Wheatstone Project

BIRDRONG AQUIFER BORE SITING ASSESSMENT

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November 2012

ONSLOW WATER SUPPLY UPGRADE PROJECT

Birdrong Aquifer Bore Siting Assessment

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REPORT

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Golder Associates

Executive Summary

Chevron Australia Pty Ltd (Chevron) engaged Golder Associates Pty Ltd (Golder) to undertake an assessment of the Birdrong Aquifer as a source for water for the township of Onslow in the Pilbara (Figure 1). As part of this investigation, Chevron has asked Golder to assess various site options and water supply production well configurations and scenarios, as outlined in their CVX CTR No. 003.

Reinterpretation of seismic data was undertaken which incorporated seismic lines previously not seen. The reinterpretation indicated faulting in the post Cretaceous sediments due to propagation of earlier faulting into the post Cretaceous sediments, in areas not previously interpreted as faulted.

The additional sites selected for standby production bores and/or monitoring bores are tabulated below.

Bore ID	Alternative	Configuration	Easting	Northing	Estimated Depth to Birdrong Sandstone (depth RL)	Estimated Thickness of Birdrong Sandstone (m)
CW1	1	Standby bore for MDW4	301780	7590590	363	10
CW2	2	New primary production bore	303250	7588810	331	10
CW3	3	Standby bore for CW2	303250	7588860	332	10

A numerical assessment of a number of abstraction scenarios for three bore configuration alternatives was made using the existing FEFLOW groundwater flow model as follows:

- Bore Configuration Alternative No. 1: MDW4 used as the primary production well with a new standby production well located nearby (CW1).
- Bore Configuration Alternative No. 2: One new production well (CW2) and MDW4 functioning as a monitoring well.
- Bore Configuration Alternative No. 3: One new production well (CW2) and one new standby production well (CW3)

The modelling results indicate that for all simulations, the Birdrong Aquifer remains fully saturated for the duration of the pumping but ceases to be flowing artesian.

If operational expenditure is ignored, the bore locations are effectively insensitive to changes in abstraction volumes as additional drawdown is countered by additional pumping effort.

In terms of groundwater water abstraction licencing, if Chevron acquire MDW4, they will have to amend the existing licence to reflect new ownership, and honour the licence conditions. For licensing of new production bores, proof of tenure or permission of land access is required, bore designs need to be approved by the DoW, hydraulic testing would need to be undertaken, and it would be necessary to demonstrate to the DoW that no deleterious impacts were likely to be imposed upon other groundwater users or the environment.

While seismic reinterpretation has reduced the risks of poor production bore targeting, actual performance of any production bore is a matter of evaluation after the bore is drilled, constructed and tested.

Should Chevron seek to acquire MDW4, there are a number of due diligence activities that should be carried out:

- Hydraulic testing
- Optical downhole camera and/or acoustic televiewer survey; and
- Various downhole geophysical surveys.

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1.0 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) has engaged Golder Associates Pty Ltd (Golder) to undertake an assessment of the Birdrong Aquifer as a source for water for the township of Onslow in the Pilbara (Figure 1). As part of this investigation, Chevron has asked Golder to assess various site options and water supply production well configurations and scenarios, as outlined in their CVX CTR No. 003.

This report describes the findings of the work that was carried out to identify target locations for new wells, based on publically available information, and then use the existing simple numerical groundwater flow model to (from CTR No. 003):

- Understand the recommended locations for siting new bores into the Birdrong Aquifer for three (3) different bore configuration alternatives and water extraction scenarios.
- Understand the 'sensitivity' of the recommended locations to changes in the required extraction amounts e.g. a range of 2.5-3.5 ML/d.
- Understand the risks and uncertainties associated with drilling a new well into the Birdrong Aquifer based on the data and model used to determine the recommended bore locations.
- For each bore configuration alternative and water extraction scenario, understand the scope of further work likely required to support the acquisition of a 5C licence.
- Understand what due diligence work Golder recommend CAPL complete prior to acquiring MDW4 from BHPB, if this is determined to be CAPL's preferred 'go-forward' alternative

2.0 BACKGROUND

Golder has previously carried out the following groundwater assessments within the Birdrong Aquifer:

- Golder 2010a: Selection of suitable well locations based on interpretation of geophysical data.
- Golder 2010b: Assessment of the salinity of groundwater within the Birdrong Aquifer. The results of this investigation were used to refine the selection of suitable sites for wells.
- Golder 2011: H2 Level Hydrogeological assessment of the Macedon Deep Well (MDW4). In this report, the well construction details and the results of hydraulic testing are documented. Well MDW4 is screened within the Birdrong Aquifer.
- Golder 2012a: 3D groundwater modelling to assess the effects on the Birdrong Aquifer, of groundwater abstraction from well MDW4. The report produced from this assessment was used as supporting documentation in an application to the Department of Water (DoW) to temporarily increase the allocation for abstraction from MDW4.
- Golder 2012b: Birdrong Aquifer Assessment - Seismic Data Availability.
- Golder 2012c: 3D groundwater modelling to assess the effects of groundwater abstraction from well MDW4 and two other proposed wells (CVX2 and CVX3). The maximum period of groundwater abstraction assessed was 20 years.
- Golder 2012d: Analysis of the existing groundwater data. 3D groundwater modelling to assess the long-term sustainability of abstracting groundwater from MDW4 and the proposed new well. Identification of potential fatal flaws associated with water quality from the Birdrong Aquifer.

3.0 SCOPE OF WORK

The Scope of Work from CVX CTR No. 003 has been reproduced in full as follows:

TASK 1: Undertake work necessary (including seismic reinterpretation if deemed required and drawdown modelling) to determine the location of new bores into the Birdrong Aquifer for each 'bore configuration alternative' and extraction scenario detailed below.

Bore Configuration Alternative No. 1: MDW4 used as the primary production well with a new standby production well into the Birdrong.

1) Extraction Scenario 1: MDW4 extracting at 2.71 ML/d. Find the optimum location (to the extent reasonably possible given the available data) for a secondary production bore to extract 2.71 ML/d based on the following criteria:
   - New bore located as close as possible to MDW4.
   - Bore also functions as a monitoring well i.e. a location that would be acceptable to Department of Water.
   - Water quality not a critical criterion as long as the water quality is equal to or better than MDW4.
   - Located within hatched area indicated on the drawing provided in email on 28 September 2012 - Birdrong Aquifer Bore Siting Assessment CTR Drawing.
   - Located as close as possible to an existing road network e.g. Onslow Road or Peedamulla Road.
2) Extraction Scenario 2: MDW4 extracting at 3.38 ML/d. Find the optimum location for a secondary production bore (to extract 3.38 ML/d) based same criteria detailed above for extraction Scenario 1.

Bore Configuration Alternative No. 2: One new production well and MDW4 functioning as a monitoring well

1) Extraction Scenario 1: MDW4 extracting at 0.05 ML/d for BHPB. Find the optimum location (to the extent reasonably possible given the available data) for a new production bore to extract 2.66 ML/d based on the following criteria:
   - New bore located as close as possible to MDW4.
   - MDW4 functions as a monitoring well i.e. a location that would be acceptable to Department of Water.
   - Water quality not a critical criterion as long as the water quality is equal to or better than MDW4.
   - Located within hatched area indicated on the drawing provided in email on 28 September 2012 - Birdrong Aquifer Bore Siting Assessment CTR Drawing.
   - Located as close as possible to an existing road network e.g. Onslow Road or Peedamulla Road.
2) Extraction Scenario 2: MDW4 extracting at 0.05 ML/d for BHPB. Find the optimum location for a new production bore to extract 3.33 ML/d based same criteria detailed above for extraction Scenario 1.

Bore Configuration Alternative No. 3: One new production well and one new standby production well

3) Extraction Scenario 1: MDW4 extracting at 0.05 ML/d. Find the optimum location (to the extent reasonably possible given the available data) for a new production well extracting 2.66 ML/d and location of a new standby well based on the following criteria:
   - New production well and standby production well located as close as possible to MDW4
   - Standby production well functions as monitoring well.
   - Water quality is not a critical criterion.

- Located within hatched area indicated on the drawing provided in email on 28 September 2012 - Birdrong Aquifer Bore Siting Assessment CTR Drawing.
- Located of bores as close as possible to an existing road network e.g. Onslow Road or Peedamulla Road.

4) Extraction Scenario 2: MDW4 extracting at 0.05 ML/d. Find the optimum location for a new production well extracting 3.33 ML/d and location of a new standby well based the same criteria detailed above for extraction scenario 1.

TASK 2: For each bore configuration alternative and scenario comment on the 'sensitivity' of the recommended locations to changes in the required extraction amounts e.g. a range of 2.5-3.5 ML/d.

TASK 3: For each bore configuration alternative and water extraction scenario, provide details of the scope of further work likely required to support the acquisition of a 5C Licence.

TASK 4: Detail the risks and uncertainties associated with drilling a new well into the Birdrong Aquifer at the locations identified i.e. the risk the bore doesn't produce the quantum of water expected. Cite previous experience with drilling deep wells.

TASK 5: If bore configuration alternative No. 1 above is CAPL's preferred 'go forward' alternative, CAPL will need to acquire MDW4 from BHPB, detail suggested 'due diligence' checks CAPL should undertake prior to acquisition of MDW4 i.e. detail any recommended testing, inspections and performance checks that should be undertake to confirm (to the extent reasonably possible) MDW4 is capable of sustainably producing between 3.05-3.71 ML/d and to support acquisition of a 5C Licence.

Subsequent to receipt of CVX CTR No. 003, the Scope of Work was modified to exclude Golder Location 5 (as an option for Onslow's source of water and Golder was instructed to focus on minimising capital expenditure and disregard operational cost considerations. Additionally, Golder were instructed to limit target selection to a segment of land east to south-east of the Macedon Project water supply well (MDW4), with an arc radius of 8 km (Figure 1).

4.0 SEISMIC INTERPRETATION

4.1 Overview

As part of the Phase 3 bore siting process, a revision of the previous seismic interpretations performed for BHP Billiton Petroleum (Golder 2010a, 2010b) has been carried out. This revision to the interpretation has been carried out in order to get an improved understanding of the structure and stratigraphy in the vicinity of the proposed bore siting area specified by Chevron, aided by the inclusion of an additional 10 seismic lines from the Coolgra and Amber Seismic Survey ("CP93") carried out in 1993 (Figure A01). These data had not been made available to Golder at the time of the BHP Billiton Petroleum project. A total of 27 seismic lines totalling approximately 275 line km have been interpreted for this project (Section 4.2).

Changes to the previous interpretations include updated horizons based on information gained from the drilling of MDW4 and review of the velocity survey data at Amber-1, and improved understanding of the faulting in the study area as a result of the improved spatial density of seismic lines. The interpretations provided with the Coolgra and Amber Seismic Interpretation Report (Pan Pacific Petroleum NL 1994) which was included with the seismic data package, were also reviewed and used to aid the interpretations provided in this report.

4.2 Seismic and Well Data

The seismic data included in The Kingdom Suite[1] seismic interpretation project comprised the following (Figure A01):

- Coolgra and Amber Seismic Survey (CP93; Pan Pacific Petroleum NL 1994): Ten lines totalling 83 km in length. The Coolgra and Amber surveys were two parts of the same survey acquired between August and December 1993. The 1995 reprocessed data were used.
- Peedamullah Seismic Survey (PP92; Buchan RJ & Matthews ER 1993): Six lines totalling 134.6 km in length.
- Amethyst Seismic Survey (CP98; Carnarvon Petroleum NL 1999): Six lines totalling 25.7 km in length.
- J84A (Esso Exploration and Production Australia Inc 1985): Three lines (J84A-004, -037, -039) totalling 18.6 km in length.
- Minderoo Seismic Survey (M81; G.F.X. Resources Pty Ltd 1981): Two lines (M81-12, -13) totalling 13.4 km in length.

To aid the seismic interpretation, information from the following wells was incorporated:

- Amber-1 (Pan Pacific Petroleum NL 1995): Velocity survey (time-depth chart) and formation tops.
- Jade-1 (Pan Pacific Petroleum NL 1993): Velocity survey (time-depth chart) and formation tops.
- Topaz-1 and Topaz-2 (Pan Pacific Petroleum NL 1995 and 1996): Formation tops.
- MDW4 (Golder 2011): Formation tops.

4.3 Interpretation

In total, 27 seismic lines totalling 275 km in length were interpreted in The Kingdom Suite seismic interpretation project. Interpretations of eight selected seismic lines in the vicinity of the bore siting area can be found in Figures A02 through A10 (highlighted in blue in Figure A01). Four key stratigraphic horizons; the Base Cretaceous Unconformity (BCU; pink horizon), top Birdrong Sandstone (light blue horizon), top Mardie Greensand (green horizon) and top Muderong Shale (dark blue horizon), were mapped across all of the seismic lines specified in Section 4.2 and shown in Figure A01. These horizons, from oldest to youngest, were mapped as follows:

- BCU: As a prominent angular unconformity, the BCU is identified regionally as the transition between the underlying strongly dipping reflectors, which exhibit a relatively high degree of faulting and folding, and the sub-horizontal, gently north-west dipping and largely unfaulted Cretaceous to Recent sedimentary units. This horizon was picked as the moderate- to high-amplitude positive reflector at the termination point of the dipping beds.
- Birdrong Sandstone and Mardie Greensand: The Birdrong Sandstone and Mardie Greensand are often too thin to individually produce defined reflections on their own. The Jade-1 and MDW4 well logs indicate that in the south-west the Mardie Greensand and Birdrong Sandstone are approximately equivalent in thickness, with the Mardie Greensand being slightly thicker. Towards the north-east, the Amber-1, Topaz-1 and Topaz-2 well logs indicate that the Birdrong Sandstone interval increase in thickness to between 15 m to 20 m while the Mardie Greensand thins to only 1 m to 2 m in thickness (well below the resolution of the data). Therefore, the interpretation of these horizons varies; in the west and south-west the Mardie Greensand is picked as the first prominent peak directly overlying the BCU, while the Birdrong Sandstone is picked as the trough (or sometimes very weak peak) between the Mardie Greensand and BCU horizons. In the east and north-east; however, the Birdrong Sandstone is

[1] http://www.ihs.com/products/oil-gas-information/analysis-software/kingdom-seismic-interpretation/index.aspx

mapped as the first prominent peak overlying the BCU, while the Mardie Greensand is mapped as a very thin layer above this, as it is technically not able to be mapped due to its thickness.

- Muderong Shale: The top Muderong Shale is identified as a prominent, continuous peak that correlates well between seismic lines.

The seismic sections also display key interpreted faults. The faulting regime is an important consideration in the well siting process as any faults which offset the very thin Birdrong Sandstone unit may impede groundwater flow. The majority of the faults are pre-Cretaceous, terminating at the BCU, although some of these faults are interpreted to continue into the overlying Cretaceous sedimentary succession. The offsets on the majority of the interpreted faults that propagate above the BCU are minor, resulting in only small displacements of the Birdrong Sandstone, Mardie Greensand and Muderong Shale units. Figures A02 to A05 show the interpreted horizons and faults in the vicinity of MDW4 and the proposed water wells (discussed in Section 4.4 below). Several faults were mapped through the Cretaceous sediments in the vicinity of these wells, although these are shown to have minor offsets through the Cretaceous section. The interpretation of these faults indicates that there are no apparent significant structural controls which would impede groundwater flow in the vicinity of the bore siting area.

Two-way travel time maps were produced for the Birdrong Sandstone and BCU horizons (Figure A11 and Figure A12) based on the interpretations along these lines and the other seismic lines shown in the figures (but not displayed as sections). These maps also display traces of some of the key faults which were able to be mapped between seismic lines in the study area (black lines with dip directions) and fault intersections on individual lines (black **+**'s). The fault traces show that the dominant fault trend around and NE of the Chevron specified bore siting area is approximately N-S to NNE-SSW. The Weelawarren Fault, a major SW-NE trending structure in the area (refer to Golder 2010a, 2010b), is located approximately 11 km to the NW of MDW4.

The time-depth (T-D) chart obtained from the velocity survey at Amber-1 is shown to overestimate the depth to the horizons at Amber-1, MDW4, Topaz-1 and Topaz-2. At the depth of the BCU, the average discrepancy between the interpreted horizons and the formation tops at these wells is approximately +0.010 s TWT (+0.020 s TWT at MDW4), an error of about 2.5% (5% at MDW4). For the creation of the updated Birdrong Sandstone and BCU depth maps (Figures A13 through A16), the Amber-1 T-D chart was modified to take into account this apparent error and help obtain an improved fit between the formation tops in the wells and the interpreted horizons in the seismic data. This modified T-D chart is expected to provide more representative depths to the BCU and Birdrong Sandstone units in the study area. It must be noted that these depth conversions are based on the crude assumption that the same velocity profile applies across the area and, therefore, should be viewed as providing indicative depths only.

Figure A14 and Figure A16 display depth maps within the Chevron specified bore siting area. Within this area, the Birdrong Sandstone depth map (Figure A14) indicates that the depth to this unit is greatest near MDW4 (approximately 358 m depth RL) and shallowest at LOC5 (approximately 300 m depth RL).

An isopach map for the Birdrong Sandstone interval (Figure A17 and Figure A18) was also created using an isochron of the interval and a constant interval velocity of 1850 ms^{-1} (as approximately indicated at Amber-1; Pan Pacific Petroleum NL 1995). In the bore siting area (Figure A18) the isopach map shows that the interpreted thickness of the unit ranges between approximately 7 m and 14 m, and is thickest towards the south-east ends of seismic lines CP93-21 and PP92-D.

4.4 Bore Siting

In the CVX CTR document dated 3 October 2012, three bore configuration alternatives are specified. For access and cost reasons, a site along Onslow Road or Peedamullah Road has been specified as the preferred option for the different bore alternatives if possible. In addition to this, a site which is close to MDW4 is preferred for proximity to the existing water treatment plant.

In terms of selecting a location based on the seismic interpretation, a site at the location of a seismic line is preferred as there is more certainty over the stratigraphy and structure than there is for sites away from seismic lines within the specified bore siting area. A site where the Birdrong Sandstone unit displays continuity and is clear of interpreted faults is an essential part of the selection criteria. It is to be noted that seismic line PP92-C was acquired alongside Onslow Road for the most part. In terms of the requirements specified above and the mapped depth to the Birdrong Sandstone, a bore site along PP92-C is the recommended option. In order to meet the water quality requirements (equal or better quality than that at MDW4) the bore site will need to be situated up-dip (i.e. south-east, or up both hydraulic and structure contour gradient) from MDW4.

Based on the consideration above, the seismic interpretation results and the hydrogeological considerations given in the following sections, the bore sites specified in Table 1 are proposed for the three specified bore configuration alternatives.

Table 1: Proposed Bore Locations and Configurations

Bore ID	Alternative	Configuration	Easting	Northing	Estimated Depth to Birdrong Sandstone (depth RL)	Estimated Thickness of Birdrong Sandstone (m)
CW1	1	Standby bore for MDW4	301780	7590590	363	10
CW2	2	New primary production bore	303250	7588810	331	10
CW3	3	Standby bore for CW2	303250	7588860	332	10

4.4.1 Bore Configuration Alternative 1

For this bore configuration alternative, MDW4 is the primary production bore. Proposed bore CW1, located approximately 50 m from MDW4, is designated primarily as a monitoring bore but constructed/completed as a production bore so that it could also function as a production bore if MDW4 became unserviceable for any reason. In this capacity as a standby/replacement bore, however, CW1 would only ever be pumped when MDW4 was not operational. Since CW1 is proposed as a monitoring bore (but with pumping bore capability if MDW4 becomes inoperable), we judge that the proximity to MDW4 (<400 m) will not be an issue with the Department of Water.

4.4.2 Bore Configuration Alternative 2

This bore configuration alternative comprises one new primary production bore and MDW4 acting as a monitoring bore. The new production bore (CW2) is located up-dip (i.e. south-east, or up both hydraulic and structure contour gradient) of MDW4 and south-east of the mapped faults interpreted on seismic line PP92-C which intersect the Birdrong Sandstone unit (Figure A03). The proposed CW2 production bore is located approximately 2.3 km from MDW4, much closer than the previously proposed LOC5 bore location. The reason for this is to minimise capital expenditure (i.e. reduced pipeline costs).

The scope of work specifies that while MDW4 should function as a monitoring well, it will also be abstracting at 0.05 ML/day. We note that the use of MDW4 as both a monitoring bore and a producing production bore, are incompatible.

4.4.3 Bore Configuration Alternative 3

This bore configuration alternative comprises one new primary production bore and one new standby production bore. The proposed new production bore (CW2) is at the same location as in Alternative 2, located up-dip (i.e. south-east, or up both hydraulic and structure contour gradient) of MDW4 and south-east of the mapped faults interpreted on seismic line PP92-C, which intersect the Birdrong Sandstone unit (Figure A03). The proposed standby bore (CW3) is located approximately 50 m from CW2 and could act as a monitoring bore for abstraction from either MDW4 or CW2, or both. CW3 would not be utilised as a production bore unless CW2 were to become unserviceable.

The scope of work specifies that while MDW4 should function as a monitoring well, it will also be abstracting at 0.05 ML/day. We note that the specified uses of MDW4 as both a monitoring bore and a production bore, are incompatible.

5.0 LONG-TERM DRAWDOWN PROJECTIONS

5.1 Introduction

A 3D groundwater model, developed in FEFLOW, was used to calculate the likely long-term groundwater drawdown that would result as a result of abstraction from the Birdrong Aquifer. The drawdown projections were assessed for an 80 year abstraction period for the following bore configuration alternatives:

- **Bore Configuration Alternative No. 1:** For this bore configuration alternative, MDW4 is to be used as the primary production bore. CW1 is designated as a standby bore and will only be pumped when MDW4 is not operational. Therefore, the groundwater modelling scenarios assessed for this bore configuration alternative only involved one pumping bore (MDW4). In addition to running simulations at rates of 2.71 ML/d and 3.38 ML/day, as requested by Chevron, Golder also simulated the drawdown effects due to pumping for an 80 year period at rates of 2.5 ML/d, 3.0 ML/d and 3.5 ML/d.

- **Bore Configuration Alternative No. 2:** For Bore Configuration Alternative No. 2, groundwater is to be abstracted at MDW4 at 0.05 ML/day. It is proposed that a new primary production well, CW2 (Figure A01 in Appendix A) is drilled. In addition to running simulations at rates of 2.66 ML/d and 3.33 ML/day, as requested by Chevron, Golder also simulated the drawdown effects due to pumping for an 80 year period at rates of 3.0 ML/d and 3.5 ML/d.

- **Bore Configuration Alternative No. 3:** For this bore configuration alternative, groundwater is to be abstracted at MDW4 at 0.05 ML/day. It is proposed that a new production well, CW2 and a new standby production well, CW3 (Figure A01 in Appendix A) are drilled. The proposed abstraction rates for the production bore for Bore Configuration Alternative 3 are similar to the proposed rates for Bore Configuration Alternative 2. Therefore modelling simulations were not run for Bore Configuration Alternative 3.

5.2 Conceptual Groundwater Model

The conceptual model described in the previous report (Golder 2012c) was used in the groundwater modelling. A summary of the hydraulic parameter values assigned to the model is presented in Table 2. The conceptual groundwater model developed for assessing the Birdrong Aquifer consists of the following elements.

- The Birdrong Aquifer was assigned a thickness of 30 m to include overlying and underlying aquifers in hydraulic connection with the Birdrong sandstone. A hydraulic conductivity of 3.0×10^{-5} m/s was assigned to the Birdrong Aquifer. The specific yield and specific storage applied to this layer in the model were 35% and 1×10^{-5} (1/m), respectively.

- The sediments overlying the Birdrong Aquifer were grouped into a single hydrostratigraphic unit with a hydraulic conductivity of 1×10^{-9} m/s. The specific yield and specific storage applied to this layer in the model were 10% and 1×10^{-5} (1/m), respectively.

- The geological formations occurring below the Birdrong Sandstone were not included in the groundwater model. Setting an impermeable boundary at the base of the Birdrong Aquifer was done to prevent upward groundwater leakage into the Birdrong Aquifer during pumping. This modelling approach was considered to be conservative.

- For the purposes of this assessment it has been assumed that the offshore extent of the Birdrong Aquifer is up to 120 km to the west of the site. It has also been assumed that the Birdrong continues with the same dip and thickness to the model boundary.

- Information on the permeability characteristics of the faults is poorly understood. For the purposes of this assessment, it has been assumed that the faults do not affect groundwater flow within the Birdrong Aquifer.
- A groundwater recharge of 1×10^{-5} m/day was applied to the outcrop of the Birdrong Aquifer to the east of Onslow. This recharge rate was obtained during the calibration of the steady state groundwater model (Golder 2012c).
- No groundwater recharge was applied over the top of overlying layer.

Table 2: Hydraulic Parameter Values Assigned to Groundwater Model

Parameter	Birdrong Aquifer	Overlying Layer
Hydraulic conductivity (m/s) (1)	3.0×10^{-5}	1×10^{-9}
Specific yield	0.35	0.10
Specific storage (1/m)	1×10^{-5}	1×10^{-5}
Groundwater recharge rate (m/d)	1×10^{-5}	-

5.3 Numerical Groundwater Model

The 3D numerical model described in the previous report (Golder 2012d) was used in this analysis. The model mesh structure used the modelling is shown in (Figure 2). A typical E-W cross-section through the modelled area is presented in Figure 3.

The following model boundaries were assigned to the model:

- The nodes along the offshore western boundary were assigned seepage face boundary conditions. A seepage face boundary is a special type of a hydraulic head boundary. Groundwater flows out of the model when calculated head is above the topographic elevation of the seepage boundary node. However, groundwater inflow into the model cannot occur through seepage boundary nodes.
- Zero hydraulic head (h = 0 m) boundary conditions were assigned to the top of Layer 1 in the offshore region to represent the sea.
- A constant groundwater recharge rate of 1×10^{-5} m/day was applied over the outcrop area of the Birdrong Aquifer.
- No flow conditions were assigned to the following model boundaries:
  - Base of model, represented by the base of the Birdrong Aquifer.
  - East of the model along the contact with the Precambrian basement.
  - Southern limit of the model. This boundary is very distant from the area of interest and the effects of the pumping are unlikely to propagate to this boundary.
  - Northern limit of the model. This boundary is very distant from the area of interest and the effects of the pumping are unlikely to propagate to this boundary.

5.4 Results

5.4.1 Bore Configuration Alternative No.1

- The groundwater drawdown projections at well MDW4 due to pumping the well at varying rates are presented in Figure 4. The projections are for groundwater drawdown at the end of an 80 year abstraction period. Increasing the pumping rate at MDW4 from 2.5 ML/day to 3.5 ML/day results in an increased projected drawdown in the pumping well of approximately 21 m.

- In the area around the pumping well, the Birdrong Aquifer is expected to remain fully saturated for the duration of the pumping.
- The projected drawdown contours at the end of 80 years of pumping for the different pumping scenarios are presented in Figure 5 to Figure 9.

5.4.2 Bore Configuration Alternative No.2

- The increase in drawdown at CW2 and MDW4 with increasing pumping rate at well CW2 is shown in Figure 10. Increasing the pumping rate at CW2 from 2.66 ML/day to 3.5 ML/day results in an increased projected drawdown in the pumping well and at MDW4 of approximately 11 m and 4.5 m, respectively.
- In the area around the pumping well, the Birdrong Aquifer is expected to remain fully saturated for the duration of the pumping.
- The projected drawdown contours at the end of 80 years of pumping for the different pumping scenarios are presented in Figure 11 to Figure 14.

5.4.3 Bore Configuration Alternative No.3

As stated in Section 5.1, the groundwater drawdown projections for this bore configuration alternative are expected to be very similar to projections for Bore Configuration Alternative No. 2.

6.0 DELIVERABLES

6.1 TASK 1

- For Bore Configuration Alternative No. 1, increasing the pumping rate at MDW4 from 2.5 ML/day to 3.5 ML/day results in an increased projected drawdown in the pumping well of approximately 21 m at the end of an 80 year abstraction period. At the end of this abstraction period, the projected drawdown at the pumping well for a pumping rate of 3.5 ML/day is approximately 46 m. In the area around the pumping, the Birdrong Aquifer is expected to remain fully saturated for the duration of the pumping. A pump will need to be installed in the well to maintain the pumping rate.
- For Bore Configuration Alternative No.2, the maximum groundwater drawdown projections at well CW2 and MDW4 due to pumping from CW2 at 3.5 ML/day are approximately 44.6 m and 18 m, respectively. Increasing the pumping rate at CW2 from 2.66 ML/day to 3.5 ML/day results in an increased projected drawdown in the pumping well and at MDW4 of approximately 11 m and 4.5 m respectively. In the area around the pumping bores, the Birdrong Aquifer is expected to remain fully saturated for the duration of the pumping. Pumps will need to be installed in the wells to maintain the desired pumping rates.
- The groundwater drawdown projections for Bore Configuration Alternative No. 3 are expected to be very similar to projections for Bore Configuration 2.

6.2 TASK 2 and TASK 3

Without the consideration of operational expenditure, the well locations identified are insensitive to changes in the abstraction volumes. This is because the modelled abstraction rates over the 80 year period modelled do no fully depressurise the aquifer or impact upon other users or the environment. Any additional depressurisation is simply countered by additional pumping effort.

In terms of the acquisition of a 5C Licence, should Chevron acquire the well and the rights to take water from the MDW4, then licensing is a matter of amending the existing licence to reflect the new ownership. Chevron would then have to honour the licence conditions.

In the case of licensing for new wells, proof of ownership or tenure, or permission to drill on another's land would need to be demonstrated to the DoW. The well design would need to be approved by the DOW, and upon completion, the well would need to be hydraulically tested. It would also be necessary to demonstrate to the DoW that no deleterious impacts were likely to be imposed upon other groundwater users or the environment.

6.3 TASK 4

The risk that a new well targeting the Birdrong aquifer does not produce the quantum of water required cannot be discounted until the well is drilled and tested. Typically, groundwater wells in sedimentary basins with established, proven aquifers are drilled without any refined targeting techniques. The seismic reinterpretation undertaken in this study, incorporating additional seismic data not used in the targeting of the highly successful MDW4, greatly reduces the risk that a well won't perform adequately; however, the level of success can only be quantified once the well is drilled and tested. The risk of inadequate yield may be further reduced by drilling into the folded sedimentary formations below the Cretaceous Unconformity, simply because the additional depth may intersect additional favourable aquifer material. Notwithstanding, it is a matter of evaluation after the well is drilled.

Golder staff experience with drilling deep wells includes a >500 m deep artesian (but not flowing artesian) well into the Parmelia Formation at Mogumber West in the Perth Basin, for irrigation of a horticultural enterprise. This well was drilled **without** sophisticated targeting based on seismic or other geophysical techniques; however, a conceptual understanding of the basin hydrogeology indicated that a well drilled into the appropriate stratigraphic formations was likely to be successful. Indeed, one of the purposes of the well (and why it was favourably received by the regulators) was that there was no geological control in the area such that the well became the geological control in that area. Upon successful completion and hydraulic testing, the well proved to be easily sufficient for the irrigation requirements (>1 GL/annum).

6.4 TASK 5

Should Chevron seek to acquire MDW4 from BHPB, 'due diligence' checks that should be undertaken prior to acquisition of MDW4 are as follows:

- Hydraulic testing - replicate previous hydraulic test work and groundwater quality sampling to identify whether there has been any reduction in well performance or water quality since abstraction commenced. Previously MDW4 was step tested for 4 steps of 90 minutes each at 6.9, 10.1, 17.7 and 35 L/s respectively, although these rates are dependent upon the equipment available on the day of the test. Constant rate testing was undertaken at 12.3 L/s over 72 hours. This rate and duration were selected in consultation with the Department of Water, after consideration of the difficulties in management of discharge at the surface. Should site circumstances have changed since the initial test work carried out in 2011, hydraulic testing at an increased rate and duration should be evaluated in order to maximise the amount of hydraulic information that could be obtained from a new set of tests.
- Optical downhole camera survey and/or acoustic televiewer to inspect the casing and screens; and
- Various downhole surveys to assess the integrity of well casing, screens, and the cement occupying the annulus between the well casing and the wall of the drill hole. There is a whole suite of available survey tools and methods including:
  - Multifinger Caliper Tool
  - Sonic logging
  - Cement Bond Tool
  - Cement Evaluation Tool
  - Corrosion and Protection Evaluation Tool
  - Ultrasonic Imaging Tool
  - Pipe analysis tool.

7.0 REFERENCES

Buchan RJ & Matthews ER 1993: EP110 Seismic Interpretation Report. Peedamullah Seismic Survey. Report Prepared for Pan Pacific Petroleum NL.

Carnarvon Petroleum NL 1999: Final Report, Amethyst Seismic Survey, EP110.

Esso Exploration and Production Australia Inc 1985: Final Report for the J84A Seismic Survey.

Digital Exploration Limited 1994a: Data Processing Report, 1993 Coolgra Seismic Survey, Land Acquisition, EP110 West Australia. Report prepared for Pan Pacific Petroleum NL.

Digital Exploration Limited 1994b: Data Processing Report, 1993 Amber Seismic Survey, Land Acquisition, EP110 West Australia. Report prepared for Pan Pacific Petroleum NL.

G.F.X. Resources Pty Ltd 1981: Minderoo Seismic Survey, EP-110, Carnarvon Basin, Western Australia. Report prepared for Pan Pacific Petroleum NL.

Golder 2010a: Macedon Water Well Geologic Study, Seismic Interpretation and Well Log Analysis Report. Report No. 1078208343_R001_Rev0.0 dated 22 October 2010. Report prepared for BHP Billiton Petroleum Pty Ltd by Golder Associates (NZ) Limited.

Golder 2010b: Macedon Water Well Geologic Study, Water Salinity Considerations for Well Location Report. Report No. 1078208343_R002_Rev0.0 dated 26 November 2010. Report prepared for BHP Billiton Petroleum Pty Ltd by Golder Associates (NZ) Limited.

Golder 2011: Macedon Deep Well, H2 Level Hydrogeological Assessment. Report No. 117646002-003-R-Rev1. Report prepared for BHP Billiton Petroleum Pty Ltd by Golder Associates Pty Ltd.

Golder 2012a: Macedon Deep Well, Supplementary H2 Level Assessment Report. Supplementary H2 Level Assessment Report. Report No. 117642115-022-R-Rev0. Report prepared for BHP Billiton Petroleum Pty Ltd by Golder Associates Pty Ltd.

Golder 2012b: Birdrong Aquifer Assessment - Seismic Data Availability. Technical Memorandum 127646019-002-M-Rev0, 6 July 2012.

Golder 2012c: Birdrong Aquifer Assessment, Groundwater Modelling of the Birdrong Aquifer. Report No. 127646-019-R-Rev0. Report prepared for Chevron Australia Pty Ltd by Golder Associates Pty Ltd.

Golder 2012d: Birdrong Aquifer Water Source Fatal Flaw Analysis. Wheatstone Social Infrastructure. Onslow Water Infrastructure Upgrade Project. Report No. 127646019-004-R-RevA. Report prepared for Chevron Australia Pty Ltd by Golder Associates Pty Ltd.

Pan Pacific Petroleum NL 1993: Jade No.1 Well Completion Report.

Pan Pacific Petroleum NL 1994: EP110, Amber Area, Seismic Interpretation Report.

Pan Pacific Petroleum NL 1995: Amber-1 Well Completion Report. EP110, Carnarvon Basin.

Report Signature Page

GOLDER ASSOCIATES PTY LTD

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Associate and Principal Hydrogeologist

DMT/PM,BK/slj

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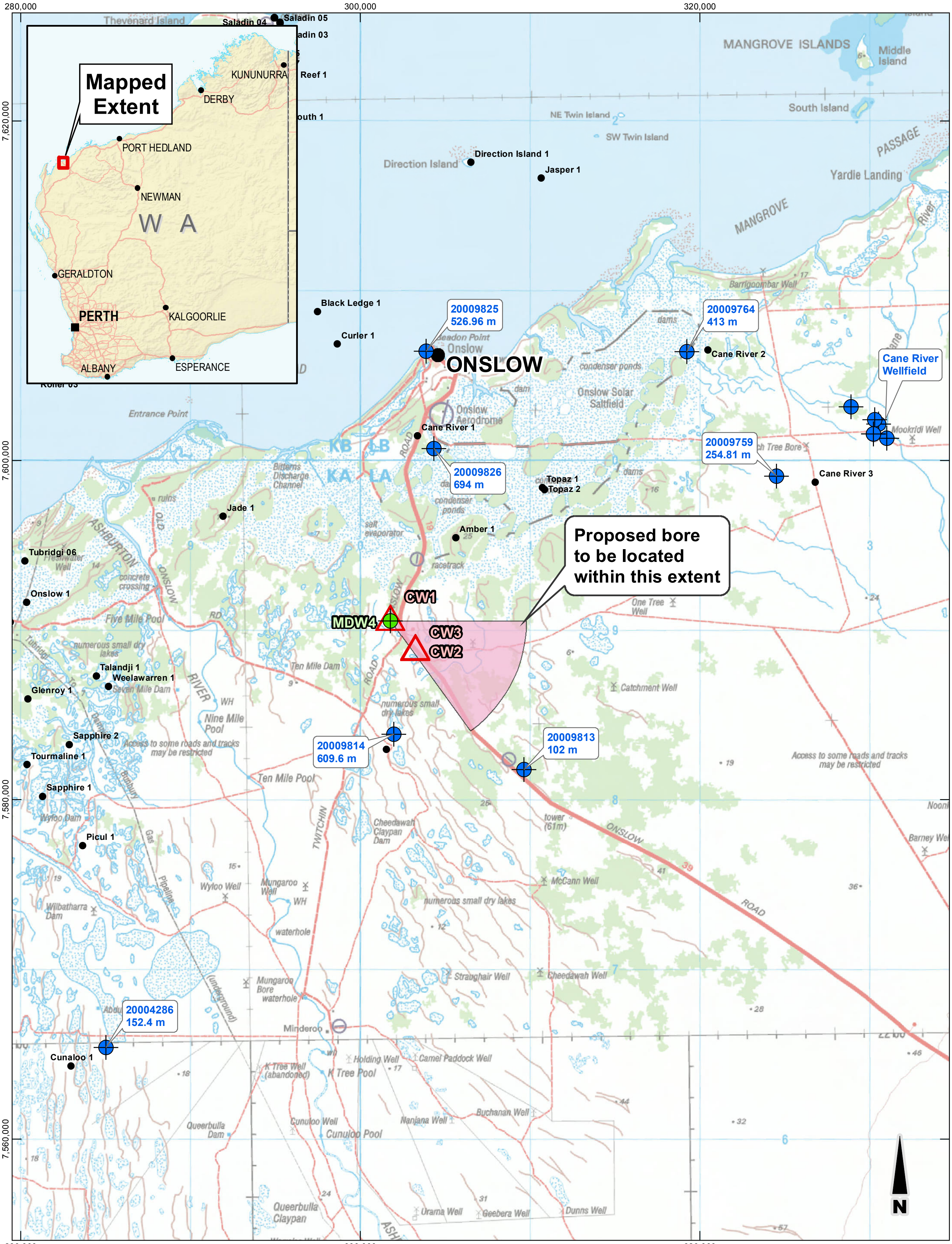

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CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-005-R-Rev0
DATE 22 Nov 2012
COMPILED GGW
APPROVED DMT

0 3 6 9 12 km

SCALE (at A4) 1:300,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

COPYRIGHT
Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

LEGEND
- Proposed Well
- Macedon Deep Well
- WIN Site (WIN Site ID, Bore Depth, m)
- Petroleum Well
- Proposed Bore Siting Extent

Birdrong Aquifer Bore Siting Assessment

SITE AND WELL LOCATIONS

FIGURE 1

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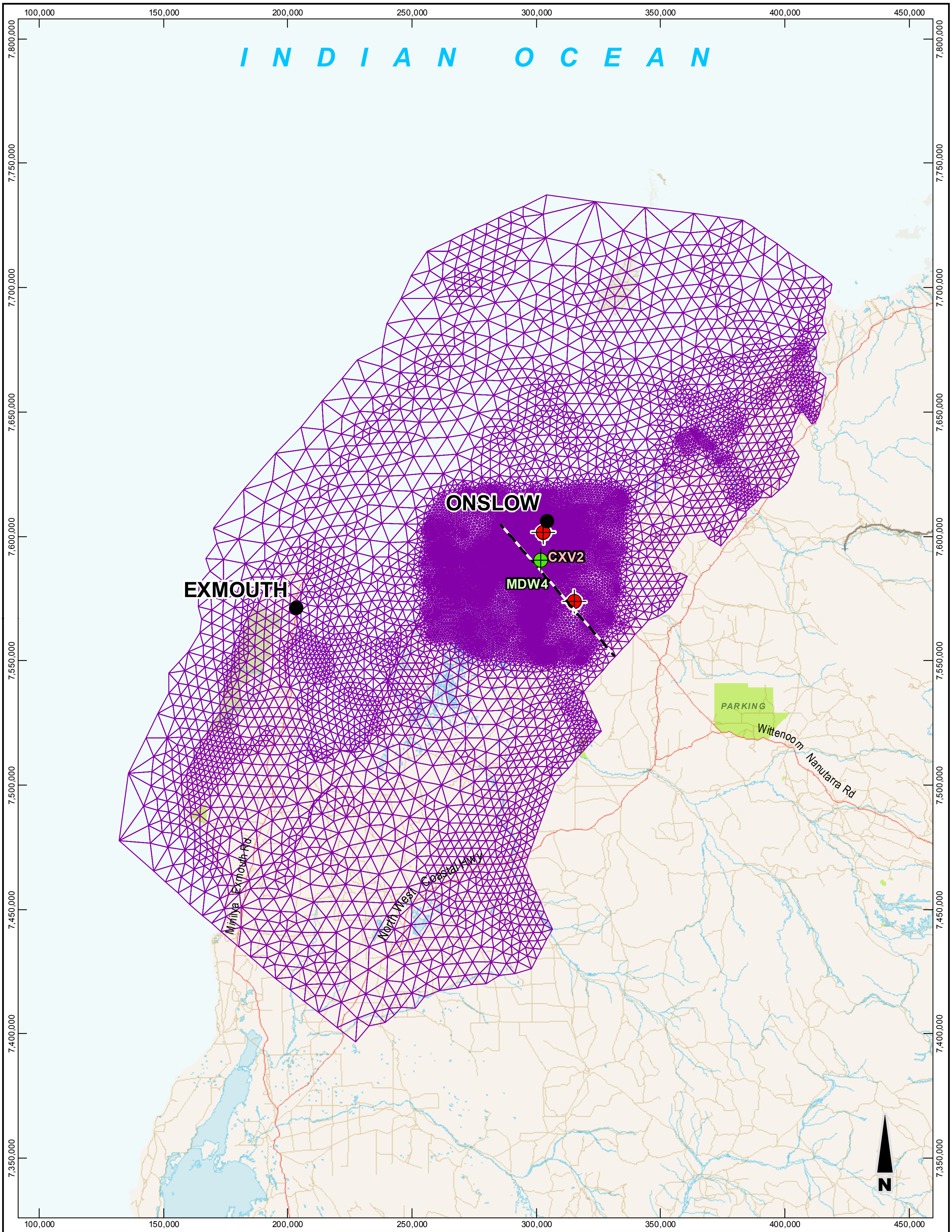

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CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-005-R-Rev0
DATE 21 Nov 2012
COMPILED GGW
APPROVED DMT

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km

SCALE (at A4) 1:2,000,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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Topgraphical data sourced from StreetPro Display 2009.

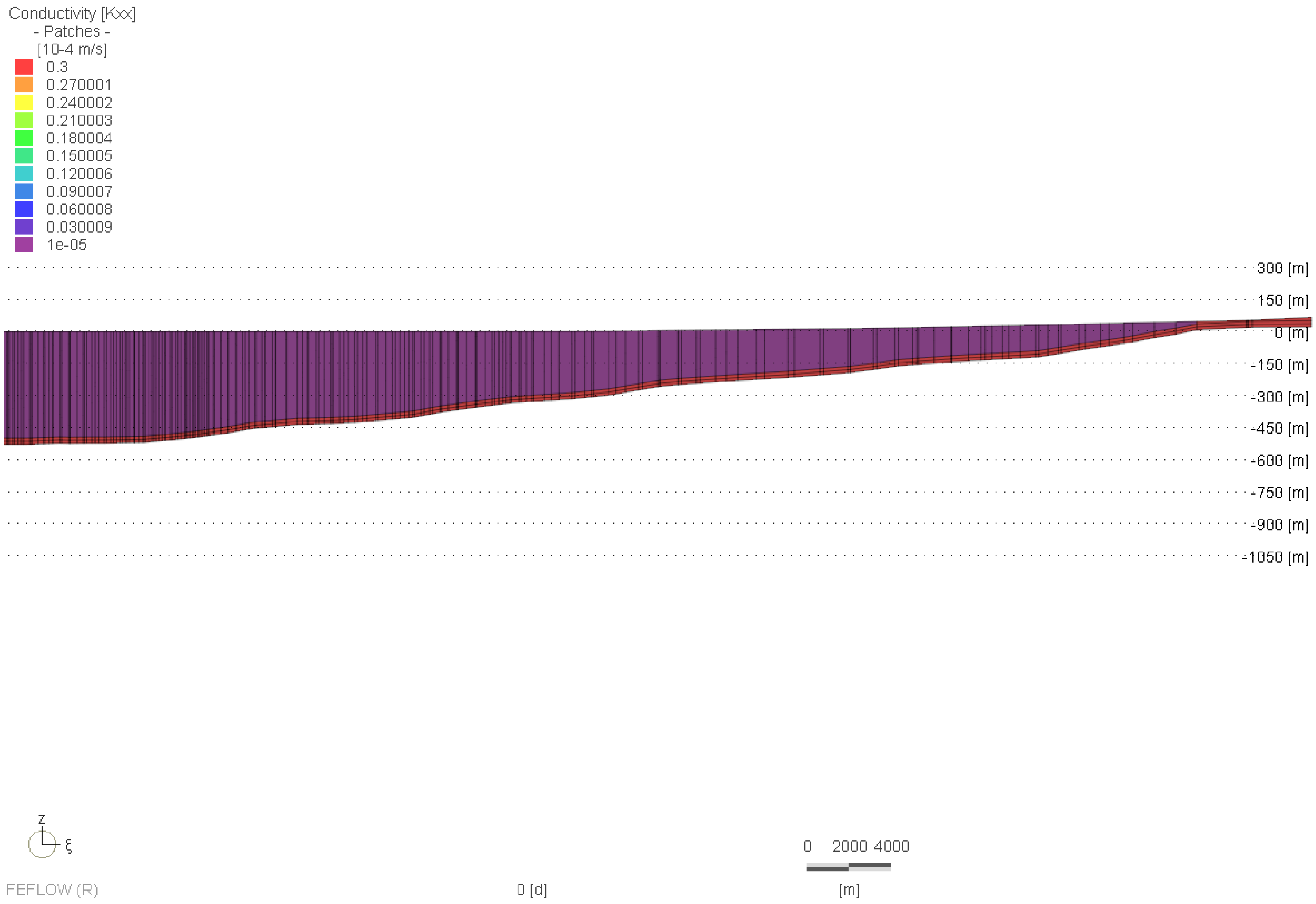
LEGEND
Proposed Well Location
Macedon Deep Well
Cross Section
Model Mesh

Birdrong Aquifer Bore Siting Assessment

MODEL MESH STRUCTURE

FIGURE 2

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R005\Rev0\127646019-005-R-F002-Rev0.mxd



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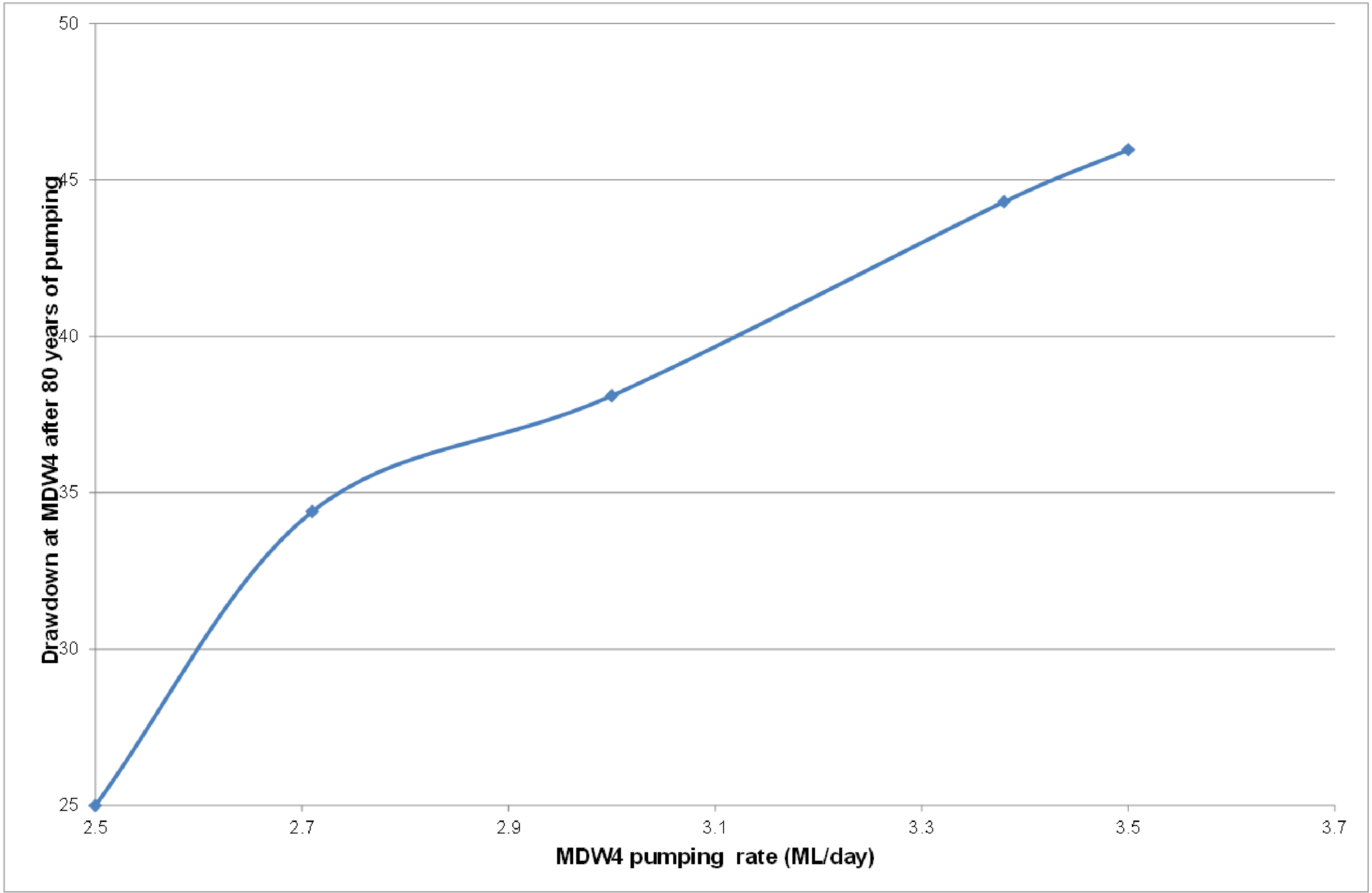
DOCUMENT 127646019-005-R-Rev0
DATE 21 Nov 2012
COMPILED GGW
APPROVED DMT

Birdrong Aquifer
Bore Siting Assessment

TYPICAL E-W CROSS-SECTION THROUGH MODELLED AREA

FIGURE 3

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R005\Rev1\127646019-005-R-F003-Rev0.mxd



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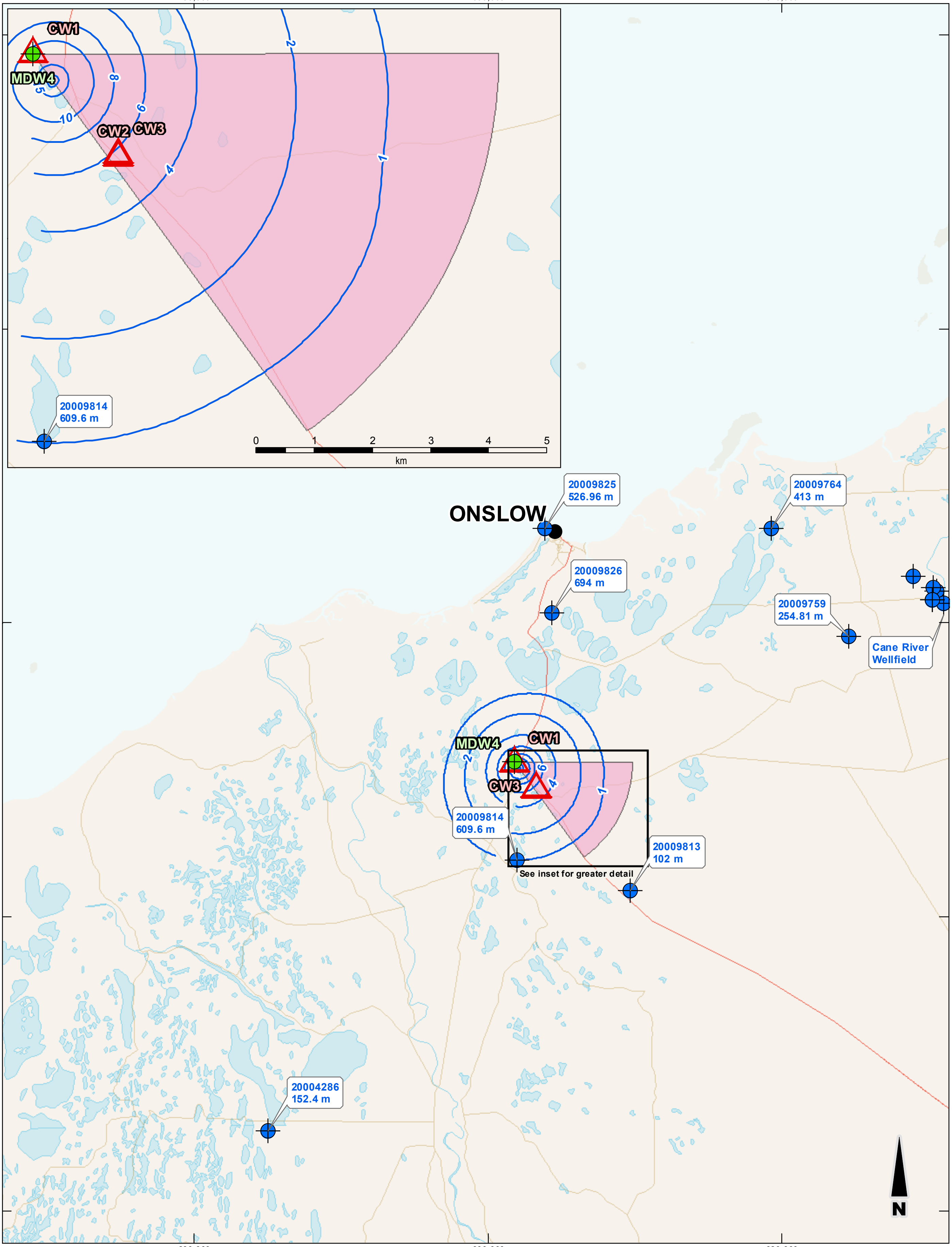
DOCUMENT 127646019-005-R-Rev0
DATE 26 Nov 2012
COMPILED GGW
APPROVED DMT

Birdrong Aquifer
Bore Siting Assessment

PROJECTED DRAWDOWN AT THE END OF AND 80 YEAR ABSTRACTION PERIOD: BORE CONFIGURATION ALTERNATIVE 1

FIGURE 4

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R005\Rev0\127646019-005-R-F004-Rev0.mxd



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DOCUMENT 127646019-005-R-Rev0
DATE 22 Nov 2012
COMPILED GGW
APPROVED DMT

0 5 10 15
km

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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WIN Sites sourced from DoW 2012.

LEGEND
Proposed Well
Macedon Deep
Proposed Bore Siting Extent
WIN Site
Drawdown Contour (m)

Birdrong Aquifer
Bore Siting Analysis

DRAWDOWN AT THE END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 1, PUMPING RATE AT MDW4 = 2.5 ML/DAY

FIGURE 5

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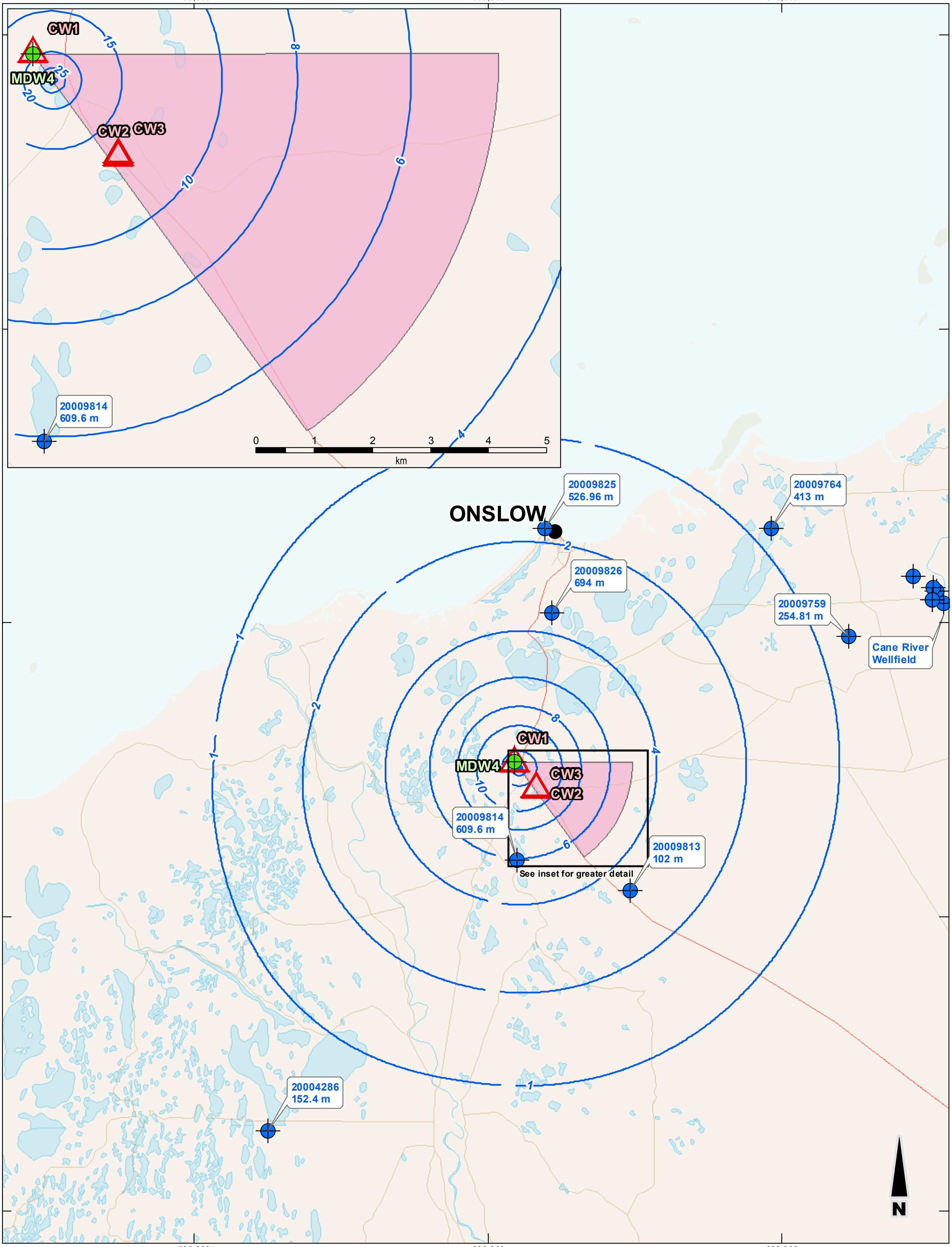

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DOCUMENT	127646019-005-R-Rev0
DATE	22 Nov 2012
COMPILED	GGW
APPROVED	DMT

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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WIN Sites sourced from DoW 2012.

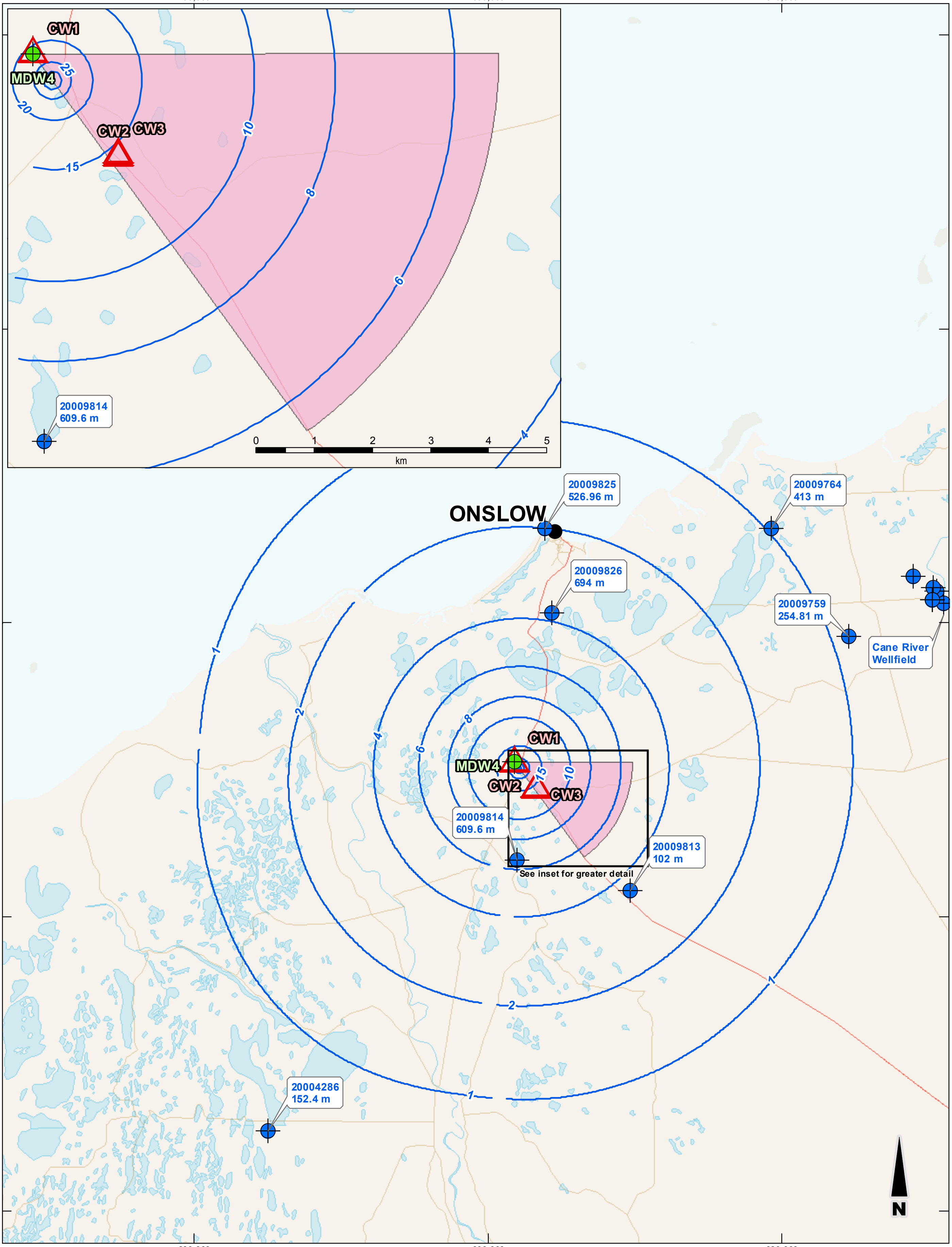
LEGEND
Proposed Well
Macedon Deep Well
Proposed Bore Siting Extent
WIN Site
Drawdown Contour (m)

Birdrong Aquifer
Bore Siting Analysis

DRAWDOWN AT THE END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 1, PUMPING RATE AT MDW4 = 2.71ML/DAY

FIGURE 6

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R005\Rev0\127646019-005-R-F006-Rev0-A1_S2.71.mxd



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DOCUMENT 127646019-005-R-Rev0
DATE 22 Nov 2012
COMPILED GGW
APPROVED DMT

0 5 10 15
km

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

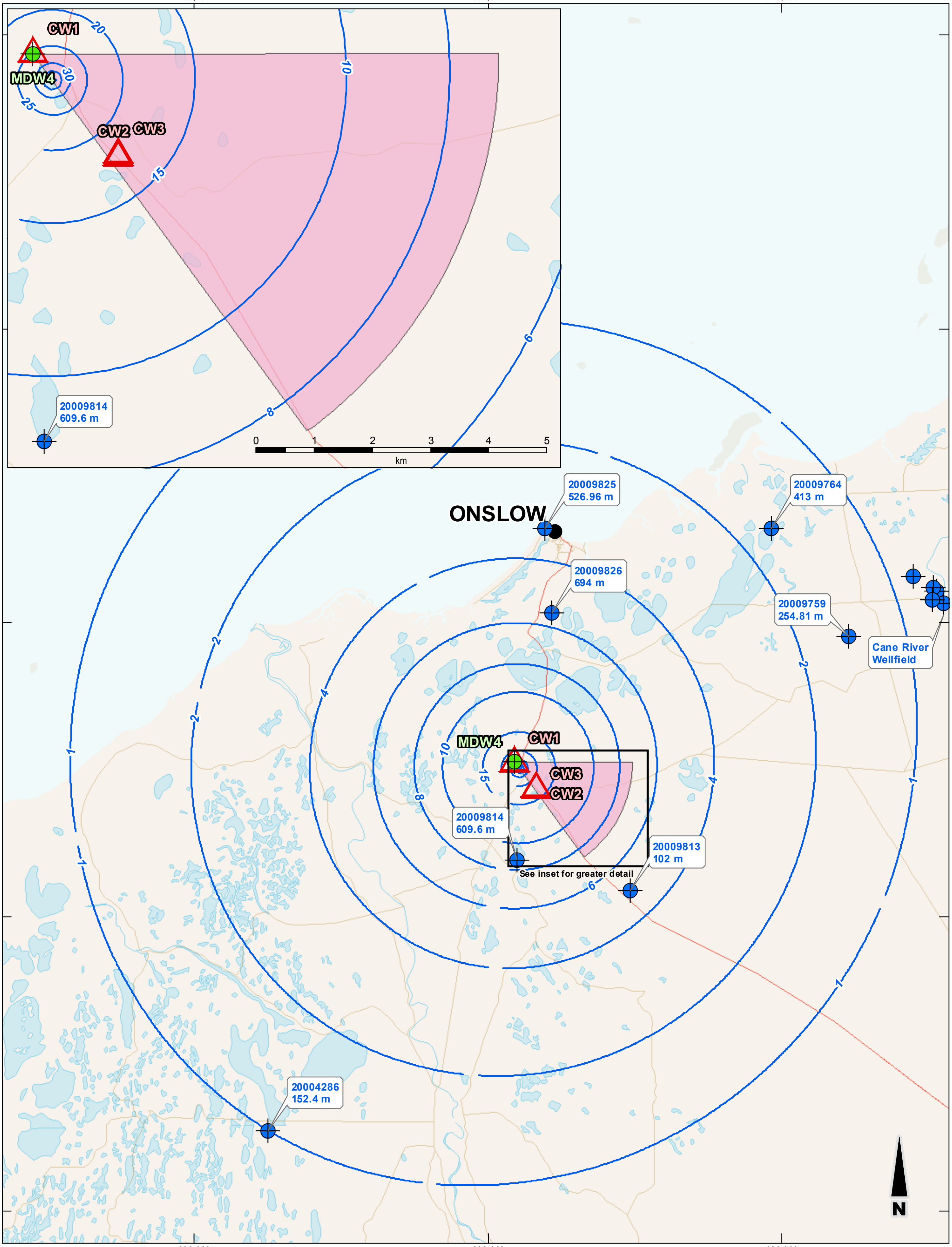
LEGEND
- Proposed Well
- Macedon Deep Well
- Proposed Bore Siting Extent
- WIN Site
- Drawdown Contour (m)

Birdrong Aquifer
Bore Siting Analysis

DRAWDOWN AT THE END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 1, PUMPING RATE AT MDW4 = 3.0 ML/DAY

FIGURE 7

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R005\Rev0\127646019-005-R-F007-Rev0-A1_S3.0.mxd



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CLIENT	Chevron Australia Pty Ltd
DOCUMENT	127646019-005-R-Rev0
DATE	22 Nov 2012
COMPILED	GGW
APPROVED	DMT

0 5 10 15
km

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

LEGEND
- Proposed Well
- Macedon Deep Well
- Proposed Bore Siting Extent
- WIN Site
- Drawdown Contour (m)

Birdrong Aquifer
Bore Siting Analysis

DRAWDOWN AT END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 1, PUMPING RATE AT MDW4 = 3.38 ML/DAY

FIGURE 8

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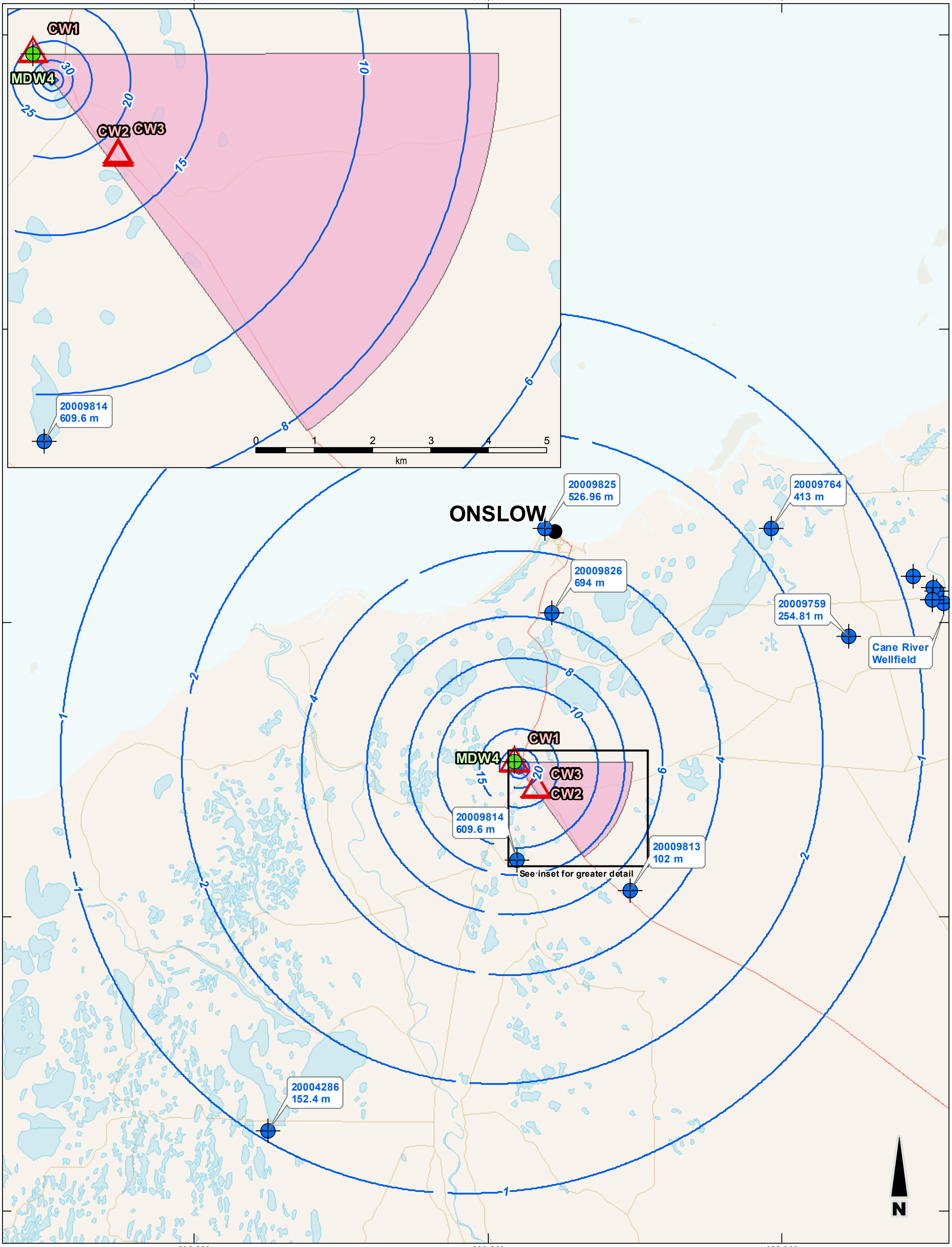

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CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-005-R-RevA
DATE
COMPILED GGW
APPROVED DMT

0 5 10 15
km

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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WIN Sites sourced from DoW 2012.

LEGEND
- Proposed Well
- Macedon Deep Well
- Proposed Bore Siting Extent
- WIN Site
- Drawdown Contour (m)

Birdrong Aquifer Bore Siting Analysis

DRAWDOWN AT END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 1, PUMPING RATE AT MDW4 = 3.5 ML/DAY

FIGURE 9

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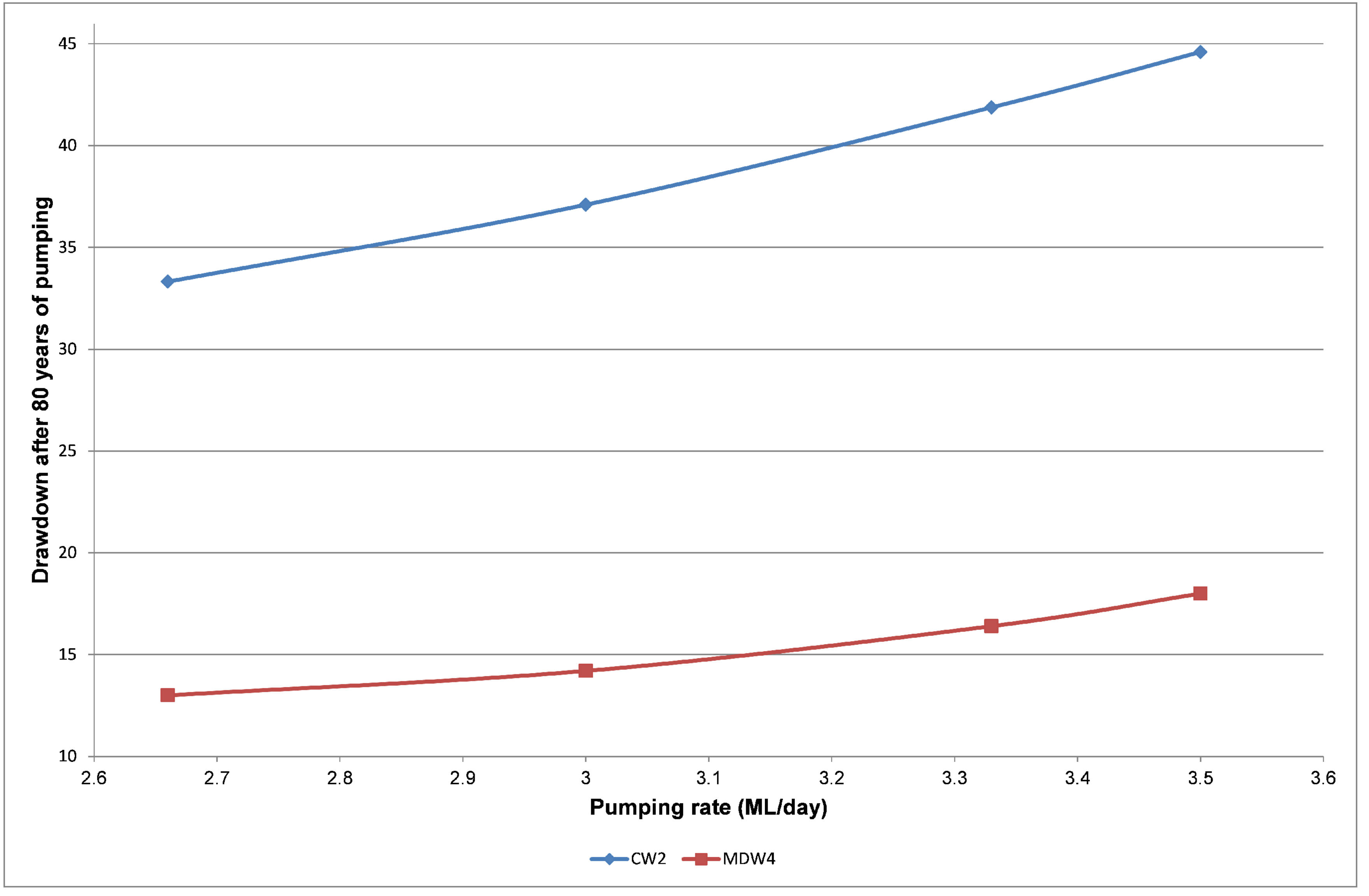

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DATE 22 Nov 2012
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Birdrong Aquifer Bore Siting Assessment

PROJECTED DRAWDOWN AT THE END OF AN 80 YEAR ABSTRACTION PERIOD: BORE CONFIGURATION ALTERNATIVE 2

FIGURE 10

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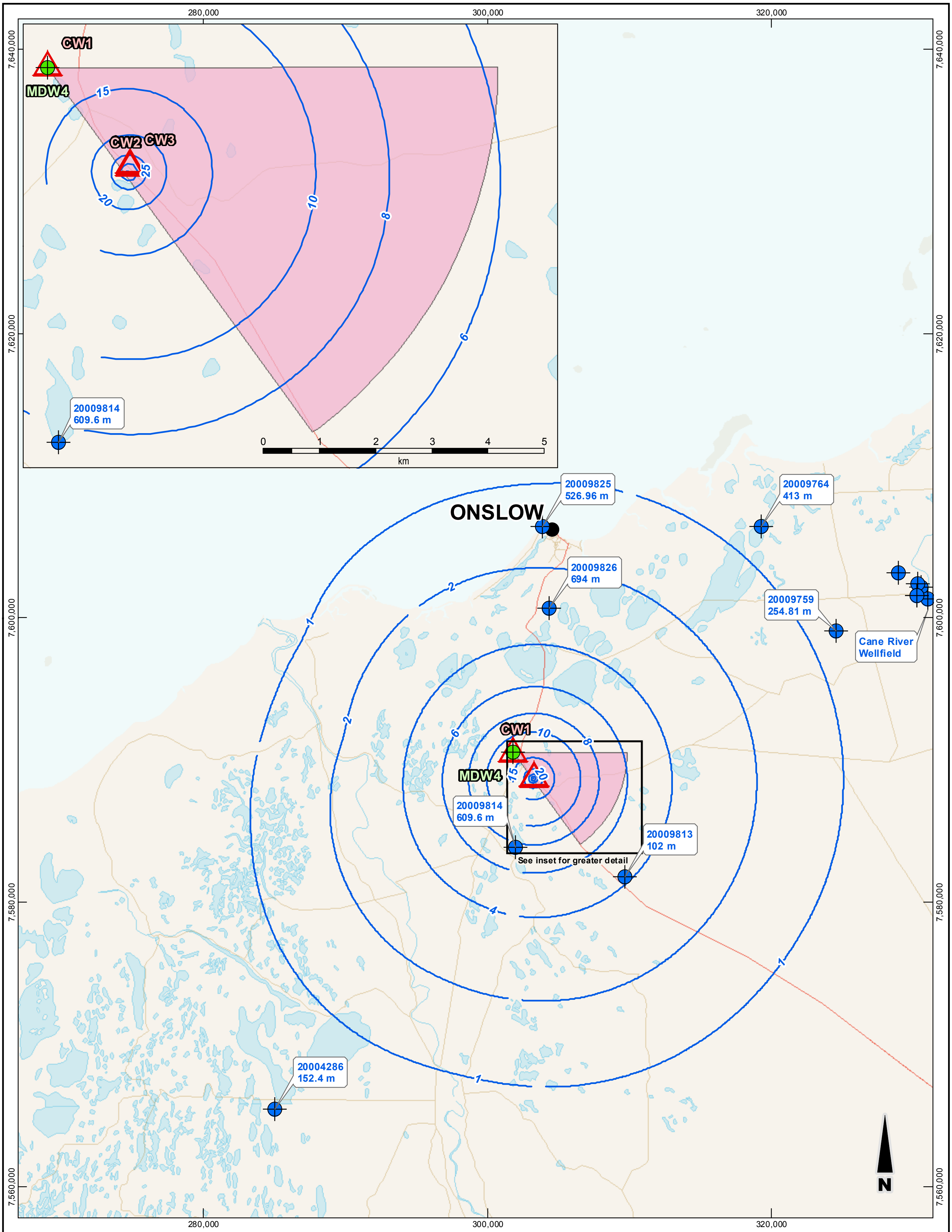

0 5 10 15
km

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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WIN Sites sourced from DoW 2012.

LEGEND
- Proposed Well
- WIN Site
- Macedon Deep Well
- Drawdown Contour (m)
- Proposed Bore Siting Extent

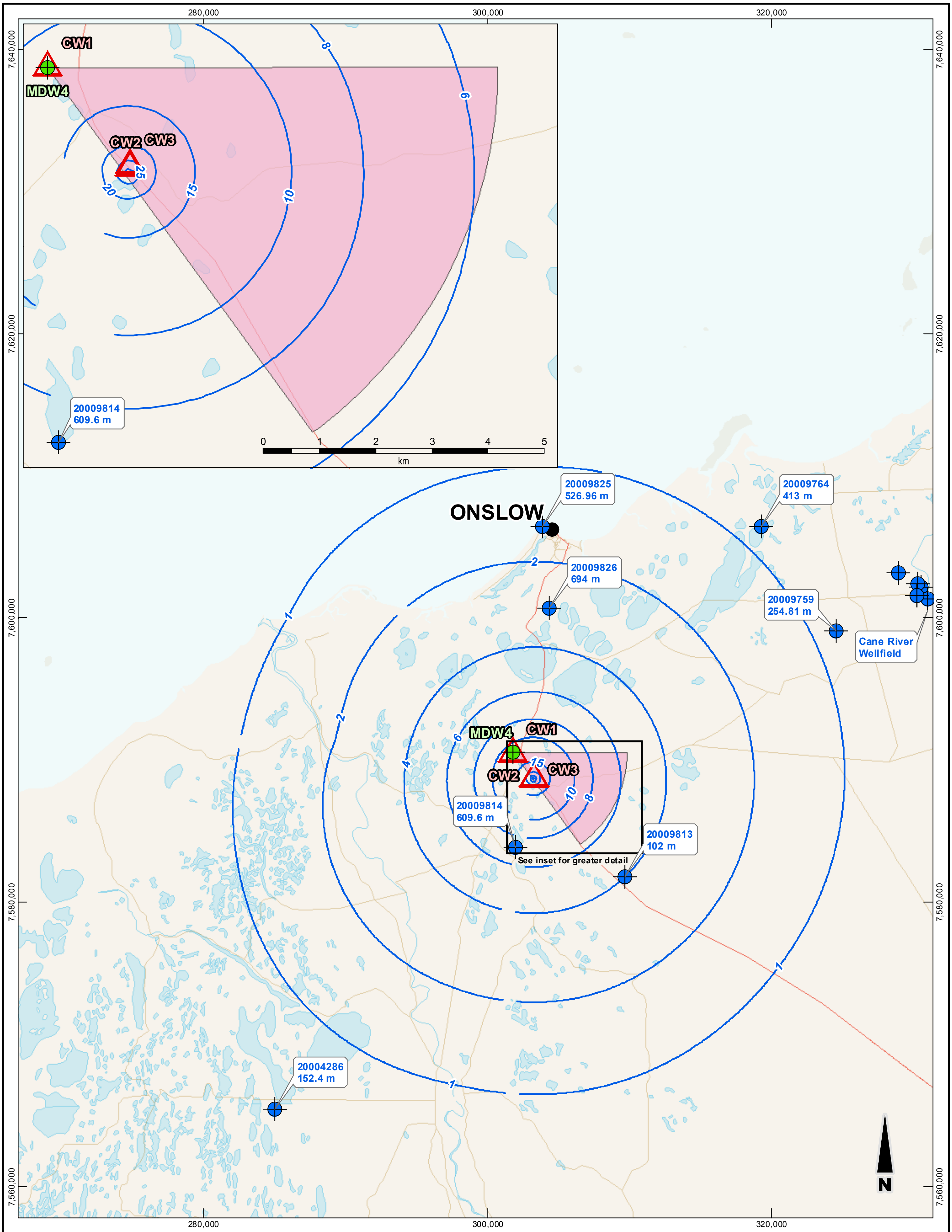
Golder Associates

CLIENT	Chevron Australia Pty Ltd
DOCUMENT	127646019-005-R-Rev0
DATE	23 Nov 2012
COMPILED	GGW
APPROVED	DMT

Birdrong Aquifer
Bore Siting Analysis

DRAWDOWN AT END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 2, PUMPING RATE AT CW2 = 2.66 ML/DAY

FIGURE 11



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DOCUMENT 127646019-005-R-Rev0
DATE 23 Nov 2012
COMPILED GGW
APPROVED DMT

0 5 10 15
km

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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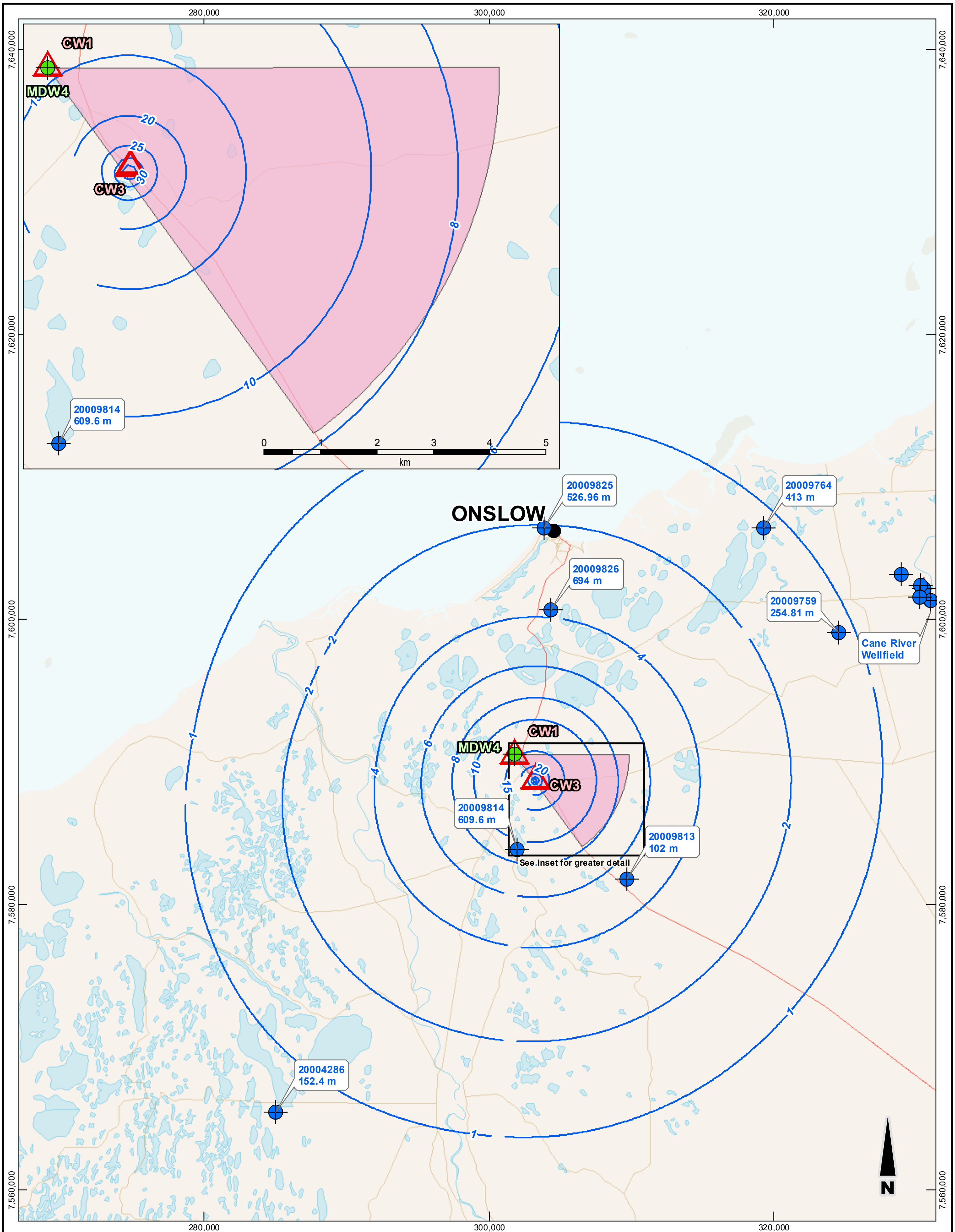
Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

LEGEND
- Proposed Well
- Macedon Deep Well
- Proposed Bore Siting Extent
- WIN Site
- Drawdown Contour (m)

Birdrong Aquifer Bore Siting Analysis

DRAWDOWN AT END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 2, PUMPING RATE AT CW2 = 3.0 ML/DAY

FIGURE 12



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CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-005-R-Rev0
DATE 23 Nov 2012
COMPILED GGW
APPROVED DMT

0 5 10 15 km

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

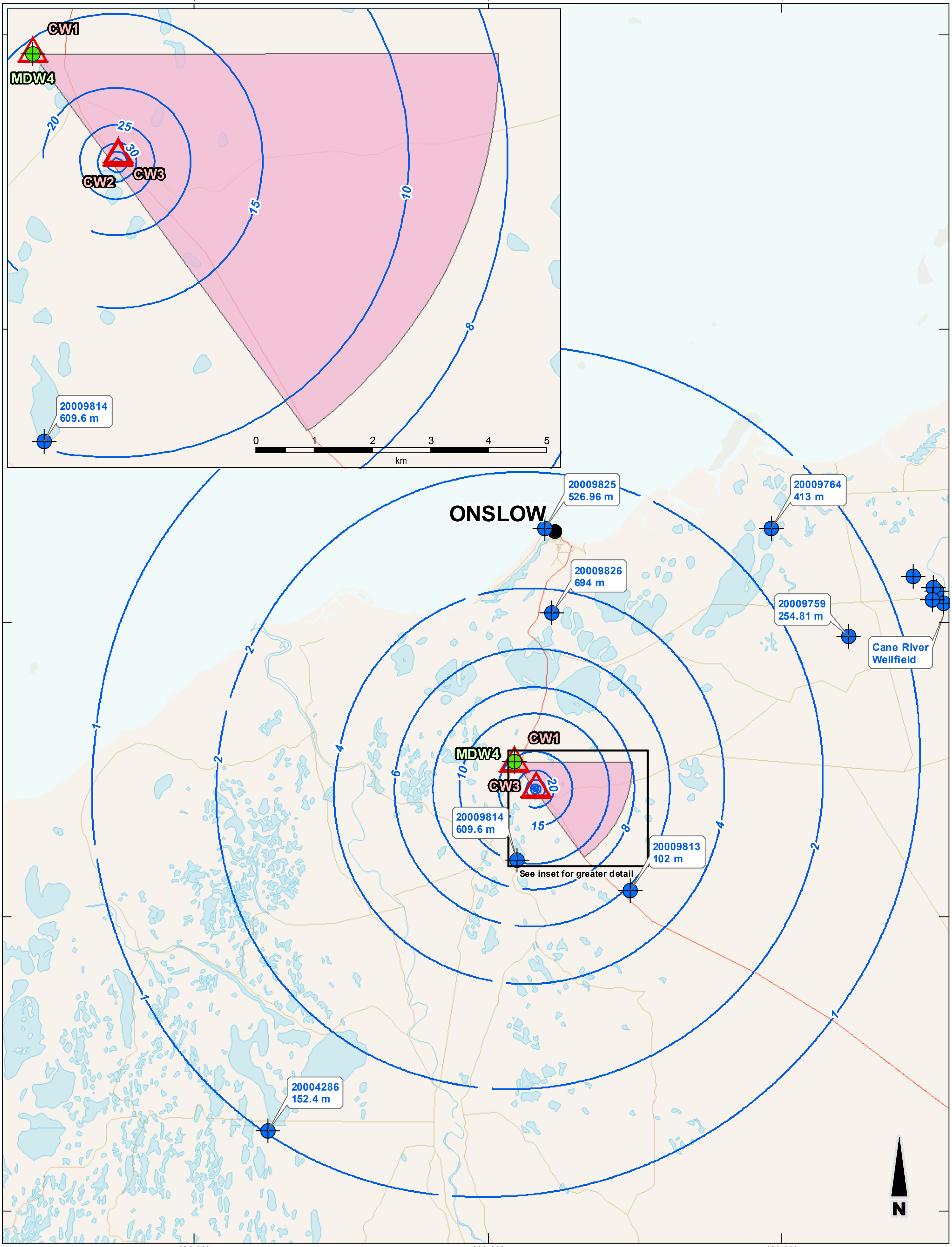
LEGEND
Proposed Well
Macedon Deep Well
Proposed Bore Siting Extent
WIN Site
Drawdown Contour (m)

Birdrong Aquifer Bore Siting Analysis

DRAWDOWN AT END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 2, PUMPING RATE AT CW2 = 3.33 ML/DAY

FIGURE 13

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R005\Rev0\127646019-005-R-F013-Rev0-A2_S3.33.mxd



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CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-005-R-Rev0
DATE 23 Nov 2012
COMPILED GGW
APPROVED DMT

0 5 10 15
km

SCALE (at A4) 1:350,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

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Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

LEGEND
Proposed Well
Macedon Deep Well
Proposed Bore Siting Extent
WIN Site
Drawdown Contour (m)

Birdrong Aquifer
Bore Siting Analysis

DRAWDOWN AT END OF AN 80 YEAR ABSTRACTION PERIOD: ALTERNATIVE NO. 2, PUMPING RATE AT CW2 = 3.5 ML/DAY

FIGURE 14

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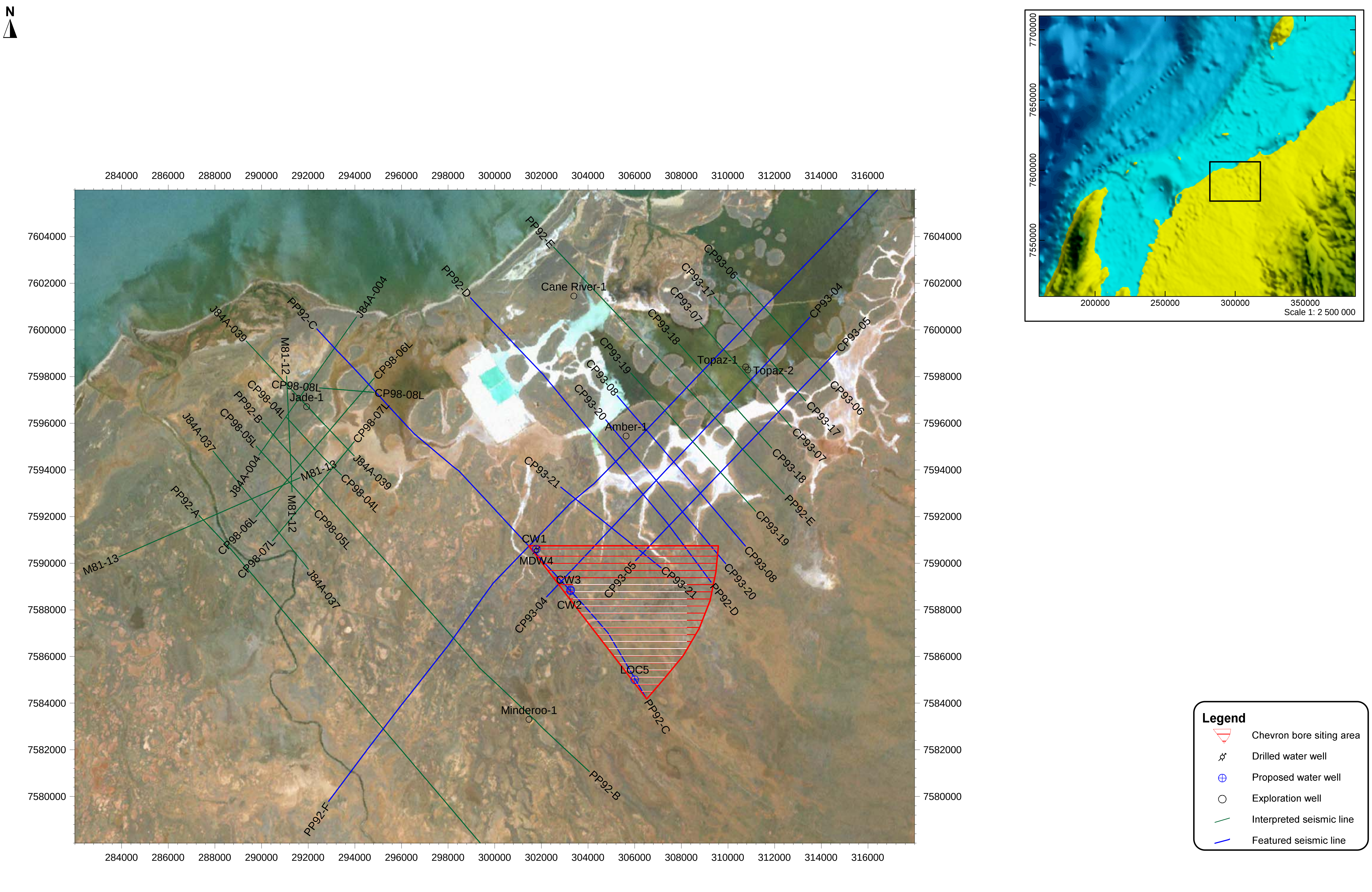
APPENDIX A

Seismic Interpretation Figures



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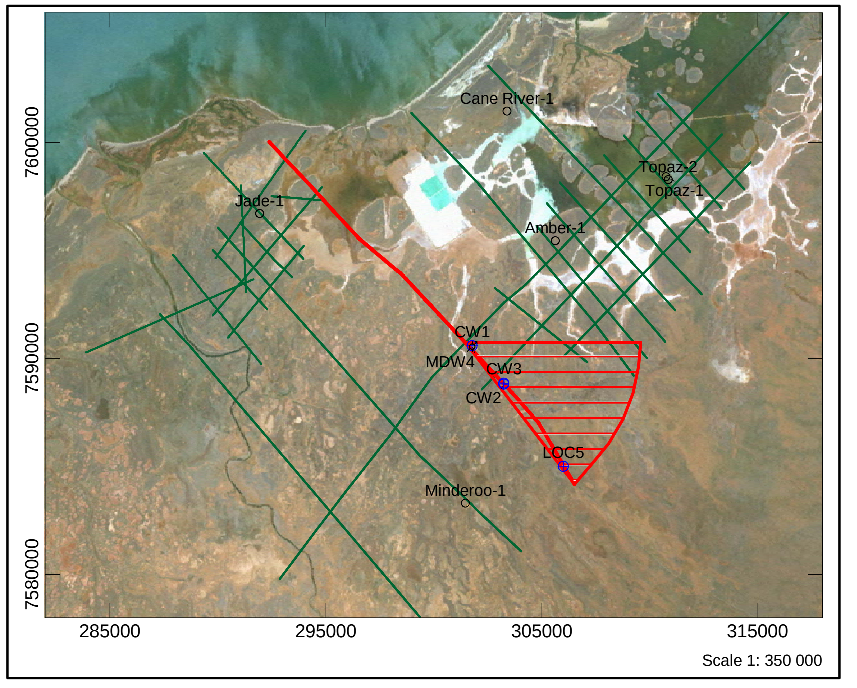
TITLE **BIRDRONG AQUIFER BORE SITING ASSESSMENT LOCALITY MAP**

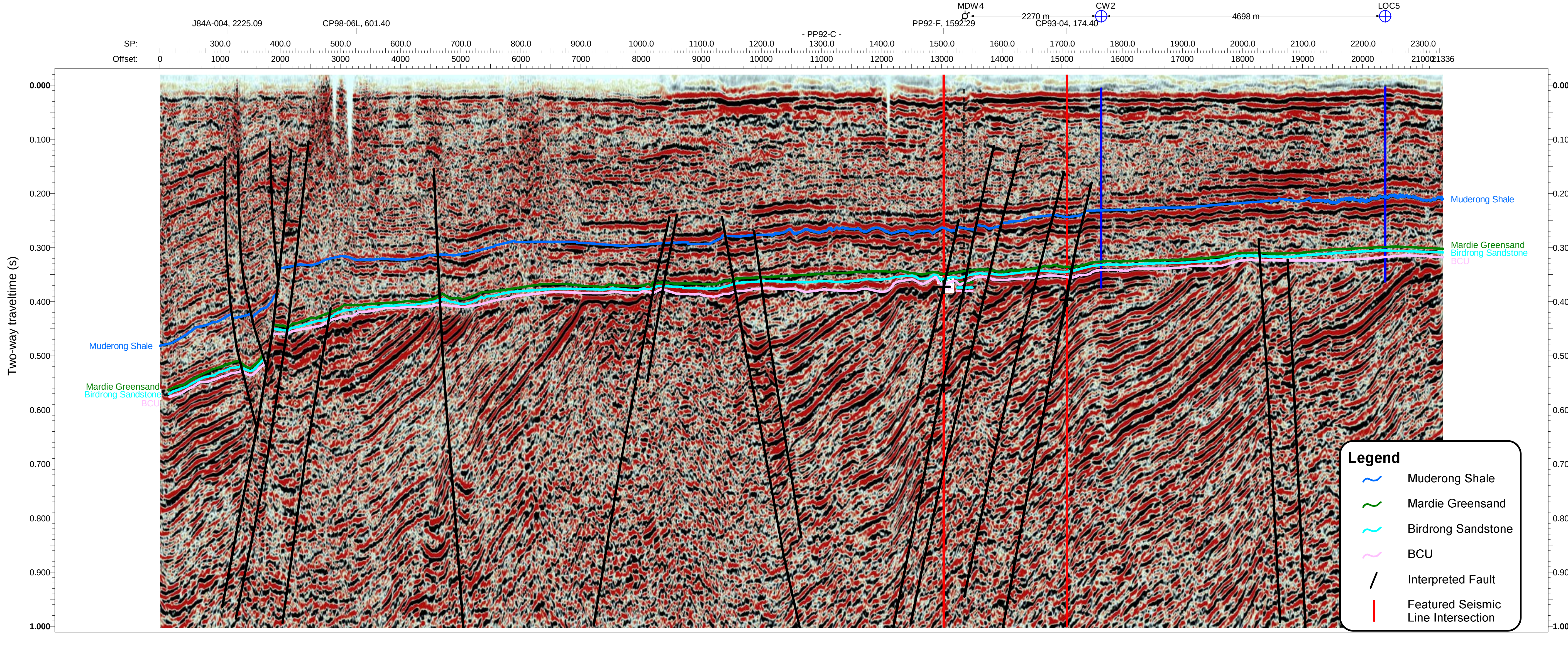
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:150 000

OCTOBER 2012

PROJECT 1278208697

A01





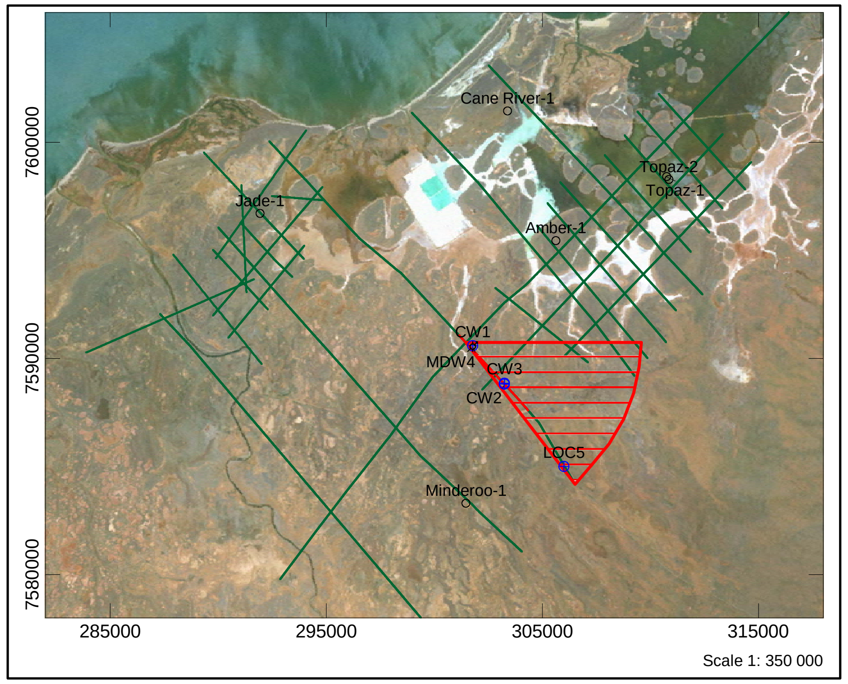
Golder Associates

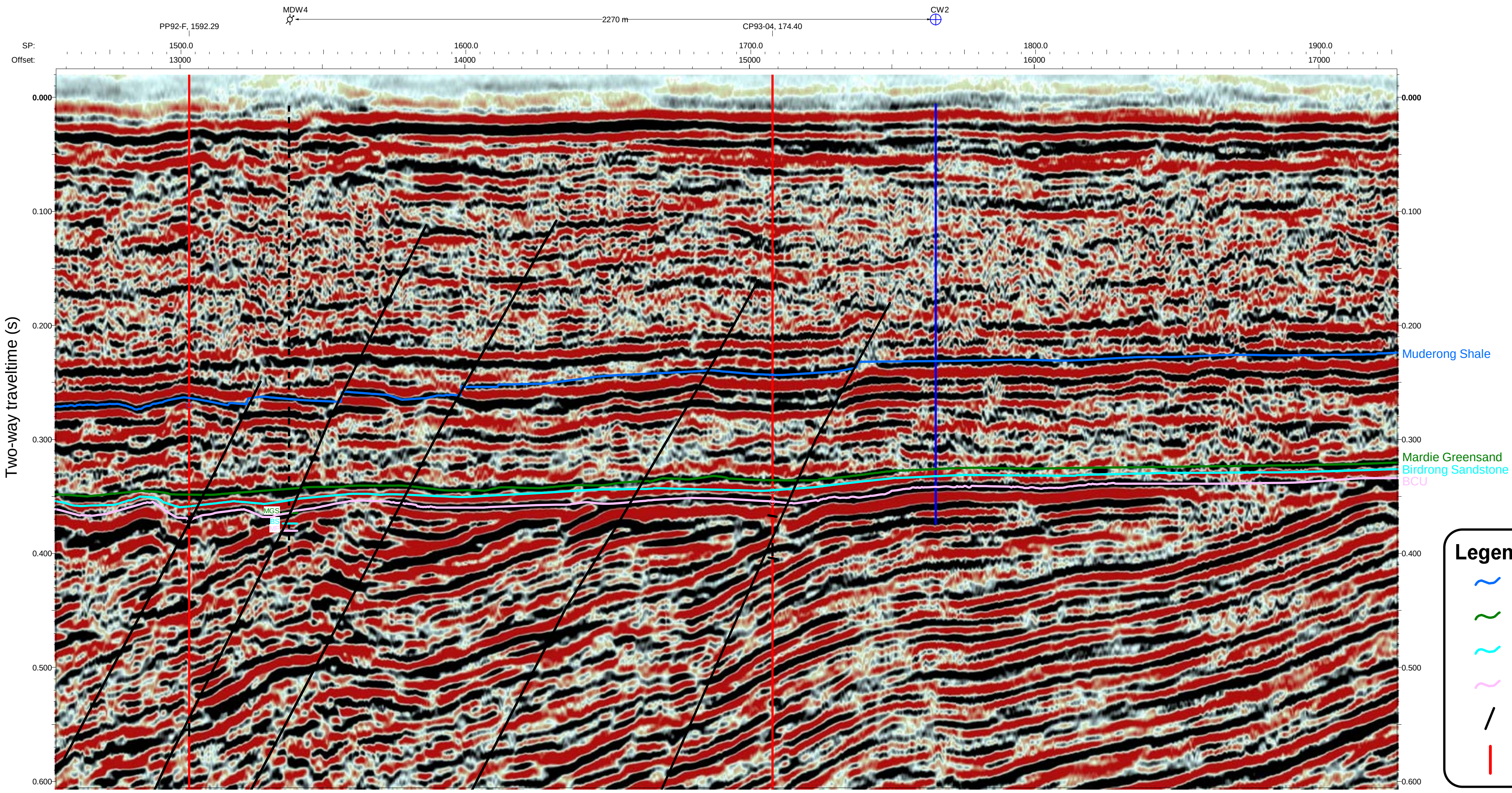
TITLE **SEISMIC LINE PP92-C**

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:70 000

OCTOBER 2012
PROJECT 1278208697

A02





Legend

- Muderong Shale
- Mardie Greensand
- Birdrong Sandstone
- BCU
- Interpreted Fault
- Featured Seismic Line Intersection

Golder Associates

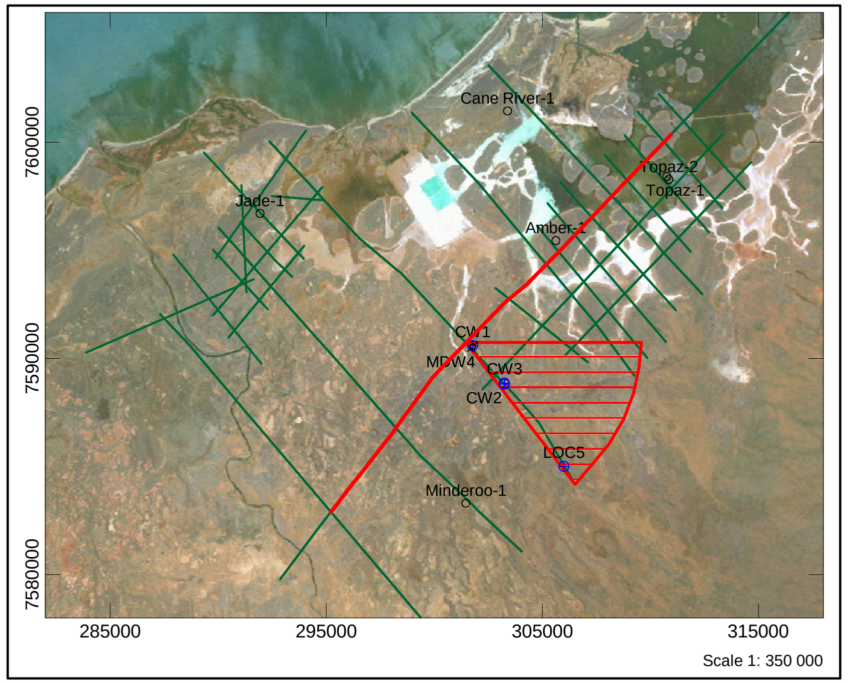
TITLE **SEISMIC LINE PP92-C (SP1457 to 1927)**

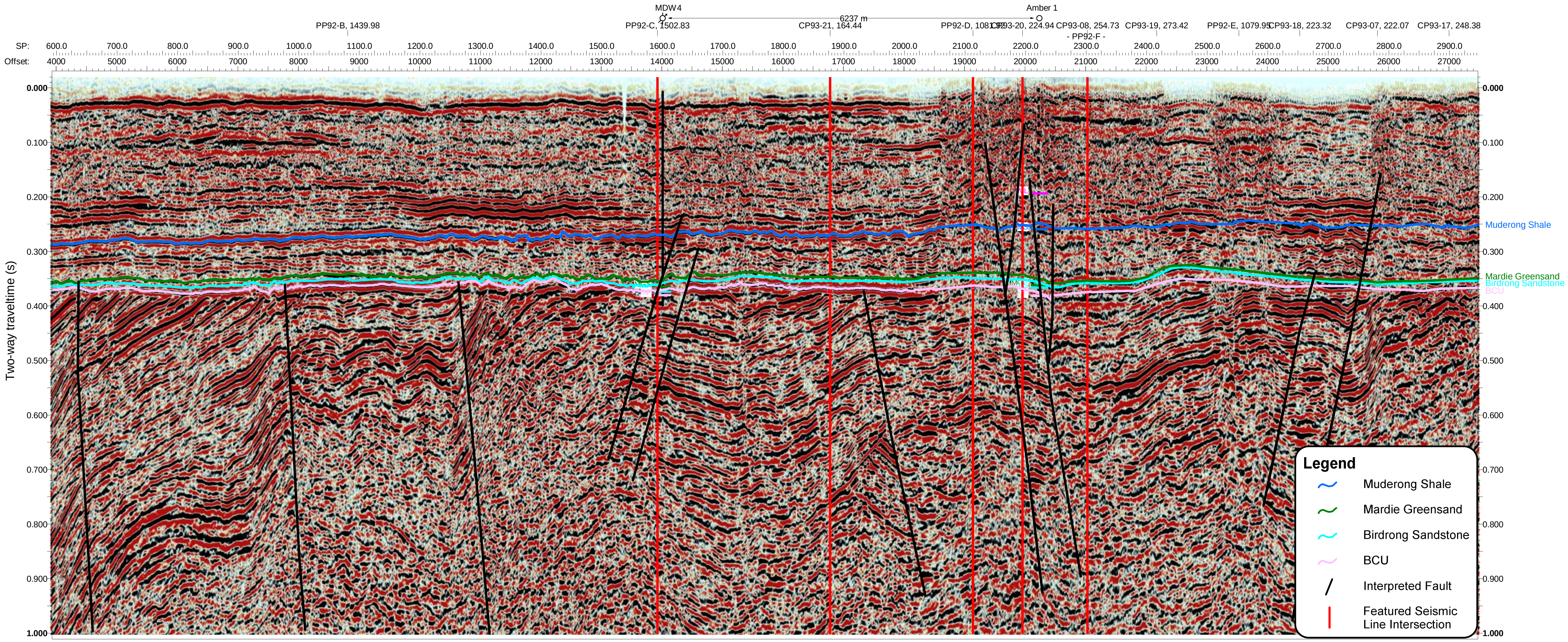
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:20 000

OCTOBER 2012

PROJECT 1278208697

A03





TITLE SEISMIC LINE PP92-F (SP593 to 2946)

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:70 000

OCTOBER 2012

PROJECT 1278208697

A04

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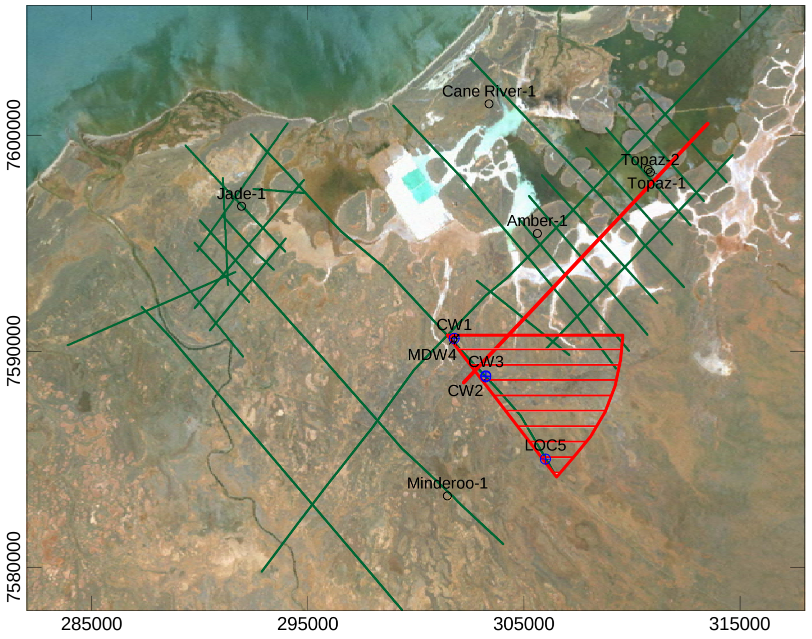

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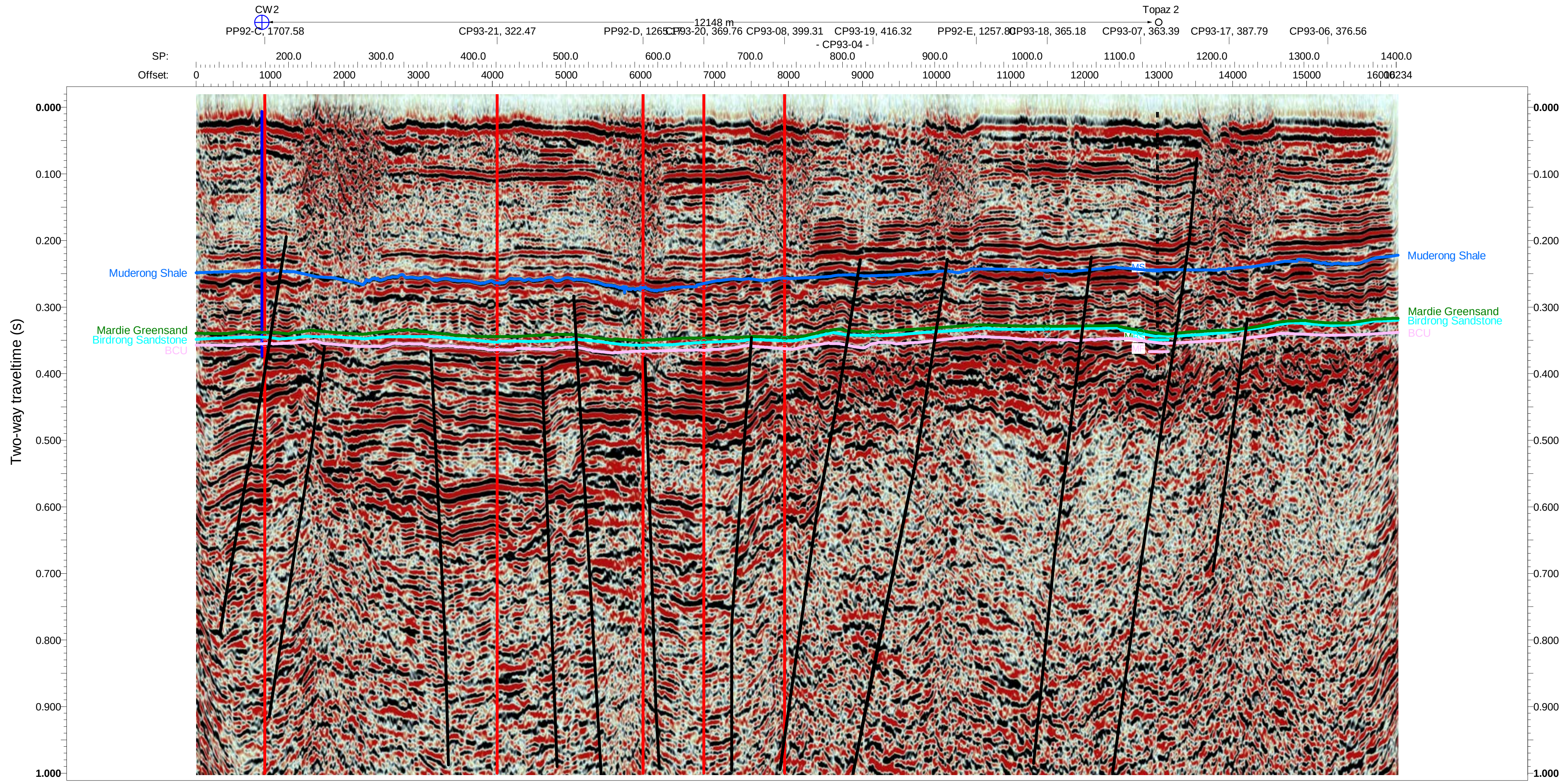


Legend

- Muderong Shale
- Mardie Greensand
- Birdrong Sandstone
- BCU
- Interpreted Fault
- Featured Seismic Line Intersection

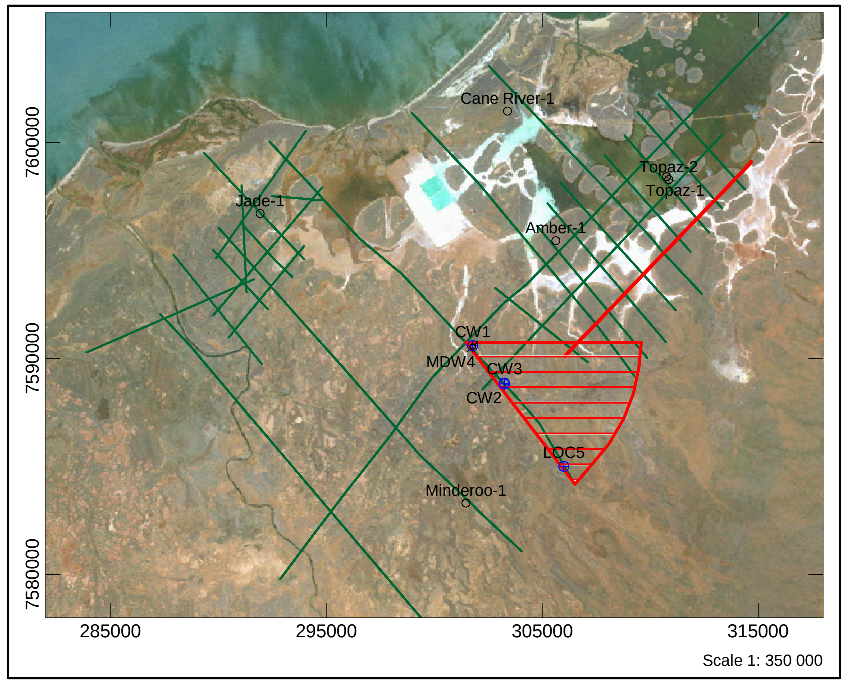
Golder Associates

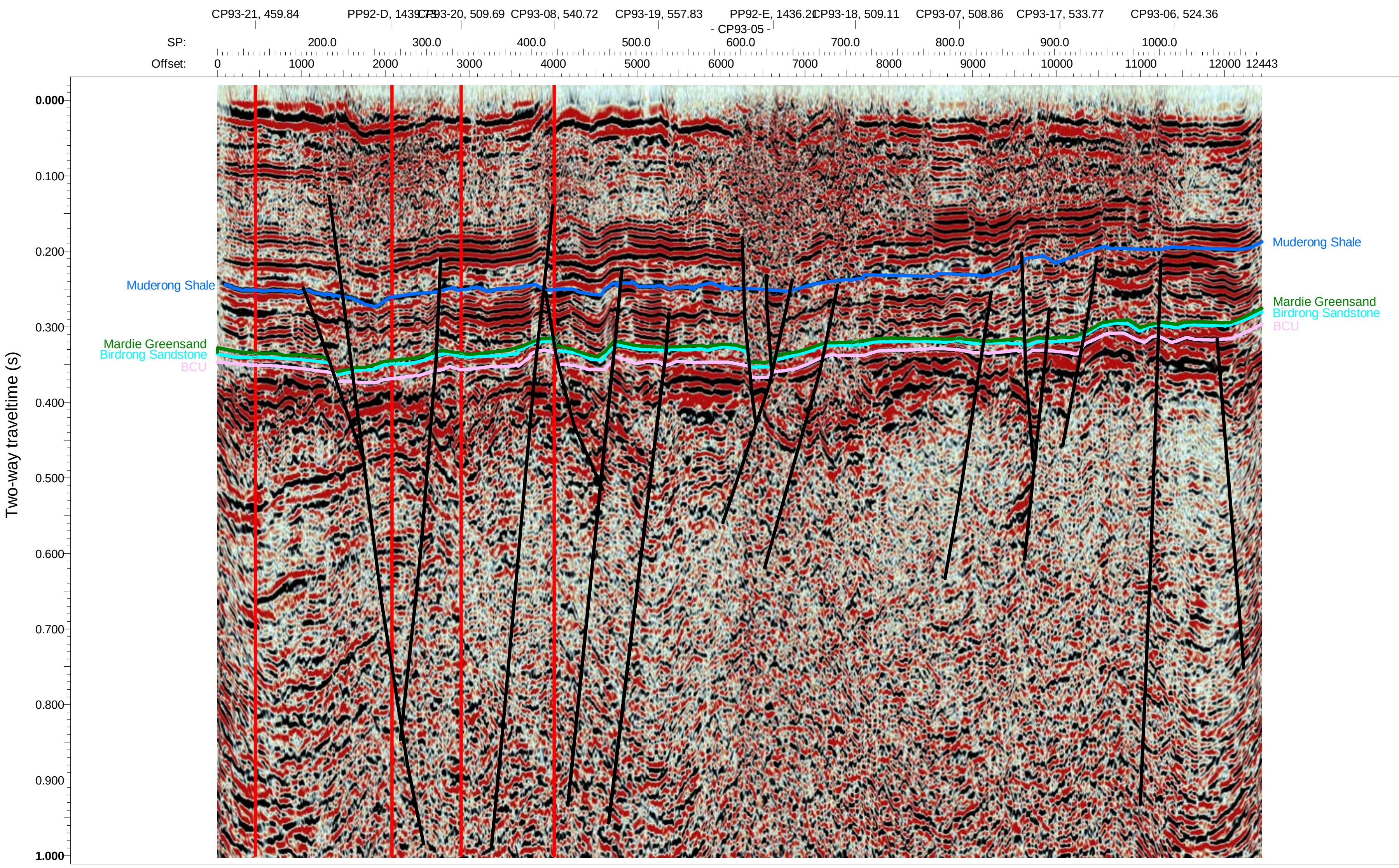
TITLE **SEISMIC LINE CP93-04**

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:70 000

OCTOBER 2012
PROJECT 1278208697

A05





Legend

- Muderong Shale
- Mardie Greensand
- Birdrong Sandstone
- BCU
- Interpreted Fault
- Featured Seismic Line Intersection

Golder Associates

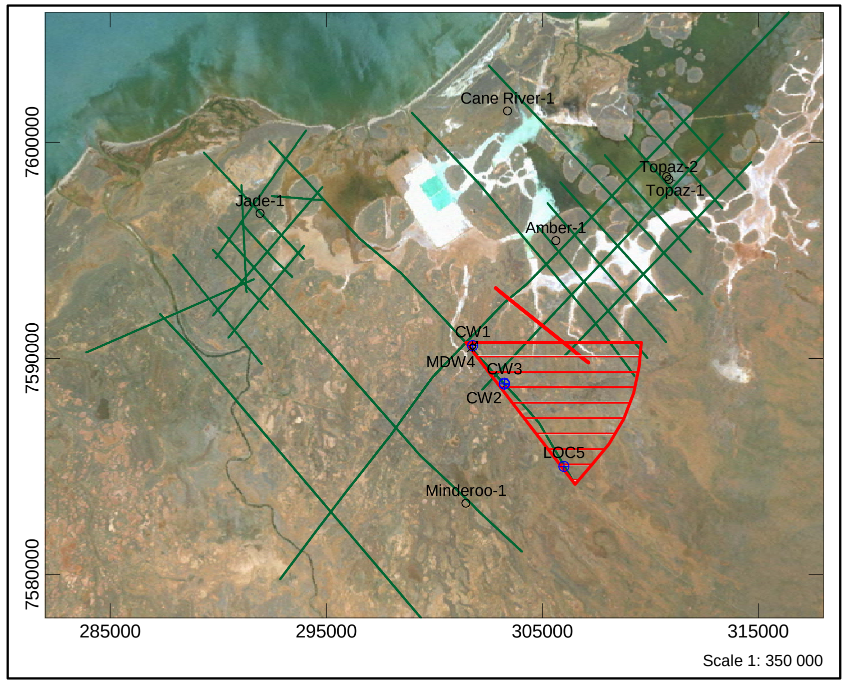
TITLE **SEISMIC LINE CP93-05**

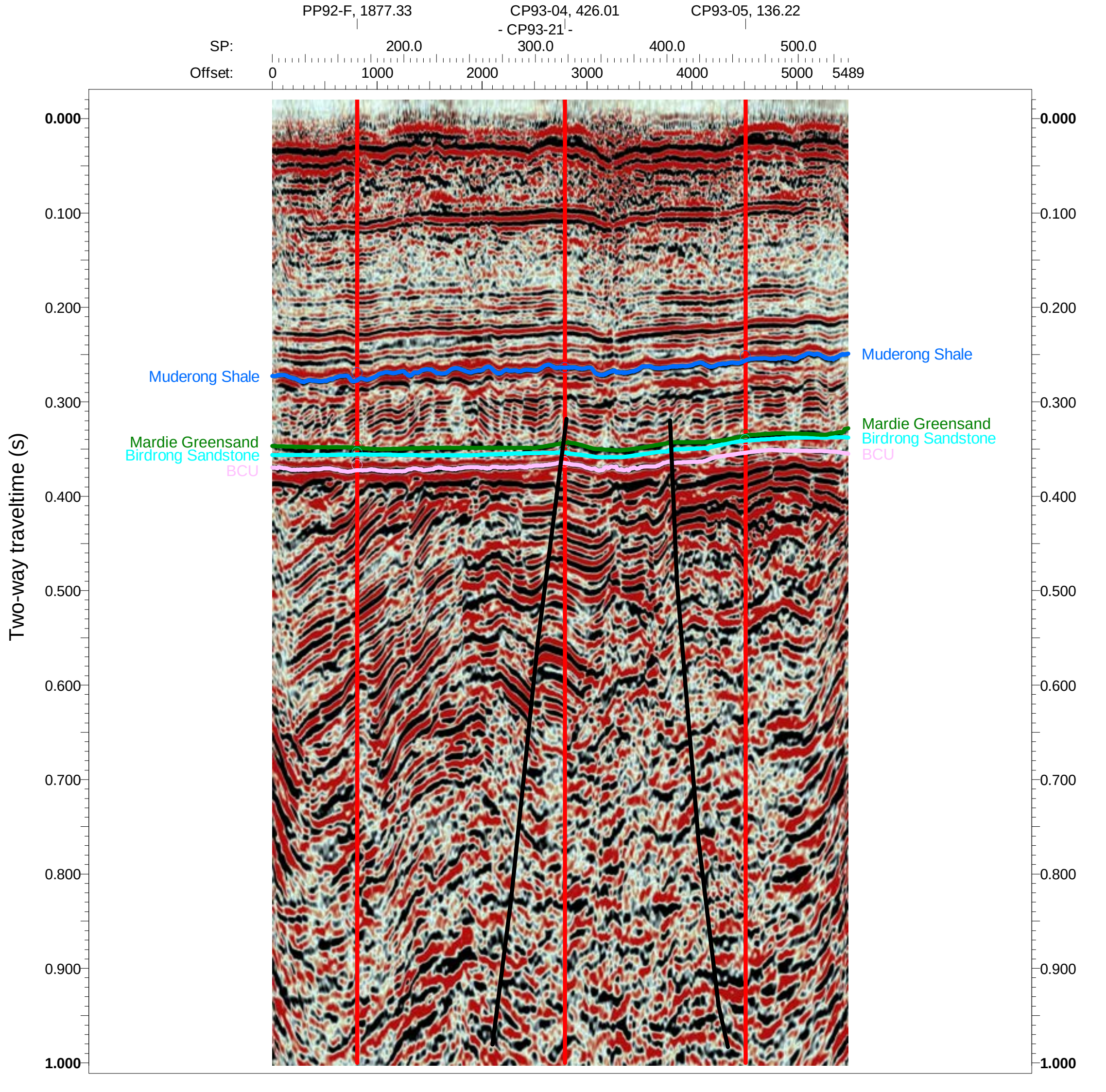
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:70 000

OCTOBER 2012

PROJECT 1278208697

A06





Legend

- Muderong Shale
- Mardie Greensand
- Birdrong Sandstone
- BCU
- Interpreted Fault
- Featured Seismic Line Intersection

Golder Associates

TITLE **SEISMIC LINE CP93-21**

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:70 000

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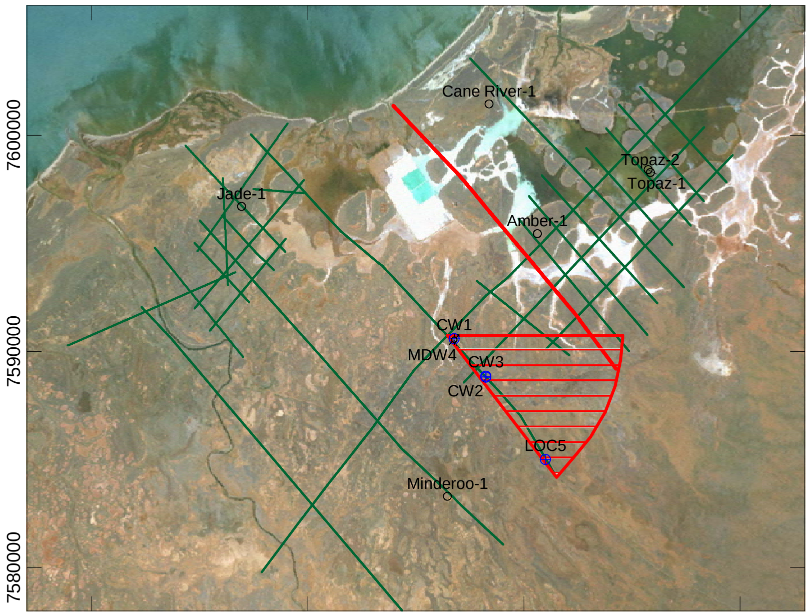
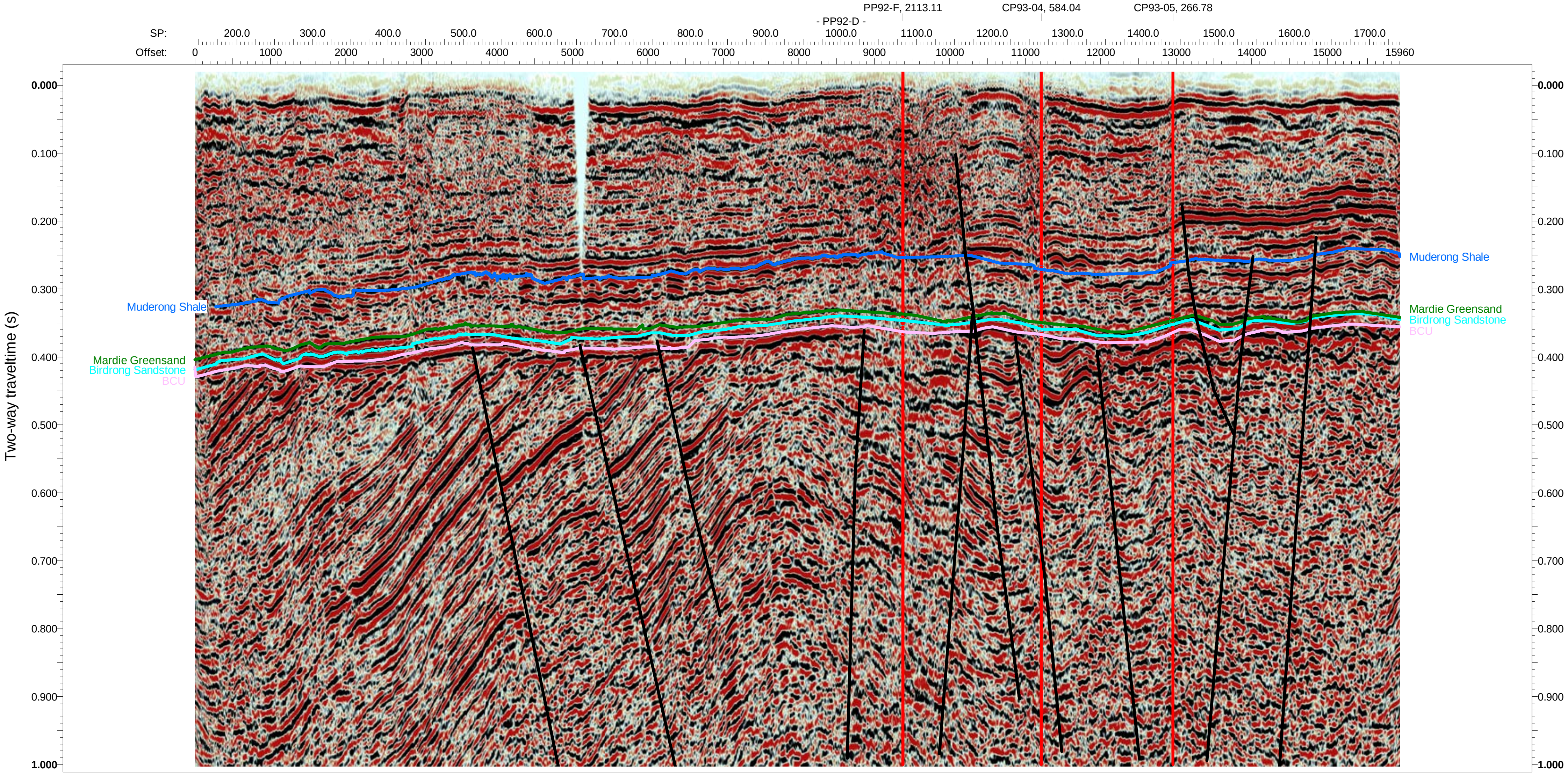
PROJECT 1278208697

A07





Legend

- Muderong Shale
- Mardie Greensand
- Birdrong Sandstone
- BCU
- Interpreted Fault
- Featured Seismic Line Intersection

Golder Associates

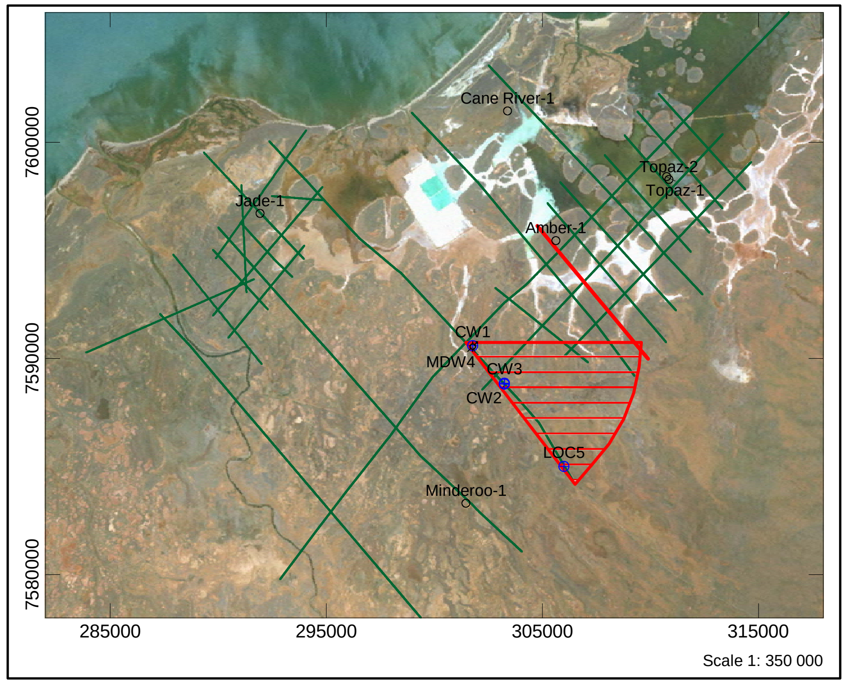
TITLE **SEISMIC LINE PP92-D**

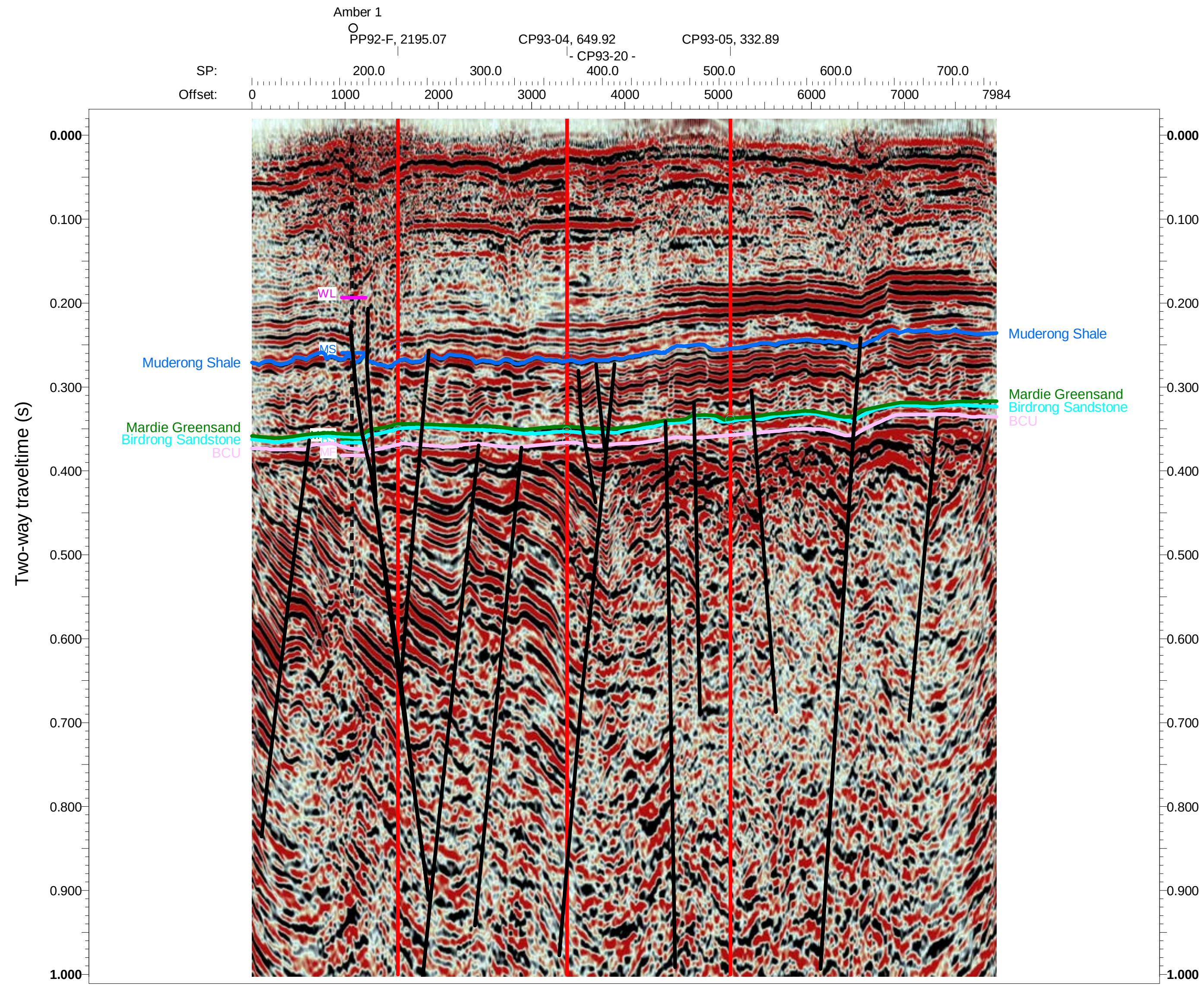
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:70 000

OCTOBER 2012

PROJECT 1278208697

A08





Legend

- Muderong Shale
- Mardie Greensand
- Birdrong Sandstone
- BCU
- Interpreted Fault
- Featured Seismic Line Intersection

Golder Associates

TITLE **SEISMIC LINE CP93-20**

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:70 000

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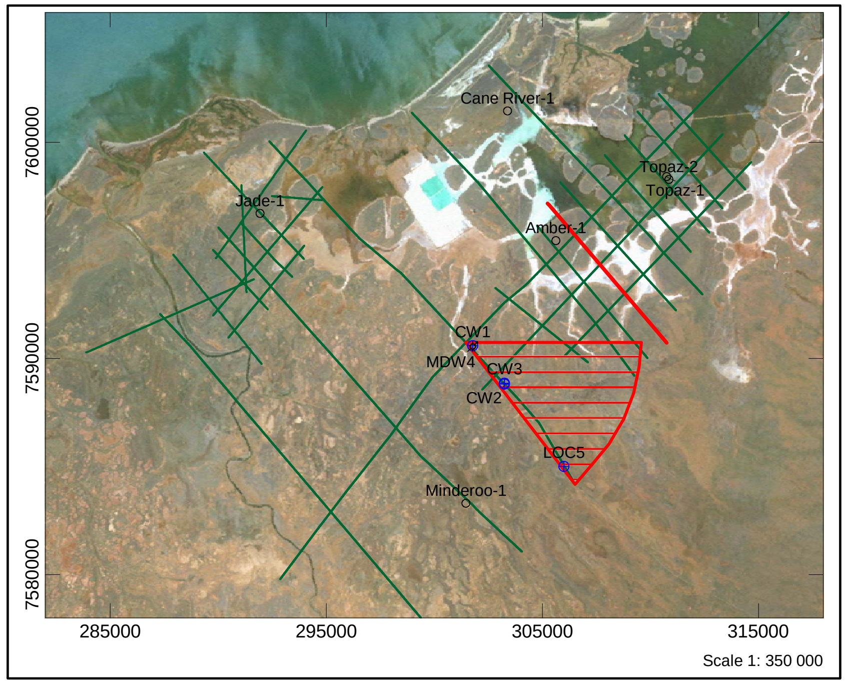
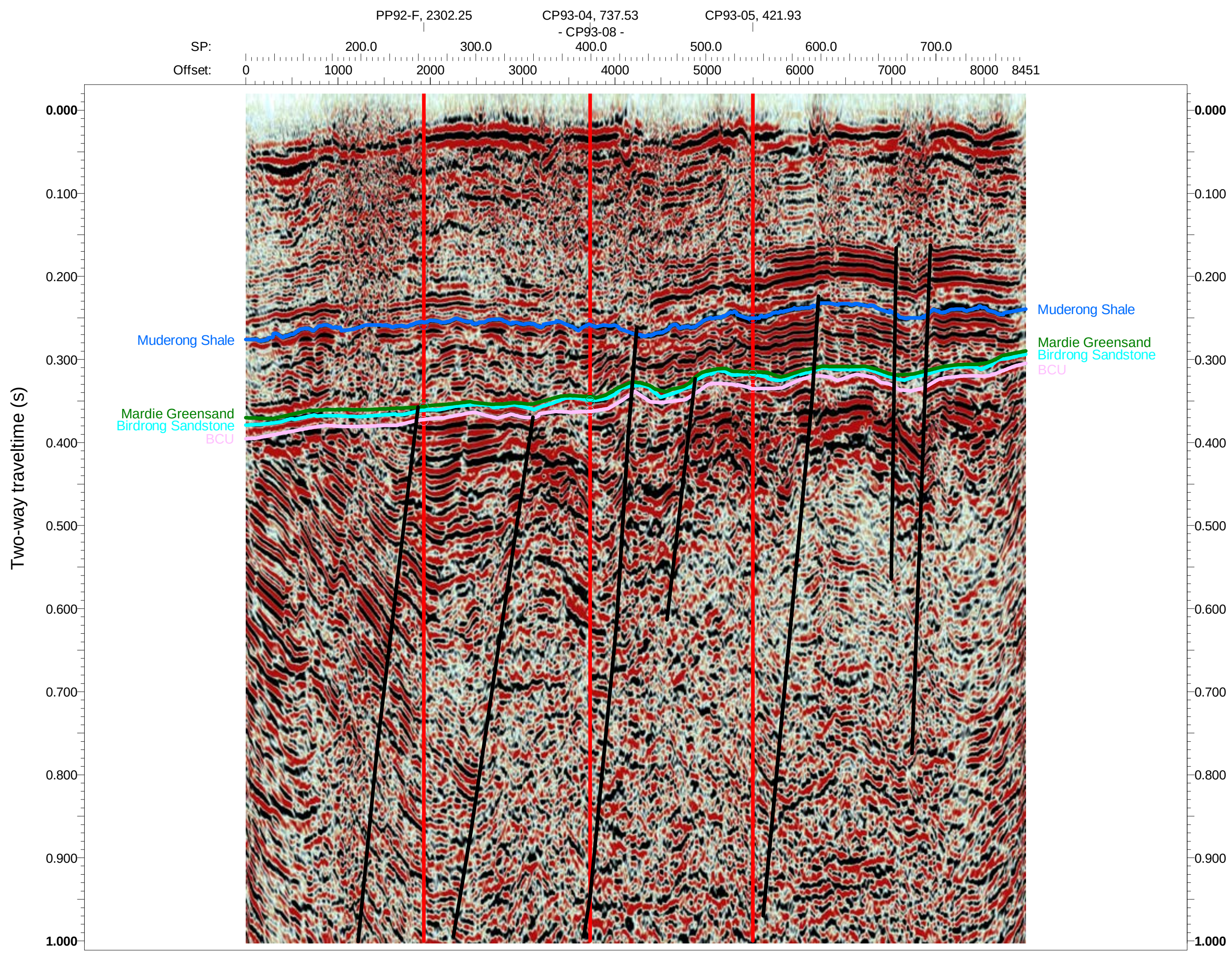
A09





Legend

- Muderong Shale
- Mardie Greensand
- Birdrong Sandstone
- BCU
- Interpreted Fault
- Featured Seismic Line Intersection

Golder Associates

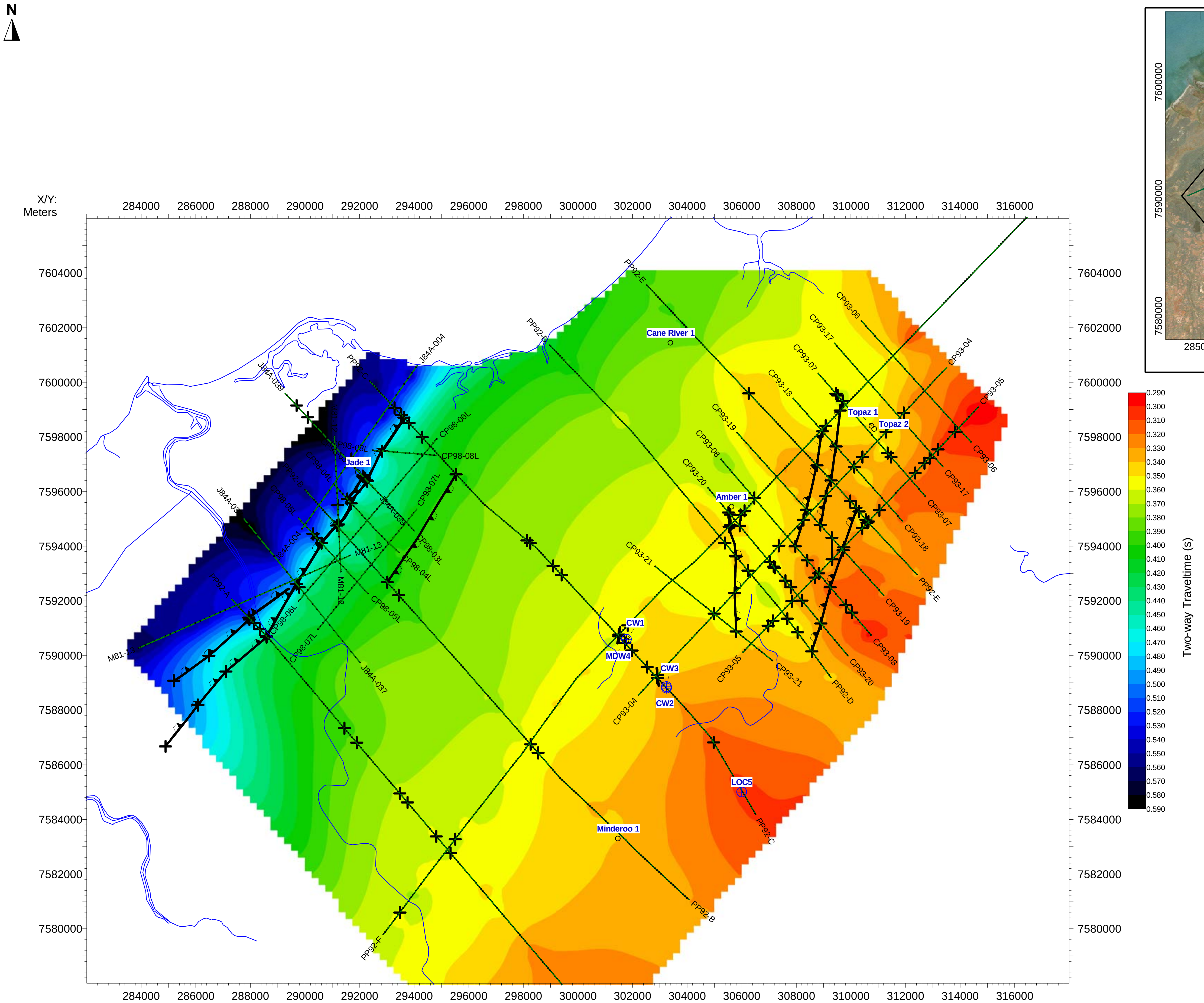
TITLE **SEISMIC LINE CP93-08**

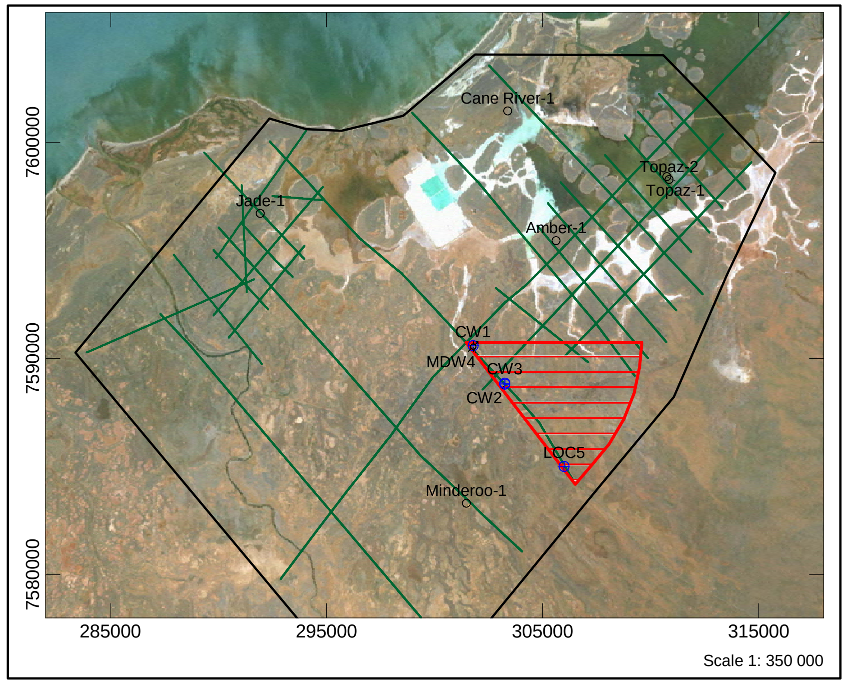
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:70 000

OCTOBER 2012

PROJECT 1278208697

A10





Legend

- Chevron bore siting area
- Drilled water well
- Proposed water well
- Exploration well
- Seismic line
- Assigned Fault[1]
- Fault Intersection

NOTES
1. [1]Assigned Faults are faults traced between at least two seismic lines.

Golder Associates

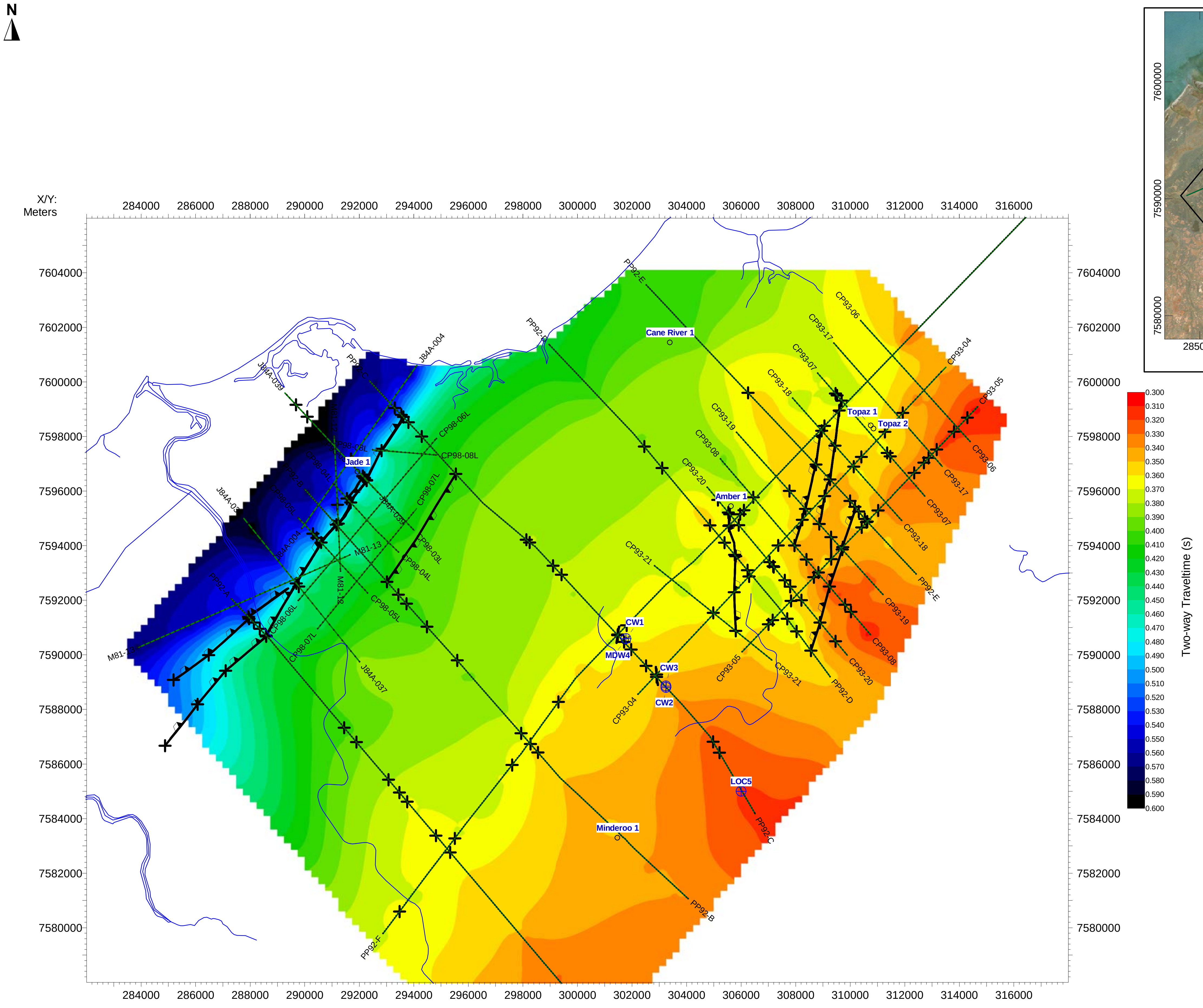
TITLE **BIRDRONG SANDSTONE TWO-WAY TRAVELTIME MAP**

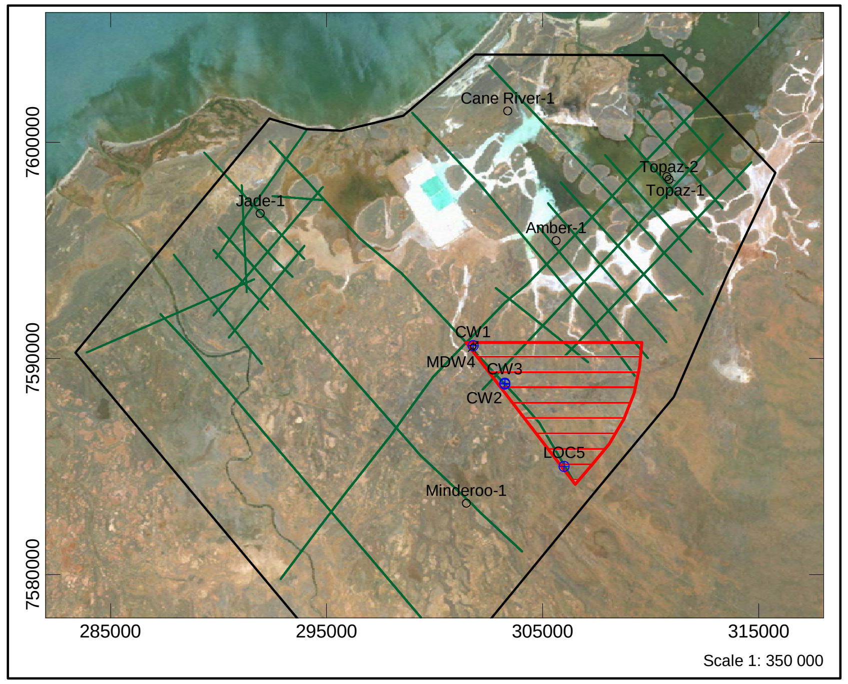
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:150 000

OCTOBER 2012

PROJECT 1278208697

A11





Legend

- Chevron bore siting area
- Drilled water well
- Proposed water well
- Exploration well
- Seismic line
- Assigned Fault[1]
- Fault Intersection

NOTES
1. [1]Assigned Faults are faults traced between at least two seismic lines.

Golder Associates

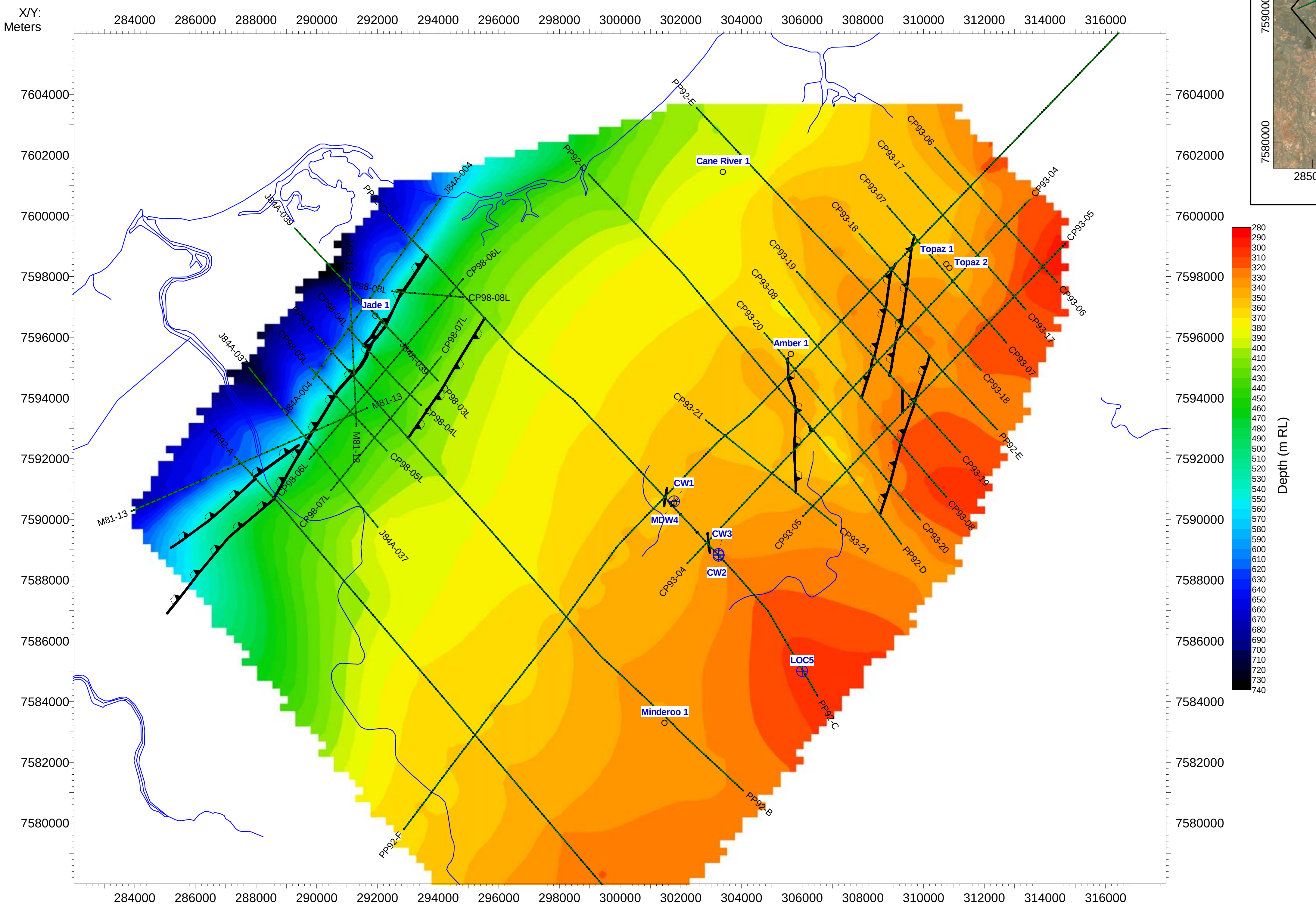
TITLE BASE CRETACEOUS UNCONFORMITY TWO-WAY TRAVELTIME MAP

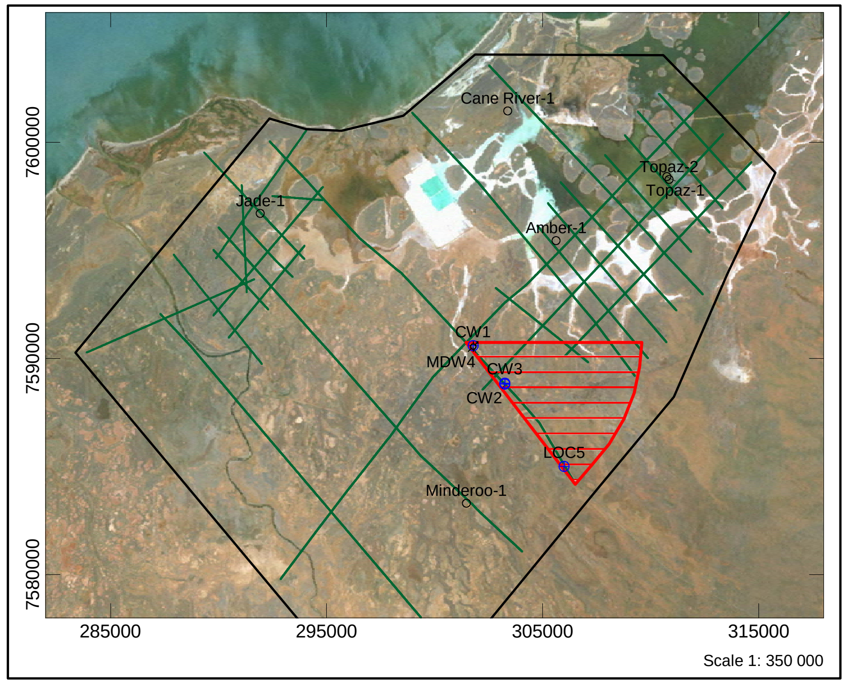
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:150 000

OCTOBER 2012

PROJECT 1278208697

A12





Legend

- Chevron bore siting area
- Drilled water well
- Proposed water well
- Exploration well
- Seismic line
- Assigned Fault[1]

NOTES
1. Depth map created using a modified Amber-1 Time-Depth Chart

Golder Associates

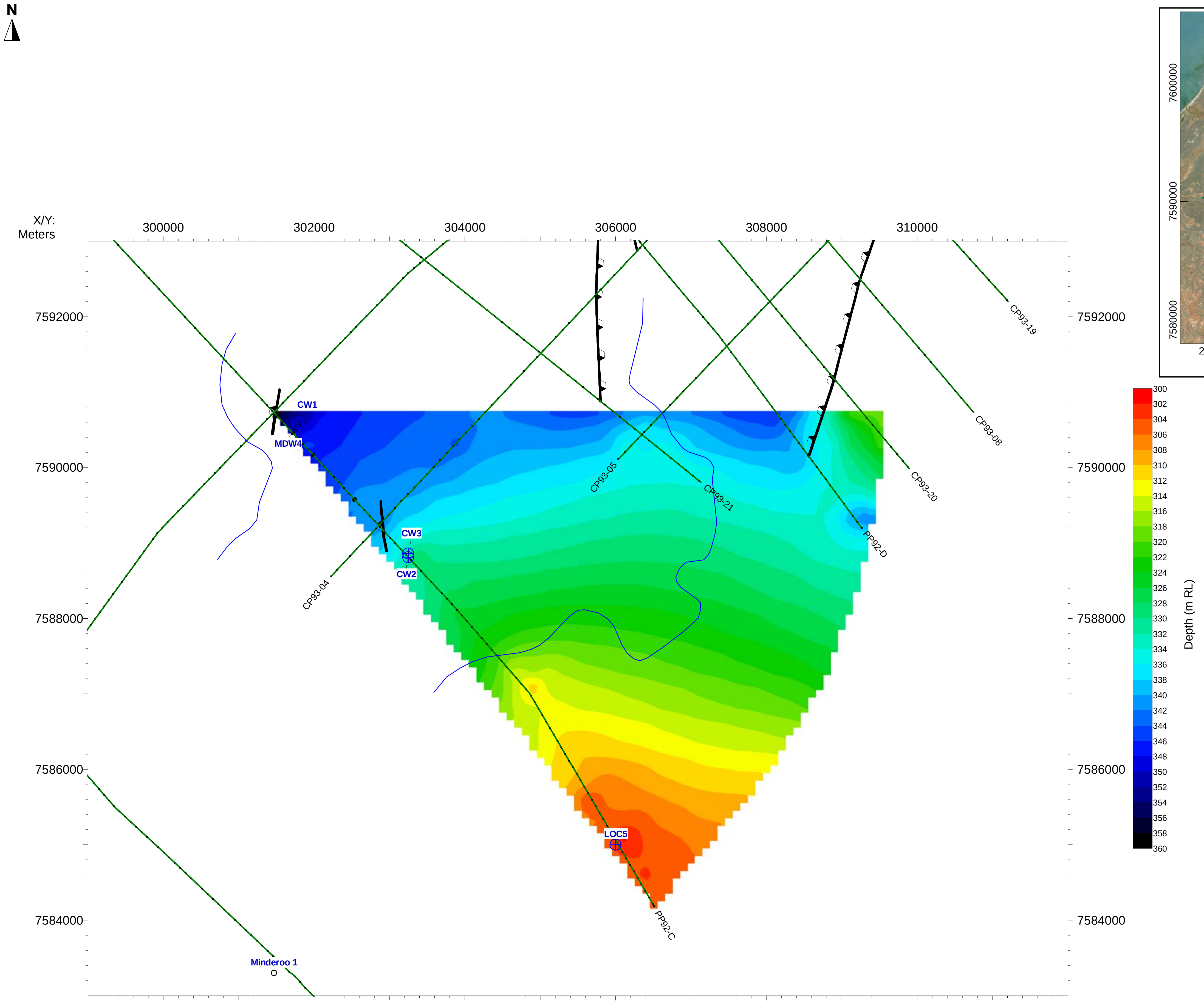
TITLE **BIRDRONG SANDSTONE DEPTH MAP**

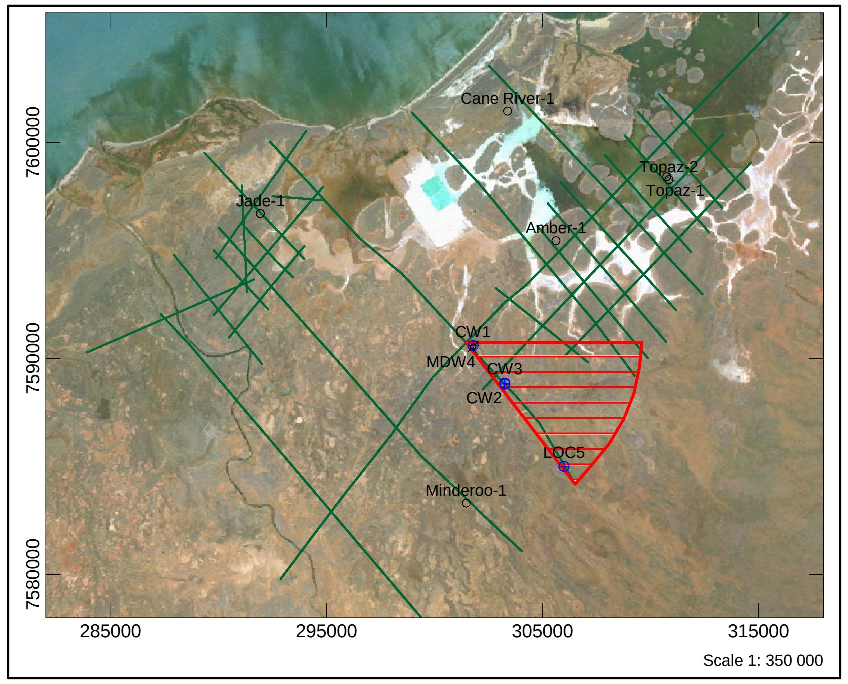
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:150 000

OCTOBER 2012

PROJECT 1278208697

A13





Legend

- Chevron bore siting area
- Drilled water well
- Proposed water well
- Exploration well
- Seismic line
- Assigned Fault[1]

NOTES
1. Depth map created using a modified Amber-1 Time-Depth Chart

Golder Associates

TITLE **BIRDRONG SANDSTONE DEPTH MAP - CHEVRON BORE SITING AREA**

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:55 000

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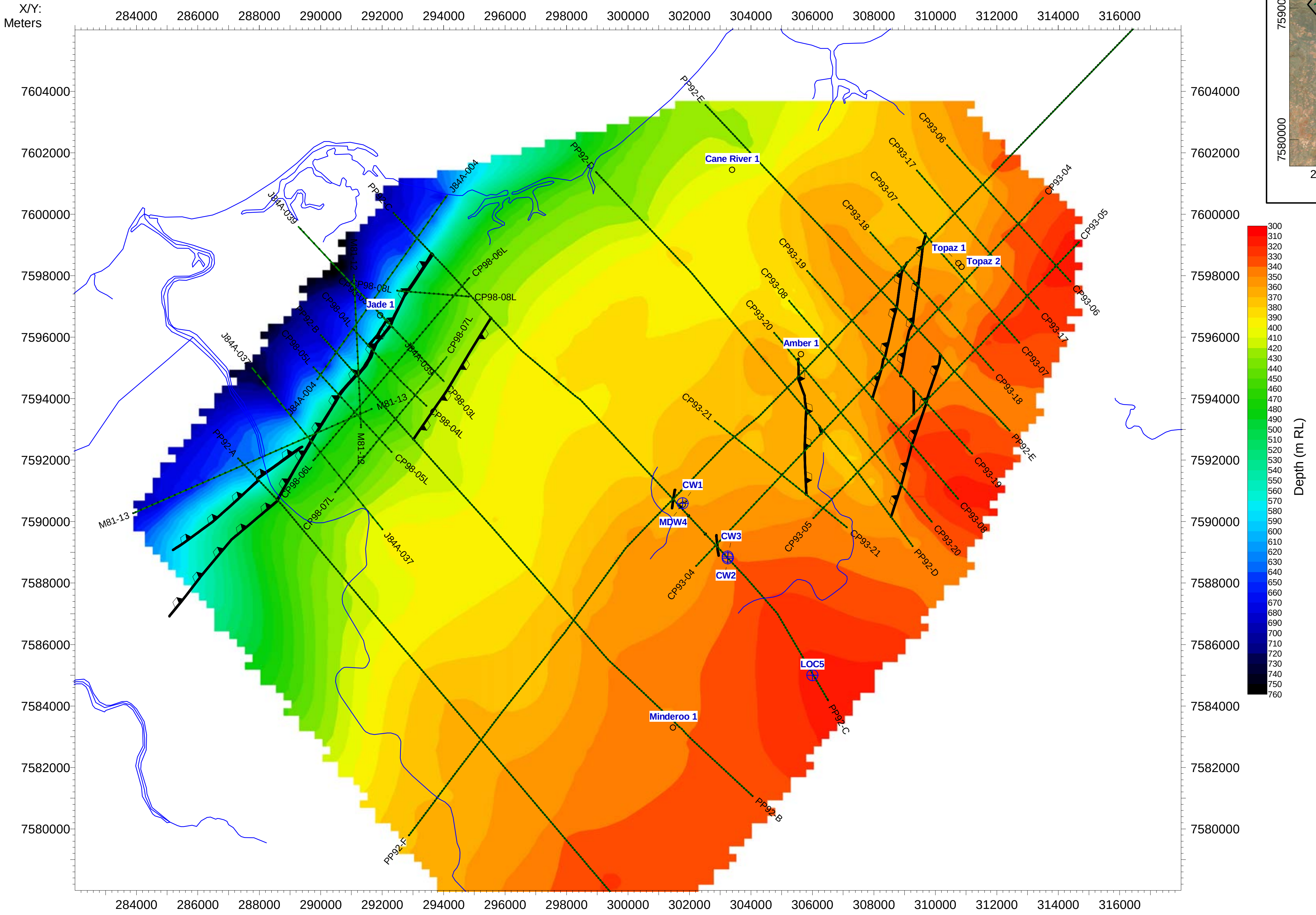
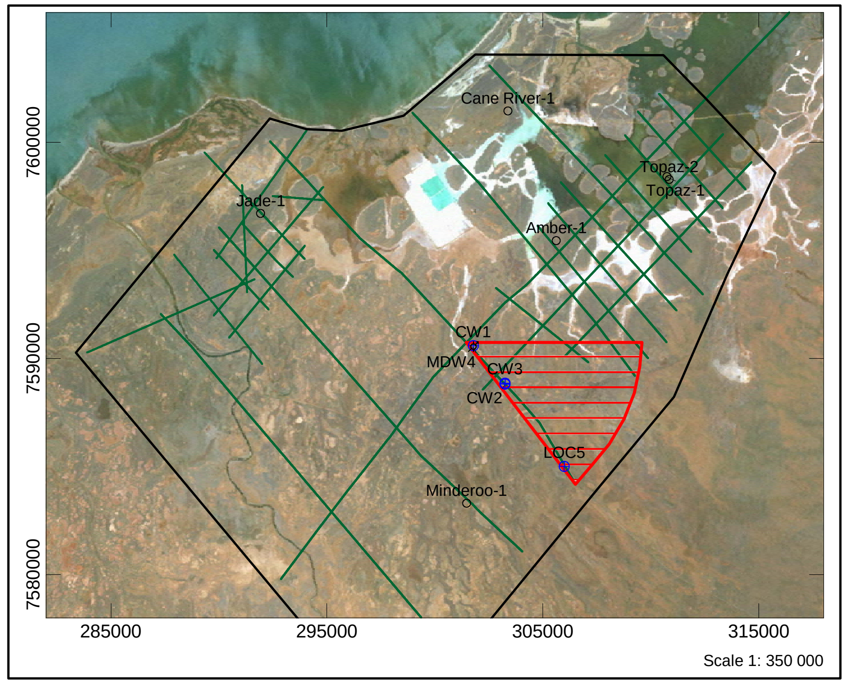
PROJECT 1278208697

A14

N





Legend

- Chevron bore siting area
- Drilled water well
- Proposed water well
- Exploration well
- Seismic line
- Assigned Fault[1]

NOTES
1. Depth map created using a modified Amber-1 Time-Depth Chart

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TITLE **BASE CRETACEOUS UNCONFORMITY DEPTH MAP**

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:150 000

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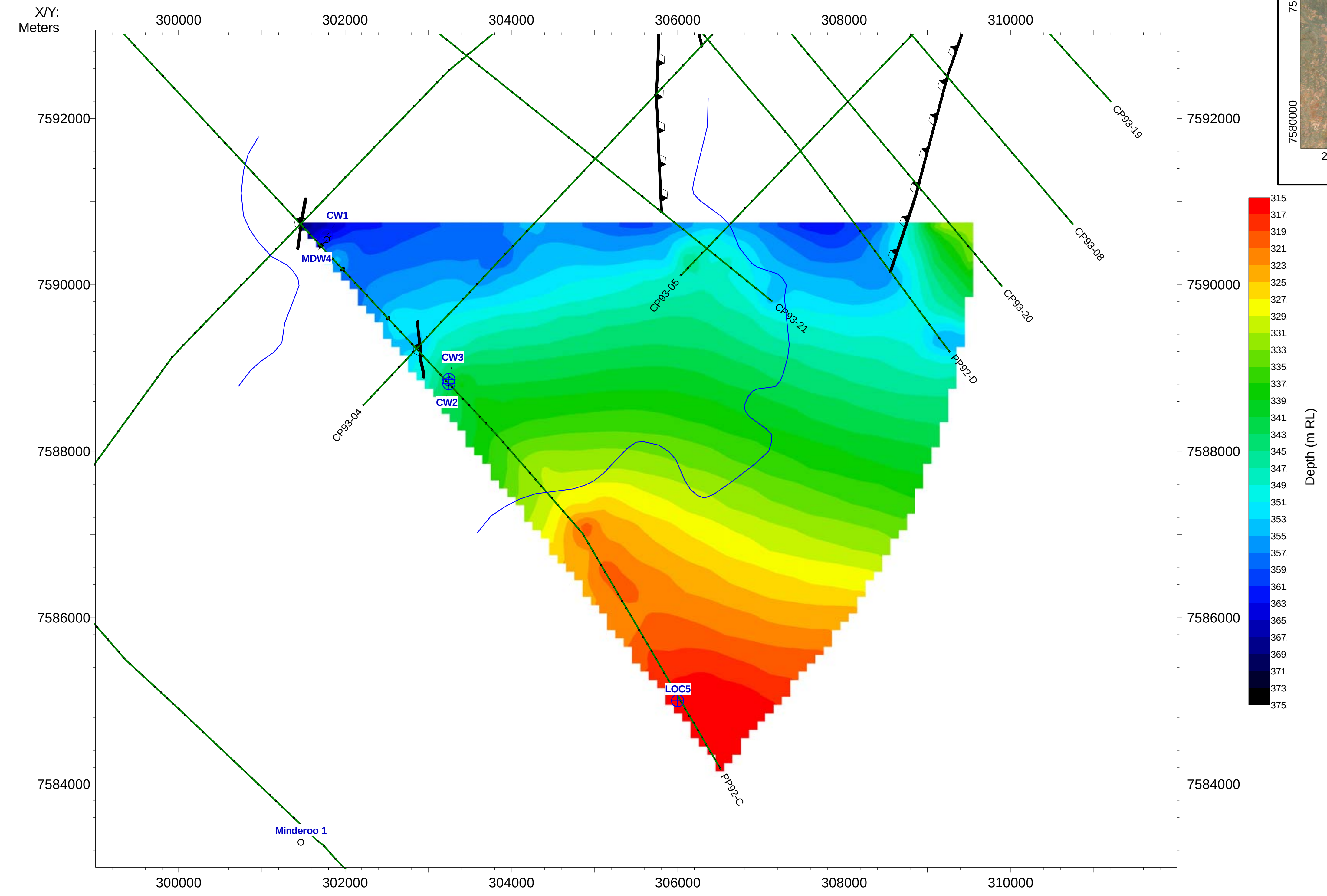
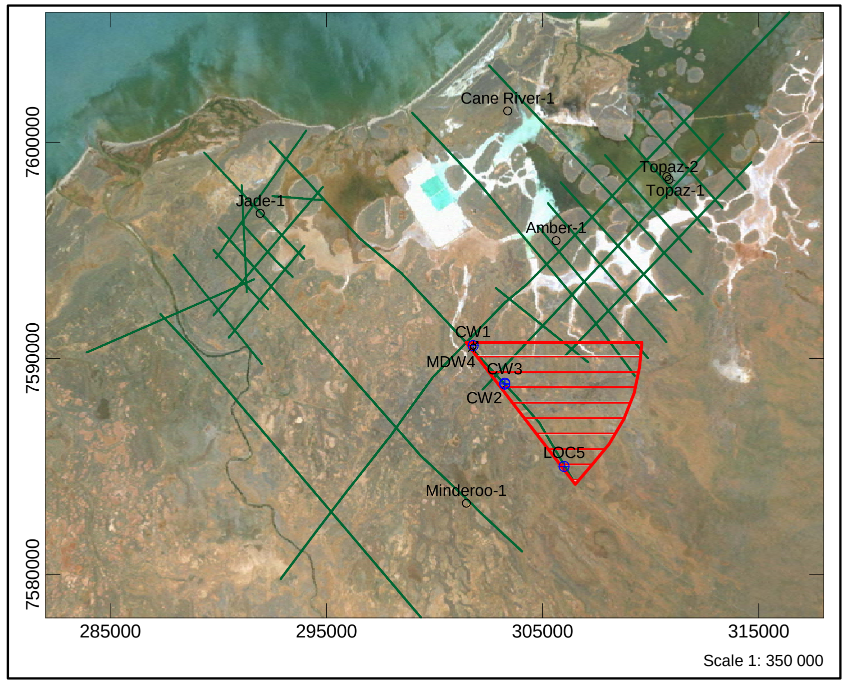
A15





Legend

- Chevron bore siting area
- Drilled water well
- Proposed water well
- Exploration well
- Seismic line
- Assigned Fault[1]

NOTES
1. Depth map created using a modified Amber-1 Time-Depth Chart

Golder Associates

TITLE **BASE CRETACEOUS UNCONFORMITY DEPTH MAP - CHEVRON BORE SITING AREA**

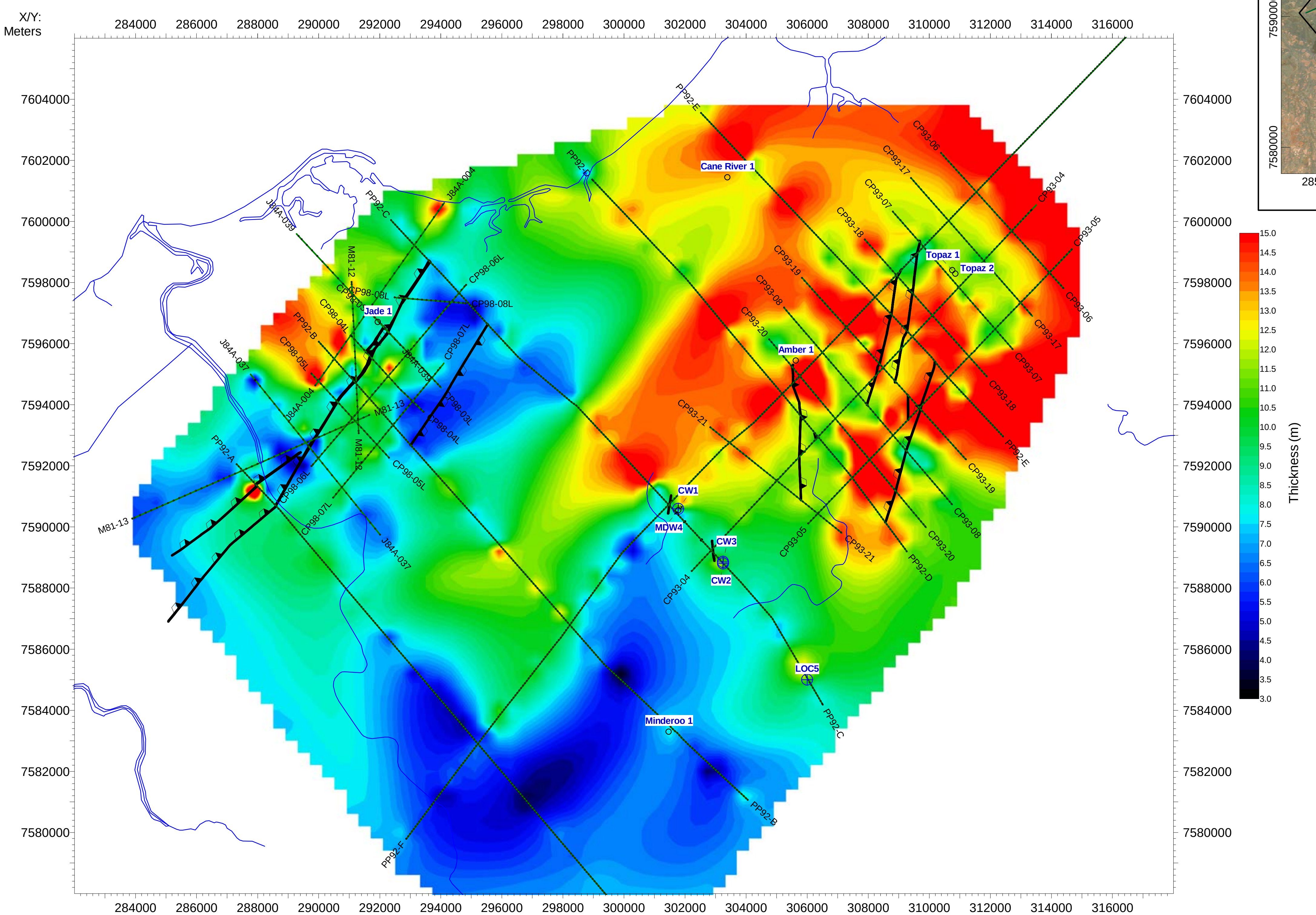
DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:55 000

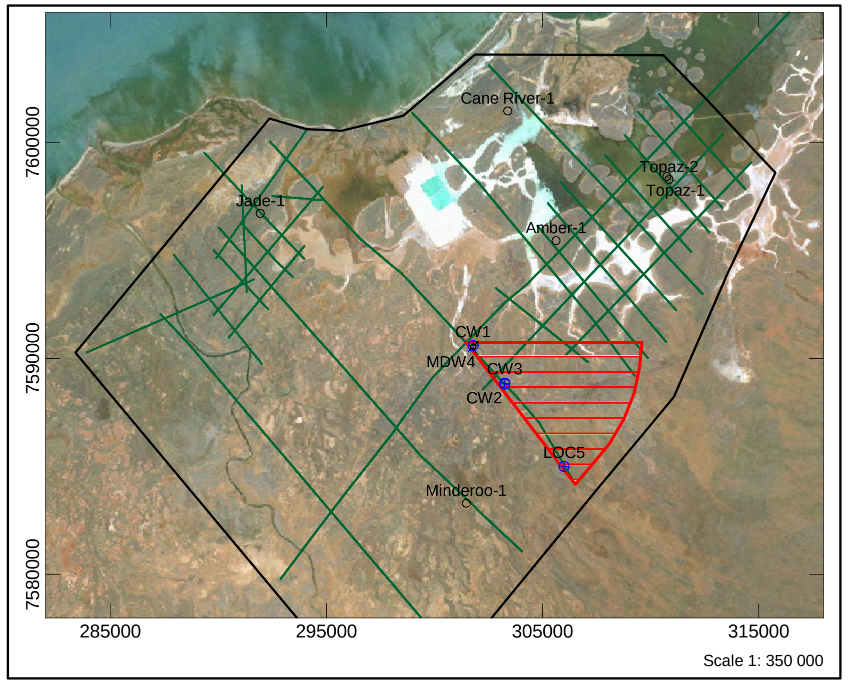
OCTOBER 2012

PROJECT 1278208697

A16

N





Legend

- Chevron bore siting area
- Drilled water well
- Proposed water well
- Exploration well
- Seismic line
- Assigned Fault[1]

NOTES
1. Isopach computed using a constant interval velocity of 1850 ms⁻¹, as approximately indicated for the Birdrong Sandstone interval at Amber-1.

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TITLE **BIRDRONG SANDSTONE ISOPACH**

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:150 000

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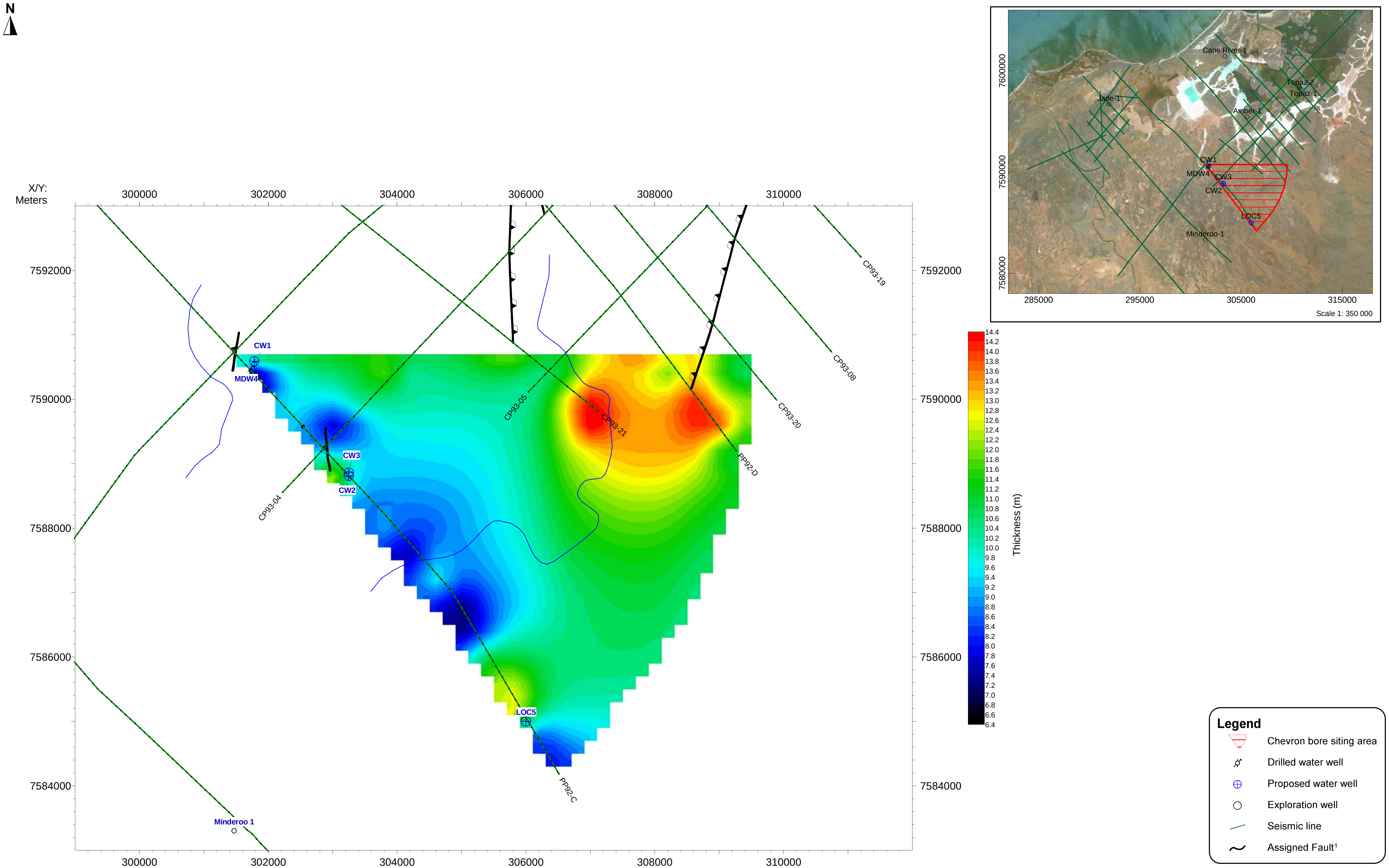
A17



NOTES
1. Isopach computed using a constant interval velocity of 1850 ms⁻¹, as approximately indicated for the Birdrong Sandstone interval at Amber-1.

Golder Associates

TITLE **BIRDRONG SANDSTONE ISOPACH - CHEVRON BORE SITING AREA**

DATUM: GDA94
PROJECTION: MGA ZONE 50
SCALE (A3) 1:55 000

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A18

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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