC Act 1999* (Biota 2010a).

Moderate Significance

- The cracking clay grasslands (CP1) are considered to be of Moderate conservation significance as they were generally in Very Good condition and were supporting species specific to this substrate (Biota 2010a).

Low Significance

- The remainder of the vegetation sub-associations are considered to be of Low conservation significance as they are relatively representative of those in the locality or are substantially invaded by Buffel Grass (**Cenchrus ciliaris*). This is not meant to imply that they have no conservation value but simply that they are of lower conservation significance than the units highlighted above.

Table 3.2: Area of extent of each vegetation unit within the Wheatstone addendum area.

Unit Code	Description	Sub-association Code	Area in Wheatstone addendum study area (ha)
Vegetation of Tidal Mudflats and Tidal Creeks			
T1	_Tecticornia_ spp. scattered low shrubs	mf	871.48
Vegetation of Coastal Sand Dunes			
CD2	_Acacia coriacea_ subsp. _coriacea_ tall shrubland over _Crotalaria cunninghamii_, _Trichodesma zeylanicum_ var. _grandiflorum_ open shrubland over _Triodia epactia_ open hummock grassland with *_Cenchrus ciliaris_ open tussock grassland	AcCRcTRzTeCEc	17.76
Vegetation of Inland Sand Dunes			
ID1	_Grevillea stenobotrya_ tall open shrubland over _Crotalaria cunninghamii_, _Trichodesma zeylanicum_ var. _grandiflorum_ open shrubland over _Triodia epactia_ open hummock grassland	GsCRcTRzTe	16.33
ID2	_Grevillea stenobotrya_ tall open shrubland over _Crotalaria cunninghamii_, _Hibiscus brachychlaenus_ open shrubland over _Triodia schinzii_, _(T. epactia)_ open hummock grassland	GsCRcHBbTsTe	0.89
ID3	_Acacia stellaticeps_ shrubland over _Triodia epactia_ hummock grassland	AstTe	33.39
ID4	_Grevillea stenobotrya_, _Acacia stellaticeps_ shrubland over _Triodia epactia_ hummock grassland and *_Cenchrus ciliaris_ tussock grassland	GsAstTeCEc	12.48
Vegetation of Coastal Sand Plains			
CS1	_Acacia tetragonophylla_ scattered shrubs over _Triodia epactia_ hummock grassland	AteTe	327.91, plus 67.87 ha in mosaic with unit CS2, 69.46 ha in mosaic with unit CP1, and 284.08 ha in mosaic with unit CS4
CS2	_Acacia tetragonophylla_ scattered shrubs over _Triodia epactia_ hummock grassland with *_Cenchrus ciliaris_ open tussock grassland	AteTeCEc	78.97, plus 67.87 ha in mosaic with unit CS1
CS4	*_Prosopis pallida_, _Acacia tetragonophylla_, _A. synchronicia_ scattered tall shrubs over _Triodia epactia_ very open hummock grassland and *_Cenchrus ciliaris_ open tussock grassland	PRpAteAsyTeCEc	229.27, plus 284.08 ha in mosaic with unit CS1, and 28.62 in mosaic with unit CP1
CS5	*_Prosopis pallida_, _Acacia sclerosperma subsp. sclerosperma_, _A. tetragonophylla_ scattered tall shrubs over _Triodia epactia_ open hummock grassland and *_Cenchrus ciliaris_ open tussock grassland	PRpAssAteTeCEc	200.65
CS6	*_Prosopis pallida_ scattered tall shrubs to tall open shrubland over _Acacia tetragonophylla_, _Atriplex bunburyana_ shrubs over _Triodia epactia_ open hummock grassland and *_Cenchrus ciliaris_ open tussock grassland	PRpAteATbTeCEc	25.42

Table 3.2: Area of extent of each vegetation unit within the Wheatstone addendum area.

Unit Code	Description	Sub-association Code	Area in Wheatstone addendum study area (ha)
Vegetation of Claypans			
C1	Bare claypan	cp	78.46
C2	*Eriachne* aff. *benthamii* open tussock grassland	ERIb	11.84, plus 17.18 ha in mosaic with unit C3
C3	*Tecticornia* spp. low shrubland	TECspp	245.30, plus 17.18 ha in mosaic with unit C2
C4	**Prosopis pallida, Atriplex bunburyana* open shrubland over *Triodia epactia* open hummock grassland and **Cenchrus ciliaris* open tussock grassland	PRpATbTeCEc	3.71
Vegetation of Clayey Plains			
CP1	*Sporobolus mitchellii, Eriachne* aff. *benthamii, E. benthamii, Eulalia aurea* tussock grassland	SPmERIbEUa	67.36, plus 28.62 ha in mosaic with unit CS4
CP2	**Prosopis pallida* scattered tall shrubs to tall open shrubland over *Acacia tetragonophylla, *Vachellia farnesiana* shrubland over *Eulalia aurea, Chrysopogon fallax, Sporobolus mitchellii* tussock grassland	PRpAteVfEUaCHfSPm	26.83
Vegetation of Drainage Lines			
D2	*Eucalyptus victrix* scattered low trees over *Acacia synchronicia, A. bivenosa* shrubland over *Triodia epactia* hummock grassland	EvAsyAbTe	3.56
D4	*Eucalyptus victrix* low trees over *Acacia tetragonophylla, A. synchronicia* tall shrubland and *Hibiscus brachychlaenus* shrubland over **Cenchrus ciliaris* tussock grassland	EvAteAsyHbrCEc	18.88

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4.0 Flora

4.1 Overview of Flora of the Wheatstone Locality

A total of 422 taxa of native vascular plants from 161 genera belonging to 58 families have been recorded from the broader Wheatstone locality through the survey work to date, along with 13 weed species[4] (see Table 4.1). These numbers represent an amalgamation of:

- 80 native taxa[5] from 48 genera and 26 families and six weed species recorded during the Wheatstone addendum survey by Outback Ecology (2010); and
- 338 native taxa from 141 genera and 53 families and 12 weed species recorded during the Wheatstone Project surveys completed by Biota (2010a);
- 232 native taxa from 130 genera and 50 families and seven weed species recorded from the northern section of the Wheatstone plant study area by OEC (2008) and from the camp and shared infrastructure corridor (SIC) study area by OEC (2009);
- 105 native taxa from 64 genera and 24 families and six weed species recorded from 16 quadrats assessed in the area by Astron (2009);
- 66 native taxa from 46 genera and 21 families and two weed species recorded from four quadrats assessed in the area by RPS (2009).

The species occurring within the Wheatstone addendum area would represent a subset of the above flora.

4.2 Threatened Flora

4.2.1 Listed Species under the *EPBC Act 1999* Occurring in the Locality

No Threatened flora listed under the Commonwealth *EPBC Act 1999* were recorded in the sections of the Wheatstone addendum area surveyed by Outback Ecology (2010). However, one species listed as "Vulnerable" under the *EPBC Act 1999* was recorded from the Wheatstone pipeline study area (Biota 2010a):

- Dwarf Desert Spike-rush (*Eleocharis papillosa*) was recorded from a tidal creek, ~800 m southwest of the Peedamulla Station turn-off along the Onslow Road. This record represents a considerable range extension for this species within Western Australia, with the nearest other known population 430 km east-southeast in the Pilbara.

  The broader distribution of this annual species in the locality is unclear, as it has not been possible to conduct further survey work since the original record was made due to poor rainfall, however it may occur more widely in periodically inundated habitats. The recorded location is approximately 4.2 km northeast of the southeastern-most point of the Wheatstone addendum area, and it is possible that this species could occur within the southeastern section of the addendum area. Further discussion of this species can be found in Biota (2010a).

No other species listed under the *EPBC Act 1999* have been previously recorded from the Onslow locality or are expected to occur in the habitats present.

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[4] *Flaveria australasica* has only recently (subsequent to all previous biological reporting) been determined to be *F. trinervia*, which is an introduced species.

[5] Based on the species list contained in Appendix G of Outback Ecology (2010); note that *Scaevola taccada* and *Acacia sclerophylla* subsp. *sclerophylla* were excluded from this tally and from the list of species in Appendix 3 of this report, as it is considered that the former is likely misdetermined and the latter is likely a mis-entry to the database of A. sclerosperma subsp. sclerosperma; *Indigofera trifoliata* was similarly considered likely to be a mis-entry of *I. trita,* and has been treated as such in this report.

4.2.2 Declared Rare Flora Occurring in the Locality

No Declared Rare Flora (DRF) species have been recorded previously from the Wheatstone locality, and none would be expected to occur in the Wheatstone addendum area. The only DRF species listed for the Carnarvon and adjacent Pilbara bioregions are known from locations several hundred kilometres inland, and typically occur on habitats not contained within the Wheatstone addendum area.

4.2.3 Priority Flora Known from the Locality

One Priority species was recorded by Outback Ecology (2010) in the Wheatstone addendum area:

- Approximately 117 individuals of *Eremophila forrestii* subsp. *viridis* (Priority 3) were recorded from four locations within the Wheatstone addendum area (Outback Ecology 2010; see Figure 4.1). This subspecies was found to be intermixed with the more common subspecies *E. forrestii* subsp. *hastieana*, and Outback Ecology (2010) note that only minor taxonomic differences separate the two. This subspecies was recorded three times from the broader locality by Biota (2010a), and is known from at least three additional locations within 7 km of the study area. Mr. Andrew Brown (DEC Kensington, pers. comm. 2009) has advised that he suspects this taxon is relatively restricted to the Onslow locality.

Based on the searches of the DEC and WA Herbarium databases conducted for OEC (2008 and 2009) and the survey work completed in the Onslow area to date (see Section 2.1.2), a number of additional Priority flora species are known to occur in the locality. Each of these species is discussed below, along with an assessment of the likelihood that it would occur in the Wheatstone addendum area:

- *Abutilon uncinatum* ms.[6] (Priority 1) was recorded from a single location towards the western end of the Wheatstone pipeline study area (see Biota 2010a), 12 km southeast of the Wheatstone addendum area. This prostrate low shrub species is now known to occur over a range of approximately 65 km in the northwestern corner of the Pilbara bioregion, with one other record in the Carnarvon bioregion, 90 km south of the most southern Pilbara record. Given that this species was not recorded during the survey by Outback Ecology (2010) and has been collected only once in the Onslow locality, it is considered unlikely to occur in the Wheatstone addendum area, however, suitable unsurveyed habitat does exist in the locality.
- *Helichrysum oligochaetum* (Priority 1) has a relatively broad distribution through the Pilbara and northern Gascoyne bioregions. The nearest population of this annual daisy to the Wheatstone addendum area is approximately 60 km to the southeast. While this species could potentially occur on clayey plains habitats of the Wheatstone addendum area, this is considered unlikely, as it has not been recorded to date from the Onslow area during several relatively large-scale surveys.
- *Carpobrotus* sp. Thevenard Island (M. White 050) (Priority 2) is only currently known from white sand dunes on islands off the Pilbara coast. This species would not occur in the Wheatstone addendum area as no suitable habitat is present.
- *Atriplex flabelliformis* (Priority 3) was recorded from five locations in the southern Wheatstone plant study area by Astron (2009) (see Figure 4.1), all associated with samphire and grassland vegetation on clayey plains (vegetation units TECspp and SPmERIbEUa). This represents a very substantial range extension for this species, with the nearest known population some 430 km east-southeast in the Fortescue Marsh. This species could potentially occur within the Wheatstone addendum area, as suitable habitat is present.
- *Eleocharis papillosa* (Priority 3); see Section 4.2.1 above.
- *Triumfetta echinata* (Priority 3) was recorded a total of 10 times in the Wheatstone locality between Astron (2009), OEC (2008, 2009) and Biota (2010a) (see Figure 4.1). *T. echinata* has

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[6] "ms." denotes a manuscript name which has not yet been published.

been recorded from a number of other locations in the Onslow area, including west of the Onslow Road at approximately 2.75 km north of the Minderoo Station turnoff (Biota unpublished data), east of the Onslow Road at approximately 6 and 10 km south of the Minderoo Station turnoff (RPS 2009), as well as at additional locations (see OEC 2009). It appears that this species is relatively widespread through the locality, however it is not common and is restricted to red sand dunes. This species could potentially occur on sand dunes in the Wheatstone addendum area.

While not formally listed, numerous other taxa were considered to be of conservation interest for various reasons (e.g. they represent apparently new (undescribed) taxa, are poorly collected, or the record represents a considerable range extension; see Section 6.2.5 in Biota 2010a). These included:

- The undescribed pea *Aenictophyton* aff. *reconditum* appears to be restricted to sand dune habitats in the Onslow locality. This taxon was recorded by OEC (2009) from a dune in the northern Wheatstone plant study area, and was recorded by Biota (2010a) from two dunes at the eastern end of the Wheatstone SIC study area and the western end of the Wheatstone pipeline study area. It is known from at least eight additional locations within 10 km of the Wheatstone addendum area hence it is considered that this species may potentially occur within the area.
- Another undescribed pea, *Vigna* sp. Hamersley clay (A.A. Mitchell PRP 113), was recorded from numerous locations on the sandy coastal plains of the Wheatstone plant study area (see Biota 2010a). This taxon appears to have a broad distribution through the Pilbara and could potentially occur on the coastal plains in the Wheatstone addendum area.
- Other species of interest, including potentially new taxa in the genera *Tecticornia, Abutilon* and *Bonamia*.

4.3 Weeds

Six introduced (weed) species were recorded by Outback Ecology (2010) within the Wheatstone addendum area (see Table 4.1).

With the recent re-determination of *Flaveria australasica* as the introduced **F. trinervia,* an additional seven species have been recorded in the Wheatstone locality (see Biota 2010a), of which five are considered likely to occur within the Wheatstone addendum area (see Table 4.1). Three of the species recorded from the Wheatstone locality (Parkinsonia and the two species of Mesquite) are Declared Plants under the *Agriculture and Related Resources Protection Act 1976* (Table 4.1). For details of the known locations of these introduced species, see OEC (2009), Biota (2010a) and Outback Ecology (2010).

Figure 4.1: Known Priority flora locations in the Wheatstone locality.

Table 4.1: Weed species recorded from the Wheatstone addendum area, or considered likely to occur.

Family	Species	Description
Weed species recorded in the Wheatstone addendum area by Outback Ecology (2010)		
Malvaceae	**Malvastrum americanum* (Spiked Malvastrum)	A common weed of Mulga vegetation, hillsides, floodplains and drainage lines; this species is widespread throughout the Kimberley, Pilbara, Gascoyne and Carnarvon bioregions. **M. americanum* was recorded once in the Wheatstone addendum area (Outback Ecology), and seven times in the broader Wheatstone locality (Biota 2010a).
Mimosaceae	**Prosopis pallida* (Mesquite)	Mesquite is an erect, thorny thicket-forming tall shrub or tree. **P. pallida* was widespread through the Wheatstone addendum area (Outback Ecology 2010) and in the broader locality (Biota 2010a). All **Prosopis* species are Declared Plants under the Western Australian *Agriculture and Related Resources Protection Act 1976,* being listed as P1 (movement of plants or their seeds prohibited) for the State, and P2 (eradicate infestation to destroy and prevent propagation each year until no plants remain) for the Onslow locality. **Prosopis* is also listed as a "Weed of National Significance" by Thorp and Lynch (2000).
	**Vachellia farnesiana* (Mimosa Bush)	A common but scattered shrubby weed of drainage areas and clayey plains in the North-west, which is sometimes abundant in areas subject to heavy grazing (e.g. near stock watering-points). This species was widespread in the Wheatstone addendum area (Outback Ecology 2010) and broader Wheatstone study area (Biota 2010a).
Passifloraceae	**Passiflora foetida* var. *hispida* (Stinking Passion Flower)	A widespread weed in the Kimberley bioregion, which has also been recorded from a number of major creeklines in the Pilbara and Carnarvon. This species was recorded from two locations in the Wheatstone addendum area by Outback Ecology (2010) and was recorded twice in the broader Wheatstone area by Biota (2010a).
Poaceae	**Cenchrus ciliaris* (Buffel Grass) and **Cenchrus setiger* (Birdwood Grass)	Tufted perennial grasses which were introduced to the Pilbara as fodder species. **Cenchrus ciliaris* has demonstrated allelopathic capacities, whereby it releases chemicals that inhibit the growth of other plants, and it is an aggressive and effective competitor with native flora species. This perennial grass forms dense tussock grasslands, particularly along creeklines, floodplains and in sandy coastal areas of the Pilbara. **C. setiger* tends to be less abundant but is often found intermixed with **C. ciliaris* through the same areas. Both species were widespread on the coastal sand plains of the Wheatstone addendum area (Outback Ecology 2010) and broader Wheatstone locality (Biota 2010a).
Additional weed species recorded in the broader locality (see Biota 2010a), and considered likely to occur in the Wheatstone addendum area		
Asteraceae	**Flaveria trinervia* (Speedy Weed)	**F. trinervia* is an annual daisy, which is a common species occurring in drainage lines and other mesic habitats in the North-west of WA. This species was previously listed as the native *F. australasica*, which was recorded from numerous locations in the broader Wheatstone locality (Biota 2010a). This species would be expected to occur in the Wheatstone addendum area.
Cucurbitaceae	**Cucumis melo* subsp. *agrestis* (Ulcardo melon)	A widespread weed throughout the Kimberley, Pilbara and Gascoyne bioregions. This trailing annual herb was recorded from eight locations in the broader Wheatstone area (Biota 2010a). This species may occur in the Wheatstone addendum area.
Mimosaceae	**Prosopis glandulosa* (Mesquite)	**P. glandulosa* was recorded by Astron (2009) in the Wheatstone locality, and could potentially occur in the Wheatstone addendum area in the same habitats as **P. pallida* (see above).
Poaceae	**Setaria verticillata* (Whorled Pigeon Grass)	This loosely tufted, annual grass species is a common weed of creeklines and Mulga vegetation in the North-west of WA, but rarely occurs in large numbers. It is widespread through the State from Kununurra to Albany. **S. verticillata* was only recorded twice in the broader Wheatstone area (Biota 2010a) to the north of the addendum area; while it may occur in the Wheatstone addendum area, it would not be expected to be abundant.

Family	Species	Description
Additional weed species recorded in the broader locality (see Biota 2010a), and considered likely to occur in the Wheatstone addendum area (continued)		
Amaranthaceae	**Aerva javanica* (Kapok Bush)	Kapok is found in various habitats and vegetation types and can be a significant weed of loose sandy substrates in coastal areas. This short-lived perennial shrub is common throughout the Pilbara and Kimberley regions, but was only recorded twice in the broader Wheatstone locality (Biota 2010a). This species is considered likely to occur in the Wheatstone addendum area as it is a weed of disturbed areas and suitable habitat, i.e. loose sandy substrate, is present in the area.
Caesalpiniaceae	**Parkinsonia aculeata* (Parkinsonia)	Parkinsonia is a Declared Plant for Western Australia under the *Agriculture and Related Resources Protection Act 1976*, being listed as P1 and P2 for the Carnarvon and Exmouth districts (see discussion above for **Prosopis pallida*). Parkinsonia is also listed as a "Weed of National Significance" by Thorp and Lynch (2000). This species was recorded only twice in the broader Wheatstone locality (Biota 2010a), in a relatively major creek to the south of the Wheatstone plant study area. Whilst not abundant in the locality, Parkinsonia may potentially occur in the Wheatstone addendum area as it is commonly found in disturbed areas.
Portulacaceae	**Portulaca oleracea* (Purslane)	This succulent, prostrate to decumbent annual herb is a very common weed of clayey and stony plains in the Pilbara, but does not appear to compete with native species. This species was recorded numerous times in the broader Wheatstone locality (Biota 2010a) and would be expected to occur in the Wheatstone addendum area.

5.0 Fauna

5.1 Terrestrial Fauna

5.1.1 Fauna Habitats

Based on inspection of aerial photography, and review of the vegetation types present, the Wheatstone addendum area was assessed as containing six of the seven primary fauna habitats identified from the overall Wheatstone study area by Biota (2010b). These comprised:

- Inland Dune: *Triodia epactia* dominated hummock grassland on inland dune system;
- Sand/Loam Plain: *Acacia* sp. over *Triodia epactia* hummock grassland on sand/loam plain;
- Buffel on Clay: *Acacia* sp. over Buffel tussock grassland on clay plain;
- Samphire: Samphire claypan;
- Tussock on Clay: Tussock grassland on clay plain; and
- Drainage: Eucalyptus victrix and Buffel tussock grassland in drainage line.

No new or substantially different habitats appear to be present in the Wheatstone addendum area based on the available vegetation mapping from Outback Ecology (2010) and inspection of aerial photography. The assessment of fauna habitat significance of Biota (2010b) over the Wheatstone study area is therefore applicable to the Wheatstone addendum area.

5.1.2 Faunal Assemblage

The systematic terrestrial fauna survey of the overall Wheatstone Project area yielded a combined total of 128 vertebrate species, comprising 51 herpetofauna species, 60 avifauna species and 17 mammals (Biota 2010b). Considering that:

- the Wheatstone addendum area is immediately adjacent to the Wheatstone study area; and
- the Wheatstone addendum area contains six primary habitat types which accounted for the great majority of the overall Wheatstone study area (Biota 2010b),

the assemblage recorded during the Biota (2010b) study is considered representative of the likely terrestrial faunal assemblage of the Wheatstone addendum area.

A total of 51 herpetofauna species were recorded from the Wheatstone study area (Biota 2010b). This comprised one tree frog (Hylidae), three ground frogs (Myobatrachidae), nine geckos (Gekkonidae), four legless lizards (Pygopodidae), 14 skinks (Scincidae), five dragons (Agamidae), three monitors (Varanidae), three blind snakes (Typhlopidae), two pythons (Pythonidae) and seven front-fanged snakes (Elapidae).

Sixty bird species were recorded within the Wheatstone study area (Biota 2010b). The total species tally comprised 34 non-passerine species and 26 passerine species from 33 families. The zebra finch (*Taeniopygia guttata*) was the most abundant species recorded (323 records), representing over 31% of recorded avifauna. The most speciose family of birds was the Accipitridae (birds of prey including Osprey, Harriers, Kites and Eagles) with eight recorded species.

Seventeen mammal species (14 native and three introduced) were recorded from the Wheatstone study area (Biota 2010b). Twelve non-volant (ground-dwelling) mammal species were recorded during the survey, comprising three dasyurids (carnivorous marsupials), two macropods (kangaroos and wallabies), five murids (murid rodents), one feline (cat) and one bovid (cloven hoofed mammal). Five bat species were also recorded including three vespertilionids (evening bats), one emballonurid (sheathtail bats) and one molossid (freetail bats).

5.1.3 Potential Short Range Endemic Fauna

No confirmed Short Range Endemic (SRE) taxa were collected during the Biota (2010b) survey of the overall Wheatstone study area, despite systematic sampling and targeted searches. The only fauna belonging to potential SRE groups collected were two pseudoscorpion taxa, which proved to be known morphotypes with wider regional distributions (Biota 2010b). The habitats and general landscape setting of the Wheatstone addendum area is essentially the same as that of the adjoining and overlapping Wheatstone study area of Biota (2010b). It is therefore considered unlikely that any SRE taxa would be present in the Wheatstone addendum area.

5.2 Subterranean Fauna

Sampling and trapping of subterranean habitats of the overall Wheatstone study area was undertaken by Biota (2010c). This sampling targeted both stygofauna (obligate, groundwater fauna) and troglofauna (obligate dwellers in terrestrial subterranean habitats occurring above the water table). A desktop review and habitat assessment was also conducted as part of this earlier study based on geology, hydrology and drilling information (Biota 2010b).

5.2.1 Troglofauna

Biota (2010c) found that the superficial lithology of the Wheatstone study area was dominated by sands, silts and clays, and concluded that this would not provide suitable habitat space for troglofauna. The assessment also found that there was very limited above watertable habitat space available for troglofauna and that the geomorphic history of the site was probably not conducive to the long-term persistence of relictual troglobitic communities (Biota 2010c). No troglobites were recorded during the three phases of field sampling that were subsequently completed, consistent with this assessment of low likelihood.

The landforms, soils, stratigraphy and general physiographic setting of the Wheatstone addendum area are essentially equivalent to that of the remainder of the Wheatstone study area. Given the findings from the Biota (2010c) assessment and field survey, it is therefore considered unlikely that any troglobitic fauna occur in the Wheatstone addendum area.

5.2.2 Stygofauna

The habitat assessment of Biota (2010c) found that the saturated strata in the study area are dominated by sands, sandstone, silt and clays. While these units generally do not contain large voids, some small and general unconsolidated areas of calcrete were identified in the Wheatstone study area. Stygofauna were subsequently collected from just two spatial locations during the sampling of Biota (2010c). The assessment concluded that there was a low risk that these were restricted to the survey area.

The sampling of Biota (2010c) did not find any evidence of a diverse or significant stygal community in the locality of the Wheatstone study area. The superficial aquifers and formations of the Wheatstone addendum area are likely to be very similar to those of the overall Wheatstone study area. The risk of any stygal species being restricted to the Wheatstone addendum area is therefore also considered to be low.

5.3 Ephemeral Fauna of Claypan Systems

As the overall Wheatstone study had the potential to directly affect claypan systems and their faunal communities, Biota (2010d) conducted a survey of these ephemeral habitats. A combined total of 141 taxa of zooplankton and macro-invertebrates were recorded during that study, with 12 classes and 21 orders represented amongst the collected fauna (Biota 2010d). Claypans containing clear water habitats were generally found to be more diverse than the turbid claypans.

Inspection of aerial photography suggests that the claypan units present in the Wheatstone addendum area are likely to be of the turbid rather than clear water type, suggesting their diversity is likely to be lower than clear-water habitats in the locality. The analysis carried out by Biota (2010d) of the larger dataset also indicate a low risk of small-scale isolation of ephemeral faunal species, consistent with the broad-scale connections of these habitats during major flood events. On this basis it is considered unlikely that the claypan faunal communities of the Wheatstone addendum area would vary substantially from those sampled in the overall Wheatstone study area (Biota 2010d).

5.4 Threatened Fauna

Based on the field survey data of Biota (2010b), and reviews of habitats and known fauna distributions conducted by that study, it was considered unlikely that any listed Schedule 1 species would occur within the Wheatstone study area. Similar conclusions can be reached in respect of the Wheatstone addendum area, given the very similar habitats and close spatial proximity (Section 5.1.1). No Schedule listed species have been recorded during any of the other surveys from sites in the Onslow locality (Biota 2010b).

The only Priority listed species recorded by Biota (2010b) were the Little Northern Freetail-bat (*Mormopterus loriae cobourgensis*; Priority 1), and the Priority 4 species the Western Pebble-mound Mouse (*Pseudomys chapmani*) and Australian Bustard (*Ardeotis australis*). *P. chapmani* would not occur in the Wheatstone addendum area due to a lack of suitable stony substrate, but the other two species would be likely to be present. Three *EPBC Act 1999* listed Migratory species (the Rainbow Bee-eater *Merops ornatus*, Fork-tailed Swift *Apus pacificus* and White-bellied Sea Eagle *Haliaeetus leucogaster*) could also occur in the addendum area, but the general assessment of Biota (2010b) would also apply to these areas. The Project is not expected to affect the conservation status of any of the Commonwealth or State listed species, as only a small proportion of local habitat suitable for the taxa would be cleared relative to their distribution in the wider region (Biota 2010b).

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6.0 Summary and Conclusions

6.1 Vegetation and Flora of the Wheatstone Addendum Area

The amount of previous work completed in the locality of the Wheatstone Project has allowed for a comprehensive desktop assessment of the Wheatstone addendum area. The most recent survey by Outback Ecology (2010) expanded the original areas surveyed (OEC 2009 and Biota 2010a) (Figure 1.1) quite extensively, but only resulted in the addition of three relatively common native flora species (*Pterocaulon sphacelatum*, *Atriplex amnicola* and *Aristida latifolia*[7]) and five vegetation units. The compositions of the five new vegetation units described by Outback Ecology (2010) are not markedly different from those found in the adjoining previous survey areas, and the units do not represent vegetation types of elevated conservation significance, except for unit ID4 which potentially supports the Priority flora species *Eremophila forrestii* subsp. *viridis*, *Triumfetta echinata* and the undescribed taxon *Aenictophyton* aff. *reconditum* (Section 3.5).

No DRF species would occur in the Wheatstone addendum area: the DRF species listed for the Carnarvon and Pilbara bioregions all occur several hundred kilometres inland. The only *EPBC Act 1999* listed flora species which could potentially occur within the Wheatstone addendum area is *Eleocharis papillosa*, which was recorded from a samphire creek 4.2 km northeast of the southeastern-most corner of the addendum area. The broader distribution of this species in the locality is unclear, as it has not been possible to conduct further survey work since the original record was made due to poor rainfall. The Priority flora species confirmed for the area, or considered likely to occur, were all recorded from the broader Wheatstone locality during previous surveys.

6.2 Fauna of the Wheatstone Addendum Area

The review conducted here suggests that the faunal habitats of the Wheatstone addendum area are essentially equivalent to those of the original Wheatstone study area. This is the case for the terrestrial fauna, subterranean fauna and ephemeral claypan fauna components of the biota. The findings of the systematic fauna surveys conducted on these faunal communities can therefore be used to infer the likely faunal values of the Wheatstone addendum area.

The available data indicate a low likelihood of Schedule fauna occurring in the Wheatstone addendum area, and a limited listing of Priority fauna. There is a low likelihood that troglobitic fauna occur in the Wheatstone addendum area and a low risk that any stygal taxa would be restricted to the area if present. Finally, while claypan habitats occur within the Wheatstone addendum area, they appear similar to the less diverse units previously sampled from the Onslow locality, and have a low likelihood of supporting restricted taxa.

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[7] It should be noted that this survey was conducted following several months of negligible rainfall, and was therefore not optimal for the collection of ephemeral flora.

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Appendix 1

Vegetation Structural Classification and Condition Ranking Scale

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Vegetation Structural Classes*

Stratum	Canopy Cover (%)				
	70-100%	30-70%	10-30%	2-10%	<2%
Trees over 30 m	Tall closed forest	Tall open forest	Tall woodland	Tall open woodland	Scattered tall trees
Trees 10-30 m	Closed forest	Open forest	Woodland	Open woodland	Scattered trees
Trees under 10 m	Low closed forest	Low open forest	Low woodland	Low open woodland	Scattered low trees
Shrubs over 2 m	Tall closed scrub	Tall open scrub	Tall shrubland	Tall open shrubland	Scattered tall shrubs
Shrubs 1-2 m	Closed heath	Open heath	Shrubland	Open shrubland	Scattered shrubs
Shrubs under 1 m	Low closed heath	Low open heath	Low shrubland	Low open shrubland	Scattered low shrubs
Hummock grasses	Closed hummock grassland	Hummock grassland	Open hummock grassland	Very open hummock grassland	Scattered hummock grasses
Grasses, Sedges, Herbs	Closed tussock grassland / bunch grassland / sedgeland / herbland	Tussock grassland / bunch grassland / sedgeland / herbland	Open tussock grassland / bunch grassland / sedgeland / herbland	Very open tussock grassland / bunch grassland / sedgeland / herbland	Scattered tussock grasses / bunch grasses / sedges / herbs

* Based on Muir (1977), and Aplin's (1979) modification of the vegetation classification system of Specht (1970): Aplin T.E.H. (1979). The Flora. Chapter 3 *In* O'Brien, B.J. (ed.) (1979). *Environment and Science.* University of Western Australia Press; Muir B.G. (1977). Biological Survey of the Western Australian Wheatbelt. Part II: Vegetation and habitat of Bendering Reserve. *Records of the Western Australian Museum, Suppl.* No. 3; Specht R.L. (1970). Vegetation. *In The Australian Environment.* 4th edn (Ed. G.W. Leeper). Melbourne.

Vegetation Condition Scale*

E = Excellent (=Pristine of BushForever) Pristine or nearly so; no obvious signs of damage caused by the activities of European man.
VG = Very Good (= Excellent of BushForever) Some relatively slight signs of damage caused by the activities of European man. For example, some signs of damage to tree trunks caused by repeated fire, the presence of some relatively non-aggressive weeds such as **Ursinia anthemoides* or **Briza* spp., or occasional vehicle tracks.
G = Good (= Very Good of BushForever) More obvious signs of damage caused by the activities of European man, including some obvious impact on the vegetation structure such as that caused by low levels of grazing or by selective logging. Weeds as above, possibly plus some more aggressive ones such as **Ehrharta* spp.
P = Poor (= Good of BushForever) Still retains basic vegetation structure or ability to regenerate to it after very obvious impacts of activities of European man, such as grazing, partial clearing (chaining) or frequent fires. Weeds as above, probably plus some more aggressive ones such as **Ehrharta* spp.
VP = Very Poor (= Degraded of BushForever) Severely impacted by grazing, very frequent fires, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species including very aggressive species.
D = Completely Degraded (= Completely Degraded of BushForever) Areas that are completely or almost completely without native species in the structure of their vegetation; i.e. areas that are cleared or 'parkland cleared' with their flora comprising weed or crop species with isolated native trees or shrubs.

* Based on Trudgen M.E. (1988). A Report on the Flora and Vegetation of the Port Kennedy Area. Unpublished report prepared for Bowman Bishaw and Associates, West Perth.

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Appendix 2

Vegetation of the Wheatstone Addendum Area

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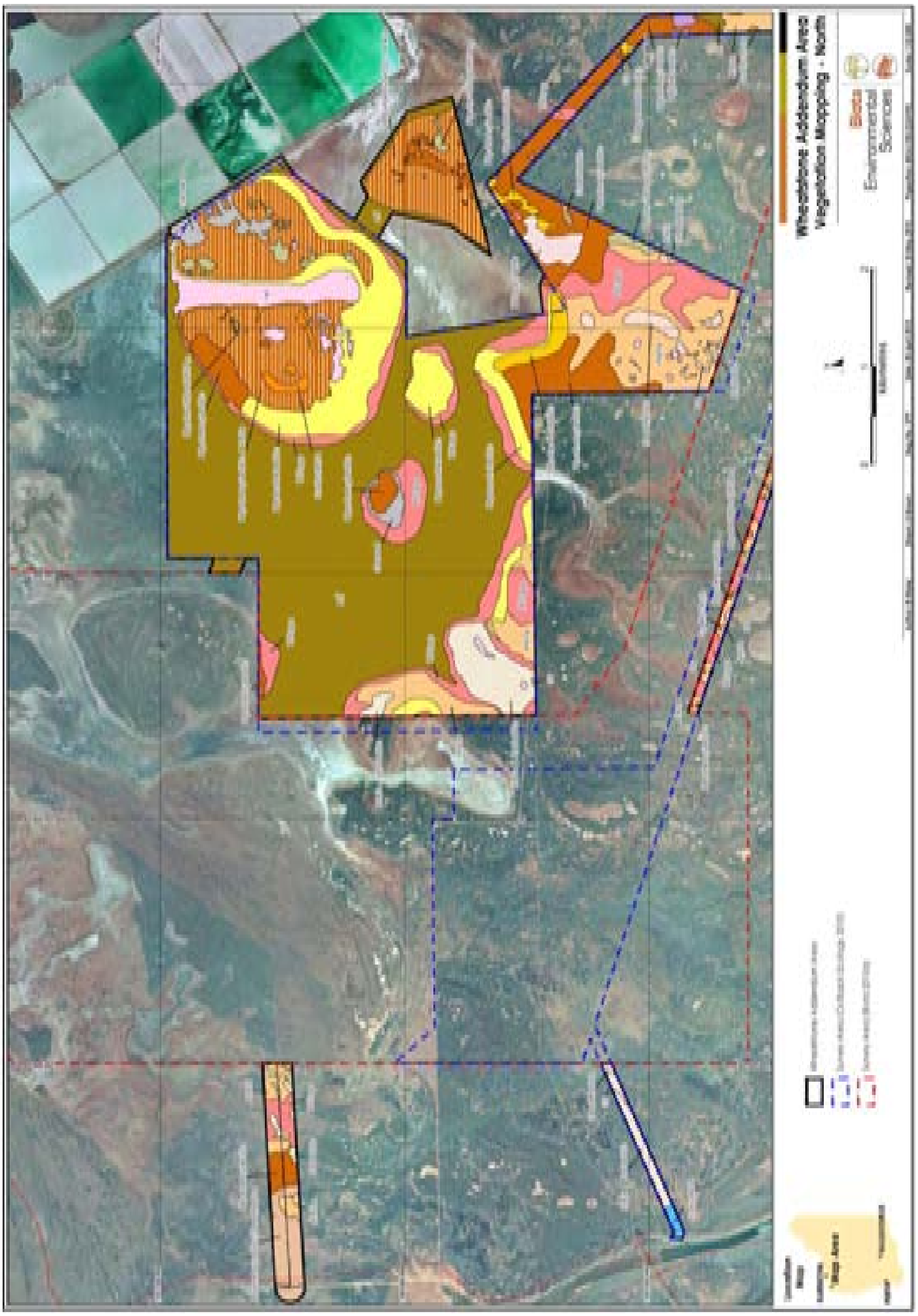
Wheatstone Project Flora and Fauna Assessment Addendum



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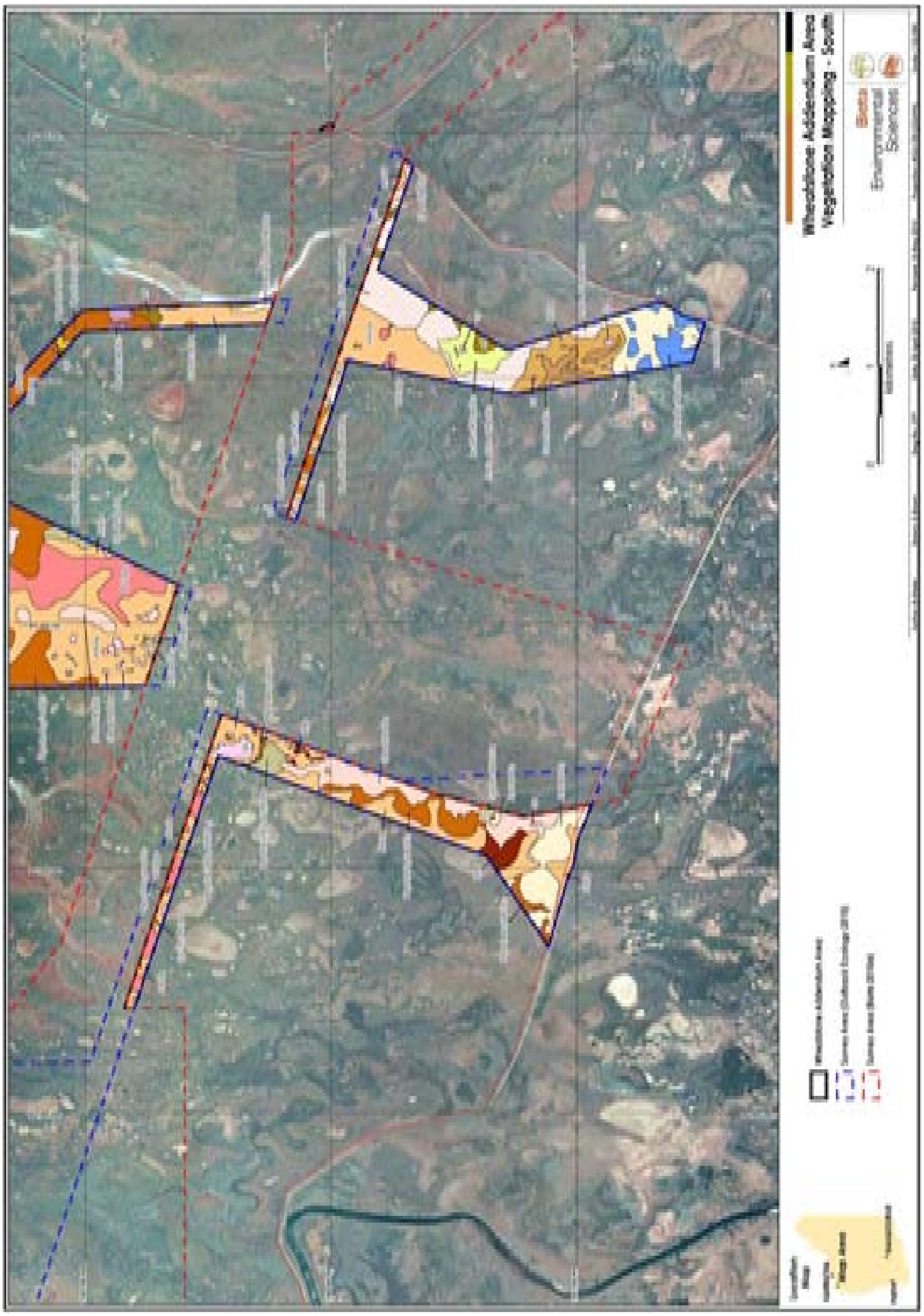
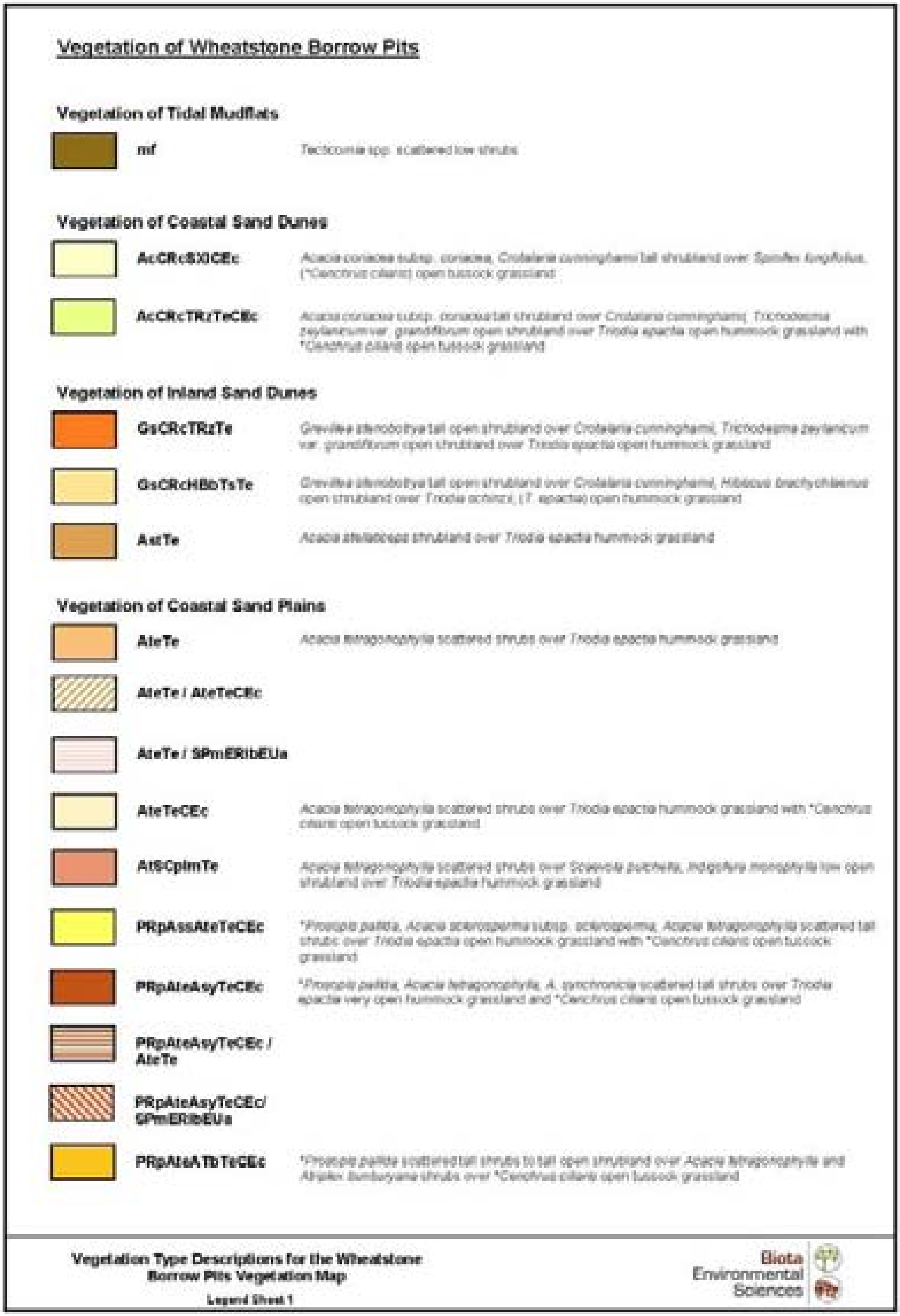

Wheatstone Addendum Area
Vegetation Mapping - South
Biota
Environmental
Sciences



Vegetation of Wheatstone Borrow Pits

Vegetation of Tidal Mudflats

🟫	**mf**	*Tecticornia* spp. scattered low shrubs

Vegetation of Coastal Sand Dunes

🟨	**AcCRcSXlCEc**	*Acacia coriacea* subsp. *coriacea*, *Crotalaria cunninghamii* tall shrubland over *Spinifex longifolius*, (**Cenchrus ciliaris*) open tussock grassland
🟩	**AcCRcTRzTeCEc**	*Acacia coriacea* subsp. *coriacea* tall shrubland over *Crotalaria cunninghamii*, *Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland

Vegetation of Inland Sand Dunes

🟧	**GsCRcTRzTe**	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii*, *Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland
🟨	**GsCRcHBbTsTe**	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii*, *Hibiscus brachychlaenus* open shrubland over *Triodia schinzii* (*T. epactia*) open hummock grassland
🟫	**AstTe**	*Acacia stellaticeps* shrubland over *Triodia epactia* hummock grassland

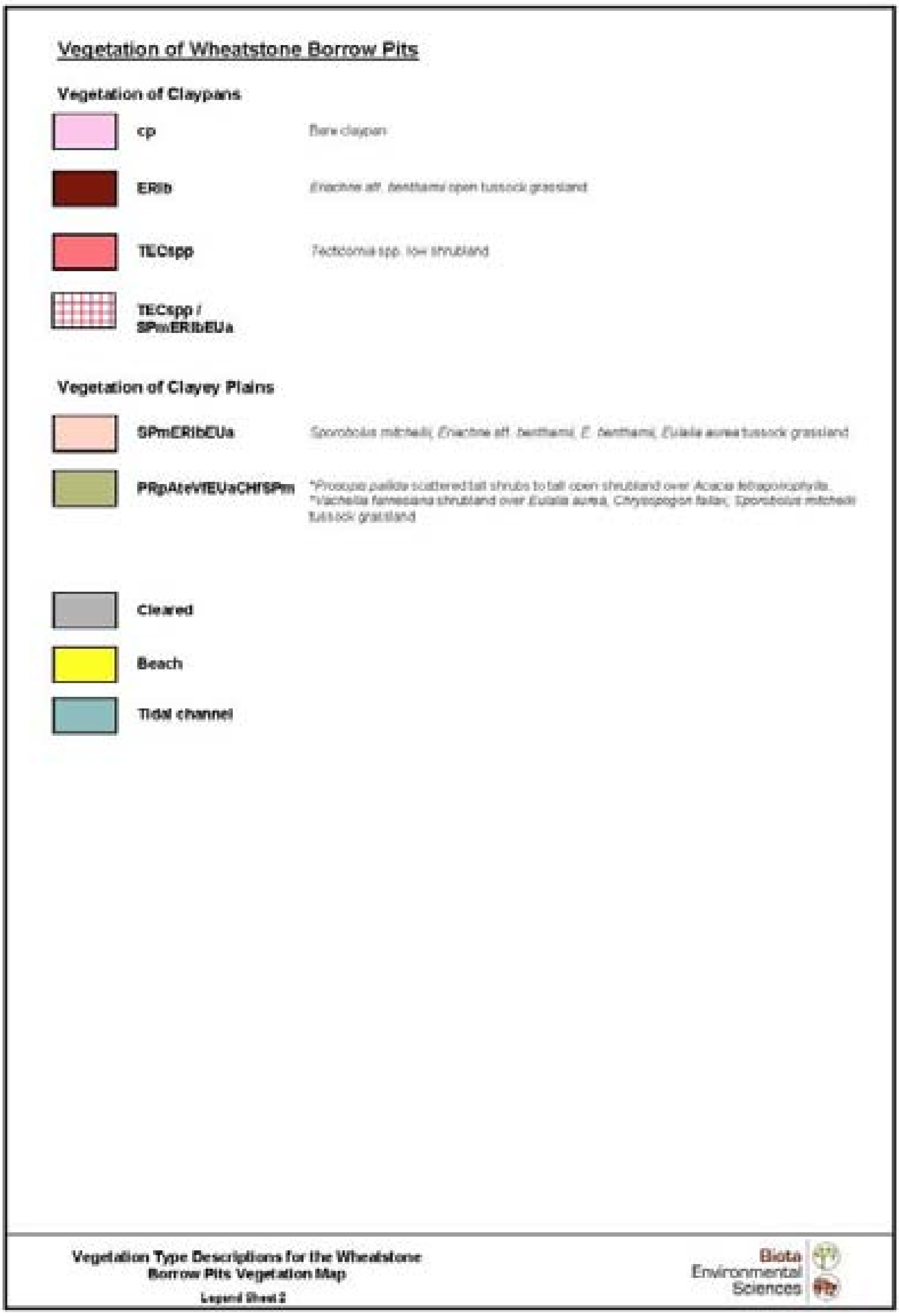
Vegetation of Coastal Sand Plains

🟧	**AteTe**	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland
▨	**AteTe / AteTeCEc**	
▤	**AteTe / SPmERIbEUa**	
🟨	**AteTeCEc**	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland
🟥	**AtSCpImTe**	*Acacia tetragonophylla* scattered shrubs over *Scaevola pulchella*, *Indigofera monophylla* low open shrubland over *Triodia epactia* hummock grassland
🟨	**PRpAssAteTeCEc**	**Prosopis pallida*, *Acacia sclerosperma* subsp. *sclerosperma*, *Acacia tetragonophylla* scattered tall shrubs over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland
🟫	**PRpAteAsyTeCEc**	**Prosopis pallida*, *Acacia tetragonophylla*, *A. synchronicia* scattered tall shrubs over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* open tussock grassland
▤	**PRpAteAsyTeCEc / AteTe**	
▨	**PRpAteAsyTeCEc/ SPmERIbEUa**	
🟧	**PRpAteATbTeCEc**	**Prosopis pallida* scattered tall shrubs to tall open shrubland over *Acacia tetragonophylla* and *Atriplex bunburyana* shrubs over **Cenchrus ciliaris* open tussock grassland

Vegetation Type Descriptions for the Wheatstone Borrow Pits Vegetation Map

Legend Sheet 1

Biota Environmental Sciences



Vegetation of Wheatstone Borrow Pits

Vegetation of Claypans

cp	Bare claypan
ERib	*Eriachne* aff. *benthamii* open tussock grassland
TECspp	*Tecticornia* spp. low shrubland
TECspp / SPmERIbEUa	

Vegetation of Clayey Plains

SPmERIbEUa	*Sporobolus mitchelli*, *Eriachne* aff. *benthamii*, *E. benthamii*, *Eulalia aurea* tussock grassland
PRpAteVfEUaCHfSPm	*Prosopis pallida scattered tall shrubs to tall open shrubland over *Acacia tetragonophylla*, *Vachellia farnesiana shrubland over *Eulalia aurea*, *Chrysopogon fallax*, *Sporobolus mitchelli* tussock grassland

Cleared
Beach
Tidal channel

Vegetation Type Descriptions for the Wheatstone Borrow Pits Vegetation Map

Legend Sheet 2

Biota Environmental Sciences

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Appendix 3

List of Flora Species Previously Recorded from the Wheatstone Locality

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Species list based on combined data from reports listed in Section 4.1.

NB. * denotes introduced species

Comparison of *Cassia* vs. *Senna* nomenclature:

Cassia artemisioides = *Senna artemisioides*
Cassia glutinosa = *Senna glutinosa* subsp. *glutinosa*
Cassia luerssenii = *Senna glutinosa* subsp. x *luerssenii*
Cassia notabilis = *Senna notabilis*
Cassia oligophylla = *Senna artemisioides* subsp. *oligophylla*
Cassia helmsii = *Senna artemisioides* subsp. *helmsii*
Cassia pruinosa = *Senna glutinosa* subsp. *pruinosa*

† denotes species recorded from the Wheatstone addendum area by Outback Ecology (2010).

Family: Acanthaceae
Rostellularia adscendens var. *clementii*
Family: Aizoaceae
Trianthema pilosa
Trianthema triquetra
† *Trianthema turgidifolia*
Family: Amaranthaceae
**Aerva javanica*
Alternanthera nana
Alternanthera nodiflora
Amaranthus mitchellii
Gomphrena affinis subsp. *pilbarensis*
Gomphrena cunninghamii
Gomphrena sordida
Hemichroa diandra
Ptilotus appendiculatus var. *appendiculatus*
Ptilotus arthrolasius
Ptilotus astrolasius var. *astrolasius*
Ptilotus axillaris
† *Ptilotus exaltatus* var. *exaltatus*
Ptilotus fusiformis
Ptilotus gomphrenoides
Ptilotus gomphrenoides var. *conglomeratus*
Ptilotus latifolius
Ptilotus macrocephalus
Ptilotus murrayi
Ptilotus obovatus
Ptilotus polystachyus var. *polystachyus*
Ptilotus villosiflorus
Family: Anthericaceae
Corynotheca flexuosissima
† *Corynotheca pungens*
Murchisonia volubilis
Family: Apiaceae
Trachymene pilbarensis
Family: Apocynaceae
† *Sarcostemma viminale* subsp. *australe*
Family: Asteraceae
Angianthus acrohyalinus
Angianthus milnei
Blumea tenella
Brachyscome cheilocarpa
Brachyscome ciliocarpa
Brachyscome iberidifolia
Calotis plumulifera

† *Centipeda minima* subsp. *macrocephala*
Decazesia hecatocephala
**Flaveria trinervia*
Minuria cunninghamii
Olearia dampieri subsp. *dampieri*
Pluchea dentex
Pluchea dunlopii
Pluchea ferdinandi-muelleri
† *Pluchea rubelliflora*
Pluchea sp. B Kimberley Flora (K.F. Kenneally 9526A)
† *Pterocaulon sphacelatum*
Pterocaulon sphaeranthoides
Rhodanthe floribunda
Rhodanthe humboldtiana
Rhodanthe stricta
† *Streptoglossa adscendens*
Streptoglossa bubakii
Streptoglossa decurrens
Streptoglossa liatroides
Streptoglossa macrocephala
Streptoglossa odora
Streptoglossa sp.

Family: Avicenniaceae
Avicennia marina
Avicennia marina subsp. *marina*

Family: Boraginaceae
Heliotropium crispatum
Heliotropium curassavicum
Heliotropium diversifolium
Heliotropium inexplicitum
Heliotropium ovalifolium
Heliotropium pachyphyllum
Heliotropium sp.
† *Trichodesma zeylanicum* var. *grandiflorum*
† *Trichodesma zeylanicum* var. *zeylanicum*

Family: Brassicaceae
Lepidium pholidogynum
† *Lepidium platypetalum*

Family: Caesalpiniaceae
Cassia aff. *oligophylla* (thinly sericeous) x *helmsii*
Cassia artemisioides
Cassia glutinosa
† *Cassia glutinosa x luerssenii*
Cassia luerssenii
Cassia notabilis
Cassia oligophylla
† *Cassia oligophylla (thinly sericeous MET 15,035)*
† *Cassia oligophylla x helmsii*
Cassia pruinosa
**Parkinsonia aculeata*
Petalostylis cassioides

Family: Campanulaceae
Wahlenbergia tumidifructa

Family: Capparaceae
Cleome uncifera subsp. *uncifera*
Cleome viscosa

Family: Caryophyllaceae
Polycarpaea corymbosa var. *corymbosa*

Family: Chenopodiaceae

- † *Atriplex amnicola*
- † *Atriplex bunburyana*
- † *Atriplex codonocarpa*
- *Atriplex flabelliformis*
- † *Atriplex semilunaris*
- *Dissocarpus paradoxus*
- *Dysphania kalpari*
- *Dysphania plantaginella*
- *Dysphania platycarpa*
- *Dysphania rhadinostachya*
- *Enchylaena tomentosa* var. *tomentosa*
- *Maireana georgei*
- *Maireana lanosa*
- *Maireana planifolia*
- *Maireana* sp.
- † *Maireana tomentosa*
- *Maireana tomentosa* subsp. *tomentosa*
- *Neobassia astrocarpa*
- † *Rhagodia eremaea*
- *Rhagodia preissii* subsp. *obovata*
- *Salsola tragus*
- † *Sclerolaena costata*
- *Sclerolaena glabra*
- *Sclerolaena recurvicuspis*
- *Sclerolaena uniflora*
- *Suaeda arbusculoides*
- *Tecticornia ? auriculata*
- *Tecticornia* ? *halocnemoides* subsp. *tenuis*
- *Tecticornia* ? sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)
- † *Tecticornia auriculata*
- *Tecticornia doleiformis*
- *Tecticornia halocnemoides*
- † *Tecticornia halocnemoides* subsp. *tenuis*
- *Tecticornia indica* subsp. ? (intergrade between leiostachya/bidens/julacea)
- *Tecticornia indica* subsp. aff. *bidens*
- *Tecticornia indica* subsp. *bidens*
- † *Tecticornia indica* subsp. *leiostachya*
- *Tecticornia pergranulata*
- *Tecticornia pergranulata* subsp. *elongata*
- *Tecticornia pergranulata* subsp. *pergranulata*
- *Tecticornia pruinosa*
- *Tecticornia pterygosperma* subsp. *denticulata*
- † *Tecticornia* sp.
- *Tecticornia* sp. (WH40-04) (T. halocnemoides complex)
- *Tecticornia* sp. (WHPH-15) (T. halocnemoides complex)
- *Threlkeldia diffusa*

Family: Convolvulaceae

- *Bonamia* aff. *linearis*
- † *Bonamia erecta*
- † *Bonamia linearis*
- *Bonamia rosea*
- *Convolvulus angustissimus* subsp. *angustissimus*
- *Cressa australis*
- † *Evolvulus alsinoides* var. *decumbens*
- *Evolvulus alsinoides* var. *villosicalyx*
- *Ipomoea coptica*
- *Ipomoea costata*

† *Ipomoea muelleri*
Ipomoea polymorpha

Family: Cucurbitaceae
† *Cucumis maderaspatanus*
**Cucumis melo* subsp. *agrestis*

Family: Cyperaceae
Bulbostylis barbata
Cyperus bulbosus
Cyperus iria
Cyperus rigidellus
Cyperus squarrosus
Eleocharis papillosa
Fimbristylis dichotoma
Fimbristylis rara
Schoenoplectus dissachanthus

Family: Elatinaceae
Bergia pedicellaris
Bergia perennis
Bergia perennis subsp. *exigua*
Bergia perennis subsp. *perennis*
Bergia trimera

Family: Euphorbiaceae
Adriana tomentosa var. *tomentosa*
Euphorbia aff. *coghlanii*
Euphorbia australis
Euphorbia australis (mid-green form)
Euphorbia biconvexa
Euphorbia boophthona
Euphorbia coghlanii
† *Euphorbia drummondii* subsp. *drummondii*
Euphorbia myrtoides
Euphorbia sharkoensis
† *Euphorbia tannensis* subsp. *eremophila*
Phyllanthus erwinii
Phyllanthus maderaspatensis

Family: Frankeniaceae
Frankenia ambita

Family: Gentianaceae
Centaurium clementii
Centaurium spicatum

Family: Geraniaceae
Erodium cygnorum

Family: Goodeniaceae
Goodenia forrestii
Goodenia lamprosperma
Goodenia microptera
Scaevola cunninghamii
Scaevola parvifolia subsp. *pilbarae*
Scaevola pulchella
Scaevola sericophylla
† *Scaevola spinescens*
† *Scaevola spinescens (broad form)*

Family: Gyrostemonaceae
Codonocarpus cotinifolius
Gyrostemon ramulosus

Family: Haloragaceae
Haloragis gossei var. *gossei*
Haloragis gossei var. *inflata*

Family: Lamiaceae
- *Dicrastylis cordifolia*
- *Pityrodia loxocarpa*
- *Pityrodia paniculata*

Family: Lauraceae
- *Cassytha aurea* var. *aurea*
- † *Cassytha capillaris*

Family: Lythraceae
- *Rotala diandra*

Family: Malvaceae
- *Abutilon* aff. *lepidum* (1) (MET 15 352)
- *Abutilon* aff. *lepidum* (4)
- † *Abutilon cunninghamii*
- *Abutilon dioicum*
- *Abutilon fraseri*
- *Abutilon lepidum*
- *Abutilon otocarpum*
- *Abutilon otocarpum (acute leaf form)*
- *Abutilon oxycarpum* subsp. *prostratum*
- † *Abutilon* sp.
- *Abutilon uncinatum*
- *Alyogyne pinoniana*
- *Gossypium australe (Burrup Peninsula form)*
- † *Hibiscus brachychlaenus*
- *Hibiscus brachysiphonius*
- *Hibiscus leptocladus*
- *Hibiscus sturtii* var. *campylochlamys*
- † *Hibiscus sturtii* var. *platychlamys*
- † *Lawrencia viridigrisea*
- † **Malvastrum americanum*
- † *Sida* aff. *fibulifera*
- *Sida* aff. *fibulifera* (B64-13B)
- *Sida* aff. *fibulifera* (M69.12)
- *Sida arsiniata*
- *Sida echinocarpa*
- *Sida pilbarensis (ferruginous form)*
- † *Sida rohlenae* subsp. *rohlenae*

Family: Marsileaceae
- † *Marsilea drummondii*
- *Marsilea exarata*
- *Marsilea hirsuta*

Family: Meliaceae
- *Owenia reticulata*

Family: Menispermaceae
- *Tinospora smilacina*

Family: Mimosaceae
- *Acacia ancistrocarpa*
- *Acacia bivenosa*
- *Acacia colei* var. *colei*
- † *Acacia coriacea* subsp. *coriacea*
- *Acacia coriacea* subsp. *pendens*
- *Acacia inaequilatera*
- *Acacia pyrifolia*
- † *Acacia sclerosperma*
- *Acacia sclerosperma hybrid*
- † *Acacia sclerosperma* subsp. *sclerosperma*
- † *Acacia sericophylla*
- *Acacia sphaerostachya*

- † *Acacia stellaticeps*
- † *Acacia synchronicia*
- † *Acacia tetragonophylla*
- *Acacia trachycarpa*
- *Acacia trudgeniana*
- *Acacia tumida* var. *pilbarensis*
- *Acacia victoriae*
- *Acacia wanyu*
- *Acacia xiphophylla*
- *Neptunia dimorphantha*
- **Prosopis glandulosa*
- † **Prosopis pallida*
- † **Vachellia farnesiana*

Family: Molluginaceae

- *Mollugo molluginea*

Family: Myoporaceae

- *Eremophila cuneifolia*
- † *Eremophila forrestii* subsp. *forrestii*
- † *Eremophila forrestii* subsp. *viridis*
- † *Eremophila longifolia*
- *Myoporum montanum*

Family: Myrtaceae

- *Corymbia candida*
- *Corymbia hamersleyana*
- *Corymbia zygophylla*
- *Eucalyptus camaldulensis* var. *obtusa*
- † *Eucalyptus victrix*
- *Eucalyptus xerothermica*
- *Melaleuca argentea*
- *Melaleuca glomerata*
- *Verticordia forrestii*

Family: Nyctaginaceae

- *Boerhavia burbidgeana*
- *Boerhavia coccinea*

Family: Papilionaceae

- *Aenictophyton* aff. *reconditum* subsp. *Onslow*
- *Aeschynomene indica*
- *Alysicarpus muelleri*
- *Canavalia rosea*
- † *Crotalaria cunninghamii* subsp. *sturtii*
- *Crotalaria medicaginea* var. *neglecta*
- *Crotalaria ramosissima*
- *Crotalaria* sp.
- † *Cullen cinereum*
- *Cullen graveolens*
- † *Cullen lachnostachys*
- † *Cullen leucanthum*
- *Cullen leucanthum* (Cape Preston form; M59.9)
- *Cullen leucochaites*
- † *Cullen martinii*
- *Cullen pogonocarpum*
- *Desmodium filiforme*
- *Indigofera boviperda* subsp. *boviperda*
- † *Indigofera colutea*
- † *Indigofera georgei*
- † *Indigofera linifolia*
- *Indigofera linnaei*
- *Indigofera monophylla*

Indigofera monophylla (Burrup form)
† *Indigofera trita*
Isotropis atropurpurea
Lotus cruentus
† *Rhynchosia minima*
Sesbania cannabina
Swainsona kingii
† *Swainsona pterostylis*
Tephrosia aff. *supina* (HD133-20)
Tephrosia aff. *supina* (MET 12,357)
Tephrosia gardneri
Tephrosia remotiflora
† *Tephrosia rosea* var. *clementii*
Tephrosia sp. B Kimberley Flora (C.A. Gardner 7300)
Tephrosia supina
Tephrosia uniovulata
Vigna lanceolata
Vigna sp. Hamersley Clay (A.A. Mitchell PRP 113)
Zornia albiflora

Family: Passifloraceae
† **Passiflora foetida* var. *hispida*

Family: Plumbaginaceae
† *Muellerolimon salicorniaceum*

Family: Poaceae
Aristida contorta
Aristida holathera var. *holathera*
Aristida holathera var. *latifolia*
† *Aristida latifolia*
Astrebla elymoides
Astrebla pectinata
Brachyachne convergens
Brachyachne prostrata
† **Cenchrus ciliaris*
† **Cenchrus setiger*
Chloris pectinata
Chloris pumilio
Chrysopogon fallax
Cymbopogon ambiguus
Cymbopogon obtectus
Cymbopogon procerus
Dactyloctenium radulans
Dichanthium sericeum subsp. *humilius*
† *Digitaria brownii*
Enneapogon caerulescens
Enneapogon polyphyllus
Enteropogon ramosus
Eragrostis aff. *falcata*
Eragrostis aff. *setifolia*
Eragrostis cumingii
Eragrostis dielsii
Eragrostis eriopoda
† *Eragrostis falcata*
Eragrostis leptocarpa
Eragrostis pergracilis
Eragrostis tenellula
† *Eragrostis xerophila*
Eriachne aff. *benthamii*
Eriachne aristidea

- † *Eriachne benthamii*
- *Eriachne gardneri*
- *Eriachne helmsii*
- *Eriachne mucronata*
- *Eriachne obtusa*
- *Eriachne pulchella* subsp. *dominii*
- *Eriochloa pseudoacrotricha*
- *Eulalia aurea*
- *Iseilema dolichotrichum*
- *Iseilema eremaeum*
- *Iseilema macratherum*
- *Iseilema membranaceum*
- *Leptochloa digitata*
- *Leptochloa fusca* subsp. *muelleri*
- *Panicum decompositum*
- *Panicum laevinode*
- *Paraneurachne muelleri*
- *Paspalidium clementii*
- *Setaria dielsii*
- **Setaria verticillata*
- *Sorghum plumosum*
- *Spinifex longifolius*
- *Sporobolus australasicus*
- *Sporobolus mitchellii*
- *Sporobolus virginicus*
- *Triodia brizoides*
- † *Triodia epactia*
- *Triodia lanigera*
- *Triodia pungens*
- *Triodia schinzii*
- *Tripogon loliiformis*
- *Triraphis mollis*
- *Urochloa holosericea* subsp. *velutina*
- *Whiteochloa airoides*
- *Yakirra australiensis* var. *australiensis*

Family: Polygalaceae

- *Polygala* aff. *isingii*

Family: Portulacaceae

- *Calandrinia ptychosperma*
- **Portulaca oleracea*
- *Portulaca pilosa*

Family: Primulaceae

- *Samolus* sp. *Millstream* (M.I.H. Brooker 2076)
- *Samolus* sp. *Shark Bay* (M.E. Trudgen 7410)

Family: Proteaceae

- † *Grevillea eriostachya*
- † *Grevillea stenobotrya*
- † *Grevillea wickhamii* subsp. *hispidula*
- *Hakea lorea* subsp. *lorea*
- *Hakea stenophylla* subsp. *stenophylla*

Family: Rhizophoraceae

- *Ceriops tagal*

Family: Rubiaceae

- *Synaptantha tillaeacea* var. *tillaeacea*

Family: Santalaceae

- *Santalum lanceolatum*

Family: Sapindaceae

- *Diplopeltis eriocarpa*

Family: Scrophulariaceae
- *Mimulus gracilis*
- *Mimulus uvedaliae*
- *Peplidium aithocheilum*
- *Stemodia grossa*
- † *Stemodia* sp. *Onslow* (A.A. Mitchell 76/148)

Family: Solanaceae
- *Nicotiana occidentalis*
- *Nicotiana occidentalis* subsp. *occidentalis*
- *Nicotiana rosulata* subsp. *rosulata*
- *Nicotiana* sp.
- *Solanum diversiflorum*
- *Solanum ellipticum*
- † *Solanum horridum*
- † *Solanum lasiophyllum*
- *Solanum phlomoides*
- *Solanum sturtianum*

Family: Stackhousiaceae
- *Stackhousia muricata*

Family: Sterculiaceae
- *Melhania oblongifolia*
- *Waltheria indica*

Family: Surianaceae
- *Stylobasium spathulatum*

Family: Thymelaeaceae
- *Pimelea ammocharis*

Family: Tiliaceae
- *Corchorus* aff. *laniflorus*
- *Corchorus sidoides* subsp. *vermicularis*
- *Corchorus tridens*
- *Triumfetta* aff. *chaetocarpa* (H123-10)
- *Triumfetta* aff. *chaetocarpa* (PAN3/4)
- *Triumfetta clementii*
- *Triumfetta echinata*
- † *Triumfetta* sp.

Family: Violaceae
- *Hybanthus aurantiacus*

Family: Zygophyllaceae
- *Tribulus astrocarpus*
- *Tribulus hirsutus*
- *Tribulus hystrix*
- *Tribulus macrocarpus*
- *Tribulus occidentalis*

Appendix J1

Wheatstone Project Terrestrial Fauna Survey

Tables

Figures

Plates

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Biota Environmental Sciences

Wheatstone Project Terrestrial Fauna Survey

Prepared for URS Australia Pty Ltd and Chevron Australia Pty Ltd

January 2010

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1.0 Summary

1.1 Background

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future 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 plants.

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). The investigations outlined in this report have been conducted to support these environmental impact assessment processes. Biota Environmental Sciences Pty Ltd (Biota) was subcontracted through URS Australia Pty Ltd (URS) to provide an assessment of the terrestrial fauna occurring in habitats within a study area encompassing the Wheatstone project footprint area and surrounds. The extent of this study area was approximately 9,738 ha, encompassing the proposed gas plant facility, Shared Infrastructure Corridor (SIC), camp area, Domgas pipeline corridor and other adjacent areas that will remain undisturbed by the proposal.

The scope of the study was to:

- review and consolidate relevant findings of previous fauna surveys in Onslow locality, including a desktop review of mangrove fauna;
- undertake a Level 2 fauna survey consistent with relevant EPA Guidance Statements;
- complete a survey of terrestrial fauna to meet the requirements of the Wheatstone Project Environmental Scoping Document
- identify and assess the local and regional conservation significance of the fauna assemblage and habitats present in the study area;
- document the vertebrate and potential short-range endemic (SRE) invertebrate fauna assemblage within the defined study area using established sampling techniques; and
- identify fauna of particular conservation significance (particularly Schedule and Priority listed species, as well as potential SRE taxa).

1.2 Methodology

The single-phase survey was conducted from 14th to 23rd of April 2009. A systematic census of terrestrial fauna assemblages, including avifauna, mammals and herpetofauna (reptiles and frogs), was carried out at 16 trapping sites located within seven habitat types identified from the primary impact components of the study area (the gas plant, SIC and camp areas). These broadly correspond to the sub-association vegetation units identified in the flora survey of Biota (2009a) and comprised:

- *Spinifex* and *Triodia* grassland and Buffel tussock on Primary dunes;
- *Triodia epactia* dominated hummock grassland on inland dune system;
- *Acacia* spp. over *Triodia epactia* hummock grassland on sand plain or swales;
- *Acacia* spp. over Buffel tussock on clay plains;
- Samphire claypans;
- Tussock grassland on clay plains; and
- *Eucalyptus victrix* and Buffel tussock dominated drainage line.

Open to closed mangrove shrubland, dominated by *Avicennia marina*, also occurred on the northern margins of the study area. These were not within the spatial scope of the study at the time of the field survey however, and fauna utilising this habitat were assessed ion the basis of existing data (Section 1.1).

The central component of the survey consisted of trapping grids comprising 10 pitfall traps (alternating 20 L buckets and 150 mm diameter PVC tubes) spaced at 10 m intervals and connected by a single length (100 m) of 300 mm high flywire fence. Of these, five trapping sites consisted of additional funnel traps (n=6) and Elliott box traps (n=20).

Bats were sampled via direct capture using harp nets and through echolocation call recordings. Bat echolocation calls were recorded using Anabat II and Anabat SD1 bat detector units, which detect and record ultrasonic echolocation calls emitted during bat flight.

A total of 32 avifauna censuses were completed across 16 systematic sites. Censuses were conducted between approximately 7:00 am and 1:00 pm, and were supplemented by the recording of opportunistic sightings of birds while working in the study area.

Potential SRE invertebrates were targeted at the primary systematic sites and at a further eight dedicated SRE sampling and non-systematic fauna sites along the Domgas pipeline corridor. The potential SRE taxa targeted included:

- Mygalomorphae (Trapdoor Spiders);
- Diplopoda (Millipedes);
- Pulmonata (Land Snails); and
- Pseudoscorpionida (Pseudoscorpions).

Additional non-systematic collection was also undertaken by the survey team at these sites to supplement trapping efforts, and to investigate habitats not sampled using systematic methods.

1.3 Results

1.3.1 Vertebrates

The survey yielded a combined total of 128 vertebrate species, comprising 51 herpetofauna species, 60 avifauna species and 17 mammals (Table 1.1).

Table 1.1: Number of species recorded during the Wheatstone Project fauna survey.

Fauna Group	Number of Species
Amphibians	4
Reptiles	47
Avifauna	60
Native Volant mammals (bats)	5
Native Non-Volant Mammals	9
Introduced Mammals	3
Total:	**128**

A total of 51 herpetofauna species were recorded from the study area. This comprised one tree frog (Hylidae), three ground frogs (Myobatrachidae), nine geckos (Gekkonidae), four legless lizards (Pygopodidae), 14 skinks (Scincidae), five dragons (Agamidae), three monitors (Varanidae), three blind snakes (Typhlopidae), two pythons (Pythonidae) and seven front-fanged snakes (Elapidae).

By far the most common herpetofauna species was the ground frog *Notaden nichollsi* at 1,687 individuals, accounting for 56% of the herpetofauna records. Most records of this species were from coastal and inland dunes, in response to recent rains. The skink *Lerista bipes* was the most abundant reptile species encountered during the survey, with 190 records from primary dune,

inland dune and sand/loam plain habitats. Also relatively common were the skinks *Lerista onsloviana* (n (number of records) =32) and *Ctenotus pantherinus* (n=32).
As is commonly the case, the Scincidae was the most speciose herpetofauna family with 14 species (27% of all herpetofauna species recorded).

Sixty bird species were recorded within the study area during the survey. The total species tally comprised 34 non-passerine species and 26 passerine species from 33 families. The zebra finch (*Taeniopygia guttata*) was the most abundant species recorded (323 records), representing over 31% of recorded avifauna. The most speciose family of birds was the Accipitridae (birds of prey including Osprey, Harriers, Kites and Eagles) with eight recorded species.

Inland dune habitat exhibited the highest avifauna richness during the survey, with 30 species recorded (50% of the recorded bird species). Drainage habitat also exhibited high avifauna richness with 19 species recorded.

Seventeen mammal species (14 native and three introduced) were recorded from the study area. Twelve non-volant (ground-dwelling) mammal species were recorded during the survey, comprising three dasyurids (carnivorous marsupials), two macropods (kangaroos and wallabies), five murids (murid rodents), one feline (cat) and one bovid (cloven hoofed mammal).

Five bat species were recorded within the study area including three vespertilionids (evening bats), one emballonurid (sheathtail bats) and one molossid (freetail bats).

1.3.2 Potential SRE Invertebrates

Two pseudoscorpion taxa, a group with the potential to harbour SREs, were recorded from the Wheatstone study area (*Synsphyronus* sp. '8/1 Pilbara' and *Solinus* sp. 1). The specimens of *Synsphyronus* sp. '8/1 Pilbara' collected at WHTSRE01 and WHTSRE07 all represent the same taxon. The collection sites for the specimens were situated in the Uaroo and Giralia Land Systems, both of which are widespread and well represented in the Pilbara and Carnavon bioregion.

Considering that:

- the collection sites for *Synsphyronus* sp. '8/1 Pilbara' just within this study area are separated by a distance of over 50 km;
- the Land Systems to which these sites belong are widespread, do not contain isolated remnant landforms, and are not patchily distributed in the region ;
- the habitat from which they were recorded is not isolated or restricted in the landscape (emergent *Corymbia* sp. trees over *Triodia* hummock grass plain);
- the genus exhibits a phoretic (animal-assisted) dispersal mode; and
- few other members of this genus are known to be SREs,

initial assessment indicated a low risk that this taxon represents an SRE. This was subsequently confirmed by the WA Museum, which advised that this taxon is not an SRE (Mark Harvey, WA Museum pers. comm., 2009). While only a single specimen of *Solinus* sp. 1 was recorded, it was from the same microhabitat (beneath peeling bark on a *Corymbia* tree) as the *Synsphyronus* sp. 1 specimens. Advice from the WA Museum also confirmed that this same taxon has been recorded from five other locations in the region and is also not an SRE (Mark Harvey, WA Museum pers. comm., 2009).

1.4 Conservation Significance

None of the habitats present in the Wheatstone study area are listed as Threatened Ecological Communities (TECs). The ephemeral creekline drainage habitat present at small extent in the south-west of the study area is, however, considered an 'ecosystems at risk' in the Cape Range subregion. The mangrove communities adjoining the terrestrial ecology study area are also considered 'ecosystems at risk' within the Roebourne subregion. The remaining habitat types are well represented in the locality and wider region and not of elevated conservation significance.

Based on reviews of habitats and known fauna distributions it is considered unlikely that any listed Schedule 1 species would occur within the Wheatstone study area. The Priority 1 species the Little Northern Freetail-bat (*Mormopterus loriae cobourgensis*) and the Priority 4 Western Pebble-mound Mouse (*Pseudomys chapmani*) and Australian Bustard (*Ardeotis australis*) were recorded during the field surveys, along with three *Environment Protection and Biodiversity Conservation* (*EPBC) Act 1999* listed migratory species (the Rainbow Bee-eater *Merops ornatus*, Fork-tailed Swift *Apus pacificus* and White-bellied Sea Eagle *Haliaeetus leucogaster*). In all cases, none or only a small proportion of local habitat suitable for these taxa would be cleared relative to their wider distribution in the Onslow locality and the wider region.

1.5 Comparison with other Surveys in the Locality

A detailed comparison of the faunal assemblage and individual species records from this survey with other recent surveys in the locality was completed for this study (where these data were publicly available). There have been several relevant previous fauna studies completed in the vicinity of the Wheatstone study area, including:

- Onslow Solar Saltfield three-phase terrestrial fauna survey (1996, 2000 and 2005) (Biota 2005b) (Cape Range subregion of the Carnarvon bioregion and Roebourne subregion of the Pilbara bioregion; ~33 km from the Wheatstone study area; 4 km from the north-east end of the Wheatstone study area).
- WA Museum terrestrial fauna survey at Tubridgi Point 2005 (WAM database 2009) (Cape Range subregion of the Carnarvon bioregion; ~11 km from the north-west end of the Wheatstone study area).
- Department of Environment and Conservation (DEC) Cane River Conservation Park fauna surveys at Tubridgi Point 2004 (WA Museum database 2009) (Roebourne subregion of the Pilbara bioregion; ~9 km from the south-east end of the Wheatstone study area).
- Yannarrie Salt Project Fauna Survey (Biota 2005a) (Cape Range subregion of the Carnarvon bioregion; ~33 km from the north-west end of the Wheatstone study area).
- Chevron Domgas Project Onslow Fauna Assessment (Validus 2008); (Cape Range subregion of the Carnarvon bioregion and Roebourne subregion of the Pilbara bioregion; a corridor adjoining the western margin of the current study area and overlapping the Domgas pipeline route).
- API Management Onslow Rail Corridor Terrestrial Fauna Survey (Biota 2009b); (Roebourne subregion of the Pilbara bioregion; a corridor from Red Hill station to Onslow intersecting the current study area).

Although conducted under different seasonal conditions, including additional habitats, and with somewhat differential sampling effort, this still provides useful contextual information for the current study.

A very similar listing of Threatened and migratory species to that recorded from the Wheatstone study area was recorded in these previous surveys. Consistent with the assessment presented in this report, no Schedule listed species have been recorded during any of these other surveys from sites in the Onslow locality.

The species richness recorded from the Wheatstone study area is greater than all of the Validus (2008), Yannarie Salt Project and Onslow Salt surveys (the latter of which was conducted over several phases; Biota 2005b). The data from the Wheatstone study area also share the majority of vertebrate species with these surveys. The assemblage documented in this study approaches the diversity of the Tubridgi, API rail corridors and Cane River survey, all of which were completed over either a far wider range of habitats or multiple phases. This indicates that the current survey documented an adequate proportion of the fauna, as these latter surveys were conducted over more than one phase and sampled more habitats than this study. This reflects the optimal timing of the Wheatstone Project fauna survey, under warm conditions in early autumn, following late summer cyclonic rainfall.

2.0 Introduction

2.1 Project Background

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future 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 plants.

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 MTPA of LNG. The Wheatstone Project has been referred to the Environmental Protection Authority (EPA) and the Department of the Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support these environmental impact assessment processes. Biota Environmental Sciences Pty Ltd (Biota) was subcontracted through URS Australia Pty Ltd (URS) to provide an assessment of the terrestrial fauna occurring in habitats within the Wheatstone Project footprint area and surrounds.

The extent of this study area was approximately 9,738 ha, encompassing the proposed gas production facility, camp area, Domgas pipeline corridor and other adjacent areas that will remain undisturbed by the proposal (hereafter 'the study area'). The location and spatial extent of the study area is shown in Figure 2.1.

2.2 Study Objectives and Scope

The survey was planned and implemented in accordance with EPA Position Statement No. 3 "Terrestrial Biological Surveys as an Element of Biodiversity Protection" (EPA 2002), Guidance Statement No. 56 "Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia" (EPA 2004) and Guidance Statement No. 20 "Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia" (EPA 2009).

The scope of the survey was to:

- review and consolidate relevant findings of previous fauna surveys in Onslow locality, including a desktop review of mangrove fauna;
- undertake a Level 2 fauna survey consistent with relevant EPA Guidance Statements;
- complete a survey of terrestrial fauna to meet the requirements of the Wheatstone Project Environmental Scoping Document
- identify and assess the local and regional conservation significance of the fauna assemblage and habitats present in the study area;
- document the vertebrate and potential short-range endemic (SRE) invertebrate fauna assemblage within the defined study area using established sampling techniques; and
- identify fauna of particular conservation significance (particularly Schedule and Priority listed species, as well as potential SRE taxa).

2.3 Purpose of this Report

The proposed Wheatstone Project was referred to the EPA by Chevron in 2008. The EPA determined that the proposal would be formally assessed at the level of Environmental Review and Management Programme (ERMP) under Part IV of the *Environmental Protection Act 1986*. This report describes the methodology employed for the fauna survey of the Wheatstone study area. It documents the methods and results of the survey and provides an assessment of the fauna assemblages and species recorded. This document is intended as a supporting technical document to the ERMP for the Wheatstone Project.

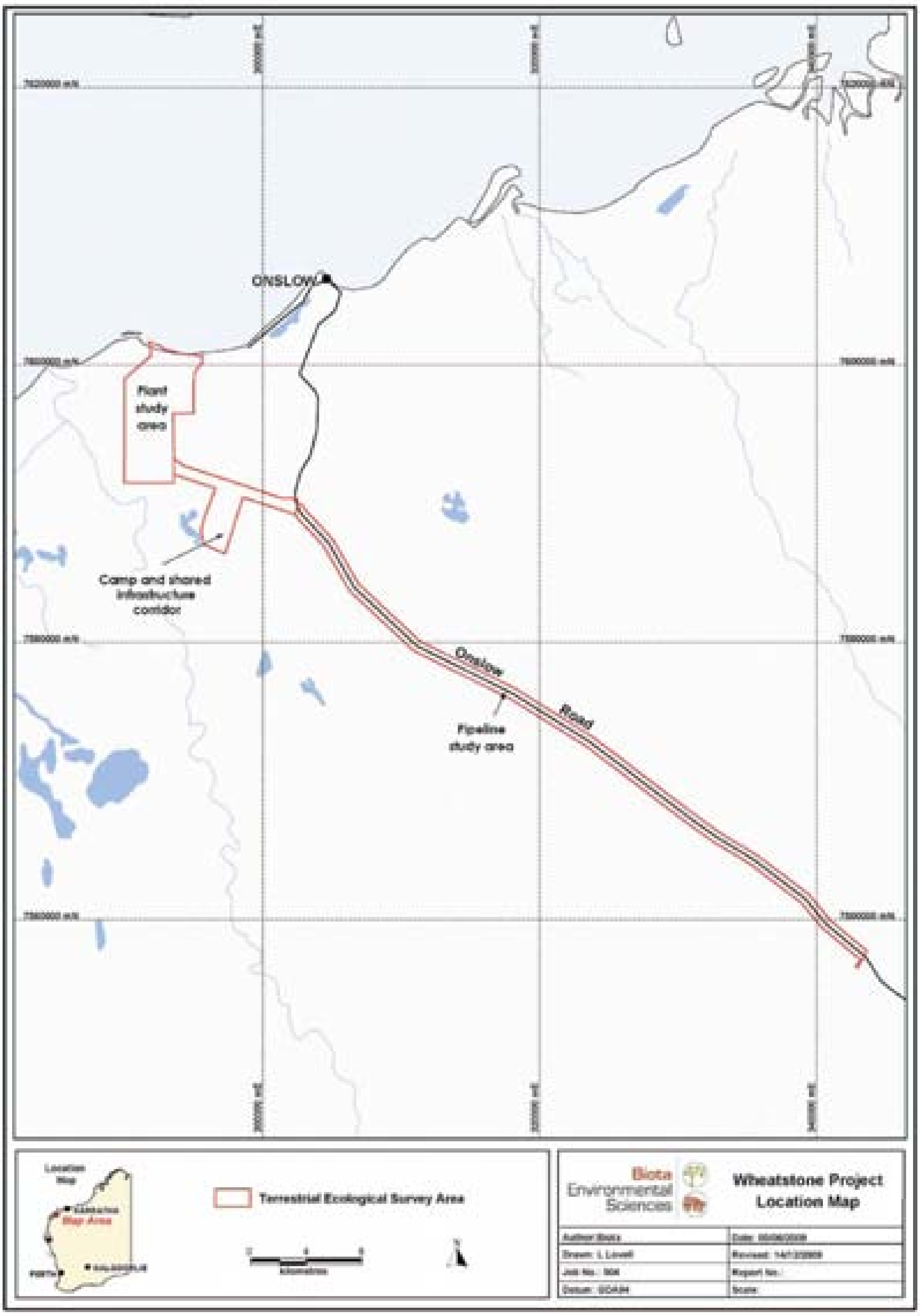

Figure 2.1: Location map and extent of the Wheatstone Project study area, showing study area extents for the main Wheatstone Project components.

2.4 Physiographic and Biological Context of the Study Area

2.4.1 Geology

The Wheatstone study area encompasses five major geological units (Table 2.1).

Table 2.1: Geological units occurring within the Wheatstone study area (as mapped by Thorne and Trendall 2001).

Unit	Geological Description
Czp	Claypan- dominant terrain- claypans with longitudinal and net dunes, and/or flat deflation lag surfaces; clay, silt, sand and gravel.
Qw	Intertidal flats and mangrove swamps- calcareous clay, silt and sand
Qs	Beaches and coastal dunes- light grey, unconsolidated and poorly consolidated quartzose calcarenite.
Qe	Longitudinal and network dunes and residual sand plains- reddish-brown to yellowish quartz sand.
Qt	Supratidal flats- calcareous clay, silt and sand with authigenic gypsum and superficial algal mats and salt crusts.

2.4.2 IBRA Bioregion and Subregions

The Interim Biogeographic Regionalisation for Australia (IBRA) recognises 85 bioregions (Environment Australia 2000). The Wheatstone study area is located at the junction between two of the IBRA bioregions, Carnarvon and the Pilbara. The majority of the study area (83%; comprising the plant study area, camp site study area and the western two-thirds of the Domgas pipeline corridor study area) lies at the north-eastern edge of the Carnarvon bioregion, while the remaining area (17%; comprising the easternmost 20 km section of the Domgas pipeline study area) lies at the south-western edge of the Pilbara region.

2.4.2.1 Carnarvon (CAR)

There are two biological subregions within the Carnarvon bioregion (Environment Australia 2000):

1. Cape Range: Rugged tertiary limestone ranges and extensive areas of red Aeolian dunefields, quaternary coastal dunes and mud flats. Acacia shrublands (*Acacia stuartii* or *A. bivenosa*) over *Triodia* on limestone and red dune fields. *Triodia* hummock grassland with sparse *Eucalyptus* trees and shrubs on the Cape Range. The Exmouth Gulf supports extensive mangroves in tidal mudflats and sheltered embayments, while the hinterland area supports a mosaic of samphire and saltbush low shrublands in saline alluvial plains.
2. Wooramel: Alluvial plains associated with downstream sections and deltas of the Gascoyne, Minilya and Wooramel rivers. *Acacia* shrublands (Mulga, Bowgada and *A. coriacea*) over bunch grasses on red sandy ridges and plains. Mangroves confined to small areas near Lake MacLeod and Carnarvon. Samphire and saltbush low shrublands on saline alluvial plains in near-coastal areas.

The parts of the Wheatstone study area lying within the Carnarvon bioregion are all located within the Cape Range subregion. For further discussion of this subregion, see Kendrick and Mau (2002).

2.4.2.2 Pilbara (PIL)

There are four biological subregions within the Pilbara bioregion (Environment Australia 2000):

1. Hamersley: Mountainous area of proterozoic sedimentary ranges and plateaux with Mulga (*Acacia aneura*) low woodland over bunch grasses on fine textured soils and Snappy Gum (*Eucalyptus leucophloia*) over *Triodia brizoides* on skeletal sandy soils of the ranges.
2. The Fortescue Plains: Alluvial plains and river frontages. Salt marsh, mulga-bunch grass, and short grass communities on alluvial plains. River Gum (*Eucalyptus camaldulensis*) woodlands fringe the drainage lines. This is the northern limit of Mulga (*Acacia aneura*).
3. Chichester: Archaean granite and basalt plains supporting shrub steppe characterised by *Acacia pyrifolia* over *Triodia pungens* hummock grasses. Snappy Gum tree steppes occur on ranges.

4. Roebourne: Quaternary alluvial plains with a grass savanna of mixed bunch and hummock grasses, and dwarf shrub steppe of *Acacia translucens* over *Triodia pungens*. Samphire, *Sporobolus* and Mangal occur on marine alluvial flats. Arid tropical with summer rain.

The parts of the Wheatstone study area lying within the Pilbara bioregion are all located within the Roebourne subregion. For further discussion of this subregion, see Kendrick and Stanley (2001).

2.4.3 Land Systems

Land Systems (Rangelands) mapping covering the study area has been prepared by the Western Australian Department of Agriculture (Payne et al 1988). Land Systems are comprised of repeating patterns of topography, soils, and vegetation (Christian and Stewart 1953) (i.e. a series of "land units" that occur on characteristic physiographic types within the Land System). Table 2.2 provides a summary of the Land Systems present in the Wheatstone study area and their status in Western Australia, while Table 2.3 provides descriptions of each Land System. As Land Systems provided a broad habitat context for, and input to, survey site selection (Section 3.4.1), the location of the survey sites on Land Systems is provided in Figure 4.1.

Table 2.2: Distribution of Land Systems within the Wheatstone study area, and in the State (data from Payne et al. 1988 and van Vreeswyk et al. 2004).

Land System	**Total Area in the State (ha)**	**General Distribution through the State**	**Area within Wheatstone Study area**	
			Hectares	**% of total in State**
Dune (RGEDUN)	49,302	Distributed through near-coastal areas over a range of ~170 km, from the eastern side of the Exmouth Gulf to east of Onslow; predominantly in the Carnarvon bioregion, extending into the westernmost Pilbara bioregion	931	1.9%
Giralia (RGEGIR)	362,631	Distributed over a range of >200 km from inland of Lake MacLeod to Onslow; several very large areas in the Carnarvon bioregion and numerous smaller areas within the Pilbara bioregion	1,117	0.3%
Littoral (RGELIT)	337,551	Widespread over 650 km of coastline, stretching from the base of the Exmouth Gulf to east of Port Hedland; predominantly in the Carnarvon and Pilbara bioregions	1,276	0.4%
Minderoo (RGEMNO)	144,436	Localised to an area of ~90 km by 40 m within the northern section of the Carnarvon bioregion, but well represented within this area	463	0.3%
Onslow (RGEONS)	74,022	Widespread towards the coast in both the Carnarvon and Pilbara bioregions, extending from the eastern side of the Exmouth Gulf to the Fortescue River	3,136	4.2%
Stuart (RGESTT)	276,685	Localised but well represented within the western section of the Pilbara bioregion, with occasional occurrences in the adjacent Gascoyne bioregion	560	0.2%
Uaroo (RGEUAR)	1,412,819	Widespread in the northwest region from inland of Lake MacLeod to the eastern Pilbara; occurrences in the Carnarvon, Gascoyne and Pilbara bioregions.	2,255	0.2%
State Total	**2,657,446**			

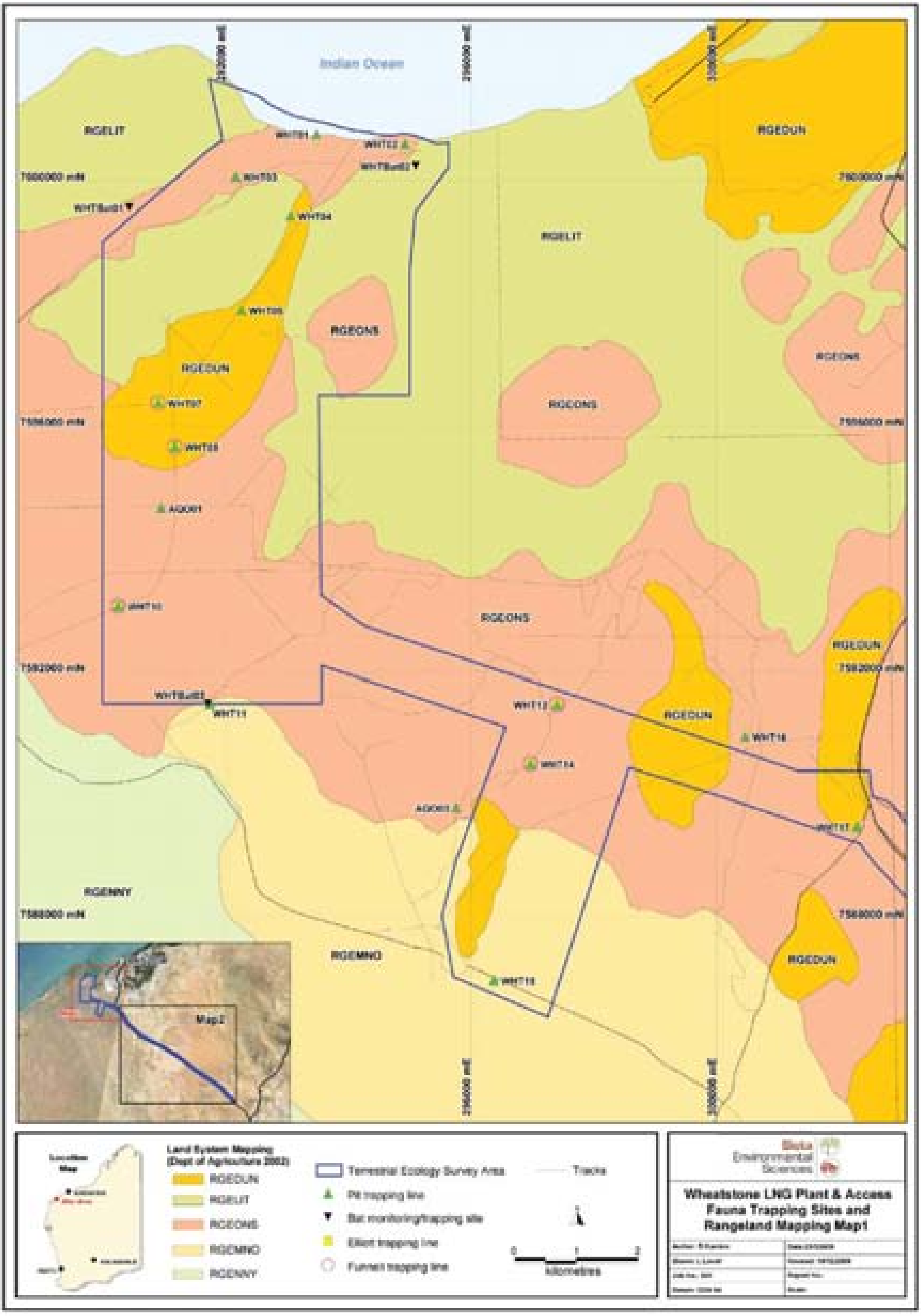

Figure 2.2: Rangelands and fauna trapping sites within the Wheatstone study area (Map 1 – western portion of study area).

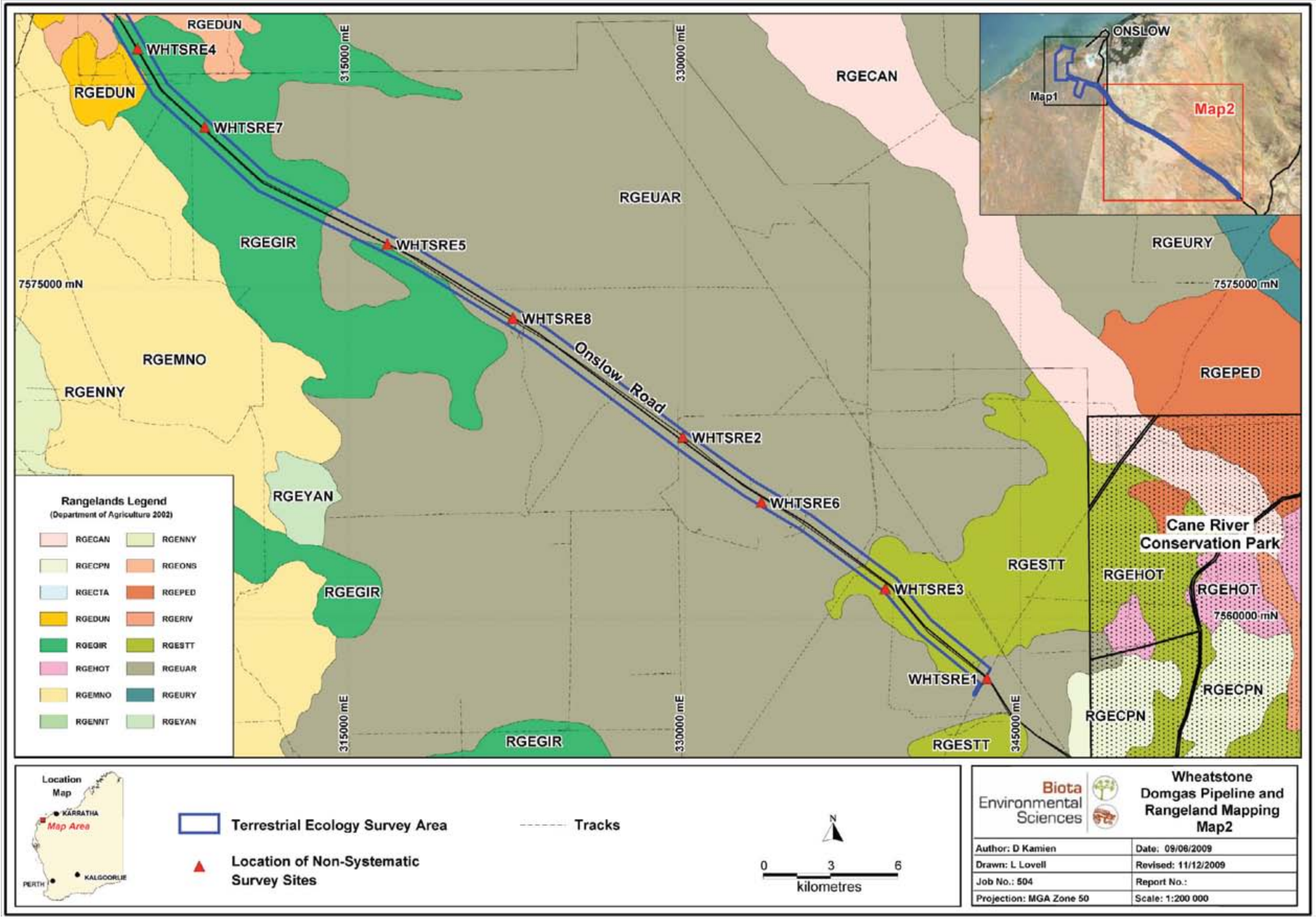

Figure 2.3: **Rangelands and Wheatstone study area (Map 2 – eastern portion of study area).**

Table 2.3: **Descriptions of Land Systems in the Wheatstone study area** (from van Vreeswyk et al. 2004, Payne et al. 1987).

Land System	Description
Dune	Dunefields supporting soft spinifex grasslands; vegetation mostly in very good condition; occurs in the northern section of the development area including portions of the Wheatstone plant study area, the Wheatstone camp study area and a small section of the Wheatstone pipeline study area.
Giralia	Linear dunes and broad sandy plains supporting hard and soft spinifex grasslands; vegetation mostly in very good condition; occurs in the central section of the Wheatstone pipeline study area.
Littoral	Bare coastal mudflats with mangroves of seaward fringes, *Tecticornia* (samphire) flats, sandy islands, coastal dunes and beaches; vegetation mostly in good to very good condition; occurs in the northern section of the Wheatstone plant study area.
Minderoo	Alluvial plains supporting tall shrublands and tussock grasslands, and sandy plains supporting hummock grasslands; vegetation mostly in good condition; occurs in the southern section of the Wheatstone camp study area.
Onslow	Sandplains, dunes and claypans supporting soft spinifex grasslands and minor tussock grasslands; vegetation mostly in good to very good condition; occurs in the northern section of the study area, including over half of the Wheatstone plant and camp study areas and a section of the Wheatstone pipeline study area.
Stuart	Gently undulating stony plains supporting hard and soft spinifex grasslands and snakewood shrublands; vegetation mostly in very good condition; occurs at the eastern end of the Wheatstone pipeline study area.
Uaroo	Broad sandy plains supporting shrubby hard and soft spinifex grasslands; vegetation mostly in good to very good condition; occurs along a large section of the central Wheatstone pipeline study area, together with a small section at the easternmost tip.

2.4.4 Vegetation Mapping

Beard (1975) mapped the vegetation of the 'Pilbara' at a scale of 1:1,000,000. The extent of the Pilbara map sheet also covered the northern part of the Carnarvon Basin Bioregion and, within this, the Carnarvon Botanical District as defined by Beard. The study area is located in this Botanical District and includes parts of two of Beard's coastal plain units:

- The Onslow Coastal Plain, which is in the Fortescue Botanical District (~ Pilbara Bioregion); and
- The Yannarie Coastal Plain, which is in the Carnarvon Botanical District (~ Carnarvon Basin Region).

The Wheatstone study area is located within the Onslow Coastal Plain and is described by Beard (1975) as follows:

> *'On the seaward fringe there is a zone of hyper-saline mud fringed by a narrow mangrove zone of Avicennia marina, or rarely by sandhills, sparsely vegetated, predominantly with Triodia epactia/pungens (Soft Spinifex). On the hard, alkaline red soils, the vegetation consists of shrub steppe, with Acacia inaequilatera and Hakea lorea as characteristic large, scattered shrubs over a general cover of Triodia epactia/pungens. Small trees of Corymbia hamersleyana may be present on drainage lines. The sandy patches have a higher density of shrub species present such as Acacia inaequilatera, A. ancistrocarpa, A. sclerosperma and A. tetragonophylla over Triodia epactia/pungens. The introduced grass species *Cenchrus ciliaris is also commonly present.'*

It should be noted that given the large scale of Beard's mapping, these units are only broadly applicable to the vegetation occurring on site. Vegetation descriptions and mapping within the Wheatstone study area are discussed in more detail in Section 4.1 and Biota (2009a).

2.4.5 Conservation Reserves in the Locality

The closest gazetted conservation reserve to the Wheatstone study area is the C-class Cane River Conservation Park, approximately 4.5 km to the east of the eastern end of the Wheatstone pipeline study area. The Cane River Conservation Park, about 100 km southeast of Onslow, extends over 148,000 ha and includes several landforms and vegetation types of particular significance not found in other conservation reserves in the Pilbara[1].

The Pilbara bioregion is listed as a medium priority for funding for land purchase under the National Reserves System Co-operative Program due to the limited representation of the area in conservation reserves. Portions of various pastoral leases in the region have been nominated for exclusion for public purposes in 2015, when the leases come up for renewal. Many of the submissions are from the Department of Environment and Conservation (DEC), with the intention of adding these areas to the existing conservation estate in order to provide a comprehensive, adequate and representative reserve system.

The National Reserves System Co-operative Program's current proposals include extensions to the Cane River Conservation Park to include the Mt Minnie Pastoral Lease, Ashburton (110,921 ha), and part of the Nanutarra Pastoral Lease, Ashburton (70,030 ha)[2]. Once this extension of the Cane River Conservation Park is implemented, the eastern 44 km section of the Wheatstone pipeline study area will be located within the Park.

2.5 Previous Fauna Studies

The most relevant previous fauna studies completed in the vicinity of the Wheatstone study area include:

- Onslow Solar Saltfield three-phase terrestrial fauna survey (1996, 2000 and 2005) (Biota 2005b) (Cape Range subregion of the Carnarvon bioregion and Roebourne subregion of the Pilbara bioregion; ~33 km from the Wheatstone study area; 4 km from the north-east end of the Wheatstone study area).
- WA Museum terrestrial fauna survey at Tubridgi Point 2005 (WAM database 2009) (Cape Range subregion of the Carnarvon bioregion; ~11 km from the north-west end of the Wheatstone study area).
- DEC Cane River Conservation Park fauna surveys at Tubridgi Point 2004 (WA Museum database 2009) (Roebourne subregion of the Pilbara bioregion; ~9 km from the south-east end of the Wheatstone study area).
- Yannarrie Salt Project Fauna Survey (Biota 2005a) (Cape Range subregion of the Carnarvon bioregion; ~33 km from the north-west end of the Wheatstone study area).
- Chevron Domgas Project Onslow Fauna Assessment (Validus 2008); (Cape Range subregion of the Carnarvon bioregion and Roebourne subregion of the Pilbara bioregion; a corridor adjoining the western margin of the current study area and overlapping the Dogmas pipeline route).
- API Management Onslow Rail Corridor Terrestrial Fauna Survey (Biota 2009b); (Roebourne subregion of the Pilbara bioregion; a corridor from Red Hill station to Onslow intersecting the current study area).

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[1] http://www.dec.wa.gov.au/news/minister-for-the-environment/new-conservation-park-for-the-pilbara.html

[2] http://www.dec.wa.gov.au/news/minister-for-the-environment/new-conservation-park-for-the-pilbara.html

3.0 Survey Methodology

3.1 Database Searches

A search of the DEC Threatened Fauna Database was conducted for the Wheatstone study area (Appendix 1). The NatureMap database of the WA Museum was also searched for records of vouchered fauna from the locality (Appendix 2). The WA Museum results were compared to the recent Wheatstone survey and past fauna surveys in the locality (Appendix 2). In addition the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* Protected Matters database was searched for fauna of conservation significance potentially occurring within the study area (Appendix 3). These investigations were conducted using an area search with a 50 km buffer. The bounding coordinates for these searches were 21.22°S, 114.49°E and 22.27°S, 115.58°E.

3.2 Survey Timing and Weather

The Wheatstone single-phase fauna survey was conducted from 14th to 23rd of April 2009. Minimum temperatures recorded at Wheatstone during the survey ranged between 20.6°C to 24.0°C and maximum temperatures ranged between 28.2°C to 34.1°C (Table 3.1).

Table 3.1: Daily meteorological observations for Onslow recorded during the survey.

Date	14/4	15/4	16/4	17/4	18/4	19/4	20/4	21/4	22/4	23/4	Mean/Total
Maximum (°C)	31.4	28.2	30.8	32.5	32.2	32.6	31.5	31.3	31.5	34.1	31.6
Minimum (°C)	20.9	24.0	20.7	20.6	21.7	20.6	20.8	22.3	23.8	20.7	21.6
Rainfall (mm)	0	0	0	0	0	0	0	0	0	0	0.0

No rain was recorded in Onslow during the survey. A total of 443.4 mm of rain fell in Onslow during the six months prior to the survey, compared to the long term average rainfall of 135.9 mm for the October to March period. The survey was therefore conducted under optimal warm conditions following a period of higher than average rainfall. A large rain event was recorded in January 2009 (238.4 mm in 24 hours on 27/01/09), followed by significant precipitation in February 2009 (Figure 3.1 and Figure 3.2).

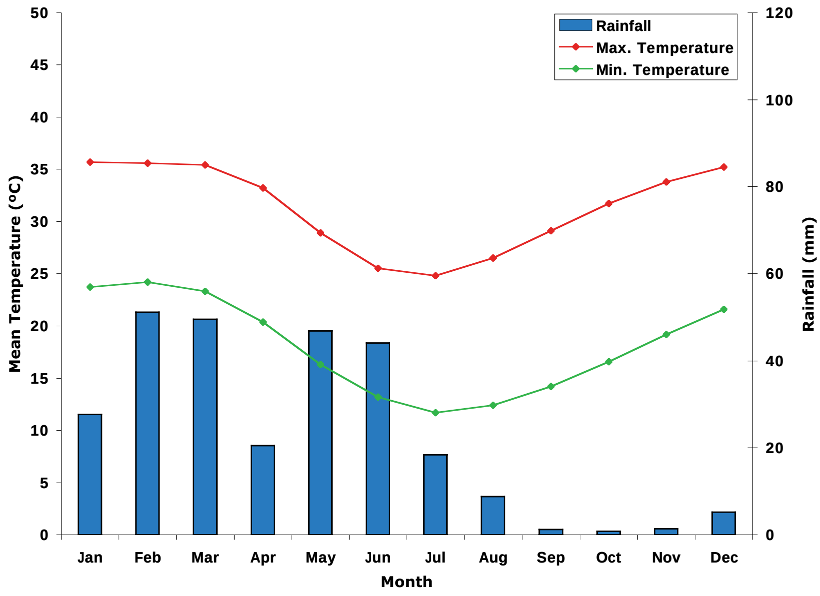

Figure 3.1: Long-term climatological summary for Onslow using data from 1887 to 2009 (data provided by the Western Australian Bureau of Meteorology).

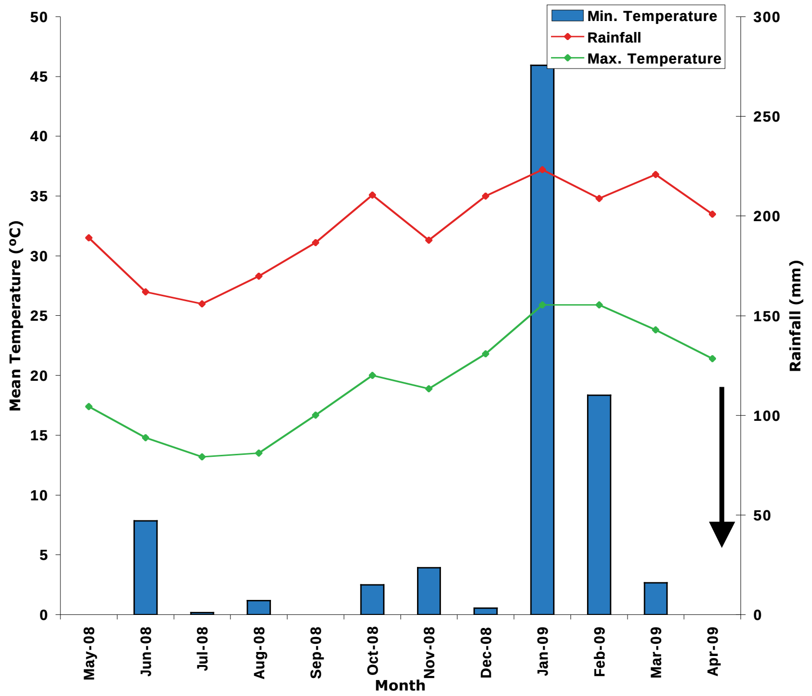

Figure 3.2: **Climatological summary for Onslow leading up to the survey period 2009** (data provided by Western Australian Bureau of Meteorology; arrow indicates timing of survey).

3.3 Fauna Survey Team

The terrestrial fauna sampling for the field survey was conducted under "Licence to Take Fauna for Scientific Purposes" No. SF006847 issued to Mr Garth Humphreys (Appendix 4). The fauna survey team comprised Mr Dan Kamien, Mr Michael Greenham, Mr Paul Sawers, and Mr Garth Humphreys (all of Biota), and Mr Mark Cowan (private contractor). All members of the study team had more than 10 years of arid zone fauna survey experience.

Analysis of bat recordings was completed by Mr Dan Kamien using reference echolocation calls from the region. Invertebrate identifications were undertaken by Mr. Dan Kamien and Dr Mark Harvey (WA Museum). GIS analysis and maps in this report were prepared by Mr Luke Lovell (Biota).

3.4 Fauna Sampling

3.4.1 Selection and Location of Survey Sites within Habitats

The principal component of the Wheatstone study consisted of systematic fauna sampling centred on 16 trapping sites. A further eight non-systematic SRE survey sites were located along the Domgas pipeline corridor. The survey sites were located in environments considered to represent the range of habitats available within the study area. Sites were initially draft selected on the basis of aerial photography and Land System mapping (Section 2.4.3).

The fauna habitat classification was then refined in the field on the basis of the dominant landform, soils and vegetation types. The classification approach does not cover all microhabitats available to the entire assemblage of invertebrate and vertebrate fauna, as this would be difficult to resolve and logistically impracticable to sample. Rather, the classifications provide a convenient broader scale framework within which to summarise species occurrence. The faunal assemblage within these habitats will depend to some extent on the Land System in which they occur (Section 2.4.3), but can also differ for each Land System (as expressed in the vegetation classification). In other words, it is often the vegetation type that best approximates a meaningful habitat classification (Figure 4.1).

In addition to sampling the range of habitats present, the number of survey sites and allocation of effort within each habitat was proportional to the relative extent of each habitat within the study area (i.e. more sites were installed in the better represented habitats in the study area). Each survey site was installed within a habitat as defined, and was selected such that equal weight was given to accessibility of the sites in terms of regular inspection of traps. Locations of trapping sites are shown in the context of Land Systems on Figure 2.2 and in the context of the habitats present in Figure 4.1. Representative photos are presented in Section 4.1

3.4.2 Trapping Effort and Layout of Trapping Grids

Systematic censusing of terrestrial fauna assemblages, including mammals and herpetofauna, consisted of a single trapping line at each of the 16 sites (Section 4.1). All the sites consisted of 10 pit-fall traps, comprising alternating 20 L buckets and PVC tubes (150 mm diameter, 600 mm deep) spaced at 10 m intervals, connected by a 90 m long by 300 mm high flywire drift fence (Figure 3.3).

Of these 16 sites, five comprised an additional six funnel traps spaced in pairs along the length of the flywire drift fence. The same five sites also comprised 20 Elliott box traps (two transects of 10 traps placed in the vicinity of the existing pitfall line). These sites were selected for Elliott trapping as evidence of scats and burrows suggested mammal taxa more likely to be collected by this sampling method might have been present. This sampling design was consistent with other trapping layouts used for relevant contextual studies previously completed in the locality (e.g. the Onslow Salt and Yanarrie Salt fauna surveys; Section 2.5). Trapping effort at each location is shown in Table 3.2.

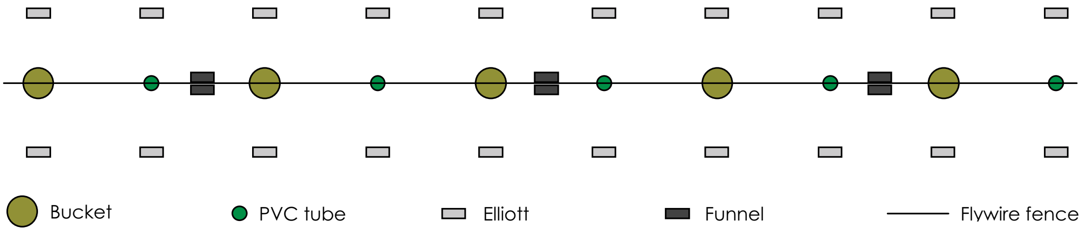

Figure 3.3: **Indicative layout of trapping grids used during the Wheatstone survey** (showing base case of pit trapping line and Elliott and funnel traps on sites where these were used; not to scale).

Table 3.2: **Location of sites and trap effort for the terrestrial fauna survey of the Wheatstone study area** (WGS84; Zone 50).

Site *	Easting mE	Northing mN	Trap Type	Date Opened	Date Closed	Nights Open	No. of Traps	Trap Effort
WHT01	293481	7600756	Pit	16/04/09	22/04/09	6	10	60
WHT02	294925	7600600	Pit	16/04/09	22/04/09	6	10	60
WHT03	292166	7600067	Pit	16/04/09	22/04/09	6	10	60
WHT04	293056	7599426	Pit	17/04/09	23/04/09	6	10	60
WHT05	292259	7597894	Pit	16/04/09	22/04/09	6	10	60
WHT07	290906	7596378	Pit	16/04/09	22/04/09	6	10	60
			Funnel	18/04/09	23/04/09	5	6	30
			Elliott	18/04/09	23/04/09	5	20	100
WHT08	291177	7595665	Pit	16/04/09	22/04/09	6	10	60
			Funnel	18/04/09	23/04/09	5	6	30
			Elliott	18/04/09	23/04/09	5	20	100
WHT10	290251	7593068	Pit	16/04/09	22/04/09	6	10	60
			Funnel	18/04/09	23/04/09	5	6	30
			Elliott	18/04/09	23/04/09	5	20	100
WHT11	291743	7591490	Pit	17/04/09	23/04/09	6	10	60
WHT12	297401	7591482	Pit	17/04/09	23/04/09	6	10	60
			Funnel	18/04/09	23/04/09	5	6	30
			Elliott	18/04/09	23/04/09	5	20	100
WHT14	296968	7590512	Pit	17/04/09	23/04/09	6	10	60
			Funnel	18/04/09	23/04/09	5	6	30
			Elliott	18/04/09	23/04/09	5	20	100

Table 3.2: Location of sites and trap effort for the terrestrial fauna survey of the Wheatstone study area (WGS84; Zone 50).

Site *	Easting mE	Northing mN	Trap Type	Date Opened	Date Closed	Nights Open	No. of Traps	Trap Effort
WHT15	296371	7586990	Pit	18/04/09	23/04/09	5	10	50
WHT16	300461	7590955	Pit	17/04/09	23/04/09	6	10	60
WHT17	302288	7589487	Pit	17/04/09	23/04/09	6	10	60
AQO01	290951	7594668	Pit	16/04/09	22/04/09	6	10	60
AQO03	295759	7589801	Pit	16/04/09	22/04/09	6	10	60
						Total Pit trap Effort		**950**
						Total Funnel Effort		**150**
						Total Elliott Effort		**500**

* Sites WHT06 and AQAO02 were preliminarily selected survey sites that were ultimately not installed due to access constraints.

3.4.3 Avifauna Sampling

Sampling of avifauna was carried out using a combination of techniques, including:

- unbounded area censuses conducted at the systematic sampling grids;
- unbounded area censuses conducted at opportunistic locations containing habitats or microhabitats likely to support previously unrecorded species; and
- opportunistic observation of avifauna while driving around the study area.

In total, 32 avifauna censuses were completed across 16 trapping sites (Table 3.3). Avifauna was sampled using 30-minute censuses at established trapping grids. Censuses were conducted between 7:00 am and 1:00 pm to coincide with daily patterns of bird activity. A total of 16 hours were dedicated to systematic avifauna censusing during the survey (Table 3.3).

Table 3.3: Date and time of systematic avifauna censuses undertaken within the Wheatstone study area.

Site	18 April 09	19 April 09	20 April 09	21 April 09	Survey Minutes
WHT01	12:05-12:35	8:20-8:50			60
WHT02	11:30-12:00	9:00-9:30			60
WHT03	12:40-13:10	7:40-8:10			60
WHT04	10:40-11:20	9:50-10:20			60
WHT05	10:05-10:35		9:25-9:55		60
WHT07	9:20-9:50		8:45-9:15		60
WHT08	8:45-9:15		8:10-8:40		60
WHT10	10:30-11:00		7:25-7:55		60
WHT11		8:05-8:35	8:00-8:30		60
WHT12	9:32-10:02	10:19-10:49			60
WHT14	8:53-9:23	9:40-10:10			60
WHT15			7:20-7:50	6:48-7:18	60
WHT16	9:13-9:43			8:35-9:05	60
WHT17	7:20-7:50	7:03-7:33			60
AQO01	8:10-8:40		7:26-7:56		60
AQO03	8:15-8:45		9:01-9:31		60
				Total	**960**

3.4.4 Bats

Bats were sampled using both direct capture methods via harp traps and echolocation call recordings by targeting mangrove and creekline habitats (Table 3.4, and Plate 3.1 to Plate 3.3).

Bat echolocation calls were recorded using Anabat II and Anabat SD1 bat detector units, which detect and record ultrasonic echolocation calls emitted during bat flight. The calls were stored on a compact flash card after being processed by an Anabat CF ZCAIM. Calls were visualised on Analook 3.3f software. Only sequences containing good quality search phase calls were considered for identification.

Table 3.4: Locations and effort of harp traps and Anabat units deployed during the Wheatstone fauna survey.

Site	Easting (mE)	Northing (mN)	Habitat	Sampling Method	Opened	Closed	Trap Effort (Nights)
WHTBat01	290429	7599569	Mangrove	Anabat Harp Trap	19/04/09	23/04/09	4
WHTBat02	295096	7600246	Mangrove	Anabat Harp Trap	19/04/09	23/04/09	4
WHTBat03	291711	7591500	Creekline	Anabat Harp Trap	19/04/09	23/04/09	4
					Total	**Anabat** **Harp Trap**	**12** **12**

Plate 3.1: Harp trap and habitat at site WHTBat01.

Plate 3.2: Harp trap and habitat at site WHTBat02.

Plate 3.3: Harp trap and habitat at site WHTBat03.

3.4.5 Non-systematic Sampling

A range of non-systematic fauna survey activities was undertaken by the survey team to supplement the trapping, and to investigate additional habitats identified during the course of the survey. These included:

- habitat specific searches for Schedule and Priority listed fauna species;
- documentation of opportunistic sightings and records;
- identification of road kills and other animal remains; and
- recording and identification of secondary signs (where possible) including tracks, scats and diggings.

These methods were used at all of the systematic trapping sites (Table 3.2; Figure 2.2) and were employed at a series of eight representative non-systematic sites along the Domgas pipeline study area (WHTSRE1 – WHTSRE08; Table 3.5; Figure 2.3). Habitat assessment, searches for Threatened fauna and targeted SRE sampling was also conducted at these latter Domgas pipeline study area sites.

3.4.6 Potential SRE Invertebrate Fauna Sampling

Specific invertebrate groups were targeted using both systematic and non-systematic collection techniques during the survey. Invertebrate groups targeted during the survey were primarily those considered to potentially support SRE taxa, which included:

- Mygalomorphae (Trapdoor Spiders);
- Diplopoda (Millipedes);
- Pulmonata (Land Snails); and
- Pseudoscorpionida (Pseudoscorpions).

Trapdoor spiders were specifically targeted by searching for burrows and excavating them with the aim of collecting and preserving individuals in 70% ethanol. One leg was removed and placed in 100% ethanol for future molecular studies. Pseudoscorpions were specifically targeted by peeling back bark of trees and searching beneath rocks. The majority of individuals were preserved in 70% ethanol for morphological identification, with a sub-sample preserved in 100% ethanol for future molecular studies. Millipedes were searched for under leaf litter and logs. Aestivating snails were targeted by digging under spinifex hummocks and in drainage gullies.

Sampling for SRE taxa was conducted at all 16 systematic survey sites, with the additional sampling effort represented by pit trapping at these locations (principally in respect of mygalomorph spiders and millipedes). A further eight unbounded dedicated SRE and opportunistic fauna sites were completed during the field survey as summarised in Table 3.5 and shown in Figure 2.3. The majority of these were situated along the Domgas corridor (Figure 2.3), given the narrow disturbance corridor for this component of the proposal (see Section 3.4.7). These were selected to provide representative sampling of the range of Land Systems and habitats present and targeted toward specific locations where SREs were judged more likely to occur (e.g. larger spinifex hummocks, rock piles and drainages). SRE searches following the methods outlined above were therefore conducted at a total of 24 sites spread across the survey are and representative of the range of habitats present, immediately following a period of rain (Section 3.2).

Table 3.5: Locations of dedicated SRE search and non-systematic fauna collection sites.

Site	Easting (mE)	Northing (mN)
WHTSRE1	343492	7557301
WHTSRE2	329917	7568223
WHTSRE3	338954	7561360
WHTSRE4	305573	7585788
WHTSRE5	316720	7576934
WHTSRE6	333423	7585788
WHTSRE7	308572	7582250
WHTSRE8	322327	7573606

3.4.7 Study Limitations

The following limitations should be recognised by the reader of this report:

- Not all sections of the study area were ground-truthed or equally sampled for fauna. Parts of the Wheatstone study area were inaccessible by vehicle, hence regular checking of fauna traps in these areas would not have been possible. However, systematic fauna sampling (the primary component of the study) was completed on the basis of trapping grid installation in habitats considered to be representative of the range of units present within the development area. In two cases, equivalent habitats were sampled immediately outside of the study area where access could not be achieved (sites WHT16 and AQO03).

- Terrestrial invertebrate sampling was targeted at a small number of specific groups that may harbour SRE taxa only.
- Given the narrow disturbance footprint, and its somewhat disturbed habitats adjoining the existing Onslow Road, no systematic vertebrate trapping was completed within the Domgas pipeline study area. A series of non-systematic, SRE fauna search and fauna habitat assessment sites were instead completed along this route to ground-truth habitats and assess species with naturally small distributions that could be affected (sites WHTSRE1 to WHTSRE8).
- As this study represents a single-phase survey it may therefore not have documented the full suite of fauna occurring in the study area. Additional, seasonal phases would probably add to the total species list. However, it should be noted that there have been a number of additional fauna surveys conducted in the region (see Section 2.5) and the recent Wheatstone survey can be adequately placed in the context of this existing data.
- As project definition is still at an early stage, this report does not provide an assessment of potential impacts and recommendations for management are not considered.

Despite the above limitations, the survey is considered to have provided an assessment of terrestrial fauna and fauna habitats suitable to support the assessment of the proposed Wheatstone Project.

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4.0 Results

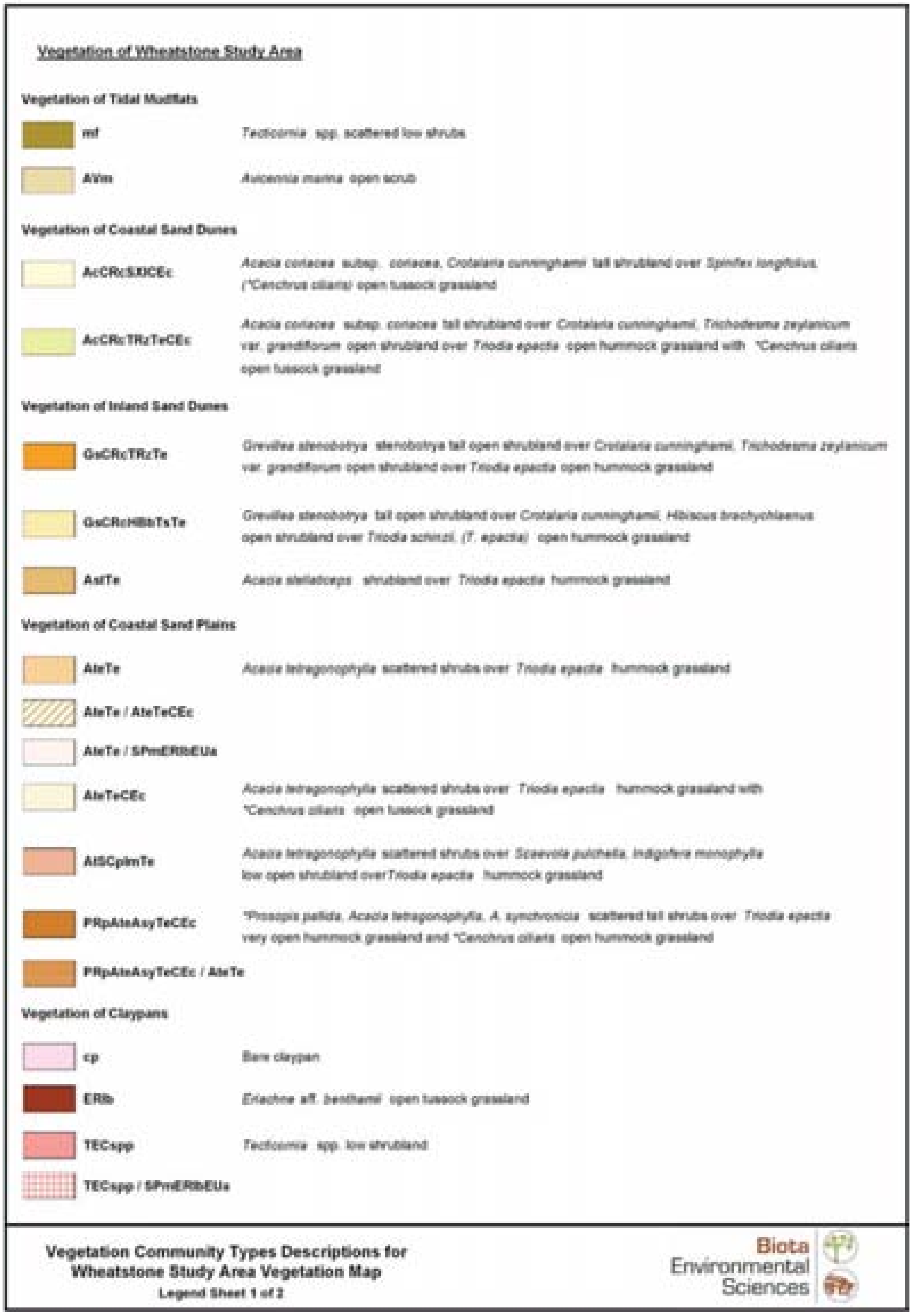
4.1 Fauna Habitats

The Plant and Camp study areas included seven main habitat units, distinguished on the basis of differences in substrate, vegetation, soils and landform (bold headings in Table 4.1). These units broadly corresponded to the vegetation sub-associations of Biota (2009b). At a finer scale, the location of the survey sites in the context of the vegetation types mapped by Biota (2009a) is shown in Figure 4.1 with the detailed vegetation type description for each site from this study given in Table 4.1. Site photographs are provided in Plate 4.1 to Plate 4.16. Three additional habitats occurred along the Pipeline study area, as sampled at non-systematic survey sites (Table 4.2).

Table 4.1: Fauna habitats sampled at systematic survey sites within the Wheatstone Plant and Camp study areas (habitats listed as Habitat Code: Habitat description).

Site	Landform	Fauna Habitat and Vegetation Description at Survey Sites	Soils
Primary Dune: Spinifex and Triodia grassland and Buffel tussock on primary dune			
WHT01	Primary Dune	*Acacia coriacea* subsp. *coriacea, Crotalaria cunninghamii* tall shrubland over *Spinifex longifolius/*Cenchrus ciliaris* open tussock grassland	Coastal Sand
WHT02	Primary Dune	*Acacia coriacea* subsp. *coriacea, Crotalaria cunninghamii* tall shrubland over *Spinifex longifolius/*Cenchrus ciliaris* open tussock grassland	Coastal Sand
Inland Dune: Triodia epactia dominated hummock grassland on inland dune system			
WHT05	Inland Dune	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland	Red Sand
WHT07	Inland Dune	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia/*Cenchrus ciliaris* open hummock grassland	Red Sand
WHT08	Inland Dune	*Crotalaria cunninghamii,* low open shrubland over *Triodia epactia* open hummock grassland	Red Sand
WHT16	Inland Dune	Scattered *Hakea stenophylla* over *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia/*Cenchrus ciliaris* open hummock grassland	Red Sand
WHT17	Inland Dune	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii, Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia/*Cenchrus ciliaris* open hummock grassland	Red Sand
Sand/Loam Plain: Acacia sp. over Triodia epactia hummock grassland on sand/loam plain			
WHT03	Swale	*Hakea stenophylla* scattered shrubs over *Acacia stellaticeps* scattered low shrubs over *Triodia epactia* open hummock grassland and **Cenchrus ciliaris* tussock grassland.	Red Sand
WHT12	Plain	*Acacia tetragonophylla* scattered low shrubs over *Triodia epactia* hummock grassland.	Loamy Sand
WHT14	Plain	*Triodia epactia* hummock grassland.	Loam
AQO01	Plain	Scattered *Acacia tetragonophylla* over *Triodia epactia* hummock grassland and **Cenchrus ciliaris* tussock grassland.	Loam
AQO03	Plain	*Acacia* spp. low open shrubs over *Triodia epactia* hummock grassland and **Cenchrus ciliaris* scattered tussock grassland.	Loamy Sand
Buffel on Clay: Acacia sp. over Buffel tussock grassland on clay plain			
WHT15	Plain	*Acacia tetragonophylla* open shrubland over **Cenchrus ciliaris/Triodia epactia* tussock grassland.	Clay
Samphire: Samphire claypan			
WHT04	Claypan	*Tecticornia* spp. low shrubland over *Eulalia aurea* tussock grassland	Clay
Tussock on Clay: Tussock grassland on clay plain			
WHT10	Plain	*Sporobolus mitchellii, Eriachne aff. benthamii, E. benthamii, Eulalia aurea* tussock grassland on low-lying clayey plains	Clay
Drainage: Eucalyptus sp. and Buffel tussock dominated drainage line			
WHT11	Creekline	*Eucalyptus victrix* open forest over *Eulalia aurea, *Cenchrus ciliaris* tussock grassland	Clay

Figure 4.1: **Location of systematic fauna survey sites in relation to the vegetation types of Biota (2009a)** (legend codes on following two pages).



Vegetation of Wheatstone Study Area

Vegetation of Tidal Mudflats

🟫	**mf**	*Tecticornia* spp. scattered low shrubs
🟨	**AVm**	*Avicennia marina* open scrub

Vegetation of Coastal Sand Dunes

⬜	**AcCRcSXlCEc**	*Acacia coriacea* subsp. *coriacea*, *Crotalaria cunninghamii* tall shrubland over *Spinifex longifolius*, (**Cenchrus ciliaris*) open tussock grassland
🟩	**AcCRcTRzTeCEc**	*Acacia coriacea* subsp. *coriacea* tall shrubland over *Crotalaria cunninghamii*, *Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland with **Cenchrus ciliaris* open tussock grassland

Vegetation of Inland Sand Dunes

🟧	**GsCRcTRzTe**	*Grevillea stenobotrya* stenobotrya tall open shrubland over *Crotalaria cunninghamii*, *Trichodesma zeylanicum* var. *grandiflorum* open shrubland over *Triodia epactia* open hummock grassland
🟨	**GsCRcHBbTsTe**	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii*, *Hibiscus brachychlaenus* open shrubland over *Triodia schinzii*, (*T. epactia*) open hummock grassland
🟧	**AsITe**	*Acacia stellaticeps* shrubland over *Triodia epactia* hummock grassland

Vegetation of Coastal Sand Plains

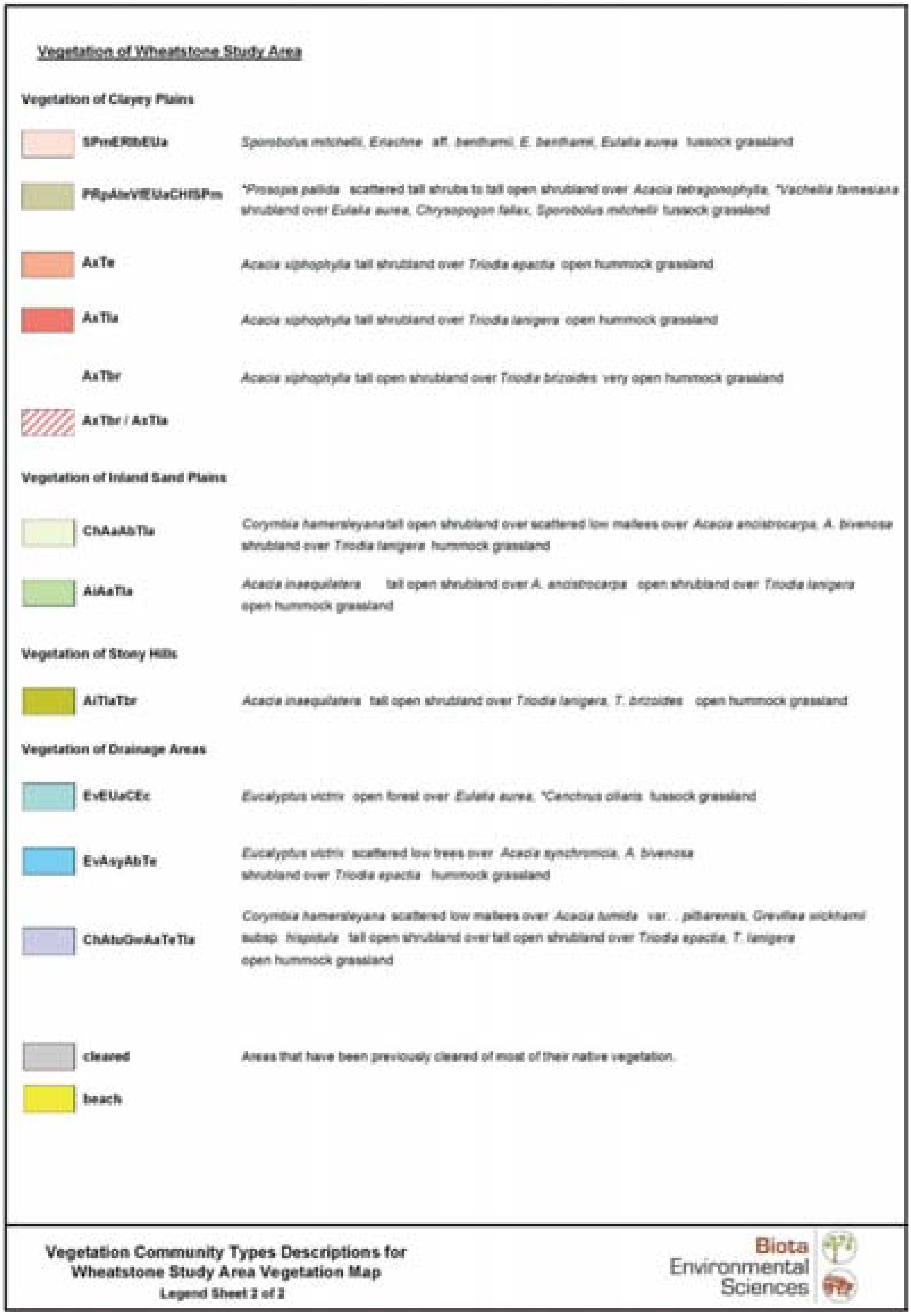
🟧	**AteTe**	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland
▨	**AteTe / AteTeCEc**	
⬜	**AteTe / SPmERbEUa**	
⬜	**AteTeCEc**	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland
🟥	**AtSCpImTe**	*Acacia tetragonophylla* scattered shrubs over *Scaevola pulchella*, *Indigofera monophylla* low open shrubland over *Triodia epactia* hummock grassland
🟧	**PRpAteAsyTeCEc**	**Prosopis pallida*, *Acacia tetragonophylla*, *A. synchronicia* scattered tall shrubs over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* open hummock grassland
🟧	**PRpAteAsyTeCEc / AteTe**	

Vegetation of Claypans

🟪	**cp**	Bare claypan
🟥	**ERb**	*Eriachne* aff. *benthamii* open tussock grassland
🟥	**TECspp**	*Tecticornia* spp. low shrubland
▦	**TECspp / SPmERbEUa**	

Vegetation Community Types Descriptions for
Wheatstone Study Area Vegetation Map
Legend Sheet 1 of 2

Biota
Environmental
Sciences



Vegetation of Wheatstone Study Area

Vegetation of Clayey Plains

⬜	**SPmERbEUa**	*Sporobolus mitchelli, Eriachne* aff. *benthamii, E. benthamii, Eulalia aurea* tussock grassland
🟫	**PRpAteVfEUaCHfSPm**	**Prosopis pallida* scattered tall shrubs to tall open shrubland over *Acacia tetragonophylla, *Vachellia farnesiana* shrubland over *Eulalia aurea, Chrysopogon fallax, Sporobolus mitchelli* tussock grassland
🟧	**AxTe**	*Acacia xiphophylla* tall shrubland over *Triodia epactia* open hummock grassland
🟥	**AxTla**	*Acacia xiphophylla* tall shrubland over *Triodia lanigera* open hummock grassland
	AxTbr	*Acacia xiphophylla* tall open shrubland over *Triodia brizoides* very open hummock grassland
▨	**AxTbr / AxTla**	

Vegetation of Inland Sand Plains

⬜	**ChAaAbTla**	*Corymbia hamersleyana* tall open shrubland over scattered low mallees over *Acacia ancistrocarpa, A. bivenosa* shrubland over *Triodia lanigera* hummock grassland
🟩	**AiAaTla**	*Acacia inaequilatera* tall open shrubland over *A. ancistrocarpa* open shrubland over *Triodia lanigera* open hummock grassland

Vegetation of Stony Hills

🟨	**AiTlaTbr**	*Acacia inaequilatera* tall open shrubland over *Triodia lanigera, T. brizoides* open hummock grassland

Vegetation of Drainage Areas

🟦	**EvEUaCEc**	*Eucalyptus victrix* open forest over *Eulalia aurea, *Cenchrus ciliaris* tussock grassland
🟦	**EvAsyAbTe**	*Eucalyptus victrix* scattered low trees over *Acacia synchronicia, A. bivenosa* shrubland over *Triodia epactia* hummock grassland
🟪	**ChAtuGwAaTeTla**	*Corymbia hamersleyana* scattered low mallees over *Acacia tumida* var. . *pilbarensis, Grevillea wickhamii* subsp. *hispidula* tall open shrubland over tall open shrubland over *Triodia epactia, T. lanigera* open hummock grassland

⬜	**cleared**	Areas that have been previously cleared of most of their native vegetation.
🟨	**beach**	

Vegetation Community Types Descriptions for
Wheatstone Study Area Vegetation Map
Legend Sheet 2 of 2

Biota
Environmental
Sciences

Plate 4.1: Site WHT01

Plate 4.2: Site WHT02

Plate 4.3: Site WHT03

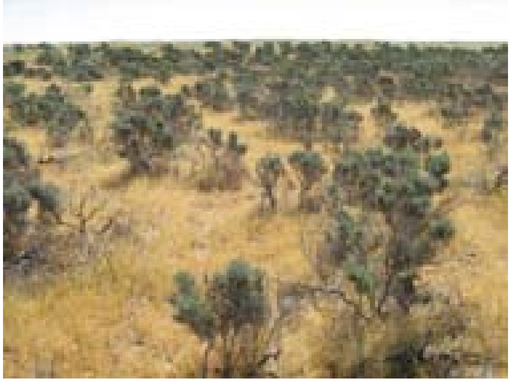


Plate 4.4: Site WHT04

Plate 4.5: Site WHT05

Plate 4.6: Site WHT07

Plate 4.7: Site WHT08

Plate 4.8: Site WHT10

Plate 4.9: Site WHT11

Plate 4.10: Site WHT12

Plate 4.11: Site WHT14

Plate 4.12: Site WHT15

Plate 4.13: Site WHT16

Plate 4.14: Sit WHT17

Plate 4.15: Site AQO01

Plate 4.16: Site AQO03

Table 4.2: **Fauna habitats of non-systematic fauna and SRE survey sites within the Pipeline study area** (see Table 3.5 and Figure 2.3 for site locations).

Site	Landform	Vegetation Description	Soils
		Rocky hills and outcrops	
WHTSRE1, WHTSRE3	Rocky hill	Quartzite rocky hills with scattered *Acacia inaequilatera* over very open *Triodia* spp. hummock grassland	Stony sand
		Acacia spp. over Triodia epactia hummock grassland on sand/loam plain	
WHTSRE2	Plain	*Triodia epactia* hummock grassland on plains with scattered termitaria and emergent *Corymbia hamersleyana* trees and *Acacia* spp. shrubs.	Clay loam
WHTSRE4, WHTSRE8	Plain	*Triodia* spp. hummock grassland on plains with scattered termitaria	Clay loam
		Snakewood (Acacia xiphophylla) over Triodia hummock grasslands on clay plains	
WHTSRE6	Plain	*Acacia xiphophylla* - *Acacia ancistrocarpa* shrubland over *Triodia lanigera* hummock grassland	Clay loam
		Corymbia hamersleyana over Acacia spp. shrubs and hummock grasslands	
WHTSRE5	Plain	Scattered *Corymbia hamersleyana* over *Acacia* spp. shrubs and *Triodia lanigera* hummock grassland with scattered termitaria	Sandy loam
WHTSRE7	Broad drainage	Scattered *Corymbia hamersleyana* over *Acacia* spp. shrubs over *Triodia lanigera* hummock grassland	Clay loam

4.2 Vertebrate Fauna Overview

A combined total of 128 vertebrate species representing 51 families was recorded during the Wheatstone survey. Table 4.3 provides a summary of the number of species recorded from each major vertebrate group during the survey.

Table 4.3: **Number of species recorded during the Wheatstone survey.**

Fauna Group	Number of Species
Amphibians	4
Reptiles	47
Avifauna	60
Native Volant mammals (bats)	5
Native Non-Volant Mammals	9
Introduced Mammals	3
Total:	**128**

4.3 Herpetofauna

4.3.1 The Assemblage

The survey yielded a combined total of 51 herpetofauna species from the study area (Table 4.4). This total comprised one tree frog (Hylidae), three ground frogs (Myobatrachidae), 11 geckos (Gekkonidae), four legless lizards (Pygopodidae), 14 skinks (Scincidae), seven dragons (Agamidae), three monitors (Varanidae), three blind snakes (Typhlopidae), two pythons (Pythonidae) and seven front-fanged snakes (Elapidae). Representative photographs of some of the herpetofauna species collected are provided in Plate 4.17 to Plate 4.22.

By far the most common herpetofauna species was the ground frog *Notaden nichollsi* at 1,687 individuals, accounting for 56% of the herpetofauna records (Table 4.4). Most records of this species were from Primary Dunes and Inland Dunes, in response to recent rains. The skink *Lerista bipes* was the most abundant reptile species encountered during the survey, with 190 records from Primary Dune, Inland Dune and Sand/Loam Plain habitats. Also relatively common were the skinks *Lerista onsloviana* (n (number of records)=32) and *Ctenotus pantherinus* (n=32).

Inland Dune habitat exhibited the highest herpetofauna richness within the study area with 38 species, representing 74% of the herpetofauna recorded during the survey. Inland Dune habitat was common within the study area and as a result this habitat was sampled more frequently than some of the other habitats. Somewhat lower, but similar species richness was recorded from Primary Dunes and Sand/Loam Plains (Table 4.4). As is commonly the case, the Scincidae was the most speciose herpetofauna family with 14 species (27% of all herpetofauna species recorded).

Table 4.4: **Herpetofauna recorded from the Wheatstone study area** ('Non'= records from non-systematic sampling and spotlighting).

	Primary Dune		Inland Dune					Sand/Loam Plain					Buffel on Clay	Samphire	Tussock on Clay	Drainage	Non	Total
FAMILY Species Name	**WHT01**	**WHT02**	**WHT05**	**WHT07**	**WHT08**	**WHT16**	**WHT17**	**WHT03**	**WHT12**	**WHT14**	**AQO01**	**AQO03**	**WHT15**	**WHT04**	**WHT10**	**WHT11**		
HYLIDAE																		
Litoria rubella																2	1	**3**
MYOBATRACHIDAE																		
Cyclorana maini											6					2		**8**
Neobatrachus aquilonius						1			18			2						**21**
Notaden nichollsi	128	612	45	60	48	83	222	107	252	60	11	55	4	-				**1,687**
GEKKONIDAE																		
Diplodactylus conspicillatus			8		1			10	1									**20**
Gehyra pilbara																	1	**1**
Gehyra punctata																	1	**1**
Gehyra variegata				1														**1**
Heteronotia binoei	2	2	1		3	1					1							**10**
Lucasium stenodactylum	1			3				4										**6**
Nephrurus levis	2	1		1	3	3		3	1									**14**
Strophurus jeanae	1	2		1	4													**8**
Strophurus strophurus		2	2															**4**
PYGOPODIDAE																		
Delma nasuta						1												**1**
Delma tincta				1	1										1	5		**8**
Lialis burtonis	1	6															1	**8**
Pygopus nigriceps		1	1															**2**
AGAMIDAE																		
Ctenophorus caudicinctus																	2	**2**
Ctenophorus isolepis	2	5		1					1			1					3	**13**
Ctenophorus nuchalis	2	1		1			2						1	1				**8**
Diporiphora winneckei	4	2		2														**8**
Pogona minor			1	1		1						4						**7**
SCINCIDAE																		
Ctenotus calurus			1															**1**
Ctenotus grandis	2	1		3	1	1			1									**9**
Ctenotus hanloni						1			2	7		1						**11**
Ctenotus iapetus	1	2	1		2	7	2		1		1							**17**
Ctenotus pantherinus		3	1	2	2		1	2	7	2		5	4		2	1		**32**

Table 4.4: **Herpetofauna recorded from the Wheatstone study area** ('Non'= records from non-systematic sampling and spotlighting).

	Primary Dune		Inland Dune					Sand/Loam Plain					Buffel on Clay	Samphire	Tussock on Clay	Drainage	Non	Total
FAMILY **Species Name**	**WHT01**	**WHT02**	**WHT05**	**WHT07**	**WHT08**	**WHT16**	**WHT17**	**WHT03**	**WHT12**	**WHT14**	**AQO01**	**AQO03**	**WHT15**	**WHT04**	**WHT10**	**WHT11**		
Ctenotus rufescens				1	1			1	1	2								**6**
Ctenotus saxatilis	3	1				1	1											**6**
Ctenotus schomburgkii							1											**1**
Eremiascincus fasciolatus	2		4	5	4	3		1		1		5						**25**
Lerista bipes	12	16	24	22	25	27	27	9	13	7		8						**190**
Lerista clara	3		1			7	3			1	3					1		**19**
Lerista onsloviana	5	5	3	4	8	5		1			1							**32**
Menetia greyii	3			2				1	1	2			1		1			**11**
Tiliqua multifasciata										1								**1**
VARANIDAE																		
Varanus brevicauda						2	1	1			2	1						**7**
Varanus caudolineatus	2		3	2	2			4										**13**
Varanus eremius							4	1	4	2		2	1					**14**
TYPHLOPIDAE																		
Ramphotyphlops ammodytes					2		2						1			1		**6**
Ramphotyphlops grypus	1		5	2	3	2	2			1	1							**17**
Ramphotyphlops hamatus										1						1		**2**
PYTHONIDAE																		
Antaresia stimsoni													2				3	**5**
Aspidites melanocephalus															1		2	**3**
ELAPIDAE																		
Demansia psammophis	1	1		1		1		2	1	2					2			**11**
Furina ornata			2				1				1							**4**
Pseudechis australis		1		1													1	**3**
Pseudonaja modesta								1										**1**
Pseudonaja nuchalis		1		3			1		1							1		**7**
Simoselaps anomalus	1	1																**2**
Suta punctata										1								**1**
Number of Individuals	**179**	**665**	**103**	**120**	**110**	**147**	**270**	**148**	**305**	**90**	**27**	**84**	**14**	**1**	**7**	**14**	**15**	**2,299**
Number of Species	**21**	**20**	**16**	**22**	**16**	**17**	**14**	**15**	**15**	**14**	**9**	**10**	**7**	**1**	**5**	**8**	**9**	**51**
Number of Species/Habitat	**26**		**38**					**30**					**7**	**1**	**5**	**8**	**9**	

Plate 4.17: The gecko Nephrurus levis.

Plate 4.18: The gecko Diplodactylus conspicillatus.

Plate 4.19: The pygopodid Pygopus nigriceps.

Plate 4.20: The pygopodid Lialis burtonis.

Plate 4.21: Stimson's Python Antaresia stimsonii.

Plate 4.22: The elapid snake Simoselap anomalus.

Five reptile species were collected during non-systematic sampling at sites along the Domgas pipeline study area:

- *Gehyra punctata* (n=16 at site WHTSRE1);
- *Gehyra pilbara* (n=36 specimens from within termite mounds at sites WHTSRE2);
- *Ctenophorus caudicinctus* (n=3 at sites WHTSRE1 and WHTSRE 4);
- *Ctenophorus isolepis* (n=1 at site WHTSRE5); and
- *Pseudechis australis* (n=1 at site WHTSRE6).

None of these species are of elevated conservation significance. While collections were limited at these non-systematic Domgas Pipeline study area sites, the habitats present suggest that the herpetofauna assemblage documented by the overall study would be representative of the suite of species present in this area.

4.3.2 Regional Endemism and Restricted Taxa

Lerista onsloviana is the only recorded herpetofauna species during the survey that is considered endemic to the Onslow locality (Storr et al. 1999). It has been recorded a number of times from elsewhere in the locality (Biota 2005b; Storr et al. 1999).

4.3.3 Herpetofauna of Conservation significance

No herpetofauna of conservation significance were recorded during the survey.

4.4 Avifauna

4.4.1 The Assemblage

Sixty bird species were recorded from the Wheatstone Project study area. Thus comprised 34 non-passerine species and 26 passerine species from 33 families (Table 4.5).

The zebra finch (*Taeniopygia guttata*) was the most abundant species recorded (323 records), representing over 31% of recorded avifauna. The most speciose family of birds was the Accipitridae (birds of prey including Osprey, Harriers, Kites and Eagles) with eight recorded species.

Inland Dune habitat exhibited the highest avifauna richness during the survey, with 30 species (50% of recorded species). Though this is partly a function of relative sampling effort, this habitat type also had greater structural diversity and more flowering plants than other habitats. Drainage habitat also exhibited high avifauna richness (19 species), considering only a single site represented this habitat within the study area.

A total of 15 bird species were recorded from non-systematic sampling sites along the Domgas pipeline study area ('Non' records in Table 4.5). The majority of the species were in common with the habitats sampled by the systematic survey sites, but six additional species were added through non-systematic sampling: Emu (WHTSRE6), Dusky Woodswallow (WHTSRE1), Whistling Kite (WHTSRE1), Pied Butcherbird (WHTSRE2), Crested Bellbird (WHTSRE7) and Spinifex Pigeon (WHTSRE7) (Table 4.5). None of these latter species are of elevated conservation significance.

4.4.2 Regional Endemism and Restricted Taxa

There were no bioregional endemic birds recorded during the Wheatstone survey.

4.4.3 Avifauna of Conservation Significance

The Australian Bustard (*Ardeotis australis*; Priority 4) was the only bird species of State conservation significance recorded during the recent Wheatstone survey. Explanations of conservation rankings and more details on species of conservation significance are provided in Section 5.3. Three species listed as Migratory under the Commonwealth *EPBC Act 1999* (*Merops ornatus*, *Apus pacificus* and *Haliaeetus leucogaster*) were also recorded during the survey (see Section 5.3).

Table 4.5: **Avifauna recorded within the Wheatstone study area** ('Opp'=opportunistic records not associated with a specific systematic sampling location; 'Non'=records from non-systematic sampling sites).

		Primary Dune		Inland Dune					Sand/Loam Plain					Buffel on Clay	Samphire	Tussock on Clay	Drainage			
FAMILY **Species Name**	**Common Name**	**WHT01**	**WHT02**	**WHT05**	**WHT07**	**WHT08**	**WHT16**	**WHT17**	**WHT03**	**WHT12**	**WHT14**	**AQO01**	**AQO03**	**WHT15**	**WHT04**	**WHT10**	**WHT11**	**Opp**	**Non**	**Total**
CASUARIIDAE																				
Dromaius novaehollandiae	Emu																	1	1	**2**
TURNICIDAE																				
Turnix velox	Little Button-quail					1	1	1	1					1	3		1	3	1	**13**
PELECANIDAE																				
Pelecanus conspicillatus	Australian Pelican		1																	**1**
ANATIDAE																				
Anas superciliosa	Pacific Black Duck																41			**41**
ARDEIDAE																				
Ardea garzetta	Little Egret																	2		**2**
Ardea sacra	Eastern Reef Heron	1																		**1**
OTIDIDAE																				
Ardeotis australis	Australian Bustard									4										**4**
LARIDAE																				
Larus novaehollandiae	Silver Gull	5		6											5					**19**
Sterna caspia	Caspian Tern																			**2**
ACCIPITRIDAE																				
Aquila audax	Wedge-tailed Eagle					1		3												**4**
Circus assimilis	Spotted Harrier											1								**1**
Elanus caeruleus axillaris	Black-shouldered Kite							1								2				**3**
Haliaeetus leucogaster	White-bellied Sea-Eagle																	2		**2**
Haliastur indus girrenera	Brahminy Kite		1																	**1**
Haliastur sphenurus	Whistling Kite					1		1	1	1			1				4	1	1	**11**
Hamirostra melanosternon	Black-breasted Buzzard						1													**1**
Pandion haliaetus cristatus	Osprey		1																	**1**
FALCONIDAE																				
Falco cenchroides	Australian Kestrel	2		2	2		1		1		1	1	1	1		1	1		2	**16**
Falco longipennis	Australian Hobby		1																	**1**
COLUMBIDAE																				
Geopelia cuneata	Diamond Dove							1						1						**2**
Geopelia striata	Peaceful Dove															2	1			**3**
Geophaps plumifera	Spinifex Pigeon																	2	2	**4**

		Primary Dune		Inland Dune					Sand/Loam Plain					Buffel on Clay	Samphire	Tussock on Clay	Drainage			
FAMILY **Species Name**	**Common Name**	**WHT01**	**WHT02**	**WHT05**	**WHT07**	**WHT08**	**WHT16**	**WHT17**	**WHT03**	**WHT12**	**WHT14**	**AQO01**	**AQO03**	**WHT15**	**WHT04**	**WHT10**	**WHT11**	**Opp**	**Non**	**Total**
Ocyphaps lophotes	Crested Pigeon	3			3		2	5				3							2	**18**
PSITTACIDAE																				
Cacatua roseicapilla	Galah	6	15					4	7				24	4			2			**62**
Cacatua sanguinea	Little Corella	20												3		35	20			**78**
Melopsittacus undulatus	Budgerigar					5										3	11		15	**34**
Nymphicus hollandicus	Cockatiel							13					2				1			**16**
Platycercus zonarius	Australian Ringneck																6			**6**
CUCULIDAE																				
Chrysococcyx basalis	Horsfield's Bronze Cuckoo				1						1			2						**4**
STRIGIDAE																				
Ninox novaeseelandiae	Boobook Owl																	1		**1**
AEGOTHELIDAE																				
Aegotheles cristatus	Australian Owlet-nightjar																	1		**1**
APODIDAE																				
Apus pacificus	Fork-tailed Swift			2																**2**
HALCYONIDAE																				
Dacelo leachii	Blue-winged Kookaburra																1			**1**
MEROPIDAE																				
Merops ornatus	Rainbow Bee-eater	2	3	3	4					1	2			4			4			**23**
MALURIDAE																				
Malurus lamberti	Variegated Fairy-wren	26	3				2	1		4	2		1	1	9					**49**
Malurus leucopterus	White-winged Fairy-wren			11	15	4	5		5	4	5	9	2							**60**
ACANTHIZIDAE																				
Gerygone tenebrosa	Dusky Gerygone																	4		**4**
MELIPHAGIDAE																				
Certhionyx niger	Black Honeyeater			10	3	3	2									3			4	**25**
Lichenostomus keartlandi	Grey-headed Honeyeater														1					**1**
Lichenostomus virescens	Singing Honeyeater	7	10	6	2	2	3	8	1		2		2	8		1			2	**54**
Lichmera indistincta	Brown Honeyeater		1				3			1	1			1			4			**11**
CINCLOSOMATIDAE																				
Psophodes occidentalis	Western Wedgebill							1		2										**3**
PACHYCEPHALIDAE																				
Oreoica gutturalis	Crested Bellbird							1												**2**

		Primary Dune		Inland Dune					Sand/Loam Plain					Buffel on Clay	Samphire	Tussock on Clay	Drainage			
FAMILY **Species Name**	**Common Name**	**WHT01**	**WHT02**	**WHT05**	**WHT07**	**WHT08**	**WHT16**	**WHT17**	**WHT03**	**WHT12**	**WHT14**	**AQO01**	**AQO03**	**WHT15**	**WHT04**	**WHT10**	**WHT11**	**Opp**	**Non**	**Total**
DICRURIDAE																				
Grallina cyanoleuca	Magpie-lark							1					1	1			4			**7**
Rhipidura leucophrys	Willie Wagtail	1			1		1										2		1	**6**
CAMPEPHAGIDAE																				
Coracina novaehollandiae	Black-faced Cuckoo-shrike				1		1									1	2		1	**6**
ARTAMIDAE																				
Artamus cinereus	Black-faced Woodswallow																1			**1**
Artamus cyanopterus	Dusky Woodswallow																		4	**4**
CRACTICIDAE																				
Cracticus nigrogularis	Pied Butcherbird																		1	**1**
CORVIDAE																				
Corvus bennetti	Little Crow															1				**1**
Corvus orru cecilae	Torresian Crow				14			4	2		1	2		1			1			**25**
HIRUNDINIDAE																				
Cheramoeca leucosternus	White-backed Swallow		1																	**1**
Hirundo ariel	Fairy Martin	3													1					**4**
Hirundo nigricans	Tree Martin			1				2	1											**4**
MOTACILLIDAE																				
Anthus australis australis	Australian Pipit											1			2				1	**4**
ALAUDIDAE																				
Mirafra javanica horsfieldii	Singing Bushlark		4		5			5	8	1	9	6		5	1	3				**47**
SYLVIIDAE																				
Cincloramphus mathewsi	Rufous Songlark											1		4						**5**
ESTRILDIDAE																				
Emblema pictum	Painted Finch						8													**8**
Taeniopygia guttata	Zebra Finch	19	52	15	17	6	19	22	38	22	19	11	19	30	14	9	5		6	**323**
ZOSTEROPIDAE																				
Zosterops luteus	Yellow White-eye		10																	**10**
	Number of Individuals	**95**	**103**	**56**	**68**	**23**	**49**	**74**	**65**	**40**	**43**	**35**	**53**	**67**	**36**	**61**	**112**	**17**	**44**	**1,047**
	Number of Species	**12**	**13**	**9**	**12**	**8**	**13**	**17**	**10**	**9**	**10**	**9**	**9**	**15**	**8**	**11**	**19**	**9**	**15**	**60**
	Number of Species/Habitat	**20**		**30**					**20**					**15**	**8**	**11**	**19**			

4.5 Mammals

4.5.1 The Assemblage

A total of 14 native mammal species was recorded from the study area (Table 4.6 and Table 4.7). Nine non-volant (ground-dwelling) native mammal species were recorded during the survey, comprising three dasyurids (carnivorous marsupials), two macropods (kangaroos and wallabies) and four murids (murid rodents). Three introduced mammal species were recorded: one murid, one feline (cat) and one bovid (cloven hoofed mammal) (Table 4.6).

The most commonly recorded mammal species was the introduced *Mus musculus* (House Mouse), with 12 records representing 31% of the non-volant mammal records during the survey. The majority of house mice were captured via Elliott trapping from tussock grassland habitat on clay substrate (site WHT10).

Three mammal species were recorded during non-systematic sampling at sites along the Domgas pipeline study area, two of which (*Macropus robustus* and the Cow *Bos Taurus*) were widely recorded during the study. As with the herpetofauna, the range of habitats present along the corridor suggest that the mammal assemblage documented by the overall study would also be representative of the suite of species present in this area. A single mammal species, *Pseudomys chapmani*, was recorded only from the Domgas Pipeline study area (Section 4.5.3).

Five bat species were recorded within the study area, including three vespertilionids (evening bats), one emballonurid (sheathtail bats) and one molossid (Freetail bats) (Figure 4.2 to Figure 4.6; and Table 4.7). Harp trapping within the study area did not result in the direct capture of any bats. The documented species were based solely on recorded call sequences.

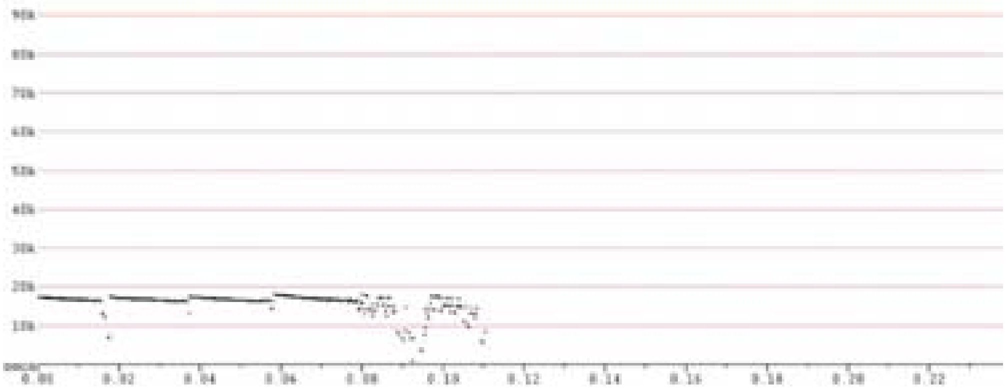


Figure 4.2: **Saccolaimus flaviventris representative call sequence**

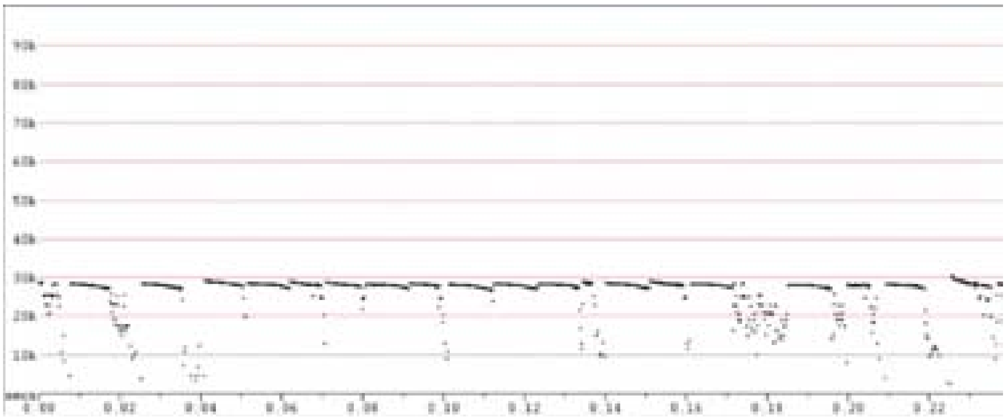


Figure 4.3: **Mormopterus loriae cobourgensis representative call sequence.**

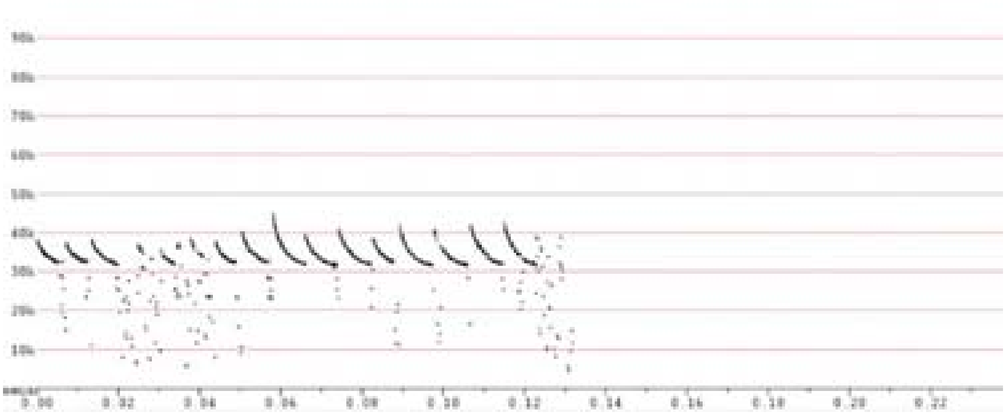


Figure 4.4: **Chalinolobus gouldii representative call sequence**

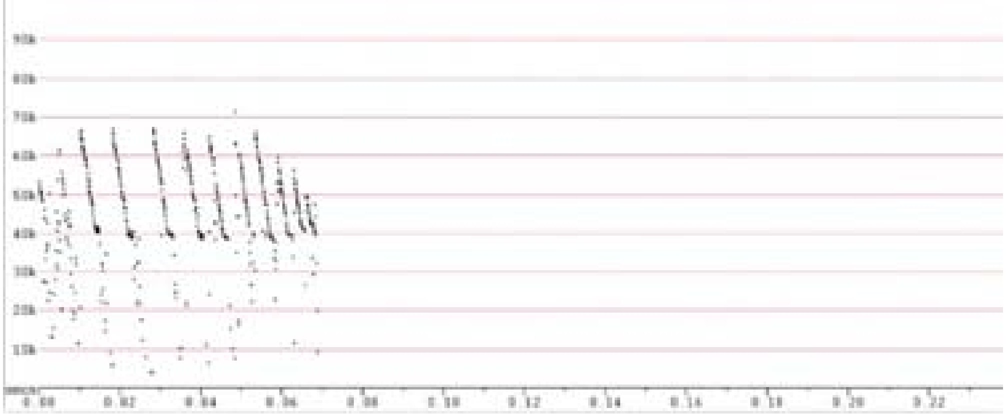


Figure 4.5: **Scotorepens greyii representative call sequence.**

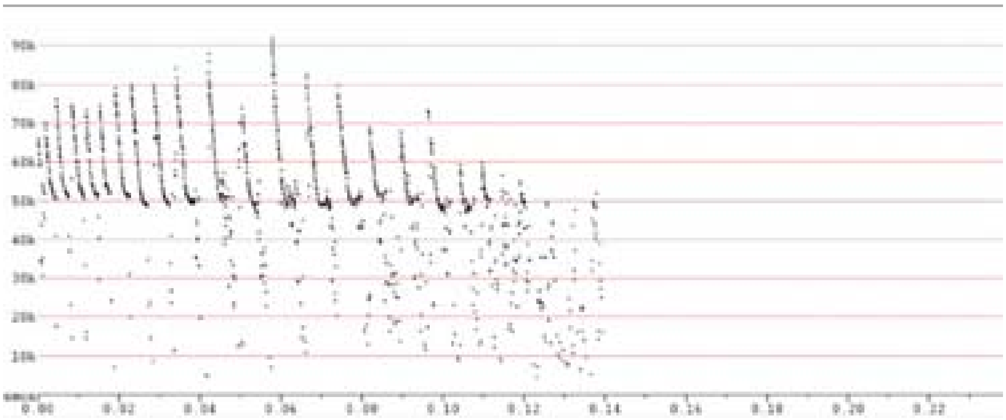


Figure 4.6: **Vespadelus finlaysoni representative call sequence.**

Table 4.6: **Non-volant mammals recorded during the Wheatstone survey** ('Non'=records from non-systematic sampling sites).

		Primary Dune		Inland Dune					Sand/Loam Plain					Buffel on Clay	Samphire	Tussock on Clay	Drainage	Non	Total
FAMILY **Species Name**	**Common Name**	**WHT01**	**WHT02**	**WHT05**	**WHT07**	**WHT08**	**WHT16**	**WHT17**	**WHT03**	**WHT12**	**WHT14**	**AQO01**	**AQO03**	**WHT15**	**WHT04**	**WHT10**	**WHT11**		
DASYURIDAE																			
Ningaui timealeyi	Pilbara Ningaui													1					**1**
Planigale ingrami	Long-tailed Planigale									1				2					**3**
Sminthopsis macroura	Stripe-faced Dunnart						1	2					1						**4**
MACROPODIDAE																			
Macropus robustus	Euro Kangaroo																	3	**3**
Macropus rufus	Red Kangaroo								1								2		**3**
MURIDAE																			
**Mus musculus*	House Mouse							1			1		1			6	1		**12**
Notomys alexis	Spinifex Hopping Mouse						1						T						**2**
Pseudomys chapmani	Western Pebble-mound mouse																	M	**1**
Pseudomys desertor	Desert Mouse		1					2	1										**4**
Pseudomys hermannsburgensis	Sandy Inland Mouse				1	3	2								1				**7**
FELIDAE																			
**Felis catus*	Cat	T																	**1**
BOVIDAE																			
**Bos taurus*	Domestic cattle																1	1	**1**
	Number of Individuals	**0**	**1**	**0**	**1**	**5**	**4**	**5**	**2**	**1**	**1**	**0**	**2**	**3**	**1**	**6**	**3**	**5**	**40**
	Number of Species	**0**	**1**	**0**	**1**	**2**	**3**	**3**	**2**	**1**	**1**	**0**	**2**	**2**	**1**	**1**	**3**	**12**	**12**
	Number of Species/Habitat	**2**		**5**					**6**					**2**	**1**	**1**	**2**	**3**	

T - denotes track, M - denotes pebble mound

Table 4.7: **Volant mammals (bats) recorded during the Wheatstone survey.**

FAMILY **Species Name**	**Common Name**	**WHTBat01**	**WHTBat02**	**WHTBat03**
EMBALLONURIDAE				
Saccolaimus flaviventris	Yellow-bellied Sheathtail Bat	E	–	E
MOLOSSIDAE				
Mormopterus loriae cobourgensis	Little Northern Freetail-bat	E	E	–
VESPERTILIONIDAE				
Chalinolobus gouldii	Gould's Wattled Bat	E	E	E
Scotorepens greyii	Little Broad-nosed Bat	–	–	E
Vespadelus finlaysoni	Inland Cave Bat	E	–	–
	Number of species	**4**	**2**	**3**

E - denotes echolocation call recording

4.5.2 Regional Endemism and Restricted Taxa

There were no bioregional endemic mammals recorded during the Wheatstone survey.

4.5.3 Mammals of Conservation significance

No mammal species listed under the Commonwealth *EPBC Act 1999* were recorded during the survey. Two State-listed species occurred in the study area, with echolocation calls of the Little Northern Freetail-bat *Mormopterus loriae cobourgensis* (Priority 1) recorded and a single, inactive Pebble-mound Mouse *Pseudomys chapmani* (Priority 4) mound was recorded from the south-eastern end of the Domgas pipeline route (site WHTSRE1). Explanations of conservation rankings and more details on these mammal species of conservation significance are provided in Section 5.3.

4.6 Potential SRE Invertebrates

Taxonomic groups of invertebrates with naturally small distributions are described as SRE taxa and are characterised by poor dispersal capabilities, confinement to disjunct habitats and low fecundity (Harvey 2002, Ponder and Colgan 2002, EPA 2009). Given the importance of short-range endemism to the conservation of biodiversity, the assessment of such invertebrate taxa is a potentially important component of impact assessment. Examples of taxonomic groups that show high levels of short-range endemism in this respect include mygalomorph spiders, millipedes, pseudoscorpions and freshwater and terrestrial molluscs. Taxa belonging to these groups have the potential to be SREs.

4.6.1 Pseudoscorpions

Two potential SRE pseudoscorpions were recorded from the Wheatstone study area; *Synsphyronus* sp. '1/8 Pilbara' (family Garypidae) and *Solinus* sp.1 (family Garypinidae) (Table 4.8; Plate 4.23 and Plate 4.24). All specimens were collected from underneath bark of *Corymbia hamersleyana* trees in the Pipeline corridor stud area. Identification of pseudoscorpion specimens was conducted by Mr Dan Kamien with reference to the Biota image database produced from previous identifications provided by Dr Mark Harvey (WA Museum). Confirmed identifications were subsequently provided by the WA Museum, who advised that neither taxon is an SRE (see Section 5.4).

Table 4.8: Pseudoscorpions recorded within the Wheatstone study area.

Taxon	Location	Number
Synsphyronus sp. '1/8 Pilbara'	WHTSRE01	5
Synsphyronus sp. '1/8 Pilbara'	WHTSRE07	10
Solinus sp. 1	WHTSRE05	1

Plate 4.23: Synsphyronus sp. '1/8 Pilbara' (family Garypidae)

Plate 4.24: Solinus sp. 1 (family Garypinidae)

4.6.2 Other Potential SRE Invertebrates

Despite thorough searching at dedicated SRE survey sites by four experienced zoologists (Section 3.4.6), no mygalomorph spiders, land or freshwater snails, or millipedes were recorded within the Wheatstone study area. Two old mygalomorph burrows were found during transect searches at site WHTSRE3, but both were abandoned and substantially weathered. The likelihood that potential SRE taxa would be restricted at small spatial scale within the study area is discussed further in Section 5.4.

4.7 Mangrove Fauna

4.7.1 Overview

Mangrove intertidal systems provide habitat to a wide range of vertebrate and invertebrate fauna. This includes guilds of bird and bats species which are considered to be largely restricted to mangal and associated littoral habitats (Hutchings and Recher 1982, Johnstone 1990, Churchill 2008) and a wide range of marine invertebrate fauna. On the Pilbara coast, the latter falls into two main components:

- invertebrates more strongly associated with the mangal itself (including mud whelks *Terebralia* spp., the fiddler crab *Uca flammula* and a variety of insects and spiders); and
- mangrove sediment infauna (burrowing or more strongly marine invertebrates including polychaete worms, annelid worms, flatworms, and a range of molluscs) (Hutchings and Recher 1982, Duke 2006).

Marine invertebrates of the mangrove zone have been addressed in separate studies for the Wheatstone Project and will not be considered further here.

4.7.2 Mangrove Avifauna

Johnstone (1990) identified a guild of 11 bird species that are largely or exclusively associated with mangrove habitats along the Pilbara coast. These represent a subset of the more diverse mangrove avifauna present in more tropical parts of the State, largely due to reduced mangrove species and structural diversity in the subtropical Pilbara bioregion (Johnstone 1990).

While no dedicated mangrove bird transects were completed as part of the current survey, some mangrove specialist species were recorded opportunistically during bat sampling and field work in adjoining samphire habitats (Table 4.5). Field avifauna data were previously collected by Halpern Glick Maunsell (HGM) (1998) in the mangroves of nearby Middle Creek, and LeProvost (1991) also recorded avifauna from mangrove habitats in the Onslow-Ashburton delta locality. In addition, the regional scale work of Johnstone (1990) included a site at the mouth of the Ashburton River (site D21 of that study). Together, these data allow the mangrove avifauna of the Wheatstone study area to be characterised as summarised in Table 4.9.

Table 4.9: Mangrove specialist avifauna recorded in mangrove habitats within or adjacent to the Wheatstone study area.

Species	This survey	HGM (1998)	LeProvost (1991)	Johnstone (1990)
Butroides striatus Mangrove Heron		*	*	*
Geopelia humeralis Bar-shouldered Dove			*	*
Halcyon chloris Mangrove Kingfisher			*	
Pachycephala melanura Mangrove Golden Whistler		*	*	
Pachycephala lanioides White-breasted Whistler			*	*
Rhiphidura phasiana Mangrove Grey Fantail		*	*	*
Gervgone tenebrosa Dusky Gerygone	*	*	*	*
Zosterops luteus Yellow White-eye	*	*	*	*
Artamus leucorhynchus White-breasted Woodswallow	*	*	*	*

Nine species of mangrove dependent birds have therefore been recorded in the low, largely *Avicennia marina* dominated mangrove habitats in and adjacent to the Wheatstone study area (Table 4.9). The species present are amongst the most widespread of the mangrove specialists, with distributions extending along the Pilbara coast and into the extensive mangrove habitats of the Kimberley region (Johnstone 1990).

4.7.3 Other Mangrove Vertebrates

Few other terrestrial vertebrates routinely occur in mangrove habitats in the Onslow locality. Euros *Macropus robustus* were periodically recorded from the upper limit of the mangrove zone south of Tubridgi Point by Biota (2005a) and they are also likely to occur periodically in the landward mangroves of the Wheatstone study area. The Long-nosed Water-dragon *Lophognathus longirostris* also occurs in the landward portion of mangrove habitats (Biota and HGM 2000, Biota 2009), and is the only terrestrial reptile likely to be routinely present in these habitats in the Wheatstone study area. The Saltwater Crocodile *Crocodylus porosus* has been reported as occurring in the Onslow locality in recent years, and may occasionally be present in tidal creeks adjoining the Wheatstone study area (see Section 5.3.2).

The Mangrove Mud Snake *Ephalophis grayae* (Plate 4.25) was recorded from Middle Creek by HGM (1998), and is routinely sighted on ebb tides in mangrove creeks in the Onslow locality (G. Humphreys, Biota, pers. obs). (Biota 2005) also recorded *E. grayae* and the Banded Mangrove Snake *Hydrelaps darwiniensis* from similar mangrove habitat in East Exmouth Gulf to the south of the Wheatstone study area. Both hydrophiid snake species are relatively widespread along the arid and tropical mangrove coast of Western Australia (Storr et al. 1996).

Plate 4.25: Mangrove Mud Snake Ephalophis grayae.

The Northern Free-tail Bat *Mormopterus loriae coburgensis*, a mangrove specialist, was confirmed as occurring in mangrove habitats in the Wheatstone study area during this survey (Section 3.4.4). This species' wider distribution encompasses the West Australian coastal areas from Derby to Exmouth Gulf. It is an Australian endemic (Churchill 2009) and is listed as a Priority 1 species by DEC (Section 5.3.3). This species has been recorded as roosting in small sports and crevices in dead upper branches of the mangrove *Avicennia marina*. Individuals emerge early in the evening in groups of up to 100 individuals above the mangrove canopy, before dispersing to forage alone or in pairs. They are restricted to mangroves and immediately adjacent areas (Churchill 2009). *M. loriae* preys on insects above and beside the forest canopy.

5.0 Conservation Significance

5.1 Threatened Fauna Statutory Framework

Native fauna species that are rare, threatened with extinction, or have high conservation value are specially protected by law under the WA *Wildlife Conservation Act 1950-1979*. In addition, many of these species are listed under the Commonwealth *EPBC Act 1999*.

5.1.1 Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

Fauna species of national conservation significance are listed under the *EPBC Act 1999*, and have been classified as 'critically endangered', 'endangered', 'vulnerable' or 'conservation dependent' (broadly consistent with International Union for Conservation of Nature (IUCN) categories: http://intranet.iucn.org/webfiles/doc/SSC/RedList/redlistcatsenglish.pdf).

Migratory wader species are also protected under the *EPBC Act 1999*. The national List of Migratory Species consists of those species listed under the following International Conventions:

- Japan-Australia Migratory Bird Agreement (JAMBA);
- China-Australia Migratory Bird Agreement (CAMBA); and
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

5.1.2 Western Australian *Wildlife Conservation Act 1950-1979*

Classification of rare and endangered fauna under the *Wildlife Conservation (Specially Protected Fauna) Notice 2008* recognises four distinct schedules of taxa:

Schedule 1 - taxa are fauna which are rare or likely to become extinct and are declared to be fauna in need of special protection;

Schedule 2 - taxa are fauna which are presumed to be extinct and are declared to be fauna in need of special protection;

Schedule 3 - taxa are birds which are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction, which are declared to be fauna in need of special protection; and

Schedule 4 - taxa are fauna that are in need of special protection, otherwise than for the reason mentioned in paragraphs (1), (2) and (3).

In addition to the above, fauna are also classified under five different Priority codes:

Priority One **Taxa with few, poorly known populations on threatened lands.**
Taxa which are known from a few specimens or sight records from one or a few localities on lands not managed for conservation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

Priority Two **Taxa with few, poorly known populations on conservation lands, or taxa with several, poorly known populations not on conservation lands.**
Taxa which are known from few specimens or sight records from one or a few localities on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

Priority Three	**Taxa with several, poorly known populations, some on conservation lands.** Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.
Priority Four	**Taxa in need of monitoring.** Taxa which are considered to have been adequately surveyed or for which sufficient knowledge is available and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands. Taxa which are declining significantly but are not yet threatened.
Priority Five	**Taxa in need of monitoring.** Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years

5.2 Fauna Habitat Conservation Value

None of the habitats present in the Wheatstone study area are listed as Threatened Ecological Communities (TECs). However, ephemeral creekline drainage communities similar to that present at site WHT11 are considered ‘ecosystems at risk’ within the Cape Range subregion (Kendrick and Mau 2002). In the current study, this habitat type constituted less than 1% by area of the current study area (shown in blue at site WHT11 at the south-west corner of the Plant study area on Figure 4.1). In addition, the mangrove communities adjoining the study area are also considered ‘ecosystems at risk’ within the Roebourne subregion, an area that covers the northern section of the Carnarvon IBRA region (Kendrick and Stanley 2001).

Vegetation mapping (Biota 2009), Land Systems mapping (Section 2.4.3), previous surveys in the locality (Section 2.5), and field ground-truthing during this study, all indicate that the remaining habitat types are well represented in the locality and wider region and not of elevated conservation significance.

5.3 Schedule and Priority Fauna

Six species of conservation significance were recorded within the Wheatstone study area:

- Little Northern Freetail-bat (*Mormopterus loriae cobourgensis*) (State: Priority 1): Echolocation calls recorded via the Anabat recorder from mangrove habitat at sites WHTBat01 and WHTBat02.
- Australian Bustard (*Ardeotis australis*) (State: Priority 4): Four individuals were record from *Acacia* sp. over *Triodia* sp. hummock grassland at site WHT12.
- Western Pebble-Mound Mouse (*Pseudomys chapmani*) (State: Priority 4): Recorded from a single inactive mound at the south-east end of the Domgas Pipeline corridor (site WHTSRE1)).
- Rainbow Bee-eater (*Merops ornatus*) (Federal: Migratory): Recorded on 23 occasions across eight sites representing a range of habitat types.
- Fork-tailed Swift (*Apus pacficifus*) (Federal: Migratory): Recorded on a single occasion at one coastal survey site over dune habitat.
- White-bellied Sea Eagle (*Haliaeetus leucogaster*) (Federal: Migratory): Recorded on two occasions opportunistically with the study area.

Based on known fauna distributions and habitat preferences, an additional 10 Schedule or Priority species may potentially occur within the study area (Table 5.1; Appendices 1, 2 and 3). The Orange Leaf-nosed Bat *Rhinonicteris aurantius* was listed in database searches (Appendix 1, 2 and 3) but was not considered any further here due to the lack of suitable cave roosts sites in the study area (Churchill 1991). The Northern Quoll *Dasyurus hallucatus* (State: Schedule 1, Federal: Endangered) was also yielded by the *EPBC Act 1999* search tool. This species was also not considered further as none of the core Land Systems in which it occurs in the bioregion are present in the study area (Biota 2009d), and it has never been recorded in previous surveys in the locality (Section 5.6). Database searches also indicated that 12 species listed as Migratory under the *EPBC Act 1999* could occur in the locality (three of which were recorded during the current survey as noted above). None of the database-listed migrants are associated with or dependent on the terrestrial habitats considered in this study and no impacts on their conservation status would be expected as a result of the Wheatstone development. Given this, these species are not considered in any detail.

Table 5.1: Fauna of conservation significance occurring or potentially occurring within the Wheatstone study area.

Species Name	Common Name	Conservation Significance	
		State Level	Federal Level
Recorded from the Wheatstone study area			
Mormopterus loriae cobourgensis	Little Northern Freetail-bat	Priority 1	–
Pseudomys chapmani	Western Pebble-mound Mouse	Priority 4	–
Ardeotis australis	Australian Bustard	Priority 4	–
Apus pacificus	Fork-tailed Swift	–	Migratory
Merops ornatus	Rainbow Bee-eater	–	Migratory
Haliaeetus leucogaster	White-bellied Sea-Eagle	–	Migratory
Recorded from the other surveys in the locality [1]			
Neochmia ruficauda subclarescens	Star Finch (western)	Priority 4	–
Sminthopsis longicaudata	Long-tailed Dunnart	Priority 4	–
Leggadina lakedownensis	Short-tailed Mouse	Priority 4	–
Yielded by database searches of species potentially occurring in the locality [2]			
Pezoporus occidentalis	Night Parrot	Schedule 1, Endangered	Critically Endangered
Falco peregrinus	Peregrine Falcon	Schedule 4	–
Crocodylus porosus	Saltwater Crocodile	Schedule 4	Migratory
Dasycercus blythi	Brush-tailed Mulgara	Priority 4	–
Burhinus grallarius	Bush Stone-curlew	Priority 4	–
Falco hypoleucos	Grey Falcon	Priority 4	–
Numenius madagascariensis	Eastern Curlew	Priority 4	–
Charadrius veredus	Oriental Plover	–	Migratory
Ardea alba	Great Egret	–	Migratory
Ardea ibis	Cattle Egret	–	Migratory
Hirundo rustica	Barn Swallow	–	Migratory
Glareola maldivarum	Oriental Pratincole	–	Migratory
Numenius minutes	Little Curlew	–	Migratory
Puffinus pacificus	Wedge-tailed Shearwater	–	Migratory
Sterna anaethetus	Bridled Tern	–	Migratory
Sterna caspia	Caspian Tern	–	Migratory

[1] WA Museum records, Biota database, and Biota 2005a and b

[2] Naturemap, DEC Threatened Fauna Database, *EPBC Act 1999* Protected Matters Search tool

5.3.1 Schedule 1 Species

Night Parrot (Pezoporus occidentalis)

Distribution: Night Parrots have been reported from every state on the Australian mainland. Suitable habitat occurs, or has occurred, across most of the inland, covering at least half of the continent. Records are sparsely distributed, however there do appear to be concentrations of records in western Queensland and the eastern Pilbara (Higgins 1999). There is an unconfirmed record from Minga Well north of the Fortescue Marsh (approximately 100 km north of Newman, and 250 km east of Brockman) and one from near Yandicoogina on the edge of the Marshes (Dr Rob Davis, University of WA, pers. obs.). This species was last recorded in the vicinity of the Wheatstone study area in 1967 near Mount Stuart, approximately 40km east of the North-west Coastal Highway, a significant distance outside the Wheatstone study area.

Ecology: Night Parrots typically inhabit areas where there is dense, low vegetation, which provides them shelter during the day. Most records come from hummock grasslands with spinifex (*Triodia* sp.), from areas dominated by samphire or, particularly, where these two habitats are juxtaposed.

Likelihood of Occurrence: Although not impossible, the Night Parrot is considered highly unlikely to occur within the study area. This view is based on the lack of preferred habitat, the local level of feral predator activity, and the period since the last reliable sighting in the west Pilbara (over 40 years).

5.3.2 Schedule 4 Species

Peregrine Falcon (Falco peregrinus)
Distribution: The Peregrine Falcon has an almost cosmopolitan distribution, but is absent from most deserts and the Nullarbor Plain (Johnstone and Storr 1998).

Ecology: The Peregrine Falcon, like other birds of prey, is a relatively long-lived species, with low reproductive rates and low population density. These factors, combined with the fact that they are a top end predator and limited by their prey, make them particularly vulnerable to human impact. This species inhabits a wide range of habitats including forest, woodlands, wetlands and open country (Pizzey and Knight 1997).

Likelihood of Occurrence: It is possible that the Wheatstone study area falls within the home range of this species and may periodically be present.

Potential Impacts: Peregrine Falcons prefer cliff faces as nest sites. As there were no cliffs observed in the vicinity of the study area, no potential nest sites for this species would be affected. No impacts on this species would be expected.

Saltwater Crocodile (Crocodylus porosus)
Distribution: Saltwater Crocodiles inhabit coastal rivers, mangroves, swamps and open sea in northern Australia, extending inland via major rivers and floodplains (Wilson and Swan 2008).

Ecology: Adult Saltwater Crocodiles feed on fish, turtles, birds and mammals. The breeding season occurs during the wet season, between October and May. Females construct a mound of grasses and reeds, usually close to permanent water.

Likelihood of Occurrence: There have been recent reliable sightings of C. porosus in the Ashburton River and it is possible that the species could occur in the mangrove tidal creeks adjoining the Wheatstone study area.

5.3.3 Priority 1 Species

Little Northern Freetail-bat (Mormopterus loriae cobourgensis)
Distribution: Endemic to Australia, this species' distribution encompasses the Western Australian coastal areas from Derby to the Exmouth Gulf (Churchill 1998).

Ecology: This species is a mangrove specialist, restricted to mangrove forest and adjacent areas (Churchill 1998). It has previously been recorded roosting in small crevices in dead upper branches of the mangrove *Avicennia marina* (Churchill 1998) (the dominant mangrove species the intertidal zone adjacent to the Wheatstone study area). Individuals emerge early in the evening in groups of up to 100 individuals above the mangrove canopy, before dispersing to forage alone or in pairs. *M. loriae* prey on insects above and beside the forest canopy. They give birth to single young, which are born in the wet season (summer) (Churchill 1998).

Likelihood of Occurrence: This species was recorded via echolocation call during the recent Wheatstone survey (Table 4.7 and Figure 4.3).

5.3.4 Priority 4 Species

Long-tailed Dunnart (Sminthopsis longicaudata)
Distribution: The Long-tailed Dunnart inhabits rocky, rugged habitat in the Pilbara and adjacent upper Gascoyne region, and east to the central Northern Territory and South Australia (Menkhorst and Knight 2001).

Ecology: This species typically occurs on plateaus near breakaways and scree slopes, and on rugged boulder-strewn scree slopes.

Likelihood of Occurrence: The Long-tailed Dunnart was once considered to be rare and possibly threatened, however research has now shown that it is relatively common and widespread but is restricted to its preferred specific habitat. This species has been recorded near Onslow by the WA Museum (Appendix 2) and could potentially occur within the Wheatstone Study area.

Brush–tailed Mulgara (Dasycercus blythi)
Overview: Until recently, there was considerable taxonomic confusion within the genus *Dasycercus*. For the last 30 years only one species, *D. cristicauda*, was recognised, and this was listed as Schedule 1 (Vulnerable). More recently, based on genetic and morphological attributes, two species are now recognised: the Crest-tailed Mulgara, *D. cristicauda* and the Brush-tailed Mulgara, *D. blythi* (Woolley 2005, 2006). The former species is still listed by the DEC as Schedule 1, while *D. blythi* is listed as a Priority 4 species.

Woolley (2005, 2006) distinguished these two species on the following characteristics:

- appearance of black hairs on the distal half of the tail (a brush in *D. blythi* versus a dorsal crest in *D. cristicauda*);
- the number of upper pre-molar teeth (two in *D. blythi* versus three in *D. cristicauda*); and
- in females, the number of teats (six in *D. blythi* versus eight in *D. cristicauda*).

Distribution: The Brush-tailed Mulgara occurs in spinifex sand plain habitat across the arid zone of Western Australia, the Northern Territory and Queensland. Mulgara were formerly widespread in sandy deserts but they are now rare and patchily distributed. Recent records are from the Great Victoria, Gibson, Great Sandy, Little Sandy and Tanami deserts, the Pilbara, Gascoyne, Murchison, north-eastern Goldfields, the Central Ranges region and Carnarvon basin (Kennedy Range).

Ecology: The Brush-tailed Mulgara inhabits spinifex grasslands, and larger colonies coincide with relatively well-watered areas such as paleo-drainage channels or drainage lines in sandplain or sand dune habitats (Maxwell et al. 1996). They have a diet of small vertebrates and larger invertebrates. Little is known about breeding of Brush-tailed Mulgara, although females with up to six young in the pouch have been captured in September. Among captive animals, mating has been observed in May to June, with young born in late June to August. Individuals have been known to come into breeding condition each year for six years (Woolley 2008).

Likelihood of Occurrence: There are no records of Mulgara from the area encompassing the Wheatstone study area within the WA Museum FaunaBase database or the DEC Threatened and Priority fauna database. The Brush-tailed Mulgara may potentially occur within the Wheatstone study area based on its broader distribution, thought it has never been recorded during previous surveys in the locality (Section 5.6).

Western Pebble-mound Mouse (Pseudomys chapmani)
Distribution: The Western Pebble-mound Mouse is confined to the central and eastern Pilbara including Karijini National Park (Menkhorst and Knight 2001).

Ecology: The species is found on stony hillsides with hummock grasslands (Menkhorst and Knight 2001) and is common to very common in suitable habitat within the Hamersley and Chichester subregions of the Pilbara bioregion. The Western Pebble-mound Mouse is well known for its behaviour of constructing extensive mounds of small stones covering areas from 0.5 to 9.0 square meters (Van Dyck and Strahan 2008). Mounds are most common on spurs and gentle slopes where suitably sized stones are present.

Likelihood of Occurrence: An abandoned mound was recorded at the eastern end of the Domgas pipeline corridor at 343492mE, 7557301mN (site WHTSRE01).

Short-tailed Mouse (Leggadina lakedownensis)
Distribution: Since 1997, the number of records of this species has increased substantially, such that it has now been recorded extensively in the Pilbara (Biota database). In WA, the distribution of this species includes the Pilbara and Kimberley regions (Menkhorst and Knight 2001).

Ecology: Regional records suggest that the primary mainland habitat for this species comprises areas of cracking clay and adjacent habitats, although it has also been recorded from hilltops (Dr Peter Kendrick, DEC Karratha, pers. comm. 2003) and sandy coastal areas near Onslow.

Likelihood of Occurrence: Although not recorded during the recent survey, *L. lakedownensis* has been recorded in the vicinity during previous surveys (Section 5.6; Appendix 2).

Australian Bustard (Ardeotis australis)
Distribution: The Australian Bustard occurs over much of Western Australia, with the exception of the more heavily wooded southern portions of the State.

Ecology: This species prefers open or lightly wooded grassland, including *Triodia* sp. sandplains, and is considered scarce to common depending on season and habitat (Johnstone and Storr 1998).

Likelihood of Occurrence: The Australian Bustard was recorded on four occasions at a single site within the Wheatstone study area. Records from previous surveys demonstrate that this bird is relatively common within the area.

Bush Stone-curlew (Burhinus grallarius)
Distribution: The Bush Stone-curlew is widespread throughout much of Australia. It remains common in tropical Australia but has declined significantly particularly in temperate regions (Marchant and Higgins 1993). Populations appear secure in the Pilbara (Ron Johnstone, WA Museum, pers. comm. 2003).

Ecology: The Bush Stone-curlew is nocturnal and inhabits sparsely grassed, lightly timbered forest or woodland.

Likelihood of Occurrence: Although not recorded during this survey, this species may potentially occur within the study area.

Star Finch (Neochmia ruficauda subclarescens)
Distribution: The Star Finch is endemic to Australia where it is found from the Pilbara to south-eastern Australia. It remains most common in the tropics where its abundance is highly variable.

Ecology: This species is typically recorded from reed beds and adjacent vegetation communities along permanent waterways in the Pilbara. It is considered to be resident in most of its range but, as with all finches, individuals can wander widely. Its ecology in the Pilbara is not well known but it has been observed feeding on the seed of sedges (*Cyperus* spp.) and Buffel Grass (*Cenchrus ciliaris*) (Dr Mike Craig, pers. obs.). In other parts of its range it feeds mainly on seeds, but insects are a common part of the diet during the breeding season. The main threat to the species is considered to be overgrazing by stock along waterways, which destroys the riparian vegetation on which they depend (Garnett and Crowley 2000).

Likelihood of Occurrence: Although Star Finches were not recorded during the recent survey, the species is known to occur in the vicinity (WA Museum records Appendix 2) and is recorded in the DEC threatened fauna database near Onslow. It may occur in riverine habitats adjoining the study area associated with the Ashburton River.

Grey Falcon (Falco hypoleucos)

Distribution: In Western Australia, the Grey Falcon is a scarce species that typically occurs north of 26°S.

Ecology: This species mainly inhabits lightly wooded coastal and riverine plains (Johnstone and Storr 1998). *F. hypoleucos* may also occur near wetlands where surface water attracts prey. This falcon preys primarily on birds, especially parrots and pigeons, using high-speed chases and stoops; reptiles and mammals are also taken. It utilises old nests of other birds of prey and ravens, usually high in a living eucalypt near water or a watercourse. Peak egg-laying season is in late winter and early spring and two or three eggs are laid.

Likelihood of Occurrence: Grey Falcons were not recorded during the recent survey, however it has been recorded in the vicinity in the DEC threatened fauna database and suitable habitat occurs in the wider locality (Appendix 1).

Eastern Curlew (Numenius madagascariensis)
Distribution: The Eastern Curlew occurs throughout coastal Western Australia, south to Bunbury (Johnstone and Storr 1998).

Ecology: This species occurs mainly on tidal mudflats and also on sandy beaches and rarely near coastal lakes, including salt field ponds (Johnstone and Storr 1998). The Eastern Curlew breeds in northern Asia and is a summer migrant to Australia. It is moderately common in the Pilbara.

Likelihood of Occurrence: Although this species has the potential to occur within the Wheatstone project area, its preferred habitat is tidal mudflats. Although mudflats within the regular tidal range occur close to the Wheatstone Project area, they do not fall within the study area. Those present in the study area (vegetation type 'mf' in Figure 4.1), are supratidal salt flats and would not provide routine foraging habitat for this species.

5.3.5 Migratory Species Occurring in the Study Area

Fork-tailed Swift (Apus pacificus)
Distribution: The distribution of the Fork-tailed Swift is temporally and spatially extremely patchy, but the species visits most parts of the State (Johnstone and Storr 1998).

Ecology: With its irruptive nature, this species may on occasion be present over most open habitats. It is present in Western Australia from September to May, and is noted as often occurring prior to or after cyclone activity (Johnstone and Storr 1998).

Likelihood of occurrence: The species was recorded once from two individuals at site WHT05 during the survey, but would not be resident in this location.

Rainbow Bee-eater (Merops ornatus)
Distribution: Occurs through the majority of the western third of Western Australia where free water is relatively readily available. May occur in many areas as either a casual or transitory species.

Ecology: This species forages aerially for insects and nests in burrows in the ground (Higgins 1999). It occurs in lightly wooded habitats that provide suitable (sandy) soil for nesting and a tall stratum of vegetation for perching.

Likelihood of occurrence: This species was recorded 23 times during the survey and is likely to be a routine visitor to the study area.

White-bellied Sea-eagle (Haliaeetus leucogaster)
Distribution: The White-bellied Sea-eagle occurs in most coastal habitats around Western Australia, in addition to much of eastern Australia (Johnstone and Storr 1998).

Ecology: Diet comprises mostly fish, nesting seabirds and coastal ground fauna. Breeding activity is almost entirely limited to islands (Johnstone and Storr 1998).

Likelihood of occurrence: This species was recorded opportunistically twice from the study area, both in coastal locations. The species is likely to be a routine visitor to the coastal portions of the study area.

5.4 Potential SRE Invertebrates

Two pseudoscorpion taxa, a group with the potential to harbour SREs, were recorded from the Wheatstone study area (Section 4.6). The specimens of *Synsphyronus* sp. '8/1 Pilbara' collected at WHTSRE01 and WHTSRE07 all represent the same taxon (Section 4.6.1) (Mark Harvey, WA Museum, pers. comm., 2009).

The pseudoscorpion genera *Solinus* and *Synsphyronus* have been collected by Biota from several other locations in the Pilbara region. *Synsphyronus* spp. has been collected from West Turner approximately 30 km West of Tom Price (Biota 2009c), along the Pilbara Iron rail approximately 60 km north-north-east of Tom Price (Biota 2008b), and from Mesa K in the Robe Valley, near Pannawonica (Biota 2007). *Solinus* sp. has been collected at Cape Lambert (Biota 2008c), and in the vicinity of Tom Price (Biota 2008d). None of these previous collections have been determined as SREs by the WA Museum.

The collection sites for the specimens were situated in the Uaroo and Giralia Land Systems. Uaroo ('*Broad sandy plains supporting shrubby hard and soft spinifex grasslands*') is the fourth most widespread land system in the Pilbara bioregion at 987,066 ha (van Vreeswyk et al. 2004). Giralia ('*Broad sand plains with large linear dunes; hard and soft spinifex pastures*'; Payne et al. (1988)) is less widespread in the Pilbara at 19,676 ha, but is widespread in the Carnarvon bioregion with a further 342,955 ha (a total of 362,631 ha in the State).

Considering that:

- the collection sites for *Synsphyronus* sp. '8/1 Pilbara' just within this study area are separated by a distance of over 50 km (Figure 2.3);
- the Land Systems to which these sites belong are widespread, do not contain isolated remnant landforms, and not patchily distributed in the region ;
- the habitat from which they were recorded is not isolated or restricted in the landscape (emergent *Corymbia* sp. trees over *Triodia* hummock grass plain);
- the genus exhibits a phoretic (animal assisted) dispersal mode; and
- few other members of this genus are known SREs,

initial assessment indicated a low risk that this taxon represents an SRE. This was subsequently confirmed by the WA Museum, which advised that this taxon is not an SRE (Mark Harvey, WA Museum pers. comm., 2009). While only a single specimen of *Solinus* sp. 1 was recorded, it was from the same microhabitat (beneath peeling bark on a *Corymbia* tree) as the *Synsphyronus* sp. 1 specimens. Advice from the WA Museum also confirmed that this same taxon has been recorded from five other locations in the region and is also not an SRE (Mark Harvey, WA Museum pers. comm., 2009).

5.5 Conservation Significance Summary

The single-phase survey of the Wheatstone study area yielded a combined total of 129 vertebrate species comprising 52 herpetofauna, 60 avifauna and 17 mammal species (including three introduced species). The species recorded were generally representative of the taxa commonly recorded in this part of the bioregion. This is consistent with the available habitat data, which indicate that no restricted or uncommon geological units or land systems occur within the study area (Table 2.1 and Table 2.2).

None of the habitats present in the Wheatstone study area are listed as TECs, though the ephemeral creekline drainage habitat present at small extent in the south-west of the study area is considered 'ecosystems at risk' in the Cape Range subregion (Section 5.2). While outside the scope of the terrestrial fauna survey, the mangrove communities adjoining the terrestrial ecology study area are also considered 'ecosystems at risk' within the Roebourne subregion (Kendrick and Stanley 2001). The remaining habitat types are well represented in the locality and wider region and not of elevated conservation significance (Section 5.2).

Based on reviews of habitats and known fauna distributions it is considered unlikely that any listed Schedule 1 species would occur within the Wheatstone study area. The Priority 1 species the Little Northern Freetail-bat (*Mormopterus loriae cobourgensis*) and the Priority 4 Western Pebble-mound Mouse (*Pseudomys chapmani*) and Australian Bustard (*Ardeotis australis*) were recorded during the field surveys, along with three *EPBC Act 1999* listed migratory species (the Rainbow Bee-eater *Merops ornatus*, Fork-tailed Swift *Apus pacificus* and White-bellied Sea Eagle *Haliaeetus leucogaster*). In all cases, none or only a small proportion of local habitat suitable for these taxa would be cleared relative to their wider distribution in the region.

5.6 Comparison with other Surveys in the Locality

Appendix 2 presents a detailed comparison of the faunal assemblage and individual species records from this survey in context with other recent surveys in the locality (where these data were publicly available). Although conducted under different seasonal conditions, including additional habitats, and with somewhat differential sampling effort, this still provides useful contextual information for the current study. Table 5.2 summarises the results from these surveys.

Table 5.2: Comparison of the results of the Wheatstone Project fauna survey with other recent fauna studies in the locality.

	No. of Species				
Survey	**Herpetofauna**	**Avifauna**	**Mammals**	**Total**	**Formally Listed Species**
Wheatstone Project (this study)	51	60	17	**128**	*Ardeotis australis* (Priority 4) *Merops ornatus* (Migratory) *Haliaeetus leucogaster* (Migratory) *Apus pacficifus* (Migratory) *Mormopterus l. cobourgensis* (Priority 1) *Pseudomys chapmani* (Priority 4)
Yannarie Salt Project (Biota 2005a)	35	33	9	**77**	*Ardeotis australis* (Priority 4) *Merops ornatus* (Migratory)
Onslow Salt (Biota 2005b)	36	29	15	**80**	*Ardeotis australis* (Priority 4) *Merops ornatus* (Migratory) *Haliaeetus leucogaster* (Migratory) *Leggadina lakedownensis* (Priority 4)
Tubridgi Gas Plant and Cane River Conservation Park (WAM 2009)	78	51	18	**147**	*Ardeotis australis* (Priority 4) *Merops ornatus* (Migratory) *Mormopterus l. cobourgensis* (Priority 1) *Pseudomys chapmani* (Priority 4) *Leggadina lakedownensis* (Priority 4) *Smithopsis longicaudata* (Priority 4)
API Onslow Rail Corridor (Biota 2009a)	49	75	18	**147**	*Ardeotis australis* (Priority 4) *Neochmia ruficauda* (Priority 4)
Chevron Domgas pipeline (Validus 2008)	27	55	10	**92**	*Ardeotis australis* (Priority 4) *Merops ornatus* (Migratory)

The Threatened and migratory species recorded by other surveys in the locality represent a similar assemblage to those recorded from the Wheatstone study area (Table 5.2). Consistent with the assessment presented in this report (Section 5.3), no Schedule listed species have been recorded during any of the other surveys from sites in the Onslow locality.

The species richness recorded from the Wheatstone study area is greater than all of the Validus (2008), Yannarie Salt Project and Onslow Salt surveys (the latter of which was conducted over several phases; Biota 2005b) (Table 5.2). The data from the Wheatstone study area also share the majority of vertebrate species with these surveys. The assemblage documented in this study approaches the diversity of the Tubridgi, API rail corridors and Cane River survey, all of which were completed over either a far wider range of habitats or multiple phases. This indicates that the current survey documented an adequate proportion of the fauna, as these latter surveys were conducted over more than one phase and sampled more habitats than this study. This reflects the optimal timing of the Wheatstone Project fauna survey, under warm conditions in early autumn, following late summer cyclonic rainfall.

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Appendix 1

Department of Environment and Conservation Threatened Fauna Database Search Results

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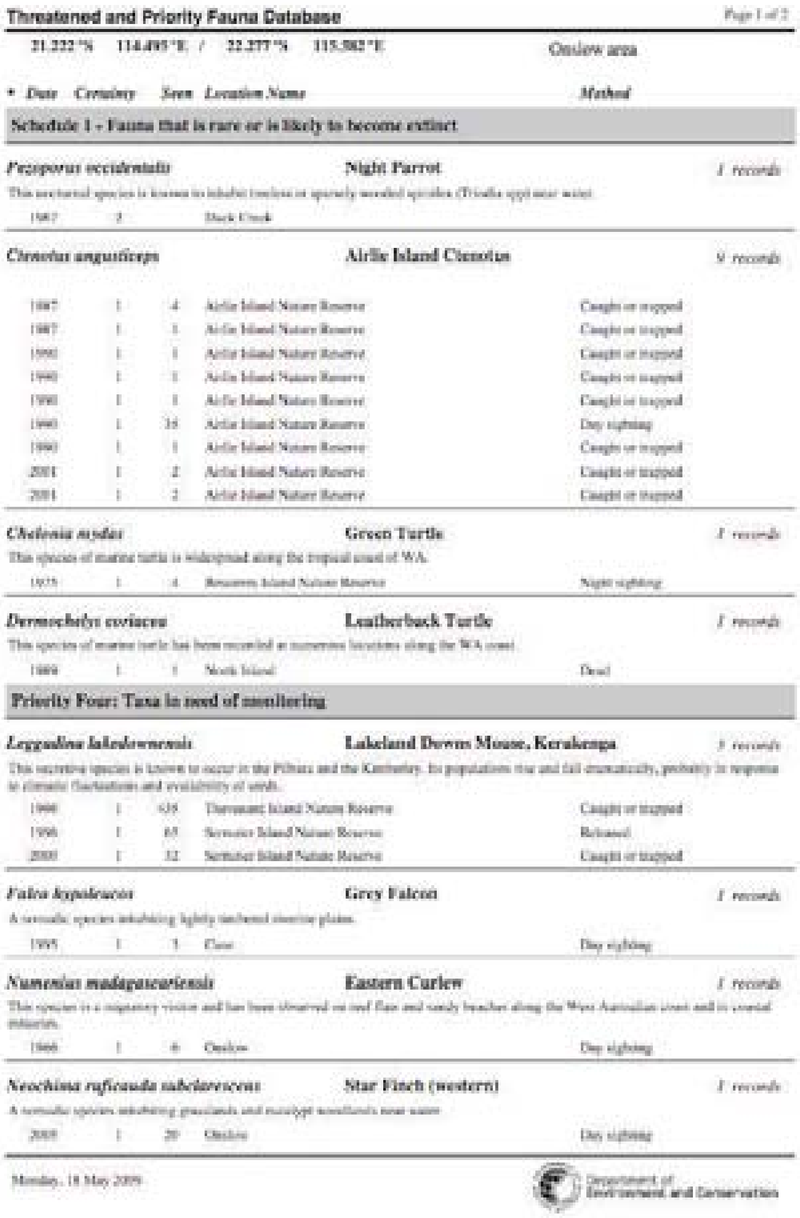

Threatened and Priority Fauna Database Page 1 of 2

21.222 °S 114.495 °E / 22.277 °S 115.582 °E Onslow area

* *Date*	*Certainty*	*Seen*	*Location Name*	*Method*

Schedule 1 - Fauna that is rare or is likely to become extinct

Pezoporus occidentalis **Night Parrot** *1 records*

This nocturnal species is known to inhabit treeless or sparsely wooded spinifex (Triodia spp) near water.

1987	2		Duck Creek	

Ctenotus angusticeps **Airlie Island Ctenotus** *9 records*

1987	1	4	Airlie Island Nature Reserve	Caught or trapped
1987	1	1	Airlie Island Nature Reserve	Caught or trapped
1990	1	1	Airlie Island Nature Reserve	Caught or trapped
1990	1	1	Airlie Island Nature Reserve	Caught or trapped
1990	1	1	Airlie Island Nature Reserve	Caught or trapped
1990	1	16	Airlie Island Nature Reserve	Day sighting
1990	1	1	Airlie Island Nature Reserve	Caught or trapped
2001	1	2	Airlie Island Nature Reserve	Caught or trapped
2001	1	2	Airlie Island Nature Reserve	Caught or trapped

Chelonia mydas **Green Turtle** *1 records*

This species of marine turtle is widespread along the tropical coast of WA.

1975	1	4	Bessieres Island Nature Reserve	Night sighting

Dermochelys coriacea **Leatherback Turtle** *1 records*

This species of marine turtle has been recorded at numerous locations along the WA coast.

1989	1	1	North Island	Dead

Priority Four: Taxa in need of monitoring

Leggadina lakedownensis **Lakeland Downs Mouse, Kerakenga** *3 records*

This secretive species is known to occur in the Pilbara and the Kimberley. Its populations rise and fall dramatically, probably in response to climatic fluctuations and availability of seeds.

1990	1	638	Thevenard Island Nature Reserve	Caught or trapped
1998	1	65	Serrurier Island Nature Reserve	Released
2000	1	32	Serrurier Island Nature Reserve	Caught or trapped

Falco hypoleucos **Grey Falcon** *1 records*

A nomadic species inhabiting lightly timbered riverine plains.

1995	1	1	Cane	Day sighting

Numenius madagascariensis **Eastern Curlew** *1 records*

This species is a migratory visitor and has been observed on reef flats and sandy beaches along the West Australian coast and in coastal estuaries.

1966	1	6	Onslow	Day sighting

Neochmia ruficauda subclarescens **Star Finch (western)** *1 records*

A nomadic species inhabiting grasslands and eucalypt woodlands near water.

2009	1	20	Onslow	Day sighting

Monday, 18 May 2009

Department of Environment and Conservation

Threatened and Priority Fauna Database

21.222 °S 114.495 °E / 22.277 °S 115.582 °E Onslow area

* *Date*	*Certainty*	*Seen*	*Location Name*	*Method*

- Information relating to any records provided for listed species:-
  Date: date of recorded observation.
  Certainty (of correct species identification): 1=Very certain; 2=Moderately certain; and 3=Not sure.
  Seen: Number of individuals observed.
  Location Name: Name of reserve or nearest locality where observation was made.
  Method: Method or type of observation.

Appendix 2

Western Australian Museum NatureMap Search: Comparison with Wheatstone Fauna and Previous Surveys

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Comparison of herpetofauna recorded during the Wheatstone, Straits and Onslow surveys and herpetofauna collected by the Western Australian Museum (WAM) between 21.22°S, 114.49°E and 22.27°S, 115.58°E

FAMILY **Species Name**	**Wheatstone (this study)**	**Straits (Biota 2005a)**	**Onslow (Biota 2005b)**	**Tubridgi and Cane River (WAM 2009)**
HYLIDAE				
Litoria rubella	x			x
MYOBATRACHIDAE				
Cyclorana maini	x			x
Neobatrachus aquilonius	x			x
Neobatrachus fulvus		x		
Notaden nichollsi	x	x		x
GEKKONIDAE				
Diplodactylus conspicillatus	x	x	x	x
Diplodactylus pulcher				x
Gehyra pilbara	x	x	x	x
Gehyra purpurascens				x
Gehyra punctata	x			x
Gehyra variegata	x	x	x	x
Heteronotia binoei	x	x	x	x
Lucasium stenodactylum	x		x	x
Lucasium wombeyi				x
Nephrurus levis	x	x	x	x
Rhynchoedura ornata				x
Strophurus jeanae	x			x
Strophurus strophurus	x	x		x
PYGOPODIDAE				
Delma haroldi		x		x
Delma nasuta	x			x
Delma pax				x
Delma tincta	x		x	x
Lialis burtonis	x	x		x
Pygopus nigriceps	x		x	x
AGAMIDAE				
Amphibolurus gilberti				x
Amphibolurus longirostrus				x
Ctenophorus caudicinctus	x			x
Ctenophorus isolepis	x			x
Ctenophorus femoralis		x	x	x
Ctenophorus nuchalis	x	x	x	x
Ctenophorus rubens		x	x	x
Diporiphora winneckei	x	x		x
Pogona minor	x		x	x
SCINCIDAE				
Ctenotus calurus	x			
Ctenotus duricola				x
Ctenotus grandis	x		x	x
Ctenotus hanloni	x	x	x	x
Ctenotus Helenae				x
Ctenotus iapetus	x	x	x	x
Cenotus maryani			x	x
Ctenotus pantherinus	x	x	x	x
Ctenotus rufescens	x	x		x
Ctenotus saxatilis	x	x	x	x
Ctenotus schomburgkii	x			

FAMILY **Species Name**	**Wheatstone (this study)**	**Straits (Biota 2005a)**	**Onslow (Biota 2005b)**	**Tubridgi and Cane River (WAM 2009)**
Cyclodomorphus melanops				x
Eremiascincus fasciolatus	x	x	x	x
Glaphyromorphus isolepis		x		x
Lerista bipes	x	x	x	x
Lerista clara	x	x	x	x
Lerista elegans		x		x
Lerista onsloviana	x	x		x
Lerista planiventralis				x
Lerista rolfei				x
Lerista uniduo				x
Lerista verhmens				x
Notoscincus ornatus		x		x
Menetia greyii	x	x	x	x
Morethia ruficauda				x
Tiliqua multifasciata	x		x	x
VARANIDAE				
Varanus acanthurus				x
Varanus brevicauda	x	x	x	x
Varanus Bushi				x
Varanus caudolineatus	x			
Varanus eremius	x	x	x	x
Varanus gouldii		x	x	x
Varanus panoptes			x	
Vranus tristis				x
TYPHLOPIDAE				
Ramphotyphlops ammodytes	x		x	x
Ramphotyphlops grypus	x	x	x	x
Ramphotyphlops hamatus	x		x	x
PYTHONIDAE				
Antaresia stimsoni	x		x	x
Aspidites melanocephalus	x			
ELAPIDAE				
Demansia psammophis	x	x		x
Demansia rufescens				
Disteira major				x
Disteira stokesii				x
Egernia depressa				x
Ephalophis greyae		x	x	x
Furina ornata	x		x	x
Hydrelaps darwiniensis		x		
Hydrophis ocellatus				x
Pseudechis australis	x			x
Pseudonaja modesta	x	x		x
Pseudonaja nuchalis	x		x	x
Simoselaps anomalus	x		x	x
Suta punctata	x		x	x
Total species	**51**	**35**	**36**	**78**
Grand Total	**87**			

Comparison of avifauna recorded during the Wheatstone, Straits and Onslow surveys and avifauna collected by the Western Australian Museum between 21.22°S, 114.49°E and 22.27°S, 115.58°E

FAMILY Species Name	Common Name	Wheatstone	Straits	Onslow	WAM
CASUARIIDAE					
Dromaius novaehollandiae	Emu	x	x		
PHASIANIDAE					
Coturnix pectoralis	Stubble Quail				x
TURNICIDAE					
Turnix velox	Little Button-quail	x	x		
PELECANIDAE					
Pelecanus conspicillatus	Australian Pelican	x		x	x
ANHINGIDAE					
Anhinga melanogaster	Darter			x	
PHALACROCORACIDAE					
Phalacrocorax melanoleucos	Little Pied Cormorant			x	
PODICIPEDIDAE					
Poliocephalus poliocephalus	Hoary-headed Grebe			x	
ANATIDAE					
Anas gracilis	Grey Teal			x	
Anas superciliosa	Pacific Black Duck	x			
RALLIDAE					
Porzana fluminea	Australian Spotted Crake				X
ARDEIDAE					
Ardea garzetta nigripes	Little Egret	x			
Ardea sacra	Eastern Reef Heron	x		x	
Ardea novaehollandiae	White-faced Heron				x
Butorides striatus	Stiated Heron				x
CICONIIDAE					
Ephippiorhynchus asiaticus	Black-necked Stork				x
OTIDIDAE					
Ardeotis australis	Australian Bustard	x	x	x	x
SCOLOPACIDAE					
Calidris acuminata	Sharp-tailed Sandpiper			x	x
Calidris canutus	Red Knot				x
Charadrius leschenaultii	Greater Sand Plover				x
Calidris ferruginea	Curlew Sandpiper			x	
Calidris ruficollis	Red-necked Stint			x	
Limosa lapponica	Bar-tailed Godwit				x
Numenius madagascariensis	Eastern Curlew			x	x
HAEMATOPODIDAE					
Haematopus fuliginosus	Sooty Oystercatcher				x
Haematopus longirostris	Pied Oystercatcher				x
CHARADRIIDAE					
Charadrius ruficapillus	Red-capped Plover			x	
Erythrogonys cinctus	Red-kneed Dotterel			x	
RECURVIROSTRIDAE					
Cladorhynchus leucocephalus	Banded Stilt				
Himantopus himantopus	Black-winged Stilt				
Recurvirostra	Red-necked Avocet				

FAMILY **Species Name**	**Common Name**	**Wheatstone**	**Straits**	**Onslow**	**WAM**
novaehollandiae					
LARIDAE					
Larus novaehollandiae	Silver Gull	x			
Sterna caspia	Caspian Tern	x		x	
Sterna nereis	Fairy Tern				x
Sterna nilotica	Gull-billed Tern			x	
Sterna dougallii	Roseate Tern				x
ACCIPITRIDAE					
Aquila audax	Wedge-tailed Eagle	x	x		
Aquila morphnoides	Little Eagle			x	
Circus approximans	Swamp Harrier			x	
Circus assimilis	Spotted Harrier	x	x		
Elanus caeruleus axillaris	Black-shouldered Kite	x	x	x	
Haliaeetus leucogaster	White-bellied Sea-Eagle	x		x	
Haliastur indus girrenera	Brahminy Kite	x			
Haliastur sphenurus	Whistling Kite	x	x		
Hamirostra melanosternon	Black-breasted Buzzard	x			
Milvus migrans	Black Kite				x
Pandion haliaetus cristatus	Osprey	x			
FALCONIDAE					
Falco cenchroides	Australian Kestrel	x	x	x	x
Falco longipennis	Australian Hobby	x			
Falco subniger	Black Falcon				x
COLUMBIDAE					
Geopelia cuneata	Diamond Dove	x			x
Geopelia humeralis	Bar-shouldered Dove				x
Geopelia striata	Peaceful Dove	x			x
Geophaps plumifera	Spinifex Pigeon	x			
Ocyphaps lophotes	Crested Pigeon	x			
PSITTACIDAE					
Cacatua roseicapilla	Galah	x	x		
Cacatua sanguinea	Little Corella	x	x		
Melopsittacus undulatus	Budgerigar	x			x
Nymphicus hollandicus	Cockatiel	x		x	x
Platycercus zonarius	Australian Ringneck	x			x
CUCULIDAE					
Chrysococcyx basalis	Horsfield's Bronze Cuckoo	x	x	x	
STRIGIDAE					
Ninox novaeseelandiae	Boobook Owl	x			
TYTONIDAE					
Tyto alba	Barn Owl				
AEGOTHELIDAE					
Aegotheles cristatus	Australian Owlet-nightjar	x			
APODIDAE					
Apus pacificus	Fork-tailed Swift	x			
HALCYONIDAE					
Dacelo leachii	Blue-winged Kookaburra	x			x
Todiramphus sanctus	Sacred Kingfisher		x		
Todiramphus chloris	Collared Kingfisher				x
MEROPIDAE					
Merops ornatus	Rainbow Bee-eater	x	x	x	x
MALURIDAE					
Malurus lamberti	Variegated Fairy-wren	x			
Malurus leucopterus	White-winged Fairy-wren	x	x	x	x

FAMILY **Species Name**	**Common Name**	**Wheatstone**	**Straits**	**Onslow**	**WAM**
ACANTHIZIDAE					
Gerygone levigaster	Mangrove Gerygone	x			
Gerygone tenebrosa	Dusky Gerygone				x
MELIPHAGIDAE					
Certhionyx niger	Black Honeyeater	x			
Epthianura aurifrons	Orange Chat				x
Epthianura tricolor	Crimson Chat		x		x
Lichenostomus keartlandi	Grey-headed Honeyeater	x			
Lichenostomus penicillatus	White-plumed Honeyeater				x
Lichenostomus virescens	Singing Honeyeater	x	x		x
Lichmera indistincta	Brown Honeyeater	x	x		x
Manorina flavigula	Yellow-throated Miner				x
CINCLOSOMATIDAE					
Psophodes occidentalis	Western Wedgebill	x			
PONATOSTOMIDAE					
Pomatostomus temporalis	Grey-crowned Babbler				x
PACHYCEPHALIDAE					
Oreoica gutturalis	Crested Bellbird	x			
Pachycephala lanioides	White-breasted Whistler				x
Pachycephala melanura	Mangrove Golden Whistler				x
DICRURIDAE					
Grallina cyanoleuca	Magpie-lark	x			
Rhipidura leucophrys	Willie Wagtail	x	x		
Rhipidura phasiana	Mangrove Grey Fantail				X
CAMPEPHAGIDAE					
Coracina novaehollandiae	Black-faced Cuckoo-shrike	x	x		
Lalage tricolor	White-winged Triller		x		
ARTAMIDAE					
Artamus cinereus melanops	Black-faced Woodswallow	x		x	x
Artamus cyanopterus	Dusky Woodswallow	x			
Artamus leucorhynchus	White-breasted Woodswallow		x		
Artamus personatus	Masked Woodswallow				x
CRACTICIDAE					
Cracticus nigrogularis	Pied Butcherbird	x	x		
Cracticus torquatus	Grey Butcherbird				x
Cracticus tibicen	Australian Magpie				x
CORVIDAE					
Corvus bennetti	Little Crow	x	x		x
Corvus orru cecilae	Torresian Crow	x	x		
HIRUNDINIDAE					
Cheramoeca leucosternus	White-backed Swallow	x	x	x	
Hirundo ariel	Fairy Martin	x	x		
Hirundo neoxena	Welcome Swallow		x		
Hirundo nigricans	Tree Martin	x	x		x
MOTACILLIDAE					
Anthus australis australis	Australian Pipit	x	x	x	
ALAUDIDAE					
Mirafra javanica horsfieldii	Singing Bushlark	x		x	
SYLVIIDAE					
Cincloramphus cruralis	Brown Songlark		x		
Cincloramphus mathewsi	Rufous Songlark	x			

FAMILY **Species Name**	**Common Name**	**Wheatstone**	**Straits**	**Onslow**	**WAM**
Eremiornis carteri	Spinifexbird		x		x
Mirafra javanica	Singing Bushlark		x		x
ESTRILDIDAE					
Emblema pictum	Painted Finch	x			
Neochima ruficauda	Star Finch				x
Taeniopygia guttata	Zebra Finch	x	x	x	x
ZOSTEROPIDAE					
Zosterops luteus	Yellow White-eye	x			x
	Total Species	**60**	**33**	**29**	**51**
	Grand Total	**113**			

Comparison of mammals recorded during the Wheatstone, Straits and Onslow surveys and mammals collected by the Western Australian Museum between 21.22°S, 114.49°E and 22.27°S, 115.58°E

FAMILY **Species Name**	**Common Name**	**Wheatstone**	**Straits**	**Onslow**	**WAM**
TACHYGLOSSIDAE					
Tachyglossus aculeatus	Short-beaked Echidna		x	x	
DASYURIDAE					
Dasykaluta rosamondae	Kaluta		x	x	x
Ningaui timealeyi	Pilbara Ningaui	x		x	x
Planigale ingrami	Long-tailed Planigale	x		x	
Planigale maculata	Common Planigale			x	
Sminthopsis longicaudata	Long-tailed Dunnart				x
Sminthopsis macroura	Stripe-faced Dunnart	x	x		x
Sminthopsis youngsoni	Lesser Hairy-footed Dunnart		x	x	x
MACROPODIDAE					
Macropus robustus	Euro Kangaroo	x	x		
Macropus rufus	Red Kangaroo	x		x	
EMBALLONURIDAE					
Saccolaimus flaviventris	Yellow-bellied Sheathtail Bat	x			
MOLOSSIDAE					
Chaerephon jobensis	Northern Freetail Bat				x
Mormopterus loriae cobourgensis	Little Northern Freetail-bat	x			x
Tadarida australis	White-striped Freetail Bat				x
VESPERTILIONIDAE					
Chalinolobus gouldii	Gould's Wattled Bat	x			x
Scotorepens greyii	Little Broad-nosed Bat	x			x
Vespadelus finlaysoni	Inland Cave Bat	x			x
MURIDAE					
Leggadina lakedownensis	Short-tailed Mouse			x	x
**Mus musculus*	House Mouse	x	x	x	
Notomys alexis	Spinifex Hopping Mouse	x	x	x	x
Pseudomys chapmani	Western Pebble-mound mouse	x			x
Pseudomys delicatulus	Delicate Mouse				x
Pseudomys desertor	Desert Mouse	x			
Pseudomys hermannsburgensis	Sandy Inland Mouse	x		x	x
Zyzomys argurus	Common Rock Rat				x
FELIDAE					
**Felis catus*	Cat	x	x	x	
CANIDAE					
Canis Lupis	Dingo			x	
**Vulpes vulpes*	Red Fox		x		x
EQUIDAE					
Equus caballus	Horse			x	
BOVIDAE					
**Bos taurus*	Domestic cattle	x			
**Capra hircus*	Goat			x	
	Total Species	**17**	**9**	**15**	**18**
	Grand Total	**31**			

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Appendix 3

Environment Protection and Biodiversity Conservation Act 1999 Protected Matters Report

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Threatened Species	**Status**	**Presence**
Terrestrial Mammals		
Mulgara *Dasycercus cristicauda*	Vulnerable	Species or species habitat likely to occur within area
Pilbara Leaf-nosed Bat *Rhinonicteris aurantius*	Vulnerable	Species or species habitat likely to occur within area

Migratory Species	**Status**	**Presence**
Migratory Terrestrial Birds		
White-bellied Sea-Eagle *Haliaeetus leucogaster*	Migratory	Species or species habitat likely to occur within area
Rainbow Bee Eater *Merops ornatus*	Migratory	Species or species habitat likely to occur within area
Barn Swallow *Hirundo rustica*	Migratory	Species or species habitat likely to occur within area
Migratory Wetland Birds		
Great Egret, White Egret *Ardea alba*	Migratory	Species or species habitat may occur within area
Cattle Egret *Ardea ibis*	Migratory	Species or species habitat may occur within area
Oriental Plover, Oriental Dotterel *Charadrius veredus*	Migratory	Species or species habitat may occur within area
Oriental Pratincole *Glareola maldivarum*	Migratory	Species or species habitat may occur within area
Little Curlew, Little Whimbrel *Numenius minutus*	Migratory	Species or species habitat may occur within area
Migratory Marine Birds		
Fork-tailed Swift *Apus pacificus*	Migratory	Species or species habitat may occur within area
Southern Giant-Petrel *Macronectes giganteus*	Migratory	Species or species habitat may occur within area
Wedge-tailed Shearwater *Puffinus pacificus*	Migratory	Breeding known to occur within area
Bridled Tern *Sterna anaethetus*	Migratory	Breeding known to occur within area
Caspian Tern *Sterna caspia*	Migratory	Breeding known to occur within area

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Appendix 4

Department of Environment and Conservation Regulation 17 Permit

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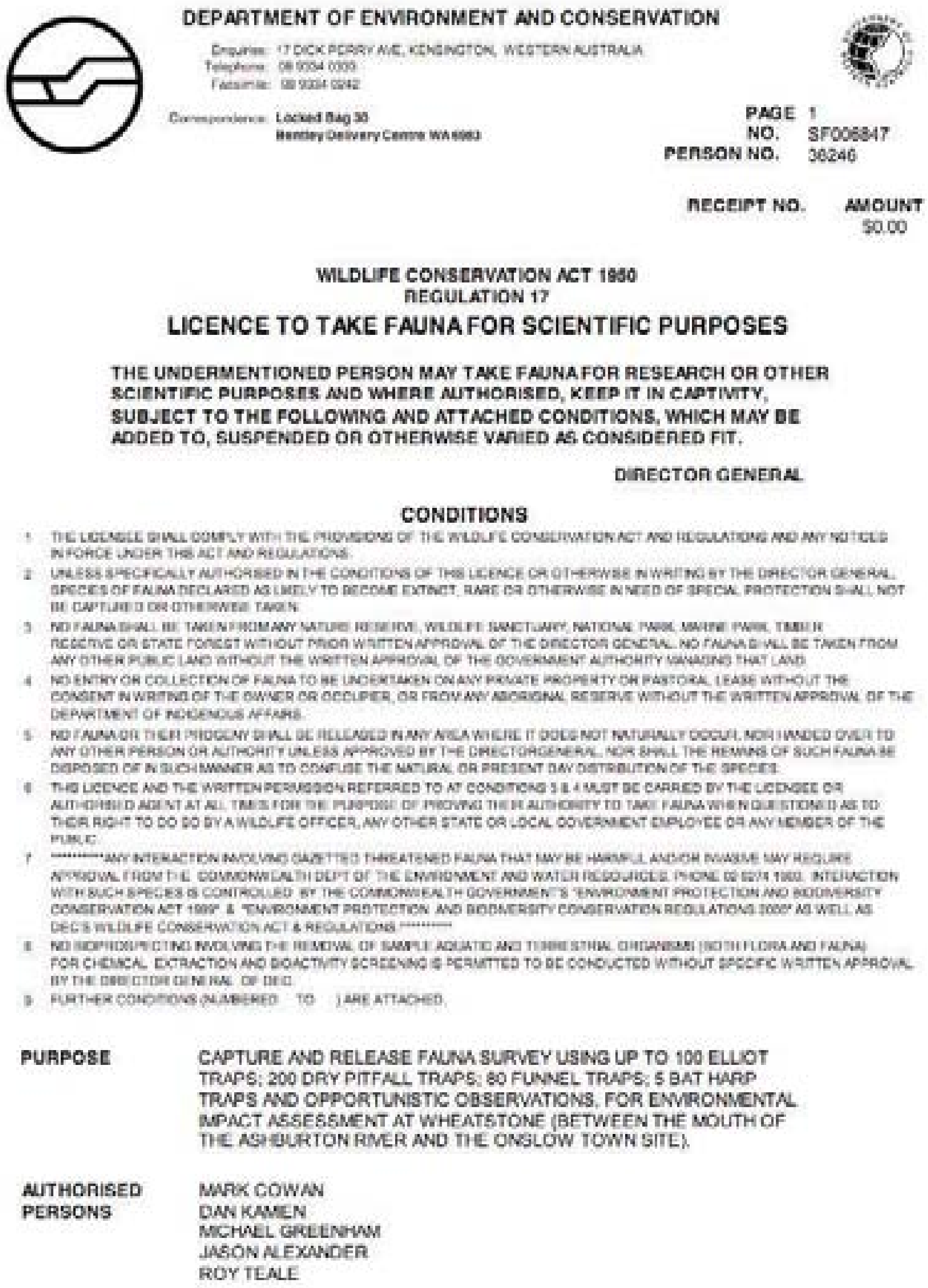

DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Enquiries: 17 DICK PERRY AVE, KENSINGTON, WESTERN AUSTRALIA
Telephone: 08 9334 0333
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Correspondence: Locked Bag 30
Bentley Delivery Centre WA 6983

PAGE 1
NO. SF006847
PERSON NO. 36246

RECEIPT NO. AMOUNT
$0.00

WILDLIFE CONSERVATION ACT 1950
REGULATION 17

LICENCE TO TAKE FAUNA FOR SCIENTIFIC PURPOSES

THE UNDERMENTIONED PERSON MAY TAKE FAUNA FOR RESEARCH OR OTHER SCIENTIFIC PURPOSES AND WHERE AUTHORISED, KEEP IT IN CAPTIVITY, SUBJECT TO THE FOLLOWING AND ATTACHED CONDITIONS, WHICH MAY BE ADDED TO, SUSPENDED OR OTHERWISE VARIED AS CONSIDERED FIT.

DIRECTOR GENERAL

CONDITIONS

1 THE LICENSEE SHALL COMPLY WITH THE PROVISIONS OF THE WILDLIFE CONSERVATION ACT AND REGULATIONS AND ANY NOTICES IN FORCE UNDER THIS ACT AND REGULATIONS.

2 UNLESS SPECIFICALLY AUTHORISED IN THE CONDITIONS OF THIS LICENCE OR OTHERWISE IN WRITING BY THE DIRECTOR GENERAL, SPECIES OF FAUNA DECLARED AS LIKELY TO BECOME EXTINCT, RARE OR OTHERWISE IN NEED OF SPECIAL PROTECTION SHALL NOT BE CAPTURED OR OTHERWISE TAKEN.

3 NO FAUNA SHALL BE TAKEN FROM ANY NATURE RESERVE, WILDLIFE SANCTUARY, NATIONAL PARK, MARINE PARK, TIMBER RESERVE OR STATE FOREST WITHOUT PRIOR WRITTEN APPROVAL OF THE DIRECTOR GENERAL. NO FAUNA SHALL BE TAKEN FROM ANY OTHER PUBLIC LAND WITHOUT THE WRITTEN APPROVAL OF THE GOVERNMENT AUTHORITY MANAGING THAT LAND.

4 NO ENTRY OR COLLECTION OF FAUNA TO BE UNDERTAKEN ON ANY PRIVATE PROPERTY OR PASTORAL LEASE WITHOUT THE CONSENT IN WRITING OF THE OWNER OR OCCUPIER, OR FROM ANY ABORIGINAL RESERVE WITHOUT THE WRITTEN APPROVAL OF THE DEPARTMENT OF INDIGENOUS AFFAIRS.

5 NO FAUNA OR THEIR PROGENY SHALL BE RELEASED IN ANY AREA WHERE IT DOES NOT NATURALLY OCCUR, NOR HANDED OVER TO ANY OTHER PERSON OR AUTHORITY UNLESS APPROVED BY THE DIRECTORGENERAL, NOR SHALL THE REMAINS OF SUCH FAUNA BE DISPOSED OF IN SUCH MANNER AS TO CONFUSE THE NATURAL OR PRESENT DAY DISTRIBUTION OF THE SPECIES.

6 THIS LICENCE AND THE WRITTEN PERMISSION REFERRED TO AT CONDITIONS 3 & 4 MUST BE CARRIED BY THE LICENSEE OR AUTHORISED AGENT AT ALL TIMES FOR THE PURPOSE OF PROVING THEIR AUTHORITY TO TAKE FAUNA WHEN QUESTIONED AS TO THEIR RIGHT TO DO SO BY A WILDLIFE OFFICER, ANY OTHER STATE OR LOCAL GOVERNMENT EMPLOYEE OR ANY MEMBER OF THE PUBLIC.

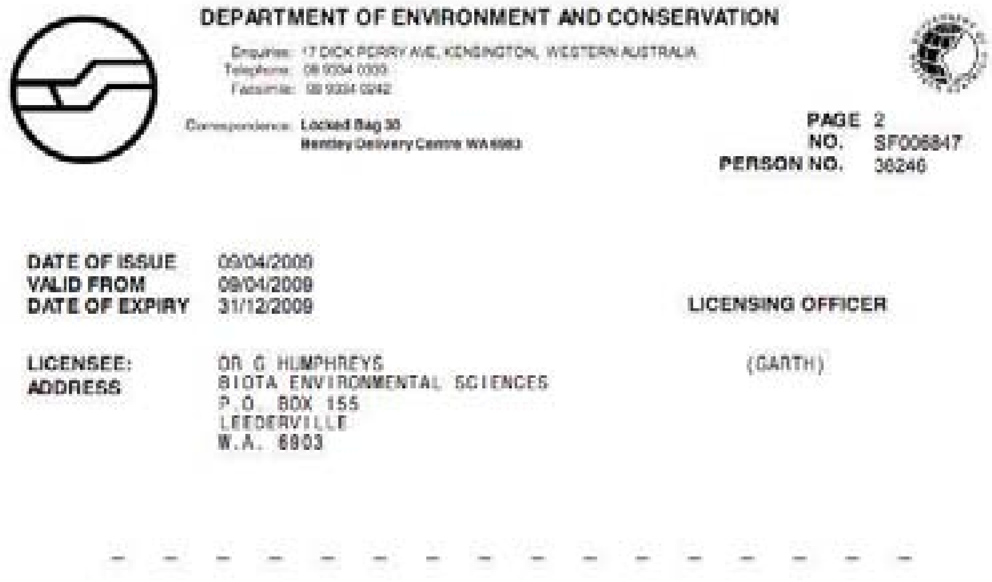
7 **********ANY INTERACTION INVOLVING GAZETTED THREATENED FAUNA THAT MAY BE HARMFUL AND/OR INVASIVE MAY REQUIRE APPROVAL FROM THE COMMONWEALTH DEPT OF THE ENVIRONMENT AND WATER RESOURCES. PHONE 02 6274 1900. INTERACTION WITH SUCH SPECIES IS CONTROLLED BY THE COMMONWEALTH GOVERNMENT'S "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999" & "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION REGULATIONS 2000" AS WELL AS DEC'S WILDLIFE CONSERVATION ACT & REGULATIONS.**********

8 NO BIOPROSPECTING INVOLVING THE REMOVAL OF SAMPLE AQUATIC AND TERRESTRIAL ORGANISMS (BOTH FLORA AND FAUNA) FOR CHEMICAL EXTRACTION AND BIOACTIVITY SCREENING IS PERMITTED TO BE CONDUCTED WITHOUT SPECIFIC WRITTEN APPROVAL BY THE DIRECTOR GENERAL OF DEC.

9 FURTHER CONDITIONS (NUMBERED TO) ARE ATTACHED.

PURPOSE CAPTURE AND RELEASE FAUNA SURVEY USING UP TO 100 ELLIOT TRAPS; 200 DRY PITFALL TRAPS; 80 FUNNEL TRAPS; 5 BAT HARP TRAPS AND OPPORTUNISTIC OBSERVATIONS, FOR ENVIRONMENTAL IMPACT ASSESSMENT AT WHEATSTONE (BETWEEN THE MOUTH OF THE ASHBURTON RIVER AND THE ONSLOW TOWN SITE).

AUTHORISED PERSONS
MARK COWAN
DAN KAMEN
MICHAEL GREENHAM
JASON ALEXANDER
ROY TEALE



DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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PAGE 2
NO. SF006847
PERSON NO. 36246

DATE OF ISSUE 09/04/2009
VALID FROM 09/04/2009
DATE OF EXPIRY 31/12/2009

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P.O. BOX 155
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W.A. 6903

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Appendix K1

Survey for Migratory Waterbirds in the Wheatstone LNG Area, November 2008 and April 2009

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CHEVRON AUSTRALIA PTY LTD

Survey for Migratory Waterbirds in the Wheatstone LNG Project Area, November 2008 and March 2009

The Wheatstone Project proposed LNG plant site (on left) and adjacent coastline, high tide, 16th March 2009 (M. Bamford)

Prepared for: URS Australia Pty Ltd
Level 3, 20 Terrace Road
East Perth, WA, 6004

Prepared by: Mike Bamford, Simon Cherriman and Mandy Bamford

M.J. & A.R. Bamford,
CONSULTING ECOLOGISTS.
23 Plover Way,
Kingsley, WA, 6026

December 2009

EXECUTIVE SUMMARY

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). The investigations outlined in this report have been conducted to support the environmental impact assessment process. As part of this process, Bamford Consulting Ecologists was commissioned by URS Australia Pty Ltd to undertake studies on migratory waterbirds at the general Wheatstone Project area. This encompassed wetlands and the adjacent coastline up to ***ca.*** 30km from the Project area, and is herein referred to as the survey area. This study aimed to determine the species of migratory waterbirds present, their abundance during migration periods and to identify locations of importance for them within and adjacent to the Wheatstone Project area. Migratory waterbirds are listed as migratory under the Federal ***Environment Protection and Biodiversity Conservation Act*** 1999 (EPBC Act) and under Schedule 3 of the ***WA Wildlife Conservation Act*** 1950. Although the original scope was for migratory waterbirds to be counted in the survey, non-migratory waterbirds were also counted to provide additional information. Pelagic species were not included.

The survey area was visited from 12th to 16th November 2008 and 15th to 17th March 2009, and as much as possible of the waterbird habitat in the general area was assessed. There were, however, some restrictions on access and an aerial survey could not take place during the November survey. The surveys were conducted at appropriate times and coincided with high tides and the peak migration period of most migratory waterbird species in the region. Waterbird habitats in the area include tidal coastlines, mangroves, tidal flats behind the coastline, claypans, marshes and the Ashburton River (which is tidal below Urala Ford and has a permanent pool [Five Mile Pool] above the ford).

Fifty-eight waterbird species in total were observed during the two field surveys, of which 24 species were migratory. A total of 39 migratory waterbird species could be expected in the area, but most of the migratory waterbird species not observed probably occur only as vagrants.

Waterbird numbers in November 2008 were low throughout the survey area, with the greatest numbers of individuals seen on Town Beach in Onslow (maximum number of 584 waterbirds, compared with a total for the entire survey area of 798). Town Beach is probably favoured because its low tidal flats include fine silts and muds, whereas most of the other beach slopes and adjacent low tidal sand flats in the area are sandy and were found to be low in invertebrate abundance. In addition, an extensive area of reef flat is exposed near Town Beach (at Beadon Point) during low tides, and this provided suitable habitat for some waterbird species to forage and roost. The coastline west of Hooley's Creek and therefore immediately adjacent to the Wheatstone Project was the next most important survey sector, with eight migratory waterbird species and a total count of 121 waterbirds (68 migratory) recorded. In comparison, important sites in the general region support thousands and even tens of thousands of waterbirds.

The most abundant waterbird species in November were the Common Tern (migratory, with a single count of 285 on Town Beach) and the Silver Gull (non-migratory, maximum count of 176 with most also on Town Beach). The only other waterbird species with maximum counts of more than 50 birds were the Red-necked Stint (migratory) and the Red-capped Plover (non-migratory).

Based on results from the November 2008 survey, the regional significance of the Wheatstone Project area and adjacent coastline for waterbirds in general and migratory waterbirds during southward migration appears to be low. The area may meet the Ramsar criterion of international importance for waterbirds (supporting 1% of a population of a species) for only one species, the migratory Common Tern (Asian race ***Sterna hirundo longipennis***, with a maximum count of 285 on Town Beach), although this is based on a minimum population estimate of 25,000 whereas the population could be up to 1,000,000 (Scott and Delaney 2002). The estimate for this population is very uncertain. Three migratory species, the Whimbrel (maximum count of 9, most in mangroves of the Ashburton River delta), Eastern Curlew (maximum count of 10 in Beadon Creek) and the Sanderling (maximum count of 39, most on Town Beach), may be present in regionally important numbers, but this is based on uncertain estimates of regional populations. These counts are well below the Ramsar criteria for these species.

Higher numbers of waterbirds were recorded in March 2009, with a maximum number of 3,663. However, the species and their distributions were very different from those observed in November 2008. Compared with the November survey, low numbers of waterbirds were observed on the marine coast. Conversely, near-coastal claypans and flats, and inland marshes, supported high numbers of waterbirds. These had been dry in November. Large numbers of terns were observed on near-coastal claypans near the existing Tubridgi Gas Plant, while a flock of 2,000 migratory waterbirds was present on the tidal flats between the Wheatstone Project area and the Onslow salt ponds. Much higher numbers of migratory waterbirds are known regionally, from Exmouth Gulf and Barrow Island.

Additionally in the March survey, the freshwater marshes that lie inland from Onslow supported high numbers of non-migratory waterbird species including ducks, herons and ibis. These areas are likely to be regionally significant wetlands as they are poorly represented in the south-western Pilbara.

Across the two surveys, the main concentrations of waterbirds were on: Town Beach; near-coastal tidal flats near the existing Tubridgi Gas Plant; near-coastal tidal flats between the Wheatstone Project area and the Onslow salt ponds; and on inland freshwater marshes. Waterbird numbers were low in a regional context except for ducks, herons and ibis on the inland freshwater marshes (March only). The greatest concentration of migratory waterbirds was on near-coastal tidal flats between the Wheatstone Project area and the Onslow Salt evaporation ponds and consisted of an estimated 2,000 migratory waterbirds observed during an aerial survey. These birds were probably roosting and/or foraging close to or within the Wheatstone Project area. However, any impact on these sites from the Wheatstone Project is unlikely to be significant, as this near-coastal claypans and tidal flats habitat is extensive in the Onslow region. Additionally, migratory waterbirds are known to feed and roost close to industrial areas in many parts of the world, and appear unaffected by lights, noise and other human interactions.

Overall the study found that the area at and surrounding the proposed Wheatstone Project does not support important numbers of migratory waterbirds, with impacts upon migratory waterbirds (and other waterbirds) that are present anticipated to be low.

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 (see Figure 1). 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). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

Bamford Consulting Ecologists was commissioned by URS Australia Pty Ltd to undertake studies on migratory waterbirds at the general Wheatstone Project area and along the adjacent coastline, herein referred to as the survey area (see Figures 2 and 3). These studies aimed to determine the species of migratory waterbirds present, their abundance during migration periods, the importance of the area for migratory waterbirds and to identify locations of importance for them within and adjacent to the Wheatstone Project area. Non-migratory waterbirds were included in the survey to provide additional information.

Two field surveys were conducted, the first survey being undertaken in November 2008, during the southward migration of migratory waterbirds, and the second in March 2009 during the northward migration period. The second survey also coincided with wet season conditions. This report presents the results of a literature review, and the field surveys carried out in November 2008 and March 2009.

2. SITE DESCRIPTION

The proposed site for the Wheatstone Project lies on the coast approximately 12 km west-south-west of Onslow, between the mouth of the Ashburton River and Hooley Creek (see Figure 1). It is within a few kilometres of the Old Onslow townsite and the existing environment consists of primary and secondary sand-dunes and tidal flats. Locations visited during surveys are indicated on Figures 2 and 3. Key waterbird habitats are illustrated on Plates 1 to 5 and include:

- Coastline (Plate 1). Mostly sandy beaches and some tidal shoreline which generally has a sandy substrate except at Town Beach in Onslow.
- Mangroves (Plate 2). Extensive behind the coastline around river and creek systems, particularly at the Ashburton River.
- Tidal flats (Plate 3). These lie behind the mangroves and are flooded by high tides and rainfall. They were dry in November 2008 but extensively flooded in March 2009.
- Ashburton River (Plate 4). Tidal below Urala Ford and with a permanent pool (Five Mile Pool) upstream of the ford.
- Inland claypans, freshwater marshes and wetlands (Plate 5). These occupy low-lying areas on the floodplain and paleo-channels of the Ashburton River. Most claypans are highly turbid and support little vegetation, while the marshes are clear and extensively vegetated, including chenopod shrubs, grasses and submerged aquatic plants (such as the fern ***Marsilea***).
- Salt ponds. These are the evaporation ponds of Onslow salt and except for the intake area, have a high salinity and support few birds.

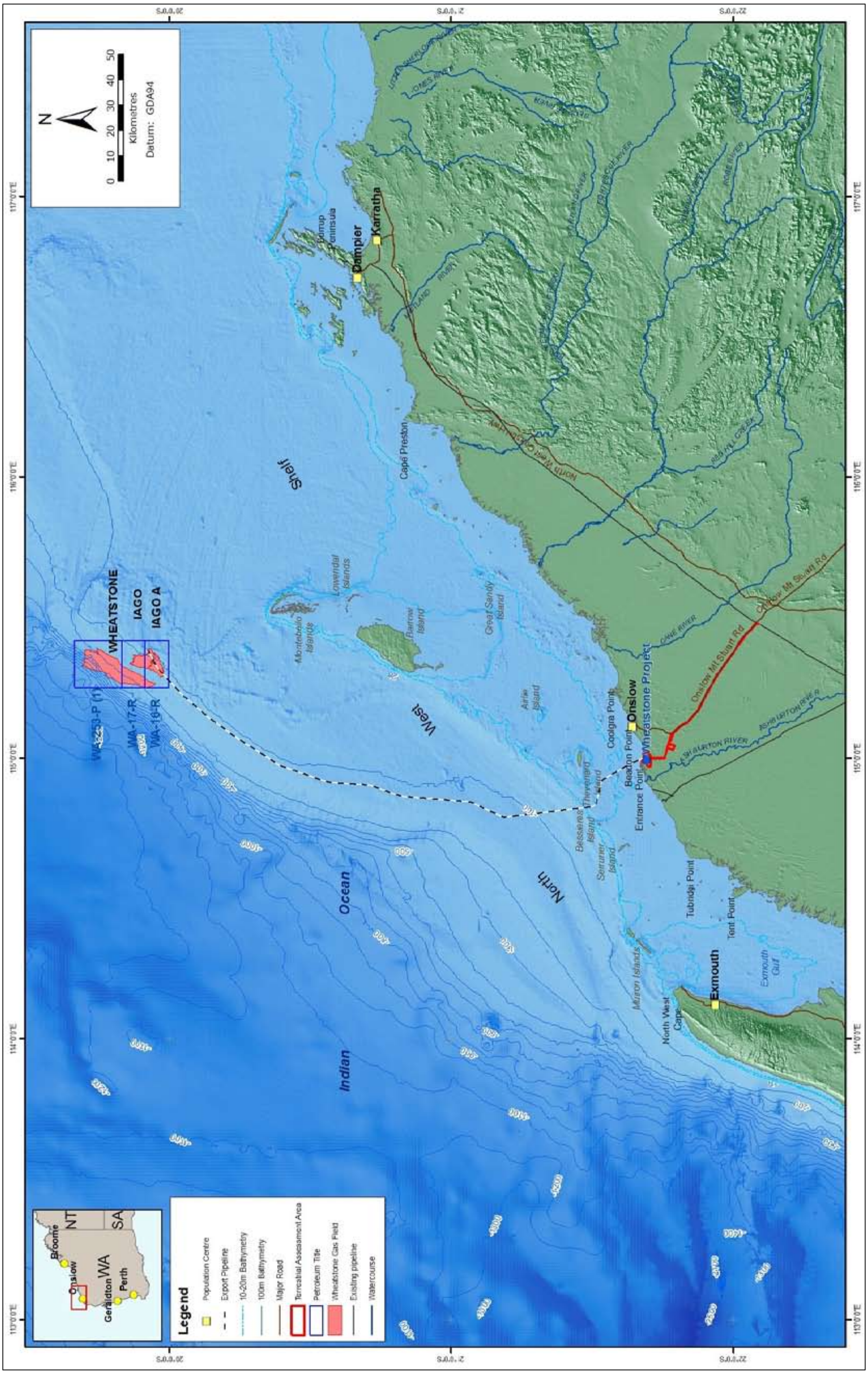

Figure 1. Location of the Wheatstone Project.

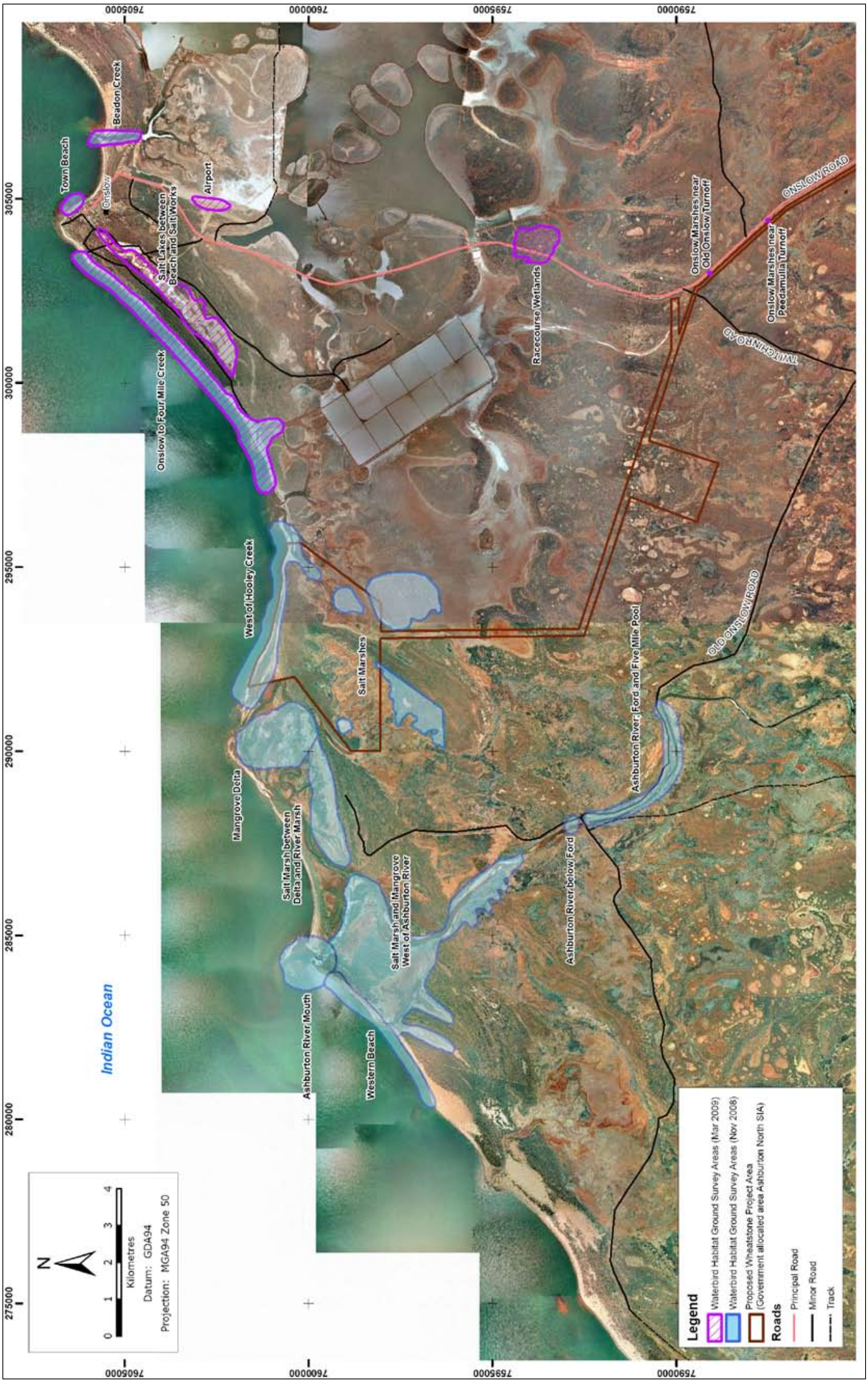

Figure 2. The Wheatstone Project Area and Migratory Waterbird Ground Survey Areas.

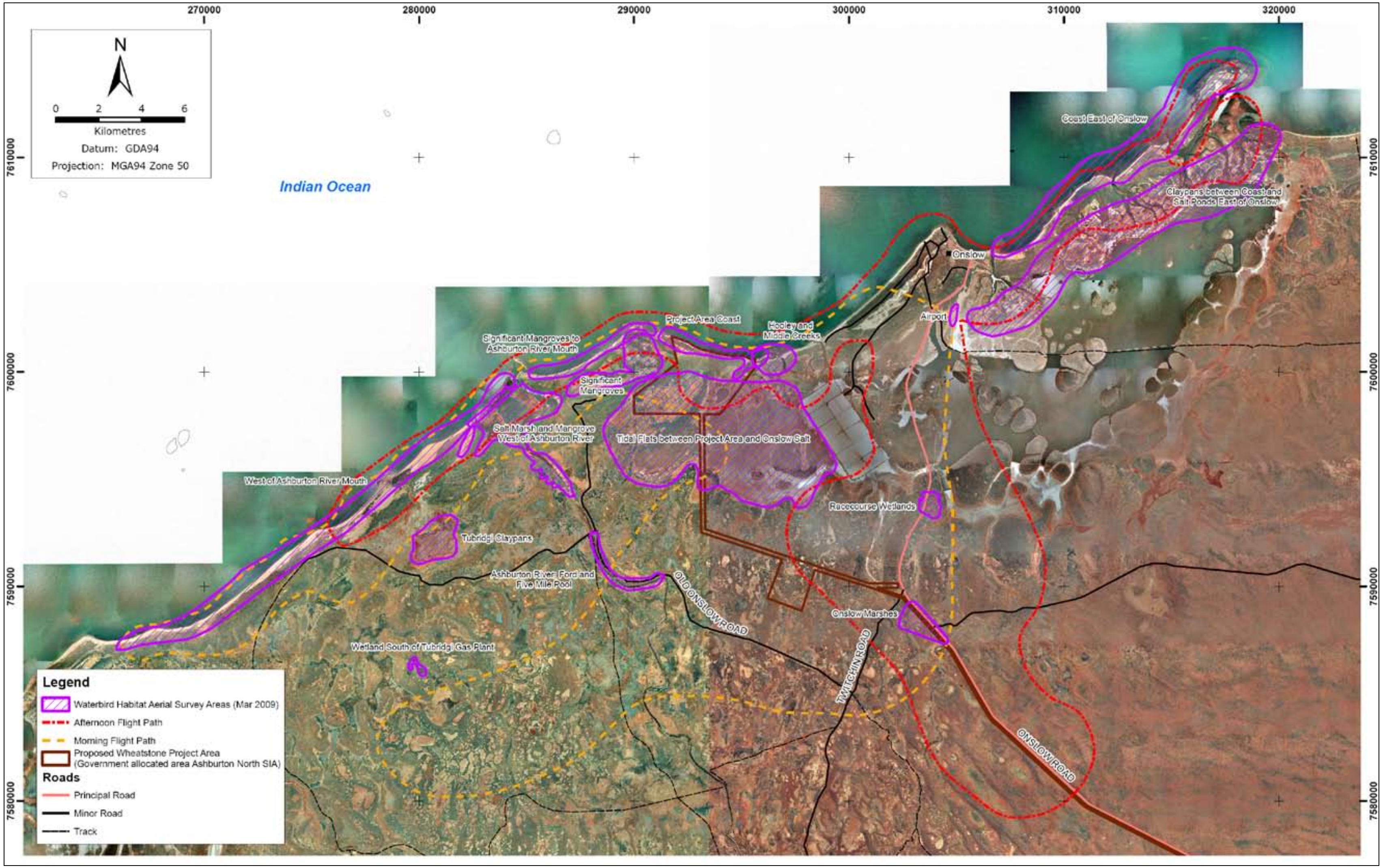

Figure 3. The Wheatstone Project Area, Flight Paths and Main Migratory Waterbird Habitats Observed During Aerial Survey.

Plate 1. Coastline adjacent to the proposed LNG plant site, high tide, 16th March 2009.

Plate 2. Mangroves along a tidal creek system near Coolgra Point, east of Onslow.

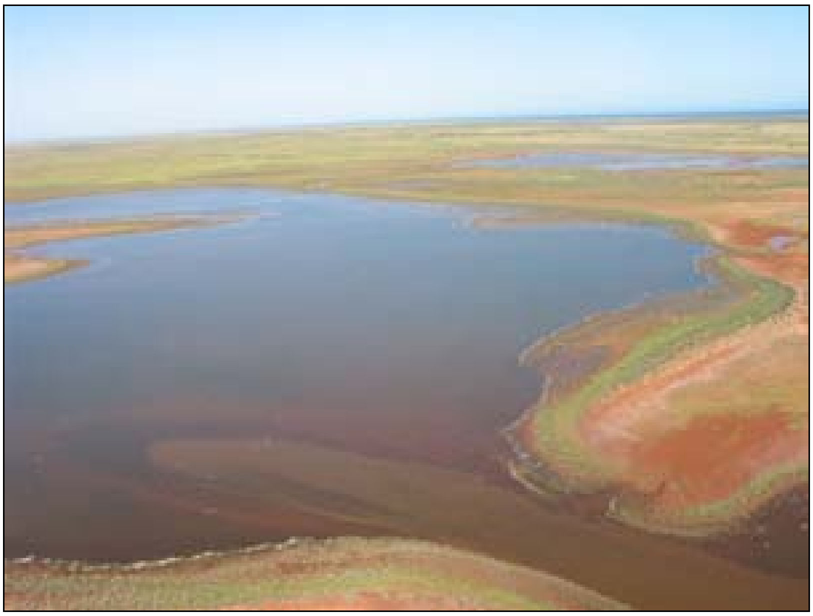

Plate 3. Near-coastal tidal flats west of the Ashburton River.

Note: These were flooded by rainfall and very high tides in March but were dry in November when even spring tides were lower than in March. The white birds flying across the foreground are Gull-billed Terns.

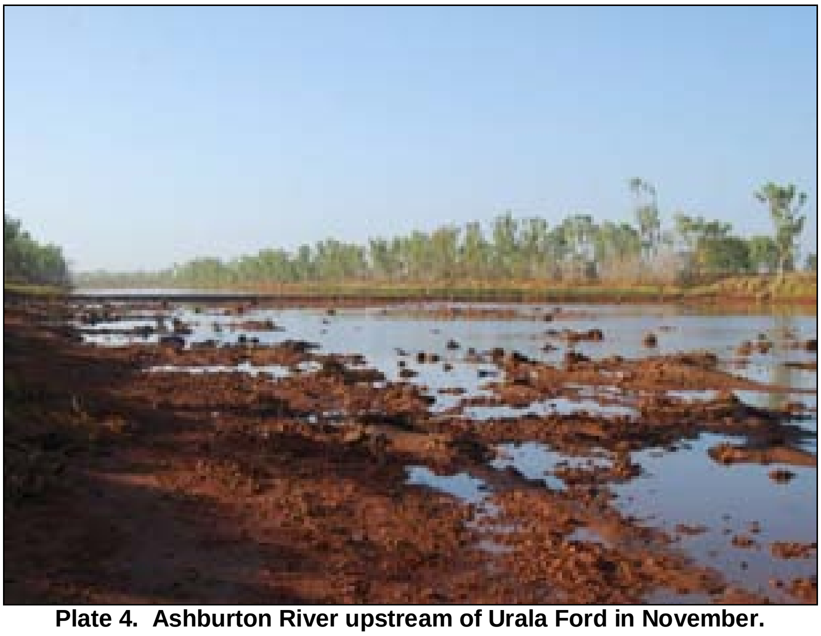

Plate 4. Ashburton River upstream of Urala Ford in November.

Note: This site was inaccessible from the ground in March due to high water levels.

Plate 5. Inland claypans and freshwater marshes south of Onslow.

Note: The marshes in the background, behind Onslow Road, are vegetated and were where most waterbirds were observed.

3. METHODS

3.1 Definition of Migratory Waterbirds

For the purposes of this investigation, migratory waterbirds are those species of waterbirds listed as migratory under the Commonwealth ***Environment Protection and Biodiversity Conservation Act*** 1999 (EPBC Act) and under Schedule 3 of the ***WA Wildlife Conservation Act*** 1950. These include all species of sandpipers (Scolopacidae) that visit Australia, as well as some plovers (Charadriidae), pratincoles (Glareolidae), terns (Laridae), egrets (Ardeidae), ibis (Threskiornithidae) and birds of prey (Accipitridae). Note that some listed migratory species are not migratory in Australia, but are included under the EPBC Act because the same species are migratory in other countries and are listed as such under the Bonn Convention, to which Australia is a signatory. There are also several listed migratory species that are not waterbirds. These have been included in this review. Waterbirds which are not migratory and not listed under the EPBC Act were also counted. These included ducks and swans (Anatidae), grebes (Podicipedidae) darters (Anhingidae), cormorants (Phalacrocoracidae) and pelicans (Pelecanidae). Pelagic waterbirds such as albatrosses (Diomedeidae) and shearwaters (Procellariidae) were not surveyed.

3.2 Literature Review

Migratory waterbirds previously recorded from the survey area were investigated through a review of the following databases: Faunabase (WA Museum), the Birds Australia Atlas Database, the WA Department of Environment and Conservation (DEC) Threatened and Priority Fauna Database, and the EPBC Protected Matters Search Tool (see References for details). For all databases, the search area was approximately 21º to 22ºS and 114º 30' to 115º 30'E. In addition, records from the Bamford Consulting Ecologists database for the Onslow area were reviewed. Records in this database are derived from unpublished records that have resulted from previous surveys in the area in December 2004, September 2005 and November 2006 (M. Bamford unpubl. data). Regional information on waterbird species and abundance was obtained from the Yannerie Solar a Straits Initiative (2006), Gorgon Joint Venturers (2005) and Bamford et al. (2008). Results of a migratory waterbird survey conducted by AECOM (2009) in the Onslow to Ashburton River area in January 2009 were also accessed.

3.3 Field Investigations

Two field surveys were conducted, one in November 2008 and one in March 2009. The first field investigation was conducted from 12th to 16th November 2008, and was carried out by Dr Mike Bamford (B.Sc. Hons. Ph.D.) and Mr Simon Cherriman (B.Sc. Hons.). The second survey was conducted from 15th to 17th March 2009, and was carried out by Dr Mike Bamford and Mr Peter Smith (Assoc. Dip. Agric.). The field work was undertaken under Regulation 17 Licence No: SF6542.

The field investigations covered the survey area, encompassing the coastline and wetlands up to approximately 30 km from the Wheatstone Project area. Field work involved ground counts (November 2008 and to some extent March 2009) and aerial surveys (March 2009 only). The ground survey in November 2008 visited all wetlands in the survey area (most were dry at this time) but only part of the coastline. In March 2009, inland wetlands were extensive and difficult to access from the ground, but aerial surveys covered the entire survey area. A Squirrel helicopter was used for the aerial survey, enabling extensive views from height, so that wetlands containing birds could be identified and approached closely for counting.

3.3.1 November 2008

The timing of the November survey was designed to coincide with spring tides and with the southward migration period of the majority of migratory waterbirds, as that is when numbers are highest on the Pilbara coast (Bamford ***et al.*** 2008). Spring tides are favoured for waterbird surveys, as the bird numbers are concentrated during high water, making the identification of important roost sites possible, and making the birds relatively easy to count. Therefore, most waterbird counts were conducted within a few hours of the high tide. The time and height of high tides were (for Beadon Creek, data from the website of the National Tide Centre of the Bureau of Meteorology):

Date	Time	Height
12th November	10:31	2.10m
12th November	22:02	2.52m
13th November	11:15	2.22m
13th November	22:47	2.64m
14th November	11:55	2.29m
14th November	23:30	2.72m
15th November	12:34	2.30m
16th November	00:13	2.73m
16th November	13:13	2.27m

The high tides coinciding with surveys occurred from late morning to early afternoon. Some survey work was also conducted during rising and falling tides when foraging areas could be identified.

Field work involved visiting the coastline from Beadon Creek (south-eastern boundary of Onslow) to west of the Ashburton River mouth, the Ashburton River from the ocean to upstream of Five Mile Pool, and salt marsh and mangrove areas (where these were accessible). Locations visited are illustrated on Figure 2. The general programme of events for the November surveys was as follows:

- 12th November. Tide falling. Town Beach of Onslow.
- 13th November. High tide. Wheatstone Project area beach (from Hooley's Creek as far as a deep tidal channel at 291 300E, 7 601 735N).
- 14th November. High tide. Salt marsh and mangroves of Ashburton River delta east of river mouth, and parts of Ashburton River. Also visited salt marshes within the Wheatstone Project area.
- 15th November. Rising and high tide. Ashburton River from Five Mile Pool to river mouth, tidal flats, salt marsh and mangroves west of river mouth, and tidal coastline from river mouth west to about 3km to the west-south-west. Also visited Beadon Creek (falling tide), Four Mile Creek (high and low tides), beach from Four Mile Creek to Onslow, and Town Beach (low tide).
- 16th November. Rising tide. Ashburton River around Urala Ford and tidal flats between Old Onslow and Wheatstone Project area.

Two areas of shoreline could not be visited: between Four Mile and Hooley's Creek (although much of this was scanned with telescopes), and between the Ashburton River mouth and a tidal channel at 291300E, 7601735N. These areas could not be accessed overland and access by boat or aircraft was not possible at the time. The lack of an aircraft, either helicopter or fixed-wing, also meant that an aerial survey was not possible. However, these areas were surveyed from the air in March 2009, were found to support few waterbirds and therefore the lack of an aircraft during the November 2008 survey was not believed to be a significant deficiency.

3.3.2 March 2009

During the second survey of March 2009, ground access (either by vehicle or helicopter) was poor due to recent rains, and therefore the ground surveys conducted in November 2008 could not all be repeated. However, aerial surveys did take place, which had been a deficiency of the November 2008 survey. The aerial surveys covered all locations visited by land in November 2008, as well as many areas that had not been visited previously (see Figures 2 and 3). Compared with the November 2008 survey, the near-coastal wetlands and claypans were flooded rather than dry, and the freshwater wetlands further inland (marshes referred to in this report as the Racecourse Wetlands, marshes south of Old Onslow turnoff and marshes near Peedamulla turnoff) were very prominent. These had also been dry in November 2008.

The time and height of high tides during the March 2009 survey were (for Beadon Creek, data from the website of the National Tide Centre of the Bureau of Meteorology):

Date	Time	Height
15th March	01:39	2.56m
15th March	13:48	2.88m
16th March	02:08	2.41m
16th March	14:12	2.76m
17th March	02:35	2.23m
17th March	14:32	2.61m

Tides were generally higher than they had been in November 2008.

The general programme of events for the second survey was as follows:

- 15th March. High tide. Town Beach, Beadon Creek, Four Mile Creek, beach between Onslow Jetty and Four Mile Creek, and salt lakes between Four Mile Creek Road and salt works. Also racecourse wetlands along Onslow Road south of Onslow.
- 16th March. Aerial survey, two phases:
    - Phase 1, 09:25 to 11:15. Rising tide. Coastline from Onslow to west of the Tubridgi Gas Plant, all near-coastal claypans back to Onslow Salt Works, including regionally significant Ashburton River mangroves, Five Mile Pool of the Ashburton River, freshwater wetlands south of Tubridgi Gas Plant, similar freshwater wetlands adjacent to racecourse wetlands, tidal flats adjacent to airport.
    - Phase 2, 13:15 to 15:00. High tide. Claypans between coast and Onslow Salt evaporation ponds, including intake area of ponds, major eastern mangrove complex, coast west of Onslow to about half way between Ashburton River mouth and Tubridgi Gas Plant, claypans west of Onslow Salt works including regionally significant Ashburton River mangroves, freshwater wetlands east and west of Onslow Road.
- 17th March. Low tide. Town Beach and mouth of Beadon Creek. Ground counts of Onslow freshwater marshes around racecourse and further south. Three main locations of freshwater marshes ground-counts were:

Location	Easting	Northing
Racecourse Wetlands	303500	7593800
South of Old Onslow turnoff	302990	7589100
Near Peedamulla turnoff	304420	7587510

The aerial surveys, conducted by a Jayrow Squirrel helicopter, were carried out mostly at a height of about 100 m and involved frequent manoeuvring to get good views of birds. At this height (and less) it was possible to identify some but not all bird species. The differences between some species are very subtle and can only be determined at close range. This is commonly the case in aerial surveys of migratory waterbirds.

3.4 Limitations of investigations

During the November 2008 survey period, conditions were ideal but access to the coast was restricted because boats and aircraft were not available. As a result, some sections of the coastline were not surveyed during November 2008. An aerial survey was conducted in March 2009. This was especially valuable as ground access along tracks in the areas was severely restricted due to flooding at this time. A limitation of the March 2009 survey was that, due to restricted ground access, species identification was limited to those species that could be identified from the air, and to species observed from the available ground areas.

The effect of these limitations on the study was minimal as all areas were covered in at least one of the surveys, and areas where birds were concentrated, for example Town Beach, were covered in both surveys.

4. RESULTS

4.1 Waterbirds in the survey area

From the literature review, a list of the waterbird species observed or expected in the Wheatstone Project area was derived (Table 1). The Wheatstone Project area may support up to 90 waterbird species, although not all these species would be expected to be present regularly and some probably occur only as vagrants. The 63 species observed in surveys undertaken by Bamford Consulting Ecologists in the region from 2004 to 2006 (Appendix 1), and/or in the November 2008 and March 2009 surveys, are probably those that can be expected to be present regularly. Fifty-eight of these 63 species, representing 64% of the total number of waterbird species that may be present at some time, were observed in the five day survey of November 2008 and/or the three day survey in March 2009.

Thirty-eight of the waterbird species listed in Table 1 are migratory, and 26 of these were recorded in 2004-2006 and/or 2008-2009. Twenty-three were observed in November 2008 while only 15 were recorded in March 2009. Migratory species not observed may occur only as vagrants.

Table 1. Waterbirds, including migratory species, observed or expected in the Wheatstone survey area.

Family	Species		Mig.	Review	2004-2006	Nov 2008	Mar 2009
Anatidae (Ducks, Swans)	***Cygnus atratus***	Black Swan		E			X
	Anas superciliosa	Pacific Black Duck		O		X	X
	Dendrocygna eytoni	Plumed Whistle-Duck		O			X
	Malacorhynchus membranaceus	Pink-eared Duck		O			X
	Anas gracilis	Grey Teal		O			X
	Aythya australis	Hardhead		O			X
	Chenonetta jubata	Australian Wood Duck		O			X
Podicipedidae (Grebes)	***Tachybaptus novaehollandiae***	Australasian Grebe		O			
	Poliocephalus poliocephalis	Hoary-headed Grebe		O			
Anhingidae (Darters)	***Anhinga melanogaster***	Darter		O		X	
Phalacrocoracidae (Cormorants)	***Phalacrocorax carbo***	Great Cormorant		O	X	X	
	Phalacrocorax varius	Pied Cormorant		O	X	X	
	Phalacrocorax sulcirostris	Little Black Cormorant		O	X	X	X
	Phalacrocorax melanoleucos	Little Pied Cormorant		O		X	X
Pelecanidae (Pelicans)	***Pelecanus conspicillatus***	Australian Pelican		O		X	X
Ardeidae (Herons, Egrets, Bitterns)	***Ardea pacifica***	White-necked Heron		O		X	X
	Ardea novaehollandiae	White-faced Heron		O	X	X	X
	Ardea modesta	Eastern Great Egret	mig	O	X	X	X
	Ardea intermedia	Intermediate Egret		E			
	Ardea garzetta	Little Egret		O		X	X
	Ardea sacra	Eastern Reef Egret	mig	O	X	X	X
	Ardea ibis	Cattle Egret	mig	E			
	Butorides striatus	Striated Heron		O	X	X	
	Nycticorax caledonicus	Nankeen Night Heron		O			
Threskionithidae (Ibises and Spoonbills)	***Plegadis falcinellus***	Glossy Ibis	mig	E			
	Threskiornis molucca	Australian White Ibis		E			
	Threskiornis spinicollis	Straw-necked Ibis		O			X
	Platalea flavipes	Yellow-billed Spoonbill		O	X		
Ciconiidae (Storks)	***Ephippiorhynchus asiaticus***	Black-necked Stork		O			X
Accipitridae	***Pandion cristatus***	Eastern Osprey	mig	O		X	X
	Haliastur indus	Brahminy Kite		O	X	X	
	Haliaeetus leucogaster	White-bellied Sea-Eagle	mig	O	X	X	X
	Circus approximans	Swamp Harrier		O			X
Gruidae (Cranes)	***Grus rubicundus***	Brolga		O		X	
Rallidae (Rails)	***Gallirallus philippensis***	Buff banded Rail		E			
	Porzana fluminea	Australian Spotted Crake		O			
	Porzana tabuensis	Spotless Crake		E			
	Gallinula ventralis	Black-tailed Native-hen		E			
	Fulica atra	Eurasian Coot		E			X

Note: Columns indicate EPBC listed migratory species (mig.); the results of the database and literature review (E - expected in area, O - observed in area); species observed during surveys undertaken by Bamford Consulting around Onslow from 2004 to 2006; and species observed in November 2008 and March 2009.

Table 1 (cont.)

Family	Species	Mig.	Review	2004-2006	Nov 2008	Mar 2009
Scolopacidae (Sandpipers)	***Gallinago stenura*** Pin-tailed Snipe	mig	O			
	Limosa limosa Black-tailed Godwit	mig	O			
	Limosa lapponica Bar-tailed Godwit	mig	O	X	X	X
	Numenius minutus Little Curlew	mig	O			
	Numenius phaeopus Whimbrel	mig	O	X	X	X
	Numenius madagascariensis Eastern Curlew	mig	O	X		X
	Tringa stagnatilis Marsh Sandpiper	mig	O			
	Tringa nebularia Common Greenshank	mig	O	X	X	X
	Tringa glareola Wood Sandpiper	mig	E		X	
	Tringa cinereus Terek Sandpiper	mig	O			
	Tringa hypoleucos Common Sandpiper	mig	O	X	X	
	Tringa brevipes Grey-tailed Tattler	mig	O	X	X	X
	Arenaria interpres Ruddy Turnstone	mig	O	X	X	X
	Calidris canutus Red Knot	mig	O			
	Calidris tenuirostris Great Knot	mig	O		X	
	Calidris alba Sanderling	mig	O	X	X	
	Calidris ruficollis Red-necked Stint	mig	O	X	X	
	Calidris subminuta Long-toed Stint	mig	O			
	Calidris acuminata Sharp-tailed Sandpiper	mig	O		X	
	Calidris ferruginea Curlew Sandpiper	mig	O			
	Limicola falcinellus Broad-billed Sandpiper	mig	O			
Burhinidae (Stone-curlews)	***Burhinus grallarius*** Bush Stone-curlew		E	X		
	Esacus neglectus Beach Stone-curlew		O			
Haematopodidae (Oystercatchers)	***Haematopus longirostris*** Pied Oystercatcher		O	X	X	
	Haematopus fuliginosus Sooty Oystercatcher		O	X		X
Recurvirostridae (Stilts, Avocets)	***Himantopus himantopus*** Black-winged Stilt		O		X	X
	Clardorhynchus leucocephalus Banded Stilt		O			
	Recurvirostra novaehollandiae Red-necked Avocet		O			X
Charadriidae (Plovers)	***Vanellus miles*** Masked Lapwing		O			
	Vanellus tricolour Banded Lapwing		O			
	Pluvialis squatarola Grey Plover	mig	O	X		
	Pluvialis fulva Pacific Golden Plover	mig	O	X		
	Charadrius ruficapillus Red-capped Plover		O	X	X	X
	Charadrius mongolus Lesser Sand Plover	mig	O	X	X	X
	Charadrius leschenaultii Greater Sand Plover	mig	O	X	X	
	Charadrius melanops Black-fronted Dotterel		O		X	
	Charadrius veredus Oriental Plover	mig	O			
Glareolidae (Pratincoles)	***Stiltia isabella*** Australian Pratincole		O			
	Glareola maldivarum Oriental Pratincole	mig	O		X	

Note: Columns indicate EPBC listed migratory species (mig.); the results of the database and literature review (E - expected in area, O - observed in area); species observed during surveys undertaken by Bamford Consulting around Onslow from 2004 to 2006; and species observed in November 2008 and March 2009.

Table 1 (cont.)

Family	Species	Mig.	Review	2004-2006	Nov 2008	Mar 2009
Laridae (Gulls, Terns)	***Larus novaehollandiae*** Silver Gull		O	X	X	X
	Sterna nilotica Gull-billed Tern		O	X	X	X
	Sterna caspia Caspian Tern	mig	O	X	X	X
	Sterna bengalensis Lesser Crested Tern	mig	O	X	X	
	Sterna bergii Crested Tern	mig	O			X
	Sterna dougalli Roseate Tern		O		X	
	Sterna hirundo Common Tern	mig	O	X	X	X
	Sterna albifrons Little Tern	mig	O		X	X
	Sterna nereis Fairy Tern		O	X		
	Sterna anaethetus Bridled Tern		O			
	Sterna hybrida Whiskered Tern		O			X
	Sterna leucoptera White-winged Black Tern	mig	O		X	

Note: Columns indicate EPBC listed migratory species (mig.); the results of the database and literature review (E - expected in area, O - observed in area); species observed during surveys undertaken by Bamford Consulting around Onslow from 2004 to 2006; and species observed in November 2008 and March 2009.

4.2 Other migratory species in the survey area

In addition to migratory waterbirds, three migratory landbirds (listed under the EPBC Act) may be present and two of these have been recorded in recent surveys. These species are presented in Table 2. Numbers present are low and outside the Wheatstone Project area. The Rainbow Bee-eater and Barn Swallow were common in Onslow townsite.

Table 2. Migratory species (that are not waterbirds) observed or expected in the survey area.

Family	Species	Review	2004-2006	Nov 2008	Mar 2009
Apodidae (Swifts)	***Apus pacificus*** Fork-tailed Swift	O			
Meropidae (Bee-eaters)	***Merops ornatus*** Rainbow Bee-eater	O	X	X	X
Hirundinidae (Swallows)	***Hirundo rustica*** Barn Swallow	E	X		X

Note: Columns indicate the results of the database and literature review (E - expected in area, O - observed in area), species observed during surveys undertaken by Bamford Consulting around Onslow from 2004 to 2006, and species observed in November 2008 and March 2009.

4.3 The distribution and abundance of waterbirds in the survey area

While the presence of migratory waterbirds is of interest, these are highly mobile species that can be expected to be observed almost anywhere. Of greater importance than the presence/absence of species are sites where large numbers of waterbirds occur, and therefore the surveys concentrated on counting waterbirds and determining the locations of these sites important for roosting and foraging. The results of the November 2008 waterbird counts are presented in Tables 3, 4 and 5, and for March 2009 in Tables 6, 7 and 8.

During the November survey, waterbird numbers were low throughout the Wheatstone Project area (see Table 3, the summary on Table 4 and Appendix 2), with Town Beach supporting well over half of all the waterbirds counted during the study. Town Beach also supported the greatest number of species; 22 waterbird species of which 16 were migratory species. The coastline west of Hooley's Creek and therefore immediately adjacent to the Wheatstone Project was the next most important survey sector, with 11 migratory species and a total waterbird count of 121 (68 migratory) compared with 584 (412 migratory) on Town Beach.

The November survey counts of individual species across the survey area are presented in Table 5. Even when maximum counts are pooled from different survey sites, making the assumption of little movement of birds between sites, the total number of waterbirds surveyed was only 798 (529 migratory). The most abundant species were the Common Tern (migratory, with a single count of 285 on Town Beach) and the Silver Gull (non-migratory, maximum count of 176 with most also on Town Beach). The only other species with maximum counts of more than 50 birds were the Red-necked Stint (migratory) and the Red-capped Plover (non-migratory).

The number of waterbirds observed from ground and aerial surveys during the March survey are shown in Tables 6 and 7 respectively, with total numbers estimated to be present shown in Table 8. During the March survey, the estimated number of waterbirds present (3,663) was higher than in the November 2008 survey, and the distribution of the birds was also very different. In November, birds were concentrated on Town Beach in Onslow and at Urala Ford on the Ashburton River, with small numbers at coastal sites such as the mouth of the Ashburton River. In contrast, in the March survey numbers were low at Town Beach (13 species detected, 10 migratory), and the Ashburton River appeared to support few birds. Instead, numbers of waterbirds were high on near-coastal claypans and flats, and on the Onslow freshwater marshes. These areas (which include the Wheatstone Project area) had been dry in November, but supported the majority of birds in March. Except for one flock of 2,000 small migratory waders, the majority of waterbirds were non-migratory species such as ducks, ibis, gulls and terns. Some of the waterbirds present (eg. Black-necked Stork, Plumed Whistle-Ducks) are more typical of the Kimberley and occur in only small numbers in the Pilbara; the March records represent these birds at the extreme south of their range.

Table 3. Waterbird counts, November 2008.

Species	Town Beach	Town Beach	Beadon Creek	Onslow to Four Mile Creek	West of Hooley's Creek	Mangrove Delta	Salt marsh between delta and river mouth	Ashburton River below ford	Ashburton River below ford	Ashburton River; ford and Five Mile Pool	Ashburton River mouth	Salt marsh and mangrove west of Ashburton River	Western Beach
Date	12/11	15/11	15/11	15/11	13/11	14/11	16/11	14/11	15/11	15/11	15/11	15/11	15/11
Tide	falling	low	high	falling	high	high	rising	high	rising	NA	rising	rising	high
Pacific Black Duck										5			
Darter										1			
Great Cormorant										1			
Pied Cormorant	3												
Little Black Cormorant											1		
Little Pied Cormorant										1			
Australian Pelican					9	1				3			
White-faced Heron							2		1				
Eastern Great Egret										1			
Eastern Reef Egret					1								
Little Egret					1					1	1		
Striated Heron					1	1							
Eastern Osprey	1										1		2
Brahminy Kite				1									
White-bellied Sea-Eagle									1			3	
Brolga												7	
Bar-tailed Godwit	1	1		1	19						2		5
Whimbrel	1				2	6							
Common Greenshank	1			1	7				1	4			
Common Sandpiper	1	1		1		2				1			

Note: Migratory species are shaded in grey.

Table 3 (cont.)

Species	Town Beach	Town Beach	Beadon Creek	Onslow to Four Mile Creek Coast	West of Hooley's Creek Coast	Mangrove Delta	Salt marsh between delta and river mouth	Ashburton River below ford	Ashburton River below ford	Ashburton River above Urala Ford	Ashburton River mouth	Salt marsh and mangrove west of Ashburton River	Western Beach
Date	12/11	15/11	15/11	15/11	13/11	14/11	16/11	14/11	15/11	15/11	15/11	15/11	15/11
Tide	falling	low	high	falling	high	high	rising	high	rising	NA	rising	rising	high
Grey-tailed Tattler		16				1				3			
Ruddy Turnstone		2											
Great Knot				2		2		2			5		
Sanderling	6	17			10						2		
Red-necked Stint	43	15					4	5					
Sharp-tailed Sandpiper										2			
Pied Oystercatcher	1			1									
Black-winged Stilt										2			
Grey Plover								1					
Red-capped Plover	31	38		2	38	1	11	1			1		
Lesser Sand Plover	6												
Greater Sand Plover	23	5		2	9	1	1		4	1	1		1
Black-fronted Dotterel										1			
Oriental Pratincole										2			
Silver Gull	170	81	45	8	4				1	2	3		1
Gull-billed Tern	1			1								2	
Caspian Tern	3			1	4				1		1		1
Lesser Crested Tern	5				8						1		
Roseate Tern	2												
Common Tern	285	1			1								
Little Tern	5		2	2	6	2		2			2		
White-winged Black Tern	2				1								

Note: Migratory species are shaded in grey.

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Table 4. Summary of waterbird distribution, November 2008.

Survey area	All waterbirds		Migratory species	
	Count	Species	Count	Species
Town Beach	584	22	412	16
Beadon Creek	47	2	2	1
Onslow to Four Mile Creek coast	23	12	10	7
West of Hooley's Creek coast	121	16	68	11
Mangrove Delta	17	9	14	6
Salt marsh; delta to Ashburton River mouth	18	4	5	2
Ashburton River below Urala Ford	20	11	17	8
Ashburton River above Urala Ford	31	16	14	7
Ashburton River mouth	21	12	15	8
Salt marsh and mangrove west of Ashburton River mouth	12	3	3	1
Western beach	10	5	9	4

Note: Counts for each area are pooled from the highest counts if that area was surveyed more than once (see Table 3). See Figure 2 for locations of survey areas.

Table 5. Summary of waterbird counts, November 2008.

Species	Highest single count	Pooled counts
Pacific Black Duck	5	5
Darter	1	1
Great Cormorant	1	1
Pied Cormorant	3	3
Little Black Cormorant	1	1
Little Pied Cormorant	1	1
Australian Pelican	9	9
White-faced Heron	2	2
Eastern Great Egret	1	1
Eastern Reef Egret	1	1
Little Egret	1	2
Striated Heron	1	2
Eastern Osprey	2	3
Brahminy Kite	1	1
White-bellied Sea-Eagle	3	3
Brolga	7	7
Bar-tailed Godwit	19	29
Whimbrel	6	9
Common Greenshank	7	14
Common Sandpiper	2	5
Grey-tailed Tattler	16	20
Ruddy Turnstone	2	2
Great Knot	5	9
Sanderling	17	29
Red-necked Stint	43	52
Sharp-tailed Sandpiper	2	2
Pied Oystercatcher	1	1
Black-winged Stilt	2	2

Notes: 1. The pooled count consists of all counts of a species made at different locations during the survey, except where it was highly likely that such counts were of the same birds.

2. Migratory species are shaded in grey.

Table 5 (cont.)

Species	Highest single count	Pooled counts
Grey Plover	1	1
Red-capped Plover	38	51
Lesser Sand Plover	6	6
Greater Sand Plover	23	30
Black-fronted Dotterel	1	1
Oriental Pratincole	2	2
Silver Gull	170	176
Gull-billed Tern	2	2
Caspian Tern	4	4
Lesser Crested Tern	8	9
Roseate Tern	2	2
Common Tern	285	285
Little Tern	6	9
White-winged Black Tern	2	3
Total (all species)	712	798
Total (migratory species)	461	529

Notes: 1. The pooled count consists of all counts of a species made at different locations during the survey, except where it was highly likely that such counts were of the same birds.

2. Migratory species are shaded in grey.

Table 6. Waterbird counts from ground surveys, March 2009.

Species	Town Beach	Town Beach	Beadon Creek	Beadon Creek	Onslow to Four Mile Creek	Salt lakes between beach and salt works	Racecourse wetlands	Racecourse wetlands	Onslow Marshes near Old Onslow Turnoff	Onslow Marshes near Peedamulla turnoff	Airport
Date	15/03	17/03	15/03	17/03	15/03	15/03	15/03	17/03	17/03	17/03	16/03
Tide	high	low	high	low	high	high	NA	NA	NA	NA	low
Pacific Black Duck									1 (6)	150	
Plumed Whistle-Duck										20	
Pink-eared Duck										40	
Grey Teal										300 (6)	
Hardhead										12 (4)	
Little Pied Cormorant									1		
Australian Pelican										1	
White-faced Heron							12		30		
White-necked Heron									3	1	
Eastern Reef Egret			1								
Little Egret		1									
Straw-necked Ibis							600			19	
Eurasian Coot										20	
Eastern Osprey		1									
Swamp Harrier							2	2			
Eastern Curlew		1	10								
Whimbrel		1									
Common Greenshank		1									

Notes: 1. Migratory species are shaded in grey.
2. Numbers in parenthesis are chicks.
3.See Figure 2 for locations of survey areas.

Table 6 (cont.)

Species	Town Beach	Town Beach	Beadon Creek	Beadon Creek	Onslow to Four Mile Creek	Salt lakes between beach and salt works	Racecourse wetland	Racecourse wetlands	Onslow Marshes near Old Onslow Turnoff	Onslow Marshes near Peedamulla turnoff	Airport
Date	15/03	17/03	15/03	17/03	15/03	15/03	15/03	17/03	17/03	17/03	16/03
Tide	high	low	high	low	high	high	NA	NA	NA	NA	low
Grey-tailed Tattler		8									
Ruddy Turnstone		1									
Black-winged Stilt						9					
Red-necked Avocet						20					
Red-capped Plover				1	1	10					
Lesser Sand Plover		2									
Silver Gull	24	44	8	2	17	12					3
Gull-billed Tern											10
Caspian Tern		1									
Crested Tern	5	3			2						
Whiskered Tern							100	6			10
Common Tern	1	6									
Little Tern		3									

Notes: 1. Migratory species are shaded in grey.
2. Numbers in parenthesis are chicks.
3. See Figure 2 for locations of survey areas.

Table 7. Waterbird counts from aerial surveys, March 2009.

Species	Hooley and Middle Creeks	Hooley Hooley and Middle Creeks	Project area coast	Coast east of Onslow	Significant mangroves to Ashburton River Mouth	Significant mangroves to Ashburton River Mouth	West of Ashburton River mouth	Tubridgi claypans	Significant mangroves	Tidal flats between Project area & Onslow Saltea claypans	Claypans between coast and salt ponds east of Onslow	Four Mile Pool of Ashburton River	Wetland south of Tubridgi gas plant	Racecourse wetlands	Onslow Marshes	Airport
Date	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/11	16/11
Tide	low	high	low	high	low	high	low	low	low	low	high	low	low	low	high	low
Black Swan								5		10					100	
Pacific Black Duck													100			
Grey Teal								3		30					200	50
Australian Wood Duck															6	
Little Black Cormorant											7					
Australian Pelican	4							20			10					
White-faced Heron												2			30	
White-necked Heron															20	
Eastern Great Egret															3	
Eastern Reef Egret							3		10		6					
Straw-necked Ibis													12	150	80	
Black-necked Stork									2							
Eastern Osprey											1					
White-bellied Sea-Eagle											1					
Large waders											10					
Medium waders							40									
Small waders	10		20	260		20		50		2000	30					

Notes: 1. Where possible, species are indicated.
2. Migratory species are shaded in grey (although some small waders may be non-migratory species).
3. See Figure 3 for locations of survey areas.

Table 7 (cont.)

Species	Hooley and Middle Creeks	Hooley and Middle Creeks	Project area coast	Coast east of Onslow	Significant mangroves to Ashburton River	Significant mangroves to Ashburton River Mouth	West of Ashburton River mouth	Tubridgi claypans	Significant mangroves	Project area claypans	Claypans between coast and salt ponds east of Onslow	Five Mile Pool of Ashburton River	Wetland south of Tubridgi gas plant	Racecourse wetland	Onslow Marshes	Airport
Date	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03	16/03
Tide	low	high	low	high	low	high	low	low	low	low	high	High	high	high	high	high
Bar-tailed Godwit					5		3									
Common Greenshank						12				15						
Sooty Oystercatcher				2												
Black-winged Stilt								60	2		6				3	100
Silver Gull	10	30	5		95	65	50			70	20					100
Gull-billed Tern						5		100	20	150	100					50
Crested Tern					50	80										
Medium terns					35	150		400		100						50

Notes: 1. Where possible, species are indicated.
2. Migratory species are shaded in grey (although some small waders may be non-migratory species).
3. See Figure 3 for locations of survey areas.

Table 8. Summary of waterbird counts, March 2009.

Species	Highest single count	Pooled counts
Black Swan	115	115
Pacific Black Duck	150	157
Plumed Whistle-Duck	20	20
Pink-eared Duck	40	40
Grey Teal	306	306
Australian Wood Duck	6	6
Little Black Cormorant	7	7
Little Pied Cormorant	1	1
Australian Pelican	24	34
White-faced Heron	30	32
White-necked Heron	20	20
Eastern Great Egret	3	3
Eastern Reef Egret	13	13
Little Egret	1	1
Straw-necked Ibis	600	600
Black-necked Stork	2	2
Eastern Osprey	1	1
White-bellied Sea-Eagle	1	1
Swamp Harrier	1	1
Bar-tailed Godwit	8	8
Eastern Curlew	10	10
Whimbrel	1	1
Common Greenshank	15	15
Grey-tailed Tattler	8	8
Ruddy Turnstone	1	1
Sooty Oystercatcher	2	2
Black-winged Stilt	100	109
Red-necked Avocet	20	20

Notes: 1. The pooled count consists of all counts of a species made at different locations during the survey, except where it was highly likely that such counts were of the same birds.

2. Migratory species are shaded in grey.

Table 8 (cont.)

Species	Highest single count	Pooled counts
Red-capped Plover	10	11
Lesser Sand Plover	2	2
Silver Gull	100	215
Gull-billed Tern	150	270
Caspian Tern	1	1
Common Tern	6	6
Little Tern	3	3
Whiskered Tern	100	100
Crested Tern	80	80
Large shorebirds#	10	10
Medium shorebirds#	40	40
Small shorebirds#	2000	2070
Total (all species)	3408	3743
Total (migratory species)	2124	2194

Notes: 1. The pooled count consists of all counts of a species made at different locations during the survey, except where it was highly likely that such counts were of the same birds.

2. Migratory species are shaded in grey.

3. # These were from aerial surveys and could not be identified. All are likely to be migratory species of sandpipers and/or plovers; may have been mostly Red-necked Stints.

5. THE SIGNIFICANCE OF THE SURVEY AREA FOR WATERBIRDS

Sites are recognised as being important for waterbirds when they regularly support large numbers. The most widely-used criteria are those of the Ramsar Convention (Ramsar Convention Bureau 2000), which recognise sites as important if they support:

- 20,000 waterbirds;
- 1% of a species' population; or
- 0.25% of a migratory species' population on passage.

Population estimates for waterbirds in the East Asian-Australasian region are available from Delaney and Scott (2002) and Bamford ***et al.*** (2008), and are presented in Appendix 2 for those species recorded in the survey area. Except for the Common Tern (***Sterna hirundo)***, the counts for waterbird species from both surveys are all well below any criterion of international significance. The sub-species ***Sterna hirundo longipennis*** breeds in northern Asia and spends the non-breeding period in south-eastern Asia and northern Australia, and has a minimum population estimate (from Delaney and Scott 2002) of 25,000. Therefore, the count of 285 on Town Beach on 12th November 2008 meets the 1% criterion for this species, based on the minimum population estimate. It should be noted, however, that Delaney and Scott (2002) provide a population range of which the maximum is 1,000,000 and, with such uncertainty, the Onslow count is therefore likely to be of less significance.

The Ramsar approach with a percentage of the population as a criterion of significance is applied at the international level, but the approach can also be used within a country or geographic region. For example, Watkins (1993) calculated Australian population estimates for shorebirds and used these to apply a country 1% criterion to identify nationally (as opposed to internationally) important sites. Australian population estimates (where available) are also presented in Appendix 2, but all the study counts are well below 1% criteria based on these estimates. Note that there is no Australian estimate for the Common Tern, as the estimate of 25,000 is for Australia and south-east Asia.

Bamford ***et al.*** (2008) provide population estimates for the Pilbara and Gascoyne coastline (see Appendix 2) and even at this regional scale, numbers of waterbirds in the survey area were generally very low. The only exceptions are:

- Whimbrel, with a maximum count of 9 and a regional estimate of 350;
- Eastern Curlew, with a maximum count of 10 and a regional estimate of 200; and
- Sanderling, with a maximum count of 29 and a regional estimate of 200.

The counts of these species could therefore be considered regionally significant, but it should be noted that the regional estimates were based on very little data. Most Whimbrels (count of 6 on 14th November) were seen in the delta mangroves east of the Ashburton River mouth, while the highest single count of the Sanderling was 17 on Town Beach (15th November). The count of 10 Eastern Curlews was made at the mouth of Beadon Creek on 16th March. Some other waterbird counts made in March, such as 20 Plumed Whistling Duck on a freshwater marsh along Onslow Road (17th March), are of regional interest because the birds are on the edge of their normal range, but the species is abundant further north and the ducks were probably a vagrant group passing through.

Important sites in the Gascoyne and Pilbara region that are recognised in the review by Bamford ***et al.*** (2008) are the Dampier Saltworks and Barrow Island. Based on work carried out for Chevron Texaco's Gorgon Project (Gorgon Joint Venture [2005]), the latter supports almost 20,000 waterbirds regularly and has three migratory species present in internationally significant numbers (Red-necked Stint, Ruddy Turnstone and Grey-tailed Tattler). The eastern and southern coastlines of Exmouth Gulf also support many thousands of waterbirds, including large numbers of migratory species, for example, an estimate of 3,050 Grey-tailed Tattlers in January 2005 (Yannerie Solar, 2006). Maximum counts of waterbirds (including migratory species) for Barrow Island and Exmouth Gulf are presented in Appendix 1, and are compared with maximum counts from the Wheatstone study. In almost all species, the maximum counts around Onslow are very low compared with Barrow Island and Exmouth Gulf. Exceptions are species that are in low numbers across all three areas, or species that were observed on the inland freshwater wetlands; a habitat not present at Barrow Island or Exmouth Gulf. The only count data presented for the Dampier Saltworks by Bamford ***et al.*** (2008) are counts of 3,000 Curlew Sandpipers and 1,833 Oriental Plover; neither species has been recorded during the Wheatstone study.

The January 2009 migratory waterbird count by AECOM (2009) recorded even lower numbers than in November 2008 or March 2009, with a maximum counts of 10 Common Terns and 9 Sanderlings being the highest counts of any migratory species.

Given the location of the Wheatstone Project area is close to several locations where waterbird numbers are high, and with tidal flats and input of sediments from the Ashburton River, the very low numbers of waterbirds in November 2008, and along the coast in March 2009, were unexpected. However, the shorelines are predominantly composed of a coarse, sandy substrate, rather than the fine silts that typically support the high densities of invertebrates upon which most migratory waterbirds feed. There was little evidence of invertebrate activity (e.g. worm and mollusc trails) on most of the sandy shorelines and low tidal sand flats exposed during low tide at the mouth of tidal creeks and the Ashburton River. The URS (2008 and 2009) surveys of the marine intertidal habitats found the invertebrate fauna of the seaward beach slopes and low tidal sand flats habitat to be extremely limited, while the mangroves and adjacent high tidal mud flats were more productive and supported dense crab populations. Fine sediments occur amongst mangroves, which migratory waterbirds generally avoid, and at Town Beach in Onslow, which was the one location where at least locally significant numbers of waterbirds were present. Whimbrels are one of the few migratory shorebirds to regularly forage amongst mangroves, while the Sanderling is one of the few sandpipers to regularly use sandy shorelines, so the presence of possibly regionally significant numbers of these two species is to be expected.

Compared with the November 2008 survey, low numbers of waterbirds were observed on the marine coast in March 2009 (Table 6), although some terns, including the Crested Tern and Gull-billed Tern, and migratory shorebirds (e.g. Bar-tailed Godwit and Common Greenshank) were recorded. The large difference between the November and March results is probably because the near-coastal claypans and flats were flooded, causing many species to congregate and feed in these areas. These wetlands were dry in November, but due to a combination of recent rains and very high tides, had become inundated. Both terns and migratory waders were observed, although not all birds could be identified to the species level as this is difficult to achieve from a moving helicopter and ground access was poor.

The main concentrations of birds on the near-coastal tidal flats were observed near the existing Tubridgi Gas Plant, and between the Wheatstone Project area and the Onslow salt ponds. Birds were present in these areas during the March survey only, when the locations were flooded, and the birds were roosting and foraging across the shallows and small islands. Many birds were therefore roosting and/or foraging close to or within the Wheatstone Project area. However, any impact on these sites from the Wheatstone Project is unlikely to be significant, as this near-coastal claypans and tidal flats habitat is extensive in the Onslow region. Additionally, migratory waterbirds are known to feed and roost close to industrial areas in many parts of the world, and appear unaffected by lights, noise and other human interactions (Davidson and Rothwell, 1993). Furthermore, the numbers of waterbirds recorded in March at some sites were only locally high, with much larger regionally significant numbers being present on the east coast of the Exmouth Gulf (Yannerie Solar a Straits Initiative, 2006).

During the March 2009 survey, high numbers of waterbirds, most of which were ducks, herons and ibis, (but potentially some migratory waders) were recorded on the Onslow freshwater marshes (Table 7), which had also become flooded from recent rains. Localised rainfall that creates favourable breeding conditions is known to attract birds from a broad area, and these numbers are locally and possibly regionally significant. These wetlands are therefore likely to be regionally important for waterbirds, as such freshwater wetlands are poorly represented in the south-western Pilbara.

Overall the surveys found that the area at and surrounding the proposed Wheatstone Project does not support important numbers of migratory waterbirds, while impacts upon migratory waterbirds (and other waterbirds) that are present are anticipated to be low.

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Appendices

Appendix 1. Maximum counts of waterbirds, including migratory species, at the Dampier Saltworks (Bamford ***et al.*** [2008] and Bamford consulting database), Barrow Island (Gorgon Joint Venturers [2005]), and Exmouth Gulf (Yannerie Solar a Straits Initiative [2006]). Maximum counts from the present study are presented for comparison.

Species	Maximum count		
	Wheatstone study	Barrrow Island	Exmouth Gulf
Plumed Whistling Duck	20		
Black Swan	115		
Australian Wood Duck	6		
Pacific Black Duck	157		
Grey Teal	306		
Pink-eared Duck	40		
Darter	1		4
Great Cormorant	1		
Pied Cormorant	3	659	1
Little Black Cormorant	7	11	2
Little Pied Cormorant	1	11	142
Australian Pelican	34	24	50
White-faced Heron	32	8	90
White-necked Heron	20		
Eastern Great Egret	3	1	19
Eastern Reef Egret	13	73	11
Little Egret	2	10	150
Striated Heron	2	12	1
Straw-necked Ibis	600		
Black-necked Stork	2		
Eastern Osprey	3	41	2
Brahminy Kite	1	11	2
White-bellied Sea-Eagle	3	11	2
Brolga	7		
Bar-tailed Godwit	29	1070	410
Eastern Curlew	10	8	19
Whimbrel	9	97	80
Common Greenshank	15	255	16
Common Sandpiper	5	41	3
Grey-tailed Tattler	20	2634	3050
Ruddy Turnstone	2	1733	21
Great Knot	9	432	
Sanderling	29	177	3
Red-necked Stint	52	7611	298
Curlew Sandpiper	0	168	6
Sharp-tailed Sandpiper	2	9	

Appendix 1 (cont.)

Species	Maximum count		
	Wheatstone study	Barrrow Island	Exmouth Gulf
Sooty Oystercatcher	2	95	3
Pied Oystercatcher	1	362	137
Black-winged Stilt	2		
Red-necked Avocet	20		
Grey Plover	1	188	3
Red-capped Plover	51	355	151
Lesser Sand Plover	6	811	
Greater Sand Plover	30	903	245
Black-fronted Dotterel	1		
Oriental Pratincole	2	5	
Silver Gull	215	892	339
Gull-billed Tern	270	12	10
Caspian Tern	4	232	116
Crested Tern	80	2098	142
Lesser Crested Tern	9	318	50
Roseate Tern	2	7300	
Common Tern	285	1708	40
Little Tern	9	37	7
White-winged Black Tern	3	314	

Appendix 2. Population estimates for waterbirds recorded in the Wheatstone Project area in November 2008 and/or March 2009.

Species	EAA Flyway	Australia	Pilbara and Gascoyne coast
Plumed Whistling Duck	100,000	100,000	NA
Black Swan	300,000	300,000	NA
Australian Wood Duck	NA	NA	NA
Pacific Black Duck	200,000	100,000	NA
Grey Teal	100,000	100,000	NA
Pink-eared Duck	NA	NA	NA
Darter	NA	NA	NA
Great Cormorant	NA	NA	NA
Pied Cormorant	NA	NA	NA
Little Black Cormorant	NA	NA	NA
Little Pied Cormorant	NA	NA	NA
Australian Pelican	100,000	100,000	NA
White-faced Heron	1,000,000	1,000,000	NA
White-necked Heron	100,000	100,000	NA
Eastern Great Egret	NA	NA	NA
Eastern Reef Egret	100,000	NA	NA
Little Egret	NA	NA	NA
Striated Heron	NA	NA	NA
Straw-necked Ibis	500,000	500,000	NA
Black-necked Stork	31,000	30,000	NA
Eastern Osprey	NA	NA	NA
Brahminy Kite	NA	NA	NA
White-bellied Sea-Eagle	NA	NA	NA
Brolga	25,000	25,000	NA
Bar-tailed Godwit	325,000	185,000	5,000
Eastern Curlew	38,000	28,000	200
Whimbrel	100,000	28,000	350
Common Greenshank	60,000	19,000	1,000
Common Sandpiper	25,000	NA	1,000
Grey-tailed Tattler	50,000	45,000	5,000
Ruddy Turnstone	35,000	20,000	2,500
Great Knot	375,000	360,000	5,000
Sanderling	22,000	10,000	200
Red-necked Stint	325,000	270,000	25,000

Appendix 2 (cont.)

Species	EAA Flyway	Australia	Pilbara and Gascoyne coast
Curlew Sandpiper	180,000	118,000	30,000
Sharp-tailed Sandpiper	160,000	140,000	0
Sooty Oystercatcher	11,500	11,500	NA
Pied Oystercatcher	11,000	11,000	NA
Black-winged Stilt	300,000	300,000	NA
Red-necked Avocet	107,000	107,000	NA
Grey Plover	125,000	NA	500
Red-capped Plover	95,000	95,000	NA
Lesser Sand Plover	140,000	25,000	2,000
Greater Sand Plover	110,000	73,000	2,000
Black-fronted Dotterel	15,500	15,500	NA
Oriental Pratincole	2,880,000	2,880,000	0
Silver Gull	1,000,000	1,000,000	NA
Gull-billed Tern	NA	NA	NA
Caspian Tern	1,000	1,000	NA
Crested Tern	NA	NA	NA
Lesser Crested Tern	NA	NA	NA
Roseate Tern	NA	NA	NA
Common Tern	25,000	NA	NA
Little Tern	4,500	4,500	NA
White-winged Black Tern	25,000	25,000	NA

Notes: 1. Estimates are global (for the East Asian-Australasian Flyway, from Delaney and Scott 2002 and Bamford ***et al.*** 2008), Australian and for the Pilbara and Gascoyne (from Bamford ***et al.*** 2008).

2. Estimates are not available for all species. (NA = not available)

3. Where a population range is given (as by Delaney and Scott 2002), the lower limit only is provided.

4. Shading indicates migratory species.

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Appendix L1

Claypan Ephemeral Fauna Survey

Tables

Figures

Plates

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Biota
Environmental
Sciences

Professor Brian Timms

Wheatstone Project
Claypan Ephemeral Fauna Survey

Prepared for Chevron Australia Pty Ltd and URS Australia Pty Ltd

January 2010

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1.0 Summary

1.1 Project Background

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future 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 plants.

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). Biota Environmental Sciences Pty Ltd (Biota) was subcontracted through URS Australia Pty Ltd (URS) to provide an assessment of the ephemeral fauna of the claypans present within the Wheatstone Project study area and surrounds.

1.2 Scope

The construction and operation of the proposed LNG plant and related infrastructure has the potential to directly affect claypan systems within the eventual project impact area and their faunal communities. As part of the baseline flora and fauna assessment, Biota was commissioned to undertake a survey comprising a series of strategically timed sampling phases targeting claypan fauna. This survey area comprised:

- the Wheatstone project study area (encompassing the gas plant area, the Shared Infrastructure Corridor (SIC), camp area and Domgas pipeline corridor); and
- reference areas outside of the Wheatstone Project study area that would remain undisturbed in the wider locality.

The scope of the current study was to document the claypan fauna within the overall survey area. The specific objectives of the work were to:

- sample available claypan and ephemeral aquatic sites within or near the Wheatstone Project study area for the presence of locally endemic fauna ('Study Area' sites);
- sample similar claypan units in the locality that are outside of the proposed Wheatstone Project study areas ('Reference' sites);
- record physico-chemical parameters of the sampled sites;
- identify the fauna collected to species level wherever possible to place them into local and regional context; and
- use multivariate analysis of presence-absence data to assess relationships between faunal assemblages in different sites as an indicator of high or low likelihood of endemism.

1.3 Methodology

The survey was conducted over a two-month period during 2009, with approximately three weeks between each of the three survey phases. The program was designed to collect data on the succession of faunal life cycles in ephemeral claypans immediately after initial submersion of the pans. To this end, the first survey phase was conducted shortly after the passing of Cyclone Dominic in late January.

Sampling encompassed a selection of claypans and temporary water bodies within the overall survey area. Sampling locations were classified as 'Study Area' (within the Wheatstone Project study area) or 'Reference' (sites in the wider locality that would remain undisturbed by the Wheatstone

Project). Sample sites were initially chosen via aerial photography to provide spatial coverage of the Study Area and Reference areas and to include both visible habitat types (coastal and inland wetlands). A total of 24 sites (12 Study Area and 12 Reference) were sampled during the study, representing the range of claypan habitat types present in the survey area. The sampled sites were broadly categorised as turbid or clear water claypans, and were further subdivided into six habitat types based on water salinity, turbidity and extent of vegetation cover. The majority of the claypans present in the survey area were turbid in nature (18 out of 24; 75%; Table 1.1).

Table 1.1: Summary of claypan habitat types at each of the survey sample locations.

	Claypan type	Study Area Sites	Reference Sites	No. of Sites
Turbid (n=18)	Turbid claypan - vegetated	CWP11, CWP15, CWP21, CWP24	CWP08, CWP09, CWP22	7
	Turbid claypans - unvegetated	CWP07, CWP12, CWP16, CWP23, CWP25	CWP02, CWP04, CWP10, CWP17, CWP18, CWP20	11
Clear (n=6)	Samphire swamps - vegetated	-	CWP03, CWP05	2
	Artificial, freshwater wetlands	CWP01	-	1
	Large, freshwater wetlands	-	CWP19	1
	Marine wetlands	CWP13, CWP14	-	2

The field sampling was conducted using a range of different sampling techniques. These targeted the two main suites of fauna known to inhabit claypan systems; zooplankton and macro-invertebrates.

1.4 Results

The three-phase Wheatstone Project claypans survey recorded a combined total of 141 taxa of zooplankton and macro-invertebrates. Twelve classes and 21 orders were represented amongst the collected fauna, as summarised in Table 1.2.

Table 1.2: Summary of the representation of taxonomic classes and orders amongst the fauna collected from sample sites during this study.

Phylum/Subphylum	Class	Order	No. of Taxa
Sarcodina (amoebae)	Tubulinea	Arcellinida	3
Ciliophora (ciliate protists)	Ciliatea	Peritrichida	1
Rotifera (rotifers)	Monogononta	Flosculariaceae	5
		Ploima	29
Plathyhelminthes (flat worms)	Turbellaria (flat worms)	Neorhabdocoela	1
Annelida (segmented worms)	Oligochaeta	Tubificida	1
Arthropoda	Arachnida	Acarina (mites)	2
Mollusca	Gastropoda (snails)	Basommatophora	1
Crustacea	Branchiopoda	Anostracha (fairy shrimps)	6
		Diplostraca (clam shrimps)	7
		Notostraca (Shield shrimps)	1
		Cladocera (water fleas)	12
	Copepoda (copepods)	Calanoida	3
		Cyclopoida	2
	Ostracoda (ostracods)	Mystacocaridida	9
	Malaocstraca	Decapoda (prawns)	1
Hexapoda	Insecta	Odonata (dragonflies)	8
		Hemiptera (bugs)	13
		Coleoptera (beetles)	24
		Trichoptera (caddisflies)	1
		Diptera (flies)	11
		Total:	**141**

Zooplankton sampling collected an overall total of 59 taxa across the three phases of the survey. The clear water habitats sampled were consistently more diverse than the turbid sites. The taxa contributing this richness varied somewhat across the phases, with rotifers dominating the clear water assemblage in Phase I, while branchiopod crustaceans were well represented in both habitats throughout the survey. Only two species were found in the turbid claypans despite many more of these being sampled than clear water sites.

Macro-invertebrate sampling collected an overall total of 82 taxa across the three phases of the survey. As with the zooplankton, the clear water habitats sampled were more diverse than the turbid claypans during Phases I and II. This was mostly due to the greater number of coleopteran and dipteran taxa in the clear water sites during these phases compared to the turbid sites. By Phase III, when many of the pans were drying out, the diversity overall had dropped substantially from its peak in the second phase, and the two broad habitat types were very similar in species richness. Individual clear water sites were, however, more diverse than individual turbid claypans

Four previously uncollected and undescribed species were recorded during this survey. Three of these four taxa were collected from only Reference sites, or from both Study Area and Reference sites, with the clam shrimp *Limnadia* n. sp. only collected from Study Area site CWP01; an artificial pan on the roadside in the Domgas corridor. An indeterminate flatworm *Mesostoma* sp. was also collected only from this latter site.

1.5 Conclusions

The risk of any fauna species being restricted in distribution to the Wheatstone Project Study Area can be assessed by considering:

- what can be demonstrated about the wider distribution of the individual species recorded from Study Area sites;
- the overall similarity or distinctiveness of the Study Area claypans compared to those in Reference areas; and
- evidence of biophysical processes and landscape features that may promote or diminish local endemism.

A total of 92 invertebrate taxa were recorded from Study Area sites sampled during this survey. Ninety of these taxa (98%) have been demonstrated to occur at least as far as Reference areas in the locality, with the majority widely distributed in the bioregion or beyond. The two taxa that are currently only known from Study Area sites, *Limnadia* n. sp. (a clam shrimp) and *Mesostoma* sp. (a flatworm), both came from site CWP01. This site is an artificial wetland formed from roadside flooding of an old materials sourcing area. As such, it seems very unlikely that these records represent natural locally endemic distributions.

Similarity analysis of the site assemblage data indicate that, sampling effects aside, the Study Area sites contain effectively equivalent suites of invertebrate fauna to those represented in Reference sites in the immediate locality. This pattern of equivalent suites of species in similar units appears consistent with landscape-scale processes that occur in the area during flood events. Evidence from Cyclone Dominic, and the nature of the topography, suggest that under major flood events the aquatic habitats of many of the claypans become interconnected through surface flooding. The extent of this connection would be related to the magnitude of the flood event. It is likely however that the majority of cyclones would result in similar patterns of surface hydrology, given the low elevation of the topography and the proximity of the Ashburton River.

This presents a scenario of relatively reduced risk of species isolation to individual claypans at this local scale, which is consistent with the outcome of the community similarity analysis, the distribution of individual species recorded from Study Area sites, and the findings of this survey in general.

Given the above, it appears unlikely that any significant claypan fauna diversity values would be compromised should the proposal proceed in its current form.

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2.0 Introduction

2.1 Project Background

Chevron proposes to construct and operate a multi-train LNG plant and a Domgas plant 12 km south west of Onslow on the Pilbara Coast (Figure 2.1). The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future 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 plants.

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 MTPA of LNG. The Wheatstone Project has been referred to the EPA and DEWHA. The investigations outlined in this report have been conducted to support these environmental impact assessment processes. Biota was subcontracted through URS to provide an assessment of the ephemeral fauna of the claypans present within the Wheatstone Project study area and surrounds.

2.2 Background on Claypan Fauna

Claypans are a type of ephemeral wetland often found in arid or semi-arid regions of the world (Hancock and Timms 2002). They are described as “natural, shallow depressions” which are flooded during rain events and dry up seasonally due to evaporation (Hancock and Timms 2002). Structurally, claypans are comprised and named for the impervious clay layer that makes up the base of the pan that restricts runoff and seeping (Timms 2002). As claypans are naturally filled from rainwater, they are predominantly freshwater systems that are often highly turbid. They often contain either no vegetation or a low density of emergent plants such as *Tecticornia verrucosa*, *Muehlenbaeckia florulenta* and *Agrostis australasica* (Halse et al. 2004).

The fauna of claypans is unique and, depending on the stage of the filling/drying cycle, is dominated by either phyllopod crustaceans or opportunistic insects (Hancock and Timms 2002). Both suites of fauna have adapted specialised methods of coping with the unpredictability of these habitats, with most claypan insects having the ability to fly, increasing the range of dispersal in search of suitable habitat. Common claypan crustaceans, such as Fairy Shrimp, Clam shrimp and Shield Shrimp, have adapted to ephemeral pool life by the evolution of not only eggs that are desiccation resistant, but also require a temporary dormant state before hatching after submersion to survive. Due to this adaptation, many pans will only harbor one generation of most crustacean groups before succeeding to an insect dominated environment. This type of succession is reset by the habitat drying out for a time. Claypan fauna have also adapted to cope with these narrow windows of time to grow and reproduce.

2.3 Scope of this Study

The floodplains surrounding the Wheatstone Project area contain many aquatic systems including a large number of ephemeral pools and claypans. While these pools can be filled at other times of the year, they are most commonly filled during cyclonic events between the months of December to March, when the region receives the majority of its annual rainfall.

A review of the literature suggests that there has been very little previous work done on the claypans surrounding Onslow. The only other sampling of claypan ephemeral fauna in the locality has been completed by the Department of Environment and Conservation (DEC). This sampling was very limited in the Onslow area and was undertaken as part of the DEC Pilbara Biological Survey. This regional study was not complete at the time of preparing this report.

Figure 2.1: **Locality plan showing the extent of the Wheatstone Project study area.**

The construction and operation of the proposed LNG plant and related infrastructure has the potential to directly affect claypan systems within the eventual project impact area and their faunal communities. As part of the baseline flora and fauna assessment, Biota was commissioned to undertake a series of strategically timed sampling phases targeting claypan fauna. The spatial extent of this survey encompassed the Wheatstone Project study area (Figure 2.1) and other claypans in the wider locality.

The scope of the current study was to document the claypan fauna present in the Wheatstone Project study area and surrounds. The specific objectives of the work were to:

- sample available claypan and ephemeral aquatic sites within or near the Wheatstone Project study area for the presence of locally endemic fauna ('Study Area' sites);
- sample similar claypan units in the locality that are outside of the proposed Wheatstone Project study area ('Reference' sites);
- record physico-chemical parameters of the sampled sites;
- identify the fauna collected to species level wherever possible to place them into local and regional context; and
- use multivariate analysis of presence-absence data to assess relationships between faunal assemblages in different sites as an indicator of high or low likelihood of endemism.

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3.0 Methodology

3.1 Survey Timing and Meteorological Conditions

The Wheatstone Project claypan survey was conducted over a two-month period during 2009, with approximately three weeks between each survey phase. The programme was designed to collect data on the succession of faunal life cycles in ephemeral claypans in and around the survey area immediately after initial submersion of the pans. To this end, the primary survey was commenced shortly after the passing of Cyclone Dominic in late January. The survey phases were as follows:

- Phase 1: 14th – 16th February 2009;
- Phase 2: 10th – 14th March 2009; and
- Phase 3: 6th – 9th April 2009.

Data recorded by the Australian Bureau of Meteorology (BoM) show that rainfall for the six months prior to sampling exceeded the average rainfall expected for those months (Table 3.1). Wetter than usual conditions were combined with the effects of Category 2 Cyclone Dominic, which brought 275.5 mm of rain to the region over a three-day period. This provided ideal conditions for claypan and opportunistic invertebrate fauna.

Table 3.1: Weather summary for the Onslow region for the six months preceding the Chevron Wheatstone claypan surveys as recorded at the Onslow Airport (source: BoM 2009).

	Aug	Sep	Oct	Nov	Dec	Jan
Mean Daily Min. Temp (°C)	13.5	16.7	20.0	18.9	21.8	25.9
Mean Daily Max. Temp (°C)	28.3	31.1	35.1	31.3	35.0	37.3
Total Monthly Rainfall 2008-09 (mm)	7.0	0.0	15.0	23.6	3.2	275.6
Average monthly rainfall (mm)	9.9	1.3	0.9	3.1	3.0	39.7

3.2 Claypan Survey and Analysis Team

The study team for the three field surveys for this project consisted of:

- Phase 1: Dr Brian Timms (Private Consultant), Dr Phil Runham and Mr Jason Alexander (both of Biota);
- Phase 2: Dr Brian Timms, Dr Phil Runham and Mr Jason Alexander; and
- Phase 3: Mr Jason Alexander and Ms Jessica Cairnes (Biota).

The project was coordinated by Garth Humphreys of Biota. Dr Brian Timms undertook species level identification of all zooplankton, micro and macro-invertebrates collected, with the exception of the collected ostracods, which were identified by Dr Stuart Halse (Bennelongia Environmental Consultants), and rotifers and cladocerans, which were identified by Dr Russel Shiel (Adelaide University). The study team leaders have more than a decade of experience working on aquatic invertebrates, with Dr Brian Timms in particular well recognised as an Australian authority.

3.3 Approach to Survey Design

Claypan sampling for the Wheatstone Project encompassed a selection of claypans and temporary water bodies within the proposed gas area, and the Shared Infrastructure Corridor (SIC) and the Domgas pipeline (Figure 3.1). Sampling locations were classified as 'Study Area' (within the Wheatstone Project study area) or 'Reference' (sites that would remain undisturbed by the proposal). Sample sites were initially chosen via aerial photography to provide spatial coverage of Study Area and Reference sites and to include both visible habitat types (coastal and inland wetlands). Sites were later altered during field events in response to changing environmental conditions and access restrictions. Sites were also modified to incorporate different habitat types not visible from aerial photography (such as vegetation presence).

3.4 Sampling Effort and Claypan Types

A total of 24 sites (12 Study Area and 12 Reference) were sampled during the survey, representing the range of claypan habitat types present. The sampled sites were broadly categorised as turbid or clear water claypans, and were further subdivided into six habitat types based on water salinity, turbidity and extent of vegetation cover (Table 3.2). The majority of the claypans present in the survey area were turbid in nature (18 out of 24; 75%; Table 3.2).

Table 3.2: Summary of claypan habitat types at each of the survey sample locations.

	Claypan type	Study Area Sites	Reference Sites	No. of Sites
Turbid (n=18)	Turbid claypan - vegetated	CWP11, CWP15, CWP21, CWP24	CWP08, CWP09, CWP22	7
	Turbid claypans - unvegetated	CWP07, CWP12, CWP16, CWP23, CWP25	CWP02, CWP04, CWP10, CWP17, CWP18, CWP20	11
Clear (n=6)	Samphire swamps - vegetated	-	CWP03, CWP05	2
	Artificial, freshwater wetlands	CWP01	-	1
	Large, freshwater wetlands	-	CWP19	1
	Marine wetlands	CWP13, CWP14	-	2

The location and approximate extent of the sampled pans are shown in Figure 3.1, with representative plates showing the habitats sampled provided in Plate 3.1 to Plate 3.6.

Plate 3.1: A vegetated turbid claypan (CWP08).

Plate 3.2: An unvegetated turbid claypan (CWP02).

Plate 3.3: A samphire swamp (CWP05)

Plate 3.4: A freshwater, artificial wetland (CWP01).

Plate 3.5: A clear, marine wetland (site CWP13).

Plate 3.6: A large, freshwater wetland (CWP19).

Several of the sites were repeatedly sampled during the study as detailed in Table 3.3. An attempt was made to maintain continuity of sampling locations between survey phases, however conditions and access restrictions were such that repeat sampling was often not possible. Three claypans, located adjacent to Onslow Road, were the only sites that could be sampled on all three survey phases, with a further five sites able to be sampled on two occasions (Table 3.3).

Table 3.3: Location details for sampling sites, 'Study Area' or 'Reference' status, general description, area of extent, and phases during which they were sampled (coordinates in WGS84 datum).

Site	Status	Coordinates (m E, m N)	~Area (ha)	Habitat description and site type	Phases Sampled		
					I	II	III
CWP01	Study Area	304505, 7587310	0.46	Artificial, freshwater wetland (vegetation in water or around edge)	√	√	√
CWP02	Reference	303667, 7587774	5.87	Turbid claypan – unvegetated (no vegetation in water or around edge)	√	√	√
CWP03	Reference	303648, 7594466	0.13	Samphire swamp - vegetated (vegetation throughout water body)	√	√	Dry
CWP04	Reference	302936, 7592507	0.76	Turbid claypan – unvegetated (little vegetation in water and around edge)	√	√	√
CWP05	Reference	302650, 7591540	4.83	Samphire swamp – vegetated (vegetation throughout water body)	√	√	Dry
CWP07	Study Area	304348, 7587203	0.01	Turbid claypan – unvegetated (no vegetation in water or around edge)		√	Dry
CWP08	Reference	304220, 7587164	1.32	Turbid claypan - vegetated (some vegetation throughout water body)		√	√
CWP09	Reference	294048, 7591134	15.69	Turbid claypan - vegetated (large, patchy vegetation throughout water)		√	Dry
CWP10	Reference	293969, 7591138	1.06	Turbid claypan – unvegetated (no vegetation in water or around edge).		√	√
CWP11	Study Area	297891, 7590302	0.17	Turbid claypan - vegetated (patchy vegetation throughout water body)		√	Dry
CWP12	Study Area	297819, 7590294	2.20	Turbid claypan – unvegetated (no vegetation in water or around edge)		√	Dry
CWP13	Study Area	290500, 7599014	601 *	Clear marine wetland (large, tidally influenced, fringing vegetation)		√	√
CWP14	Study Area	290420, 7598961	601 *	Clear marine wetland (sedimented, some fringing vegetation)		√	√
CWP15	Study Area	290902, 7595209	5.45	Turbid claypan - vegetated (some vegetation throughout water body)		√	Dry
CWP16	Study Area	291006, 7595257	0.78	Turbid claypans – unvegetated (interconnected, with no vegetation)		√	Dry
CWP17	Reference	288986, 7594097	0.44	Turbid claypan - unvegetated (no vegetation in water or around edge)		√	Dry
CWP18	Reference	282938, 7587754	5.49	Turbid claypan - unvegetated (no vegetation in water or around edge)		√	Dry
CWP19	Reference	285135, 7587502	0.25	Large freshwater wetland (densely vegetated)		√	√
CWP20	Reference	294069, 7591470	0.30	Turbid claypan - unvegetated (no vegetation in water or around edge)			√
CWP21	Study Area	298678, 7590905	3.67	Turbid claypan – vegetated (some grass vegetation)			√
CWP22	Reference	283419, 7588043	0.36	Turbid claypan – vegetated (some fringing vegetation)			√
CWP23	Study Area	296024, 7591772	0.26	Turbid claypan - unvegetated (no visible vegetation)			√
CWP24	Study Area	296190, 7589853	4.15	Turbid claypan – vegetated (some grass vegetation)			√
CWP25	Study Area	297668, 7591152	6.37	Turbid claypan - unvegetated (large, with no visible vegetation).			√

* CWP13 and CWP14 both part of the same large marine wetland unit (see Figure 3.1).

Note - CWP06 was a nominally chosen site that was never sampled and therefore not included above.

Figure 3.1: Extent of the survey area, showing location and size of sampled claypans within ('Study Area') and outside ('Reference') of the Wheatstone Project study area.

Photographs of all claypans sampled during this study are provided in Appendix 1. A more detailed account of the sampling that could be achieved during each phase of the study follows in Sections 3.4.1 to 3.4.3.

3.4.1 Summary of Phase I Sampling

The first sampling phase was completed from the 14th – 16th of February 2009 at a total of five ephemeral systems sampled (CWP01 – CWP05). Due to recent rainfall and that helicopters were not able to be used, sampling access was restricted to main bitumen roads. All sampled sites were situated adjacent to the main Onslow Road. Additionally, due to inclement weather, fieldwork was terminated one day earlier than anticipated and the field team demobilised from site.

3.4.2 Summary of Phase II Sampling

The second phase of claypan sampling took place from the 10th – 14th of March 2009, with a total of 18 claypans and isolated wetland systems sampled both within the designated Study Area as well as in associated Reference areas. Five of the sites visited had been sampled previously in the initial phase (Table 3.3).

3.4.3 Summary of Phase III Sampling

The final phase of claypan sampling took place from the 6th - 9th of April 2009. A total of 14 sites were successfully sampled for invertebrates, however seven of the 14 sites were too shallow to measure water chemistry. Ten sites previously sampled were dry and therefore unable to be sampled. Three of the sites sampled during Phase III had also been sampled during both of the first two phases, with eight sites sampled consecutively in both Phase II and Phase III (Table 3.3).

3.5 Claypan Sampling Methods

The field sampling was conducted using a range of different sampling techniques. These targeted the two broad suites of fauna known to inhabit claypan systems: zooplankton and macro-invertebrates.

3.5.1 Zooplankton

Zooplankton were sampled with the use of a 35 µm net (150 mm x 270 mm) attached to a collection jar that was dragged slowly through the water column so as to stir as little sediment as possible. Due to the nature of plankton, trawling was done for one minute in a representative portion of each claypan before the bulked sample was collected.

A specialised 35 µm micro-invertebrate net (170 mm diameter) was utilised at sites where aquatic vegetation was a prevalent habitat type. This net had a collection jar attached as well as a grid-like sieve over the mouth of the net, allowing it to be dragged through floating and submerged vegetation collecting smaller invertebrates and filtering out larger leaf and organic matter.

Ethanol was then added to bring the bulked sample to a concentration of over 70% (the minimum required concentration when preserving invertebrates for morphological identification). Abundances of individual taxa within each were sample visually estimated under a dissecting microscope using a log scale.

3.5.2 Macro-invertebrates

A 1 mm mesh net was used to sample for macro-invertebrates. Trawling lasted a minimum of 10 minutes, and was often completed in two to three sessions of 3 to 5 minutes each. This involved running the net along the benthos of the site, agitating the sediment slightly to stir up potential invertebrates. At each site, care was taken to sample all microhabitat types.

Collected bulk samples were placed in a small amount of water on a sorting tray where they were sorted through before several (~10) individuals from each representative morphotype were placed in 100% ethanol for preservation. Abundances of individual taxa within each were sample visually estimated using a log scale. Additional specimens of those taxa of interest, such as Anostraca or Conchostraca, were also collected.

3.5.3 Water Chemistry

Physico-chemical properties of each site were recorded using a Hydrolab Quanta system. This was performed prior to invertebrate sampling to avoid disturbance to physical properties due to the stirring of the water and sediment when using nets. Parameters recorded included pH, conductivity (mS/cm), salinity (PSS), dissolved oxygen (mg/L), redox potential (mV), temperature (°C) and turbidity (NTU). Physical properties were not recorded in sites where the depth of the claypan was less than 5 cm due to the inability to sufficiently submerge probes.

3.6 Data Management and Analysis

Once collected, samples were labelled in the field with site codes, sample names and dates to aid in specimen tracking. All collected samples were transported to the Biota laboratory in Perth, where macro-invertebrates were further sorted into different morphotypes, using a dissecting microscope (magnification up to 40x), before being distributed to relevant specialists for further identification (see Section 3.2).

Average community composition over the three sampling phases in the zooplankton and among macro-invertebrates was subjected to non-metric multi-dimensional scaling (nMDS) ordination procedure in PRIMER v6 (Clarke and Gorley 2006). This analysis was conducted in order to determine quantitative differences between the sites. All data were expressed in log abundances, prior to the construction of similarity matrices using the Bray-Curtis similarity coefficient. These were then used to construction ordination diagrams, which visually represent similarities between sites. A one-way ANOSIM (Analysis of Similarities) was used to test whether differences between groups of similar sites were significant. If the R statistic value was greater than 0.75, then the groups were considered significantly different.

3.7 Study Limitations

The majority of the proposed Wheatstone Project area was inaccessible by vehicle during the first sampling phase and helicopter access was not possible at that time. This limited the spatial adequacy of the Phase I sampling. Ten of the 24 sites were also dry during the third phase and therefore could not be sampled. As a result, there were few replicate sites within the proposed LNG plant and camp impact areas, and none that spanned all three phases. However, the claypans that were able to be consistently sampled are representative of the units present in the locality and therefore, despite these limitations, the study is considered to have adequately characterised the fauna of the claypans in the survey area.

4.0 Results

4.1 Overview

The three-phase Wheatstone Project claypans survey recorded a combined total of 141 taxa of zooplankton and macro-invertebrates. Twelve classes and 21 orders were represented amongst the collected fauna, as summarised in Table 4.1. A complete taxonomic resume of the fauna collected during the study is provided in Appendix 2.

Table 4.1: Summary of the representation of taxonomic classes and orders amongst the fauna collected from sample sites during this study.

Phylum/Subphylum	Class	Order	No. of Taxa
Sarcodina (amoebae)	Tubulinea	Arcellinida	3
Ciliophora (ciliate protists)	Ciliatea	Peritrichida	1
Rotifera (rotifers)	Monogononta	Flosculariaceae	5
		Ploima	29
Plathyhelminthes (flat worms)	Turbellaria (flat worms)	Neorhabdocoela	1
Annelida (segmented worms)	Oligochaeta	Tubificida	1
Arthropoda	Arachnida	Acarina (mites)	2
Mollusca	Gastropoda (snails)	Basommatophora	1
Crustacea	Branchiopoda	Anostracha (fairy shrimps)	6
		Diplostraca (clam shrimps)	7
		Notostraca (shield shrimps)	1
		Cladocera (water fleas)	12
	Copepoda (copepods)	Calanoida	3
		Cyclopoida	2
	Ostracoda (ostracods)	Mystacocaridida	9
	Malaocstraca	Decapoda (prawns)	1
Hexapoda	Insecta	Odonata (dragonflies)	8
		Hemiptera (bugs)	13
		Coleoptera (beetles)	24
		Trichoptera (caddisflies)	1
		Diptera (flies)	11
		Total:	**141**

Examples of macro-invertebrate taxa commonly recorded during this study are provided in Plate 4.1 to Plate 4.8.

Plate 4.1: Order Acarina (water mite).

Plate 4.2: Order Anostraca (fairy shrimps)

Plate 4.3: Order Diplostraca (clam shrimps)

Plate 4.4: Order Notostraca (shield shrimps)

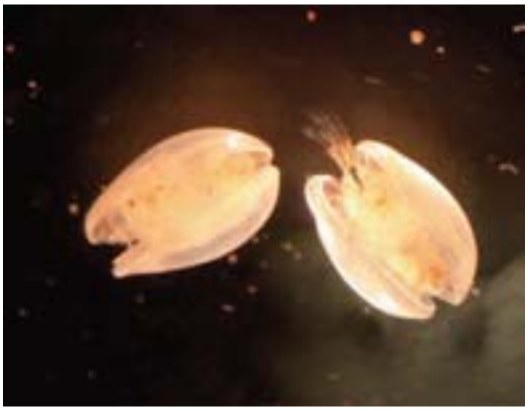

Plate 4.5: Order Ostracoda (ostracods).

Plate 4.6: Order Odonata (dragon flies)

Plate 4.7: Order Hemiptera (true bugs).

Plate 4.8: Order Coleoptera (beetles)

4.2 Zooplankton

4.2.1 Overview of Zooplankton Sampling Results

Zooplankton sampling collected an overall total of 59 taxa across the three phases of the survey. Table 4.2 summarises the changes in diversity in different taxonomic groups through the three sampling phases at turbid claypan sites and clear water sites.

Table 4.2: Summary of number of zooplankton by taxonomic group in turbid and clear water claypans during the three sampling phases (pooled data from all sites within each major claypan type).

	No. of Taxa					
	Phase I		**Phase II**		**Phase III**	
Taxon	**Turbid**	**Clear Water**	**Turbid**	**Clear Water**	**Turbid**	**Clear Water**
Protista	1	3	1	1	1	
Branchiopoda	5	8	8	9	3	8
Copepoda	1	3	2	4	2	3
Ostracoda	1	3	4	6	3	4
Rotifera	1	16	1	8	1	1
Total:	**9**	**33**	**16**	**28**	**10**	**16**

The clear water habitats sampled were consistently more diverse than the turbid claypans (Table 4.2). The taxa contributing this richness varied somewhat across the phases, with rotifers dominating the clear water assemblage in Phase I, while branchiopod crustaceans were well represented in both habitats throughout the survey. Rotifers were diverse in the clear water sites (e.g. CWP03, CWP05 and CWP19) with the greatest number of species of all the zooplankton. By contrast only two species were found in the turbid claypans and one in the most turbid claypans (CWP04), despite many more of these being sampled than clear water sites.

Nine previously undescribed species were recorded during the zooplankton sampling component of the survey (all of which are denoted by ‘n. sp.’ in the remainder of this document). While all are undescribed, comparisons with the reference material from the DEC Pilbara Biological Survey (PBS) indicated that five of these taxa have previously been recorded elsewhere in the region as outlined below:

- *Bennelongia* n. sp. (Ostracoda) (corresponds to 414 of DEC PBS);
- *Cypricercus* n. sp. (Ostracoda) (corresponds to 69 of DEC PBS);
- *Cypricercus* n. sp. (Ostracoda) (corresponds to 442 of DEC PBS);
- *Heterocypris* n. sp. (Ostracoda) (corresponds to 66 of DEC PBS); and
- *Enteroplea* n. sp. (Rotifera) (corresponds to PSW08; Russ Shiel, pers. comm.)

The distribution of the remaining four undescribed species collected during this survey not represented in the DEC PBS collection is summarised in Table 4.3. Three of the four taxa were collected from only Reference sites (or from both Study Area and Reference), with *Limnadia* n. sp. only collected from CWP01; an artificial pan on the roadside in the Domgas corridor (Table 4.3).

Table 4.3: Records of undescribed branchiopod species collected for the first time during zooplankton sampling completed in the survey area.

Taxon	**Study Area sites**	**Reference sites**
Caenestheria n. sp.	-	CWP02
Eocyzicus n. sp.	CWP01	CWP19
Diaphanosoma n. sp.	CWP11, CWP12, CWP16,	CWP02, CWP04, CWP08, CWP09, CWP10, CWP17, CWP18, CWP20
Limnadia n. sp.	CWP01	-

A detailed discussion of the results of each sampling phase follows in Sections 4.2.2 to 4.2.4, providing a discussion of the species recorded and other observations on changes in community structure and habitat relationships.

4.2.2 Phase I (February 2009)

Only five sites could be sampled during Phase I (CWP01 – CWP05; Section 3.4.1). The zooplankton results differed markedly amongst the types of pans sampled during this phase. A total of 38 zooplankton taxa were recorded from the five sites sampled during Phase I. Table 4.4 outlines the representation of zooplankton taxa amongst the sampled sites.

Table 4.4: Site by taxon representation of zooplankton in claypans sampled during Phase I (numbers = log value relative abundances; most abundant taxa within each site highlighted in bold; FW=Freshwater Wetland).

		Turbid Sites		**Clear Water Sites**		
		Turbid clay pan - Unvegetated		**Artificial FW**	**Samphire swamp**	
	Taxa	**CWP02**	**CWP04**	**CWP01**	**CWP03**	**CWP05**
Protista	*Arcella* sp.				1	1
	Arcella bathystoma				0.1	
	Arcella discoides					0.1
	Epistylus sp.	1				
Branchipoda	*Branchinella macraeae*			**2**		
	Branchinella pinderi	0.5				
	Branchinella pinnata			0.25		
	Limnadia n. sp.			0.75		
	Limnaopsis birchii			0.5		
	Diaphanosoma n. sp.	**1**	**3.5**			
	Moina micrura			**2**	**2**	**2.5**
	Alona sp.			0.1	0.1	
	Caenestheria sarsi		0.75			
	Caenestheriella packardi	0.1		0.1		
	Boeckella triarticulata			0.1		
Copepoda	*Calamoecia halsei*	**1.5**	**1.75**			
	Mesocyclops sp.			**2**		3
	Thermocyclops sp.			0.5	0.5	3
	Copepod nauplii			**3**		**5**
Ostraco	*Bennelongia australis*				**2.5**	3
	Bennelongia n. sp. (414 of DEC)		0.5	1		
	Cypretta 'triangulum'			0.5		
Rotifera	Indet. Bdelloid rotifer				0.1	
	Asplanchnopsis multiceps					0.1
	Anuraepsis fissa			0.1		
	Anuraepsis sp.					0.1
	Brachionus quadridentatus				0.2	
	Platyais quadricornis				0.5	0.5
	Conchilus natans					0.1
	Euchlanis sp.				0.5	0.5
	Ptygura cf cystallina			0.5		
	Hexrathra sp.	0.1				
	Lecane luna			1	0.5	0.5
	Colurella unicinata bisuspidata			0.1		
	Cephalodella forficula			0.5	0.5	1
	Enteroplea n. sp. (PSW08)					0.1
	Polyarthra dolichoptera			1	1	0.5
	Trichocera sp.				0.5	0.5

The two turbid sites (CWP02 and CWP04), had a zooplankton dominated by the calanoid copepod *Calamoecia halsei* and the cladoceran *Diaphanosoma* n. sp. (Table 4.4). There was a notable absence of cyclopoid copepods and rotifers. In addition, the colonial ciliate *Epistylus* sp. only occurred in these turbid claypans; an early indication of its commonness in these habitats in subsequent phases.

The two samphire swamp sites (CWP03 and CWP05) had similar zooplanktons, dominated by the cladoceran *Moina micrura*, the ostracod *Bennelongia australis* and many copepod and rotifer taxa, including *Platyias quadricornis, Euchlanis* sp.*, Lecane luna* and *Polyarthra dolichoptera*

(Table 4.4). Both sites lacked calanoid copepods, which is unusual for such open water sites. The artificial site CWP01, which had water intermediate in turbidity between the clearest and most turbid sites (Appendix 3), was similar in faunal composition to the samphire swamps and distinct from that of the turbid claypans (CWP02 and CWP04). It too was dominated by *Moina micrura*, cyclopoid copepods and a variety of rotifers, but lacked *Bennelongia australis*, and had a small presence of the widespread calanoid copepod *Boeckella triarticulata* (Table 4.4).

4.2.3 Phase II (March 2009)

Species richness was the greatest during Phase II with 39 species recorded (Table 4.5). The pans had been submerged for approximately five weeks during this phase and many more sites could be sampled. With an increase in the number of sample sites, the distinctiveness of the turbid claypans became even more apparent. The zooplankton from these sites was dominated by various combinations of *Calamoecia halsei, Diaphanosoma* n. sp. and the colonial ciliate *Epistylus* sp. (Table 4.5). In some turbid sites, two cladocerans (*Moina* sp. and *Daphnia projecta*) and the ostracod *Bennelongia* n. sp. 414 were also common. There was little to separate the fauna of the vegetated and unvegetated turbid claypans during Phase II (Table 4.5).

The clear water sites (with the addition of site CWP19) also maintained their distinctiveness during this phase. The calanoid copepod *Boeckella triarticulata* now dominated in site CWP01, while the calanoid copepod *Diaptomus lumholtzi* (a species with tropical affinities; Timms and Morton 1988) dominated in CWP19 (Table 4.5). By comparison, no calanoid copepods were collected from the two samphire swamps during Phase 2 (CWP03 and CWP05). Site CWP03 yielded very little fauna in general, perhaps due to its severe shallowing since Phase I. CWP05 continued to be dominated by cyclopoid copepods, with reduced numbers of the cladoceran *Moina micrura* and almost no rotifers. CWP01 was similar to CWP05, in regards to cyclopoids and a great reduction in rotifers, but with a continued importance of *Moina micrura* (Table 4.5).

A variety of ostracods were collected from the non-turbid sites during Phase II (particularly CWP19), but also to a lesser degree in the vegetated turbid claypans CWP08 and CWP12 (Table 4.5). No zooplankton were collected from the marine sites (CWP13 and CWP14; Table 4.5).

4.2.4 Phase III (April 2009)

By April, many sites were drying and shallow (<10 cm deep), so the zooplankton was declining. This was particularly the case for very shallow and turbid claypans (such as CWP23, CWP24 and CWP25). The marine sites CWP13 and CWP14 again yielded no fauna (Table 4.6). In contrast, the deeper (>10 cm) sites CWP01, CWP04 and CWP19 still yielded a diverse zooplankton during Phase III. A total of 24 zooplankton species was recorded during this final phase.

In turbid claypans, *Calamoecia halsei* was still the dominant, and often the only, zooplankton taxon (Table 4.6). This was the case for both vegetated and unvegetated turbid claypans. Other characteristic claypan species such as *Epistylus* sp., *Asplanchna* sp., *Diaphanosoma* n. sp. and *Bennelongia* n. sp. 414 were still present in some sites. The distinctive elements of sites CWP01 and CWP19 from Phase I persisted, but were perhaps less important (e.g. *Diaptomus lumholtzi* in site CWP19), while some new elements became conspicuous (e.g. *Diaphanosoma excisum* in CWP01 and *Alona* sp. and *Macrothrix* sp. in CWP19).

Table 4.5: Site by taxon representation of zooplankton in claypans during Phase II (numbers=log relative abundances; most abundant taxa in bold; 'O'='Others'; 'FW'=Fresh Wetland).

		Turbid Sites												**Clear Water Sites**					
		Turbid claypan - unvegetated									**Turbid claypan - vegetated**			**Artificial FW**	**Samphire swamp**		**Marine wetland**		**Large FW**
	Taxa	**CWP02**	**CWP04**	**CWP07**	**CWP10**	**CWP11**	**CWP12**	**CWP16**	**CWP17**	**CWP18**	**CWP08**	**CWP09**	**CWP15**	**CWP01**	**CWP03**	**CWP05**	**CWP13**	**CWP14**	**CWP19**
O	*Mesostoma* sp.													0.1					
	Epistylus sp.	**1.5**			**1.5**	1			**1**	**0.5**	1.5		0.5						
Branchipoda	*Branchinella halsei*		0.5				0.1	0.5		**0.5**			0.2						
	Branchinella pinderi	0.1																	
	Branchinella pinnata									0.2									
	Caenestheria sarsi							0.1											
	Caenestheria n. sp.	0.1																	
	Caenestheriella packardi													1					
	Eocyzicus n. sp.													0.1					0.2
	Boeckella triarticulata													**3**					
	Daphnia projecta					0.2					0.5								
	Ceriodaphnia cornuta													0.1					0.2
	Simocephalus latirostris													0.1					0.1
	Diaphanosoma excisum													0.5					**1.5**
	Diaphanosoma n. sp.	1	0.5		1	**2**	**0.5**	0.1	0.1	0.1	**2.5**	0.2							
	Moina micrura													**3**		0.1			1
	Moina sp.		0.5				0.1	0.1	0.5				0.1						
	Macrothrix sp.														**0.3**				
	Alona sp.															0.1			
Copepoda	*Calamoecia halsei*	1	**2**	**0.5**	**2**	**2.5**	**1.5**	**2.5**	**1.5**		**2.5**	**1**	**2**						
	Diaptomus lumholtzi																		**2.5**
	Mesocyclops sp.		0.2											2		1			0.5
	Thermocyclops sp.																		1
Ostracoda	*Bennelongia australis*																		0.5
	Bennelongia n. sp. (414 of DEC)	0.1						1	0.1		0.5		0.2						0.5
	Cypricercus n. sp. (69 of DEC)													0.5		**0.5**			
	Cypricercus n. sp. (442 of DEC)		0.1								0.1								
	Cypretta 'triangulum'													0.5					0.5
	Heterocypris n. sp. (66 of DEC)														0.1				
	Ostracod 'medium flat base'				0.1	0.1	0.2												
	Zonocypris kalimna		0.5																0.5
Rotifera	*Asplanchna seiboldi*					0.2			0.5										
	Brachionus quadridentatus															**0.5**			
	Euchlanis sp.													0.1					0.1
	Ptygura cf *cystallina*													0.2					
	Hexrathra sp.																		0.1
	Enteroplea n. sp. (PSW08)														0.1				
	Eosphora najas													0.1					
	Moptoammata cerberus													0.1					

Table 4.6: **Site by taxon representation of zooplankton in claypans during Phase III** (numbers=log relative abundances; most abundant taxa in bold; 'O'=Other; 'FW'=Fresh Wetland).

		Turbid Sites										Clear Water Sites			
		Turbid claypan – vegetated						Turbid claypan – unvegetated				Artificial FW	Marine wetland		Large FW
	Taxa	**CWP02**	**CWP04**	**CWP10**	**CWP20**	**CWP23**	**CWP25**	**CWP08**	**CWP21**	**CWP22**	**CWP24**	**CWP01**	**CWP13**	**CWP14**	**CWP19**
O	*Epistylus* sp.	0.5			0.5				0.5						
Branchiopoda	*Daphnia projecta*		0.1									0.1			
	Simocephalus latirostris											0.1			0.1
	Diaphanosoma excisum											0.5			0.2
	Diaphanosoma n. sp.	0.5	0.5	0.1	0.2			0.1							
	Moina micrura		1									**1**			
	Macrothrix sp														0.5
	Alona sp.											0.2			0.5
	Dunhevedia crassa														0.2
	Leberis cf. *diaphanus*														0.2
Copepoda	*Boeckella triarticulata*											**2.5**			
	Calamoecia halsei	**1**	**2**	**0.5**	**1.5**	**0.5**	**0.2**	**0.3**	**0.5**	**1.5**	**0.1**				
	Diaptomus lumholtzi														1
	Mesocyclops sp.		0.1												
	Thermocyclops sp.														**1.5**
Ostracoda	*Bennelongia australis*											0.1			0.5
	Bennelongia n. sp. (414 of DEC)									0.1					
	Cypretta 'triangulum'											0.1			
	Cypricercus n. sp. (69 of DEC)							0.1							0.2
	Heterocypris n. sp. (66 of DEC)														**1**
	Ostracod 'small round 2 eyes'				0.1										
Rotifera	Indet. Bdelloid rotifer														
	Asplanchna sieboldi		0.1												
	Ptygura cf *cystallina*											0.5			

4.3 Macro-invertebrates

4.3.1 Overview of Survey Results

Macro-invertebrate sampling collected an overall total of 82 taxa across the three phases of the survey. Table 4.8 summarises the changes in diversity in different taxonomic groups through the three sampling phases at turbid claypan sites and clear water sites.

Table 4.7: Summary of number of macro-invertebrate taxa per taxonomic group in turbid and clear water claypans during the three sampling phases (pooled data from all sites in each major claypan type).

	No. of Taxa					
	Phase I		Phase II		Phase III	
Taxon	**Turbid**	**Clear Water**	**Turbid**	**Clear Water**	**Turbid**	**Clear Water**
Branchiopoda	6	9	4	4	2	1
Odonata	3	6	6	7	4	5
Hemiptera	3	8	9	9	7	3
Coleoptera	5	16	14	18	12	11
Diptera	1	6	1	6	1	3
Other	1	5	3	8	2	4
Total:	**19**	**50**	**37**	**52**	**28**	**27**

As with the zooplankton, the clear water habitats sampled were more diverse than the turbid claypans during Phases I and II (Table 4.2). This was mostly due to the greater number of coleopteran and dipteran taxa in the clear water sites during these phases compared to the turbid sites. By Phase III, when many of the pans were drying out, the diversity overall had dropped substantially from its peak in the second phase, and the two broad habitat types were very similar in species richness. Individual clear water sites were, however, more diverse than individual turbid claypans (see Section 4.3.4).

Excluding taxa that were also collected during zooplankton sampling (Section 4.2.1), two previously undescribed species were recorded during the macro-invertebrate sampling component of the survey. While both of these beetle taxa are undescribed, comparisons with the reference material from the DEC PBS indicate that both have previously been recorded elsewhere in the region as outlined below:

- *Haliplus* n. sp. (Coleoptera) (corresponds to DEC PBS sp. '*testudo*' light); and
- *Berosus* n. sp. (Coleoptera) (corresponds to DEC PBS sp. 4).

A detailed discussion of the results of each macro-invertebrate sampling phase follows in Sections 4.3.2 to 4.3.4, providing a discussion of the species recorded and other observations on changes in community structure and habitat relationships.

4.3.2 Phase I (February 2009)

The few sites sampled in Phase I contained large numbers of branchiopods (fairy shrimps, clam shrimps, shield shrimps), in addition to adult beetles, many juvenile odonates, hemipterans and larval beetles (Table 4.8). The large ostracod, *Bennelongia* n. sp. 414 was also common in most sites, and the mosquito *Culex starkeae* very common in site CWP03. A total of 56 macro-invertebrate taxa was recorded from the five sites sampled during Phase I (Table 4.8).

This was the only phase when many of the larger branchiopod species were recorded. This included *Branchinella macraeae, B. dubia, Limnadopsis tatei, Caenestheria* n. sp. and *Triops australiensis*. Some of the branchiopod taxa, including *B. pinderi, Limnadopsis birchii* and *Caenestheria sarsi* were hardly encountered in Phase II collections (Section 4.3.3) and not at all during Phase III (Section 4.3.4). Differentiation between turbid and clear sites was obvious with the very turbid claypan CWP02 the only site yielding *B. pinderi* and *Caenestheria* n. sp. and the two samphire swamps (CWP03 and CWP05) the only sites where *Limnadopsis birchii* was recorded (Table 4.8). CWP01, a clear water site, was the most diverse (Table 4.8).

There was little differentiation evident among the insect invertebrate fauna recorded from the sites during Phase I. Most odonates and hemipterans were juveniles and unidentifiable to species level. Interestingly at this early stage, the turbid claypan CWP02 was almost devoid of insects, except for the beetle *Eretes australis* (which was common in almost all claypans in later phases). Sites CWP01, CWP03 and CWP05 had the greatest insect species richness (10 to 16), while turbid claypans had lower insect species richness (1-12; Table 4.8). These differences in species richness continued and became more pronounced in later sampling phases (Sections 4.3.3 and 4.3.4).

4.3.3 Phase II (March 2009)

Sampling during Phase II recorded a total of 60 macroinvertebrate taxa from the 18 sites sampled (Table 4.9). Despite some decrease in branchiopod diversity, overall species richness increased significantly during Phase II compared to Phase I (see Table 4.7). This was partly because more sites were sampled, but also more species were present in four of the five sites sampled during Phase I. The most obvious change in diversity was due to many extra beetle taxa, and the collection of mature and therefore identifiable backswimmer specimens. This occurred in the turbid claypans as well as in other wetland types sampled, with the exception of the two marine sites (CWP13 and CWP14). The latter were consistently almost devoid of macroscopic fauna.

One fairy shrimp species, *Branchinella halsei*, was restricted to the turbid claypan sites in Phase II, when it had previously only been recorded in one turbid site (CWP04; Table 4.8 and Table 4.9). The large ostracod, *Bennelongia* n. sp. 414 was almost ubiquitous throughout all sites, though was apparently now absent from the samphire swamps (Table 4.9). Other common species typifying the turbid sites during Phase II included *Hemicordulia tau*, *Caenestheria sarsi, Anisops nasutus, A. stali,* and *Allodessus bistrigatus*, with the beetle *Eretes australis* often dominating (Table 4.9).

No species united the clear water sites, perhaps because of their diversity of habitat type or because too few examples were sampled to detect trends. Nevertheless, *Limnadia* n. sp occurred only in CWP01, *Eocyzicus* n. sp. occurred mainly in non-turbid sites, odonates other than *Hemicordulia tau* were far more common in clear water sites than in turbid claypans and *Anisops canaliculatus* was uncommon and restricted to clear water sites (Table 4.9). Many of the low frequency species also occurred only in non-turbid sites (e.g. *Berosus puchella, Enochrus deserticola*, and all the chironomids). While backswimmers bred in most sites, including the turbid claypans, most beetle genera for which larvae were encountered (*Berosus, Cybister, Eretes, Haliplus, Hyphydrus, Hydrophilus*) were recorded only in clear water sites (Table 4.9). The exception was *Cybister* sp. whose large larvae were commonly encountered in all habitat types.

While the turbid claypan sites had similar core species, species richness varied widely amongst them (from 4 to 21; Table 4.9). At a minimum, some sites had just a subset of the core species, while others had most or all of these, plus many others not commonly found in claypans. While some of this variability was probably due to chance sampling effects, differences in turbidity, water depth and in the extent of vegetation may also have influenced species richness. Turbidity varied from 1,480 to > 5,999 units (the upper limit of the instrument which was well exceeded in some claypans), depth from 2-80 cm, and amount of vegetation varied from none to a wide band of littoral grasses and *Marsilea* (Appendix 1). The typical claypan had a turbidity >5,999 NTUs (Section 4.4), depth of 10-20 cm and no vegetation or scattered clumps of *Leptochloa fusca*.

The best option to analyse any influencing factor was on the possible positive influence of aquatic vegetation on species richness. However, this failed to show any relationship ($p=0.245$, not significant), possibly because even though it utilised five replicates in each group (vegetated vs non-vegetated), the amount of vegetation present was not quantified. There were insufficient replicates of other factors such as depth and turbidity to mount statistical tests, and any relationship was probably non-linear. Despite this, it is thought that species richness was inhibited by the absence of vegetation, very shallow depths (< 5 cm) and very high turbidity (> 6,000 NTU).

Table 4.8: **Site by taxon representation of macro-invertebrates in claypans sampled during Phase I** (numbers = log = relative abundances; most abundant taxa in each site in bold; FW=Fresh Wetland).

		Turbid Sites		Clear Water Sites		
		Turbid claypan - unvegetated		Artificial FW	Samphire swamp	
	Taxa	**CWP02**	**CWP04**	**CWP01**	**CWP03**	**CWP05**
Branchipoda	*Branchinella macraeae*			**3**		
	Branchinella dubia			0.5		
	Branchinella pinderi	**1.5**				
	Branchinella halsei		**2.5**			
	Branchinella occidentalis	0.1	0.1			
	Limnadopsis birchii			1	1	0.5
	Limnadopsis tatei			1	1	0.5
	Limnadia n. sp.			**3**		
	Caenestheria sarsi	1	1.5		1.5	
	Caenestheria n. sp.	1				
	Caenestheriella packardi			1.5		
	Eocyzicus n. sp.			0.5		0.1
	Triops australiensis	0.5	1.5	1.5	0.1	
Ost	*Bennelongia australis*			1	0.5	0.5
	Bennelongia n. sp. (414 of DEC)		**3**	1		
Odonoata	*Hemianax papuensis*			1.5	0.1	1
	Hemicordulia tau		1			
	Orthetrum caledonicum				**1.5**	**1.5**
	Trapezostigma loewi		0.1			
	Austrolestes aridus					0.5
	Ischnura heterostricta			0.5		
	Xanthoagrion erythroneurum					
Hemiptera	*Anisosp nasutus*			1		
	Anisops stali			0.5		
	Anisops sp. juv.		0.5	1	0.5	1
	Agraptocorixa eurynome			0.1		
	Agraptocorixa parvipunctata					0.1
	Micronecta sp. juv.				0.1	1
	Diplonychus eques juv.		1			0.5
	Lethocerus distinctifemur juv.			0.1		
	Paraplea sp.		0.25			
Coleoptera	*Allodessus bistrigatus*			0.1		
	Berosus approximans			0.1		0.1
	Berosus macumbensis			1	0.5	1
	Berosus sp. (DEC sp. 4)			1	1	1
	Dineutus australis			1		
	Enochrus elongatus			0.1		
	Eretes australis	1	1	1.5		1
	Haliplus n. sp. (*testudo* 'light')			0.1		0.5
	Hydroglyphus grammopterus		0.1		0.1	0.5
	Hyphydrus lyratus			0.5		
	Curculionid sp. 2			0.1		
	Allodessus sp. larva					0.1
	Berosus sp. larva		0.25	0.5	0.5	
	Eretes sp. larva		0.5	0.5	**1.5**	1
	Cybister sp. larva		0.25			0.5
	Hyphydrus sp. larva					0.1
Diptera	*Hydrophilus* sp. larva			0.5	1	0.5
	Culex starkeae				1	
	Chironomus sp.				0.2	
	Polypedilum sp.		0.1		0.2	
	Tanytasus sp.				0.5	
	Stratiomyid larva					0.1
Oth	*Nais communis*			0.1		
	Hydrachna sp.				0.1	0.1
	Isidorella sp.				0.1	

Table 4.9: **Site by taxon representation of macro-invertebrates in claypans sampled during Phase II** (numbers = log value relative abundances; most abundant taxa within each site highlighted in bold; FW = Freshwater Wetland).

		Turbid Sites												Clear Water Sites					
		Turbid claypan – unvegetated									Turbid claypan - unvegetated			Artificial FW	Samphire swamp		Marine wetland		Large FW
	Taxa	**CWP02**	**CWP04**	**CWP07**	**CWP10**	**CWP11**	**CWP12**	**CWP16**	**CWP17**	**CWP18**	**CWP08**	**CWP09**	**CWP15**	**CWP01**	**CWP03**	**CWP05**	**CWP13**	**CWP14**	**CWP19**
Branchiopoda	*Branchinella halsei*		1.2		0.2	1	**2.5**	**2**					**1.5**						
	Branchinella occidentalis		0.1							0.2	0.5								
	Limnadia n. sp.													0.1					
	Limnadopsis birchii																		0.1
	Eocyzicus n. sp.		1				0.5		0.5				0.5			0.5			**1.5**
	Caenestheria sarsi		0.5	0.1		1.5	1	**2**			1		1						
	Caenestheriella packardi													**2**		0.1			0.5
Odonoata	*Hemianax papuensis*		0.1				0.2							0.1	0.1	**1.5**			1
	Hemicordulia tau		0.5		0.5	0.1	0.5	0.1			0.5		0.5		0.2				
	Orthetrum caledonicum														**2**				
	Trapezostigma loewi						0.2								0.2				0.5
	Austrolestes aridus						**1.5**	0.5			1								1
	Ischnura heterostricta		**2.5**									0.1		**2.5**	**1.5**				
	Xanthoagrion erythroneurum										1		0.2			2			0.5
Hemiptera	*Agraptocorixa parvipunctata*		0.5				0.1												
	Anisops canaliculatus													0.5	0.1	0.1			
	Anisops nasutus	0.5		0.5	**1**	1	**1.5**	0.5			0.5	1	**2**	0.5	**2**	**1**			
	Anisops paraexigerus											0.1		1					0.1
	Anisops stali	1	**2**	**1**	**1**	**1.5**	**2**	**2**	**1.5**	**1**	1	1	**2**	1	0.1	0.5			**2**
	Anisops theinemanni	0.1		0.5				0.5	**1.5**		0.1								**1.5**
	Diplonynchus eques		0.2				0.1					0.5		0.5					
	Laccotrephes tristis			0.1															
	Limnogonus fossarum		1			0.1		0.5			0.5		0.5		0.5				0.1
	Micronecta sp.														**1.5**				
	Paraplea sp.		0.1																0.1
Coleoptera	*Ranatra diminuta*				0.2						2								
	Allodessus bistrigatus	0.1	1	0.5	0.1	0.5	0.1		0.2			0.5	0.5			1			0.2
	Berosus approximans					0.1		0.1						0.1	0.1				
	Berosus macumbensis														0.1			0.1	
	Berosus n. sp. (DEC sp. 4)		1			0.1		0.5					0.1	0.1	0.5				0.1
	Berosus puchella													0.1					0.1
	Copelatus nigrolineatus													0.1					
	Cybister tripunctatus						0.1	0.1			0.1								
	Dineutes australis	0.1	1	**1**							0.5			0.5		**1**			0.5
	Enochrus elongatus		0.5										0.1			0.1			

Table 4.9: **Site by taxon representation of macro-invertebrates in claypans sampled during Phase II** (numbers = log value relative abundances; most abundant taxa within each site highlighted in bold; FW = Freshwater Wetland).

		Turbid Sites												Clear Water Sites					
		Turbid claypan – unvegetated									Turbid claypan - unvegetated			Artificial FW	Samphire swamp		Marine wetland		Large FW
	Taxa	CWP02	CWP04	CWP07	CWP10	CWP11	CWP12	CWP16	CWP17	CWP18	CWP08	CWP09	CWP15	CWP01	CWP03	CWP05	CWP13	CWP14	CWP19
Coleoptera (cont.)	*Enochrus deserticola*																		0.2
	Eretes australis	**2**	**1.5**	**2**	**2**	**2**	**1.5**	**2.5**	**2**	**2**	**2**	**1.5**	**1.5**	0.5		0.1			
	Haliplus n. sp. (*testudo* 'light')					0.1										0.1			0.5
	Hydroglyphus grammopterus		**2**												0.1	0.2			
	Hyphydrus lyratus		0.5			0.1	0.5				0.5			0.2		0.1			
	Laccophilus sharpi		0.5		0.1	0.1	0.2	0.1	0.1			0.2	0.2	0.1					0.2
	Curculionid sp. 1									0.1									
	Curculionid sp. 2													0.1					
	Cybister sp. larva		1		0.1	0.1	0.5				1		0.1	0.1		0.1			**1.5**
	Haliplus sp. larva																		0.1
	Hyphydrus sp. larva		0.5											0.5		0.1			
Diptera	*Triplectides australis*															0.5			
	Culex starkeae														**2**	**1**			0.2
	Chironomus sp.														0.5	0.5			
	Dicrotendipes sp.														0.2				
	Polypedilum sp.														0.2	0.5			
	Tanytasus sp.														0.5	0.5			
Acari	*Arrenurus* sp. (sp. 15 of DEC)							0.1			0.1			0.5		0.5			0.5
	Hydrachna sp.															0.5			0.1
Other	*Isidorella* sp.																		0.1
	Bennelongia n. sp. (414 of DEC)	**1.5**	**1.5**		**1**	1	**2.5**	**2**	0.5		**1.5**	**1.5**	**2**	**2**					**2**
	Juvenile penaeid decapod																	0.5	
	Hydrophilus brevispina			0.1										0.1					
	Hydrophilus sp. larva													0.1					1
	Juvenile marine fish																	**0.1**	

4.3.4 Phase III

By April, many sites had dried, but with the addition of six more claypans, a total of 14 sites was sampled (Section 3.4.3). The marine pans were again lacking macro-invertebrates and the clear water sites CWP1 and CWP19 were the most diverse (18 and 19 species respectively; Table 4.10). This compared to an average of less than half the taxa in the turbid claypan sites. Forty-three macro-invertebrate taxa were recorded in total during this phase, as detailed in Table 4.10.

Branchiopod diversity was the lowest of the three sampling phases, and the occurrence of other insect groups had also decreased somewhat from Phase II. For large branchiopods the average number of species per site had decreased from 4.8 in Phase I, to 1.6 in Phase II and to 0.5 in the final phase. Odonates also decreased to 1.2 species per site in Phase III compared to 1.8 in Phase I and 1.9 in Phase II). Many odonates were going through a second generation in the deeper clear water sites during Phase III (mainly CWP01 and CWP19). Hemipterans and most beetle taxa appeared to have only had a single generation. In the case of the large beetle *Cybister tripunctatus*, larvae were only maturing in April so that it was most common and widespread during the final phase (Table 4.10). The other common beetle, especially in turbid claypans, was *Eretes australis*; its abundance was probably not due to recently matured larvae, but to its hardiness and liking for turbid sites (see Hancock and Timms 2002).

Again, the ostracod *Bennelongia* n. sp. 414, *Anisops nasutus* and *Eretes australis*, occurred in almost all sites, with the latter far more common in turbid claypans than in other habitats (Table 4.10). There was little obvious distinction between sites based on branchiopod composition or on insect composition. *Anisops canaliculatus* was again not found in turbid claypans, and neither were *Micronecta* sp. or any of the chironomid taxa. This may have been a function of sampling effort rather than true distributional change. Some species previously found only in turbid claypans were recorded at clear water sites during Phase III (e.g. *Berosus puchella, Enochrus deserticola*). Overall, the difference in community composition between sites sampled during Phase III was the least pronounced of the three sampling phases.

Table 4.10: Site by taxon representation of macro-invertebrates in claypans sampled during Phase III (numbers = log value relative abundances; most abundant taxa highlighted in bold; FW=Freshwater Wetland).

		Turbid Sites										Clear Water Sites			
		Turbid claypan - unvegetated						Turbid claypan - vegetated				Artificial FW	Samphire swamp		Large FW
	Taxa	**CWP02**	**CWP04**	**CWP10**	**CWP20**	**CWP23**	**CWP25**	**CWP08**	**CWP21**	**CWP22**	**CWP24**	**CWP01**	**CWP13**	**CWP14**	**CWP19**
Branch	*Branchinella halsei*		0.5			0.5					0.1				
	Eocyzicus n. sp.		0.1												
	Caenestheriella packardi											**1**			**1**
Odonata	*Diplacodes bipunctata*														**1**
	Hemianax papuensis											0.1			**1**
	Hemicordulia tau		0.5			0.2			0.1			0.2			
	Orthetrum caladonicum											**1**			0.5
	Trapezostigma loewi					0.1									
	Austrolestes aridus		2												
	Ischnura heterostricta							0.5		0.5		**1.5**			**1.5**
Hemiptera	*Agraptocorixa parvipunctata*	0.1								0.1					
	Anisops canaliculatus											**1**			**1**
	Anisops nasutus	0.5	0.5	0.2	**1**	0.1	0.5	0.2	**0.2**	0.2	**1**	0.5			
	Anisops paraexigerus	0.1			0.5						**0.5**				
	Anisops stali	0.5	1	**0.5**	0.5	0.5		0.5	1	**1.5**					
	Anisops thienemanni		0.5												
	Lethocercus distinctifemur				0.1				**0.2**	0.1					
	Limnogonus fossarum		0.1					0.5	0.1						
	Micronecta sp.											**1**			0.5
Coleoptera	*Allodessus bistrigatus*					**1.5**	0.1	0.1	0.1	0.2	0.1				
	Berosus nr. *josephenae*									0.1					
	Berosus macumbensis									0.1					
	Berosus sp. (pilbara 15)							0.1	0.1	**1**		0.1			
	Berosus puchella								0.1	0.1					
	Cybister tripunctatus		0.1	0.1	0.5	0.5		0.2	0.1	0.2		0.1			
	Dineutus australis									0.5					0.5
	Enochrus deserticola							0.1	0.1						
	Eretes australis	**2**	**2**	**2**	**1**	**1**	**1**	0.5	**1**	**1.5**		0.1			0.5
	Haliplus n. sp. (*testudo* 'light')											0.5			**1**
	Hydroglyphus grammopterus									0.1					
	Hyphydrus lyratus											0.5			0.5
	Laccophilus sharpi							0.5	0.5	0.5	0.1				
	Berosus sp. larva		0.1												0.1
	Cybister sp. larva		0.1					0.1							0.1
	Halipid sp. larva														0.1
	Hyphydrus sp. larva											0.1			
Diptera	*Polypedilum* sp.											0.2			0.2
	Tanytarsus sp.											0.2			
	Anopheles annulipes									0.1					0.1
Other	*Hydrachna* sp.									0.5		0.1			**1**
	Isidorella sp.											**1**			0.5
	Bennelongia n. sp. 414	**1**	**1**	0.1	0.5	0.5	0.2	**1.5**	**0.2**	**1**	**0.5**	0.2			**1**
	Juvenile marine fish													**0.1**	

4.4 Site Physico-chemical Parameters

The full suite of physico-chemical parameters measured at each site during the study are provided in Appendix 3. Some sites could not be measured on all occasions due to access constraints or insufficient water in the pans. Mean values for key parameters measured during the study at the claypan habitat types are presented in Figure 4.1 to Figure 4.4.

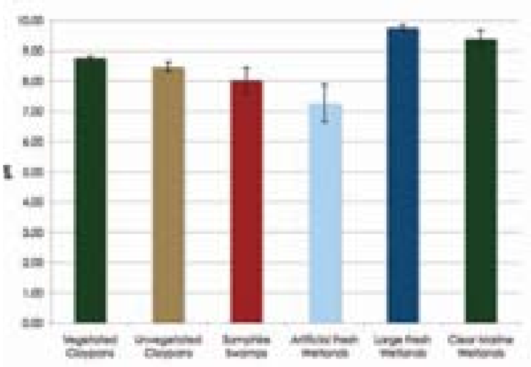

Figure 4.1: Mean pH of sites across the study (bars = standard errors).

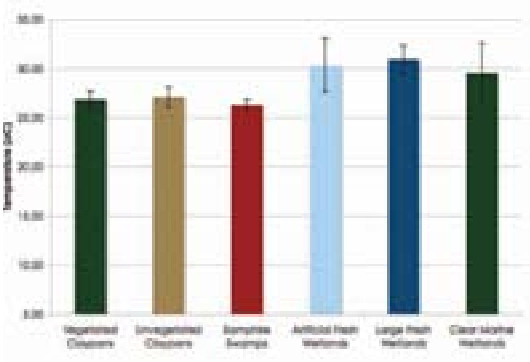

Figure 4.2: Mean temperature of sites across the study (bars = standard errors).

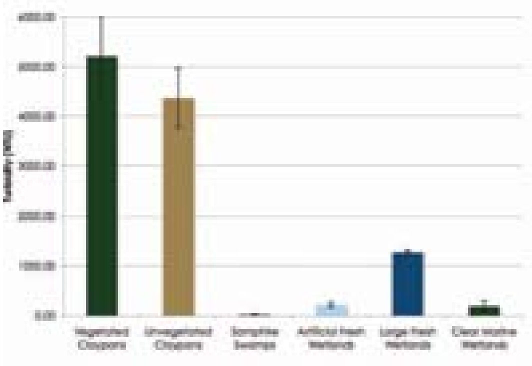

Figure 4.3: Mean turbidity of sites across the study (bars = standard errors).

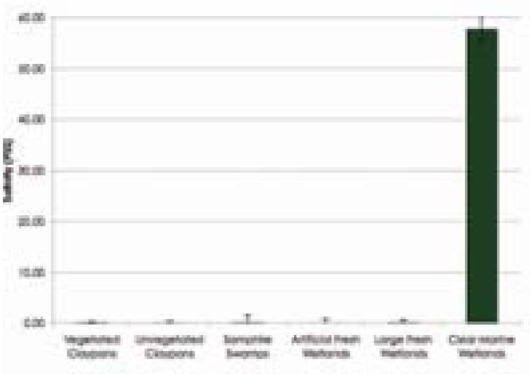

Figure 4.4: Mean salinity of sites across the study (bars = standard errors).

For some parameters, there was minimal difference between the types of habitats sampled. Temperature and pH showed little variation with all sites being slightly basic and between 25o and 30o C (Figure 4.2 and Figure 4.1 respectively).

Other attributes varied markedly amongst claypan types, particularly turbidity. (Figure 4.3; Appendix 3). The turbid claypans had values several orders of magnitude greater than other habitats. Vegetated claypans tended to be somewhat more turbid than unvegetated ones on average (Figure 4.3), though this difference was not significant (Student's t=0.68, p=0.51). Salinity was also dramatically higher in sites CWP13 and CWP14 (the marine wetlands), confirming that these are tidally influenced and ecologically distinct from the remainder of the sites sampled (Figure 4.4).

4.5 Analysis

A non-metric multi-dimensional scaling (nMDS) was completed on both the zooplankton and macro-invertebrate site data sets (Figure 4.5 and Figure 4.6 respectively). Both the resultant ordinations showed similar results. The various types of clear water sites, CWP01, CWP03, CWP005 and CWP19, were loosely grouped to the upper left and the turbid claypan sites grouped somewhat more tightly to the right. The marine sites were excluded from this analysis due to the paucity of data from these sites (n=2 records from the whole survey).

Among the clear water sites, CWP03 and CWP05 were somewhat more similar to each other than the others, probably reflecting that both were dominated by samphires (Figure 4.5 and Figure 4.6). Among the turbid claypans sites, CWP18, CWP23, CWP24 and CWP25 all fell on the margins of the main grouping. This is likely to be because they were only sampled once and just prior to drying when conditions were likely to be extreme (see Section 3.4.2). Turbid claypan sites CWP04 and CWP08 were the closest to the clear water sites, probably because they had more aquatic vegetation than the other turbid sites, resulting in higher species richness and taxa atypical of turbid claypans. The analysis also confirmed the observations from each phase that there was little to distinguish the vegetated and unvegetated turbid sites: sites from theses two types of claypans are interspersed on the ordinations (Figure 4.5 and Figure 4.6). ANOSIM did, however, confirm that the two higher tier groups, clear water versus turbid sites, were significantly different (R=0.849).

The proportion to which various taxa contributed to these two main groups can also be expressed as a percentage (Table 4.11). The species contributing most to the clear water grouping included various rotifers (as a group), *Moina micrura, Arcella* spp., *Bennelongia australis* and *Thermocyclops* sp. amongst the zooplankton (Table 4.11). Clear water sites were characterised by many macro-invertebrates, including *Diplacodes bipunctata, Hemianax papuensis, Ischnura heterosticta* and *Culex starkeae* (Table 4.11).

The turbid claypan grouping had fewer key taxa, including *Calamoecia halsei* and *Epistylis* sp. among the zooplankton, and *Eretes australis, Anisops stali, Bennelongia* n. sp. 414 and *Anisops nasustus* among the macro-invertebrates (Table 4.11).

Table 4.11: Contribution by various taxa to differences between the two groups of wetlands.

Clear Water Species	% Contribution	Turbid Claypan Species	% Contribution
Zooplankton		**Zooplankton**	
Rotifers grouped	27.5	*Calamoecia halsei*	77.7
Moina micrura	22.8	*Epistylis* sp.	12.1
Arcella spp.	15.3	*Diaphanosoma* n. sp.	6.7
Bennelongia australis	12.8		
Thermocyclops sp.	11.1		
Mesocyclops sp.	5.4		
Macro-invertebrates		**Macro-invertebrates**	
Diplacodes bipunctata	15.0	*Eretes australis*	40.2
Hemianax papuensis	8.1	*Anisops stali*	19.3
Ischnura heterostricta	6.7	*Bennelongia* n. sp. 414	14.3
Culex starkeae	6.2	*Anisops nasutus*	10.6
Anisops stali	5.8	*Allodessus bistrigatus*	3.8
Dineutes australis	5.4	*Branchinella halsei*	2.2
Limnadopsis birchii	4.7		
Anisops nasutus	4.4		
Limnadopsis tatei	3.5		
Polypedilum sp.	3.4		
Eocyzicus n. sp.	3.2		
Bennelongia n. sp. 414	3.0		
Orthetrum caledonicum	2.6		
Arrenurus sp. 15	2.5		
Caenestheriella packardi	2.4		
Xanthoagrion erythroneurum	2.0		

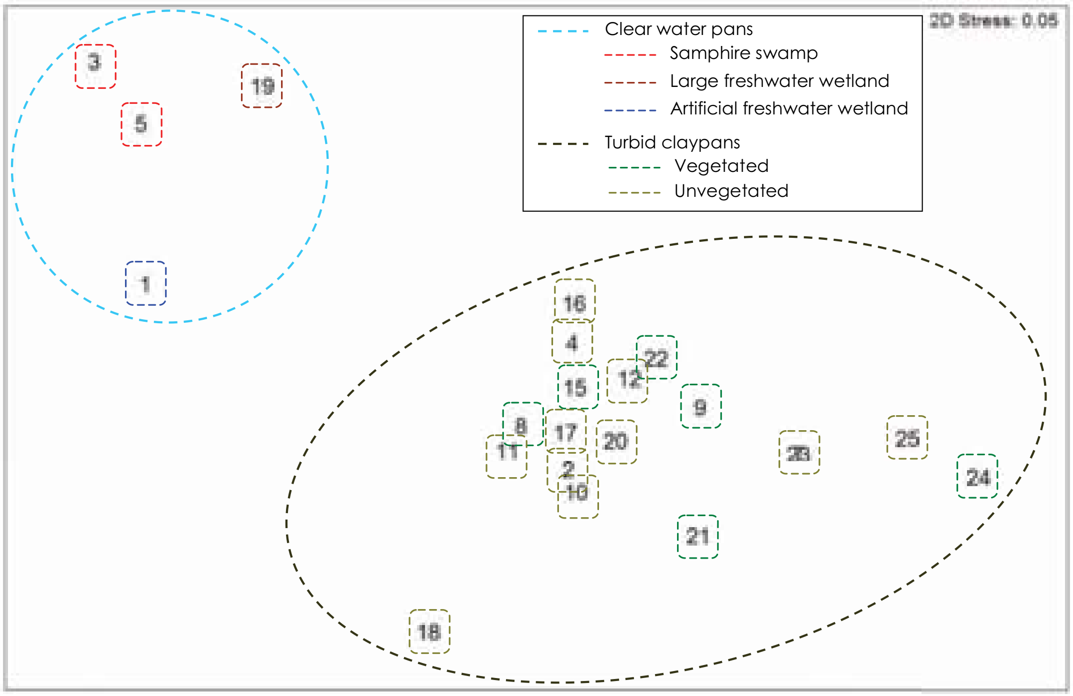

Figure 4.5: **nMDS plot of the sample sites based on pooled zooplankton data.**

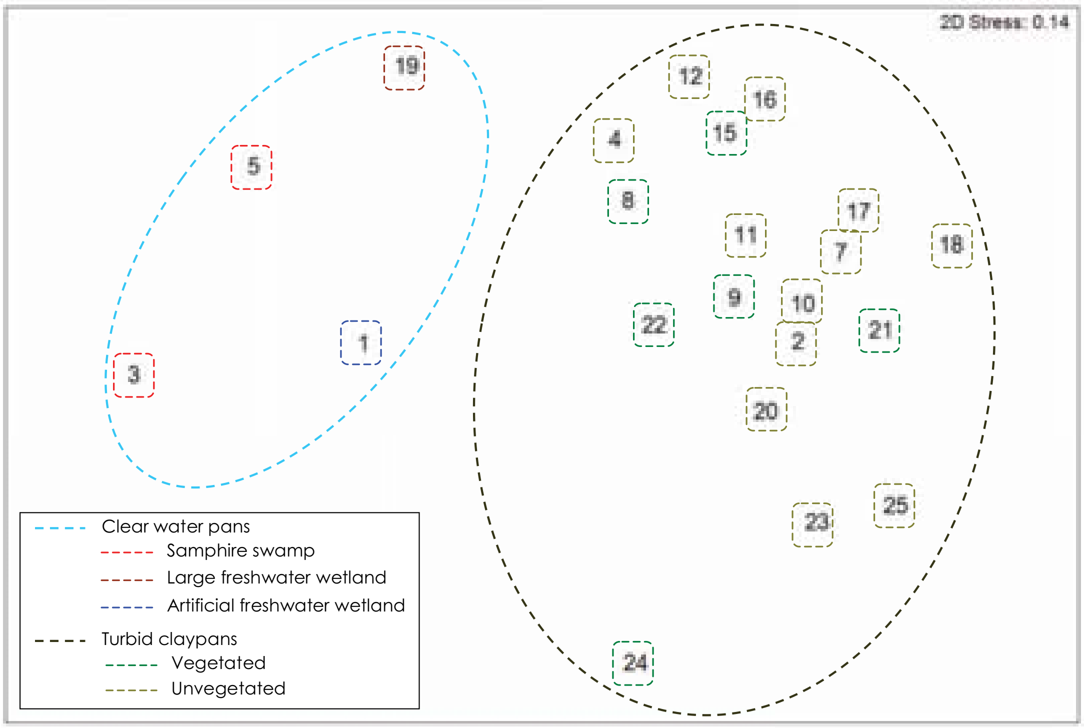

Figure 4.6: **nMDS plot of the sample sites based on pooled macro-invertebrate data.**

It was notable that there were no large branchiopods among the most important of the species contributing to the dissimilarity of each group. *Limnadopsis birchii, L. tatei* and *Eocyzicus* n. sp. did appear among the list of lesser important macro-invertebrates defining the clear water group, while *Branchinella halsei* appeared as a less important species on the turbid claypan list (Table 4.11). It is likely that branchiopods would have assumed a greater role had more sites been sampled during Phase I when this order was more common. Many species appeared in only one or two sites during Phase I, but were probably more widespread sites across the survey area. Examples include *Branchinella pinderi, Caenestheria sarsi* and *Caenestheria* n. sp. in turbid claypans, and *Branchinella pinnata, B. dubia,* and *Limnadia* n. sp. in the clear water sites.

Besides showing the main species contributing to the uniqueness of each group of wetlands, Table 4.11 also highlights the difference in diversity between the groups. In both zooplankton and macro-invertebrates, the clear water sites are far more diverse with more species contributing to their character than in the turbid claypans. Fewer species were more dominant in the turbid sites (i.e. in each case much of the distinctiveness is due to just one species) than in the clear water sites.

5.0 Discussion

5.1 Zoogeography and Broad Scale Distribution

The great majority of the insects recorded from the Onslow wetlands are widespread, with many known almost Australia wide (e.g. the odonates *Anisops stali, Diplonynchus eques, Cybister tripunctatus, Allodessus bistrigatus* and *Anopheles annulipes*), or at least of tropical distribution (e.g. *Lethocercus distinctifemur, Paraplea* sp., *Berosus puchella*). Both the apparent new species recorded by this study (*Berosus* n. sp. and *Haliplus* n. sp.) were also recorded during the DEC Pilbara survey and are not restricted to the sites sampled during this survey (Section 4.3.1).

All the rotifers and protists present are worldwide species as expected, though the new species of *Enteroplea* (*Enteroplea* n. sp.) is so far known only from the Pilbara bioregion (Russ Shiel, pers. comm. 2009). Also of interest is the recording of two rotifers (*Lecane* cf. *eswari* and *Lecane* cf. *formosa*) in Australia for the first time, and four rotifers (*Lacinularia* cf. *racemovata*, Ceph*alodella intuta, Eosphora thoides* and *Trichocera obtusidens*) in Western Australia for the first time. None of these new occurrences were from claypans within the project Study Area.

Among the crustaceans, there are many different distribution patterns, some of which may be restricted at smaller spatial scales. Distributions include:

- some taxa that are found elsewhere in the world (e.g. *Dunhevedia crassa*);
- many that are widespread in Australia (e.g. *Branchinella occidentalis, Limnadopsis* spp., *Caenestheriella packardi, Boeckella triarticulata, Ceriodaphnia cornuta, Diaphanosoma excisum, Bennelongia australis* and *Daphnia projecta*);
- others that are tropical (eg. *Branchinella dubia, Diaptomus lumholtzi, Simocephalus latirostris*); and
- many of the branchiopods and ostracods that are more localised.

Among the Branchipoda, *Branchinella halsei* occurs scattered through much of Western Australia, *B. macraeae* and *B. pinderi* occur in the Pilbara, and *Caenestheriella sarsi* in northern Western Australia (Timms 2002 and unpublished data). Among the copepods, *Calamoecia halsei* occurs in the northwest of Western Australia (Bayly 1998) and among the ostracods, all of the undescribed species recorded during this survey occur elsewhere in the Pilbara (Section 4.2.1). This leaves the undescribed branchiopods *Limnadia* n. sp., *Eocyzicus* n. sp., *Caenestheria* n. sp. and *Diaphanosoma* n. sp. which are apparently known only from the Onslow area. Only *Eocyzicus* n. sp., *Diaphanosoma* n. sp. and *Limnadia* n. sp. occurred in wetlands within the Wheatstone Project area and the first two taxa also occurred in Reference sites sampled outside of the Study Area during this survey. Only *Limnadia* n. sp. is currently only known from a Study Area site as discussed further in Section 5.2.

A limitation of this study was the lack of samples from the primary Study Area in Phase I, soon after the initial filling of the wetlands (Section 3.7). If Study Area claypans had been studied at that time, then some would have been likely to have yielded typical claypan species such as *B. pinderi, Caenestheria* n. sp. and *Caenestheria sarsi,* and perhaps *B. macraeae* and *B. halsei*, all known early colonisers of freshly filled claypans in this area.

From the limited data available here and elsewhere in the Pilbara it appears *B. pinderi* only occurs in extremely turbid waters, whereas in clear waters, the typical fairy shrimps are either *B. macraeae* or *B. halsei*. In these latter clear claypans, it seems that *B. halsei* is the characteristic species. However, it cannot be ruled out that a few of the most turbid Study Area sites would have had *B. pinderi* and *Caenestheria* n. sp. (as judged by their presence in the Phase I samples from Reference site CWP02; an extremely turbid claypan). In Phase II sampling one individual of *Caenestheria* n. sp. was recovered from CWP15, indicating it probably lived in the early stages of infilling in this claypan, but no *B. pinderi* were found other than in CWP02, where the species was recorded in Phase I and II. Given the apparent rarity of these species it is important that highly turbid claypans in the Onslow locality be conserved if possible, if the sites in the project Study Area are lost.

Considering the data on species phenology and their distribution among sites, the lack of Phase I data from the project area is, in practical terms, inconsequential. There is enough information from outside the Study Area to surmise the processes in Study Area claypans. Certainly, they support a unique invertebrate fauna assemblage, a few elements of which are of limited distribution at larger scale, but these species also occur in the locality outside of the Study Area.

It remains to consider the Onslow claypans in the context of claypans Australia-wide. Although claypans are common in the Australian arid zone and in a few places elsewhere in the world (e.g. South Africa - Seaman et al. (1995), Texas - Kennedy et al. (1998)), little is known of their limnology. Typically, claypans are small, shallow, hard-floored, intermittent, alkaline, turbid, fresh waters with a distinct fauna dominated by large branchiopod and opportunistic insects with life cycles geared for ephemerality and unpredictability of habitat (Geldenhuys 1982, Wiggens et al. 1980, W.D.Williams 1985, D.D. Williams 2006). In Australia, most is known about claypans in the Paroo of the north-western Murray-Darling Basin (Timms and Bouton 2001, Hancock and Timms 2002, Timms, 2002) and claypans in Western Australia, the Wheatbelt (Halse et al. 2004, Pinder et al. 2004) and Carnarvon area (Halse et al. 2000).

Species richness is generally lower in claypans than in other local fresh waters; a feature that was also documented in this study. For instance in the Paroo, claypans averaged about 28 species of macro-invertebrates per site, whereas other freshwaters ranged from 31 to 71 species (Timms and Boulton 2001). In this study, the difference was even more marked with an average of 46 species per site in the clear waters and only 14 in turbid claypans. Note that although following the same methods and relative abundance scoring, the tallies are otherwise not directly comparable as the Paroo totals are cumulative from many samplings, while the figures in this study are based on three sampling events.

While claypans have many distinctive features, most claypan districts have sites that have some different characters. In the Paroo the presence of canegrass, *Ergarostis australis* seemed to make only a slight difference between sites (Timms 1999), but at Onslow the presence of grass clumps of *Leptochloa fusca* was suspected of slightly increasing species richness. More extensive littoral vegetation, as in CWP04 at Onslow, could also function to increase species richness. Greater depth, and by implication a different hydrology, was associated with differing species composition in the Wheatbelt (Pinder et al. 2004). In the Paroo claypans, the presence of fringing trees added leaf litter that attracted a greater diversity of insects (Hancock and Timms 2002), but this factor was not relevant to Onslow. Finally, age of filling can be important, for example Timms (2002) noted a decrease of diversity with time after the initial filling period of a few weeks. In the Onslow area, this influence was seen in many sites in April, as they dried and became very shallow. While the Onslow claypans are typical of generalised claypans in Australia, their very high turbidity, red colour, lower species richness and different dominant species sets them apart. The pans sampled in this study do, however, appear to be representative of those in the locality and inspection of aerial photography shows large numbers of similar units, particularly to the south-west toward Turbridgi Point.

5.2 Risk of Species Restriction to the Wheatstone Project Study Area

The risk of any fauna species being restricted in distribution to the Wheatstone Project Study Area can be assessed by considering:

- what can be demonstrated about the wider distribution of the individual species recorded from Study Area sites;
- the overall similarity or distinctiveness of the Study Area claypans compared to those in Reference areas; and
- evidence of biophysical processes and landscape features that may promote or diminish local endemism.

These aspects are evaluated below.

- **Distribution of Species Recorded from Study Area Sites**

A full listing of all 92 invertebrate taxa recorded from Study Area sites sampled during this survey is presented in Table 5.1. Ninety of these (98%) have been demonstrated to occur at least as far as Reference areas in the locality, with the majority widely distributed in the bioregion or beyond.

Table 5.1: All taxa recorded from Study Area sites and number of Reference sites from which they were also recorded (species otherwise collected during the DEC PBS denoted by 'PBS'; if previously from other documented locations elsewhere by 'E'; taxa only known from Study Area sites shown in bold).

		No. of Reference Sites			No. of Reference Sites
Branchiopoda (20 taxa)	*Alona* sp.	2	Hemiptera (14 taxa)	*Agraptocorixa eurynome*	E
	Boeckella triarticulata	E		*Agraptocorixa parvipunctata*	E
	Branchinella dubia	E		*Anisops canaliculatus*	E
	Branchinella halsei	E		*Anisops nasutus*	E
	Branchinella macraeae	E		*Anisops paraexigerus*	E
	Branchinella pinnata	E		*Anisops* sp. juv.	2
	Caenestheria sarsi	E		*Anisops stali*	E
	Caenestheriella packardi	E		*Anisops theinemanni*	E
	Ceriodaphnia cornuta	E		*Anisosp nasutus*	E
	Daphnia projecta	E		*Diplonynchus eques*	E
	Diaphanosoma excisum	E		*Laccotrephes tristis*	E
	Diaphanosoma n. sp.	1		*Lethocerus distinctifemur* juv.	E
	Eocyzicus n. sp.	5		*Limnogonus fossarum*	E
	Limnadia n. sp.	-		*Micronecta* sp.	2
	Limnaopsis birchii	E	Coleoptera (20 taxa)	*Allodessus bistrigatus*	E
	Limnadopsis tatei	E		*Berosus approximans*	E
	Moina micrura	E		*Berosus macumbensis*	E
	Moina sp.	2		*Berosus* n. sp. (DEC sp. 4)	PBS
	Simocephalus latirostris	E		*Berosus puchella*	E
	Triops australiensis	E		*Berosus* sp. (pilbara 15)	PBS
Copepoda (4 taxa)	*Calamoecia halsei*	E		*Berosus* sp. larva	2
	Copepod nauplii	2		*Copelatus nigrolineatus*	E
	Mesocyclops sp.	3		*Curculionid* sp. 2	1
	Thermocyclops sp.	1		*Cybister* sp. larva	7
Ostracoda (5 taxa)	*Bennelongia australis*	E		*Cybister tripunctatus*	E
	Bennelongia n. sp. (414)	PBS		*Dineutus australis*	E
	Cypretta 'triangulum'	E		*Enochrus deserticola*	E
	Cypricercus n. sp. (69)	PBS		*Enochrus elongatus*	E
	Ostracod 'medium base'	1		*Eretes australis*	E
Rotifera (10 taxa)	*Anuraepsis fissa*	E		*Eretes* sp. larva	2
	Asplanchna seiboldi	E		*Haliplus* n. sp. (testudo 'light')	2
	Cephalodella forficula	E		*Hyphydrus lyratus*	E
	Colurella unicinata	E		*Hyphydrus* sp. larva	3
	Eosphora najas	E		*Laccophilus sharpi*	E
	Euchlanis sp.	E	Diptera (2 taxa)	*Polypedilum* sp.	3
	Lecane luna	E		*Tanytarsus* sp.	3
	Moptoammata cerberus	E	Other Taxa (10 taxa)	*Arrenurus* sp. (sp. 15 of DEC)	PBS
	Polyarthra dolichoptera	E		*Hydrachna* sp.	3
	Ptygura cf cystallina	E		*Hydrophilus brevispina*	E
Odonata (7 taxa)	*Austrolestes aridus*	E		*Hydrophilus* sp. larva	3
	Hemianax papuensis	E		*Isidorella* sp.	2
	Hemicordulia tau	E		Juvenile marine fish	E
	Ischnura heterostricta	E		Juvenile penaeid decapod	E
	Orthetrum caladonicum	E		*Nais communis*	E
	Trapezostigma loewi	E		*Epistylus* sp.	5
	Xanthoagrion erythroneurum	E		**Mesostoma sp.**	-

The two taxa that are currently only known from Study Area sites: *Limnadia* n. sp. (a clam shrimp) and *Mesostoma* sp. (a flatworm), both came from site CWP01 (see Table 4.5 and Table 4.8). This site is an artificial wetland formed from roadside flooding of an old materials sourcing area. As such, it seems very unlikely that these records represent locally endemic natural distributions. The overall findings of this study, that only 2 of the 92 species recorded are currently only known from the Study Area, is consistent with this. It is likely that further sampling effort, particularly targeting similar microhabitats in the locality, would also confirm the wider distribution of these two taxa.

- **Community Similarity**

Given the limitations on sampling effort and evenness in this study (Section 3.7), an overall assessment of the risk of fauna species being restricted to Study Area can be provided by the nMDS arising from the community similarity analysis (Section 4.5). Figure 5.1 shows a modified version of the nMDS plot illustrating site similarity based on macro-invertebrate faunal composition.

Turbid claypan Study Area sites are interspersed with the Reference area sites on Figure 5.1. Of the clear water Study Area sites, only CWP01 shows any indication of distinctness and this site contained no unique taxa (i.e. all species recorded from CWP01 were found in at least one Reference wetland; Section 4.0).

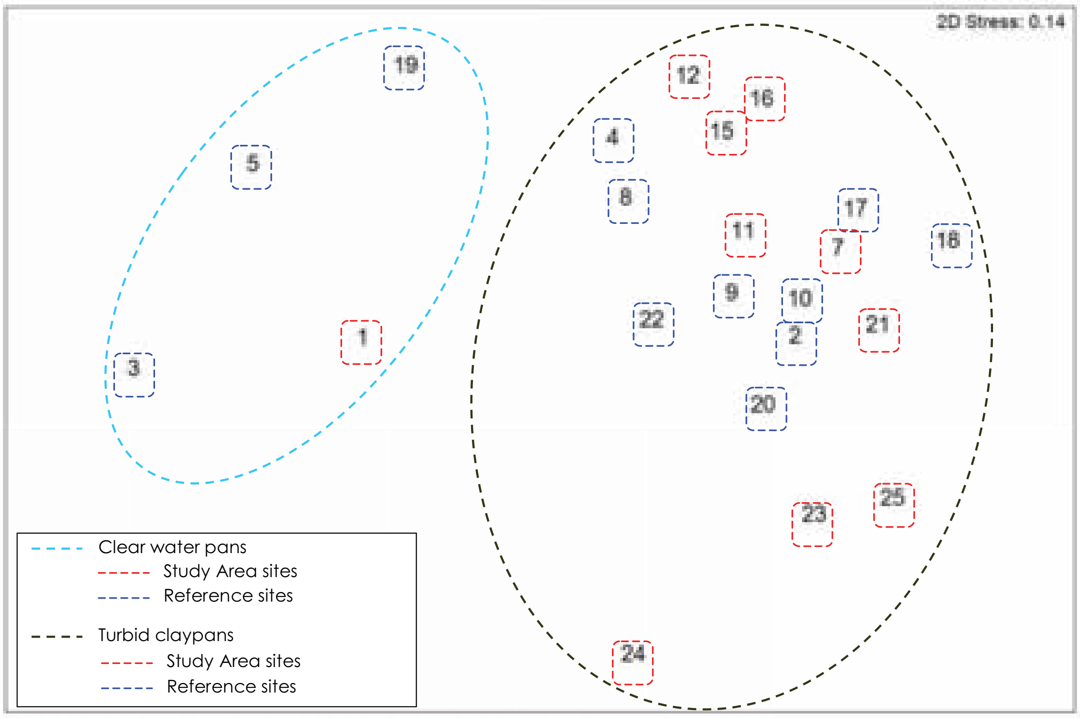

Figure 5.1: **Macro-invertebrate nMDS plot illustrating relationships between Study Area and Reference sites.**

The results of this study therefore indicate that, sampling effects aside, the Study Area sites contain effectively equivalent suites of invertebrate fauna to those represented in Reference sites in the immediate locality. It is also worth noting that the sites with the most diverse and distinctive communities are the freshwater pans outside of the proposed Wheatstone Project area.

- **Community Similarity**

The pattern of equivalent suites of species in similar units appears consistent with landscape-scale processes that occur in the area during flood events. Plate 5.1 shows part of the survey area immediately after Cyclone Dominic.

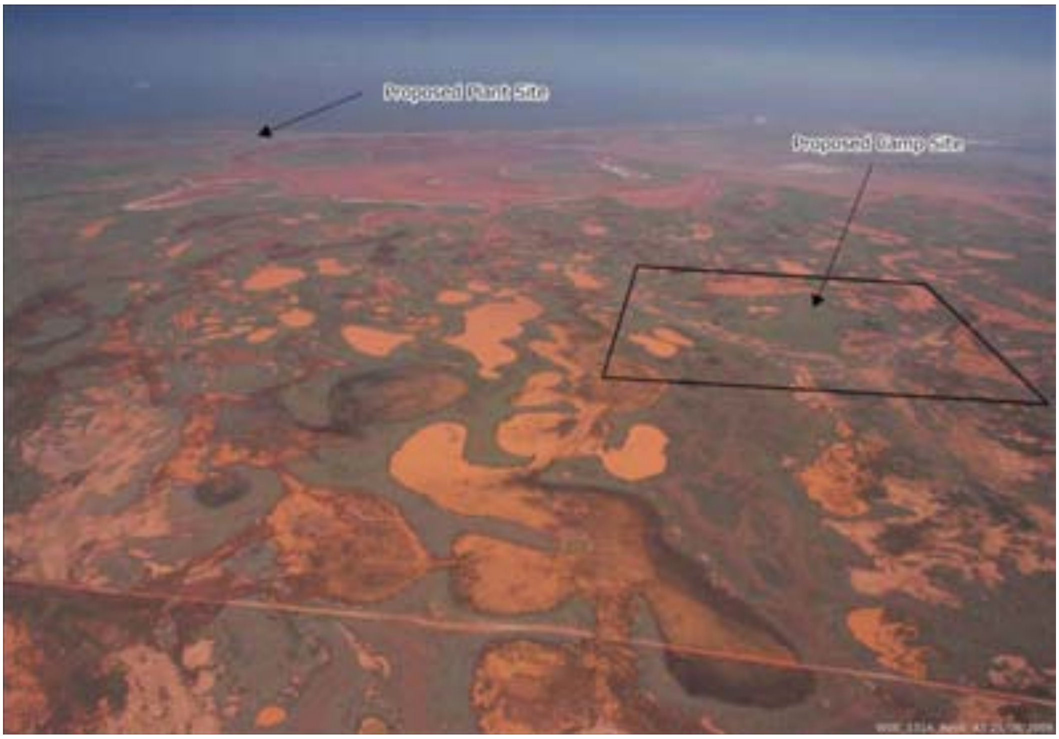

Plate 5.1: **Flooding in the southern portion of the survey area after Cyclone Dominic, showing nominal Camp and Plant site locations and claypans joined by surface flooding (source: URS Australia).**

This suggests that, under major flood events, the aquatic habitats of many of the claypans become interconnected through surface flooding. The extent of this connection would be related to the magnitude of the flood event. It is likely however that the majority of cyclones would result in similar patterns of surface hydrology, given the low elevation of the topography and the proximity of the Ashburton River. This presents a scenario of relatively reduced risk of species isolation to individual claypans at this local scale, which is consistent with the outcome of the nMDS (Figure 5.1), the distribution of individual species recorded from Study Area sites, and the findings of this study in general.

Given the above, it appears unlikely that any significant claypan fauna diversity values would be compromised should the proposal proceed in its current form.

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6.0 Glossary of Terms

Branchiopod	-	A member of the Class Branchiopoda; freshwater crustaceans.
MDS	-	Multidimensional Scaling; a method of assessing similarities or dissimilarities in data sets.
Microhabitat	-	A small-scale habitat within a broader habitat unit, that possesses localised properties.
Odonate	-	A member of the order Odonata (dragonflies).
Taxon	-	Any group or rank in a biological classification into which related organisms are classified (plural = taxa).

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Appendix 1

Photographs of all Claypans Sample Sites

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CWP01


CWP02


CWP03


CWP04


CWP05


CWP07


CWP08


CWP09

CWP10

CWP11

CWP12

CWP13

CWP14

CWP15

CWP16

CWP17

CWP18

CWP19

CWP20

CWP21

CWP22

CWP23

CWP24

CWP25

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Appendix 2

Complete Species List

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Phylum/Subphylum	**Class/Subclass**	**Order**	**Species**
Sarcodina	Tubulinea	Arcellinida	*Arcella bathystoma*
			Arcella discoides
Ciliophora	Ciliatea	Peritrichida	*Epistylus* sp.
Rotifera	Monogononta	Flosculariaceae	*Conchilus natans*
			Hexarthra mira
			Lacinularia cf. racemovata
			Ptygura cf crystallina
		Ploima	*Anuraeopsis fissa*
			Anuraeopsis sp.
			Asplanchna sieboldii
			Asplanchniopsis multiceps
			Branchionus quadridentatus
			Cephalodella intuta
			Cephalodella forficula
			Cephalodella cf. *tenuiseta*
			Cephalodella cf. *ventripes*
			Colurella uncinta bucuspidata
			Enteroplea n. sp. (PSW8)
			Eosphora najas
			Eosphora thoides
			Euchlanis dilatata
			Euchlanis meneta
			Lecane cf. *eswari*
			Lecane cf. *fromosa*
			Lecane cf. *luna*
			Lecane sp.
			Lepadella sp.
			Notommata cerberus
			Notommata tripus
			Platyias quadricornis
			Polyarthra dilichoptera
			Trichocerca obtusidens
			Trichocera sp.
			Indet. Bdelloid Rotifer
Platyhelminthes	Turbellaria	Neorhabdocoela	*Mesostoma sp.*
Annelida	Oligochaeta	Tubificida	*Nais communis*
Arthropoda	Arachnida	Acarina	*Arrenurus* sp. (sp. 15 of DEC)
			Hydrachna sp.
Mollusca	Gastropoda	Basommatophora	*Isidorella* sp.
Crustacea	Branchiopoda	Anostraca	*Branchinella dubia*
			Branchinella halsei
			Branchinella macraeae
			Branchinella pinnata
			Branchinella pinderi
			Branchinella occidentalis
		Diplostraca	*Limnadia* n. sp.
			Limnadopsis birchii
			Limnadopsis tatei
			Eocyzicus n. sp.
			Caenestheria sarsi
			Caenestheria n. sp.
			Caenestheriella packardi
		Notostraca	*Triops australis*
		Cladocera	*Daphnia projecta*
			Ceriodaphnia cornuta
			Simocephalus latirostris
			Diaphanosoma excisum
			Diaphanosoma n. sp.
			Latonopsis sp.
			Moina micrura

Phylum/Subphylum	Class/Subclass	Order	Species
			Moina sp.
			Macrothrix sp.
			Alona sp.
			Dunhevedia crassa
			Leberis cf *daphniodes*
	Copepoda	Calanoida	*Boeckella triarticulata*
			Calamoecia halsei
			Diaptomus lumholtzi
		Cyclopoida	*Mesocyclops* sp.
			Thermocyclops sp.
	Ostracoda	Mystacocaridida	*Bennelongia australis*
			Bennelongia n. sp. 414
			Bennelongia n. sp.
			Cypretta 'triangulum'
			Cypricercus n. sp. 69
			Cyrpicercus n. sp. 442
			Heterocypris n. sp. 66
			Ostracoda 'small round 2 eyes'
			Zonocypris kalimna
	Malacostraca	Decapoda	Juvenile penaeid decapod
Hexapoda	Insecta	Odonata	*Diaplacodes bipunctata*
			Hemianax papuensis
			Hemicordulia tau
			Orthetrum caledonicum
			Trapezostigma loewi
			Austrolestes aridus
			Ischnura heterostricta
			Xanthoagrion erythroneurum
		Hemiptera	*Agraptocorixa eurynome*
			Agraptocorixa parvipunctata
			Anisops canaliculatus
			Anisops nasutus
			Anisops paraexigerus
			Anisops stali
			Anisops theinemanni
			Diplonynchus eques
			Laccotrephes tristis
			Lethocercus distinctifemur
			Limnogonus fossarum
			Micronecta sp.
			Paraplea sp.
		Coeloptera	*Ranatra diminuta*
			Allodessus bistrigatus
			Berosus approximans
			Berosus nr. *josephenae*
			Berosus macumbensis
			Berosus n. sp. ('pilbara sp 4')
			Berosus puchella
			Copelatus nigrolineatus
			Cybister tripunctatus
			Dineutes australis
			Enochrus elongatus
			Enochrus deserticola
			Eretes australis
			Haliplus n. sp. (*testudo 'light'*)
			Hydroglyphus grammopterus
			Hyphydrus lyratus
			Hydrophilus brevispina
			Laccophilus sharpi
			Curculionid sp. 1

Phylum/Subphylum	**Class/Subclass**	**Order**	**Species**
			Curculionid sp. 2
			Cybister sp. larva
			Haliplus sp. larva
			Hyphydrus sp. larva
		Trichoptera	*Hydrophilus* sp. larva
		Diptera	*Triplectides australis*
			Anopheles annulipes
			Culex starkeae
			Chironomus sp.
			Dicrotendipes sp.
			Polypedium sp.
			Tanytarsus sp.
			Trichocera sp.
			Ceratopogonid larva
			Stratiomyid larva

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Appendix 3

Physico-chemical Data

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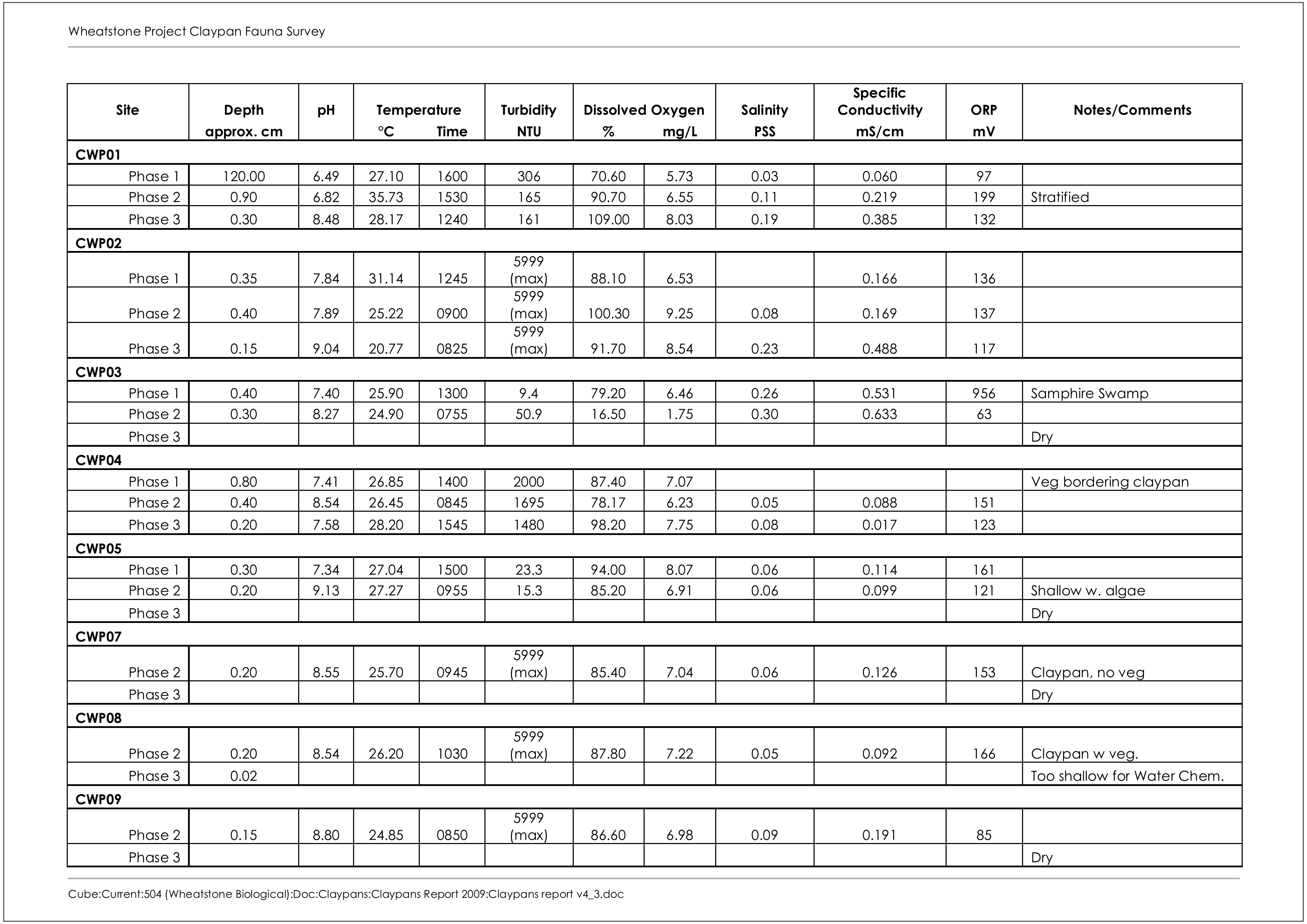

Site	Depth	pH	Temperature		Turbidity	Dissolved Oxygen		Salinity	Specific Conductivity	ORP	Notes/Comments
	approx. cm		°C	Time	NTU	%	mg/L	PSS	mS/cm	mV	
CWP01											
Phase 1	120.00	6.49	27.10	1600	306	70.60	5.73	0.03	0.060	97	
Phase 2	0.90	6.82	35.73	1530	165	90.70	6.55	0.11	0.219	199	Stratified
Phase 3	0.30	8.48	28.17	1240	161	109.00	8.03	0.19	0.385	132	
CWP02											
Phase 1	0.35	7.84	31.14	1245	5999 (max)	88.10	6.53		0.166	136	
Phase 2	0.40	7.89	25.22	0900	5999 (max)	100.30	9.25	0.08	0.169	137	
Phase 3	0.15	9.04	20.77	0825	5999 (max)	91.70	8.54	0.23	0.488	117	
CWP03											
Phase 1	0.40	7.40	25.90	1300	9.4	79.20	6.46	0.26	0.531	956	Samphire Swamp
Phase 2	0.30	8.27	24.90	0755	50.9	16.50	1.75	0.30	0.633	63	
Phase 3											Dry
CWP04											
Phase 1	0.80	7.41	26.85	1400	2000	87.40	7.07				Veg bordering claypan
Phase 2	0.40	8.54	26.45	0845	1695	78.17	6.23	0.05	0.088	151	
Phase 3	0.20	7.58	28.20	1545	1480	98.20	7.75	0.08	0.017	123	
CWP05											
Phase 1	0.30	7.34	27.04	1500	23.3	94.00	8.07	0.06	0.114	161	
Phase 2	0.20	9.13	27.27	0955	15.3	85.20	6.91	0.06	0.099	121	Shallow w. algae
Phase 3											Dry
CWP07											
Phase 2	0.20	8.55	25.70	0945	5999 (max)	85.40	7.04	0.06	0.126	153	Claypan, no veg
Phase 3											Dry
CWP08											
Phase 2	0.20	8.54	26.20	1030	5999 (max)	87.80	7.22	0.05	0.092	166	Claypan w veg.
Phase 3	0.02										Too shallow for Water Chem.
CWP09											
Phase 2	0.15	8.80	24.85	0850	5999 (max)	86.60	6.98	0.09	0.191	85	
Phase 3											Dry

Site	Depth	pH	Temperature		Turbidity	Dissolved Oxygen		Salinity	Specific Conductivity	ORP	Notes/Comments
	approx. cm		°C	Time	NTU	%	mg/L	PSS	mS/cm	mV	
CWP10											
Phase 2	0.25	8.70	25.75	0920	5999 (max)	86.50	7.07	0.08	0.159	129	
Phase 3	0.02										Too shallow for Water Chem.
CWP11											
Phase 2	0.15	8.74	25.80	1000	5999 (max)	91.40	7.61	0.10	0.196	147	
Phase 3											Dry
CWP12											
Phase 2	0.15	8.73	27.80	1040	1594	91.40	7.23	0.05	0.164	160	
Phase 3											Dry
CWP13											
Phase 2	0.15	9.56	34.90	1300	0	154.00	8.52	41.82	61.300	101	Marine Pan. Connected
Phase 3	0.02		23.40	0855	202						Too shallow for Water Chem.
CWP14											
Phase 2	0.15	9.77	34.77	1330	8.4	130.90	7.87	31.40	47.600	101	Smaller marine pan. Disconnected
Phase 3	0.15	8.54	25.10	0925	348	105.70	1.46	99.99	10.000	120	
CWP15											
Phase 2	0.02										Too shallow for Water Chem.
Phase 3											Dry
CWP16											
Phase 2	0.05	8.96	34.97	1500	5999 (max)	88.60	6.10	0.20	0.429	108	No grass
Phase 3											Dry
CWP17											
Phase 2	0.05	9.15	22.12	0845	5999 (max)	98.80	8.82	0.16	0.331	127	
Phase 3											Dry
CWP18											
Phase 2	0.02										Too shallow for Water Chem.
Phase 3											Dry
CWP19											
Phase 2	0.50	9.77	27.46	1034	77.4	111.00	9.00	0.10	0.204	134	Swamp
Phase 3	0.30	9.73	34.38	1430	302	166.50	10.75	0.19	0.389	92	Lots of Algal growth

Site	Depth approx. cm	pH	Temperature °C	Temperature Time	Turbidity NTU	Dissolved Oxygen %	Dissolved Oxygen mg/L	Salinity PSS	Specific Conductivity mS/cm	ORP mV	Notes/Comments
CWP20											
Phase 3	0.02										Too shallow for Water Chem.
CWP21											
Phase 3	0.10	8.77	27.66	1215	5999 (max)	97.60	7.59	0.26	0.531	99	
CWP22											
Phase 3	0.20	8.93	29.73	1340	2000	103.30	7.65	0.28	0.576	139	
CWP23											
Phase 3	0.02										Too shallow for Water Chem.
CWP24											
Phase 3	0.02										Too shallow for Water Chem.
CWP25											
Phase 3	0.02										Too shallow for Water Chem.

C – Degrees Celsius
NTU – Nephelometric Turbidity Unit
mg/L - Milligrams per litre
PSS – Practical Salinity Scale
mS/cm – Micro-seimens per centimetre
mV - Millivolts

Appendix M1

Subterranean Fauna Assessment

Tables

Figures

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Biota
Environmental
Sciences

Wheatstone Project Subterranean Fauna Assessment

Prepared for URS Australia Pty Ltd and Chevron Australia Pty Ltd

January 2010

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1.0 Summary

1.1 Project Background

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast (Figure 2.1). The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future 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 plants.

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 MTPA of LNG. The Wheatstone Project has been referred to the Environmental Protection Authority (EPA) and the Department of the Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support these environmental impact assessment processes. Biota Environmental Sciences Pty Ltd (Biota) was subcontracted through URS Australia Pty Ltd (URS) to provide an assessment of any subterranean fauna occurring in habitats within the Wheatstone Project area and surrounds.

1.2 Study Objectives and Scope

The components of the Wheatstone Project area are shown in Figure 2.1. The primary focus of this study was on the Plant portion of the Wheatstone Project area, where both desktop assessment and survey work were completed. Limited subterranean disturbance is predicted in the Shared Infrastructure Corridor (SIC) and this part of the project area was subject to a desktop assessment only. There were no drilling data available for the Camp component of the project area at the time of preparing this report, but its proximity suggests that the SIC is also representative of the Camp area. No subterranean impacts would be expected within the Domgas pipeline corridor and this area was not considered as part of this study. The “study area” hereafter is therefore the Plant area and the SIC area, though the latter was subject to desktop assessment only

The assessment was planned and implemented in accordance with EPA Guidance Statement No. 54 “Sampling of Subterranean Fauna in Groundwater and Caves” (EPA 2003) and EPA Guidance Statement No. 54a “Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia” (EPA 2007).

Two broad categories of fauna are generally considered to comprise the true subterranean fauna:

1. Stygofauna: groundwater-dwelling, aquatic fauna (including stygobites; obligate groundwater dwellers); and
2. Troglofauna: obligate dwellers in caves, karst and other voids; terrestrial subterranean fauna occurring above the water table (troglobites).

Both ecological groups were considered in this assessment.

1.3 Methods

1.3.1 Desktop Assessment

The likelihood of stygofauna or troglofauna occurring in the study area was assessed using a combination of existing information and site-specific habitat data. Based on the outcomes of this review, the study area was assigned a likelihood to support stygofauna or troglofauna of ‘Low’, ‘Moderate’ or ‘High/Definite’. This assessment was followed up and validated by a field sampling programme targeting both faunal groups in the Plant portion of the study area (Section 1.3.2).

1.3.2 Field Survey

A total of 18 boreholes were sampled for troglofauna during three phases of sampling in the Plant portion of the study area, yielding 54 borehole-sampling events comprising 96 traps. The casings for the boreholes used in this study were designed to maximise their use in subterranean fauna sampling, with cased slotting both above and below the water table.

Sampling of the aquifer for stygofauna was undertaken over three phases by the use of modified plankton haul nets. Each bore sampled was dragged a minimum of five times. All 18 study area boreholes that were sampled for troglofauna were also sampled for stygofauna during Phase I. A further nine bores were then sampled for stygofauna during Phase II. In addition, three Onslow Salt Pty Ltd boreholes were also sampled for stygofauna during Phase I in locations outside of the study area on the outskirts of the Onslow town site. The 18 Plant area bores sampled during Phase I were then re-sampled during Phase III. A total of 30 bores were therefore sampled for the stygofauna component of this study.

1.4 Desktop Assessment

1.4.1 Troglofauna

Consistent with regional geology, the above water table lithology of the study area is dominated by sands, silts and clays; none of which would provide suitable habitat space for troglofauna. There is also generally only a very thin stratum of available potential habitat between the ground surface and the water table. This averages a depth of 2.5 m from ground surface across the representative drill locations and is less than this in many areas. Effectively, this indicates that in most situations in the study area, there is generally only what would be regarded as soil and subsoil strata present before the relatively shallow water table is reached.

In addition, the broader coastal plain of the study area is periodically inundated by major flood events associated with cyclones, hinterland flows and storm surge (URS 2009a, Biota 2009). There are also no major hills, mesa or rocky ridge landforms present that may have been continuously emergent during these historical events to act as potential refugia. These factors indicate a generally low likelihood of a significant troglobitic community having persisted over the long term and currently occurring in the study area.

Based on the nature of the landforms, the stratigraphy of the site, and the small amount of habitat space available, it appears unlikely that the study area would support a significant troglobitic community. On the basis of habitat information then, the study area was assigned a ‘Low’ likelihood of supporting troglofauna.

1.4.2 Stygofauna

The saturated strata in the study area are dominated by sands, sandstone, silt and clays. These formations generally do not contain large voids and do not normally support as diverse stygal communities as more transmissive units such as calcrete and alluvial aquifers. Typical fauna present in sand aquifers include worm taxa, and copepods and ostracods. These smaller body sized animals reflect the smaller interstices available in these types of units.

Some small areas of calcrete occur in two of the boreholes, but these very thin and isolated lenses would not significantly alter the above. In addition, limestone was noted in two boreholes in the SIC part of the study area, but the recorded voids were typically filled with clay or silty clay.

Considering the aquifer habitats present, and that stygal animals have been collected in the locality, it is probable that stygofauna occur in the study area. These are likely to occur in superficial brackish lenses in sand and sandstone aquifers within the study area and the immediate vicinity, and other fauna may occur in larger aquifers associated with the Ashburton River in the wider locality further outside of the study area. The nature of the groundwater systems, geology and lithology of the area suggest that this fauna may be limited to a subset of smaller body-type taxa of marine lineage. On the basis of available habitat information then, the study area would be assigned a 'Moderate' likelihood of supporting stygofauna.

1.5 Field Survey Results

1.5.1 Troglofauna

The three sampling phases of the troglofauna survey yielded an overall total of 14,398 invertebrate specimens, representing eight orders. All of these specimens were surface or soil invertebrates that were not troglomorphic.

1.5.2 Stygofauna

No stygofauna were collected from 27 of the 30 groundwater bores sampled in this study. Two stygal taxa were collected from three of the bores during the Phase I sampling, with no fauna collected during the second and third phases.

The copepod *Phyllopodopsyllus thiebaudi*, which was recorded from bore E013F, is a widespread species that has previously been recorded from Barrow Island (Biota 2007b), amongst other locations (Karanovic et al. 2001), and is not restricted to the Onslow locality. The copepod records are from a bore that is situated on the beach proper, almost into intertidal habitat, consistent with the marine lineage of this genus.

The oligochaete worm Enchytraeidae sp. 1 was recorded from the immediately adjacent boreholes E005G-S and E005F. The morphological nature of the recorded taxa, small and vermiform (worm-like) body size and structure, is consistent with the types of strata and aquifers present. The vermiform morphology of Enchytraeidae sp. 1 and other stygal oligochaetes allow them to occur in sand aquifers and other saturated lithology with small-scale interstices. This also means sand units do not form barriers to gene flow as they may for other larger-bodied stygofauna and it is unlikely that the species represented by the Enchytraeidae sp. 1 specimens is restricted to an area the size of the study area.

1.6 Conclusions

No troglobites have been recorded from the study area during the three phases of field sampling documented in this report. This result is consistent with the nature of the subterranean habitats present in the study area and there appears to be a low likelihood that troglofauna occur in the study area or the immediate surrounds.

Stygofauna have been confirmed as occurring in the study area, but only at low frequency and from just two spatial locations. Two taxa have been collected (the copepod *Phyllopodopsyllus thiebaudi* and the oligochaete Enchytraeidae sp. 1). Based on confirmed distributional data, there is no risk that *P. thiebaudi* is restricted to the study area. Given the ecology and distributional patterns of stygal oligochaetes in similar habitats elsewhere in the region (for Enchytraeidae sp. 1), it is unlikely that this taxon is restricted to the study area.

The survey results therefore do not suggest a diverse or significant stygal community occurs in the aquifers beneath the study area. The results from field sampling in the Plant part of the study area, and the similarity of the habitats, suggest there is no requirement for sampling in the SIC and Camp areas. Both the fauna recorded during field surveys, and the nature of the subterranean habitats, suggest a low level of risk that any stygal species would be restricted to the study area.

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2.0 Introduction

2.1 Project Background

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast (Figure 2.1). The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future 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 plants.

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 MTPA of LNG. The Wheatstone Project has been referred to the Environmental Protection Authority (EPA) and the Department of the Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support these environmental impact assessment processes. Biota Environmental Sciences Pty Ltd (Biota) was subcontracted through URS Australia Pty Ltd (URS) to provide an assessment of any subterranean fauna occurring in habitats within the Wheatstone Project area and surrounds.

2.2 Study Scope and Objectives

The components of the Wheatstone Project area are shown in Figure 2.1. The primary focus of this study was on the Plant portion of the Wheatstone Project area (Figure 2.1), where both desktop assessment and survey work were completed. Limited subterranean disturbance is predicted in the Shared Infrastructure Corridor (SIC) and this part of the project area was subject to a desktop assessment only. There were no drilling data available for the Camp component of the project area at the time of preparing this report, but its proximity suggests that the SIC is also representative of the Camp area. No subterranean impacts would be expected within the Domgas pipeline corridor and this area was not considered as part of this study. The “study area” hereafter is therefore the Plant area and the SIC area, though the latter was subject to desktop assessment only.

The assessment was planned and implemented in accordance with EPA Guidance Statement No. 54 “Sampling of Subterranean Fauna in Groundwater and Caves” (EPA 2003) and EPA Guidance Statement No. 54a “Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia” (EPA 2007).

The scope and objectives of the study were to:

- undertake a habitat-based desktop assessment, consistent with relevant EPA Guidance Statements;
- undertake systematic sampling for subterranean fauna in boreholes consistent with relevant EPA Guidance Statements; and
- assess the significance of the subterranean fauna habitats, taxa and communities present and place these into wider context where possible.

2.3 Purpose of this Report

The proposed Wheatstone Project was referred to the EPA by Chevron in 2008. The EPA determined that the proposal would be formally assessed at the level of Environmental Review and Management Programme (ERMP) under Part IV of the *Environmental Protection Act 1986*.

This report describes the methodology employed for the desktop subterranean fauna assessment of the study area. It documents the methods and results of the field survey and provides an assessment of the subterranean fauna habitats and taxa recorded. This document is intended as a supporting technical document to the ERMP for the Wheatstone Project.

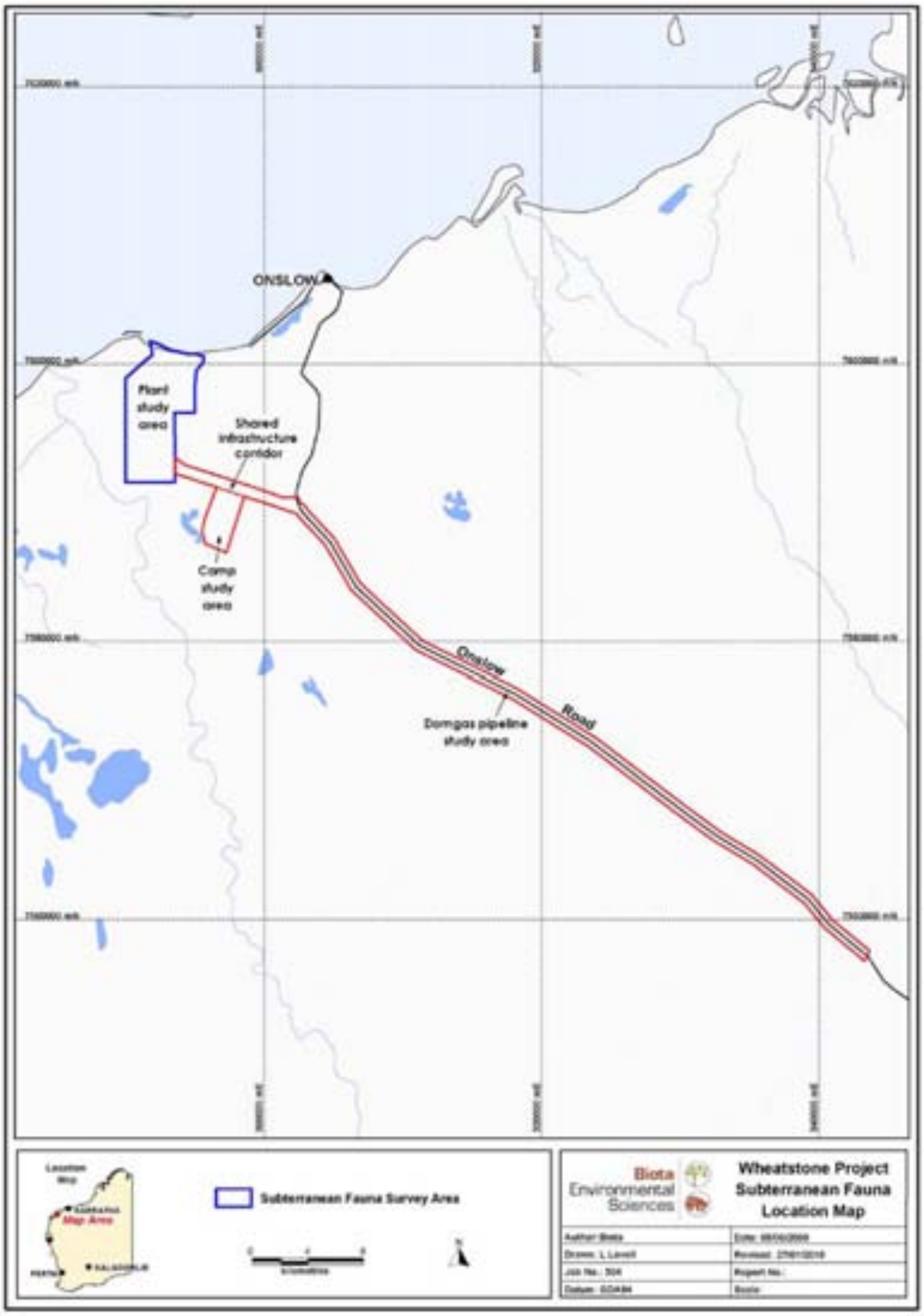

Figure 2.1: Wheatstone Project locality plan and project area components.

2.4 Summary Background on Subterranean Fauna

Two broad categories of fauna are generally considered to comprise the true subterranean fauna:

1. Stygofauna:	groundwater-dwelling, aquatic fauna (including stygobites; obligate groundwater dwellers); and
2. Troglofauna:	obligate dwellers in caves, karst and other voids; terrestrial subterranean fauna occurring above the water table (troglobites).

Stygofauna inhabit groundwater, sometimes occurring close to the surface. They are highly specialised to, and obligate dwellers of, subterranean groundwater habitats ('stygobites'; Humphreys 2000). Stygofauna are known to be present in a variety of rock types including karst (limestones, calcrete), fractured rock (e.g. granite) and porous rock (e.g. alluvium, gravels) (Marmonier et al. 1993). Stygal animals known from Western Australia include a range of crustacean taxa (typically the most abundant), platyhelminthes, oligochaetes, water mites and beetles (Humphreys 1999, Watts and Humphreys 1999, Biota unpublished data). While some stygal species may have restricted distributions, they are generally more widely distributed than troglobites (Lamoreux 2004). Extant stygofauna are derived from both marine and freshwater surface lineages that have descended into subterranean habitats (Humphreys 1999).

Troglobites occur in the strata between the superficial soil layer and the water table, where suitable habitat space is available. Troglobitic fauna has historically been collected primarily from karstic limestone systems in Western Australia (at Cape Range, Barrow Island and in the Kimberley; Harvey 1988, Biota 2002, Humphreys 2001). Recent work along the Robe River has, however, also collected this fauna from vuggy and cavernous strata in pisolitic mesa formations (Biota 2006). Troglobites are increasingly being collected from geological formations where they have previously not been recorded (e.g. conglomerate laterite; Biota 2008a), suggesting they may be more widespread than originally thought.

Troglobitic fauna species potentially have very restricted distributions and as a result, potential short-range endemism (*sensu* Harvey 2002) is common in this fauna. In the semi-arid and arid zones, the troglobitic fauna is generally considered to be relictual rainforest litter fauna, having arisen from tropical fauna lineages that descended into subterranean environments during the aridification of Australia (in the late Miocene; Humphreys 1993, Biota 2006). This is inferred from affinities of the taxonomic groups represented amongst the troglofauna with other extant taxa in tropical climates. These groups include the Schizomida, Pseudoscorpionida, Araneae, Scolopendrida, Polydesmida, Diplura, Thysanura, Coleoptera and Blattodea (Humphreys 2001, Biota 2006).

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3.0 Methods

3.1 Desktop Assessment

The likelihood of stygofauna or troglofauna occurring in the study area was assessed using a combination of existing information and site-specific habitat data. Inputs considered in this process included:

1. the likely spatial extent of subterranean impacts associated with the Wheatstone Project as understood at this stage (to define the geological and landform units that may be affected);
2. regional geology mapping;
3. hydrological and hydrogeological information from other technical studies completed for the Wheatstone Project (where available);
4. site specific geomorphological assessment (based on field inspection);
5. drill logs from boreholes drilled in the project area as part of geotechnical and hydrogeological work being undertaken for the Wheatstone Project; and
6. previous sampling in the locality and the results of relevant published and unpublished studies on subterranean fauna from the region.

Based on the outcomes of this review, the study area was assigned a likelihood to support stygofauna or troglofauna of 'Low', 'Moderate' or 'High/Definite'.

3.2 Field Survey

3.2.1 Study Team

Field sampling for troglofauna and stygofauna was undertaken by Mr Garth Humphreys, Mr Michael Greenham, Mr Dan Kamien, Ms Jessica Cairnes, Mr David Keirle and Mr Paul Sawers (all of Biota). Mr Jason Alexander, Ms Jess Cairnes and Mr David Keirle completed sorting of recovered troglofauna litter traps and stygofauna samples, along with order level invertebrate identifications. Stygofauna species identifications were completed by Jane McRae of Bennelongia Pty Ltd. Overall project coordination and direction was provided by Mr Garth Humphreys.

3.2.2 Troglofauna

3.2.2.1 Sampling Effort

A total of 18 boreholes were sampled for troglofauna over three phases of sampling, yielding 54 borehole-sampling events comprising 96 trap samples (Table 3.1). This exceeds the requirements of EPA (2007), which indicates 60 samples over two phases. The casings for the dedicated subterranean fauna boreholes used in this study were designed to maximise their use in subterranean fauna sampling, with cased slotting both above and below the water table. The locations of the drillholes were also selected to provide spatial coverage of the study area, sampling of the main landform units (Section 4.1.2.1) and to be of sufficient number to meet the requirements of EPA (2007). Trap effort within each borehole and vertical positioning of the traps was determined from a review of the drill logs (see Section 3.2.2.2). In most cases, there was very limited potential habitat space available to sample between the ground surface and the water table (typically in the order of one to two metres; Table 3.1). The location of the sample points is shown in Figure 3.1, with further details on the drillholes provided in Appendix 1.

Three phases of troglofauna sampling were completed for the project:

- Phase I: traps installed on 9th June 2009; recovered 22nd July 2009 (a sampling period of 44 days);
- Phase II: traps installed on 22nd July 2009; recovered 7th September 2009 (a sampling period of 48 days); and
- Phase III: traps installed on 7th September 2009; recovered 26th October 2009 (a sampling period of 49 days).

Table 3.1: Details of Wheatstone Project study area troglofauna and stygofauna sampling sites and effort (coordinates in WGS84 datum, Zone 50; 'm btc' = metres below top of casing; locations shown in Figure 3.1).

							Troglofauna Effort							Stygofauna Effort		
Bore No.	Northing	Easting	Depth (m)	Cased Depth (m)	Blank (m btc)	Water table (m btc)	Sampleable metres	Troglofauna Traps (m btc)			No. of Traps – Phase I	No. of Traps – Phase II	No. of Traps – Phase III	No. of hauls – Phase I	No. of hauls – Phase II	No. of hauls – Phase III
E002G-S	291156	7595091	5	4.6	1.2	2.97	1.77	1.5		1	1	1	1	5	-	5
E002F	291153	7595088	15	14.2	0.8	2.86	2.06	1.5	2.5	2	2	2	2	5	-	5
E003F	291105	7595517	20.6	20.6	0.85	5.44	4.59	1.5	3	3	3	3	3	5	-	5
E004F	291243	7595540	21.1	21.1	2	6.9	4.9	2.5	4.5	3	3	3	3	5	-	5
E005G-S	291484	7596954	3.3	3.3	0.7	2.3	1.6	1	2	2	2	2	2	5	-	5
E005F	291482	7596953	13.7	13.7	2	2.25	0.25	2.1		1	1	1	1	5	-	5
E006F	292538	7598296	15.3	15.3	1	1.17	0.17	1.1		1	1	1	1	5	-	5
E007F	292716	7598612	18.5	17.5	1	1.67	0.67	1.5		1	1	1	1	5	-	5
E008F	293243	7599460	16	16	0.5	5.07	4.57	1.5	3	3	3	3	3	5	-	5
E009F	293256	7599398	16	16	0.5	4.75	4.25	1.5	3	3	3	3	3	5	-	5
E010F	293465	7599682	20	20	0.5	2.08	1.58	1.5		1	1	1	1	5	-	5
E011F	294123	7600692	18	17.5	0.9	1.46	0.56	1.2		1	1	1	1	5	-	5
E013F	295014	7600692	19.5	19.5	1	1.14	0.14	1		1	1	1	1	5	-	5
E015F	290894	7596347	20	17.5	1	4.36	3.36	1.5	3	3	3	3	3	5	-	5
E016F	290313	7596330	15	15	1	3.17	2.17	1.5	3	2	2	2	2	5	-	5
E016G-S	290313	7596335	5	5	1	3.11	2.11	1.5	3	2	2	2	2	5	-	5
E018F	293917	7600300	15	14.5	1	1.8	0.8	1.5		1	1	1	1	5	-	5
E021F	293984	7600707	15	14	1.5	1.74	0.24	1.6		1	1	1	1	5	-	5
E012F	294956	7600455	16.6	16.6	1.3	0.79	-	-	-	-	-	-	-	-	5	-
E017F	290021	7596325	20	18.6	19.4	1.87	-	-	-	-	-	-	-	-	5	-
E019G-D	293684	7600753	34	33.5	30.5	-	-	-	-	-	-	-	-	-	5	-
E032FG-D	294583	7600425	21	21	19	2.18	-	-	-	-	-	-	-	-	5	-
E027FG-I	293132	7598679	18	18	16	2.06	-	-	-	-	-	-	-	-	5	-
E033FG-D	293169	7600364	41	40	37	3.04	-	-	-	-	-	-	-	-	5	-
E014F	291024	7599363	15.5	15	1	-	-	-	-	-	-	-	-	-	5	-
E024FG-I	291590	7599722	15	8	6	2.13	-	-	-	-	-	-	-	-	5	-
E023FG-D	292463	7600535	34	34	31	5	-	-	-	-	-	-	-	-	5	-
										Total:	32	32	32	90	45	90

Figure 3.1: Location of drillholes sampled and assessed for troglofauna and stygofauna during the field survey.

3.2.2.2 Sampling Methods

Troglofauna were sampled by means of custom-built litter traps suspended within the boreholes. Traps were constructed from 50 mm internal diameter PVC irrigation pipe cut to a length of 180 mm. Each trap had a series of 20 mm holes drilled in the side and traps remained open at the upward end.

Leaf litter material was gathered locally from the ground surface. The collected litter was soaked in water and irradiated in a microwave oven on maximum power setting (to kill any surface invertebrates present and assist in break-down). Wet leaf litter was added to the traps and kept in sealed plastic bags until immediately prior to insertion into the boreholes. Traps were installed such that they were in contact with the interior of the sampled bore once installed. Traps were left installed in the ground for a minimum of six weeks to allow sufficient time for colonisation by any troglofauna present (Section 3.2.2.1). A total of 96 traps were installed over three sampling phases (Table 3.1). Traps were recovered and stored in labelled bags for return to a laboratory in Perth for sorting.

3.2.2.3 Specimen Sorting, Curation and Data Management

Fauna specimens were recovered from the traps using specially designed tullgren funnel units. Leaf litter from each trap was placed in a sieve over which an aluminium lamp containing a 25-watt bulb was situated. This created a temperature gradient, which causes invertebrates in the litter sample to move toward the bottom of the funnel. A funnel was situated below the sieve to which a collecting vessel containing 100% ethanol was attached. Leaf litter was left in the tullgren funnels for a period of 24 hours, after which the time the leaf litter was dry and all invertebrates were in the collection container.

Fauna specimens collected via the tullgren funnels were identified to the order or family level using dissecting microscopes (Olympus SZ40 and SZ61). Collected specimens were assigned a unique specimen number based on borehole location and tracked on customised data sheets. Specimens were curated in 100% ethanol to provide for either morphological or molecular analysis.

3.2.3 Stygofauna

3.2.3.1 Stygofauna Sampling Effort and Techniques

Stygofauna sampling followed a similar format to other stygofauna sampling projects undertaken for previously completed environmental impact assessments in the Pilbara region (e.g. Biota 2007a and 2007b). Methodologies, sampling effort and approach were consistent with those outlined in EPA Guidance Statements 54 (EPA 2003) and 54a (EPA 2007).

Sampling of the aquifer for fauna was undertaken by the use of modified plankton haul nets. These sampling nets are constructed from 70 µm plankton mesh, with a 50 mm aperture attached to a weighted catch jar. Each bore was dragged a minimum of five times. On the final haul, the net was agitated gently, which acts to stir the benthos layer and any fauna for more effective specimen collecting. On the surface, the net was flushed thoroughly with water and the resulting combined sample placed in a marked container and into a shaded esky to store the sample for sorting.

Following the completion of each sample, the nets were thoroughly rinsed with water and inspected before use at another hole. This prevented the risk of transferring specimens between aquifers and boreholes. All 18 study area boreholes that were sampled for troglofauna were also sampled for stygofauna during Phase and III (Table 3.1 and Figure 3.1). A further nine bores were also sampled for stygofauna during Phase II (Table 3.1 and Figure 3.1). In addition, three Onslow Salt Pty Ltd boreholes were also sampled for stygofauna during Phase I in locations outside of the study area on the outskirts of the Onslow town site (Bores 1/97 – 3/97; Appendix 1). Thirty bores have therefore been sampled across three occasions for the stygofauna component of this study. EPA (2007) indicates at least 10 bores be sampled in the impact area, which has been exceeded by the current study.

3.2.4 Specimen Sorting, Curation and Data Management

Samples were returned to Perth and sorted in a laboratory under an Olympus SZ40 dissecting microscope (magnification up to 40x). Recovered specimens were tracked using customised tracking forms and preserved in 100% ethanol (to provide for either morphological or molecular analysis).

4.0 Results

4.1 Desktop Assessment

4.1.1 Geology

A review of Thorne and Trendall (2001) indicates that the study area encompasses five major geological units (Table 4.1).

Table 4.1: Geological units occurring within the study area (source: Thorne and Trendall 2001).

Unit	Geological Description
Czp	Claypan- dominant terrain- claypans with longitudinal and net dunes, and/or flat deflation lag surfaces; clay, silt, sand and gravel.
Qw	Intertidal flats and mangrove swamps- calcareous clay, silt and sand
Qs	Beaches and coastal dunes- light grey, unconsolidated and poorly consolidated quartzose calcarenite.
Qe	Longitudinal and network dunes and residual sand plains- reddish-brown to yellowish quartz sand.
Qt	Supratidal flats- calcareous clay, silt and sand with authigenic gypsum and superficial algal mats and salt crusts.

None of these geological units are currently recognised as core habitat types for troglofauna (Section 2.4). The formations are dominated by clay and sands, which generally limit habitat space for troglobites. If calcarenite strata are competent and well developed these could provide potential habitat for troglofauna. However, most observations on site and drilling results (Section 4.1.2.2), indicate poorly-consolidated, friable material, interspersed with sand and clays.

4.1.2 Potential Troglofauna Habitats

4.1.2.1 Landforms

URS (2009a), which assessed a larger study area encompassing that of this review, considered that partially lithified and unconsolidated alluvial sediments, mainly red sands, dominate the terrestrial landscapes of the study area. In more coastal areas, these are overlain in places by sediments of marine origin, including mainly shelly sands and reworked alluvial sands.

On-site inspection during field work indicates that four broad landform units occur in the study area:

- coastal beach dunes with superficial limestone platform in intertidal zone;
- low-lying claypans;
- linear dunes; and
- inter-dune swales and broad plains.

Subject to site access, borehole drilling locations were selected to provide for sampling of the range of these units. Drillhole locations are shown in Figure 3.1, with further details provided in Appendix 1 and Appendix 2.

4.1.2.2 Above Water Table Habitats

One factor in assessing the potential value of the study area for troglofauna is to assess the depth of habitat space available for this fauna. This is effectively the difference between the superficial soil strata and the water table. A review of drilling information supplied by URS indicates that this is limited in the study area (Table 4.2) (Appendix 2).

Table 4.2: Depth of potential habitat space for troglofauna in the study area ('m bgl' = metres below ground level; stratigraphic information sourced from URS drill logs; See Figure 3.1 for locations of boreholes and Appendix 2 for full logs).

Bore No.	Location	Water table (m bgl)	Above water table stratigraphy (m bgl)
E002F	Plant	2.36	Sandy clay (0-1 m), silty clay and silty sand (1-2 m)
E003F	Plant	4.38	Sand (0-1 m), calcareous sandstone (1-3 m), gravel and sand (3-4 m)
E004F	Plant	5.93	Sand (0-1 m), sandstone (1-2 m), sand (2-3 m), sands and sandstone (3-6 m)
E005F	Plant	2.10	Gravelly sand (0-1 m), calcareous sandstone (0-2 m)
E006F	Plant	1.10	Silty, sandy clay and sand (0-1 m)
E007F	Plant	1.62	Silty clay (0-1 m), sandstone (1-2 m)
E008F	Plant	5.02	Sand (0-2 m), silty sand (2-4 m), oolitic limestone (4-5 m)
E009F	Plant	4.66	Silty sand (0-3 m), oolitic limestone (3-5 m)
E010F	Plant	1.99	Sand and silty sand (0-2 m)
E011F	Plant	0.86	Sand (core loss) (0-1 m)
E013F	Plant	1.00	Sand (core loss) (0-1 m)
E015F	Plant	3.84	Sand (core loss) (0-1 m), sand (1-3 m)
E016F	Plant	3.11	Sand and silty sand (0-3 m)
E018F	Plant	1.57	Sand, silty sand and clay (0-2 m)
E021F	Plant	1.00	Sand (0-1 m)
E046FG-I	Plant	2.98	Silty sand (0-1 m), clayey sand (1-2 m), sandy clay (2-5 m)
E046FG-S	Plant	2.73	Silty sand (0-1 m), clayey sand (1-2 m), sandy clay (2-6 m)
E047FG-D	SIC	NA	Sand (0-1.5), sandy clay (1.5-2.5),
E047FG-I	SIC	1.1	Silty Sand (0-1 m), clayey sand (1-1.5 m)
E047FG-S	SIC	2.09	Sand (0-1.5 m), sandy clay (1.5-2 m)
E048FG-I	SIC	2.84	Silty clayey sand (0-1.5 m), clayey sand (1.5-1.75 m), sandy clay (1.75-2.25 m), silty clay (2.25-2.5), calcarenite (2.5-3 m)
E048FG-S	SIC	3.5	Silty clayey sand (0-1.5 m), sandy clay (1.5-2 m), silty sandy gravel (2-2.5 m), calcarenite (2.5-3 m), silty sand (3-3.5 m)
E052FG-D	SIC	1.12	Silt sandy clay (0-0.5 m), clay (0.5-1 m), sand (1-1.5 m)
E052FG-S	SIC	1.38	Silt sandy clay (0-0.5 m), clay (0.5-0.6 m), sand (0.6-1 m), clayey silty sand (1-2 m)

Consistent with regional geology (Section 4.1.1), the above water table lithology of the study area is dominated by sands, silts and clays; none of which would provide suitable habitat space for troglofauna. Some locations do show thin strata of sandstone and oolitic limestone (particularly E003F, E004F, E005F, E008F and E009F; Table 4.2), which are formations that can contain void space. However, in most cases drill logs indicate that this is comprised of separate clasts, oolites and very narrow cemented bands interspersed with up to 75% sand, rather than massive or karstic formations.

There is also generally only a very thin stratum of available potential habitat between the ground surface and the water table. This averages a depth of 2.5 m from ground surface across the representative drill locations and is less than this in many areas (Table 4.2). Effectively, this indicates that in most situations in the study area, there is generally only what would be regarded as soil and subsoil strata present before the relatively shallow water table is reached. In addition, the broader coastal plain of the study area is periodically inundated by major flood events associated with cyclones, hinterland flows and storm surge (URS 2009, Biota 2009). There are also no major hill, mesa or rocky ridge landforms present that may have been continuously emergent during these historical events to act as potential refugia. These factors indicate a generally low likelihood of a significant troglobitic community having persisted over the long term and currently occurring in the study area.

4.1.3 Stygofauna

4.1.3.1 Below Water Table Habitats

Drill logs from the study area were also reviewed in respect of below water table habitats to assess their potential to support stygofauna (Table 4.3). Drillhole locations are shown in Figure 3.1.

Table 4.3: Below water table habitats in the study area ('m bgl' = metres below ground level; stratigraphic information sourced from URS drill logs; See Figure 3.1 for locations of boreholes and Appendix 2 for full logs).

Bore No.	Location	Drilled depth (m bgl)	Below water table formations (m bgl)
E002F	Plant	15.0	Silty clay (3-5 m), limestone (5-6 m), clay and silty clay (6-11 m), sandstone (11-15 m)
E003F	Plant	20.6	Gravel and sand (4-11 m), clay (11-18 m), conglomerate (18-20 m)
E004F	Plant	21.1	Sandstone and sand (6-9 m), clay and claystone (9-21 m)
E005F	Plant	13.7	Sandstone (2-3 m), sand (3-6 m), clay (6-12 m), conglomerate (12-14 m)
E006F	Plant	15.3	Gravel and sand (1-7 m), clay (7-11 m), sand and sandstone (11-15 m)
E007F	Plant	18.5	Silty sand and clay (2-10 m), clayey sand (10-18 m)
E008F	Plant	16.0	Sand and silty sand (5-11 m), silty sand and sandstone (11-16 m)
E009F	Plant	16.0	Sand (5-11 m), silty and clayey sand and sandstone (11-16 m)
E010F	Plant	20.0	Silty and clayey sand (0-20 m)
E011F	Plant	18.0	Sandstone and sand (1-6 m), Siltstone (6-10 m), clay (0-17 m), claystone (17-18 m)
E013F	Plant	19.5	Sandstone and sand (1-6 m), Siltstone (6-10 m), clay (0-17 m), claystone (17-18 m)
E015F	Plant	20.0	Clayey sand (4-6 m), clay (6-8 m), sand (9-12 m) calcrete (13-14 m), clay (14 – 20 m)
E016F	Plant	15.0	Silty sand (4-6 m), silty, sandy and gravelly clay (6-15 m)
E018F	Plant	15.0	Clay (2-4 m), clayey sand and sandstone (4-6 m), gravelly and silty clay (6-15 m)
E021F	Plant	15.0	Sandstone (2-3 m), sand (3-10 m), clay (10-14 m), clay and calcrete (14-15 m)
E046FG-I	Plant	14.2	Sandy clay (3-5 m), clayey sand (5-8 m), sandy clay (8-12 m), claystone (12- 14.2 m)
E046FG-S	Plant	6	Sandy clay (3-4.5 m), clayey sand (4.5-6 m).
E047FG-D	SIC	56	Clay (3-9 m), sandy clay (9-12 m), clay (12-18 m), sandy silty clay (18- 23 m), saprock (23-26 m), limestone (26-49 m), silty sand (49-50 m), clacerenite (50-51 m), silty clay (51-54 m), clayey silt (54-56 m)
E047FG-I	SIC	12	Clay (3-8.5 m), sandy clay (8.5-11 m), clay (11-13 m)
E047FG-S	SIC	6	Weathered sandstone and calcrete (2-2.5 m), sandy clay (2.5-3 m), clay (3-6 m)
E048FG-I	SIC	15.5	Silty sand (3-4 m), clayey silty sand (4-5 m), clay (5-5.5 m), sandy clay (5.5-7 m), clayey sand (7-9 m), sand (9-12.5 m), sandy gravel (12.5-14 m), claystone (14-15.5 m).
E048FG-S	SIC	6	Silty sand (3.5-4 m), clayey silty sand (4-5 m), clayey sand (5-5.5 m), sandy clay (5.5-6 m)
E052FG-D	SIC	35	Clayey sand (1.5-5 m), Sandy silty clay (5-9 m), silty clayey sand (9-10.5 m), calcarenite (10.5-13.5), sandy clay (13.5-16 m), gravelly clay (16-17.5 m), conglomerate (17.5-23 m), limestone (23-27 m), conglomerate (27-30 m), limestone (30-35 m).
E052FG-S	SIC	5	Clayey sand (2-3 m), silty clayey sand (3-4.5 m), sandy silty clay (4.5-5 m).

The saturated strata in the study area are dominated by sands, sandstone, silt and clays (Table 4.3). These formations generally do not contain large voids and do not normally support as diverse stygal communities as more transmissive units such as calcrete and alluvial aquifers. Typical fauna present in sand aquifers include worm taxa, and copepods and ostracods. These smaller body sized animals reflect the smaller interstices available in these types of units. Some small areas of calcrete occur in three of the boreholes, but these very thin and isolated lenses would not significantly alter the above.

Significant limestone strata are present at depth in the SIC part of the study area (Table 4.3). Drill logs indicate that vugs and fractures occur within the limestone at depths between 23 m and 49 m. Although limestone with such voids often contains stygal communities, in this case the likelihood is reduced as the drill logs indicate that these vugs and fractures in the study are mostly filled with clay or silty clay.

4.1.3.2 Groundwater

Data supplied by URS indicate that aquifer water quality varies across the study area and with depth. For comparison purposes, seawater salinity has an EC of approximately 50 mS/cm.

Groundwater salinities in the study area varied from brackish in mostly shallow bores (ranging from 12.7 mS/cm to 44.0 mS/cm) through to hypersaline values of almost four times seawater concentrations (a maximum of 187.6 mS/cm in bore E002a). The majority of the study area appears to be underlain by groundwater of brackish through hypersaline salinity, with ECs ranging from 61.3 mS/cm to around double seawater at 107.8 mS/cm (URS 2009b). This is consistent with other work in the locality, which has shown the presence of hypersaline groundwater at depth below the Onslow coastal plain (e.g. Biota 2008b). These other studies have also collected depth profiles showing the presence of shallow brackish lens overlying the typical hypersaline deeper groundwater. These superficial lenses are typically recharged on a periodic basis by major freshwater rain and flood events. The collection of similar profile data was conducted by URS (2009b) and indicated that a fresher superficial lens was very thin if present at all.

Stygofauna may occur in aquifers of seawater concentrations, and also in somewhat more hypersaline waters (Watts and Humphreys 1999, Biota 2007b), but would be unlikely to occur in the most hypersaline groundwater recorded in the study area (Strayer 1994). The available water quality data therefore do not preclude stygofauna occurring in the study area, though it would be more likely that fauna of marine lineages would be present. The more superficial systems containing brackish to marine salinity groundwater would be most likely to represent habitat for stygofauna, subject to the lithology of individual locations (Section 4.1.3.1).

4.1.4 Previous Records of Subterranean Fauna

There has been limited previous sampling for subterranean fauna in the Wheatstone Project locality. Searches conducted of the Western Australian Museum's database revealed records of stygofauna from three locations in the Ashburton River, Minderoo and Tubridgi Point localities (Table 4.4).

Table 4.4: Previous WA Museum stygofauna collection locations from the locality (data courtesy of Dr Bill Humphreys, WA Museum).

Site	Northing	Easting	Taxa and location
Concrete well	269568	7587644	Ostracoda; 22 km southwest of the study area
Minderoo Homestead well	299227	7567740	Amphipoda:Melitidae; 24 km south of the study area
River Well	299100	7565895	Ostracoda; Copepoda:*Microcyclops varicans*; 25 km south of the study area

4.1.5 Summary Assessment

Based on the nature of the landforms, the stratigraphy of the site, and the small amount of habitat space available (Section 4.1.2.2), it appears unlikely that the study area would support a significant troglobitic community. On the basis of habitat information then, the area would be assigned a 'Low' likelihood of supporting troglofauna (Section 3.1).

Considering the subterranean habitats present (Section 4.1.3.1 and Section 4.1.3.2), and that stygal animals have been collected in the locality (Section 4.1.4), it is probable that stygofauna occur in the study area. These are likely to occur in superficial brackish lenses in sand and sandstone aquifers within the study area, and other fauna may occur in larger aquifers associated with the Ashburton River in the wider locality outside of the study area. The nature of the groundwater systems, geology and lithology of the area suggest that this may be limited to a subset of smaller body-type taxa of marine lineage. On the basis of habitat information then, the area would be assigned a 'Moderate' likelihood of supporting stygofauna (Section 3.1).

4.2 Stygofauna Sampling Results

No stygofauna were collected from 27 of the 30 groundwater bores sampled in this study. Two stygal taxa were collected from three of the bores as outlined in Table 4.5. Both taxa were collected during the Phase I sampling, with no additional records of any stygal taxa from Phase II and III.

Table 4.5: Details of stygofauna collected from study area sampling bores (n=number of specimens, location of bores shown in Figure 3.1).

Site	Taxa	n	Comments
E005G-S	Oligochaeta: Enchytraeidae sp. 1	1	Same taxon as specimen from E005d (juvenile)
E005F	Oligochaeta: Enchytraeidae sp. 1	1	Same taxon as specimen from E005c (juvenile)
E013F	Copepoda: *Phyllopodopsyllus thiebaudi*	200+	Sub-sample of 40 representative specimens preserved. Collected from beach site.

The oligochaete worm specimens were both juvenile and identification past family level is not possible with the collected material. The copepod *Phyllopodopsyllus thiebaudi* is a widespread species that has previously been recorded from Barrow Island (Biota 2007b), amongst other locations (Karanovic et al. 2001), and is not restricted to the Onslow locality. The copepod records are from a bore that is situated on the beach proper, almost into intertidal habitat (E013F; Figure 3.1), consistent with the marine lineage of this genus.

The morphological nature of the recorded taxa, small and vermiform (worm-like) body size and structure, is consistent with the types of strata and aquifers present (Section 4.1). The vermiform nature of Enchytraeidae sp. 1 and other stygal oligochaetes allow them to occur in sand aquifers and other saturated lithology with small-scale interstices. This also means sand units do not form barriers to gene flow as they may for other larger-bodied stygofauna and it is unlikely that the species represented by the Enchytraeidae sp. 1 specimens is restricted to an area the size of the study area.

4.3 Troglofauna Sampling Results

The three sampling phases of the troglofauna survey yielded an overall total of 14,398 invertebrate specimens, representing eight orders (Table 4.6 to Table 4.8). All of these specimens were surface or soil invertebrates that were not troglomorphic.

Table 4.6: Summary of invertebrates collected during the Phase I troglofauna sampling.

	Taxon					
Site	Acarina	Collembola	Hymenoptera	Isoptera	Oligochaeta	Total
E002G-S	50	1				51
E002F		2				2
E003F	50	107				157
E004F	150	150				300
E005G-S	50	50				100
E005F	100	70		35		205
E006F	2					2
E007F	50	15				65
E008F	115	150				265
E009F	54	130				184
E010F	2					2
E011F	6	16				22
E013F	50	50				100

Table 4.6: Summary of invertebrates collected during the Phase I troglofauna sampling.

	Taxon					
Site	Acarina	Collembola	Hymenoptera	Isoptera	Oligochaeta	Total
E015F	19	150				169
E016F	100	9	1			110
E016G-S	100	16			2	118
E018F	50	50				100
E021F	50	19				69
Total:	998	985	1	35	2	2,021

Table 4.7: Summary of invertebrates collected during the Phase II troglofauna sampling.

	Taxon					
Site	Acarina	Collembola	Isoptera	Diptera	Nematoda	Total
E003F	280	463	3	35		781
E004F	262	283		1		546
E005G-S	170	178				348
E005F	500	300		1	1	802
E007F	33	53				86
E008F	622	780				1,402
E009F	26	211				237
E010F	37	150				187
E011F	4	7				11
E013F	4	800				804
E015F	53	318			2	373
E016G-S	337	600			4	941
E016F	420	64				484
E018F	63	17				80
E021F	400	250				650
Total:	3,211	4,474	3	37	7	7,732

Table 4.8: Summary of invertebrates collected during the Phase III troglofauna sampling.

	Taxon						
Site	Acarina	Coleoptera	Collembola	Diptera	Hymenoptera	Isoptera	Total
E002F	4		5				9
E002G-S	100		100	1			201
E003F	112	1	57				170
E004F	75	1	280		1		357
E005F	100		200				300
E005G-S	35					50	85
E006F	25		150				175
E007F	70		300				370
E008F	230		1,250	2			1,482
E009F	300		53	1			354
E010F	9			2			11
E011F	70	1					71
E013F	17		7	1			25
E015F	45		300			70	415
E016F	70	2	150	1		25	248
E016G-S	200		8	1		22	231
E018F	34		7				41
E021F			100				100
Total:	1,496	5	2,967	9	1	167	4,645

No troglobitic animals have therefore been recorded from the study area, which is again consistent with the desktop habitat assessment (Section 4.1).

5.0 Discussion and Conclusions

No troglobites have been recorded from the Plant component of the study area during the three phases of field sampling documented in this report. This result is consistent with the nature of the subterranean habitats present in the overall study area (Section 4.1.2.2), and there appears to be a low likelihood that troglofauna occur in the study area.

Stygofauna have been confirmed as occurring in the study area, but only at low frequency and from just two spatial locations (Section 4.2). Two taxa have been collected (the copepod *Phyllopodopsyllus thiebaudi* and the oligochaete Enchytraeidae sp. 1; Section 4.2). Based on confirmed distributional data, there is no risk that *P. thiebaudi* is restricted to the study area (Section 4.2). Given the ecology and distributional patterns of stygal oligochaetes in similar habitats elsewhere in the region (for Enchytraeidae sp. 1; Section 4.2), it is unlikely that this taxon is restricted to the study area.

The results therefore do not suggest a diverse or significant stygal community occurs in the aquifers beneath the study area. Both the fauna recorded and the nature of the subterranean habitats suggest a low level of risk that any stygal species would be restricted to the study area.

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Appendix 1

Details of Boreholes Sampled During this Study

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Wheatstone Project Bores

Bore No.	Status	Location		Drilled		Depth Drilled	Cased Depth	Casing		Collar Height	Airlift Yield	Airlft Duration	Field Water Quality		Static Water Level	
		Northing	Easting	Started	Completed			Blank	Slotted				EC	pH		
		(mN)	(mE)			(m)	(m)	(m)	(m)	(m)	(L/sec)	(mins)	(mS/cm)		(m btc)	(m bgl)
E002G-S	Shallow	291156	7595091	30/3/09	31/3/09	5	4.6	1.2	4	0.64	0.3	21.0	65.0	8.0	2.97	2.33
E002F	Sub	291153	7595088	31/3/09	1/4/09	15	14.2	0.8	13.9	0.50	0.5	30.0	117.9	7.8	2.86	2.36
E003F	Sub	291105	7595517	29/3/09	1/4/09	20.6	20.6	0.85	19.6	1.06	0.9	40.0	101.1	7.72	5.44	4.38
E004F	Sub	291243	7595540	25/3/09	29/3/09	21.1	21.1	2	20.1	0.97	0.8	40	102.9	7.65	6.90	5.93
E005G-S	Shallow	291484	7596954	5/4/09	5/4/09	3.3	3.3	0.7	2.6	0.2	0.1	30	12.7	8.9	2.3	2.10
E005F	Sub	291482	7596953	5/4/09	6/4/09	13.7	13.7	2	12.7	0.14	0.3	40	83.0	7.9	2.25	2.11
E006F	Sub	292538	7598296	6/04/2009	7/4/09	15.3	15.3	1	14.7	0.07	0.5	40	128.8	7.5	1.17	1.10
E007F	Sub	292716	7598612	13/04/2009	13/4/09	18.5	18.5	1	17.5	0.05	1	45	135.9	7.71	1.67	1.62
E008F	Sub	293243	7599460	18/04/2009	19/4/09	16	16	0.5	15.5	0.05	1	40	124.4	7.37	5.07	5.02
E009F	Sub	243256	7599398	19/04/2009	20/4/09	16	16	0.5	15.5	0.09	1.5	45	128.8	7.44	4.75	4.66
E010F	Sub	293465	7599682	17/04/2009	18/4/09	20	20	0.5	19.5	0.09	1.5	40	124	7.27	2.08	1.99
E011F	Sub	294123	7600692	12/04/2009	14/4/09	18	17.5	0.9	17.1	0.6	1.6	30	77.3	7.85	1.46	0.86
E013F	Sub	295014	7600692	10/04/2009	11/4/09	19.5	19.5	1	18.8	0.14	1.2	28	91.6	7.7	1.14	1.00
E015F	Sub	290894	7596347	8/04/2009	9/4/09	20	17.5	1	16.9	0.52	0.5	45	104.2	7.7	4.36	3.84
E016G-S	Shallow	290313	7596335	6/04/2009	6/4/09	5	5	1	4	0.01	na	na	44.0	8.1	3.11	3.10
E017F	Sub	290022	7596324	1/04/2009	3/4/09	20	18.6	19.4	3.9	0.8	2	45	107.8	7.5	1.87	1.07
E018F	Sub	293917	7600300	19/04/2009	20/4/09	15	14.5	1	13.5	0.23	0.5	1	25.1	7.58	1.8	1.57
E021F	Sub	293984	7600707	20/04/2009	21/4/09	15	14	1.5	14	0.74	1	43	85.5	7.85	1.74	1.00
E012F	Sub	294956	7600455	21/04/2009	22/4/09	16.6	16.6	1.3	15.3	0	1.7	40	111.7	7.32	0.79	0.79
E017F	Sub	290021	7596325	1/04/2009	3/4/09	20	18.6	19.4	3.9	0.8	2	45	107.8	7.5	1.87	1.07
E019G-D	Deep	293684	7600753	29/04/2009	3/5/09	34	33.5	30.5	3	0.28	2	35	161.9	6.36	na	na
E032FG-D	deep	294583	7600425	7/05/2009	9/5/09	21	21	19	2	0.16	0.3	45	139.9	7.54	2.18	2.02
E027FG-I	interm	293132	7598679	12/05/2009	13/5/09	18	18	16	2	0.16	0.5	45	172.4	7.39	2.06	1.90
E033FG-D	deep	293169	7600364	17/5/09	21/5/09	41	40	37	3	0.15	2	10	175.5	7.21	3.04	2.89
E014F	sub	291024	7599363	23/5/09	24/5/09	15.5	15	1	14	0.09	0.5	40	105.6	7.47	na	na
E024FG-I	interm	291590	7599722	26/5/09	27/5/09	15	8	6	2	0.18	1.5	20	73.8	7.7	2.13	1.95
E023FG-D	deep	292463	7600535	27/5/09	29/5/09	34	34	31	3	0.14	2.5	20	162.7	7.01	5.00	4.86
E046FG-I	Sub	293199	7593723	14/10/09	17/10/09	14.2	14.2	na	na	0	0.5	na	77.1	na	2.98	2.98
E046FG-S	Shallow	293201	7593721	17/10/09	17/10/09	6	6	na	na	0	0.25	na	83.5	na	2.73	2.73
E047FG-D	Deep	294211	7592307	18/10/09	22/10/09	56	56	na	na	0	0.5	na	78.0	na	na	na
E047FG-I	Sub	294211	7592310	22/10/09	22/10/09	12	13	na	na	1	0.25	na	126.5	na	2.1	1.1
E047FG-S	Shallow	294211	7592312	18/10/09	22/10/09	6	6.2	na	na	0.2	0.2	na	57.9	na	2.29	2.09
E048FG-I	Sub	296274	7591598	14/10/09	17/10/09	15.5	13	na	na	0	2.0	na	91.2	na	2.84	2.84
E048FG-S	Shallow	293201	7593721	28/10/09	28/10/09	6	6	na	na	0	0.1	na	50.7	na	3.5	3.5
E052FG-D	Deep	300274	7590245	23/10/09	27/10/09	35	36	na	na	1	0.4	na	175.7	na	2.12	1.12
E052FG-S	Shallow	300274	7590245	27/10/09	27/10/09	5	5	na	na	0	0.25	na	92.8	na	1.38	1.38

Onslow Salt Pty Ltd Bores

Bore No.	Location		Depth Drilled (m)
	Northing (mN)	Easting (mE)	
1/97	303736	7602999	6.2
2/97	303874	7604062	12.3
3/97	304410	7605707	9.1

Appendix 2

Drill Logs for Wheatstone Boreholes

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URS BORE COMPLETION REPORT

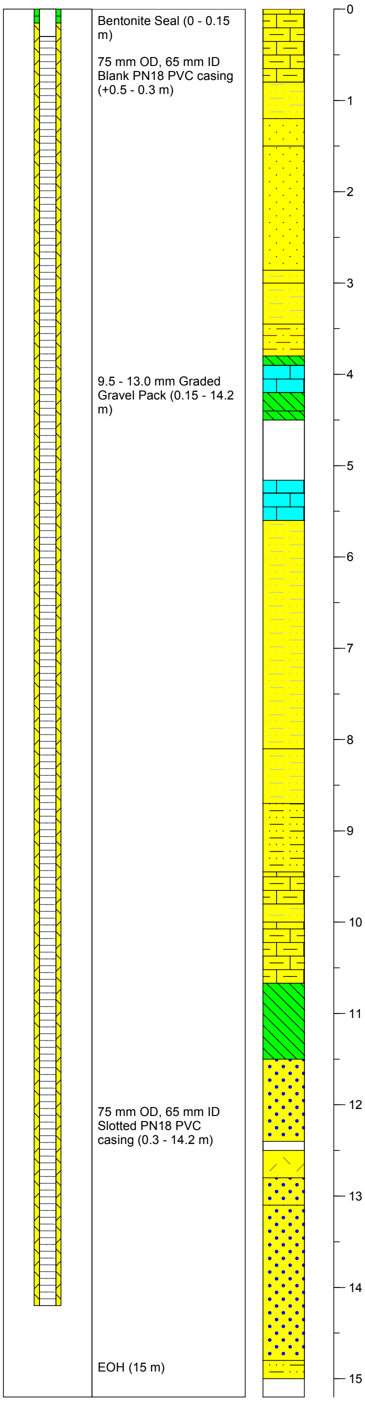
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E002F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**15 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**14.2 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E002**	EASTING	**0291153 mE**
START DATE	**31/3/09**	NORTHING	**7595088 mN**
COMPLETION DATE	**1/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**2.36 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SANDY CLAY: Red brown, very fine to medium, quartz, sub angular, 2% coarse, 70% fine.		
SILTY CLAY: Red brown, fine clay, damp, minor silt, sand and coarse quartz grains.		
SILTY SAND : Red brown, medium to fine grained, becoming dry, moderately sorted, sub angular, minor clay.		
SILTY SAND : Red brown, medium to fine grained, becoming dry, moderately sorted, sub angular, minor clay.		
SILTY CLAY: Red brown, ferruguors fragments, very fine silty clay, minor bands of hard moderately cemented clay.		
SILTY CLAY: Red brown, ferruguors fragments, very fine silty clay, minor bands of hard moderately cemented clay.		
CEMENTED SAND: Light brown to pale grey, cemented quartz, shell sandstone nodules, clayey matrix, red brown clay, moderately well sorted, sub angular.		
CLAY: Light to mid brown to red brown, marine sediments, calcareous, coral, shell fragments, well cemented.		
LIMESTONE: Dark red brown clayey matrix, white cream calcareous coral, hard, nodules.		
CLAY: Dark red brown, minor fine to very fine quartz garins, well consolidated.		
CLAY: Red brown to dark grey, nodules, well cemented.		
CORE LOSS: Core Loss/ SPT, red brown, silty sand.		
LIMESTONE: Red brown, unconsolidated, soft, moderately weathered, large shell fragments, highly cemented limestone nodules, well cemented.		
LIMESTONE: Red brown, minor medium to fine sand, quartz, calcareous, minor limestone nodules, well cemented.		
SILTY CLAY: Dark red brown, silty, well consolidated, lake clays, minor limestone, sandstone nodules, CaCO3 test is positive.	117.9 mS/cm	0.5 L/sec
SILTY CLAY: Red brown, fine silty clay, becoming well consolidated, minor nodules of coral, CaCO3.		
SILTSTONE: Red brown, clay/ silt marine, CaCO3/ coral nodules/ fragments, moderately well consolidated, hard.		
SANDY CLAY: Red brown, fine to medium grained quartz, poorly sorted, sub rounded, silty clay.		
SILTY CLAY: Red brown, minor sand, very fine grained silty clay, minor (10%) medium quartz sand, minor organics.		
SANDY CLAY: Red Brown to pale grey, mottled in parts, fine to medium grained, quartz, sub rounded, minor rounded holes, well consolidated, hard, moderately well sorted.		
CLAY: Red brown, silty clay, soapy texture, lake clay, minor grey calcareous sandy nodules, minor black organics.		
SANDSTONE: Red brown, silty clay matrix, very fine to medium grained quartz, well sorted, sub rounded, well consolidated, minor organics, varying degrees of deposition, minor well cemented sandstone bands, grey quartz sand, possibly weathered pebbles.		
SAND : Red brown, fine to medium grained, very well sorted, sub-rounded to sub angular, well consolidated.		
CLAYEY SAND : Red brown, as above becoming slightly clayey, hard, minor medium to coarse quartz grains.		
SANDSTONE: Red brown, silty clay matrix, fine to medium quartz sand, sub-angular, poorly sorted, minor fresh to highly weathered sandy nodules, vuggy, calcareous.		
SANDSTONE: Red brown, fine to coarse gravel, sub-angular to sub-rounded, moderately hard, clayey, minor pale grey quartz sandstone bands/ veins.		
SILTSTONE: Red brown, silty, fine to medium sand, quartz, hard, well consolidated.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

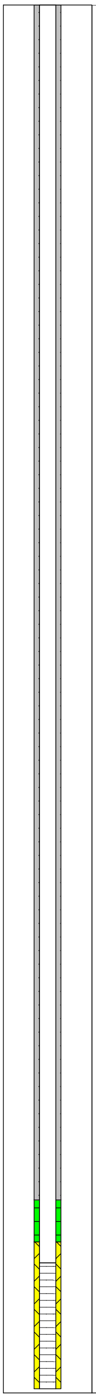
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E002G-D**
DESCRIPTION	**Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**33.1 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**33 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E002**	EASTING	**0291158 mE**
START DATE	**25/3/09**	NORTHING	**7595091 mN**
COMPLETION DATE	**30/3/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**3.49 m bgl**		

BORE CONSTRUCTION



Backfill (0 - 28.5 m)

75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.4 - 30 m)

Bentonite Seal (28.5 - 29.5 m)

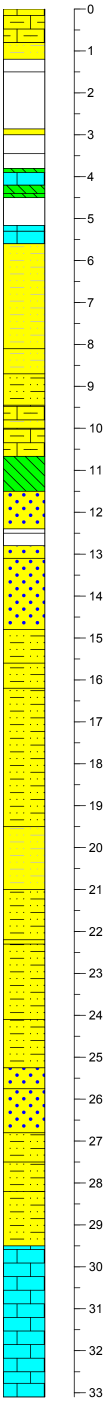
9.5 - 13.0 mm Graded Gravel Pack (29.5 - 33 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (30 - 33 m)

EOH (33.1 m)

LITHOLOGY

DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SANDY CLAY: Red brown, very fine to medium, quartz, sub angular, 2% coarse, 70% fine.		
SILTY CLAY: Red brown, fine clay, damp, minor silt, sand and coarse quartz grains.		
SILTY SAND : Red brown, medium to fine grained, becoming dry, moderately sorted, sub angular, minor clay.		
CORE LOSS: Core Loss/ SPT, red brown, silty sand.		
SILTY CLAY: Red brown, ferruginous fragments, very fine silty clay, minor bands of hard moderately cemented clay.		
SPT		
CEMENTED SAND: Light brown to pale grey, cemented quartz, shell sandstone nodules, clayey matrix, red brown clay, moderately well sorted, sub angular.		
CLAY: Light to mid brown to red brown, marine sediments, calcareous, coral, shell fragments, well cemented.		
LIMESTONE: Dark red brown clayey matrix, white cream calcareous coral, hard, nodules.		
CLAY: Dark red brown, minor fine to very fine quartz garins, well consolidated.		
CLAY: Red brown to dark grey, nodules, well cemented.		
CORE LOSS: Core Loss/ SPT, red brown, silty sand.		
LIMESTONE: Red brown, unconsolidated, soft, moderately weathered, large shell fragments, highly cemented limestone nodules, well cemented.		
LIMESTONE: Red brown, minor medium to fine sand, quartz, calcareous, minor limestone nodules, well cemented.		
SILTY CLAY: Dark red brown, silty, well consolidated, lake clays, minor limestone, sandstone nodules, CaCO3 test is positive.		
SILTY CLAY: Red brown, fine silty clay, becoming well consolidated, minor nodules of coral, CaCO3.		
SILTSTONE: Red brown, clay/ silt marine, CaCO3/ coral nodules/ fragments, moderately well consolidated, hard.		
SANDY CLAY: Red brown, fine to medium grained quartz, poorly sorted, sub rounded, silty clay.		
SILTY CLAY: Red brown, minor sand, very fine grained silty clay, minor (10%) medium quartz sand, minor organics.		
SANDY CLAY: Red brown to pale grey, mottled in parts, fine to medium grained, quartz, sub rounded, minor rounded holes, well consolidated, hard, moderately well sorted.		
CLAY: Red brown, silty clay, soapy texture, lake clay, minor grey calcerous sandy nodules, minor black organics.		
SANDSTONE: Red brown, silty clay matrix, very fine to medium grained quartz, well sorted, sub rounded, well consolidated, minor organics, varying degrees of deposition, minor well cemented sandstone bands, grey quartz sand, possibly weathered pebbles.		
SAND : Red brown, fine to medium grained, very well sorted, sub-rounded to sub angular, well consolidated.		
CLAYEY SAND : Red brown, as above becoming slightly clayey, hard, minor medium to coarse quartz grains.		
SANDSTONE: Red brown, silty clay matrix, fine to medium quartz sand, sub-angular, poorly sorted, minor fresh to highly weathered sandy nodules, vuggy, calcareous.		
SANDSTONE: Red brown, fine to coarse gravel, sub-angular to sub-rounded, moderatley hard, clayey, minor pale grey quartz sandstone bands/ veins.		
SILTSTONE: Red brown, silty, fine to medium sand, quartz, hard, well consolidated.		
SILTSTONE: Red brown, siltstone, grey, highly cemented sandstone, calcareous calcrete/ silcrete.		
SILTSTONE: Red brown, siltstone, minor fine grained sand, grey, soapy textured siltstone, positive acid test, mottled.		
SILTY CLAY: Red brown, silty, well consolidated.		
SILTSTONE: Red bown, silty, well consolidated, hard, grey nodules, calcareous, becoming sandy at 21.5 m, moderately well cemented, sub-angular quartz.		
SANDSTONE: Red brown, clayey, fine to medium grained, sub-angular, moderately sorted, moderately consolidated, minor gypsum.		
SILTSTONE: Red brown, silty, minor black staining/ mineral on bedding/ joint planes, well consolidated, clayey, vuggy texture, crumbly.		
SILTSTONE: Red brown, silty, well consolidated, hard, minor, grey banding/ veins, soapy texture, minor sugary carbonate.		
SANDSTONE: Red brown, fine to medium grained quartz, sub-angular, siltstone matrix, well consolidated, mottled with carbonate nodules.		
SANDSTONE: Red brown, fine to medium quartz grains, silty matrix, hard, well consolidated, minor solution channels (1 mm diameter).		
SILTSTONE: Red brown to pale brown, silty, minor sand, minor black mineral, fine grained, hard, very well cemented, mottled with nodules, cemented sandstone, medium grained.		
SILTSTONE: Red brown, fine to medium grained quartz sand in siltstone matrix, hard, well consolidated, minor sugary carbonate.		
SILTSTONE: Red brown, siltstone becoming clayey, soft, crumbly, mottled sandy grey porous holes, minor black mineral, sugary texture carbonate, weathered.		
LIMESTONE: Cream white, moderately weathered, cavernous, vuggy, minor gypsum crystals, hard bands, siliceous, fine to medium sand, quartz, white in part, positive acid test.	187.6 mS/cm	2.0 L/sec
LIMESTONE: Yellow brown, highly weathered, silty, sugary texture, minor gypsum, minor fine to medium quartz sand.		

DRAWN BY **CO** DATE **24/06/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

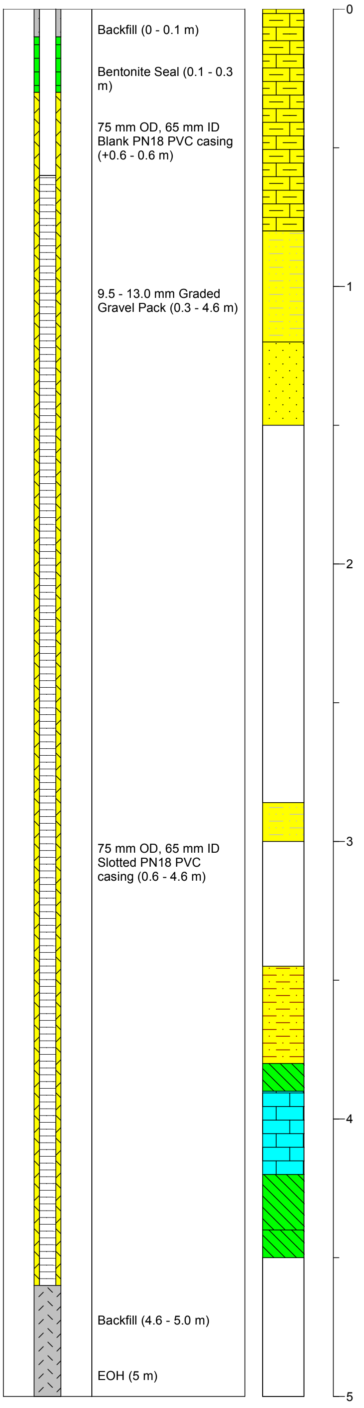
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E002G-S**
DESCRIPTION	**Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**4.6 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E002**	EASTING	**0291156 mE**
START DATE	**30/3/09**	NORTHING	**7595091 mN**
COMPLETION DATE	**31/3/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**2.33 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



SANDY CLAY: Red brown, very fine to medium, quartz, sub angular, 2% coarse, 70% fine.

SILTY CLAY: Red brown, fine clay, damp, minor silt, sand and coarse quartz grains.

SILTY SAND : Red brown, medium to fine grained, becoming dry, moderately sorted, sub angular, minor clay.

CORE LOSS: Core Loss/ SPT, red brown, silty sand.

SILTY CLAY: Red brown, ferruginous fragments, very fine silty clay, minor bands of hard moderately cemented clay.

SPT

CEMENTED SAND: Light brown to pale grey, cemented quartz, shell sandstone nodules, clayey matrix, red brown clay, moderately well sorted, sub angular.

CLAY: Light to mid brown to red brown, marine sediments, calcareous, coral, shell fragments, well cemented.

LIMESTONE: Dark red brown clayey matrix, white cream calcareous coral, hard, nodules.

CLAY: Dark red brown, minor fine to very fine quartz garins, well consolidated.

CLAY: Red brown to dark grey, nodules, well cemented.

CORE LOSS: Core Loss/ SPT, red brown, silty sand.

FIELD EC: 65.0 mS/cm

AIRLIFT YIELD: 0.3 L/sec

DRAWN BY **CO** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

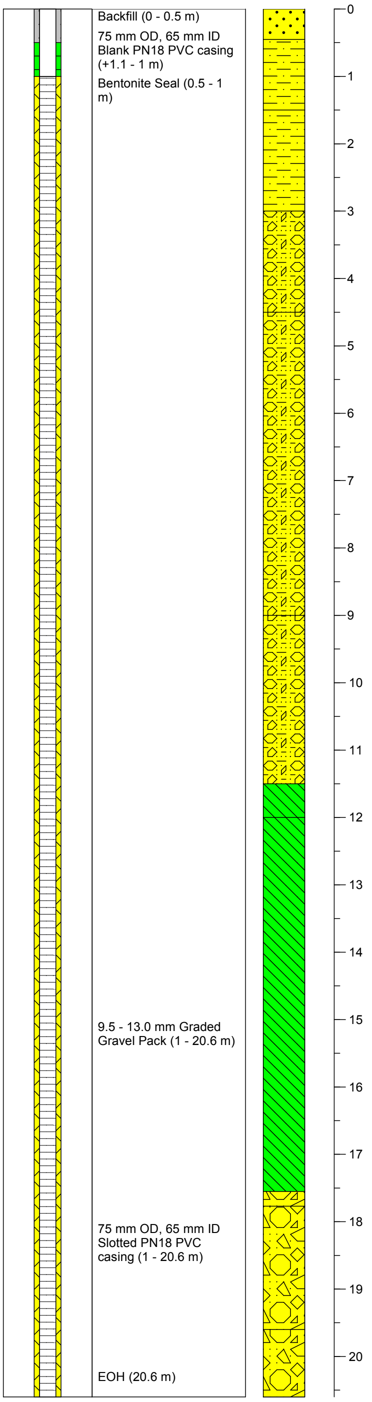
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E003F**
DESCRIPTION **Subterranean Fauna Monitoring bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond**
TOTAL DRILLED DEPTH **20.6 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **20.6 m**
CASING DIAMETER **65 mm ID**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E003**
START DATE **30/3/09**
COMPLETION DATE **1/4/09**
LOGGED BY **GB**
SWL **4.38 m bgl**
EASTING **291105 mE**
NORTHING **7595517 mN**
R.L. OF COLLAR **TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Moderately sorted siliceous, unlithified, brown/grey.		
SAND/CALCAREOUS SANDSTONE: Sand is poorly sorted, siliceous, unlithified, brown grey, with calcareous sand clasts (cemented) to 10 mm in size. Approx 10% limestone clasts and 75% brown sand.		
SAND/CALCAREOUS SANDSTONE: As above but with hard, lithified bands of calcareous sandstone at 1.9 m, 2.42 m, 2.67 m and 2.9 m. Bands are approx 3 mm wide, shell fragments throughout < 3 mm in size.		
GRAVEL AND SAND: Brown, siliceous, unlithified, moderately weathered, rounded. Moderately sorted with common shell fragments to 10 mm throughout.		
GRAVEL AND SAND: As above becoming darker, red to brown Still unconsolidated. Minor organic material at 5 - 5.1 m.	101.1 mS/cm	0.9 L/sec
GRAVEL AND SAND: As above but no gravel. Small angular <4 mm flakes of ironstone between 9.0 and 9.4 m. Sand is approx. 80% quartz, 10% mica, 10% other (feldspar, organics, ironstone, calcareous material). Grains are moderately sorted and sub angular. Brown clay, minor ironstone shale chips.		
CLAY: Stiff, brown, minor banding.		
CLAY: Stiff brown clay. Very fine grained, weathered (mottled between) 14.5 - 15 m. Blackish oxidation throughout. Aquitard (minor carbonaceous shinning).		
CONGLOMERATE: Moderately lithified, angular to sub rounded clasts (approx. 70% quartz). Banded iron formation, volcanic shale, siltstone and jasper in a matrix (approx. 30% very fine grained clay) matrix is strongly weathered.		
CONGLOMERATE: Mottled brown clay. Partially lithified, very fine grained, siliceous.		
CONGLOMERATE: Same as above.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

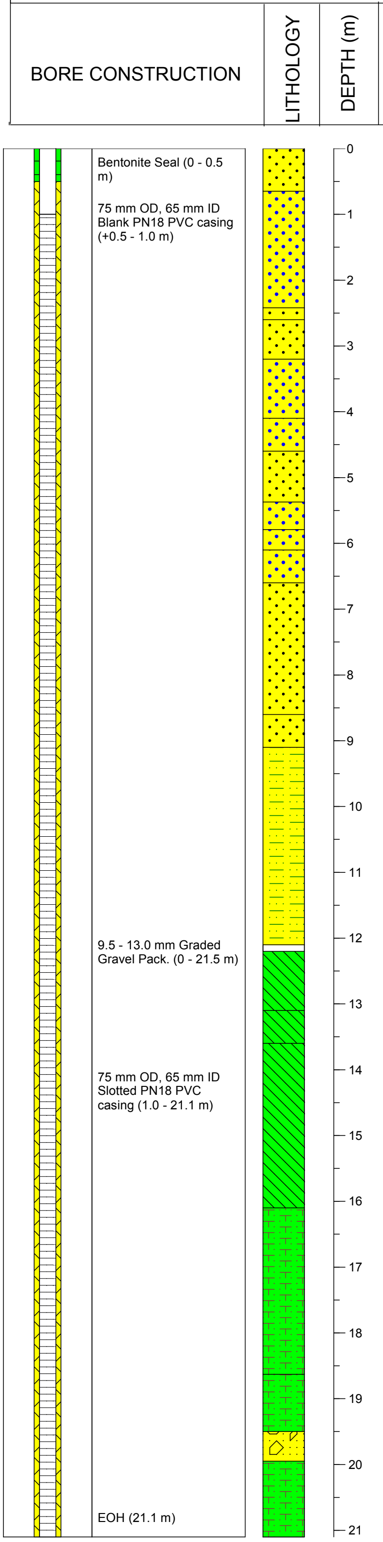
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E004F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond**
TOTAL DRILLED DEPTH **21.1 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **21.1 m**
CASING DIAMETER **65 mm**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E004**
START DATE **26/3/09**
COMPLETION DATE **29/3/09**
LOGGED BY **GB**
SWL **5.93 m bgl**
EASTING **0291246 mE**
NORTHING **7595552 mN**
R.L. OF COLLAR **TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Red, dry, minor silt and clay, small proportion of silcrete gravel (20%).		
SANDSTONE: Porous, fine to medium grained, siliceous with shell fragments, moderate to strongly weathered, some areas only partially lithified.		
SAND: Brown - red, unlithified, moderately weathered, well sorted.		
SAND: As above, moderately lithified.		
SANDSTONE: Brown - red, weak to moderately lithified, calcareous sandstone, weakly weathered, fine to medium grained, siliceous, moderately sorted, minor small (<2 mm) shell fragments (<10%).		
SANDSTONE: Slightly calcareous, fine to medium grained, well sorted, well rounded, moderately lithified, becomes hard at base, siliceous (minor shell fragments < 5%).		
SAND: Shingle, shelly beach sand, well defined boundary at both horizons, poorly sorted, almost conglomerate like, large (< 25 mm wide) shell fragments (about 60%) occur in a matrix of fine to medium grained quartz and calcareous material.		
SANDSTONE: Calcareous, moderately lithified, some shell material (about 25%), largely fine to medium grained siliceous material, moderately sorted.		
SANDSTONE: Calcareous, more sandy, coarse grained, good porosity and permability, minor beach material (10%), moderately lithified and weathered, moderately sorted.		
SANDSTONE: As above, slightly more shell material (about 20%), unlithified.		
SAND: Brown, unlithified, slightly weathered, well to moderately sorted, fine to medium grained, siliceous, some black organic material (about 10%).		
SAND: Brown, calcareous, slightly weathered, about 15% shelly shingle (10 mm) supported by a sandy matrix.		
CLAYEY SAND: Deep red, oxidised, strongly weathered, fine grained, well sorted, siliceous, sand (70 %) clay (30 %).	102.9 mS/cm	0.8 L/sec
CORE LOSS		
CLAY: Brown, very fine grained, 80% clay 20% fine sand, minor organic material, well sorted, weathered.		
CLAY: Brown, as above, moderately to well sorted, with some minor gravel (quartz grains) about 10 %.		
CLAY: As above, getting harder/ finer, almost claystone.		
CLAYSTONE: Brown - red, hard, moderately lithified, moderately mottled, minor (<10%) black organics.		
CLAYSTONE: Brown - red, fine grained, mottled, weathered, (about 30%) silt, odd shaped gravel to <5 mm.		
POLYMITIC CONGLOMERATE: Poorly sorted angular clasts of basalt, ironstone, quartz and undifferentiated sediment, matrix consists of brown, red silty clay, matrix 60% - clasts 40%.		
CLAYSTONE: Red - brown, 20% silt, mottled, sharp transition from above paleochannel deposit.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

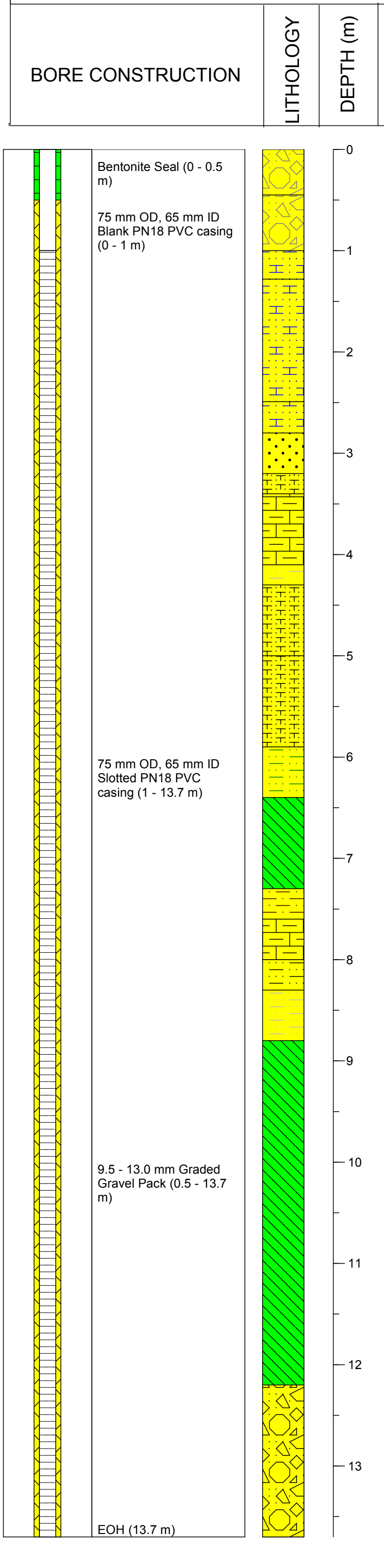
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E005F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond**
TOTAL DRILLED DEPTH **13.7 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **13.7 m**
CASING DIAMETER **65 mm ID**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E005**
START DATE **1/4/09**
COMPLETION DATE **3/4/09**
LOGGED BY **GB/BP**
SWL **2.11 m bgl**
EASTING **291482 mE**
NORTHING **7596954 mN**
R.L. OF COLLAR **TBA**



DESCRIPTION	FIELD EC	AIRLIFT YIELD
GRAVELLY SAND: Brown/red, siliceous. Gravel is calcareous and sandy with angular clasts.		
GRAVELLY SAND: Brown/red, siliceous. Gravel is calcareous and sandy with angular clasts, larger grain size and frequency.		
CALCAREOUS SANDSTONE: Fine to medium grained. Compacted.		
CALCAREOUS SANDSTONE: Gravel 90%, with minor fine grained sand. Plenty of shell material.		
CALCAREOUS SANDSTONE: Gravel 90%, with minor fine grained sand. Plenty of shell material with more sand (60%) and smaller sandstone clasts.		
SAND: Brown sand with 30% sandstone gravel. Sand is poorly sorted, siliceous.		
SILTY SAND: Pale red brown, very fine to medium quartz sand sub angular, moderately sorted, silty matrix.		
SANDY CLAY: Brown, very fine to fine grained, carbonaceous, minor gypsum, silty, abundant, black material.		
SILTY CLAY: Shall fragments brown, very fine to fine quartz sand calcareous, shell fragments up to 20 mm.		
SILTY SAND: Pale red brown, calcareous, very fine to fine quartz, minor angular gravel poorly sorted.		
SILTY SAND: Sub angular, moderately sorted, shell fragments, soft.		
CLAYEY SAND: Red brown, very fine to fine grained quartz, sub angular, moderately sorted, silty matrix.		
CLAY: Red brown, very fine, quartz sand, well compacted.		
SILT: Red brown silty sand.	83.0 mS/cm	0.3 L/sec
SANDY CLAY: Red brown, Fine to medium grained quartz, silty clay.		
SANDY SILT: Red brown, very fine to medium grained quartz, sub angular, moderately sorted, blacker mottle, organic/oxidised.		
SILTY CLAY: Red brown, black, mottled, well compacted.		
CLAY: Red brown, very well compacted, hard, minor black mottled, minor hole/channels.		
CONGLOMERATE: Small <20 mm Pebbles of siltstone and other rocks cemented in a clayey matrix.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

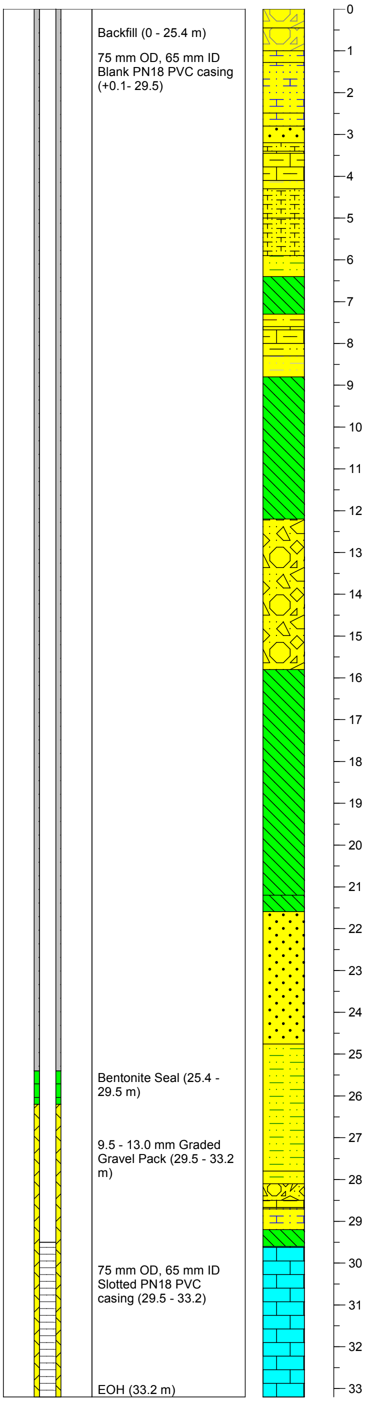
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E005G-D**
DESCRIPTION **Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**33.2 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**33.2 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E005**	EASTING	**291482 mE**
START DATE	**1/4/09**	NORTHING	**7596954 mN**
COMPLETION DATE	**3/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB/BP**		
SWL	**2.73 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



GRAVELLY SAND: Brown/red, siliceous. Gravel is calcareous and sandy with angular clasts.

GRAVELLY SAND: Brown/red, siliceous. Gravel is calcareous and sandy with angular clasts, larger grain size and frequency.

CALCAREOUS SANDSTONE: Fine to medium grained. Compacted.

CALCAREOUS SANDSTONE: Gravel 90%, with minor fine grained sand. Plenty of shell material.

CALCAREOUS SANDSTONE: Gravel 90%, with minor fine grained sand. Plenty of shell material with more sand (60%) and smaller sandstone clasts.

SAND: Brown sand with 30% sandstone gravel. Sand is poorly sorted, siliceous.

SILTY SAND: Pale red brown very fine to medium quartz sand sub angular, moderately sorted, silty matrix.

SANDY CLAY: Brown, very fine to fine grained, carbonaceous, minor gypsum, silty, abundant, black material.

SILTY CLAY: Shall fragments brown very fine to fine quartz sand calcareous, shell fragments up to 20mm. Soft.

SILTY SAND: Pale red brown, calcareous, very fine to fine quartz, minor angular gravel poorly sorted.

SILTY SAND: Sub angular, moderately sorted, shell fragments, soft.

CLAYEY SAND: Red brown, very fine to fine grained quartz, sub angular, moderately sorted, silty matrix.

CLAY: Red brown, very fine, quartz sand, well compacted.

SILT: Red brown silt little sand.

SANDY CLAY: Red brown, Fine to medium grained quartz, silty clay.

SANDY SILT: Red brown, very fine to medium grained quartz, sub angular, moderately sorted, blacker mottle, organic/oxidised.

SILTY CLAY: Red brown, black, mottled, well compacted.

CLAY: Red brown, very well compacted, hard, minor black mottled, minor hole/channels.

CONGLOMERATE: Small <20mm Pebbles of siltstone and other rocks cemented in a clayey matrix.

CLAY: Mottled clay, fine grained. Approx. 80% clay. Red/brown/grey. Moderately sorted. Minor organics. Carbonaceous staining. Approx.5% calcareous sandstone. Pebbles scattered throughout.

CLAY: Mottled clay, fine grained. Approx. 80% clay. Red/brown/grey. Moderately sorted. Minor organics. Carbonaceous staining. Approx.5% calcareous sandstone. Pebbles scattered throughout.

SAND: Brown sand, deeply weathered, siliceous (mainly quartz), minor (approx.20%) clay. Minor mottling grains are sub angular, moderately sorted.

CLAYEY SAND: Mottled , brown/red/grey approx. 50% clay. Well to moderately sorted. Siliceous.

CLAYEY SAND: Mottled , brown/red/grey approx. 50% clay. Well to moderately sorted. Siliceous but with minor gravel/nodules of calcareous sandstone.

GRAVEL: Sandy clay. Gravel is <10 mm. Sub rounded. Quartz, calcareous sandstone, siltstone.

SANDY CLAY: Mottled , brown/red/grey approx. 50% clay. Well to moderately sorted. Siliceous.

CALCAREOUS SANDSTONE: Nodule pebbles, moderately sorted, medium grained, siliceous

CALCAREOUS SANDSTONE: Nodule pebbles, moderately sorted, medium grained, siliceous.

CLAY: Brown, very fine to fine grained.

LIMESTONE: Cream- yellow. Cemented by fine to medium grained poorly sorted calcareous sandstone. Lenses of dolomite throughout (blue-grey) fine grained. Periwinkle fossil observed here. Weathered in fracture. Fracture throughout. AQUIFER.

FIELD EC: 103.0 mS/cm

AIRLIFT YIELD: 0.7 L/sec

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

URS

BORE COMPLETION REPORT

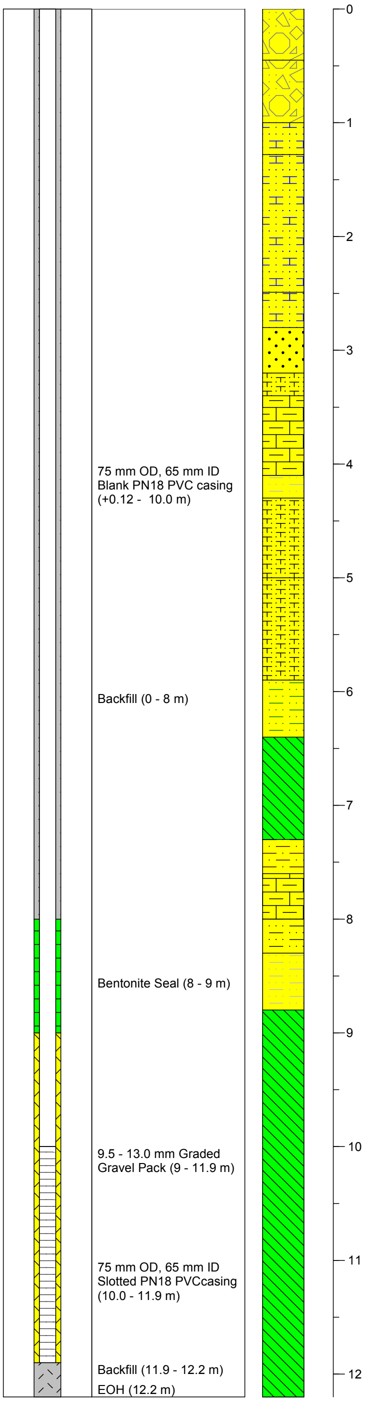
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E005G-I**
DESCRIPTION	**Intermediate Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**12.2 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**11.9 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E005**	EASTING	**291482 mE**
START DATE	**1/4/09**	NORTHING	**7596954 mN**
COMPLETION DATE	**3/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB/BP**		
SWL	**2.18 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
GRAVELLY SAND: Brown/red, siliceous. Gravel is calcareous and sandy with angular clasts.		
GRAVELLY SAND: Brown/red, siliceous. Gravel is calcareous and sandy with angular clasts, larger grain size and frequency.		
CALCAREOUS SANDSTONE: Fine to medium grained. Compacted.		
CALCAREOUS SANDSTONE: Gravel 90%, with minor fine grained sand. Plenty of shell material.		
CALCAREOUS SANDSTONE: Gravel 90%, with minor fine grained sand. Plenty of shell material with more sand (60%) and smaller sandstone clasts.		
SAND: Brown sand with 30% sandstone gravel. Sand is poorly sorted, siliceous.		
SILTY SAND: Pale red brown very fine to medium quartz sand sub angular, moderately sorted, silty matrix.		
SANDY CLAY: Brown, very fine to fine grained, carbonaceous, minor gypsum, silty, abundant, black material.		
SILTY CLAY: Shell fragments brown very fine to fine quartz sand calcareous, shell fragments up to 20 mm. Soft.		
SILTY SAND: Pale red brown, calcareous, very fine to fine quartz, minor angular gravel poorly sorted.		
SILTY SAND: Sub angular, moderately sorted, shell fragments, soft.		
CLAYEY SAND: Red brown, very fine to fine grained quartz, sub angular, moderately sorted, silty matrix.		
CLAY: Red brown, very fine, quartz sand, well compacted.		
SILT: Red brown silt little sand.		
SANDY CLAY: Red brown, fine to medium grained quartz, silty clay.		
SANDY SILT: Red brown, very fine to medium grained quartz, sub angular, moderately sorted, blacker mottle, organic/oxidised.		
SILTY CLAY: Red brown, black, mottled, well compacted.		
CLAY: Red brown, very well compacted, hard, minor black mottled, minor hole/channels.	96.0 mS/cm	0.2 L/sec

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BORE COMPLETION REPORT

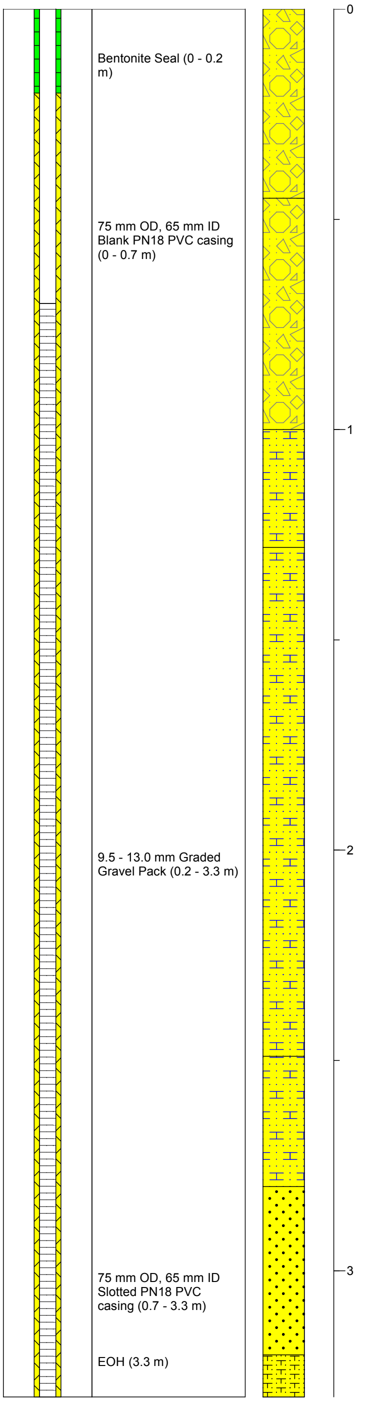
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E005G-S**
DESCRIPTION **Shallow Groundwater Monitoring Bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond**
TOTAL DRILLED DEPTH **3.3 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **3.3 m**
CASING DIAMETER **65 mm ID**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E005**
START DATE **1/4/09**
COMPLETION DATE **3/4/09**
LOGGED BY **GB/BP**
SWL **2.10 m bgl**
EASTING **291482 mE**
NORTHING **7596954 mN**
R.L. OF COLLAR **TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
GRAVELLY SAND: Brown/red, siliceous. Gravel is calcareous and sandy with angular clasts.		
GRAVELLY SAND: Brown/red, siliceous. Gravel is calcareous and sandy with angular clasts, larger grain size and frequency.		
CALCAREOUS SANDSTONE: Fine to medium grained. Compacted.		
CALCAREOUS SANDSTONE: Gravel 90%, with minor fine grained sand. Plenty of shell material.		
CALCAREOUS SANDSTONE: Gravel 90%, with minor fine grained sand. Plenty of shell material with more sand (60%) and smaller sandstone clasts.		
SAND: Brown sand with 30% sandstone gravel. Sand is poorly sorted, siliceous.	12.7 mS/cm	0.1 L/sec
SILTY SAND: Pale red brown very fine to medium quartz sand sub angular, moderately sorted, silty matrix.		

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BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

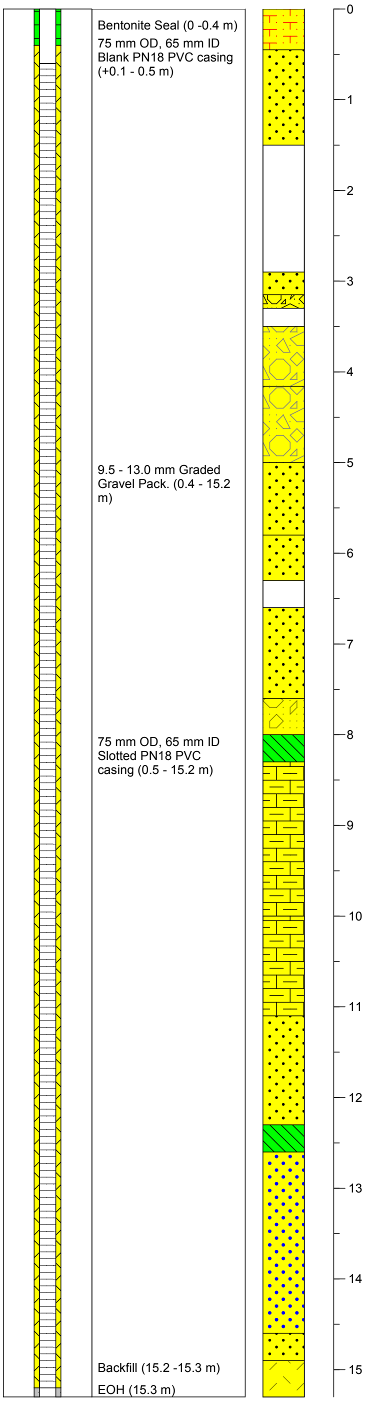
BOREHOLE **E006F**

DESCRIPTION

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**15.3 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**15.2 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E006**	EASTING	**292537 mE**
START DATE	**6/4/09**	NORTHING	**7598300 mN**
COMPLETION DATE	**7/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**BP/CO**		
SWL	**1.10 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



SANDY SILTY CLAY: Brown - red, siliceous, very fine grained, moderately weathered.

SAND: Brown - yellow - red, minor clay componet (about 20%), to 1 m bgl, mature siliceous sand, fine grained, moderately to well sorted, dominantly sub angular to sub rounded, quartz.

CORE LOSS: Brown - red, unlithified, moderately weathered, well sorted.

SAND: Brown, similar to 0.45 - 1.5 m.

GRAVEL: Brown - red, weak to moderately lithified, calcareous sandstone, weakly weathered, fine to medium grained, siliceous, moderately sorted, minor small (<2 mm) shell fragments (<10%).

CORE LOSS: Slightly calcareous, fine to medium grained, well sorted, well rounded, moderately lithified, becomes hard at base, siliceous (minor shell fragments <5%).

GRAVELLY SAND: Shingle, shelly beach sand, well defined boundary at both horizons, poorly sorted, almost conglomerate like, large (<25 mm wide) shell fragments (about 60%) occur in a matrix of fine to medium grained quartz and calcareous material.

GRAVELLY SAND: Calcareous, moderately lithified, some shell material (about 25%), largely fine to medium grained siliceous material, moderately sorted.

SAND: Calcareous, more sandy, coarse grained, good porosity and permability, minor beach material (10%), moderately lithified and weathered, moderately sorted.

SAND: As above, slightly more shell material (about 20%), unlithified.

CORE LOSS: Brown, unlithified, slightly weathered, well to moderately sorted, fine to medium grained, siliceous, some black organic material (about 10%).

SAND: Brown, calcareous, slightly weathered, about 15% shelly shingle (10 mm) supported by a sandy matrix as above lithology.

GRAVELLY SANDY CLAY: Deep red, oxidised, strongly weathered, fine grained, well sorted, siliceous, sand (70%) clay (30%).

CLAY: Red brown, 5% sand, sub rounded, high plasticity. — FIELD EC: 128.8 mS/cm — AIRLIFT YIELD: 0.5 L/sec

SANDY CLAY: Brown, very fine grained, 80% clay 20% fine sand, minor organic material, well sorted, weathered.

SANDY CLAY: Brown, as above, moderately to well sorted, with some minor gravel (quartz grains etc.) about 10%.

SAND: As above, getting harder/ finer, almost claystone.

CLAY: Brown - red, hard, moderately lithified, moderately mottled, minor (<10%) black organics.

SANDSTONE: Brown - red, fine grained, mottled, weathered, (about 30%) silt, odd shaped gravel to <5 mm.

SAND: Poorly sorted angular clasts of basalt, ironstone, quartz and undiff sedimentary, matrix consists of brown, red silty clay, matrix 60% - clasts 40%.

CLAYEY SAND : Red - brown, 20% silt, mottled, sharp transition from above paleochannel deposit.

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

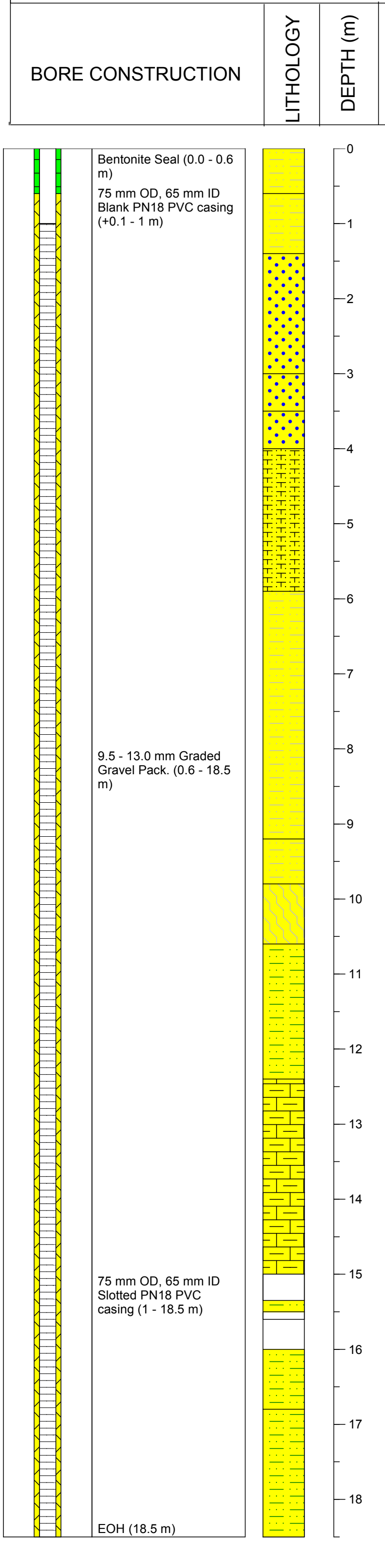
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E007F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**18.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**18.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E007**	EASTING	**0292711 mE**
START DATE	**8/4/09**	NORTHING	**7598613 mN**
COMPLETION DATE	**11/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CO**		
SWL	**1.62 m bgl**		



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SILTY CLAY: Red brown, moderately weathered, well sorted, 5% silt, high plasticity, very fine, mottled, minor quartz present.		
SILTY CLAY: Red brown, moderately weathered, well sorted, 5% silt, high plasticity, very fine, mottled, minor quartz present.		
SANDSTONE: Pale Tan, high shell content, very well cemented to moderately cemented, lots of cavities. Carbonate sand. Sand is fine to coarse grained, poorly sorted, sub rounded to sub angular calcrete (SPT/Core Loss 1.5 - 2.1 m).		
SANDSTONE: Pale Tan, high shell content, very well cemented to moderately cemented, lots of cavities. Carbonate sand. Sand is fine to coarse grained, poorly sorted, sub rounded to sub angular calcrete (SPT/Core Loss 1.5 - 2.1 m).		
SANDSTONE: Grey brown, poorly consolidated, well rounded, and moderately sorted, high shell content, Foraminifera Present. Minor quartz.		
SILTY SAND: Grey brown, poorly consolidated, well rounded, and moderately sorted, high shell content, Foraminifera Present. Minor quartz.		
SILTY CLAY: Red brown, well consolidated, well sorted. Silt surrounded. Minor shell fragments at top (most likely contained from unit above) minor mottling mid plastic going to low with depth.7.8-7.9 m Minor gravel sandstone fragments. 8.2-8.5 m striations on core, clay slightly softer.	135.9 mS/cm	1 L/sec
SILTY CLAY: Red brown, gets sandier over the next metre until 9.7 m it is sandier clay as above.		
SANDY GRAVEL: Red brown, coarse, sub rounded gravel in a very fine to coarse, poorly sorted sand. Sand is well cemented and surrounded. Gravel made of quartz 5 - 25 mm, sandstone is 3 - 30 mm and contains fossils.		
CLAYEY SAND: Red brown, poorly consolidated sand with approx. 5% clay. Sandstone gravel 5 - 25 mm which contains fossils, quartz, ironstone. Sand is medium to coarse, well sorted, sub rounded.		
SANDY CLAY: Red brown nodules of well cemented sandstone. Sandstone is quartz and ironstone in a fine to medium grained sand. Layers of micro fossils. Sand is finer well sorted, sub rounded. Clay has poor plasticity. 14.5 m on has mottle in core.		
CORE LOSS		
CLAYEY SAND: Red brown, minor sand which is sub angular, poorly sorted quartz. Sandstone nodules 5 - 20 mm sub rounded well cemented, major quartz and ironstone.		
CORE LOSS		
CLAYEY SAND: Red brown, fine to coarse sand, sub rounded, micro and macro fossil content. Quartz major 10% clay, mid plastic.		
CLAYEY SAND: 30% Quartz feldspar sandstone conglomerate, well lithified. Red brown matrix, same as 16.0 - 16.8 m.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

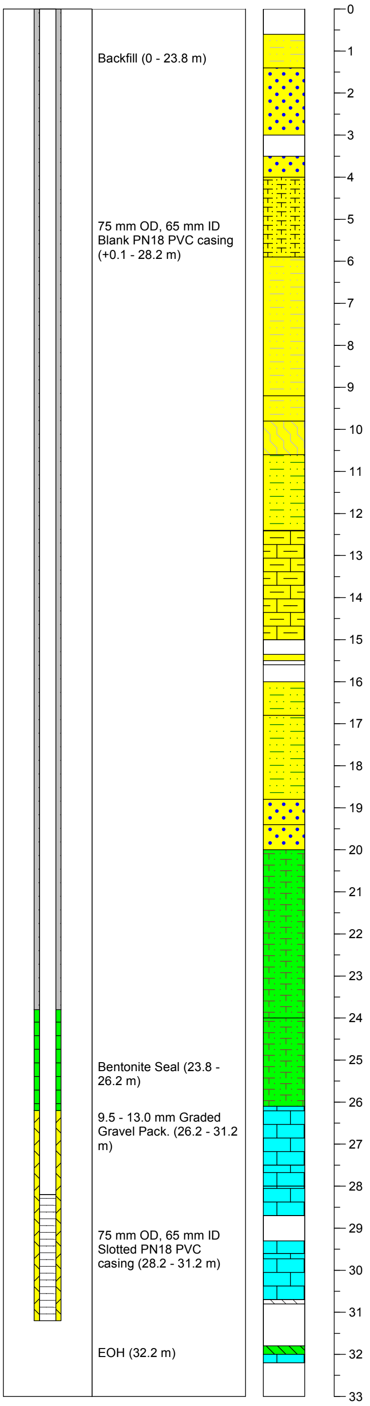
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E007G-D**
DESCRIPTION	**Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**32.2 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**31.2 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E007**	EASTING	**0292711 mE**
START DATE	**8/4/09**	NORTHING	**7598613 mN**
COMPLETION DATE	**11/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**2.03 m bgl**		

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD



SPT/ CORE LOSS

SILTY CLAY: Red brown, moderately weathered, well sorted, 5% silt, high plasticity, very fine, mottled, minor quartz present.

SANDSTONE: Pale Tan, high shell content, very well cemented to moderately cemented lots of cavities. Carbonate sand. Sand is fine to coarse, poorly sorted, sub rounded to sub angular calcrete. (SPT/Core Loss 1.5 - 2.1 m)

SPT/ CORE LOSS

SANDSTONE: Grey brown, poorly consolidated, well rounded, and moderately sorted, high shell content, Foraminifera Present. Minor quartz.

SILTY SAND: Grey brown, poorly consolidated, well rounded, and moderately sorted, high shell content, Foraminifera Present. Minor quartz.

SILTY CLAY: Red brown, well consolidated, well sorted. Silt surrounded. Minor shell fragments at top (most likely contained from unit above) minor mottling mid plastic going to low with depth.7.8-7.9 m Minor gravel sandstone fragments. 8.2-8.5 m striations on core where clay got stuck to bit and turn with it, clay slightly softer.

SILTY CLAY: Red brown, gets sandier over the next metre until 9.7 m it is sandier clay as above.

SANDY GRAVEL: Red brown, coarse, sub rounded gravel in a very fine to coarse, poorly sorted sand. Sand is well cemented and surrounded. Gravel made of quartz 5-25 mm, sandstone is 3-30 mm and contains fossils.

CLAYEY SAND: Red brown, poorly consolidated sand with approx. 5% clay. Sandstone gravel 5 - 25 mm which contains fossils, quartz, ironstone. Sand is medium to coarse, well sorted, sub rounded.

SANDY CLAY: Red brown nodules of well cemented sandstone. Sandstone is quartz and ironstone in a fine to medium grained sand. Layers of micro fossils. Sand is finer well sorted, sub rounded. Clay has poor plasticity. 14.5 m on has mottle in core.

CORE LOSS

CLAYEY SAND: Red brown, minor sand which is sub angular, poorly sorted quartz. Sandstone nodules 5-20 mm sub rounded well cemented, major quartz and ironstone.

CORE LOSS

CLAYEY SAND: Red brown, fine to coarse sand, sub rounded, micro and macro fossil content. Quartz major 10% clay, mid plastic.

CLAYEY SAND: 30% Quartz feldspar sandstone conglomerate, well lithified. Red brown matrix, same as 16.0 - 16.8 m.

SANDSTONE: Red brown, conglomerate, highly lithified, Clasts of 5-25mm included quartz, banded iron formation, Calcareous limestone. Massive matrix of clay.

SANDSTONE: Same as above but less lithified.

CLAYSTONE: Pale grey, red brown stain, very firm, minor silt. Minor ooids present. Well sorted 23.55 m layer that is a broken up, lightly lithified claystone layer. 23.8 m - mottles present. 21.8 m - burrows present.

CLAYSTONE: Red brown, high content of pale grey conglomerate clasts. These are made up of clasts, ironstone, BIF, in a calcareous, very grained matrix.

LIMESTONE: Very pale tan to yellow, moderately weathered calcarean cemented with very fine sand. Trace fossils, very low primary porosity, decent secondary porosity, minor burrows. Formation is quite broken and loose in core.

LIMESTONE: Major cavities at 27.5m for absent half a metre. Lost water return at 27.4 m.

LIMESTONE: Yellow white, unweathered brecciated limestone, breccia is a mixure of Dolerite, BIF and Ironstone. Sandstone. Limestone has minor cavities and there is a very minor presence of burrows, minor iron staining. Matrix is mainly very fine sand, however, there are areas that are coarse sand this is likely the result of cavity filled and re-cemented.

CAVITIES/CORE LOSS

LIMESTONE: Pale tan, slightly weathered, very broken, same as above but more broken.

LIMESTONE: Yellow white, same as 28.0-28.7 m, with large cavities at 30.1 - 30.3 m.

GYPSUM: Clear Platy Structure.

CORE LOSS: Massive cavity.

CLAY: Yellow brown, medium to coarse grained sand. Sub rounded, poorly sorted, clay has medium plasticity.

LIMESTONE: Pale Tan, same as 29.3 - 29.6 m.

FIELD EC	AIRLIFT YIELD
176.2 mS/cm	2.0 L/sec

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

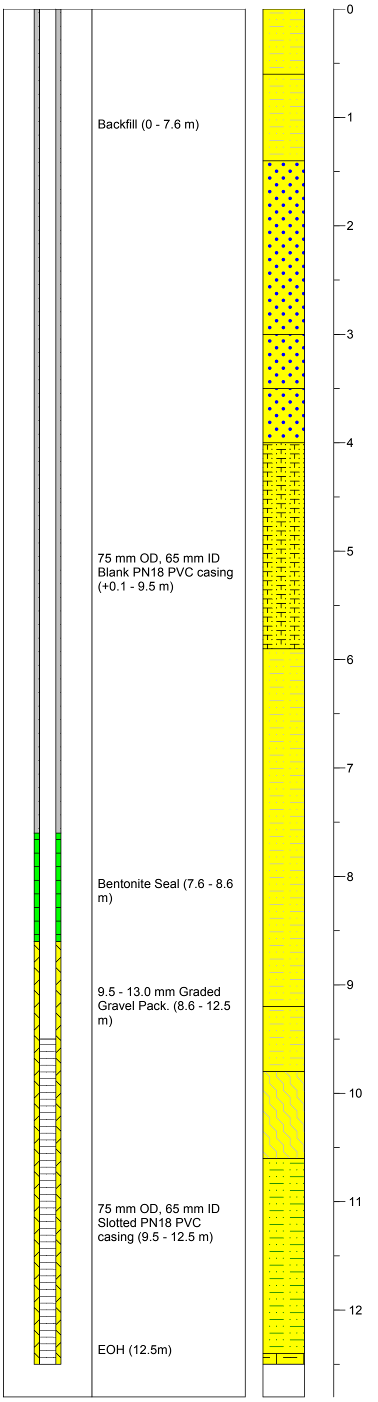
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E007G-I**
DESCRIPTION	**Intermediate Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**12.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**12.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E007**	EASTING	**0292711 mE**
START DATE	**8/4/09**	NORTHING	**7598613 mN**
COMPLETION DATE	**11/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**1.59 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION

SILTY CLAY: Red brown, moderately weathered, well sorted, 5% silt, high plasticity, very fine, mottled, minor quartz present.

SILTY CLAY: Red brown, moderately weathered, well sorted, 5% silt, high plasticity, very fine, mottled, minor quartz present.

SANDSTONE: Pale Tan, high shell content, very well cemented to moderately cemented lots of cavities. Carbonate sand. Sand is fine to coarse, poorly sorted, sub rounded to sub angular calcrete. (SPT/Core Loss 1.5 - 2.1 m).

SANDSTONE: Pale Tan, high shell content, very well cemented to moderately cemented lots of cavities. Carbonate sand. Sand is fine to coarse, poorly sorted, sub rounded to sub angular calcrete. (SPT/Core Loss 1.5 - 2.1 m).

SANDSTONE: Grey brown, poorly consolidated, well rounded, and moderately sorted, high shell content, Foraminifera Present. Minor quartz.

SILTY SAND: Grey brown, poorly consolidated, well rounded, and moderately sorted, high shell content, Foraminifera Present. Minor quartz.

SILTY CLAY: Red brown, well consolidated, well sorted. Silt surrounded. Minor shell fragments at top (most likely contained from unit above) minor mottling mid plastic going to low with depth.7.8 - 7.9 m Minor gravel sandstone fragments. 8.2 - 8.5 m striations on coret, clay slightly softer.

SILTY CLAY: Red brown, gets sandier over the next metre until 9.7 m it is sandier clay as above.

SANDY GRAVEL: Red brown, coarse, sub rounded gravel in a very fine to coarse, poorly sorted sand. Sand is well cemented and surrounded. Gravel made of quartz 5 - 25 mm, sandstone is 3 - 30 mm and contains fossils.

CLAYEY SAND: Red brown, poorly consolidated sand with approx. 5% clay. Sandstone gravel 5 - 25 mm which contains fossils, quartz, ironstone. Sand is medium to coarse, well sorted, sub rounded.

SANDY CLAY: Red brown nodules of well cemented sandstone. Sandstone is quartz and ironstone in a fine to medium grained sand. Layers of micro fossils. Sand is finer well sorted, sub rounded. Clay has poor plasticity. 14.5 m on has mottle in core.

FIELD EC	AIRLIFT YIELD
135 mS/cm	0.7 L/sec

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

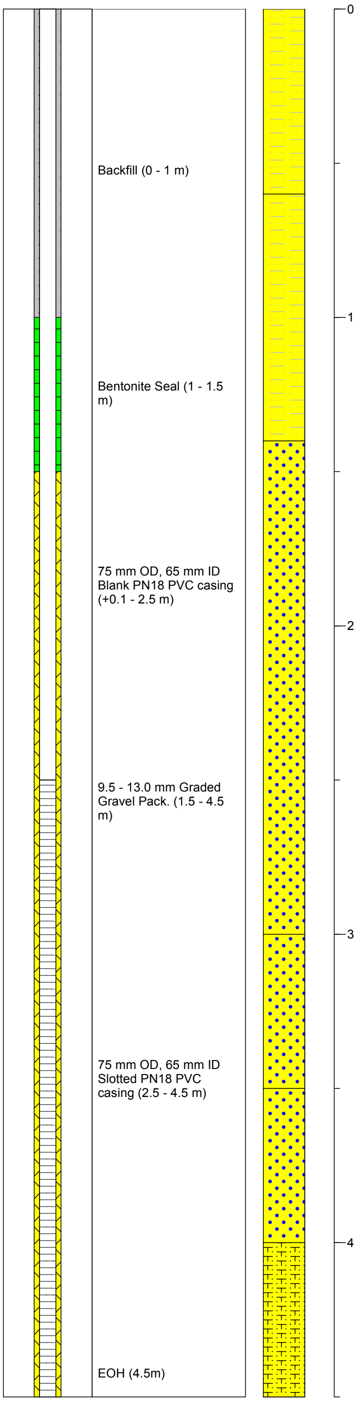
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E007G-S**
DESCRIPTION **Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**4.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**12.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E007**	EASTING	**0292711 mE**
START DATE	**8/4/09**	NORTHING	**7598613 mN**
COMPLETION DATE	**11/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CO**		
SWL	**1.63 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SILTY CLAY: Red brown, moderately weathered, well sorted, 5% silt, high plasticity, very fine, mottled, minor quartz present.		
SILTY CLAY: Red brown, moderately weathered, well sorted, 5% silt, high plasticity, very fine, mottled, minor quartz present.		
SANDSTONE: Pale Tan, high shell content, very well cemented to moderately cemented lots of cavities. Carbonate sand. Sand is fine to coarse, poorly sorted, sub rounded to sub angular calcrete. (SPT/Core Loss 1.5 - 2.1 m)		
SANDSTONE: Pale Tan, high shell content, very well cemented to moderately cemented lots of cavities. Carbonate sand. Sand is fine to coarse, poorly sorted, sub rounded to sub angular calcrete. (SPT/Core Loss 1.5 - 2.1 m)	73.1 mS/cm	0.9 L/sec
SANDSTONE: Grey brown, poorly consolidated, well rounded, and moderately sorted, high shell content, Foraminifera Present. Minor quartz.		
SILTY SAND: Grey brown, poorly consolidated, well rounded, and moderately sorted, high shell content, Foraminifera Present. Minor quartz.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

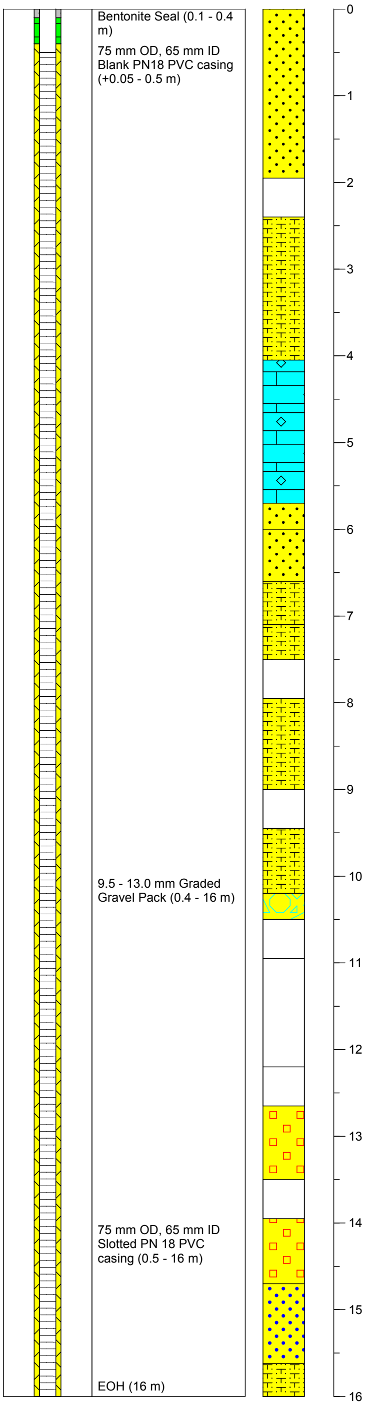
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E008F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond**
TOTAL DRILLED DEPTH **16 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **16 m**
CASING DIAMETER **65 mm ID**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E008**
START DATE **18/4/09**
COMPLETION DATE **19/4/09**
LOGGED BY **CO**
SWL **5.02 m bgl**
EASTING **293243 mE**
NORTHING **7599460 mN**
R.L. OF COLLAR **TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Red brown, sub rounded to sub angular, poorly sorted, poorly consolidated, quartz major sand. Minor silt.		
CORE LOSS		
SILTY SAND: Red brown, sub rounded to sub angular, poorly sorted, poorly consolidated, quartz major sand. Minor silt.		
OOLITIC LIMESTONE: Pale tan, moderately hard, fossil rich, 80% ooid is calcareous cement with occasional large shell fragments. Minor quartz present.		
SAND: Red brown, well consolidated, medium grained, sub angular to sub rounded, moderately sorted. No fossils		
SAND: Red brown, poorly consolidated, medium grained, sub angular to sub rounded, moderately sorted. No fossils		
SILTY SAND: Red brown, sub rounded to sub angular, poorly sorted, poorly consolidated, quartz major sand. Minor silt.		
SILTY SAND: Red brown (pale) sub rounded to sub angular, fine to medium grained, poorly sorted with 5% silt, quartz major. Moderately consolidated, high fossil content.		
SPT		
SILTY SAND: Red brown (pale) sub rounded to sub angular, fine to medium grained, poorly sorted with 5% silt, quartz major. Moderately consolidated, high fossil content.		
SPT	124.4 mS/cm	1.0 L/sec
SILTY SAND: Red brown, sub angular to sub rounded, medium grained, moderately sorted sand with 2% silt. Major quartz which has a minor iron staining. Minor mica, minor mottling. Occasional quartz pebbles, moderately consolidated.		
GRAVELLY CLAYEY SAND: Red brown 5-30 mm gravel in a well consolidated clayey sand matrix. Gravel is well cemented sandstone with clasts of quartz, ironstone. Its sub angular but is just a little rounded on the edges to suggest minor transformation. Sand is sub angular to sub rounded, medium gravel, moderate sorted with 5% clay.		
SPT		
SPT		
SPT		
GRAVELLY SILTY SAND: 5 - 10 mm gravel is a mod to poorly consolidated silty sand. Gravel is made up of clasts of sandstone, bif, quartz. Sand is sub angular to sub rounded (80 % sub angular) moderately sorted, 2 % silts several sandstone layers about 2 cm thick - 13.27 -13.47 m		
SPT		
GRAVELLY SILTY SAND: 5 - 10 mm gravel is a mod to poorly consolidated silty sand. Gravel is made up of clasts of sandstone, bif, quartz. Sand is sub angular to sub rounded (80 % sub angular) moderately sorted, 2 % silts several sandstone layers about 2 cm thick - 13.27 -13.47 m		
SANDSTONE: Sandstone red brown, moderately weathered, well cemented fine to course grained, poorly sorted, sub rounded to sub angular. Pebbles of quartz. Feldspar present. Sand is quartz. Vuggy and minor, small borrows.		
SILTY SAND: Red brown, moderately consolidated, medium to fine sand. Sub rounded, moderately sorted with 5% silt. Major iron staining. Quartz major.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

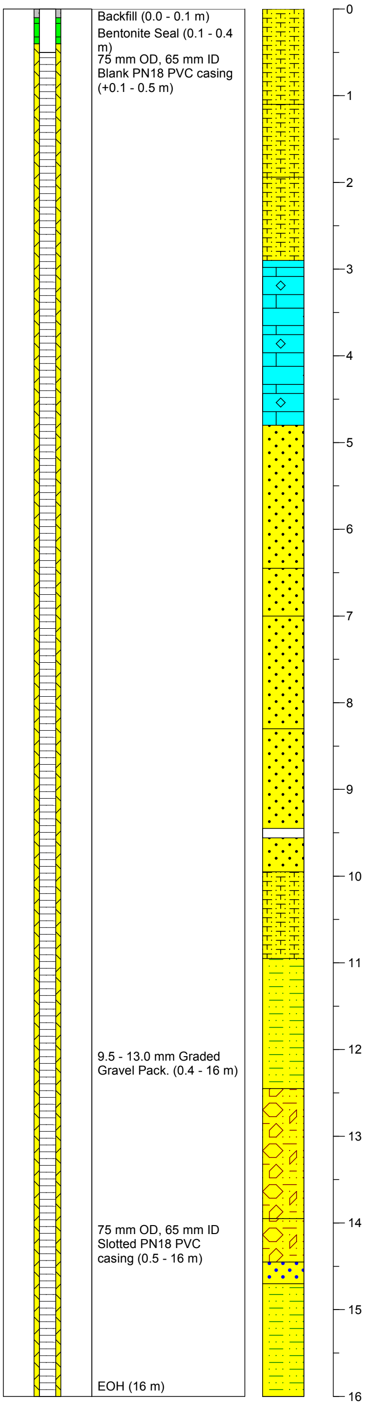
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E009F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**16**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**16**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E009**	EASTING	**243256 mE**
START DATE	**19/4/09**	NORTHING	**7599398 mN**
COMPLETION DATE	**20/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CO**		
SWL	**4.66 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SILTY SAND: Red brown sub rounded to sub angular (mostly sub angular) moderately sorted, poorly consolidated, quartz major sand with 2% silt.		
SILTY SAND: 50% gravel. Pale red brown, same silty sand as above with well cemented, calcareous sandstone gravel. Sandstone is quartz dominant with feldspar. Grain size is fine to medium grained and poorly sorted cement is pale tan.		
SILTY SAND: 30% gravel, pale red brown, sub rounded to sub angular (mostly sub angular), moderately sorted, poorly consolidated, quartz major sand with 2% silt.		
OOLITIC LIMESTONE: Pale tan yellow moderately hard, fossil rich 80% ooids, remainder is calcareous cement with occasional shell fragments, minor quartz.		
OOLITIC LIMESTONE: Pale yellow brown oolitic limestone pale tan yellow moderately hard, fossil rich 80% ooids. Remainder is calcareous cement with occasional shell fragments, minor quartz.		
SAND: Dark brown sand fine to coarse grained, poorly sorted, poorly consolidated. Sub rounded to sub angular. Fossiliferous, lots of ooids / minor shell fragments - some up to 80 mm in length. High quartz content. Cemented sand layers at 5.14 - 5.16 m, 5.37 - 5.53 m, and 5.78 - 5.83 m.		
SAND: Dark brown sand, fine to coarse grained, poorly sorted, poorly consolidated. Sub rounded to sub angular. Fossil content see lots of ooids minor shell fragments - some up to 80 mm in length. High quartz content.		
SAND: Pale grey tan. Fine to medium grained, sub rounded to sub angular, poorly sorted, poorly consolidated. Less quartz then in the above calcareous sand. High ooid content, shell fragment.	128.8 mS/cm	1.5 L/sec
SAND: Dark brown sand fine to coarse grained, poorly sorted, poorly consolidated. Sub rounded to sub angular. Fossil content, ooids present, minor shell fragments - some up to 80mm in length. High quartz content. Cemented sand layers at 5.14 - 5.16 m, 5.37 - 5.53 m, and 5.78 - 5.83 m.		
CORE LOSS		
SAND: Dark brown sand, fine to coarse grained, poorly sorted, poorly consolidated. Sub rounded to sub angular. Fossil content see lots of ooids minor shell fragments - some up to 80 mm in length. High quartz content. Cemented sand layers at 5.14 - 5.16 m, 5.37 - 5.53 m, and 5.78 - 5.83 m.		
SILTY SAND: Silty sand, red brown, fine to medium grained sand, sub rounded, moderately consolidated. Quartz major, with feldspar. No fossil content, 15% silt.		
CLAYEY SAND: Red brown, fine to medium grained sand, sub rounded, moderately consolidated. Quartz major, with feldspar. No fossil content 20% clay and gravel present. Gravel is highly calcareous calculite. Angular 10 - 30 mm clasts. Fossils and quartz also mottling present.		
PALEOCHANNEL DEPOSIT: Red brown fine to medium grained, sub rounded to sub angular, poorly sorted well consolidated sand with 5% silt and 40%. Gravel is made up of sandstone dolerite and bif sized from 5 - 40 mm		
PALEOCHANNEL DEPOSIT: Red brown fine to medium grained, sub rounded to sub angular, poorly sorted well consolidated sand with 5% silt and 40%. Gravel is made up of sandstone dolerite and bif sized from 5 - 40 mm		
SANDSTONE: Yellow brown calcareous, quartz major with feldspar. Poorly cemented. Sand is fine to medium grained. Sub rounded to sub angular, poorly sorted.		
CLAYEY SAND: Red brown, fine to medium grained, sub rounded to sub angular, poorly sorted well consolidated sand.		

DRAWN BY **CE** DATE **26/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

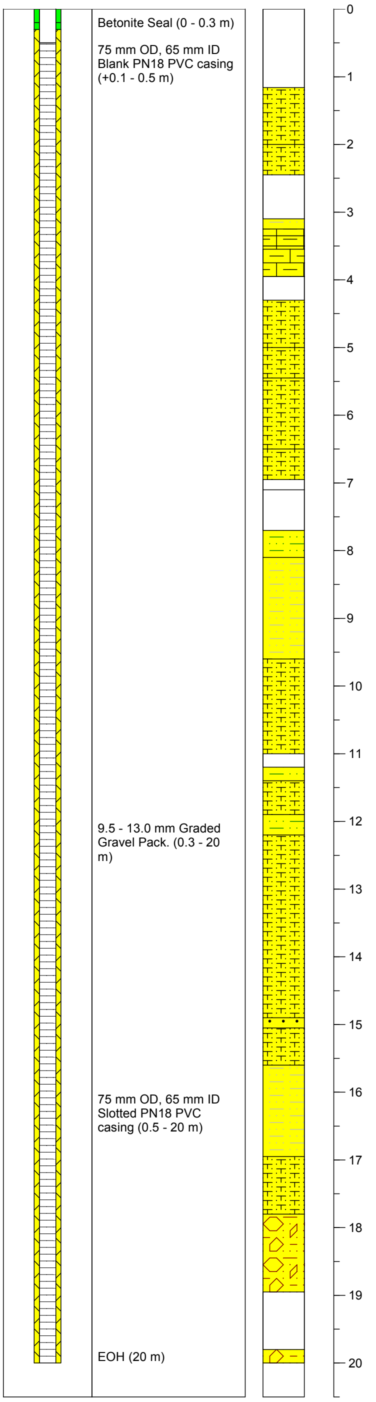
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E010F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**20 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**19.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E010**	EASTING	**293462 mE**
START DATE	**14/4/09**	NORTHING	**7599684 mN**
COMPLETION DATE	**16/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CO**		
SWL	**1.99 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



CORE LOSS

SILTY SAND: Red brown sand is sub rounded to sub angular, poorly sorted, massive quartz major. Silt is only 5% of sample. Sample is poorly consolidated.

SILTY SAND: Red brown sand is sub rounded to sub angular, poorly sorted, massive quartz major. Silt is only 5% of sample. Sample is poorly consolidated.

CORE LOSS: Core loss

SILTY CLAY: Red brown, weathered, well sorted, poor plastic clay 1 to 3 cm brown layer that appears to have micro fossils and sub rounded fine grained quartz.

SANDY CLAY: Brown unweathered, mid plasticicity clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present.

SANDY CLAY: Same as above but slightly less consolidated.

SANDY CLAY: Brown unweathered, mid plasticicity clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present.

CORE LOSS: Core loss

SILTY SAND: Brown unweathered, mid plastic clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present. Lithified well in patches. Micro and macro fossils.

SILTY SAND: Brown unweathered, mid plastic clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present. Lithified well in patches. Micro and macro fossils.

SILTY SAND: Brown, fine to medium sand with 3% silt. Moderately sorted. Very large ooid content. Poorly consolidated. Sand rounded to sub rounded. Occasional fragments of quartz 1 - 4 mm.

SILTY SAND: Brown, fine to medium sand with 3% silt. Moderately sorted. Very large ooid content. Poorly consolidated. Sand rounded to sub rounded. Occasional fragments of quartz 1-4 mm.

CORE LOSS: Core loss

CORE LOSS: Brown, fine to medium sand with 3% silt. Moderately sorted. Very large ooid content. Poorly consolidated. Sand rounded to sub rounded. Occasional fragments of quartz 1-4 mm.

CLAYEY SAND: Brown fine sand with 10% clay, well sorted. No fossils. Slightly more consolidated. Major quartz, sub angular grains, slight iron staining.

SILTY CLAY: Red brown, well sorted with clasts of sandstone 10-25 mm. Poorly plastic. Sandstone is highly lithified, matted. Quartz major. Micro fossils present. Carboniferous with sub angular grains. Minor burrows.

SILTY SAND: Brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content. | 124 mS/cm | 1.5 L/sec

CORE LOSS: Core loss

CLAYEY SAND: Brown fine sand with 10% clay, well sorted. No fossils. Slightly more consolidated but still pretty lose. Major, quartz sub angular, slight iron staining.

SILTY SAND: Brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

CLAYEY SAND: Brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

SILTY SAND: Brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

SAND: Sand red brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

SILTY SAND: Red brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

SILTY CLAY: Red brown, poorly sorted, plastic. No fossils or clasts. Quite stiff. Silty red brown layer, fine to medium sand, moderately sorted, 10%, silt, rounded to sub rounded. Quartz major with minor iron staining. Layers at 16.19 - 16.21 m, 16.34 - 16.36 m, 16.54 - 16.55 m, 16.61 - 16.65 m.

SILTY SAND: Silty sand - brown, fine to medium sand, moderately sorted, 10% silt, rounded to sub rounded, quartz major, minor iron staining. 17.0-17.45 m SPT n*=35

PALEOCHANNEL DEPOSIT: Fine to coarse sand, poorly sorted. Sub rounded to sub angular, 30% gravel. Gravel is made up of dolerite, sandstone, bif, 5 - 40 mm rounded to sub angular, very poorly sorted.

CORE LOSS: Core loss

PALEOCHANNEL DEPOSIT: Tan brown with minor sand. Gravel is medium to very coarse (15 - 70 mm). Made up of bif, dolerite, sandstone, and quartz.

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

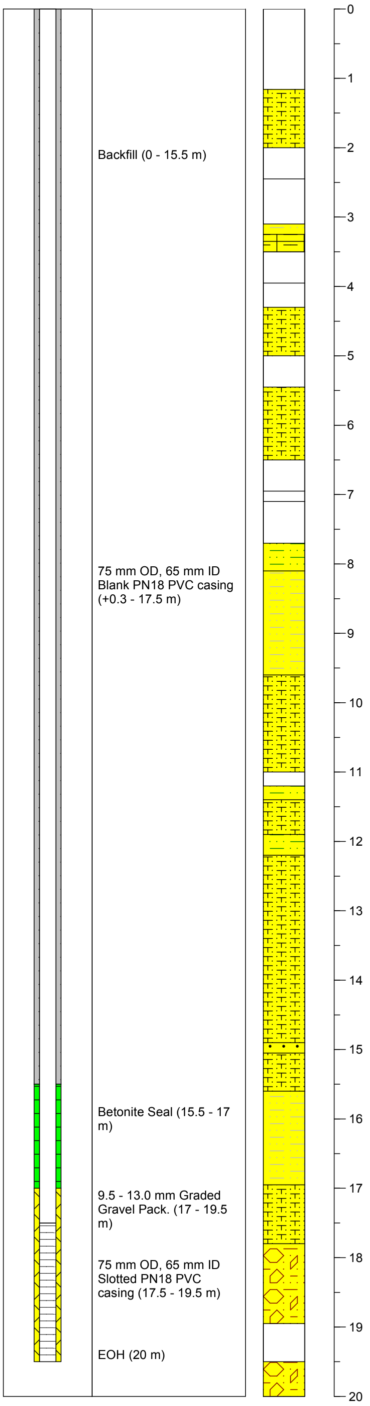
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E010G-I**
DESCRIPTION **Intermediate Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**20 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**19.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E010**	EASTING	**293462 mE**
START DATE	**14/4/09**	NORTHING	**7599684 mN**
COMPLETION DATE	**16/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CO**		
SWL	**2.23 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



DESCRIPTION:

CORE LOSS

SILTY SAND: Red brown sand is sub rounded to sub angular, poorly sorted, massive quartz major. Silt is only 5 % of sample. Sample is poorly consolidated.

SPT

CORE LOSS

SILTY CLAY: Red brown, weathered, well sorted, poor plastic clay 1 to 3 cm brown layer that appears to have micro fossils and sub rounded fine grained quartz.

SANDY CLAY: Brown unweathered, mid plasticicity clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present.

SANDY CLAY: Same as above but slightly less consolidated.

SPT

CORE LOSS

SILTY SAND: Brown unweathered, mid plastic clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present. Lithified well in patches. Micro and macro fossils.

SPT

SILTY SAND: Brown, fine to medium sand with 3% silt. Moderately sorted. Very large ooid content. Poorly consolidated. Sand rounded to sub rounded. Occasional fragments of quartz 1-4 mm.

SPT

CORE LOSS

CORE LOSS: Brown, fine to medium sand with 3% silt. Moderately sorted. Very large ooid content. Poorly consolidated. Sand rounded to sub rounded. Occasional fragments of quartz 1-4 mm.

CLAYEY SAND: Brown fine sand with 10% clay, well sorted. No fossils. Slightly more consolidated. Major quartz, sub angular grains, slight iron staining.

SILTY CLAY: Red brown, well sorted with clasts of sandstone 10-25 mm. Poorly plastic. Sandstone is highly lithified, matted. Quartz major. Micro fossils present. Carboniferous with sub angular grains. Minor burrows.

SILTY SAND: Brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

CORE LOSS

CLAYEY SAND: Brown fine sand with 10% clay, well sorted. No fossils. Slightly more consolidated but still pretty lose. Major, quartz sub angular, slight iron staining.

SILTY SAND: Brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

CLAYEY SAND: Brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

SILTY SAND: Brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

SAND: Sand red brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

SILTY SAND: Red brown fine to medium sand with 10% silt. Rounded to sub rounded. Poorly sorted. Quartz major. Minor staining. Poorly to moderately consolidated. No fossil content.

SILTY CLAY: Red brown, poorly sorted, plastic. No fossils or clasts. Quite stiff. Silty red brown layer, fine to medium sand, moderately sorted, 10%, silt, rounded to sub rounded. Quartz major with minor iron staining. Layers at 16.19-16.21 m, 16.34-16.36 m, 16.54-16.55 m, 16.61-16.65 m.

SILTY SAND: Silty sand - brown, fine to medium sand, moderately sorted, 10% silt, rounded to sub rounded, quartz major, minor iron staining. 17.0-17.45 SPT.

PALEOCHANNEL DEPOSIT: Fine to coarse sand, poorly sorted. Sub rounded to sub angular, 30% gravel. Gravel is made up of dolerite, sandstone, bif, 5-40 mm rounded to sub angular, very poorly sorted.

CORE LOSS

PALEOCHANNEL DEPOSIT: Tan brown with minor sand. Gravel is medium to very coarse (15-70 mm). Made up of bif, dolerite, sandstone, and quartz.

AIRLIFT YIELD: 3 L/sec

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

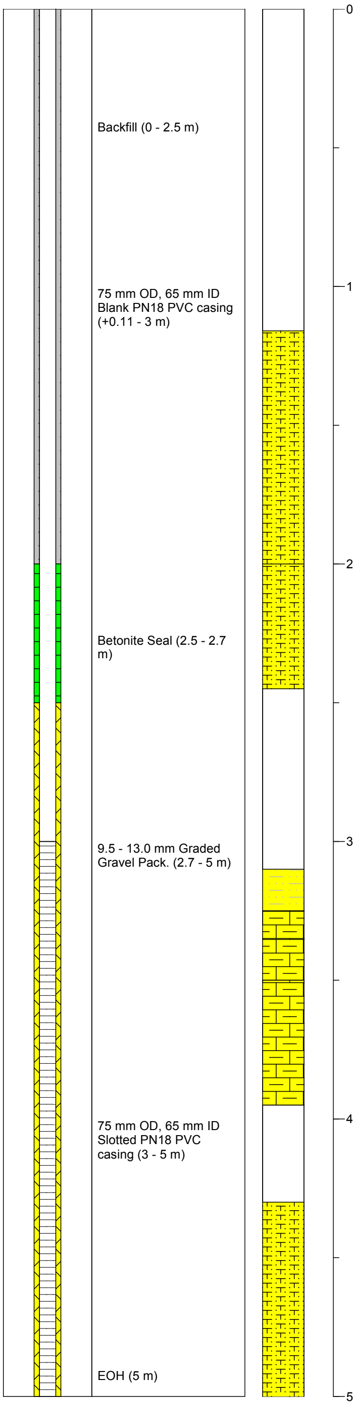
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E010G-S**
DESCRIPTION	**Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E010**	EASTING	**293462 mE**
START DATE	**14/4/09**	NORTHING	**7599684 mN**
COMPLETION DATE	**16/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CO**		
SWL	**1.94 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



DESCRIPTION	FIELD EC	AIRLIFT YIELD
CORE LOSS: Core loss		
SILTY SAND: Red brown sand is sub rounded to sub angular, poorly sorted, massive quartz major. Silt is only 5 % of sample. Sample is poorly consolidated.		
SILTY SAND: Red brown sand is sub rounded to sub angular, poorly sorted, massive quartz major. Silt is only 5 % of sample. Sample is poorly consolidated.		
CORE LOSS: Core loss		
SILTY CLAY: Red brown, weathered, well sorted, poor plastic clay 1 to 3cm brown layer that appears to have micro fossils and sub rounded fine grained quartz.		
SANDY CLAY: Brown unweathered, mid plasticity clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present.		
SANDY CLAY: Same as above but slightly less consolidated.		
SANDY CLAY: Brown unweathered, mid plasticicity clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present.		
CORE LOSS: Core loss	90.8 L/sec	0.5 L/sec
SILTY SAND: Brown unweathered, mid plastic clay 20% sand. Sand is sub rounded to sub angular, poorly sorted. Sample is partially consolidated, major shell fragments present. Lithified well in patches. Micro and macro fossils.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

URS

BORE COMPLETION REPORT

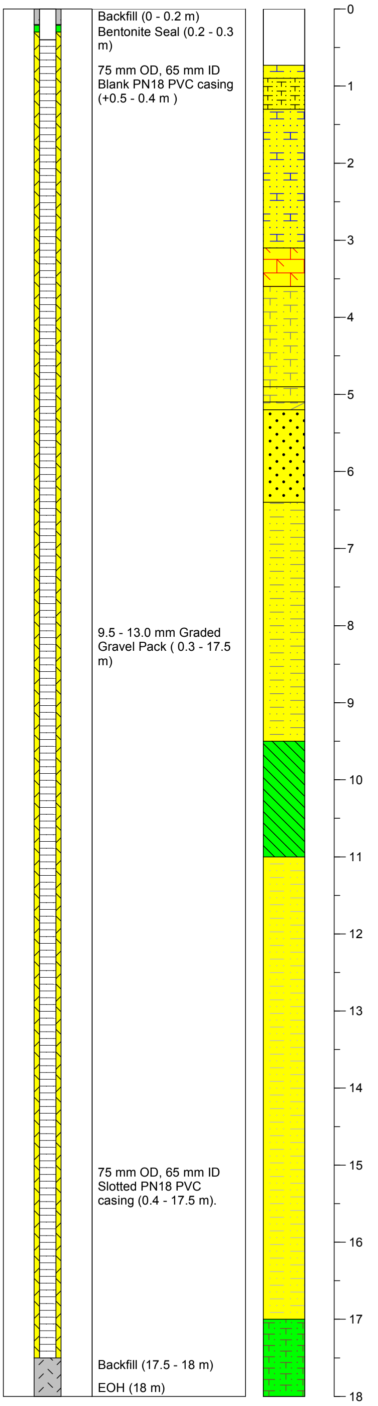
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E011F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond (Reamed - PWT)**
TOTAL DRILLED DEPTH	**18**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**17.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E011**	EASTING	**294123 mE**
START DATE	**12/4/09**	NORTHING	**7600692 mN**
COMPLETION DATE	**14/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**TBC**		
SWL	**0.86 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
CORE LOSS		
CALCAREOUS SANDSTONE: Creamy brown, vuggy, fine to medium grained sand (quartz), hard, well cemented and lithified.		
SILTY SAND: Brown, fine, well sorted, sub angular to sub rounded quartz, dark minerals (20%).		
CALCAREOUS SANDSTONE: Creamy light brown, fine to medium grained, very vuggy from 1.3 - 2 m, poorly sorted, sub angular, moderate to well sorted quartz, some shells.		
CALCAREOUS SAND: Creamy light brown, fine to medium grained, very vuggy from 1.3 - 2 m, poorly sorted, sub angular, moderate to well sorted quartz, some shells.		
SAND/SANDSTONE: Moderately lithified sand/sandstone, grading into soft, unlithified brown sand, fine to medium grained, moderate to well sorted, sub angular to sub rounded quartz, dark minerals (20%) abundant fine, rounded.		
SAND/SANDSTONE: Shell fragments and minor calcrete nodules. Moderately lithified sand/sandstone, grading into soft, unlithified brown sand, fine to medium grained, moderate to well sorted, sub angular to sub rounded quartz, dark minerals (20%) abundant fine, rounded.		
GRAVELLY SAND: Soft gravelly sandy layer, angular abundant gravels.		
SAND: Brown, fine to medium grained, becoming finer grained, well sorted, compact at base, grading to silty sand at base.		
CLAY SILT SILTSTONE: Very fine, hard red/brown coarsening towards 8.4 m, before grading to firm brown clay, smooth, moderately plastic, occasional calcrete nodules throughout.	77.3 mS/cm	1.6 L/sec
CLAY: Brown silty, in parts firm, moderately plastic, slightly mottled 30mm calcrete bands at 9.5 m, band of clayey sand, and fine at 9.6 m and 9.8 m.		
SILTY CLAY: Mottled, firm to moderate to high plasticity, patches of minor vuggy very fine sand, fine to coarse grained. Band of abundant calcrete nodules from 14.2 to 14.7 m, becomes claystone at 14.2 m, hard, calcrete and possibly carbonate inclusions, SPT refusal.		
CLAYSTONE: Creamy orange - brown, claystone/sandstone, fine to medium grained, abundant calcrete nodules, gritty, calcareous.		

DRAWN BY **CE** DATE **25/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

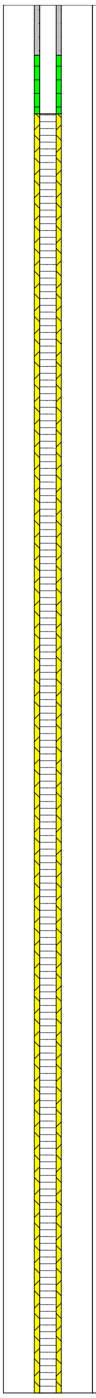
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E012F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**16.6 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**16.6 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E013**	EASTING	
START DATE	**10/4/09**	NORTHING	
COMPLETION DATE	**11/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**DL**		
SWL	**1.00 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



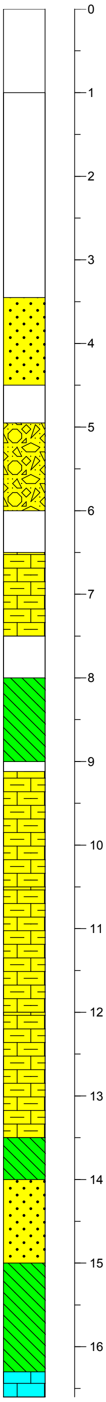
Backfill (0 - 0.6 m)

75 mm OD, 65 mm ID Blank PN18 PVC casing (0 - 1.3 m)
Bentonite Seal (0.6 -1.3 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (1.3 - 16.6 m)

9.5 - 13.0 mm Graded Gravel Pack. (1.3 16.6 m)

EOH (16.6 m)



CORE LOSS: Core Loss

SAND: Sandy, red/brown.

CORE LOSS: Core Loss

GRAVEL: Sandy, gravel, red/brown, silty, with componants up to 5 cm.

CORE LOSS: Core Loss

SANDY CLAY: Red/brown sandy clay angular.

CORE LOSS: Core Loss

CLAY: Light red/brown clay plastic with minor sand.

CORE LOSS: Core Loss

SANDY CLAY: Red/brown sandy clay, angular.

SANDY CLAY: Red sandy clay.

SANDY CLAY: Red, grey minor sandy clay with silt.

CLAY: Red/brown clay with lime grey sand lenses.

SAND: Red/brown sand with increasing clay content.

CLAY: Clay and silt, red brown with some limestone.

LIMESTONE: Red/brown solid.

FIELD EC: 91.6 mS/cm

AIRLIFT YIELD: 1.2 L/sec

DRAWN BY **CE** DATE **25/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

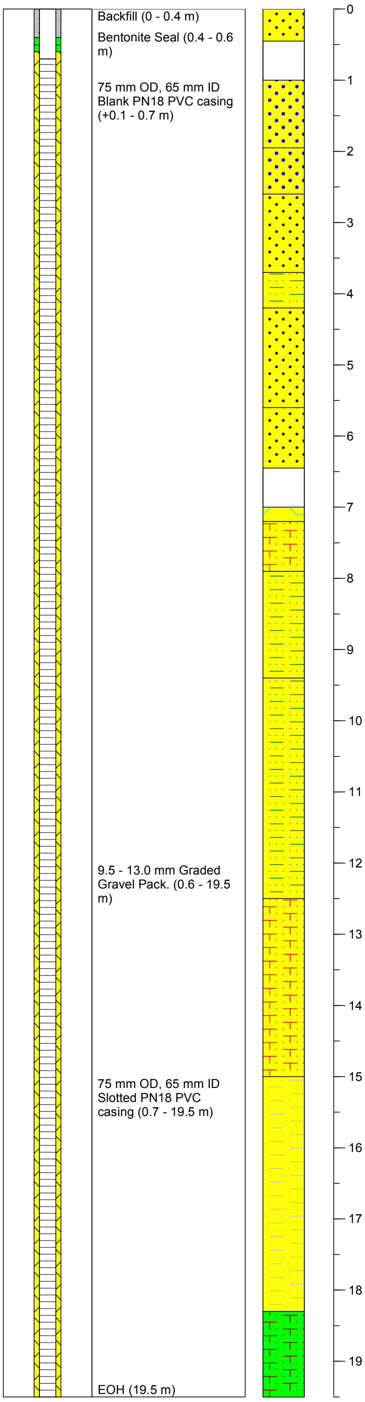
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E013F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**19.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**19.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E013**	EASTING	**295014 mE**
START DATE	**10/4/09**	NORTHING	**7600692 mN**
COMPLETION DATE	**11/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**DL**		
SWL	**1.00 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Very fine to fine grained, poor - moderately sorted, sub angular - sub rounded quartz with 15% darker minerals, 5% feldspar, loose, brownish/white.		
CORE LOSS: As above; shelly material present.		
SANDSTONE: Moderately well cemented, hard, calcareous, fine to coarse grained, poorly sorted quartz in a silty matrix, creamy orange, some shells.		
SANDSTONE: As above, fine to medium grained, becomes calcareous at 2.3 m, moderate cementing, poorly sorted, very coarse (2 mm) quartz and feldspar, angular - sub angular grains, some carbonate.		
SAND: Poor - moderate cementing, poorly sorted, sub angular - angular, fine to coarse grained quartz and feldspar, shell fragments, creamy brown. (Becomes finer grained 3 - 3.45 m, shell rich layer 3.5 - 3.6 m, loose, poorly cemented at the base).		
CLAYEY SAND: Fine grained, moderately sorted qtz / feld, soft, moderate plasticity clay, no shells, but foramnifera present, well compacted.		
SAND: Fine to medium grained, loose, sub angular - sub rounded, poor - moderately sorted, moderately hard, some cementing, no shells, qtz/feld, calcareous, becomes softer.		
SAND: Finer grained than above, brown with some clay, moderately sorted, grading into brown clayey sand, fine - very fine grained at 5.9 m.		
CORE LOSS		
CLAYEY SILT: Dark brown, firm - brittle.		
SANDY SILTY CLAY: With gravel, angular to sub rounded gravels.		
CLAYEY SAND: Grading to sandy clay, grading to silty clay. Brown - red brown, firm - hard, sand is fine grained, calcrete bands at 8.3 and 8.7 m to 20 mm in thickness, silty clay from approx. 8.8 m.		
CLAYEY SAND: Red Brown, fine grained, well sorted quartz, moderately hard, moderate - low lithification, rare patches of calcrete at around 9.6 m, patches of silty clay, hard at 10.2 m. Becomes coarser (fine - medium) grained at 11.1 m and slightly softer before grading into silty sandy clay & hard clay from 11.3 - 11.8 m, sharp contact back to clayey sand, silty, more clay from 12 m.	91.6 mS/cm	1.2 L/sec
SANDY SILTY CLAY: Red brown, as above, very fine, well sorted, mottled, fim clay, broken with finger pressure, frequent calcrete clasts, grading sandier (fine grained) at approx. 14.9 m.		
SILTY CLAY: As above, minor patches of sand with some claystone, frequent whitish calcrete nodules, hard, mottled, broken by finger pressure. Less calcrete from 16.7 m.		
CLAYSTONE SILTSTONE: Contains patches of Sandstone. Gritty, orange brown, less calcrete but there is one band at 19.3 m.		

DRAWN BY **CE** DATE **25/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

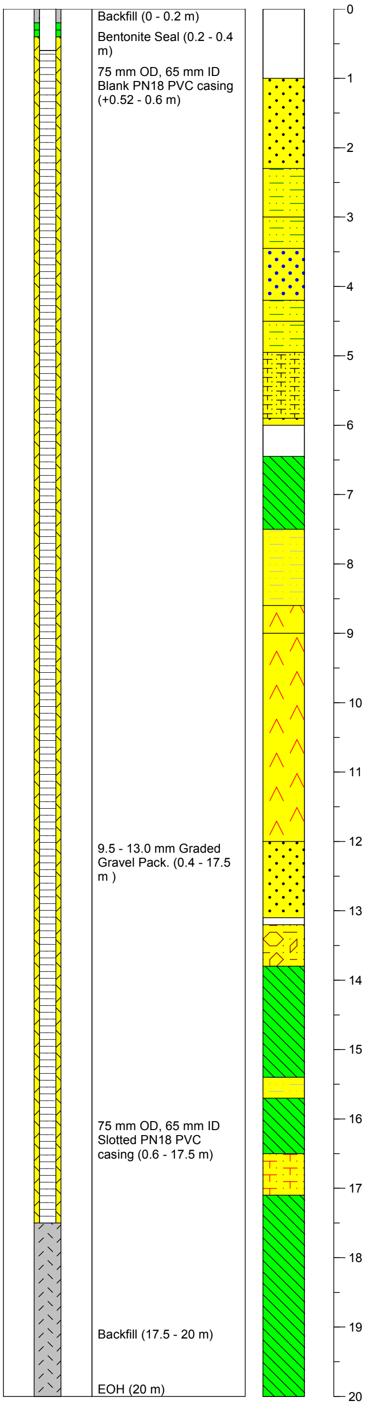
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E015F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond**
TOTAL DRILLED DEPTH **20 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **17.5 m**
CASING DIAMETER **65 mm ID**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E015**
START DATE **8/4/09**
COMPLETION DATE **9/4/09**
LOGGED BY **GB**
SWL **3.84 m bgl**
EASTING **290894 mE**
NORTHING **7596347 mN**
R.L. OF COLLAR **TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
CORE LOSS: Most likely sand.		
SAND: Red brown, fine grained, well sorted, sub angular to sun rounded (mostly sub rounded), slightly clayey (5%).		
CLAYEY SAND: Grades into clayey sand with well cemented sandstone nodules, fine grained.		
CLAYEY SAND: Fine to medium grained becomes more calcareous at 3.3 m moderately cemented, poorly sorted very coarse (2 mm) quartz feldspar angular to sub angular, some carbonate.		
SANDSTONE: Hard, moderately well cemented sandstone, medium to coarse sandy gravels quartz and minor carbonate, occassional large (up to 30 mm) shell fragments, some poorly consolidated quartz sand, creamy brown to reddy brown, sands/ sandstone, poorly sorted, generally sub angular, sandy gravel, angular.		
CLAYEY SAND: Grades into clayey sand, light brown, fine to medium grained quartz, sub angular to sub rounded, moderately sorted, minor nodules of weakly cemented whitish carbonate, sand rich and cemented sandstone at base.		
CLAYEY SAND: Grades into fine to medium grained sand, loose, sub angular to sub rounded, poor to moderately sorted, moderately hard, some cementing, no shells, quartz feldspar, calcareous, becomes softer.		
SILTY SAND: Minor clay, chocolate brown, very fine to fine grained, moderately sorted, sub angular to sub rounded (generally sub angular), quartz.		
SAND: Poorly consolidated, sand/ sandstone/ brittle with frequent well rounded ooids, minor shell fragments.		
CORE LOSS		
CLAY: Brown, firm to hard, moderately plasticity, becoming harder at base with occassional claystone nodules.		
SILTY CLAY: Brown/red, firm to hard,moderate plasticity, brittle in sections, occassional weakly cemented siltstone nodules.		
CLAYEY SILTY SAND: Red/brown, fine grained, well sorted, sub rounded quartz.		
CLAYEY SILTY SAND: As above becomes fine to medium grained, less clay from 9 -11 m, soft to slightly firm, low to medium plasticity.	104.2 mS/cm	0.5 L/sec
SAND: Red/ brown, fine to medium gained, moderately sorted, sub-angular to sub rounded quartz		
CALCRETE: Brittle		
PALEOCHANNEL DEPOSIT: Fine to coarse, poorly sorted, becoming coarser (upward fining sequence) sub angular to sub rounded, pebble size (up to 16 mm), river bed gravels to 13.5 m, gravel content to 13.8 m.		
CLAY: Red/brown, clay/ claystone, hard, very fined grained, mottled, patches of fine grained sand (quartz), sub angular to sub rounded, moderately sorted.		
SILTY CLAY: As above but silty.		
CLAY: Clay/ claystone, same as from 13.8 to 15.4 m, mottled, brittle (finger pressure), some hard calcrete and sandstone nodules.		
SANDY SILTY CLAY: Red/ brown, fine grained.		
CLAY: Creamy brown, with frequent white, hard calcrete, nodules and altered quartz rich sandstone, becomes silty 18.6 to 20.0 m, increased calcrete content, firm 18 to 19.5 m, with green/ grey brittle clay.		

DRAWN BY **CE** DATE **2/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

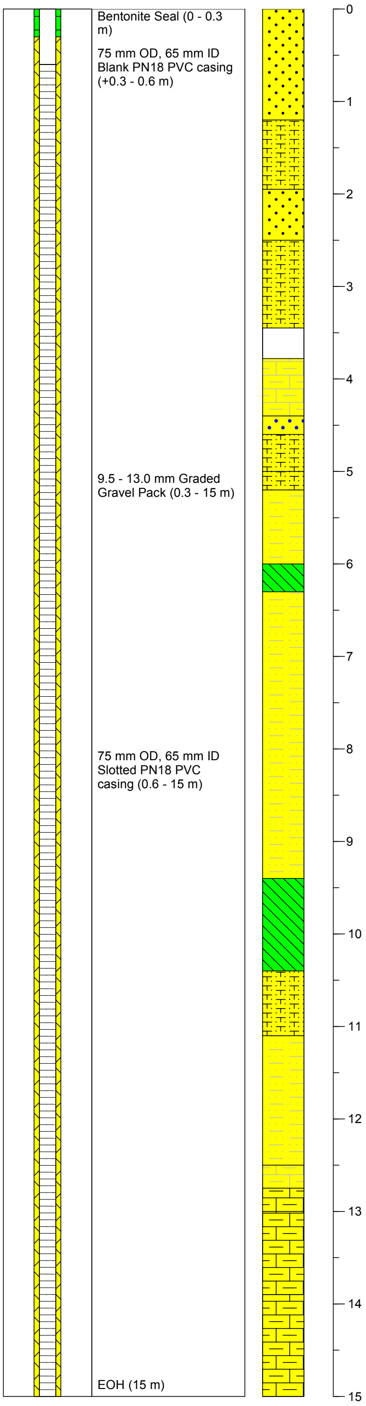
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E016F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond**
TOTAL DRILLED DEPTH **15 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **15 m**
CASING DIAMETER **65 mm ID**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E016**
START DATE **6/4/09**
COMPLETION DATE **6/4/09**
LOGGED BY **GB**
SWL **3.11 m bgl**
EASTING **0290313 mE**
NORTHING **7596335 mN**
R.L. OF COLLAR **TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Red brown, silty, fine to medium grained, sub angular, moderately sorted, soft, loose.		
SILTY SAND: Red brown, very fine to fine grained, sub angular, moderately well sorted, silty.		
SAND: Red brown, fine to medium grained, silty, poorly sorted, soft, minor cemented sandstone nodules.		
SILTY SAND: Red brown, very fine to fine grained, silty, soft, minor gravelly sandstone nodules, minor grey medium grained sandstone nodules.		
CORE LOSS: Red brown, ferruginous fragments, very fine silty clay, minor bands of hard moderately cemented clay.		
GRAVELLY CLAY: Red brown, fine to medium sand, minor cemented sand, sugary texture, minor shell fragments, moderately hard.		
SANDSTONE: Brown, well cemented, hard, oxidized in part, limestone, calcareous		
SILTY SAND: Red brown, very fine to fine grained, minor coarse quartz grains, sub angular.		
SILTY SAND: Red brown, shell fragments, very fine silty, minor white shells and gravels, well rounded.		
SILTY CLAY: Red brown to brown, fine silty sand in clay matrix, minor cemented carbonaceous fragments.		
CLAY: Red brown, silty, minor holes/ veinlets, lake clay, saline, brittle.		
SILTY CLAY: Red brown, very fine silty grains, mod sorted, soft.	96.3 mS/cm	0.1 L/sec
CLAY: Red brown, silty, soft, brittle, becoming well consolidated.		
SILTY SAND: Red brown, very fine to fine grained, sub angular, soft.		
SILTY CLAY: Red brown, very fine silty sand, clay matrix.		
GRAVELLY CLAY: Red brown, very fine to fine grained quartz sand, sub angular, brittle clay, slightly plastic, minor nodules of well cemented sandstone.		
SANDY CLAY: Red brown, as above with little nodules.		
SANDY CLAY: Red brown, fine to medium quartz sand in clay martix, minor well cemented sandstone nodules/ gravel.		
SANDY CLAY: Red brown, mottled grey, fine to medium quartz sand, hard, well cemented, nodules, well consolidated, hard.		

DRAWN BY **CO** DATE **26/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

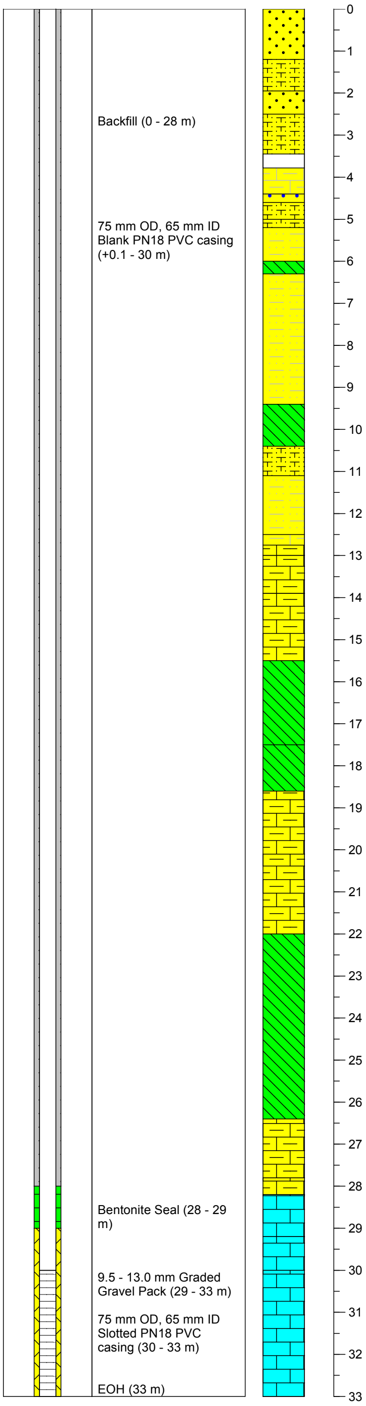
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E016G-D**
DESCRIPTION **Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**33 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**33 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E016**	EASTING	**0290313 mE**
START DATE	**3/4/09**	NORTHING	**7596335 mN**
COMPLETION DATE	**6/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**3.69 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Red brown, silty, fine to medium grained, sub angular, moderately sorted, soft, loose.		
SILTY SAND: Red brown, very fine to fine grained, sub angular, moderately well sorted, silty.		
SAND: Red brown, fine to medium grained, silty, poorly sorted, soft, minor cemented sandstone nodules.		
SILTY SAND: Red brown, very fine to fine grained, silty, soft, minor gravelly sandstone nodules, minor grey medium grained sandstone nodules.		
CORE LOSS: Red brown, ferruginous fragments, very fine silty clay, minor bands of hard moderately cemented clay.		
GRAVELLY CLAY: Red brown, fine to medium sand, minor cemented sand, sugary texture, minor shell fragments, moderately hard.		
SANDSTONE: Brown, well cemented, hard, oxidized in part, limestone, calcareous.		
SILTY SAND: Red brown, very fine to fine grained, minor coarse quartz grains, sub angular.		
SILTY SAND: Red brown, shell fragments, very fine silty, minor white shells and gravels, well rounded.		
SILTY CLAY: Red brown to brown, fine silty sand in clay matrix, minor cemented carboneous fragments.		
CLAY: Red brown, silty, minor holes/ veinlets, lake clay, saline, brittle.		
SILTY CLAY: Red brown, very fine silty grains, moderately sorted, soft.		
CLAY: Red brown, silty, soft, brittle, becoming well consolidated.		
SILTY SAND: Red brown, very fine to fine grained, sub angular, soft.		
SILTY CLAY: Red brown, very fine silty sand, clay matrix.		
GRAVELLY CLAY: Red brown, very fine to fine grained quartz sand, sub angular, brittle clay, slightly plastic, minor nodules of well cemented sandstone.		
SANDY CLAY: Red brown, as above with little nodules.		
SANDY CLAY: Red brown, fine to medium quartz sand in clay martix, minor well cemented sandstone nodules/ gravel.		
SANDY CLAY: Red brown, mottled grey, fine to medium quartz sand, hard, well cemented, nodules, well consolidated, hard.		
CLAY: Red brown, mottled grey, silty, minor fine sand, well consolidated, hard, minor cemented sandstone bands, numerous hollow rootlet/ veinlet tubes in grey clay, minor black organics on fracture/ bedding planes.		
CLAY: Red brown, mottled grey, black mineral/ organics, well consolidated, hard, brittle, minor rootlet channels, very little sand.		
SANDY CLAY: Red brown, mottled grey, minor sandstone nodules, hard, large nodules calcareous.		
SANDY CLAY: Red brown, silty to sandy, fine to medium quartz, sub angular, very well consolidated, hard, mottled grey, minor sandstone nodules, well cemented.		
CLAY: Red brown, silty, brittle, hard, well consolidated, mottled grey, minor black material (organic), minor dolerite nodules, minor pisolite gravel.		
SANDY CLAY: Red Brown, very fine to medium quartz, sub rounded to sub angular, silty brittle clay matrix, well consolidated, mottled grey, minor well cemented sandstone bands/ nodules, minor pisolite gravel.		
SANDY CLAY: Red brown, limestone nodules, sandy clay matrix, limestone breccia, cream grey, hard, well cemented.		
LIMESTONE: Trealla. Yellow cream, well cemented, calcareous, minor dolerite, minor fractures, minor weathering of fractures.		
LIMESTONE: Trealla. Yellow cream, breccia, large cobbles, shells and red brown sands, hard, infilled vuggs with clay.		
LIMESTONE: Trealla. Yellow brown, carboneous, soft, moderately weathered, medium quartz sand, mottled red brown, clayey interbedded hard cemented and weathered clayey bands, breccia.	155.9 mS/cm	2.5 L/sec

DRAWN BY **CO** DATE **26/6/09** CHECKED BY **DL** APPENDIX

URS BORE COMPLETION REPORT

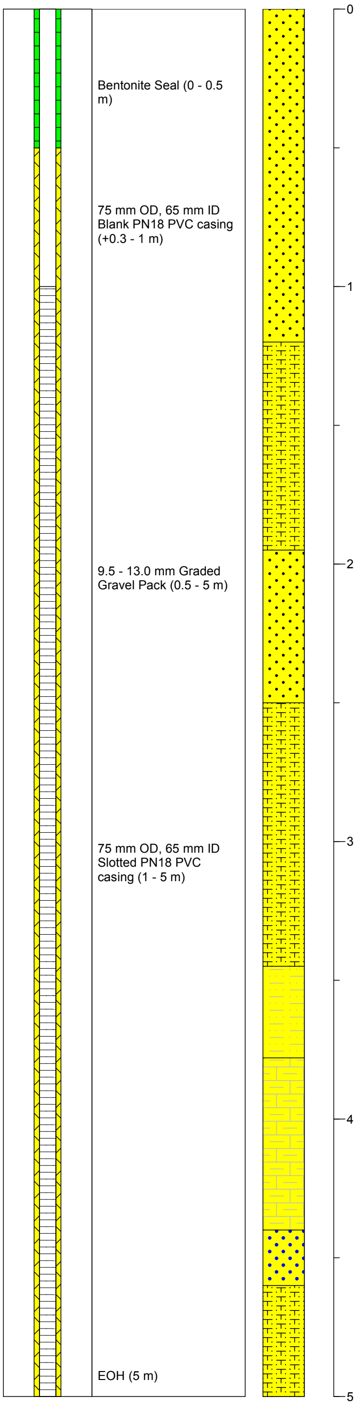
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E016G-S**
DESCRIPTION **Shallow Groundwater Monitoring Bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond**
TOTAL DRILLED DEPTH **5 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **5 m**
CASING DIAMETER **65 mm ID**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E016**
START DATE **31/3/09**
COMPLETION DATE **1/4/09**
LOGGED BY **GB**
SWL **3.10 m bgl**
EASTING **0290313 mE**
NORTHING **7596335 mN**
R.L. OF COLLAR **TBA**

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD



SAND: Red brown, silty, fine to medium grained, sub angular, moderately sorted, soft, loose.

SILTY SAND: Red brown, very fine to fine grained, sub angular, moderately well sorted, silty.

SAND: Red brown, fine to medium grained, silty, poorly sorted, soft, minor cemented sandstone nodules.

SILTY SAND: Red brown, very fine to fine grained, silty, soft, minor gravelly sandstone nodules, minor grey medium grained sandstone nodules.

SILTY CLAY: Red brown, ferruginous fragments, very fine, silty clay, minor bands of hard moderately cemented clay.

GRAVELLY CLAY: Red brown, fine to medium sand, minor cemented sand, sugary texture, minor shell fragments, moderately hard.

SANDSTONE: Brown, well cemented, hard, oxidized in part, limestone, calcareous

SILTY SAND: Red brown, very fine to fine grained, minor coarse quartz grains, sub angular.

FIELD EC: 44.0 mS/cm

DRAWN BY **CO** DATE **26/6/09** CHECKED BY **DL** APPENDIX

URS

BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

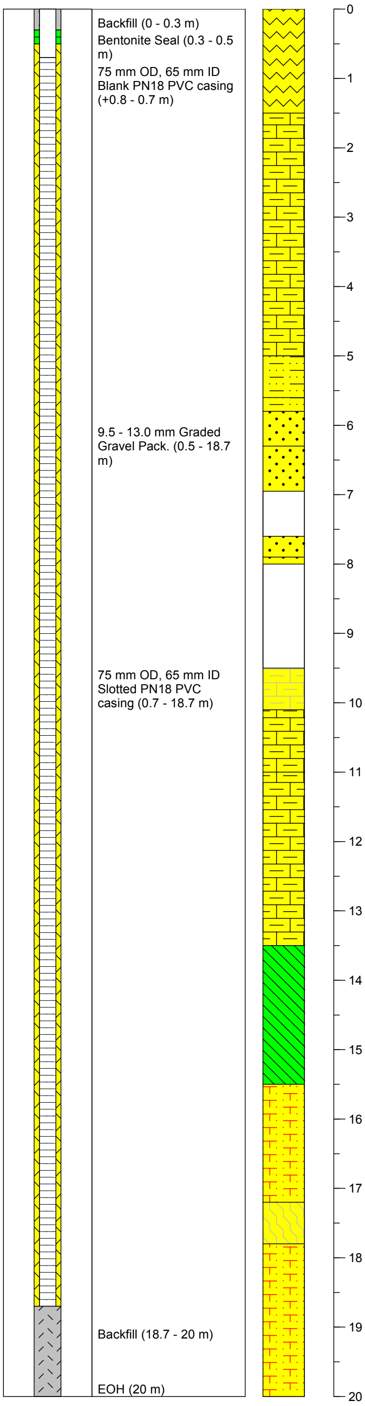
BOREHOLE **E017F**

DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**20 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**18.7 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E017**	EASTING	**292711 mE**
START DATE	**25/3/09**	NORTHING	**7598613 mN**
COMPLETION DATE	**30/3/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**1.07 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



CLAYEY SAND LOAM: Red brown, silty clay, fine to medium quartz in clay matrix, sub angular, minor roots, mottled grey/ yellow/ red clay.

SANDY CLAY: Red brown, minor gypsum crystals, damp, soft, fine to medium quartz in silty matrix, minor gravelly bands, minor grey sandy bands.

SANDY SILT: Red brown, very fine to fine gravel sand,quartz, silty, sub angular, moderately sorted, moderately competent, becoming soft.

SANDY SILT: Red brown, as above with coarse gravel, well rounded, minor river gravel.

SAND: Red brown, very fine to fine grained, sub angular to sub rounded, well sorted, loose, soft, minor gravel at 6.2 m, moderately well rounded, sand matrix.

SAND: Red brown, as above with minor silty clay matrix.

CORE LOSS

SAND: Red brown, very fine to fine gravel, quartz, well sorted, sub angular to sub rounded.

SAND: Red brown sand as above, very coarse to medium river gravel, well rounded up to 40 mm.

CORE LOSS: Gravelly.

GRAVELLY CLAY: Red brown, very coarse to medium, well rounded, clayey matrix.

SANDY CLAY: Red brown, medium quartz, well consolidated, hard.

SANDY CLAY: Red brown, slightly vuggy calcrete in silt to sandy clay matrix, minor rootlet viens, grey green on edges, minor silcrete at 12 m, siliceous, mottled with black on cracking clay joint, mottled grey, sugary.

CLAY: Red brown, mottled black and grey green, brittle, hard, well compacted.

SANDY SILTY CLAY: Red brown, very fine to medium grained quartz, sub angular, mottled grey.

SANDY GRAVEL: Red brown, fine to medium grained quartz sand, gravel up to 10 mm, well rounded, moderately hard.

SANDY SILTY CLAY: Red brown, fine to medium grained sand, mottled grey, minor nodules of well cemented sandstone, calcareous.

FIELD EC: 107.8 mS/cm

AIRLIFT YIELD: 2 L/sec

DRAWN BY **BP** DATE **26/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

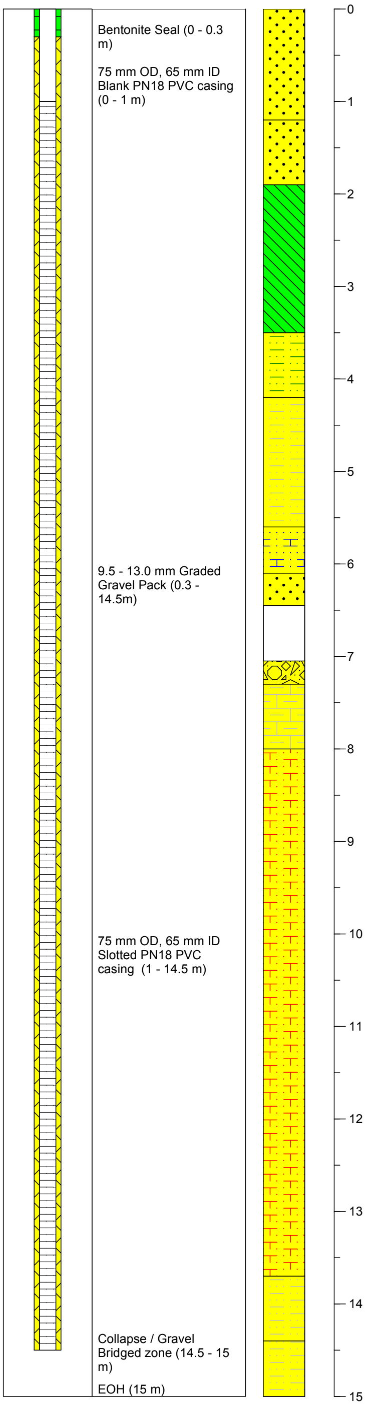
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E018F**
DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond (Reamed - PWT)**
TOTAL DRILLED DEPTH	**15 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**14.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E018**	EASTING	**293920 mE**
START DATE	**14/4/09**	NORTHING	**7600287 mN**
COMPLETION DATE	**17/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**1.57 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Brown fine to medium grained, occasional coarser grained fragments. Becoming coarser towards base, moderately sorted, sub angular to sub rounded quartz, minor feldspar and dark minerals, slightly firm.		
SAND: Grades into silty sand/silty sandy clay. Slightly firm, moderately plastic, lighter brown, fine sand.		
CLAY: Light brown, soft, moderately plastic to highly plastic, occasional patches of silty sand, harder towards base, creamy brown with (3.0 m) yellow patches, black soft, mud from 3 m and gypsum at 3.5 m approx.		
CLAYEY SAND: Grades to clayey sand, dark brown, fine, soft, low to moderately plastic.		
SILTY CLAY: Low moderately plastic, soft, dark brown.		
CALCAREOUS SANDSTONE: Fine to medium grained, vuggy, hard, well cemented, creamy orange		
SAND: Slightly clayey, angular, fine to medium grained, occasional very coarse. Poorly sorted and brown		
CORE LOSS		
GRAVEL: Angular gravels and cobble, some sub angular, creamy brown, calcareous.		
GRAVELLY CLAY: Grades to gravelly clay.		
SANDY SILTY CLAY: Silty, sandy clay, hard, brown.		0.5 L/sec
SILTY CLAY: Grades to silty, sandy clay, fine grained sand, hard.		
SILTY CLAY: Grades to patches of red, hard, mottled clasts of silty clay with frequent calcrete clasts and black spots. (Claystone, brittle, broken by finger pressure).		

DRAWN BY **CE** DATE **26/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

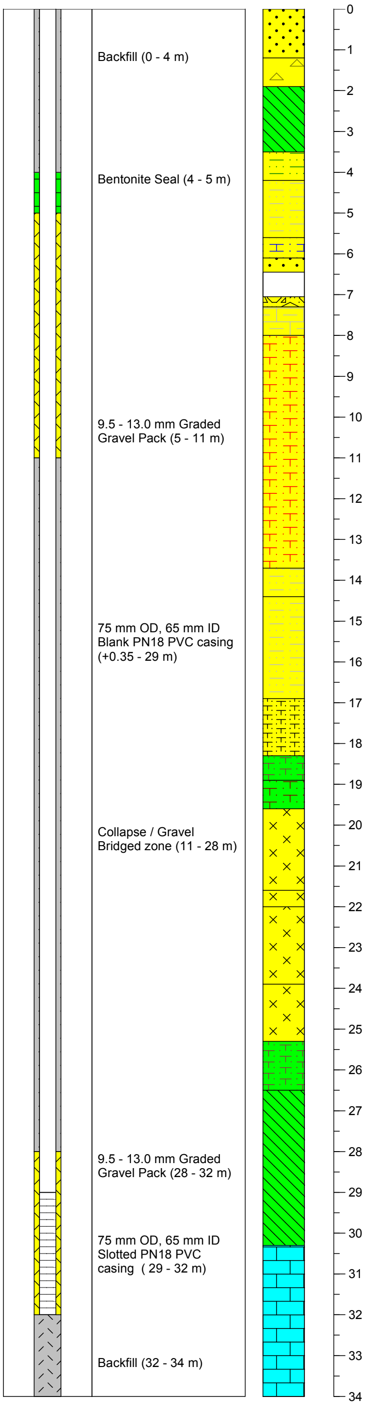
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E018G-D**
DESCRIPTION **Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond (Reamed - PWT)**
TOTAL DRILLED DEPTH	**34 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**32 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E018**	EASTING	**293920 mE**
START DATE	**14/4/09**	NORTHING	**7600287 mN**
COMPLETION DATE	**17/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**2.31 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Brown fine to medium grained, occasional coarser grained fragments. Becoming coarser towards base, moderately sorted, sub angular to sub rounded quartz, minor feldspar and dark minerals, slightly firm.		
SAND/SILTY SANDY CLAY: Grades into silty sand/silty sandy clay. Slightly firm, moderately plastic, lighter brown, fine sand.		
CLAY: Light brown, soft, moderately plastic to highly plastic, occasional patches of silty sand, harder towards base, creamy brown with (3.0 m) yellowy patches, black soft, mud from 3 m and gypsum at 3.5 m approx.		
CLAYEY SAND: Grades to clayey sand, dark brown, fine, soft, low to moderately plastic.		
SILTY CLAY: Low moderately plastic, soft, dark brown.		
CALCAREOUS SANDSTONE: Fine to medium grained, vuggy, hard, well cemented, creamy orange		
SAND: Slightly clayey, fine to medium grained with occasional very coarse angular, poorly sorted, brown		
CORE LOSS		
GRAVEL: Angular gravels and cobbles, some sub angular, creamy brown, calcareous		
GRAVELLY CLAY: Grades to gravelly clay		
SANDY SILTY CLAY: Silty, sandy clay, hard, brown		
SILTY CLAY: Grades to silty, sandy clay, fine grained sand, hard.		
SILTY CLAY: Grades to patches of red, hard, mottled clasts of silty clay with frequent calcrete clasts and black spots. (Claystone, brittle, broken by finger pressure).		
SILTY SAND: Silty sand with minor clay, dark reddish brown, very fine to fine sand, moderately lithified, brittle, firm broken by finger pressure.		
CLAYSTONE: Grades to red brown claystone, hard, brittle (finger pressure) with increasing calcrete/sandstone clasts.		
CLAYSTONE SILTSTONE: Very fine sand, well lithified, orange brown, very hard.		
SILTY CLAYSTONE: Claystone with pebbles of fine sand, hard, orange brown (lighter then above) patches of soft grey clay frequent, silty and sandy and Calcrete.		
SILTY CLAYSTONE: Sharp contact to cream, hard silty claystone, with patches of grey soft, silty clay, frequent sands/fine		
SILTY CLAYSTONE: Mottled, red with occasional sands and auth calcrete.		
SILTY CLAYSTONE: Fine to medium grained, moderately sorted, mostly sub rounded quartz, minor feldspar, red/brown, harder stronger lithified patches.		
CLAYSTONE: Grading into silty sandstone, creamy, poorly sorted, and moderately cemented very hard.		
CLAY: Weathered carbonate clayey, creamy white, very fine grained, bands of brown, fractured carbonates at top, strong calcrete, becomes more clayey at 27 m with hard unweathered inclusions (clasts) becoming fresher at 29 m, minor sandy layers, orange/red/white colour variations.		
LIMESTONE: White, hard, creamy orange clay in filled and some calcrete replacement.		2.66 mbgl

DRAWN BY **CE** DATE **26/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

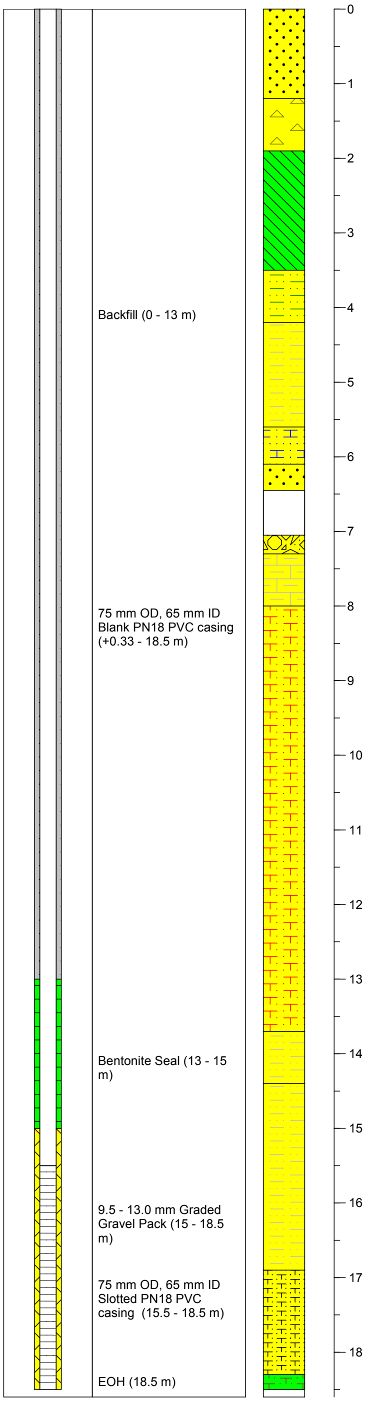
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E018G-I**
DESCRIPTION **Intermediate Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond (Reamed - PWT)**
TOTAL DRILLED DEPTH	**18.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**18.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E018**	EASTING	**293920 mE**
START DATE	**14/4/09**	NORTHING	**7600287 mN**
COMPLETION DATE	**17/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**1.85 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



SAND: Brown fine to medium grained, occasional coarser grained fragments. Becoming coarser towards base, moderately sorted, sub angular to sub rounded quartz, minor feldspar and dark minerals, slightly firm.

SAND/SILTY SANDY CLAY: Grades into silty sand/silty sandy clay. Slightly firm, moderately plastic, lighter brown, fine sand.

CLAY: Light brown, soft, moderately plastic to highly plastic, occasional patches of silty sand, harder towards base, creamy brown with (3.0 m) yellow patches, black soft, mud from 3 m and gypsum at approx. 3.5 m.

CLAYEY SAND: Grades to clayey sand, dark brown, fine, soft, low to moderately plastic.

SILTY CLAY: Low moderately plastic, soft, dark brown.

CALCAREOUS SANDSTONE: Fine to medium grained, vuggy, hard, well cemented, creamy orange.

SAND: Slightly clayey, angular, fine to medium grained, occasional very coarse. Poorly sorted and brown.

CORE LOSS

GRAVEL: Angular gravels and cobbles, some sub angular, creamy brown, calcareous.

GRAVELLY CLAY: Grades to gravelly clay.

SANDY SILTY CLAY: Silty, sandy clay, hard, brown.

SILTY CLAY: Grades to silty, sandy clay, fine grained sand, hard.

SILTY CLAY: Grades to patches of red, hard, mottled clasts of silty clay with frequent calcrete clasts and black spots. (Claystone, brittle, broken by finger pressure).

SILTY SAND: Silty sand with minor clay, dark reddish brown, very fine to fine sand, moderately lithified, brittle, firm broken by finger pressure.

1 L/sec

CLAYSTONE: Grades to red brown claystone, hard, brittle (finger pressure) with increasing calcrete/sandstone clasts.

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BORE COMPLETION REPORT

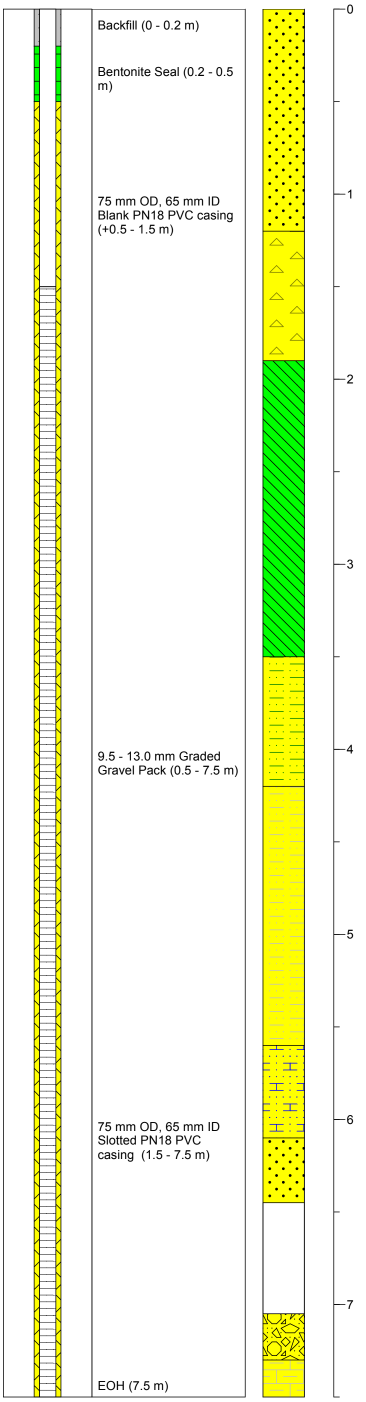
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E018G-S**
DESCRIPTION **Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**7.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**7.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E018**	EASTING	**293920 mE**
START DATE	**14/4/09**	NORTHING	**7600287 mN**
COMPLETION DATE	**17/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**1.50 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Brown fine to medium grained, occasional coarser grained fragments. Becoming coarser towards base, moderately sorted, sub angular to sub rounded quartz, minor feldspar and dark minerals, slightly firm.		
SAND/SILTY SANDY CLAY: Grades into silty sand/silty sandy clay. Slightly firm, moderately plastic, lighter brown, fine sand.		
CLAY: Light brown, soft, moderately plastic to highly plastic, occasional patches of silty sand, harder towards base, creamy brown with (3.0 m) yellowy patches, black soft, mud from 3 m and gypsum at approx. 3.5 m.		
CLAYEY SAND: Grades to clayey sand, dark brown, fine, soft, low to moderately plastic.		
SILTY CLAY: Low moderately plastic, soft, dark brown.		0.5 L/sec
CALCAREOUS SANDSTONE: Fine to medium grained, vuggy, hard, well cemented, creamy orange.		
SAND: Slightly clayey, angular, fine to medium grained, occasional very coarse. Poorly sorted and brown		
CORE LOSS		
GRAVEL: Angular gravels and cobble, some sub angular, creamy brown, calcareous.		
GRAVELLY CLAY: Grades to gravelly clay.		

DRAWN BY **CE** DATE **26/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

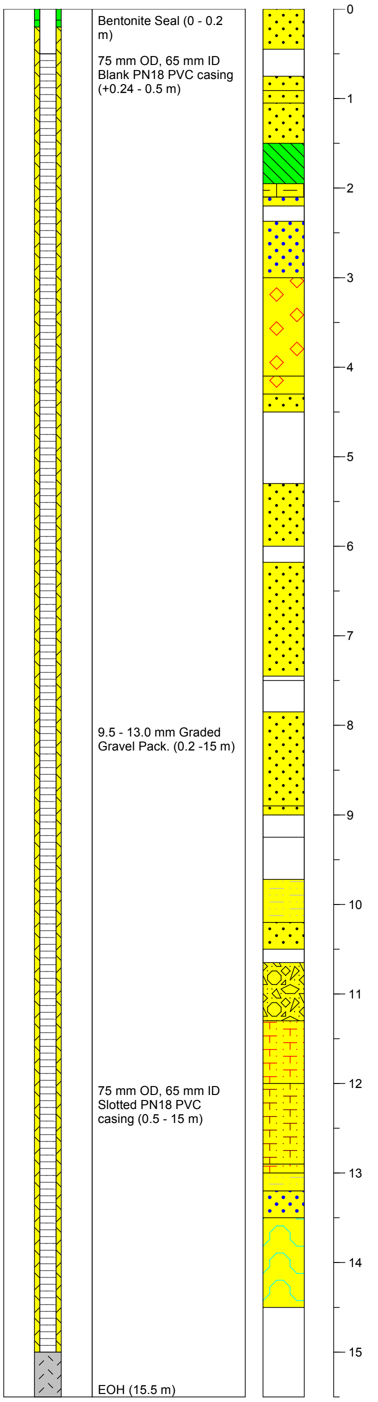
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E019F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**15.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**15 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E019**	EASTING	**293691 mE**
START DATE	**25/3/09**	NORTHING	**7600753 mN**
COMPLETION DATE	**30/3/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL			

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



SAND: Well sorted sand with shell fragments - dark brown red loose - silica 80% - k-feldspar 10% 10% other.

CORE LOSS

SAND: Dense sand, slightly clayey well sorted, brown and firm.

SAND: Dense shell layers whole shells and coral fragments in loose sand.

SAND: Firm, dense, finer grained (0.3 mm) brown/grey.

CLAY: SPT: clay with 15% sand grey/brown (noted as core loss by coffey).

SANDY CLAY: Sandy (approx. 15 - 20%) grey high plasticity.

SANDSTONE: Carbonaceous sandstone with shell fragments 1 cm grain size 0.5 mm solid.

CORE LOSS

SANDSTONE: Solid carbonaceous sandstone - old reef - shell fragments. Lots of cavities - 5cm across. Siliceous at 2.79 m and 2.85 m. Join separate layers at 2.7 m; from more coarse shell fragments to finer sand. Pore space between grains and more weathered cavities/sandstone.

CALCARENITE: Calcarenite with large shell fragments and cavities - tubes at 3.04 m, 3.10 m, large cavities from 3.29 - 3.39 m, fractures at 3.2 m, 3.47 m, 3.87 m cavities at 3.62 m - 3.68 m, large shell fragments rest is fine grained sandy cemented - sandstone calcarenite.

CALCARENITE: Solid but not cemented with fragments of calcarenite approx. 2 cm diameter.

SAND: Loose sand with calcarenite fragments.

CORE LOSS

SAND: Firm sand - slightly plastic 50% still fragments - grain size 0.5 mm red brown.

CORE LOSS

SAND: Sandy plasticity red brown 0.5 - 0.3 mm grains - few shell fragments 1.0 - 0.5 mm.

0.5 L/sec

CORE LOSS: SPT

CORE LOSS

SAND: Clay - silt - grains 0.5 - 0.3 mm firm but not solid.

SAND: More sandy.

CORE LOSS

CORE LOSS: SPT: Sandy clay silt

SILTY CLAY: Majority of sand grain size 0.3 mm red brown high plasticity.

SAND: Lighter colour and more red brown more sand grains 0.5 - 0.3 mm.

CORE LOSS

GRAVEL: Gravel 2% - more sandy sub angular silt clay red/brown, grainsize 0.5 - 0.3 mm, gravel approx.1 cm diameter sub rounded.

SANDY SILTY CLAY: Red brown 0.3 - 0.5 mm with gravel 1 - 3 cm carbonaceous slate and iron, rich mudstone and siliceous sandstone.

SILT/CLAY: SPT: Compacted brown/red 0.1 - 0.3 mm grain size plastic, friable. Very stiff.

SANDY SILTY CLAY: With gravel, angular fragments of calcium carbonate materials, fine grained solid fragments.

SILTY CLAY: Friable silt clay.

SANDSTONE: Cemented/friable sand almost sandstone.

CLAYEY SILT: Red/brown clay silt with minor sand (15%) grain size 0.5 - 0.0 mm.

DRAWN BY **CO**	DATE **12/5/09**	CHECKED BY **DL**	APPENDIX

BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

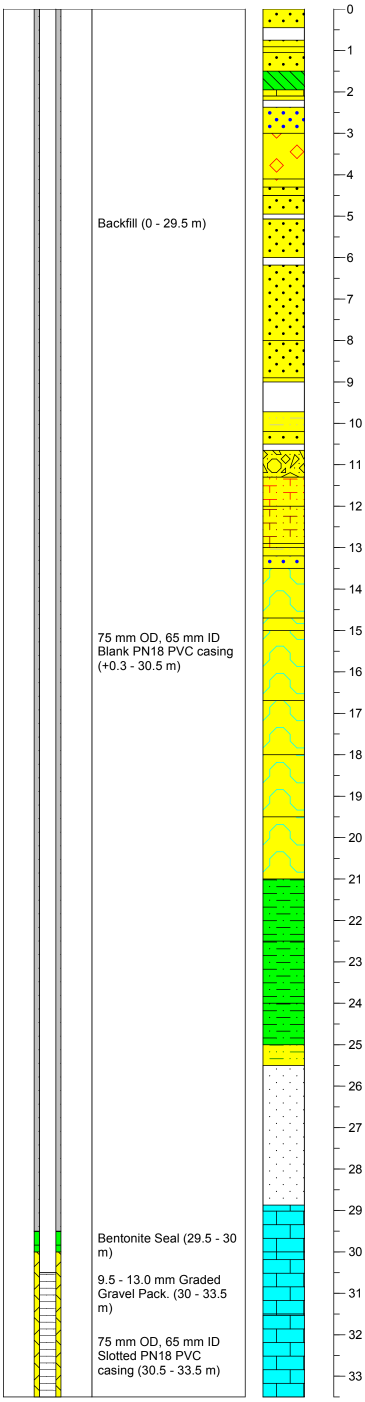
BOREHOLE **E019G-D**
DESCRIPTION **Deep Groundwater Monitoring Bore**

DRILLING COMPANY **Hagstrom Drilling**
DRILLING METHOD **PQ diamond (Reamed - PWT)**
TOTAL DRILLED DEPTH **34 m**
HOLE DIAMETER **122 mm**
TOTAL CASED DEPTH **33.5 m**
CASING DIAMETER **65 mm ID**

PROJECT NAME **Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER **42907100**
CLIENT **Chevron Australia Pty Ltd**
LOCATION **E019**
START DATE **29/4/09**
COMPLETION DATE **3/5/09**
LOGGED BY **GB**
SWL

EASTING **293688 mE**
NORTHING **7600753 mN**
R.L. OF COLLAR **TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION

SAND: Well sorted sand with shell fragments - dark brown, red loose, silica 80% - k-feldspar 10%, 10% other - mica, dark minerals.

CORE LOSS

SAND: Dense sand, slightly clayey, well sorted, brown and firm.

SAND: Dense shell layers whole shells and coral fragments in loose sand.

SAND: Firm dense, finer grained (0.3 mm) brown/grey.

CLAY: Clay with 15% sand grey/brown (noted as core loss by coffey).

SANDY CLAY: Sandy (approx. 15-20%) Grey, high plasticity.

SANDSTONE: Carbonaceous sandstone with shell fragments, 1 cm grainsize, 0.5 mm solid in hand.

CORE LOSS

SANDSTONE: Solid carbonaceous sandstone, old reef, shell fragments. Lots of cavities - 5 cm across at 12.6 m. Siliceous calcarenite 2.79 and 2.85 m. Join between to separate layers at 2.7 m from more coarse shell fragments to finer sand. Less pore space between grains and more weathered cavities/sandstone.

CALCARENITE: Large shell fragments and cavities - tubes at 3.04, 3.10 m. Cavities from 3.29 - 3.39 m, fractures at 3.2, 3.47, 3.87 m cavities at 3.62 - 3.68 m, large shell fragments rest is fine grained, sandy, cemented - sandstone calcarenite.

CALCARENITE: Solid but not cemented with fragments of calcarenite approx. 2 cm diameter.

SAND: Loose sand with calcarenite fragments.

SAND: Loose sand with clays medium plasticity, 0.5 - 0.3 mm grain size.

CORE LOSS

SAND: Firm sand - slightly plastic (50%) shell fragments - grain size 0.5 mm, red brown.

CORE LOSS

SAND: Red/brown, 0.5 - 0.3 mm grain size, few shell fragments 1.0 - 0.5 mm.

SAND: Clay, silt, grains 0.5 - 0.3 mm firm not solid.

SAND: More sandy.

CORE LOSS: Sandy clay silt.

SILTY CLAY: Some sand grainsize 0.3 mm, red/brown, high plasticity.

SAND: Lighter colour and more red brown more sand grains 0.5 - 0.3 mm.

CORE LOSS

GRAVEL: Gravel 2% - more sandy sub angular silt clay red/brown, grain size 0.5 - 0.3 mm, gravel approx. 1 cm diameter sub rounded.

SANDY SILTY CLAY: Red brown 0.3 - 0.5 mm with gravel 1 - 3 cm carbonaceous slate and iron, rich mudstone and siliceous sandstone.

SILT/CLAY: SPT compacted brown red 0.1 - 0.3 mm grain size plastic, friable, stiff.

SANDY SILTY CLAY: With gravel, angular fragments of calcium carbonate materials, fine grained sold fragments.

SILTY CLAY: Friable, silt clay.

SANDSTONE: Cemented/friable sand almost sandstone.

CLAYEY SILT: Red/brown clay silt with minor sand (15%) grain size 0.5 - 0.0 mm.

CLAYEY SILT: Red/brown clay silt with minor sand (15%) grain size 0.5 - 0.0 mm, calcium carbonate approx, 40%.

CLAYEY SILT: Hard, clay, silt, stiff, plastic, friable with large calcium carbonate clasts 40% clay red/brown mottled with black and grey (5-10%) spots - clay very fine grained.

CLAYEY SILT: Clay, rich, silt/sand, highly cemented but still friable - very stiff, 40%, mottled with black and grey, grey forming veins, sand grains approx. 20% no calcium carbonate clasts.

CLAYEY SILT: Clay rich silt with sand 5-10% of grey clay 30-40% interspersed with calcium carbonate clasts (40% of overall matrix) sub angular squares. Very stiff to hard, almost solid rock, fractured at 18.11 m, 18.23 m, 19.10 m association with grey clay layers.

CLAYEY SILT: Clay rich silt with sand 5-10% of grey clay 30-40% interspersed with calcium carbonate clasts (40% of overall matrix). Very stiff to hard. Fractured at 18.11 m, 18.23 m, 19.10 m, associated with grey, clay layers, grey layers more prominent horizontal and vertical bands fractures at 19.7 m, 20.6 m. Grey clay possibly weathered product of calcium carbonate rock.

MUDSTONE: Highly friable mudstone with calcium carbonate clasts. Fractured at 21.14 m, 21.26 m, 21.43 m, 22.3 m, and 22.33 m. No visible sand grains, clasts of mudstone veined by calcite and shell fragments, calcite veins throughout calcium carbonate rock, most clay less cemented in areas with black mottling and grey clay patches, hard and very stiff.

MUDSTONE: Clasts of lighter material sub rounded with black coating with calcite veins and grey clasts. Fractures at 22.83 m, 22.9 m, 23.48 m, 24.37 m. Becoming quite brittle, increasing calcium carbonate proportions. Fractures at 24.15 m, 24.3 m, 24.37 m, 24.47 m, 24.53 m, 24.92 m,

MUDSTONE: Clasts of lighter material sub rounded with black coatingwith calcite veins and grey clasts. Fractures at 22.83 m, 22.9 m, 23.48 m, 24.37 m. Becoming quite brittle, increasing calcium carbonate proportions. Fractures at 24.15 m, 24.3 m, 24.37 m, 24.47 m, 24.53 m, 24.92 m, 25.8 m, 25.24 m, 25.27 m, 25.34 m, mudstone also more brittle.

CLAYEY SAND: Sandier layers, clay rich, mottled black and grey etc.

CALCIUM CARBONATE: Much lighter - 80% calcium carbonate, clays predominantly grey to light brown/red. Fine grained with some sand grains 5% in mudstone fractures at 25.64 m, 26.11 m, 26.39 m, 26.79 m. Dominated by grey clay, some light red/ brown clay and hard sandy grainsize 0.3 - 0.5 mm, less fractured at 27.35 m.

LIMESTONE: Cream white hard, very fine grained (0.1-0.0 mm) fractured with angular clasts, infilled with brown/red clay silt. Very fine, sub angular grains, grey clay. Fractures 28.27 m, 28.97 m, 29.25 m, 29.61 m.

LIMESTONE: Fractured weathered limestone. Fine grained clasts, sub angular to sub rounded with red brown and grey clay. Replacement some sections quite solid. Fractures at 30.13 m, 30.25 m, 30.36 m, 30.48 m, 30.65 m, 31.4 m. Vugs in limestone 1-2 cm diameter at 30.34 m. Layer of highly fractured/weathered clay rich broken up limestone from 31.4 - 31.5 m.

LIMESTONE: Highly weathered limestone, very chalky and crumbly, quite soft grey clay in some areas, overall cores still stiff, large sections lost approx 10 cm at 31.4 -31.68 m, 32.2 - 32.3 m, 32.47 - 32.52 m, 32.70 - 32.76 m, 39.93 - 33.0 m, with some black horizontal bands.

FIELD EC	AIRLIFT YIELD
161.9 mS/cm	2 L/sec

DRAWN BY **CE**
DATE **27/5/09**
CHECKED BY **DL**
APPENDIX

URS

BORE COMPLETION REPORT

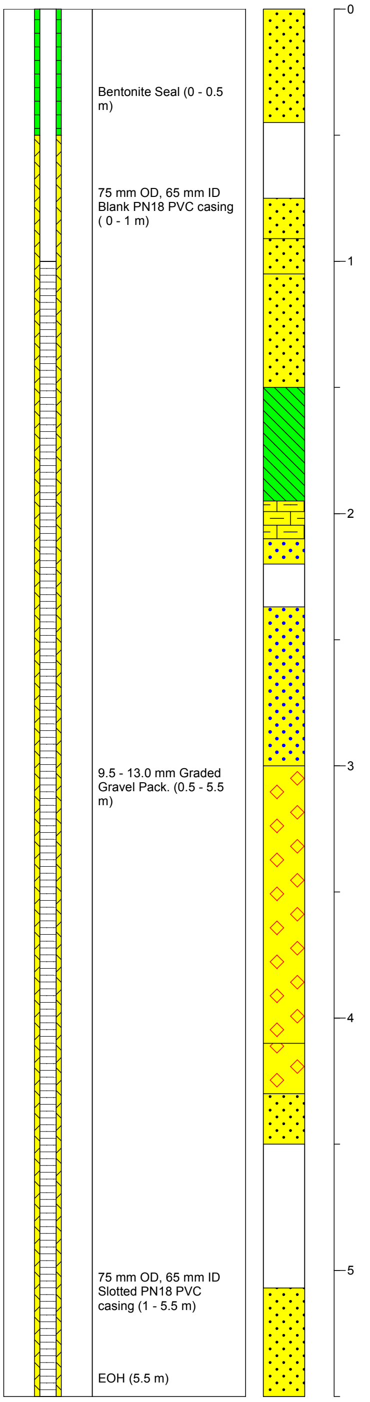
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E019G-S**
DESCRIPTION	**Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond (Reamed - PWT)**
TOTAL DRILLED DEPTH	**5.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**5.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E019**	EASTING	**293685 mE**
START DATE	**4/5/09**	NORTHING	**7600754 mN**
COMPLETION DATE	**4/5/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**MO**		
SWL			

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



SAND: Well sorted sand with shell fragments - dark brown red loose - silica 80% - k-feldspar 10%, 10% other, mica, dark minerals.

CORE LOSS

SAND: Dense sand, slightly clayey well sorted, brown and firm.

SAND: Dense shell layers whole shells and coral fragments in loose sand.

SAND: Firm dense, finer grained (0.3 mm) brown/grey.

CLAY: Clay with 15 % sand grey/brown.

SANDY CLAY: Sandy (approx. 15 - 20%) grey high plasticity

SANDSTONE: Carbonaceous sandstone with shell fragments 1 cm grain size 0.5 mm solid in hand.

CORE LOSS

SANDSTONE: Solid carbonaceous sandstone - old reef - shell fragments. Numerous cavities, 5 cm across.Siliceous calcite 2.79 and 2.85 m. Join between two separate layers at 2.7 m; from more coarse shell fragments to finer sand. Pore space between grains and more weathered cavities/sandstone.

CALCARENITE: Calcarenite with large shell fragments and cavities - tubes at 3.04 m, 3.10 m large cavities from 3.29 - 3.39 m fractures at 3.2 m, 3.47 m, 3.87 m cavities at 3.62 - 3.68 m large shell fragments rest is fine grained sandy cemented - sandstone calcarenite.

CALCARENITE: Solid but not cemented with fragments of calcarenite approx. 2 cm diameter.

SAND: Loose sand with calcarenite fragments.

CORE LOSS

SAND: Firm sand - slightly plastic (50%) shell fragments - grain size 0.5 mm, red brown.

FIELD EC: 34.5 mS/cm

AIRLIFT YIELD: 0.5 L/sec

DRAWN BY **CE** DATE **27/5/09** CHECKED BY **DL** APPENDIX

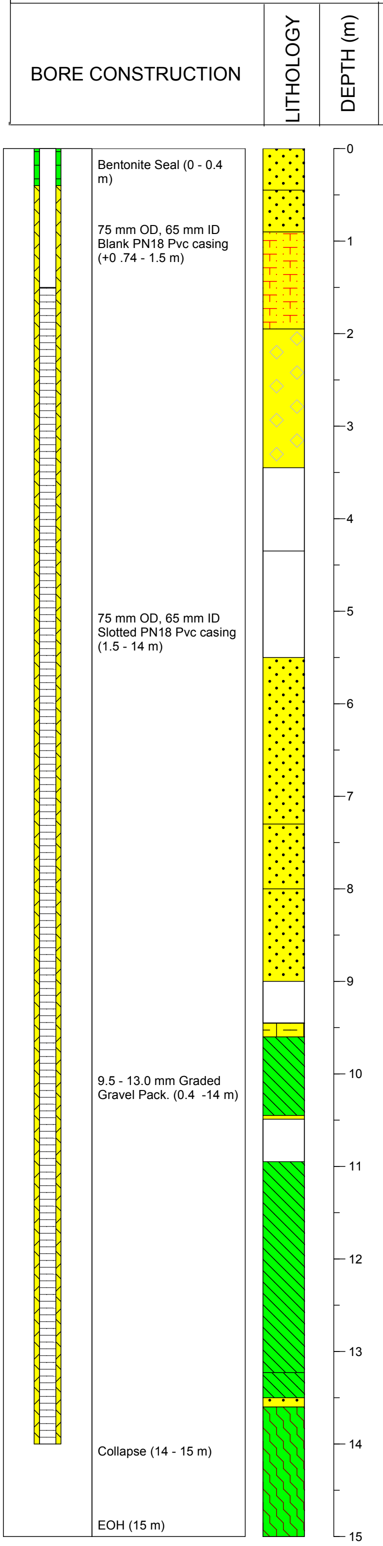
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E021F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**15 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**14 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E021**	EASTING	**293984 mE**
START DATE	**20/4/09**	NORTHING	**7600707 mN**
COMPLETION DATE	**21/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**1.00 m bgl**		



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Fine to medium grained, poor to moderately sorted, sub angular to sub rounded quartz, brown.		
SAND: Fine to medium grained, poor to moderately sorted, sub angular to sub rounded quartz, brown.		
SANDY SILTY CLAY: Orangey brown, fine to coarse, poorly sorted, angular, with some shells (bivalves).		
CALCAREOUS/SAND/ SANDSTONE: Fine to medium grained light brown moderately cemented, sub angular, minor shell fragments.		
CORE LOSS		
CORE LOSS		
SAND: Brown, fine to medium brown, moderately sorted rounded to sub angular quartz, with 5% angular feldspar, zones of weakly cemented, compact sands - becomes finer at 6 m.	85.5 mS/cm	1 L/sec
SAND: Silty dark brown.		
SAND: Becomes silty and clayey and well rounded, more compacted at 9 m.		
CORE LOSS		
SANDY CLAY: Shell fragments and rock fragments - sub rounded.		
CLAY: Dark brown fine grained, some shell fragments		
SAND: Unconsolidated.		
CORE LOSS		
CLAY: Clay fine grained dark brown 0.1 mm grain size.		
CLAY: Less clay content more friable grainsize 0.5 mm some pebbles.		
SAND: Some core loss. Sandy, clayey grain size 0.5 mm quartz sub rounded.		
CLAY/CALCRETE: More cemented hard clays and calcrete - dark grey cream.		

DRAWN BY **CE**   DATE **27/5/09**   CHECKED BY **DL**   APPENDIX

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