Technical Appendices A1, B1, C1, D1, E1 and F1

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

July 2010

Wheatstone Project

Disclaimer

In preparing this Draft Environmental Impact Statement/Environmental Review and Management Programme (Draft EIS/ERMP), Chevron Australia Pty Ltd (Chevron) has relied on material provided by specialist consultants, government agencies and other third parties who are identified in the Draft EIS/ERMP. Chevron has not verified the accuracy or completeness of the material provided by these consultants, government agencies and other third parties, except where expressly acknowledged in the Draft EIS/ERMP. Should there be any difference or inconsistency between the material presented in this Draft EIS/ERMP and that in any third-party document referred to herein (including assessments, findings, opinions, project descriptions, proposed management measures and commitments), the material presented in the Draft EIS/ERMP alone shall be taken to represent Chevron's position.

Title: Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Wheatstone Project: Technical Appendices A1, B1, C1, D1, E1 and F1

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A1.1 DEWHA Guidance and Correspondence

Australian Government

Department of the Environment, Water, Heritage and the Arts

Mr Geoffrey Strong
General Manager
Wheatstone Development
Chevron Australia Pty Ltd
GPO Box S1580
Perth WA 6845

Date: 26 August 2009
EPBC Ref: 2008/4469
EPBC contact: Liz Wilson
(02) 6274 1071
liz.wilson@environment.gov.au

Dear Mr Strong

Approval of the Scoping document
Construction and Operation of LNG and Domestic Gas Plant and Onshore and Offshore Facilities, State & Commonwealth Waters, Pilbara Coast, WA

On 22 October 2008 it was determined that a environmental impact assessment (EIS) was required for the assessment of potential impacts of the above action on matters of national environmental significance as defined under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Acting as the delegate of the Minister, I have approved the guidelines for the preparation of the draft EIS (Wheatstone Project Environmental Scoping Document, 2 June 2009) pursuant to s102 (5) of the EPBC Act.

The scoping document content has been developed jointly with the Western Australian government. I note that a new "risk-based" approach is being applied to this assessment. I anticipate that the preliminary risk assessment results will be tested throughout the assessment process, including the public consultation phase. Our Department will work closely with Chevron Australia and the WA EPA to ensure our assessment requirements are met throughout this process.

Chevron Australia Pty Ltd is now required to prepare a draft EIS for consideration under the EPBC Act in accordance with these guidelines. I anticipate that one draft EIS/Environmental Review and Management Programme (ERMP) document can be produced to meet both the Commonwealth and State requirements for the project.

If you require clarification or further information please contact the EPBC Contact for this project and quote the EPBC Reference number listed above.

Yours sincerely

Vicki Middleton

Vicki Middleton
Assistant Secretary
Environment Assessment Branch
28 August 2009

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Australian Government

Department of the Environment, Water, Heritage and the Arts

GUIDELINES FOR THE CONTENT OF A DRAFT ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME/ENVIRONMENT IMPACT STATEMENT

Construction and Operation of LNG and Domestic Gas Plant and Onshore and Offshore facilities, State and Commonwealth Waters, Pilbara Coast, WA

Environment Protection and Biodiversity Conservation Act 1999
(Reference: 2008/4469)

PREAMBLE

Chevron Pty Ltd (Chevron) proposes to develop the Wheatstone gas field within the Carnarvon Basin, approximately 200km north of Onslow and 100km from Barrow Island. The project encompasses upstream and downstream facilities. The facilities are expected to operate for a period of 30 years or more.

The key components of the offshore upstream facilities will include:

- Drilling of wells in Permit WA_253-P (ranging from 8 to 12 wells) and Permit 17-R (ranging from 4 to 6 wells)
- Installation and operation of a subsea gathering system
- Installation and operation of gas processing and wellhead platforms;
- Offshore compression equipment (required during the later stages of field life)
- Installation and operation of two export pipelines.

The key components of the onshore LNG plant downstream facilities will include:

- Processing of reservoir fluid to separate the hydrogen gas, hydrocarbon liquid, and water streams
- Pre-treatment of the gas stream to remove acid gases (such as carbon dioxide), water and other contaminants
- LNG trains to liquefy the gas to produce liquefied natural gas
- A Nitrogen Reinjection Unit for removal of nitrogen from the raw liquefied natural gas product
- LNG storage and loading facilities
- Domestic gas plant
- Water management
- Condensate stabilization and storage
- LNG and condensate tanks and facilities including loading lines either over a jetty or by subsea lines to an offshore loading facility
- Port facilities including; jetties, material offloading facilities (either as an inland harbor or part of the offshore harbour)
- Navigational channel and turning basin
- Supporting infrastructure including: airport or upgrade of existing airports, access roads, supply base, construction camp, drainage and waste water treatment, solid waste management facilities, temporary lay-down areas for construction, accommodation blocks for operations personnel, utilities such as power and water supply, storage facilities, use of rock for site preparation and pipeline stabilisation.

The proposal was referred under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) to the Minister for the Environment, Heritage and the Arts on 23 September 2008. A delegate for the Minister determined on 22 October 2008 that approval is required under the EPBC Act, and that it will be assessed by Environmental Impact Statement (EIS).

The proposed action has the potential to have a significant impact on the following matters of national environmental significance (NES) that are protected under Part 3 of the EPBC Act.

- Listed threatened species and communities (sections 18& 18A)
- Listed migratory species (sections 20 & 20A)
- Commonwealth marine areas (section 23 & 24A)

Information about the action and its relevant impacts, as outlined below, is to be provided in the EIS. This information should be sufficient to allow the Minister to make an informed decision on whether or not to approve, under Part 9 of the EPBC Act, the taking of the action for the purposes of each controlling provision.

GENERAL ADVICE ON GUIDELINES

1 GENERAL CONTENT

The EIS should be a stand-alone document that primarily focuses on the matters listed above. It should contain sufficient information to avoid the need to search out previous or supplementary reports.

The EIS should enable interested stakeholders and the Minister for the Environment, Heritage and the Arts to understand the environmental consequences of the proposed development. Information provided in the EIS should be objective, clear, and succinct and, where appropriate, be supported by maps, plans, diagrams or other descriptive detail. The body of the EIS is to be written in a clear and concise style that is easily understood by the general reader. Technical jargon should be avoided wherever possible. Cross-referencing should be used to avoid unnecessary duplication of text.

Detailed technical information, studies or investigations necessary to support the main text should be included as appendices to the EIS. It is recommended that any additional supporting documentation and studies, reports or literature not normally available to the public from which information has been extracted be made available at appropriate locations during the period of public display of the EIS. The proponent should make the EIS available on the Internet.

If it is necessary to make use of material that is considered to be of a confidential nature, the Proponent should consult with Department of the Environment, Water, Heritage and the Arts on the preferred presentation of that material, before submission to the Minister for approval for publication.

The level of analysis and detail in the EIS should reflect the level of significance of the expected impacts on the environment. Any and all unknown variables or assumptions made in the assessment must be clearly stated and discussed. The extent to which the limitations, if any, of available information may influence the conclusions of the environmental assessment should be discussed.

The proponent should ensure that the EIS addresses the matters stated in Schedule 4 of the EPBC Regulations *Matters to be addressed by draft Environmental Impact Statement* at Attachment 1.

2 FORMAT AND STYLE

The EIS should comprise three elements, namely:

- the executive summary;
- the main text of the document, and
- appendices containing detailed technical information and other information that can be made publicly available.

The guidelines have been set out in a manner that may be adopted as the format for the EIS. This format need not be followed where the required information can be more effectively presented in an alternative way. However, each of the elements must be addressed to meet the requirements of the EPBC Act and Regulations.

The EIS should be written so that any conclusions reached can be independently assessed. To this end all sources must be appropriately referenced using the Harvard standard. The reference list should include the address of any Internet "web" pages used as data sources.

The main text of the EIS should include a list of abbreviations, a glossary of terms and appendices containing:

- a copy of these guidelines;
- a list of persons and agencies consulted during the EIS;
- contact details for the Proponent; and
- the names of, and work done by the persons involved in preparing the EIS .

Maps, diagrams and other illustrative material should be included in the EIS . The EIS should be produced on A4 size paper capable of being photocopied, with maps and diagrams on A4 or A3 size and in colour where possible.

The proponent should consider the format and style of the document appropriate for publication on the Internet. The capacity of the website to store data and display the material may have some bearing on how the document is constructed.

Information about species listed under the EPBC Act should be provided in electronic format to DEWHA. The provision of this information will help facilitate decision making under the EPBC Act and assist in the protection and recovery of species and communities.

SPECIFIC CONTENT

1 GENERAL INFORMATION

This should provide the background and context of the action including:

(a) the title of the action;

(b) the full name and postal address of the designated Proponent;

(c) a clear outline of the objective of the action;

(d) legislative background for the proposal, including the NES matters protected under Part 3 of the EPBC Act and any other requirements and approvals needed under the EPBC Act;

(d) the location of the action;

(e) the background to the development of the action;

(f) how the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;

(g) the current status of the action; and

(h) the consequences of not proceeding with the action.

2 DESCRIPTION OF THE ACTION

All construction components of the action, should be described in detail. This should include the precise location of all works to be undertaken, structures to be built or elements of the action that may have impacts on matters of national environmental significance.

The above information must include details on how the works are to be undertaken (including stages of development and their timing) and design parameters for those aspects of the structures or elements of the action that may have relevant impacts.

3 FEASIBLE ALTERNATIVES

Any feasible alternatives to the action to the extent reasonably practicable, including:

(a) if relevant, the alternative of taking no action;

(b) a comparative description of the impacts of each alternative on the NES matter protected by Part 3 of the EPBC Act; and

(c) sufficient detail to make clear why any alternative is preferred to another.

Short, medium and long-term advantages and disadvantages of the options should be discussed.

4 DESCRIPTION OF THE ENVIRONMENT

A description of the environment of the proposal site and the surrounding areas that may be affected by the action must be provided.

(a) Listed threatened and migratory species (including marine species) that are likely to be present in the vicinity of the proposal should be identified and the following information provided.

- Baseline data on listed threatened and migratory species that may be present in the vicinity of the proposal including regional status, population size and distribution within the project site and adjacent habitat that may be impacted by the project.
- Details of the scope, timing (survey season/s) and methodology for studies or surveys undertaken to provide information and baseline data on the listed threatened and migratory species and their habitat in and surrounding the site. These details must be determined in consultation with recognised experts for the listed threatened and migratory species.
- Baseline data and details as mentioned above regarding any additional listed threatened and migratory species which may be impacted by the proposal and which were listed after the making of these draft EIS Guidelines.

(b) Develop and undertake a Sampling and Analysis Plan (SAP) to determine suitability and characteristics of dredge spoil.

- Ensure the SAP and the SAP Report are developed in accordance with the National Assessment Guidelines for Dredging (NAGD 2009).

(c) Develop and undertake additional offshore disposal site selections for dredge material in accordance with the National Assessment Guidelines for Dredging (NAGD 2009).

(d) A description of the Commonwealth Marine environment that is likely to be impacted by the proposal, including but not restricted to:

- significant regional habitat for listed threatened and migratory marine species.

5 RELEVANT IMPACTS

(a) The EIS must include a description of all the potential relevant impacts of the action on the ecology, hydrology and geomorphology of the project area as it relates to the NES matters protected under Part 3 of the EPBC Act, including but not restricted to:

- a detailed assessment, developed in consultation with appropriate recognised experts, of the nature and extent of the likely short-term, long-term and consequential relevant impacts on all relevant NES matters.
- the Commonwealth marine environment such as:
  - i. the potential direct, indirect and consequential impacts on regional habitat and the Commonwealth marine environment;
  - ii. impacts on other users of the area;
  - iii. the potential impacts on important amenities, navigation, culturally and historically significant sites, threatened or migratory species or sensitive habitats;
  - iv. potential impact on listed marine species;
  - v. the potential risk of pest species becoming established in the Commonwealth marine area;
  - vi. changes in air and water quality.
- a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible;
- analysis of the significance of the relevant impacts; and
- any technical data and other information used or needed to make a detailed assessment of the relevant impacts.

6 PROPOSED SAFEGUARDS AND MITIGATION MEASURES

The EIS must provide information on mitigation measures, with a particular focus on matters protected under Part 3 of the EPBC Act. Specific and detailed measures must be provided and substantiated, based on best available practices and must include the following elements.

(a) A consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including:

- a description of proposed safeguards and mitigation measures to deal with relevant impacts of the action including mitigation measures proposed to be taken by State governments, local governments or the proponent;
- assessment of the expected or predicted effectiveness of the mitigation measures;
- any statutory or policy basis for the mitigation measures; and
- the cost of the mitigation measures.

(b) A detailed Environmental Management Plan (EMP) that sets out the framework for management, mitigation and monitoring of relevant impacts of the action, including any provisions for independent environmental auditing.

The EMP needs to address the construction phase. It must state the environmental objectives, performance criteria, monitoring, reporting, corrective action, responsibility and timing for each environmental issue.

The EMP should also describe contingencies for events that may impact on the proposal.

(c) The name of the agency/s responsible for endorsing or approving each mitigation measure or monitoring program.

7 OTHER APPROVALS AND CONDITIONS

Information given on any other requirements for approval or conditions that apply, or that the Proponent reasonably believes are likely to apply, to the proposed action must include:

(a) details of any local or State Government planning scheme, or plan or policy under any local or State Government planning system that deals with the proposed action, including:

- what environmental assessment of the proposed action has been, or is being, carried out under the scheme, plan or policy; and
- how the scheme provides for the prevention, minimisation and management of any relevant impacts;

(b) a description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action;

(c) a statement identifying any additional approval that is required; and

(d) a description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.

8 CONSULTATION

Any consultation about the action, including:

(a) any consultation that has already taken place;

(b) proposed consultation about relevant impacts of the action;

(c) if there has been consultation about the proposed action, any documented response to, or result of, the consultation; and

(d) identification of affected parties, including a statement mentioning any communities that may be affected and describing their views.

9 INFORMATION SOURCES PROVIDED IN THE EIS

For information given in a draft Environmental Impact Statement, the draft must state:

(a) the source of the information;

(b) how recent the information is;

(c) how the reliability of the information was tested; and

(e) what uncertainties (if any) are in the information.

10 ENVIRONMENTAL RECORD OF PERSON(S) PROPOSING TO TAKE THE ACTION

Details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

(a) the person proposing to take the action; and

(b) for an action for which a person has applied for a permit, the person making the application.

If the person proposing to take the action is a corporation, also include details of the corporation's environmental policy and planning framework.

11 CONCLUSION

An overall conclusion as to the environmental acceptability of the proposal should be provided, including discussion on compliance with principles of ESD and the objects and requirements of the EPBC Act. Reasons justifying undertaking the proposal in the manner proposed should also be outlined.

Measures proposed or required by way of offset for any unavoidable impacts on NES matters, and the relative degree of compensation, should be highlighted.

ATTACHMENT 1

MATTERS THAT MUST BE ADDRESSED IN A ERMP AND EIS
(SCHEDULE 4 OF THE EPBC ACT REGULATIONS 2000)

1 General information

1.01 The background of the action including:

(a) the title of the action;

(b) the full name and postal address of the designated Proponent;

(c) a clear outline of the objective of the action;

(d) the location of the action;

(e) the background to the development of the action;

(f) how the action relates to any other actions (of which the Proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;

(g) the current status of the action; and

(h) the consequences of not proceeding with the action.

2 Description

2.01 A description of the action, including:

(a) all the components of the action;

(b) the precise location of any works to be undertaken, structures to be built or elements of the action that may have relevant impacts;

(c) how the works are to be undertaken and design parameters for those aspects of the structures or elements of the action that may have relevant impacts;

(d) relevant impacts of the action;

(e) proposed safeguards and mitigation measures to deal with relevant impacts of the action;

(f) any other requirements for approval or conditions that apply, or that the Proponent reasonably believes are likely to apply, to the proposed action;

(g) to the extent reasonably practicable, any feasible alternatives to the action, including:

(i) if relevant, the alternative of taking no action;

(ii) a comparative description of the impacts of each alternative on the matters protected by the controlling provisions for the action; and

(iii) sufficient detail to make clear why any alternative is preferred to another;

(h) any consultation about the action, including:

(i) any consultation that has already taken place;

(ii) proposed consultation about relevant impacts of the action; and

(iii) if there has been consultation about the proposed action — any documented response to, or result of, the consultation; and

(i) identification of affected parties, including a statement mentioning any communities that may be affected and describing their views.

3 Relevant impacts

3.01 Information given under paragraph 2.01(d) must include

(a) a description of the relevant impacts of the action;

(b) a detailed assessment of the nature and extent of the likely short term and long term relevant impacts;

(c) a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible;

(d) analysis of the significance of the relevant impacts; and

(e) any technical data and other information used or needed to make a detailed assessment of the relevant impacts.

4 Proposed safeguards and mitigation measures

4.01 Information given under paragraph 2.01(e) must include:

(a) a description, and an assessment of the expected or predicted effectiveness of, the mitigation measures;

(b) any statutory or policy basis for the mitigation measures;

(c) the cost of the mitigation measures;

(d) an outline of an environmental management plan that sets out the framework for continuing management, mitigation and monitoring programs for the relevant impacts of the action, including any provisions for independent environmental auditing;

(e) the name of the agency responsible for endorsing or approving each mitigation measure or monitoring program; and

(f) a consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including mitigation measures proposed to be taken by State governments, local governments or the Proponent.

5 Other Approvals and Conditions

5.01 Information given under paragraph 2.01(f) must include:

(a) details of any local or State government planning scheme, or plan or policy under any local or State government planning system that deals with the proposed action, including:

(i) what environmental assessment of the proposed action has been, or is being carried out under the scheme, plan or policy; and

(ii) how the scheme provides for the prevention, minimisation and management of any relevant impacts;

(b) a description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action;

(c) a statement identifying any additional approval that is required; and

(d) a description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.

6 Environmental record of person proposing to take the action

6.01 Details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

(a) the person proposing to take the action; and

(b) for an action for which a person has applied for a permit, the person making the application.

6.02 If the person proposing to take the action is a corporation — details of the corporation's environmental policy and planning framework.

7 Information sources

7.01 For information given the ERMP/EIS must state:

(a) the source of the information; and

(b) how recent the information is; and

(c) how the reliability of the information was tested; and

(d) what uncertainties (if any) are in the information.

A1.2 EPA Guidance and Correspondence

Environmental Protection Authority

The Atrium,
Level 8, 168 St Georges Terrace,
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Telephone: (08) 6364 6500.
Facsimile: (08) 6467 5557.

Postal Address: Locked Bag 33,
Cloisters Square, Perth, Western Australia 6850.
Website: www.epa.wa.gov.au

Mr Geoff Strong
General Manager, Wheatstone Development
Chevron Australia Pty Ltd
QV1, 250 St George's Terrace
PERTH WA 6000

Our ref: CRN 221795: DEC 8694
Enquiries: 6467 5409
Email: ann.stubbs@dec.wa.gov.au

Attention: Andre d'Entremont

Dear Mr d'Entremont

WHEATSTONE PROJECT (ASSESSMENT NO. 1754)

Please find enclosed a copy of the public submissions received on your draft Environmental Scoping Document (ESD) in regard to the above proposal. The Environmental Protection Authority (EPA) requires you to consider the issues raised in the submissions, and to submit a response on whether you consider that the ESD requires amendment.

The EPA will consider the response and may require changes to your ESD prior to final sign-off of the ESD if the issues are not adequately addressed.

Should you require further information please contact Ann Stubbs on phone number (08) 6467 5409 in the first instance.

Yours sincerely

for
Colin Murray
Director
Environmental Impact Assessment Division

8 May 2009

enc

Government of **Western Australia**
Department of **Environment and Conservation**

PILBARA REGION

Submission modified by A Stubbs

DATE: 1 May 2009 ***MEMO***

Subject: DEC Industry Regulation comments on Wheatstone Project Environmental Scoping Document

SUMMARY

DEC Pilbara Industry Regulation (DEC IR) has reviewed the Environmental Scoping Document (ESD) for Chevron Australia Pty Ltd, Wheatstone Project with a focus on emissions and discharges (Part V of the *Environmental Protection Act 1986 (EP Act)*) and the information required to conduct a comprehensive assessment. DEC IR believes that the proponent has identified the key issues associated with the project, conducted a reasonable assessment of the risks, and provided adequate details of the information to be presented at the ERMP stage of assessment

DEC IR, in conjunction with the proponent and other stakeholders during the scoping process, identified air, noise and wastewater emissions to the marine environment, as the highest priority discharges. The proponent has identified information that will be presented in the ERMP documentation. Comments on the adequacy of this information are broadly outlined below.

Air Emissions (High Priority)

The proposed development will produce emissions from power generation and gas processing. The nearest residence, being Onslow, is approximately 12 km north east of the project area. Given the size of the project, the potential impacts of air emissions on the Onslow community/local air quality, as well as any environmental impacts (e.g. impacts on vegetation) will need to be documented by the proponent and provided in the ERMP. Potential air quality impacts will also be a key emission assessed and regulated by DEC IR during the Part V works approval and licence stages.

DEC IR notes that the proponent has identified in the Scoping Document the need to conduct atmospheric modelling for normal and upset operating conditions, as well as the collection of background atmospheric and air quality data (Table 5.1 of the Scoping Document).

Recommendations

During both the ERMP and works approval phases, DEC IR will assess whether the proponent is proposing to use of best available technology for power generation and gas processing operations, ensuring minimal air emissions to the environment (including greenhouse emissions). The proponent will have to clearly demonstrate the use of such technology (e.g. Low-NOx burners, flare design etc.). A clear inventory of all point sources, their associated emissions and pollution control measures will need to be presented.

The proponent will also be required to demonstrate the results of air quality/atmospheric modelling, such that the ambient conditions at the nearest sensitive receptor (Onslow), as well as any other local sensitive receptors are not significantly impacted. The proponent will be required to at least meet the National Environment Protection Council's National Environmental Protection (Ambient Air Quality) and National Environment Protection (Air Toxics) Measures (**this is Part V requirement, note that as the Government has the**

intention of using the area as on industrial estate, air quality levels below the NEPM may well be required – Ann Stubbs).

The proponent will also have to outline management commitments (including monitoring regime) they propose to implement during operations in their application for approvals.

Wastewater Discharges (High Priority)

The proponent intends to discharge treated wastewater from the sewage treatment facility, RO plant and stormwater treatment facility to the marine environment. Produced formation and cooling water will also be discharged, however this has been identified for Commonwealth waters. The impact of waste water discharge to the marine environment, including impacts on water and sediment quality, and marine ecosystems will need to be documented by the proponent and provided in the ERMP. Marine discharges will also be a key emission assessed and regulated by DEC IR during the Part V works approval and licence stages.

DEC IR notes that the proponent has proposed to conduct baseline water and sediment quality surveys, as well as studies of the local marine ecosystem (including Benthic Primary Producer Habitat and marine fauna). These commitments are outlined in Table 5.1 of the Scoping Document.

Recommendations

The proponent will be required to provide in the ERMP a clear inventory of all marine discharge locations, the quality of the discharge and all pollution control measures. It will have to be demonstrated that these discharges meet the ANZECC water quality guidelines for marine water (with consideration of background levels and mixing if deemed applicable in this case) and that there are no significant impacts on the marine ecosystem.

The proponent will also have to outline management commitments/ procedures (including monitoring regime) they propose to implement during operations.

Noise Emission (High Priority)

Noise emissions are likely to be generated onsite during construction and operation of the LNG plant infrastructure and have the potential to affect the amenity of the local community. The nearest residence, being Onslow, is approximately 12 km north east of the project area. The imopact of noise on this community will need to be presented in the ERMP. Potential noise impacts will also be a key emission assessed and regulated by DEC IR during the Part V works approval and licence stages.

DEC IR notes that baseline noise surveys and noise modelling (during construction and operation) have been identified as necessary in the Scoping Document (Table 5.1).

Recommendations

In the ERMP, the proponent will be required to provide a clear inventory of all potential noise generating plant and activities and their respective contributions to noise levels experienced at sensitive receptors (namely Onslow). The proponent will have to demonstrate the use of best available technology noise control and that predicted noise levels (from modelling) are in compliance with the *Environmental Protection (Noise) Regulations 1997*. A reasonable noise monitoring program will also have to be implemented.

Dust

Dust is not foreseen as a significant emission during the operational phase, however, has the potential to be generated during the construction phase. DEC IR has noted that the proponent intends to obtain background concentrations via dust monitors and implement ongoing community/stockholder consultation.

Light Spill

Light spill could have an impact on turtles nesting activities around the Onslow Area.

Storm water/ Flood Management

The ESD has indicated that the Ashburton North site is located in a floodplain delta that is influenced by the Ashburton River and Hooley Creek and is subject to flooding and storm surge. The proponent proposes to substantially fill the processing plant site to raise the level of the land. The proponent will be completing a surface water assessment, including baseline water hydrology, baseline flood studies and the development of a conceptual surface water control system.

Recommendations

The proponent will need to demonstrate that the stormwater management can be managed such that there are no significant impacts on flora and fauna and that it can with stand potential flood events.

Dredging

Dredging will be required for the navigational channel, materials offloading facility and turning basin. The direct impacts of dredging are typically managed under Pat IV Ministerial Conditions with advice from the DEC Marine Ecosystems Branch and Environmental Management Branch. DEC IR may have some input in ensuring that any dredging spoil is disposed of appropriately. This is due to the potential for acid sulphate soils to generate runoff. DEC IR has noted that the proponent will be conducting further studies to determine the correct disposal of this spoil which is dependent on the chemical nature of the spoil material.

Cumulative impacts

As the Ashburton North area has been designated as a Strategic Industrial Area, the proponent will need to ensure potential environmental impacts are not addressed in isolation. Cumulative impacts must be addressed due to other users operating in the proposed area into the future and the close proximity to the town of Onslow.

DEC IR Approvals:

There are numerous activities proposed onsite which may be listed as prescribed activities under Schedule 1 of the *Environmental Protection Regulations 1987*. Prior to the construction and operation of these facilities, the proponent will be required to apply for a works approval and licence, as stipulated under the *Environmental Protection Act 1986*. Categories may include 10, 52, 54 (or 85), 54A (or Schedule 2, Category 4), 61 and 73.

Department of Environment and Conservation
Our environment, our future

Environmental Management Branch Memorandum

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To: **Director – Environmental Impact Assessment Division (Att: Anne Stubbs)**

Date: **5 May 2009**

Subject: **– Wheatstone Project Environmental Scoping Document**

Thank you for your letter of 17 April 2009 providing the opportunity for comment on the Environmental Scoping Document for Chevron's Wheatstone Project.

The following comments and recommendations are submitted by the Environmental Management Branch (EMB) of the Department of Environment and Conservation (DEC) on behalf of Parks and Conservation Services with input from DEC's Pilbara Region. Please note that the advice provided relates exclusively to biodiversity conservation and other matters relevant to the Department's responsibilities under *Wildlife Conservation Act 1950* and the *Conservation and Land Management Act 1984*.

In general the document provides good overall coverage of the range of potential issues, impacts and necessary areas of investigation. The proponent is encouraged to consult with DEC on an ongoing basis to discuss and agree on specific scopes and methodologies for particular biodiversity conservation related studies. Further detailed comment on specific issues and aspects of the document are provided in Attachment 1.

Attachment 1

Marine Environment

Issue: Heritage and Conservation Areas (p19).

- Doesn't recognise Barrow Island Marine Park
- Should acknowledge that the development footprint is very close to the Thevenard Island Nature Reserve and the potential for impacts.

Issue: EPBC Listed Marine Fauna (p24)

- Breeding cycles for marine turtles needs to be separated for green and flatback turtles.

Issue: Risk Based Scoping Results

- The 25 interactions that resulted in a medium risk ranking should have been included in a table. It is difficult to cross reference these to the overall risk table in the appendix.
- It is unclear how the impacts to the regionally significant Ashburton River Delta stand of mangroves have been assessed and how they are proposed to be managed. Given that major changes to surface hydrology are predicted, this issue needs to proper assessment.

Issue: Table 5.1 Environmental Factors, Risk Ratings and Proposed studies (p33)

Conservations reserves are not listed as an Environmental Factor but should be included given that proposed development footprint is very close to Thevenard Island and that the dredged channel will need to pass through the chain of islands that make up the Great Sandy Islands Nature Reserves. This should include an assessment of the risk and proposed management for the impact of the workforce on the conservation values on these islands.

Issue: Cumulative and Additive Effects (p42)

It is stated that the project will include jetties, a dredged channel and a Marine Offloading Facility that will be shared by all users of a 25MT LNG facility in the Ashburton North industrial estate. These facilities should also be available to BHP (and any other 3rd party) if they go ahead with onshore development at Ashburton North for the Scarborough and Macedon gas fields. Multiple dredged channels etc from different proponents will lead to a greater cumulative impact footprint from development in the area and shipping related infrastructure needs to be managed on a whole of precinct basis. DEC was lead to believe this was the case from meetings with the proponent and at the proponents briefing of the EPA before the release of the scoping document.

Issue: Environmental Consequence Definitions (p51)

It needs to be noted with respect to the risk assessment for the scoping phase that only a generalised environmental consequence table was used. The consequence table did not include detailed descriptions of risks specific to each environmental factor. These risks will need to be fully considered to properly ascertain risk during the assessment phase, particularly to marine fauna such as turtles.

Terrestrial Environment

Issue: Survey scope for subterranean fauna surveys

- It should be noted that if the option of groundwater extraction is pursued as part of the project adequate subterranean fauna surveys, particularly for stygofauna, will need to be undertaken within (including the extent of the groundwater drawdown cone) and adjacent to the groundwater extraction areas
- The filling of the floodplain delta in order to construct the project infrastructure will significantly alter the conditions of the potential troglofauna habitat located beneath the delta. Therefore appropriately investigation of troglofauna habitats and species (according to EPA Guidance Statement 54a) including troglofauna surveys as required, need to be undertaken beneath (and surrounding) this project foot print.
- Consultation with specialists from DEC is advised during the design and implementation of the subterranean fauna surveys.

Issue: Impact of the change in elevation required for the Ashburton North project site on surface hydrology

The ERMP will need to provide a thorough hydrological assessment of the potential impact of changes in surface water hydrology as a result of 'filling' the floodplain delta to create the Ashburton North project site. This should include details of the potential impacts of this change in topography to systems upstream and downstream of the project area, particularly Hooley Creek, the Ashburton River and ultimately the nearshore marine environment.

Issue: Water and sediment quality monitoring in the Ashburton River

The ERMP will need to include a monitoring plan for the potential impacts of water quality on the Ashburton River. Given the close proximity of development to the mouth of this river, the construction of a jetty and dredging, the effects of changes to the Ashburton River on water quality, including impacts of turbidity and sedimentation, should be included in the scoping document. Benthic Primary Producer Habitat should also be monitored given the project neighbours the Ashburton River delta stand of regionally significant mangroves.

Issue: Survey and mapping of flora and vegetation should include weed species

It is recommended that baseline flora and vegetation surveys include the identification of the presence of weed species and that the location of these species is included on the vegetation map. Control of declared or significant weed species will need to be undertaken during the construction and through the life of the operation and at closure, therefore good baseline information regarding weed locations is important.

Issue: Impacts of changes in groundwater on vegetation

The ERMP needs to address the potential impact of any changes in groundwater levels (due to proposed extraction) on groundwater dependant vegetation. If changes in groundwater are likely to impact vegetation, the ERMP will need to provide appropriate management strategies with suitable triggers for mitigation and management actions to be implemented. In order to provide this information the proponent will need to establish where the vegetation sources water and the potential feasibility of mitigation measures.

END

PARKS and CONSERVATION SERVICES

5 May 2009

Department of
Environment and Conservation

MARINE ECOSYSTEMS BRANCH
STRATEGIC POLICY DIVISION

LEVEL 8, 141 ST GEORGES TERRACE
PERTH WESTERN AUSTRALIA 6000

TO: **Anne Stubbs** Senior Environmental Officer

SUBJECT: **Wheatstone Project Environmental Scoping Document**

GENERAL COMMMENTS
Overall the Scoping document identifies a comprehensive suite of marine environmental risks and proposes studies that cover all the major issues (Table 5.1). There appear to be no major issues that have not been addressed.

The site selection process has been discussed in section 2 of the Scoping document. While this process has determined the suitability of the site in general, it should be noted that there is a lack of scientific understanding of some aspects of the site, and in particular a lack of knowledge in respect to the local marine environment. In view of this scientific uncertainty, where there is a need to specify the location of particular components of the project – such as the route of the shipping channel – the Precautionary Principle should apply. The EP Act (s4A) establishes the Precautionary Principle and specifies that application of the principle should be guided by "*an assessment of the risk-weighted consequences of various options.*" Research to calculate the environmental risks of alternative project designs in the marine environment should be undertaken as part of the Wheatstone ERMP.

Section 5.3 provides an overview of the risk scoping results. "The "High" risk rankings included:

Environmental Factor	Environmental Aspect
Benthic Primary Producer Habitat (BPPH)	Dredging
Physical Marine Environment	Dredging
Physical Marine Environment	Physical Presence of Marine Infrastructure

It is appropriate that Dredging has been identified as an important aspect that is a high to medium risk to a number of marine environmental factors. The studies that have been proposed (such as studies of benthic habitats) are suitable, but some comment is provided below in respect to additional work that should be undertaken. Generally this additional work is research designed to provided information that can be used to design the project (route of shipping channels, locations of effluent outfalls, design of small boat harbour) so as to minimize environmental impact.

It is recommended that the dynamic/ephemeral nature of BPPH (particularly seagrass) in the project area needs to be taken into consideration. Also it is important that studies of the BPPH, the geotechnical aspects of the seabed, as well as modeling of dredge turbidity are designed in a way that makes the information gained useful for the management of the dredging program and for the monitoring of dredge impacts.

Listing "Physical Marine Environment" (coastal processes) as an important environmental factor is also appropriate given that EPA Guidance Statement No 1 (GS 1) specifies Designated Regionally Significant Mangroves near the project site (GS No 1, Figures 2 and 4). The assessment of the environmental impact of the project on mangroves, as well as the approach to management of loss of habitat, should be guided by EPA Guidance Statement 1 as well as by GS 29. Again, given that the mangroves have established on a dynamic coastline, it will be important to research not simply the distribution of mangroves but also, as far as practical, the reason for the distribution (that is the physical and biological factors that determine mangrove survival).

SPECIFIC COMMMENTS

Marine ecosystem processes and dynamics are discussed at section 4.4.5. This section begins with the statement that "*The key processes affecting the development and distribution of marine flora and fauna in the region are physical*". The section then describes the major marine physical characteristics and notes the link that these characteristics have with significant biota – such as seagrass and coral.

Importantly the seasonal/episodic occurrence of cyclones, flooding and river flow is noted in the Scoping document. Clearly these are dynamic processes that are not purely seasonally (that is, not only occurring yearly), but exert influence over 5 to 10 year time periods. Research in Exmouth Gulf has shown that seagrass distribution and density changed dramatically as a direct result of cyclone Vance, and in subsequent years as a result of indirect influences (such succession of benthic plant species and possibly due to changes in the availability of nutrients). Section 4.4.3 notes that the seagrasses in the shallow water near the project site are ephemeral. This is possibly true, however, the pattern of change over time in seagrass distribution in the area is currently not well understood.

The Scoping document notes that "*In the course of the impact assessment, habitat mapping will be carried out to define the Benthic Primary Producer Habitat Management Unit and enable assessment of the significance of dredging impacts.*" (s4.4.3, page 22). However simple habitat mapping will not be sufficient. In view of the comments above, it is clear that the results of habitat mapping will need to be interpreted in a historical frame of reference as far as possible, in order to gain an understanding of the natural dynamic changes in BPPH on this energetic coast, and the processes that drive that change. This approach will aid in calculating the significance of any permanent loss of BPPH that may arise as a consequence of implementing the project, and inform mitigation, management and monitoring.

BPPH mapping will also be important in terms of interpreting the dredge modeling, and if there is a seasonal component it will be important to inform the management of the dredging program (for example particular BPPH may be more vulnerable at a particular season relative to another time of the year).

Modelling of Dredge Turbidity.
The Scoping document states (Table 5.1) that water quality monitoring, to establish the natural baseline, as well dredge plume modeling, will be undertaken. As noted above, this information will be interpreted in the light of the BPPH mapping in order to establish the environmental impact of the dredging program. The information should also be used to direct the design/layout of the shipping channel so as to avoid or minimize environmental impact (in keeping with Environmental Impact Mitigation Principles).

Rob Tregonning and Cameron Sim have already had informal discussions with Chevron and its consultants and have been brief on the approach Chevron is considering to take with respect to dredge modelling. The possibility of using the modelling to develop a program of continuous monitoring of the turbidity, linked to real time management of the dredge, was discussed. The method proposed has not been used in WA before and MEB has some reservations in respect to technical issues with the modeling. None the less, if the approach proves to be technically feasible, it represent an opportunity for enhanced precision of environmental management of dredging and potentially better environmental outcomes. It is understood that this approach is also likely to be applied to the Gorgon project and may become "industry best practice" for dredging in WA.

However, at this point of time it is untested in WA and it will still be important to establish biological monitoring parameters in order to monitor the impact of dredging directly on BPH such as coral and seagrass.

Spill and Discharge Modelling
Table 5.1 indicates that a monitoring program is proposed to describe ambient water quality and to examine seasonal changes. Hydrodynamic and water quality monitoring is proposed as a means of assessing the environmental impact of waste water disposal, including the disposal of Reverse Osmosis Brine should a desalination plant be built. This should be used to select a discharge location that avoids or minimizes environmental impact.

The results of these studies should be interpreted in the context of the "Pilbara Coastal Water Quality Consultation Outcomes" (EPA, Marine Report Series 1, 2006) and the Western Australian State Water Quality Management Strategy. This requires that the established Environmental Values and Environmental Quality Objectives are addressed. Outfall locations should be designed so as to avoid or minimize impact (especially to BPPH), and modeling (informed by Whole of effluent toxicity testing) should be used to set the minimum required area as Low Environmental Protection Area around outlets.

RECOMMENDED ADDITION OR ALTERATION TO THE TEXT

It is recommended that Table A1.5, at reference item 5C, should include in the column "primary Guidance Material" the following;

- The Western Australian State Water Quality Management Strategy and,
- The Marine Series MR1 "Pilbara Coastal Water Quality Consultation Outcomes – Environmental Values and Environmental Quality Objectives "Department of Environment, 2006.

These documents should also be referenced at Appendix 2.

CORRECTIONS

The following correction to the text is recommended;

Appendix 2 includes the following reference;
"Water and Rivers Commission State Water Quality Management Strategy No 6." This should be corrected to
Department of Environment and Conservation State Water Quality Management Strategy No 6, Implementation Framework for Western Australia for the Australian and New Zealand Guidelines for Fresh and Marine Water Quality and Water Quality Monitoring and Reporting (Guidelines Nos 4 & 7: National Water Quality Management Strategy)

4 April 2009

From: BROADHURST Lindsay (MRP) [lindsay.broadhurst@mainroads.wa.gov.au]
Sent: Friday, 1 May 2009 4:49 PM
To: Stubbs, Ann
Subject: Wheatstone Environment Scoping Document
Hello Ann,

Main Roads has reviewed the above document and would like to make the following comments:

- Traffic Study – In Table 5.1 on page 39 reference is made to a Traffic Study. This study should include early liaison with Main Roads WA and will need to assess the impacts on the adjacent regional road network that includes Onslow Road and North West Coastal Highway. The study will also need to consider what improvements will be necessary to these roads. There will also be a need for an access road from the site to Onslow Road and the investigations for this road should be undertaken in liaison with Main Roads WA.
- The above study is likely to identify the need for some road improvements and the necessary environmental requirements for these improvements and any other associated works, such as material pits for road construction, will need to be investigated and considered.

If you have any queries about the above please email or call me on 9323 4511.

Regards

Lindsay Broadhurst
Manager Road Planning

From: ABSALOM, Ben [Ben.ABSALOM@dmp.wa.gov.au]
Sent: Monday, 4 May 2009 5:00 PM
To: Submissions EIA
Subject: Wheatstone Project - Scoping document comments

Thank you for inviting the Department of Mines and Petroleum (DMP) Environment Division to provide comment for the above mentioned project.

Review of the document has raised the following queries;

- Will vegetation be cleared right out to the foot print boundaries shown in figure 4? If yes, Please detail why.
- More specific information is required on infrastructure development with EP/EMP submissions. It is acknowledged that at this stage, some areas are conceptual, however, for EP submissions, more confirmed detail is required. Comments such as those in section 3.3 '..these facilities are likely to include…', '..up to two export pipelines..' and '..compression equipment will be required possibly..' are quite broad.

The proponents approach to the risk assessment was very thorough, however DMP has the following comments regarding the risk assessment:

- Dredging of navigation channel and turning basin appears to present the highest risk of environmental impact, however the document states that only a small amount of dredge spoil will be used as plant construction fill and the rest will be dumped at sea. Are there any feasible alternatives to sea dumping of this large amount of spoil? Will further studies indicate how much of this spoil will be reused and how much will be dumped. Where will it be dumped?
- Will the outcomes of the proposed dredging studies and modelling influence where the spoil will be dumped or has this location been confirmed?
- It is acknowledged that protected marine fauna inhabit the area. The risk of discharge material having an effect on these species has been given as 'very low'. This rating appears to be conservative. Please provide further explanation to support this.
- Fire has been given a 'very low' risk ranking. If further studies (flora/fauna) indicate the presence of important species (DRF/SRE). Again this appears to be conservative, please justify further.

DMP looks forward to the outcome of the scoping document and next stage of the project moving forward.

Regards,

Ben Absalom | Environmental Assessor
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SHIRE OF ASHBURTON

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Enquiries: Amanda O'Halloran

Your Ref:

Our Ref: RD.OG.2.5

All communications to be addressed to Chief Executive Officer

1 May, 2009

Chairman
Environmental Protection Authority
Locked Bag 33
CLOISTERS SQUARE WA 6850

Attention Ms. Ann Stubbs

Dear Sir

RE: WHEATSTONE PROJECT ENVIRONMENTAL SCOPING DOCUMENT

The Shire has been involved in discussions with Chevron Australia Pty Ltd and the State Government in relation to the proposal to construct and operate a multi-train Liquefied Natural Gas (LNG) and Domestic Gas (Domgas) plant 12 km North East of Onslow on the Pilbara Coast to process gas from fields located approximately 145 km offshore in the West Carnarvon Basin. The project is referred to as the Wheatstone Project and "Ashburton North" is the proposed site for the LNG and Domgas plants. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land.

Chevron Australia Pty Ltd has prepared the *Wheatstone Project Environmental Scoping Document ("Scoping Document")* and the Shire wishes to provide the EPA with comment on the *Scoping Document.*

In the opinion of the Shire, the environmental assessment that comprises the *Scoping Document* appears to be comprehensive, however the Shire will rely upon the professional and technical assessment of the EPA to determine the quality and relevance of the information provided.

The Shire believes that although it has a more general role in advising the EPA on the *Scoping Document*, the following are specific issues that we believe should be addressed in relation to the Scoping Document or to be addressed in forthcoming in future documents:

- What is the end location/s of dredge spoil not used as landfill for site works?
- What is the timing of dredging activity (particularly near-shore works) in respect of cyclone season – i.e.: dredge plumes + cyclone induced turbidity and river outflows?
- What will the effects of a storm surge be to site?
- Where will additional landfill for site works and where will they be sourced?
- What buffer zone and/or exclusion fencing is anticipated to be established that will protect Old Onslow Townsite? In addition, the timing of the buffer zone and/or exclusion fencing would need to be established prior to works associated with any stage of the development.
- Is it intended to preclude public access to the Tramway and Jetty area or will there still be some access allowed? If access is to be limited (in any form), community consultation on this aspect alone must be undertaken.
- What recording and interpreting that part of Old Onslow for public information is anticipated.

The Shire's overall view of the *Scoping Document* is that a more holistic approach to reviewing the proposed development must be undertaken to ensure that it is truly sustainable. Using the Government of Western Australia's definition, 'sustainability' is defined as *"...meeting the needs of current and future generation through an integration of environmental protection, social advancement and economic prosperity"*

In addition, the Agenda 21 program represents international consensus on actions necessary to move the world towards the goal of sustainable development. It also recognizes that local government and the wider communities they represent are increasingly becoming the lead agencies to achieve sustainable development through the integration of environmental, economic and social goals.

Reference to the Shire and the role of local government in the *Scoping Document* is scant – generally referring to the Shire as a 'stakeholder' – which is normally acceptable, except that the Shire's legal and planning responsibilities have not been acknowledged.

The *Scoping Document* makes no specific reference to the Shire's Local Planning Scheme No. 7 and its provisions, nor is there reference to the extended process of undertaking an amendment to the Planning Scheme.

The Shire believes that Chevron Australia Pty Ltd must demonstrate that sustainable outcomes will be achieved by simultaneous improvements across the economic, social and environmental goals with an aspiration that there is no trade-off between the three. The Shire believes that it is reasonable to suggest that there is growing interest in creating a sustainable environment that is one in which there is a balance between the social and community needs, economic prosperity and the long-term preservation of the environment of Onslow and the environs. Concerns are not just restricted to sustaining the physical environment; the ability to sustain an economic, financial and social environment is also important. The Proponent should demonstrate what economic benefits social dividends there are to the district and the local Onslow community from the Project.

The Shire has become aware of some significant pressures on the community and the infrastructure of Onslow which has occurred with Chevron Australia Pty Ltd and others undertaking the feasibility assessment of the Wheatstone project. The known pressure on the Onslow community (so far) has been the impact on the availability of housing. The Shire is aware that some landowners have sought to capitalize on the influx of consultants and the like to convert dwellings in to lodging houses. Although the respective landowner may achieve a monetary benefit, the observation is that low cost housing is being targeted with the result that housing for short and long-term residents is being removed from the housing market. In an area critically short of housing, such competition arising from the Wheatstone project alone will lead to significant shifts in the societal structure of Onslow. The *Scoping Document* makes no attempt to address the significant impacts on the fabric and fibre of Onslow and importantly, what arrangements will be put in place to limit these impacts.

Accordingly, the Shire believe that a Social Impact Statement must be prepared along with an analysis of economic impacts on Onslow and the community, along with an assessment as to whether a Project represents a net public benefit under a triple bottom line assessment. The Social Impact Statement should address the impacts of all stages of the development, as it is anticipated that the impacts will be different for all stages.

In addition, the *Scoping Document* does not acknowledge the reality of the environmental and community impacts from all development either associated with or closely aligned with the Wheatstone Project and "Ashburton North" development hub. It is likely that Chevron Australia Pty Ltd would not wish to undertake assessments for the Dampier Port or the access corridor or the BHP development component. However the Shire firmly believes that an overriding assessment of the cumulative impacts on the environmental, economic, financial and social environment of Onslow and the surrounds is essential and must be established. In this regard, the *Scoping Document* must be broadened to address these matters.

Whether the EPA or other agency directs Chevron Australia Pty Ltd to assess the overall development hub is not the interest of the Shire: the clear need is that a wide ranging assessment based on sustainability principles for the Wheatstone Project and "Ashburton North" development hub must be undertaken.

It should be noted that the Shire has limited staff resources to place before Chevron Australia Pty Ltd or any other Proponent associated with the Wheatstone Project and "Ashburton North" development hub. Unlike an Application for Planning Approval or request to amend the Planning Scheme, the Shire has no opportunity to recoup fees and charges for professional planning, engineering, community and environmental services in the assessment. Accordingly, it is reasonable that the Shire should have an opportunity to achieve reimbursement for any costs it incurs in proving assessment for Project and "Ashburton North" development hub.

Should you have any queries please do not hesitate to contact the Shires Executive Manager Western Operations Amanda O'Halloran 91846001.

Yours Faithfully

Keith Pearson
Chief Executive Officer

Department of Health
Government of Western Australia
Our Ref: EHD - 01416
Enquiries: Dianne Katscherian
Phone: 9388 4948

The Chairman
Environmental Protection Authority
Locked Bag 33
CLOISTERS SQUARE WA 6850

Attention: Anne Stubbs

Dear ~~Dr Vogel~~ Paul

PROJECT NAME: **WHEATSTONE PROJECT**
ASSESSMENT NUMBER: **1754**
LEVEL OF ASSESSMENT: **ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME (ERMP)**

Thank you for the opportunity for the Department of Health (DOH) to comment on the scoping document for above named proposal.

The DOH participated in the workshops held by Chevron to trial the Risk-Based Approach proposed by the EPA. Chevron has identified in this scoping document the environmentally linked issues that have the potential to impact on public health that were raised during this process. Chevron have also committed to undertaking a Social and Health Impact Assessment which will address other health related issues.

However, the Environmental Health Directorate within DOH has reviewed the proposal and provides the following further comments.

Air Quality (AQ)

P52
AQ standards - Table A1.2 - Air Toxics

The Benzo[a]pyrene, value should read 0.0003ug/m3 not 300ug/m3 because the NEPM is 0.3ng/m3.

The convention for converting ppm to ug/m3 is based on 25C @ 1 atmosphere pressure (=24.45). Another factor appears to have been used which has resulted in slightly higher values for all the AQ levels. The conversion factor should be specified if it deviates from the convention.

Environmental Health
All Correspondence: PO Box 8172 Perth Business Centre Western Australia 6849
Grace Vaughan House 227 Stubbs Terrace Shenton Park WA 6008
Telephone (08) 9388 4999 Fax (08) 9388 4955
ABN 28 684 750 332

P41
Section 5.5 addresses the cumulative effects of AQ on flora & fauna and it is recommended that human health should also be addressed as warranted.

P2
Contents - Section Heading, Tables
Table A1.2: is on P52 not P53 and consequently the others will be out of order as well.

Mosquitoes

The Chevron Wheatstone LNG project is located in an environment that can experience significant problems with nuisance (biting) insects. Mosquitoes are likely to be the most common problem, but other biting flies, especially tabanids (March flies) and ceratopogonids (biting midge), also cause a nuisance and have caused severe allergic reactions in some people living and working in the region.

It is pleasing to note that the Project Scoping document identifies the need for drainage and stormwater ponds to be designed to limit the potential for mosquito breeding. However, other village and mine site infrastructure as well as the surrounding natural habitat have the potential to breed significant numbers of nuisance and disease vector mosquitoes. These issues should be addressed in the Social and Health Impact Assessment that is to be undertaken.

As guidance, an integrated program to manage mosquitoes and other nuisance insects should comprise, but not necessarily be limited to, the following elements:

- monitoring of larval mosquitoes in the surrounding natural environment and mine and village infrastructure to warn of the risk of nuisance/disease carrying mosquitoes and to inform the location and timing of control measures;
- chemical control of larval mosquitoes in man-made breeding sites and in natural breeding sites in close proximity to the village and the workplace;
- control of adult biting insects using fogging and/or residual surface sprays;
- source reduction (removal or modification of mosquito breeding habitat);
- appropriate location, design and maintenance of project infrastructure that have the potential to breed mosquitoes (e.g. wastewater, stormwater infrastructure); and
- provision of advice, seasonal warnings, insect screens on accommodation and enclosed workspaces, personal repellents, appropriate clothing, etc to enable employees to reduce their exposure to the bites of mosquitoes and other insects.

Alterations to topography (e.g. resulting from earthworks / pipeline installation) that enhance retention or impoundment of rainwater and runoff, or that promote scouring should be avoided in order to minimise opportunities for mosquitoes to breed. Poorly designed and/or maintained water holding infrastructure (e.g. tanks, stormwater drainage) have the potential to breed large numbers of mosquitoes and so must be designed/maintained in such a manner as to minimise mosquito breeding.

For further queries or health related information, please contact Dianne Katscherian on 9388 4948 or at dianne.katscherian@health.wa.gov.au

Yours faithfully

Jim Dodds
DIRECTOR
ENVIRONMENTAL HEALTH DIRECTORATE

4th May 2009

s:\ehd\directorate\docum\2009\spu\8594kd1.doc

Addition to Department of Health submission

Pesticide Safety:
There are general requirements for all of proponents such as Chevron – Wheatstone LNG Project to control pests (weeds, vermin, vectors, feral animals etc) on the site. Pesticide Safety recognises Chevron scoping document has identified the presence of weeds and feral animals at the site. In addition, the proponent have highlighted the issues related to clearing of the land (vegetation), and the increase activity around the mines and surrounding area from personnel and vehicles will increase of feral animals (7C) and the spread of weed (13A).

It is expected that any treatment and application of pesticides must be applied in accordance with the *Health (Pesticides) Regulations 1956*. In addition, contractors/ persons who are applying the pesticides for reward must be appropriately trained and hold a current Pesticide Licence and be employed by a Registered Commercial Pest Firm. However, if the proponent/ company wish their own employees to apply pesticide(s) as part of their Pest Management Program, then the employees should be provided with sufficient knowledge, skills, training and the personal protective equipment to safely apply the pesticide(s). Furthermore the need to adequately store, handle pesticides on site should adhere to the AS 2507:1998- Australian Standard for the storage and handling of agricultural and veterinary chemicals.

Pesticide Safety recognises Chevron will be establishing a Pest Hygiene and Quarantine management guideline and procedures (Pest Hygiene Management Plan) to control feral animals and the spread of weeds. Chevron's Pest Hygiene Management Plan should include development, implementation, monitoring and evaluating (and the Plan should be modified as required). The Plan's must include prevention and control of strategies for pests (such as weeds, vectors, vermin, feral animals etc), to include education of all employees, contractors, visitors and the public to the site. Education should cover proper disposal of waste material and ensure good hygiene practices are used to prevent pests being conveyed and attracted to operational site (and accommodation) activities.

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CAPE CONSERVATION GROUP

Ann Stubbs
Environmental Officer - Chevron Wheatstone project
Environmental Protection Authority
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168 St Georges Terrace
Perth
Ann.stubbs@dec.wa.gov.au

1 May 2009

Dear Ann,

RE: ERMP Scoping Document. Wheatstone Project 12 km from Onslow. Chevron Australia Pty Ltd. Close 04.05.09

Thank-you for the opportunity to provide comments on the above proposed project.

INTEREST IN REFERRAL

Cape Conservation Group Inc. (CCG) is a not-for-profit locally based volunteer group in Exmouth, WA. Our objective is to protect and preserve the natural environment of the North West Cape including calling for protection from the inherent impacts by the extensive oil and gas activities in the Exmouth sub-basin. With a membership of over fifty we consider ourselves a stakeholder in the above activity. CCG concerns are based on the potential impacts this project may have on matters protected by the EPBC Act as the proposed activity is in close proximity to areas of high biodiversity and ecological value (recommended for a proposed World and National Heritage listing).

CONCERNS IDENTIFIED BY CCG

While the World Heritage Boundary is yet to be formalised by the State and Federal governments, Exmouth Gulf and the Eastern margin of Exmouth Gulf (including the southern section of Urala Station) are included in the recommended optimal World Heritage listing boundaries (Bathgate report, 2004). This region has been repeatedly recognised for its environmental values and recommended for protection in State and Federal conservation planning and policy (eg: Wilson Report, 1994; Fisheries Environmental Mangement Plan for the Gascoyne Region, 2002; Pilbara Coastal Water Quality Consultation Outcomes, 2006; The Directory of Important Wetlands in Australia, 1993; Ningaloo Coast Regional Strategy, 2004 etc). Consequently, all assessments and proposals need to be considered in the context of the impact they may

- PROTECTING AND PRESERVING THE NORTH WEST CAPE NOW AND FOR FUTURE GENERATIONS -

have on these environmentally sensitive areas. Particular consideration needs to be paid to the impact on the area both during construction and operations from:

Dredging & sediment movement
Discharges
Leaks and spills
Vessel movement

A significant area of concern is acoustic emissions which need to be considered in context of other nearby acoustic (and also seismic) emissions. These may inflict a barrier on the path of migrating Humpback whales (listed as "endangered migratory species" under the Wildlife Conservation Act and a "vulnerable migratory cetacean" under the EPBC Act) and impact the behavior of resting mother-calf pods in Exmouth Gulf. These emissions may also restrict the local habitat of dugongs (protected at as a marine and migratory species in the EPBC Act). Dugongs are also listed in the Conservation of International Trade in Endangered Species (CITES) and Convention on Migratory Species (CMS) of which Australia is a signatory.

The proposed project risks loss of habitat and boat collision (both are recognized as major threats to the species) to dugongs. Further research should be made into dugong use of the area and the range of dugong populations that might also utilise Exmouth Gulf.

Concern also exists with the loss of nesting beach for marine turtles. Four marine turtles protected by the EPBC Act could have rookeries on, or near, the site including: *Caretta caretta (Loggerhead Turtle), Chelonia mydas (Green Turtle), Eretmochelys imbricata (Hawksbill Turtle) and Natator depressus (Flatback Turtle).* Significant rookeries for these species are found in the surrounding area to the south, north and on nearby islands. Surveys need to be conducted to ascertain the presence of turtle rookeries both on the site and within the light-impacting limits of the project. This should include a buffer zone and take into account cumulative impacts from actual and proposed nearby projects such as BHPB's Macedon and Exxon Mobile's Scarborough project. Development needs to avoid beach rookery loss and ensure appropriate distance so that lighting from the project does not impede turtles emerging to nest or disorientate hatchlings seeking the water.

The proposed timing and impact of activities should be considered with environmental cycles and timing of species migrations (such as those mentioned above). The timing of activities that may cause significant environmental impact, particularly when undertaken cumulatively with other site activities and those of surrounding developments, and should be carefully planned.

The environmental consequences of increased vessel activity, particularly the increased risk of vessel impact on wildlife, needs to be considered in the cumulative context of operating projects (such as those in the Exmouth sub-basin) and proposed projects in the vicinity of the Wheatstone project site (such as BHPB's Macedon project and Exxon Mobile's Scarborough project).

Vessels entering the area need to be rigorously managed to prevent invasive pest introduction. CCG recommends bench-marking actions that exceed current regulatory requirements to protect this area of high biodiveristy.

CCG requests that Exmouth Gulf not be used by vessels in any circumstances. Exmouth Gulf (included in recommended optimal boundary for World Heritage listing) is under increasing pressure from rising levels of marine vessel activity; the cumulative impact of further vessel activity needs to be avoided at all costs.

CCG holds major concerns about any proposed quarrying of limestone from regions of the Cape Range due to the extremely high value of the Cape Range karst system. The Cape Range karst system is internationally recognised for its unique, diverse and endemic subterranean fauna with significant geoevolutionary values, including evidence of evolutionary processes, speciation and fragmentation of Gondwanaland. CCG therefore requests that limestone associated with this project is sourced from sites outside the recommended optimal world heritage boundary to protect the karst system within Cape Range.

Yours Sincerely,

Jacqueline Hine
Oil and Gas Representative
Cape Conservation Group Inc.
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Jacqueline.hine@bigpond.com

HERITAGE COUNCIL

5 May 2009

Ms Ann Stubbs
Environmental Protection Authority
Locked Bag 33
Cloisters Square, PERTH 6000.

Dear Ann

Old Onslow Townsite, Onslow.
Assessment Number 1754 Wheatstone Project Environmental Review and Management Programme

Thank you for your correspondence received on April 24, 2009 regarding the Environmental Review and Management Programme for the Wheatstone Project.

We received four copies of the following document prepared by Chevron Australia Pty Ltd dated 17 April 2009:

Wheatstone Project Environmental Scoping Document

A Conservation Officer, with delegated authority from the Heritage Council, has reviewed the Environmental Scoping Document in the context of the identified heritage significance of the place. We offer the following comments :

1. The document does not include specific references to the significance of the Old Onslow Townsite as attributed in the Heritage Council's Statement of Significance, nor does it adequately explain that the place is listed on the the State Register of Heritage Places and thus is protected via the Heritage of Western Australia Act (1990).

Old Onslow Townsite is an archaelogical site comprising various structures and features, including the Police Station Complex (1893, 1906/1907) located in a natural setting on the banks of the Ashburton River, has cultural heritage significance for the following reasons:

The place is a rare example of an historical archaeological site of a former frontier settlement in the very remote area of the North West of the State.

The remaining fabric and archaeological material of the place is important for its ability to reveal information about the history of the town from its establishment in 1885 up to its abandonment in 1925.

The place was established to service the local pearling and pastoral industries in the late nineteenth century and as such has associations with development of the North- West of the State.

The place is of significance to the local Aboriginal community who have strong memories of the place in particular with regard to conflict between local Aboriginal people and European settlers and the exploitation of Aboriginal workers in the pearling and pastoralism industries.

Tel [illegible] Fax [illegible] Freecall [illegible] Email [illegible] Web [illegible]

The place is associated with a number of prominent Western Australians who took up leases in the area and were engaged in the pearling and pastoral inductries, including the Forrest family.

The place is representative of the frontier mentality and private enterprise ethic which exploited natural resources, including indigenous people, an attitude that underpinned the European colonialisim of the eighteenth and nineteenth centuries.

The plan of the town, with its centre, residential area and labourer's camps reflects European colonists attitudes towards Aboriginal, Japanese, Chinese, Malay, Filipino, Afghan and Italian workers and their familes.

The natural setting of the place, with its native vegetation and location on the bank flats of the Ashburton River, together with the ruins and archaeological remains of the individual buildings lends the place high aesthetic qualities.

The Police Station Complex has landmark value as it is the most substantial structure remaining within the townsite.

2. We currently have insufficient information to progress a full and accurate assessment of the impact of the proposal on the attributed significance of the Onslow Townsite. We recognise that the Environmental Scoping Document states that a European Heritage Study is required to fully explore these impacts. As the place is largely an archaeolgical site we recommend that an archaeolgist be included in the study team.

3. The Old Onslow Townsite Conservation Plan (Jean, Bosworth, Goulder and Hayes 1998) details in Policy 2.1 that "*the major archaeological sites should be retained insitu and conserved. These included those sites rated as having exceptional, considerable and some archaeological significance.*" The Conservation Plan also outlines that further research is required to identify the exact locations of all sites of archaeological significance generally and recommends that a "*scaled site plan based on the survey which identifies recorded and potential archaeological sites referenced to a Register with on site low level discrete markers.*" (Page 15) Two elements in this area are detailed as not being surveyed (The Store by Side Sea Jetty and the Magazine). We would suggest that these additional elements be located, surveyed and their individual signifiance assessed.

4. The existing Conservation Plan contains a series of relevant recommendations that we encourage the team completing the Heritage Impact Study to be aware of. Policy 4.1 states that "*Old Onslow Town Site should be managed primarily as a conservation reserve and an historic site with a lesser role as an open /passive recreation resource for the community. It is necessary to manage the place as part of an aesthetically significant and picturesque natural setting which is presently unmarred by visually intrusive or recent development and open space/recreation.*"

5. We also attach a copy of the Register Entry and Curtilage Diagrams for your records.

Should you have any queries regarding this advice please contact Ms Caroline Harben at caroline.harben@hc.wa.gov.au or on 9220 4118.

Yours sincerely

Stephen Carrick
A/DIRECTOR
cc: Shire of Ashburton, PO Box 567, TOM PRICE WA 6751

From: Holm, Jackie [Jackie.Holm@dpi.wa.gov.au]
Sent: Tuesday, 5 May 2009 5:51 PM
To: Stubbs, Ann
Cc: Kaucz, Wanda; WELCH, Nick
Subject: Chevron/Wheatstone scoping paper

Hi Ann

The scoping document appears comprehensive. State Government agencies and the Local Council have been working hard to outline a streamlined process for the assessment of the proposed Ashburton North Strategic Industrial Area. There are still a number of process issues that need to be discussed with relevant agencies and Chevron. The site will need to be rezoned from "Rural" to "Strategic Industrial" and as part of this process the amendment will be forwarded to EPA to set a level of assessment. Chevron should be clear about requirements for this separate process and should liaise with DPI and EPA in this regard. Due to the strategic nature of the industrial site a review of the Onslow Structure Plan is also being undertaken by DPI and the Shire, and there may be information that is required to advise this process.

The intent is not to complicate the process, but to streamline it. I would hope that Chevron make contact with DPI early in the process.

Jackie Holm

Team Leader | North Regions

State Strategic Policy Directorate

Department for Planning & Infrastructure

9264 7804

Office of Native Title
Government of Western Australia

Our Ref: 6855670: N088008
Your Ref: CRN 221796: DEC 8094
Enquires: Stephen Beesley (08) 9222 9635

May 2009

The Chairman
Environmental Protection Authority
Locked Bag 33, Cloisters Square
PERTH WA 6850

Attention: Ann Stubbs

Dear Sir

WHEATSTONE PROJECT (ASHBURTON NORTH) – ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME

Thank you for giving the Office of Native Title (ONT) an opportunity to comment on the above document.

As I understand it, the Environmental Review and Management Programme (ERMP) sets out the potential environmental impacts of the proposed project and outlines the measures necessary to protect key environmental features that may be affected by the construction and operation of the project.

I note that the site of the proposed development falls within the boundaries of the Thalanyji native title determination area. While the ERMP itself does not have any immediate impact on native title, I note that the project footprint and the proposed onshore pipeline cover parts of a number of pastoral leases and potentially part of the Cane River Conservation Park. The Thalanyji determination recognises non-exclusive native title rights and interests exist over these areas. It is likely therefore, that if the development is to go ahead there will be native title implications relating to any necessary changes in land tenure and potentially from the activities carried out during the construction and operation of the project. These issues will need to be addressed at the appropriate time by the project proponents.

The opportunity to comment on this document is appreciated. If you require any further information please contact Mr Stephen Beesley, Future Acts Manager, on telephone (08) 9222 9635.

Yours sincerely

GARY HAMLEY
EXECUTIVE DIRECTOR

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Government of **Western Australia**
Department of **Indigenous Affairs**

ENQUIRIES : LAURA GLADSTONE, SENIOR HERITAGE PLANNING OFFICER - Ph 9222 8112

OUR REF: 2009/D5979, 08/0965

YOUR REF: Wheatstone Project Assessment No 1754

Ann Stubbs
Environmental Protection Authority
Locked Bag 33
Cloisters Square
WA 6850

Dear Ms Stubbs

FEEDBACK - ENVIRONMENTAL SCOPING DOCUMENT - WHEATSTONE PROJECT

Thank you for the letter from Colin Murray, Director of the Environmental Impact Assessment Division, asking for feedback on the Wheatstone Project Environmental Scoping Document.

The Scoping Document has considered native title and heritage at clause 4.2.1 (p17). It estimates that 53% of the Onslow population is Indigenous to the area. It states that the Thalanji are the native title holders of the land in the Onslow area including the Ashburton North site, and recognises that members of the Yindjibarndi and Banyjima language groups also live in the area. The document recognises that there is at least one site, Registered midden site Amethyst 07, within the Ashburton North site, and that there is a possibility that more Aboriginal Heritage Sites will be found within the Project footprint area. A site search without the advantage of Easting and Northing coordinates for the project footprint area does show that there may also be further registered sites either in or near the proposed corridor area.

I am pleased to note that having assessed that there is a medium level risk of finding Aboriginal heritage sites, Chevron intends to complete a Cultural Heritage Study including archaeological and ethnographic surveys and consultation with local Aboriginal Groups and this Department. It is also helpful that an Aboriginal Social Impact Study to identify relevant social and cultural values associated with the project area will take place (p38).

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The Summary of Stakeholder Consultation Completed to Date confirms that Thalanyji representatives have been consulted twice, in July 2008 regarding site screening study outcomes, and concerning sites on December 2008. Yaburara / Mardudhunera, Wong Goo Tt Oo and Kuruma Marthudunera people (through the Pilbara Native Title Service) as native title claimants, were also consulted in September 2008 regarding site screening study outcomes. It might be helpful for Chevron also to inform representatives of the Yindjibarndi and Banyjima groups, as local residents, about progress on the project.

At p 19 of the document, it is stated that the onshore Domgas pipeline may be aligned through the Roebourne subregion of the Pilbara Bioregion. We would appreciate if DIA could be informed if this becomes more of a possibility. This Department is quite heavily involved with the Roebourne community and the Dampier Archipelago area generally, and has an interest in anything which may affect that community, or any surrounding heritage.

The document also informs that Cultural Aboriginal and European Heritage will be addressed as part of the EIS / ERMP processes. In Appendix 4: Stakeholder Consultation (p77) this Department is not listed as a stakeholder. I assume that this is a clerical error, as Table A1.5 Preliminary Risk Assessment Results (7F, p63) indicates a clear intention to consult the Department.

We look forward to continuing consultation with Chevron regarding the Wheatstone Project.

Yours sincerely

Pam Thorley

Pam Thorley
Assistant Director, Heritage and Culture

4 May 2009

Department of Water
Government of Western Australia

Your ref: CRN: 221796 & DEC 8694
Our ref: RF
WRD
Enquiries: Darryl Abbott 9144 2000

Environmental Protection Authority
Locked Bag 33
Cloisters Square
WA 6850
Attn: Ann Stubbs

Dear Ms Stubbs,

Re: Wheatstone Project ERMP (Assessment Number 1754) Environmental Scoping Document.

Thank you for your letter dated 17 April 2009 regarding the Wheatstone Project ERMP Environmental Scoping Document (ESD). The Department of Water (DoW), Pilbara Region has assessed the document and offers the following comments:

Water Supply

The proponent should clearly state their water requirements for both construction and operation in the ERMP and also consider the long term supply options should project expansion occur. An estimation of water supply needs is provided as 1.5GL/annum during operations. This is stated as being delivered by either a borefield (groundwater source) or from desalination of seawater (seawater source).

The ERMP should identify the selected source, and should describe its development and operation. The proposed investigative work being done to support the ERMP should determine, for any groundwater sources, the capacity of the bores, flow rates and the sustainability of the draw. Further investigations should be carried out to determine potential alternative water sources for the life of the project.

Potential impacts on surface and groundwater resources should be identified and management strategies developed. Impacts on other groundwater users and groundwater dependant ecosystems in the area, if they exist, should also be considered.

Permits and Licenses under the Rights in Water and Irrigation Act (1914)

The Department may require the proponent to apply for a Permit to Interfere with Bed and Banks (PMB) if the proposed construction activities are to interfere with the waters, bed or banks of any watercourse in the area. In order to construct or alter any bores, the proponent would be required to apply for a 26D licence to

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Construct or Alter (CAW). Drawing of water from any bores or surface sources will require a 5C Licence to take water under the RIWI Act (1914). The proponent should note that a 5C licence can not be issued unless legal access to the land is established.

Hydrocarbon and Dangerous Goods Management

Chevron should consider the need to manage and store hydrocarbons and dangerous goods in accordance with the DoW's Water Quality Protection Notes and Guidelines. Hydrocarbon management should include contingency planning for hydrocarbon and chemical spillages for all project areas. This should include identifying the risks, how the risks will be reduced and what will be the procedure in the event of a spillage, including remediation and follow up.

Flood Risk and Mitigation

The proposed locations for the onshore infrastructure would appear have potential for flood and storm surge events. The ERMP should consider the probability and impacts of these events. Assessment decisions on storm surge flooding will be conducted by Department for Planning and Infrastructure.

Summary

The DoW (Pilbara Region) requires comprehensive water source information in regards to water supply, usage and extraction management. The Department recognises that the proponent is planning to undertake hydrogeological studies and looks forward to commenting further when the results of these studies are released accompanying the ERMP document.

If you have any queries in relation to the above, please contact the Pilbara Regional Office on (08) 9144 2000.

Yours sincerely

H. Mohsenzadeh

Hamid Mohsenzadeh
Regional Manager
30 April 2009

Government of Western Australia
Department of Fisheries

Ack.
05/05/09

Fish for the future

Our Ref: 1545/99-04
Your Ref: CRN221795; DEC8694
Enquiries: Julie Lloyd (94827375)

Mr Colin Murray
Environment Protection Authority
168 St Georges Terrace
PERTH WA 6000

Dear Mr Murray

WHEATSTONE PROJECT ERMP (ASSESSMENT NO. 1754)

Thank you for the opportunity to comment on the Wheatstone Environmental Review and Management Program (Assessment No. 1754).

In addition to the risks outlined in Table A1.5, the Department of Fisheries (DoF) believes that the following areas need to be considered.

Increased anthropogenic noise and its effect on fish
Increased acoustic emissions during operations and construction will also impact on fish. Many species use acoustic cues for communication, as well as to obtain information about their environment. Acoustic cues are used to locate reefs, avoid predators and locate prey. Increased anthropogenic noise can interfere with these processes, as well as increase stress levels in fish, which in turn may lead to disruptions in reproductive patterns in fish. In order to ascertain the potential affect on fish species in the area, it is suggested that the proposed acoustic impact assessment also include fish.

Alteration of currents patterns
Any alteration of longshore flows or local current systems may have an impact on larval transportation, which in turn may affect local fish recruitment. These potential effects should be incorporated into Table A 1.5.

Biosecurity
Introduced marine species (IMS) have the capacity to impact on a wide range of

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industries, the environment, and public amenity, hence, there should be specific mention under "Environmental and Social Objective" to assess the risks and potential impacts of IMS on the environmental and socio-economic values. These risks will apply for the construction phase and ongoing operation of the project.

In reference to introduced marine pests transmitted through Vessel movements (Column 3D MNES) and their potential effect on fisheries, DoF believes that the risk ranking of Low is incorrect... There are numerous incidences of pest introduction (where hull fouling or ballast water have been the identified vector) having anywhere between "Major" and "Catastrophic" impacts. The Likelihood of such a translocation (prior to instigation of any risk mitigation) must be considered at least "Possible".

For clarification or further information regarding these issues, please contact Julie Lloyd on 94327375.

Yours sincerely

Stuart Smith
CHIEF EXECUTIVE OFFICER

5 May 2009

A1.3 Relevant International Agreements

International Agreements	
China Australia Migratory Birds Agreement	This Agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between China and Australia.
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)	The Bonn Convention aims to improve the status of all threatened migratory species through national action and international agreements between range states of particular groups of species.
International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978 (MARPOL 73/78)	This Convention aims to preserve the marine environment through the complete elimination of pollution by oil and other harmful substances and the minimisation of accidental discharge of such substances.
International Convention on Biological Diversity 1992	This Convention aims to conserve biological diversity through the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources. This includes appropriate access to genetic resources and appropriate transfer of relevant technologies, taking into account all rights over those resources and technologies.
International Convention on the Control of Harmful Anti-fouling Systems on Ships	This Convention aims to protect the marine environment and human health from ill effects of anti-fouling systems on ships.
International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) as modified by the Protocol of 1996	The Protocol prohibits the dumping of all wastes or other matter into the sea, other than identified categories (dredged material, sewage sludge, vessels and platforms, human-constructed structures at sea etc), subject to specific criteria being met.
International Labour Organisation (ILO) Declaration on Fundamental Principles and Rights at Work	The aim of the declaration is to reconcile the desire to stimulate national efforts to ensure that social progress works in parallel with economic progress and the need to respect the diversity of circumstances, possibilities and preferences of individual countries.
Japan Australia Migratory Birds Agreement	This Agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Japan and Australia.
Ramsar Convention on Wetlands of National Importance	The Ramsar Convention encourages the designation of sites containing representative, rare or unique wetlands, or wetlands that are important for conserving biological diversity.
Republic of Korea-Australia Migratory Bird Agreement	This Agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between South Korea and Australia.
United Nations Framework Convention on Climate Change and the Kyoto Protocol	The UNFCCC establishes a framework for the global reduction of six greenhouse gases (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride hydrofluorocarbons and perfluorocarbons), for member countries. The Kyoto Protocol establishes emissions targets over the period 2008 to 2012 for 38 national governments and the European Union. The Protocol also establishes mechanisms for the trading in international emissions rights and the flow of development assistance between developed and developing economies.
United Nations Universal Declaration of Human Rights	This Declaration sets the world standard for human rights, allowing all humans to live in dignity and be considered equal.

A1.4 Relevant International Guidelines

- Air Quality Guidelines, 2nd Edition, World Health Organisation Regional Office for Europe, 2000
- DNV-OS-F101:2007 – Offshore Standard: Submarine Pipeline Systems
- International Association for Public Participation Guidelines for Best Practice in Social Impact Assessment
- ISO 14001:2004 Environmental Management Systems – Requirements with guidance for use
- Netherlands and United Kingdom Offshore Chemical Notification Scheme
- Oslo and Paris Commissions Recommendation 2000/4 on Harmonized Pre-screening Scheme for Offshore Chemicals

A1.5 Relevant Commonwealth Legislation

Commonwealth Legislation	
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	The purposes of this Act are the preservation and protection from injury or desecration of areas and objects in Australia and in Australian waters, being areas and objects that are of particular significance to Aboriginals in accordance with Aboriginal tradition.
Agriculture and Related Resources Protection Act 1976	This Act provides for the management, control and prevention of certain plants and animals, for the prohibition and regulation of the introduction and spread of certain plants and of the introduction, spread and keeping of certain animals, for the protection of agriculture and related resources generally, and for incidental and other purposes.
Australian Heritage Commission Act 1975	This Act provides for the establishment of an Australian Heritage Commission.
Australian Heritage Council Act 2003	The purpose of this Act is to establish the Australian Heritage Council, and for related purposes.
Australian Maritime Safety Authority Act 1990	This act is to establish the Australian Maritime Safety Authority.
Australian Maritime Safety Authority Marine Order, Part 32	This Order prescribes matters in relation to the loading and unloading of cargo and the safe transfer of persons, from ships, off-shore industry vessels and off-shore industry mobile units.
Energy Efficiency Opportunities Act 2006	The purpose of this Act is to encourage more efficient use of energy by large energy using businesses, and for other purposes related to this.
Environment Protection and Biodiversity Conservation Act 1999	This act protects the environment, particularly Matters of National Environmental Significance (MNES). It streamlines national environmental assessment and approvals processes, protects Australian biodiversity and integrates management of important natural and culturally significant places.
Environment Protection (Sea Dumping) Act 1981	This act regulates permitted sea dumping and, under the 1996 Protocol to the London Convention, Australia is required to minimise its waste disposal into the marine environment. Approval is required under this Act for the disposal of dredged material at sea.
Hazardous Waste (Regulation of Exports and Imports) Act 1989	This Act provides for the regulation of the export and import of hazardous waste, and for related purposes.
Historic Shipwrecks Act 1976	This act protects shipwrecks that have lain in territorial waters for 75 years or more. It is an offence to interfere with any shipwreck covered by the Act.
National Environment Protection Measures Implementation Act 1998	This act provides for the implementation of national environment protection measures in respect of certain activities carried on by or on behalf of the Commonwealth and Commonwealth authorities.
National Greenhouse and Energy Reporting Act 2007	This act provides for the reporting and dissemination of information related to greenhouse gas emissions, greenhouse gas projects, energy production and energy consumption.
Native Title Act 2003	This act is about native title in relation to land or waters. It provides for the recognition and protection of native title, establishes ways in which future dealings affecting native title may proceed and set standards for those dealings, establishes mechanisms for determining claims to native title, and provides for (or permits) the validation of past acts and intermediate period acts invalidated because of the existence of native title.

Commonwealth Legislation	
Navigation Act 1912	This act requires that ships carrying oil and chemical tankers conform to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL).
Offshore Petroleum and Greenhouse Gas Storage Act 2006	This act is about petroleum exploration and recovery, and the injection and storage of greenhouse gas substances in offshore areas.
Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009	The object of these Regulations is to ensure that any petroleum activity or greenhouse gas storage activity carried out in an offshore area is carried out in an ecologically sustainable manner and in accordance with an appropriate environmental plan.
Protection of the Sea (Civil Liability) Act 1981	This act relates to civil liability for pollution damage.
Protection of the Sea (Civil Liability for Bunker Oil Pollution Damage) Act 2008	This act gives effect to the International Convention of Civil Liability for Bunker Oil Pollution Damage.
Protection of the Sea (Harmful Anti-Fouling Systems) Act 2006	This act relates to the protection of the sea from the effects of harmful anti-fouling systems (i.e. organotin compounds, biocides).
Protection of the Sea (Oil Pollution Compensation Fund) Act 1993	This act relates to oil pollution damage and provides legal recognition of the 1992 Fund. The Fund is in place for compensation for certain oil pollution damage and is implemented by the Australian Maritime Safety Authority.
Protection of the Sea (Powers of Intervention) Act 1981	This act authorises the Commonwealth to take measures for the purpose of protecting the sea from pollution by oil and other noxious substances discharged from ships.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	This act disallows any harmful discharge of sewage, oil and noxious substances into the sea and sets the demands for a shipboard waste management plan.
Quarantine Act 1908	This act implements mandatory controls in the use of seawater as ballast in ships and the declaration of sea vessels voyaging out of and into Commonwealth waters. The regulations stipulate that all information regarding the voyage of the vessel and the ballast water is declared correctly to the quarantine officers.
Radioactive Waste Management Act 2005	An Act to make provision in relation to the selection of a site for, and the establishment and operation of, a radioactive waste management facility, and for associated purposes.
Sea Installations Act 1987	This act relates to installations in the sea and their attachments. The objects of this act are to ensure that sea installations installed in adjacent areas are operated with regard to the safety of the people using them and of the people, ships and aircraft near them, to apply appropriate laws in relation to such sea installations, and to ensure that such sea installations are operated in a manner that is consistent with the protection of the environment.
Submarine Cables and Pipelines Protection Act 1963	The breaking or injuring of submarine cables and/or pipelines is a punishable offence under this act, and the penalties include fines and/or imprisonment.

A1.6 Relevant Commonwealth Policies and Guidelines

Key Commonwealth policies and guidance statements applicable to the Project include:

- Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)
- Australian Dangerous Goods Code Edition 7
- Australian Guidelines for Water Recycling (Environment Protection and Heritage Council, the Natural Resource Management Ministerial Council and the National Health and Medical Research Council)
- Australian Government Carbon Pollution Reduction Scheme White Paper, 2008
- Australian Standard 1680: 1997 – Interior Lighting
- Australian Standard 1742: 2009 – Manual of Uniform Traffic Control Devices
- Australian Standard 1940: 2004 – The Storage and Handling of Flammable and Combustible Liquids
- Australian Standard 2436: 1981 – Guide to Noise Control on Construction, Maintenance and Demolition Sites
- Australian Standard 2885 - Pipelines - Gas and Liquid Petroleum
- Australian Standard 4282: 1997 – Control of the Obtrusive Effects of Outdoor Lighting
- Australian Standard/New Zealand Standard 4360: 2004 – Risk Management
- Austroads Guide to Traffic Engineering Practice Part 2 – Roadway Capacity
- Austroads Guide to the Geometric Design of Rural Roads
- Best Practice Guidelines for the Provision of Waste Reception Facilities at Ports, Marina's and Boat Harbours Australia and New Zealand
- COAG Principles for Jurisdictions to Review and Streamline their Existing Climate Change Mitigation Measures
- Code of Practice for Antifouling and In-Water Hull Cleaning and Maintenance
- Environment Protection and Biodiversity Conservation Act Policy Statement 1.1 Significant Impact Guidelines
- Department of Environment, Water, Heritage and the Arts Guidelines for the Content of a Draft Environmental Review and Management Programme/Environmental Impact Statement
- Guidelines for Naturally Occurring Radioactive Materials 2002
- Interim Biogeographic Regionalisation for Australia
- Interim Marine and Coastal Regionalisation for Australia
- National Assessment Guidelines for Dredging 2009
- National Environmental Protection Measure for Ambient Air Quality – Commonwealth Monitoring Plan
- National Greenhouse and Energy Reporting (Measurement) Technical Guidelines 2008
- National Marine Oil Spill Contingency Plan - Australia's National Plan to Combat Pollution of the Sea by Oil and Other Noxious and Hazardous Substances
- National Occupational Health and Safety Commission (NOHSC). Approved Criteria for Classifying Hazardous Substances (NOHSC: 1008 [2002]).
- National Occupational Health and Safety Commission Standard NOHSC 2016:1996 National Code of Practice for the Control of Major Hazard Facilities
- National Strategy for the Management of Coastal Acid Sulphate Soils - Australian and New Zealand Environment Conservation Council & Agricultural and Resource Management Council of Australia and New Zealand (2000)
- National System for the Prevention and Management of Marine Pest Incursions
- National Water Initiative 2004
- National Water Quality Management Strategy
- Register of the National Estate
- Working Together to Reduce Impacts from Shipping Operations: ANZECC Strategy to Protect the Marine Environment

A1.7 Relevant Western Australian Legislation

Western Australian Legislation	
Aboriginal Heritage Act 1972	This act makes provision for the preservation on behalf of the community of places and objects customarily used by or traditional to the original inhabitants of Australia or their descendants.
Aboriginal Heritage Regulations 1974	These regulations specify the Minister's powers in relation to the Aboriginal Heritage Act 1972.
Biosecurity and Agriculture Management Act 2007	The purpose of this act is to provide for the control of certain organisms; the use of agricultural and veterinary chemicals; the identification and attainment of standards of quality and safety for agricultural products, animal feeds, fertilisers and other substances and things; the establishment of a Declared Pest Account, a Modified Penalties Revenue Account and accounts for industry funding schemes; and related matters.
Bushfires Act 1954	This act makes provision for diminishing the dangers resulting from bush fires and for the prevention, control and extinguishment of bush fires.
Conservation and Land Management Act 1984	The purpose of this act is to make better provision for the use, protection and management of certain public lands and waters and the flora and fauna and establish authorities to be responsible for such protection, and for incidental or connected purposes.
Contaminated Sites Act 2003 and *Regulations* 2006	This act provides for the identification, recording, management and remediation of contaminated sites.
Coroner Act 1996	An act to establish the office of State Coroner, to provide for a State coronial system to inquire into Western Australian deaths, to repeal the Coroners Act 1920, to amend certain other Acts.
Dangerous Goods Safety Act 2004	This act relates to the safe storage, handling and transport of dangerous goods.
Environmental Impact Assessment (Part IV Division 1) Administrative Procedures 2002	These administrative procedures set out the procedures adopted by the EPA for dealing with referrals and in the assessment of proposals covered by Division 1 of Part IV of the Act.
Environmental Protection Act 1986	This is the principal statute pertinent to environmental protection in WA. It gives the EPA overall responsibility for the prevention, control and abatement of environmental pollution and for the conservation, preservation, protection, enhancement and management of the environment.
Environmental Protection (Clearing of Native Vegetation) Regulations 2004	These regulations prescribe the conditions for clearing of native vegetation.
Environmental Protection (Controlled Waste) Regulations 2004	These regulations detail the appropriate management and handling of controlled wastes in respect to the environment.
Environmental Protection (Kwinana) (Atmospheric Wastes) Regulations 1992	These regulations set sulfur dioxide standards and limits in the Kwinana Industrial Area.
Environmental Protection (Liquid Waste) Regulations 1996	These regulations aim to reduce pollution caused by liquid waste, defining what liquid waste is and licences necessary to dispose of liquid wastes.

Western Australian Legislation	
Environmental Protection (Noise) Regulations 1997	These regulations set noise limits for industry and methods for assessing and controlling noise.
Environmental Protection (Recovery of Vapours from the Transfer of Organic Liquids) Regulations 1995	These regulations set standards for recovery of vapours from the transfer of organic liquids, with the aim to limit pollution.
Environmental Protection (Unauthorised Discharges) Regulations 2004	These regulations specify which substances are prohibited from being discharged into the environment and prohibited from being burnt so as to discharge black smoke into the environment.
Fish Resources Management Act 1994	This act and its regulations are concerned with commercial exploitation and development of fisheries and marine resources. Under the Act, development projects must be carried out so as not to adversely impact on fisheries and marine resources.
Harbours and Jetties Act 1928	This act relates to the liability of owners of ships for damage to harbours and jetties, and works connected therewith.
Health Act 1911	The purpose of this act is to consolidate and amend the law relating to public health.
Heritage of Western Australia Act 1990	This act provides for, and to encourage, the conservation of places which have significance to the cultural heritage in the State, to establish the Heritage Council of Western Australia, and for related purposes.
Land Administration Act 1997 and *Regulations* 1998	This act consolidates and reforms the law about Crown land and the compulsory acquisition of land generally.
Local Government Act 1995	This act provides for a system of local government in Western Australia. It aims to improve decision-making, community participation, accountability and efficiency in local government.
Main Roads Act 1930	The purpose of this act is to consolidate and amend the law relating to and making provision for the construction, maintenance, and supervision of highways, main and secondary roads, and other roads, the control of access to roads and for other relative purposes.
Marine and Harbours Act 1981 and *Marine and Harbours (Fuelling) Regulations* 1985	This act contains regulations to control the refuelling of ships and boats and is administered by the Department of Planning and Infrastructure (DPI).
Maritime Archeology Act 1973	This act makes provision for the preservation on behalf of the community of the remains of ships lost before the year 1900, and of relics associated with such ships.
Mining Act 1978	This act consolidates and amends the law relating to mining and for incidental and other purposes.
Petroleum and Geothermal Energy Resources Act 1967	This act and its regulations provide for the exploration and exploitation of petroleum resources, geothermal energy resources and certain other resources within certain lands of Western Australia.
Petroleum Pipelines Act 1969	This act and its regulations provide for the exploration and exploitation of petroleum resources on submerged lands adjacent to the coast of Western Australia.

Western Australian Legislation	
Petroleum (Submerged Lands) Act 1982 and *(Management of Environment) Regulations* 1999	This act and its regulations provide for the exploration and exploitation of petroleum resources on submerged adjacent to the coast of Western Australia.
Planning and Development Act 2005	This act provides for a system of land use planning and development in Western Australia.
Pollution of Waters by Oil and Noxious Substances Act 1987 and *Regulations* 1993	This act and its regulations provide for the protection of the sea and certain waters from pollution by oil and other noxious substances. This act prohibits the discharge of oil or noxious substances into Western Australian State waters, and provides for the removal of oil or any mixture containing oil from affected waters. The harbour authority and the DPI administer the Act.
Rights in Water and Irrigation Act 1914	The purpose of this act is to make provision for the regulation, management, use and protection of water resources, to provide for irrigation schemes, and for related purposes.
Shipping and Pilotage Act 1967	This act relates to shipping and pilotage in and about the ports, fishing boat harbours and mooring control areas of the State.
Soil and Land Conservation Act 1945	This act and its regulations relate to the conservation of soil and land resources, and to the mitigation of the effects of erosion, salinity and flooding.
Waterways Conservation Act 1976 and *Regulations* 1981	This act makes provisions for the conservation and management of certain waters and of the associated land and environment.
Western Australian Marine Act 1982	This act regulates navigation and shipping in Western Australian waters.
Western Australian Marine (Sea Dumping) Act 1981 and *Regulations* 1982	This act provides for the protection of the environment by regulating the dumping into the sea, and the incineration at sea, of wastes and other matter and the dumping into the sea of certain other objects.
Wildlife Conservation Act 1950	This act provides for the conservation and protection of wildlife.

A1.8 Relevant Western Australian Policies and Guidelines

The following Environmental Protection Authority (EPA) Guidance Statements have been considered and applied to the EIS/ERMP where appropriate:

- Guidance Statement 1: Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline (Final)
- Guidance Statement 2: Risk Assessment and Management: Offsite Individual Risk from Hazardous Industrial Plant.
- Guidance Statement 3: Separation Distances between Industrial and Sensitive Land Uses.Guidance Statement 6: Rehabilitation of Terrestrial Ecosystems.
- Guidance Statement 8: Environmental Noise (Draft)
- Guidance Statement 10: Application of Risk-based Assessment in EIA (Draft)
- Guidance Statement 12: Minimising Greenhouse Gases (Final)
- Guidance Statement 14: Road and Rail Transportation Noise (Preliminary Draft Version 3)
- Guidance Statement 15: Emissions of Oxides of Nitrogen from Gas Turbines (Final)
- Guidance Statement 18: Prevention of Air Quality Impacts from Land Development Sites (Final)
- Guidance Statement 29: Benthic Primary Producer Habitat Protection for Western Australia's Marine Environment (Final)
- Guidance Statement 33: Environmental Guidance for Planning and Development (Final)
- Guidance Statement 34: Linkage Between EPA Assessment and Management Strategies, Policies, Scientific Criteria, Guidelines, Standards and Measures Adopted by National Councils (Final)
- Guidance Statement 40: Management of Mosquitos by Land Developers (Final)
- Guidance Statement 41: Assessment of Aboriginal Heritage (Final).
- Guidance Statement 43: Guidance to Assist Proponents in Understanding the EPA's Requirements in Relation to the Environmental Condition on Environmental Management Systems (Final)
- Guidance Statement 47: Assessment of Odour Impacts from New Proposals (Final)
- Guidance Statement 48: Groundwater Environmental Management Areas (Draft)
- Guidance Statement 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia.
- Guidance Statement 54: Consideration of Subterranean Fauna in Groundwater and Caves During Environmental Impact Assessment in Western Australia (Final)\
- Guidance Statement 54a: Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (Draft)
- Guidance Statement 55: Implementing Best Practice in Proposals Submitted to the Environment Impact Assessment Process (Final).
- Guidance Statement 56: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (Final).

In addition to the above listed EPA Guidance statements, the following Western Australian Policies, Guidelines and Strategies have been considered and applied to the EIS/ERMP where appropriate:

- Australian and Torres Strait Islander Commission (ATSIC), Department of Indigenous Affairs (DIA) and Department of Premier and Cabinet Citizens and Civics Unit – Consulting Citizens: Engaging with Aboriginal Western Australians 2004
- Australian Pipeline Industry Association Ltd Code of Environmental Practice: Onshore Pipelines 2009
- Coastal Protection Policy for Western Australia
- Draft State Environmental (Ambient Air Policy) 2009
- Department of Environment and Conservation (DEC) Acid Sulfate Soils Guideline Series – Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes 2009
- DEC Acid Sulfate Soils Guideline Series – Treatment and Management of Acid Sulfate Soils
- DEC Air Quality and Air Pollution Modelling Guidance Notes
- DEC Contaminated Sites Guideline Management Series 2003
- DEC Interim Industry Guide to Community Involvement
- DEC Review of Waste Classification and Waste Definitions 1996 (as amended) 2005

- DEC State Water Quality Management Strategy No. 6 – Implementation Framework for Western Australia for the Australia and New Zealand Guidelines for Fresh and Marine Water Quality Monitoring and Reporting (Guidelines Nos 4 & 7: National Water Quality Management Strategy)
- Department of Health Draft Guidelines for the Use of Recycled Water in Western Australia
- Department of Industry and Resources Petroleum Guidelines: Drilling Fluids Management
- Department of Planning and Infrastructure Transport Assessment Guidelines for Developments
- Department of Water Pilbara Water in Mining Guideline 2009
- Department of Water Operational Policy No. 5.12: Hydrogeological Reporting Associated with a Groundwater Well Licence 2007
- EPA Application of Risk-based Assessment in EIA – Draft 2009
- EPA Assessment Guideline 3: Protection of Benthic Primary Producer Habitat in Western Australia's Marine Environment (Final)
- EPA Assessment Guideline 4: Towards Outcome-based Conditions (Draft)
- EPA Environmental Quality Management Framework for marine waters of the State
- EPA Guidelines for Preparing a Public Environmental Review/ Environmental Review and Management Programme 2008
- EPA Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia – Clearing of Native Vegetation with Particular Reference to the Agricultural Area
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection
- EPA Position Statement No. 5: Environmental Protection and Ecological Sustainability of the Rangelands in Western Australia
- EPA Position Statement No. 8: Environmental Protection in Natural Resource Management
- EPA Marine Report Series 1 - Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives
- Shire of Ashburton Municipal Heritage Inventory
- Shire of Ashburton Town Planning Scheme No. 7
- State Coastal Planning Policy 2.6
- State Industrial Buffer Statement of Planning Policy 4.1
- Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes – DEC Guidelines (Draft)
- van Gool, D., Tille, P. & Moore, G. 2005. *Land Evaluation Standards for Land Resource Mapping,* Department of Agriculture
- Visual Landscape Planning in Western Australia – a Manual for Evaluation, Assessment, Siting and Design 2007
- Water and Rivers Commission Statewide Policy No. 5: Environmental Water Provisions Policy for Western Australia 2000
- Western Australian Planning Commission Planning Bulletin No. 64: Acid Sulfate Soils

Appendix B1

Stakeholder Consultation

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STAKEHOLDER CONSULTATION

Stakeholder Identification

The following stakeholders have been identified and consulted as part of the Project to date:

Table 1: Stakeholders Identified and Consulted to Date

Stakeholder Category	Stakeholder Name
State Government Departments and Agencies	♦ Dampier Port Authority ♦ Department of Commerce ♦ Department of Environment and Conservation ♦ Office of the Environmental Protection Authority ♦ Department of Lands ♦ Department for Mines and Petroleum ♦ Department for Planning and Infrastructure ♦ Department of Premier and Cabinet ♦ Department of State Development ♦ Department of Water ♦ Department of Fisheries ♦ Department of Health ♦ Department of Indigenous Affairs ♦ Department of Education & Training ♦ Heritage Council of WA ♦ Fire and Emergency Services / Onslow State Emergency Services ♦ Pilbara Development Commission ♦ Water Corporation
Commonwealth Government Departments	♦ Department of the Environment, Water, Heritage and the Arts ♦ Department of Families, Housing, Community Services and Indigenous Affairs ♦ Department of Foreign Affairs and Trade ♦ Department of Prime Minister and

Stakeholder Category	Stakeholder Name
	Cabinet ♦ Department of Resources, Energy and Tourism
State and Commonwealth Ministers	♦ Prime Minister ♦ Deputy Prime Minister ♦ Treasurer ♦ Minister for Education ♦ Minister for Employment and Workplace Relations ♦ Minister for Social Inclusion ♦ Minister for Regional Development ♦ Minister for Resources and Energy ♦ Minister for Tourism ♦ Minister for Environment ♦ Minister for Foreign Affairs ♦ Minister for Trade ♦ Minister for Employment Participation ♦ Minister Assisting the Prime Minister on Government Service Delivery ♦ Parliamentary Secretary for Western and Northern Australia ♦ Premier and Minister for State Development ♦ Minister for Mines and Petroleum ♦ Minister for Energy ♦ Minister for Commerce ♦ Deputy Premier ♦ Minister for Health ♦ Minister for Indigenous Affairs
Native Title Holders	♦ Thalanyji
Other Indigenous Communities	♦ Bindi Bindi ♦ Jundaru Aboriginal Corporation (Peedamulla Station) ♦ Other Aboriginal language groups
eNGOs	♦ Greenpeace ♦ WA Conservation Council ♦ World Wildlife Fund ♦ Cape Conservation Group
Local Government	♦ Shire of Ashburton

Stakeholder Category	Stakeholder Name
	♦ Shire of Roebourne
Community	♦ Karratha - Chevron Karratha Community Reference Group ♦ Onslow-Chevron Onslow Community Reference Group ♦ Onslow Employment Project ♦ Old Onslow Committee ♦ Onslow Tourism & Progress Association ♦ Onslow Streetscape Committee ♦ Volunteer Marine Rescue Group Inc
Regional bodies	♦ Pilbara Industry Community Council ♦ Pilbara Area Consultative Committee ♦ Pilbara Division of General Practice ♦ Royal Flying Doctors Service
Local industry	♦ Ashburton Fisheries, KR Fisheries, Ausfish ♦ BHP Billiton Petroleum ♦ ExxonMobil ♦ Minderoo Station (Andrew Forrest) ♦ Northern Transport Company ♦ Onslow Salt ♦ Urala Station (BHP lease)
Tourism operators	♦ Recreation e.g. Scubaroo Dive, Blue Horizon Fishing and Diving Charters, Whale Shark & Dive, Warrior Princess Charters, Mackerel Islands, Fly Fish Charters, Norwest Airwork, White Lightening ♦ Accommodation providers: e.g. Beadon Bay Village, Sun Chalets, Ocean View, Club Thevenard, Beadon Bay Hotel, Ku'arlu Retreat, Onslow Mackerel, Nikki's restaurant
Peak bodies	♦ Chamber of Minerals and Energy of WA (CME) ♦ Chamber of Commerce and Industry of WA (CCIWA) ♦ Australian Petroleum Producers and Explorers Association (APPEA) ♦ WA Fishing Industry Council (WAFIC) ♦ Pearl Producers Association

Stakeholder Category	Stakeholder Name
	♦ Charter Boat Owners and Operators Association (CBOOA) ♦ Aquarium Specimen Collectors Association of WA (ASCA) ♦ Professional Specimen Shell Fishermen's Association of WA (PSSFA)

Stakeholder Consultation Completed to Date

Table 2: Summary of Stakeholder Consultation Completed to Date

Purpose	Stakeholder	Category	Date	Meeting Location
Inform about Wheatstone Project decision	State Premier, State and Commonwealth Ministers, Departmental Heads.	State and Commonwealth government	Jan -Apr, 08	Canberra and Perth
Convert Gorgon Reference Group into a Chevron Reference Group	Gorgon Reference Group members	Community	Feb 12, 08	Onslow
Project briefing	Onslow Community Reference Group (CRG)	Community	Mar 18, 08 Jul 8, 08 Nov 18, 08 Mar 18, 09 Jul 1, 09 Sep 16, 09 Nov 11, 09 Feb 17, 10 Apr 14, 10	Onslow
	Community	Onslow general community	Nov 18, 08 Mar 18, 09	Onslow
	Community	Karratha general community	Nov 19, 08	Karratha
	Onslow Salt	Local business	Apr 16, 08	Onslow
	Ashburton Shire Council meeting	Local Govt	Apr 15, 08 Jul 15, 08 Mar 17, 09 Nov 17, 09 Apr 21, 10	Paraburdoo Onslow Paraburdoo Tom Price

Purpose	Stakeholder	Category	Date	Meeting Location
	Roebourne Shire Council business update	Local Govt	Jul 17, 08	Roebourne
	Roebourne Shire Council meeting	Local Govt	Nov 16, 09	Roebourne
	Pilbara Development Commission	State Govt	Nov 27, 09	Port Hedland
Brief key stakeholders on site screening study outcomes	Chevron Community Reference Group	Community	Jul 8, 08 Dec 19, 08 Mar 18, 09	Onslow By phone Onslow
	Thalanyji representatives	Native Title claimants		
	Shire of Ashburton	Local Govt	Jul 15, 08	Paraburdoo
	Vince Catania	State Govt	Jul 16, 08	Onslow
	Shire of Roebourne	Local Govt	Jul 17, 08	Karratha
Project, site screening briefing	Beadon Creek Harbour Marine Advisory Committee	Local business/State Govt	Jun 29, 09 Jul 29, 08	Onslow
Project Briefing	EPA SU, DEWHA, EPA Board	State and Commonwealth govt	Aug 20, 08 Sept 18, 08 Oct 22,09	Perth Canberra Onslow
Project Briefing	Peak bodies (APPEA, Chamber of Commerce and Industry, Chamber of Minerals and Energy, American Chamber of Commerce, US Consulate)	Peak bodies	Jul-Nov, 08	Various personal briefings at Chevron or peak body offices
Brief key stakeholders re environmental referral	Karratha CRG, Onslow CRG, Shires, key eNGOs	Community/local govt	Sep 8-12, 08	By phone
Brief Cape Preston NT claimants on site screening study outcomes	Yaburara / Mardudhunera Wonn-Goo-Tt-Oo Pilbara Native Title Service (for Kuruma Marthudunera)	Native Title claimants	Sept 9-10, 08	Roebourne/ Karratha
Detailed site screening study and environmental referral briefing	Karratha CRG members	Community/local govt	Oct 7, 08	Karratha
Discussion on preliminary marine mammal and turtle survey findings	DEC	State Government	Oct 12, 08	Perth

Purpose	Stakeholder	Category	Date	Meeting Location
Project update	Belinda Robinson, Exec Director, APPEA	Peak bodies	Oct 14-16, 08	Perth, Karratha and Canberra
	State and Commonwealth Ministers, Departmental Heads	State and Commonwealth government		
Project schedule and timing	EPA Service Unit	State Govt	Nov 6, 08	Perth
Process and scheduling for EIS/ERMP	DEWHA	Commonwealth government	Dec 15, 09 Feb 19, 10	Canberra
Project overview and site comments	Onslow and districts public	Community	Nov 18, 08	Onslow
Project overview and site comments	Karratha and districts public	Community	Nov 19, 08	Karratha
Pilbara Perspectives – Project and site screening overview and site ranking workshop	Select Karratha and Onslow stakeholders (representing education, health, Ashburton and Roebourne Shires, Karratha and Onslow communities, local industries and, Pilbara Project Commission)	Community	Nov 26, 08	Onslow
Project overview and site selection process comments	Select govt stakeholders (DEC, Fisheries Dept, EPA, DoIR, DPI. Note: Conservation Council of WA failed to respond to numerous invitations and WWF declined to attend.)	State Govt	Dec 3, 08	Perth
Consultation on sites/ Native Title	Thalanyji	Native Title holders	Dec 5, 08 Aug 21, 09 Sep 16, 09 Oct 22, 09 Nov 27, 09 Dec 17-18, 09 Feb 18, 10 Mar 19, 10	Onslow Karratha
Discussions on fishing industry operations around Onslow and	Dept of Fisheries (Research Branch) WA Fishing Industry Council	State Govt Peak body	Dec 10, 08 Dec 12, 08May 21, 09	Perth Perth

Purpose	Stakeholder	Category	Date	Meeting Location
potential impacts	WA Pearling Industry Association Ashburton Fisheries Ausfish Doug Gibson Dampier Pearls Paspaley Pearls Tenerife P/L Pearling Association Bayana P/L Fishing Boat Sophie Direction Fisheries KR Fisheries MG Kailis	Peak body Local industry Local industry Local industry Local industry Local industry Local industry Local industry Local industry Local industry Local industry Local industry Local industry	March 31, 09 June 23, 09 Jul 28, 09 Jul 7, 09 Jul 8, 09 May 5, 09 May 21, 09 Jun 30, 09 Jul 9, 09 May 29, 09 May 30, 09 May 30, 09	Perth Onslow Perth
Discussion on proposed terrestrial ecological surveys	DEC	State Government	Dec 12, 08	Perth
Inform key stakeholders about site selection decision	Onslow Community Reference Group members Shire of Ashburton Shire of Roebourne	Community/Local Govt	Dec 18-19, 08	Onslow By phone/email By phone/email
Discussion on proposed marine ecological surveys	DEC	State Government	Dec 23, 08	Perth
Joint meeting with Gorgon Project	World Wildlife Fund, Conservation Council of Western Australia	ENGOs (Environmental Non-Government Organisations)	Jan 30, 09	Perth
Overview of environmental, social and health impact assessment of Wheatstone Project and risk-based scoping	WA Department of Health	State Government	Feb 9, 09 May 01, 09	Perth
Risk-based scoping workshop – Intro to process and Chevron's application	Government stakeholders (EPA Service Unit, DEC, Health, Fisheries, DIA)	State Government	Feb 17, 09	Perth
Project overview and risk-based	Department of the Environment, Water, Heritage	Commonwealth	Feb 26, 09	Canberra

Purpose	Stakeholder	Category	Date	Meeting Location
scoping	and the Arts	Government		
Risk-based scoping workshop 2 – draft risk ranking tables	Government stakeholders (EPA SU, DEC, Health, DSD, Water)	State Government	Mar 4, 09	Perth
Overview of emission impacts, air quality modelling, and monitoring	Dept of Environment and Conservation Air Quality Management	State Government	Mar 11, 09	Perth
Discussion of groundwater and water source investigations	Dept of Water	State Government	Mar 12, 09	Perth
Risk-based Scoping workshop 3 – draft Scoping Document	Government stakeholders (EPASU, DEC, Health, DSD)	State Government	Mar 16, 09	Perth
Briefing on draft Scoping document and implementation of risk-based approach	EPA Board	State Government	Apr 16, 09	Perth
Approach to dredge impact assessment and associated modelling	Department of the Environment, Water, Heritage and the Arts DEC - MEB, EPA SU	State Government	Jun 09, 09 Aug 11, 09	Canberra Perth
Discussion on Wheatstone Project, risk assessment approach, preliminary rankings and CCG general concerns	Cape Conservation Group	ENGOs (Environmental Non-Government Organisations)	Jul 22, 09	Exmouth
Briefing on draft consequence definitions and lessons learned	EPA Board	State Government	Jul 23, 09	Perth
Onslow community open day – community feedback	Onslow Community	Community	Aug 8- 9, 09 Dec 12, 09	Onslow Onslow
Discuss results from baseline ecological surveys	DEC - EMB	State Government	Aug 27, 09	Perth
Gathering anecdotal information on marine and coastal characteristics and changes, human use of nearshore islands	Onslow Community	Community	Sept 1-2, 09	Onslow

Purpose	Stakeholder	Category	Date	Meeting Location
Discuss preliminary findings of Wheatstone EIS/ERMP marine surveys	DEC	State Government	Sept 22, 09	Perth
Risk-based workshop 4 & 5 – review of risk-based approach	Government stakeholders (EPASU, DEC, Health, DSD, HEWHA) and Cape Conservation Group	State Government	Sept 29-30, 09	Perth
Update on the risk-based approach; discussion of the CUCA and shared infrastructure; Project impacts on mangroves; Submittal of the EIS/ERMP; Dredging and management plans, site tour	Government stakeholders (EPA Board, EPASU, DEWHA, DEC, DPA, DSD)	State Government & Commonwealth Government	Oct 21-22, 09	Onslow
Brief EPASU and DEC on Proposed Marine studies, including approach HD and dredge spoil modelling	EPA SU DEC (Marine Ecosystems Branch)	State Government	Aug 11, 09	Perth
Update on pipeline corridor routing through Ashburton mangrove ecosystem and impact on EIS/ERMP schedule	EPASU	State Government	Oct 20, 09 Nov 24, 09	Perth
Update on EIS/ERMP submittal and proposed review of schedule	EPA Board Chairman, EPASU	State Government	Feb 11, 10	Perth
Update on EIS/ERMP submittal and proposed review of schedule	EPASU	State Government	Jan 13,10	Perth
Project update and dredge program information	DoF, WAFIC	State Government Local industry	Feb 16, 10	Perth
Project update and dredge program information	DoF, WAFIC, Commercial fisherman	State Government Local industry	Mar 22, 10	Hillarys
Preliminary EPA comment on Draft EIS/ERMP	EPA Board Chairman	State Government	Apr 9, 10	Perth
Environmental presentation to Shire of Ashburton	Shire of Ashburton Council	Local Government	Apr 21, 10	Onslow

Purpose	Stakeholder	Category	Date	Meeting Location
Preliminary EPA comment on Draft EIS/ERMP	Office of the EPA	State Government	Apr 27, 10	Perth
Assessment of four potential borrow pits	Office of the EPA	State Government	May 10, 10	Perth
Discuss DoF comments on draft EIS/ERMP	DoF	State Government	May 11, 10 June 21, 10	Perth Perth
Discuss DIA comments on draft EIS/ERMP; provide info on Aboriginal SIA and HIA	DIA	State Government	May 11, 10	Perth
Discussions regarding DEWHA comments on Draft EIS/ERMP	DEWHA	Commonwealth Government	May 13, 10 May 27, 10	Perth/Canberra (Teleconference)
Discuss Aboriginal Heritage section of the draft EIS/ERMP	Thalanyji	Native Title holders	May 13, 10	Onslow
Project overview and potential environmental issues	Charter Boat Owners and Operators Association of WA	Peak body	May 18, 10	Fremantle
Outcomes of draft EIS/ERMP	Cape Conservation Group	ENGO	June 1, 10	Exmouth
Outcomes of draft EIS/ERMP	Conservation Council of WA	ENGO	June 3, 10	Perth
Outcomes of draft EIS/ERMP, subsequent public review	Office of the EPA A/Chair, EPA Board	State Government	June 3, 10	Perth
Draft Old Onslow Townsite Development Impact Mitigation Plan	Heritage Council of WA Development Committee WA Maritime Museum	State Government	June 15, 10	Perth
Draft EIS/ERMP, subsequent public review	DEWHA	Commonwealth Government	June 17, 10	Canberra

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Appendix C1

Air Quality Impact Assessment

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Limitations Statement

The sole purpose of this report and the associated services performed by Sinclair Knight Merz (SKM) is to assess the potential ambient air quality impacts associated with the proposed Wheatstone Project in accordance with the scope of services set out in the contract between SKM and Chevron Australia (Pty) Ltd ('the Client'). That scope of services was defined by the request of the Client.

SKM derived the data in this report primarily from the data provided by the Client, and the Australian Bureau of Meteorology. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, SKM has relied upon and presumed accurate certain information (or absence thereof) relative to the air quality impact assessment provided by the Client. Except as otherwise stated in the report, SKM has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by SKM in this report are not, and should not be considered, an opinion concerning the quality of the Wheatstone Project. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon information, drawings supplied by the Client, and information available in the public domain in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between SKM and the Client. SKM accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

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Executive Summary

Introduction

Chevron Australia Pty Ltd 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 Northern 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 the environmental impact assessment process.

Methodology

The operational phase of the Wheatstone Project would result in emissions of atmospheric pollutants from the following sources: power generation gas turbines, process area gas turbines, and flaring of hydrocarbons. Atmospheric pollutants of most likely significance include oxides of nitrogen, ozone (as a secondary pollutant) and airborne particulate matter. Emissions of the BTEX group of compounds (benzene, ethylbenzene, toluene and xylene) will occur however field monitoring conducted by the CSIRO in, and around, the Burrup Peninsula determined that there is very little enhancement of benzene and xylene adjacent to industrial areas when compared to background sites. Based on this study the BTEX group of compounds have been excluded from detailed examination. There is also the potential for oxides of sulfur to be emitted however as the available gas composition data indicates that there is no H_2S within the known fields emissions from these compounds have also been excluded from detailed examination.

Air quality criteria have been taken from National Environment Protection Measure (NEPM), Australian Environment Council (AEC)/ National Health and Medical Research Centre (NHMRC), National Occupational Health and Safety Commission (NOHSC) and the World Health Organisation (WHO) to assess whether pollutants are harmful to human health or the environment. The selected sensitive receptor for this study is the township of Onslow.

Predictive air dispersion modelling was undertaken using the TAPM software package (version 4) in order to estimate the impacts of the prescribed atmospheric pollutants on the ambient air quality. The ‘base case’ modelling for the Chevron Wheatstone Project assumed five LNG trains producing 25 MTPA of gas. A further future scenario was modelled to assess the potential cumulative impact should an additional LNG train and

Domgas facility, operated by a different project developer, locate on land adjacent to the Chevron facility in the Ashburton North Industrial Area.

Existing Air Quality

Based on the regional setting, ambient air quality in the vicinity of Ashburton North is expected to be influenced by ocean sources, biogenic emissions, particulates (windblown dust) and regional smoke from wild fires and prescribed burning activities, including the potential for photochemistry activity to occur throughout much of the year. Emissions from bushfires have been excluded from the study due to the complexity of determining emissions and the difficulty in modelling the variable short term impact of fires on an annual basis.

The modelling results predict that no exceedances of the Ambient Air Quality NEPM are likely to occur for any of the pollutants due to the existing sources in the region, including biogenic volatile organic compounds from vegetation and biogenic NO_X from soil and water. The maximum predicted concentration for any pollutant under the existing scenario was for ozone, which reached 27% of the relevant NEPM standard (4-hour average).

Summary of scenario modelling results

Atmospheric dispersion modelling was conducted for the proposed plant under a series of scenarios including:

- normal operating conditions (with and without shiploading)
- plant start-up
- emergency shutdown of a single train and
- the cumulative impacts from a combined set of sources.

With addition of the Wheatstone processing plant to the existing background sources, concentrations of all pollutants are predicted to increase under normal operating conditions yet remain below the applicable NEPM criteria. The most significant increase is predicted to occur for ozone. Under normal operating conditions with shiploading, the maximum predicted 4-hour average concentration for ozone, anywhere on the modelled grid, was 40 ppb which is below the relevant NEPM 4-hour average standard (50%). The maximum predicted 4-hour ozone concentration at Onslow is predicted to be even lower at 43% of the NEPM criteria.

Modelling of the BTEX pollutants indicate that the predicted ground level concentrations is very low with benzene having the highest predicted impact on the model grid at 8.4% of the applicable NEPM investigation level.

During start-up operations the model predicts that the maximum 1-hour concentration for ozone, anywhere on the modelled grid, is 43 ppb. The maximum predicted 1-hour ozone concentration at Onslow is predicted to be lower at 38% of the NEPM criteria during the start-up phase of operations.

During an emergency shutdown event the maximum 24-hour concentration for PM_{10}, anywhere on the modelled grid, is predicted to be 44 µg/m^3, which is equivalent to 87% of the applicable NEPM criteria. The maximum predicted 24-hour PM_{10} concentration at Onslow is predicted to be even lower at 50% of the NEPM criteria.

An assessment of deposition of NO_2 for the region surrounding the proposed Chevron Wheatstone facility, incorporating all emissions associated with existing sources and the proposed gas processing facility, indicates that 'typical high' NO_2 deposition in the region around Onslow would be 3.8 kg/ha/annum. These levels are well within WHO (2000) guidelines for assessing the risks of impacts on vegetation, being 49 to 66 kg/ha/annum (NO_2).

In addition to the five train 'base case' scenario, dispersion modelling was also conducted to determine the potential cumulative air quality impacts arising from an additional LNG train and Domgas facility located adjacent to the proposed Chevron Wheatstone facility. These are to represent the Macedon and Pilbara LNG facilities, both of which are in the planning process (but will likely come on stream following the commencement of operation of the Wheatstone project). The potential ground level concentrations resulting from the emissions of the additional LNG train have been modelled utilising the same emission parameters from the fifth LNG train at the proposed Chevron Wheatstone facility while the Domgas facility emissions were taken as identical to that used in the assessment of the Apache Domgas facility at Devils Creek. The results indicate a slight increase in all modelled pollutants though all predicted concentrations are well within the applicable NEPM criteria.

It is important to note that this modelling only provides an indication of the potential cumulative impacts of the Chevron Wheatstone facility in combination with potential additional gas processing facilities on adjacent land to the south. Further dispersion modelling will have to be conducted by the proponent/s of these facilities with more detailed emission characteristics.

Conclusions

This air quality assessment concludes with the following key findings:

- Normal and non-routine emissions from the proposed Chevron Wheatstone operations are not expected to cause any significant air quality impacts within the study area.
- Throughout the year, no exceedances of the relevant air quality standards are predicted for any of the pollutants studied.

Being mindful that further scientific work is required to determine uncertainties for modelling deposition, this assessment has predicted that the deposition of NO_2 from the proposed gas processing facility would be small, relative to the impact assessment criteria employed.

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1. Introduction

1.1. Overview

This report details the air quality impact assessment undertaken as part of the environmental approvals for the Chevron Wheatstone Project. This study comprises an assessment of the air quality impacts predicted from the construction and operation of the liquefied natural gas (LNG) development at the proposed Ashburton North hub, Western Australia.

Chevron has engaged Sinclair Knight Merz (SKM) to provide consultancy services to complete the cumulative air quality assessment for this Wheatstone Project.

The Wheatstone Project is described in the Environmental Impact Statement (EIS) / Environmental Review and Management Programme (ERMP). Selected elements of the project considered relevant to the air quality assessment are provided below.

1.2. Description of the Project

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train 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 Northern 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 the environmental impact assessment process.

1.2.1. Construction

The main infrastructure components to be constructed for the Wheatstone Project are:

- gas treatment and liquefaction trains
- domestic gas treatment trains
- LNG jetty
- LNG access channel and product loading facility
- associated terrestrial infrastructure (utilities and support infrastructure, construction and operations camps, roads, etc.)
- materials offloading facility (MOF)
- wastewater treatment plant
- LNG and condensate storage tanks.

1.2.2. Operations

The proposed onshore processing facilities accommodate five trains for LNG and hydrocarbon condensate production processes, including:

- gas and liquid reception (slug catcher and pig receiving)
- condensate treatment
- acid gas removal and dehydration
- heavy hydrocarbon removal fractionation
- liquefaction and refrigeration to create LNG
- emergency flare system
- domgas plant.
- product storage and loading

1.2.3. Air Quality Assessment Scope and Objectives

The objectives of the air quality assessment are to review the existing air quality in the vicinity of the Wheatstone Project's proposed location, establish the background air quality in the project area (including existing industrial sources), and provide an assessment of the likely future impact of atmospheric discharges on air quality during the construction and operational phases of the onshore facilities.

The following tasks have been undertaken in order to achieve these objectives:

- review of air quality issues relevant to the construction and operation of the proposal (**Section 2**).
- outline of the health and environmental effects of various parameters of concern (**Section 3).**
- outline of the ambient air quality criteria relevant to the proposal (**Section 4**).
- analysis and description of the local meteorology (**Section 5**), including
  - climate
  - prevailing meteorological conditions
  - cyclones
- analysis and description of existing ambient air quality in the region, including discussion on Area-based Emission Estimation for model input (**Section 6**).
- a description of the meteorological and air dispersion model employed and the modelling methodology (**Section 7**).
- estimation of emissions of oxides of nitrogen (NO_X), volatile organic compounds (VOC), and particulate matter with an aerodynamic diameter of ten microns or less (PM_{10}) from the proposal at its maximum expected level of operations and during upset conditions (**Section 8**).
- prediction of air quality impacts by air dispersion modelling for the maximum operational phase of the Wheatstone Project, during upset conditions, and for the cumulative air quality impacts from an additional LNG train and Domgas facility located in the Ashburton North Industrial Area (**Section 9**).

1.3. Abbreviations

All abbreviations used in this report are provided in **Appendix A**.

2. Project Overview and Air Quality Issues

This section briefly describes the key elements of the proposal, and places the project in context with its location and environmental (air quality) setting. The location of the project and the extent of the study area for the air quality assessment can be seen in **Figure 6-1**. The air pollutants expected to arise from the construction and operation of the LNG and Domgas plant at Ashburton North are also identified.

2.1. Overview

The Wheatstone Project will produce hydrocarbons from petroleum titles WA-253-P and WA-17-R, which are held 100% by Chevron. The Ashburton North site, located 12 km southwest of Onslow on the Pilbara coast, will consist of two 4.3 MTPA LNG processing trains and possibly three 5.47 MTPA LNG processing trains, for a total processing capability of 25 MTPA. The co-located Domgas plant will have a capacity equal to 15% of LNG sales, and will include onshore pipeline installation to tie in to the existing infrastructure of the Dampier-to-Bunbury Natural Gas Pipeline (Chevron 2009a).

2.2. Project Implementation

The onshore gas processing facilities are designed to treat gas to remove hydrocarbon liquids, water, carbon dioxide (CO_2) and other impurities prior to the liquefaction of the gas to produce LNG. LNG, along with other separated products (condensate and stabilised condensate), will be stored in tanks prior to export to international markets. The treatment process will produce some atmospheric emissions, principally NO_X, carbon monoxide (CO), CO_2, particulate matter and volatile organic compounds (VOCs).

Key project characteristics relevant to the air quality assessment are summarised in **Table 2-1**.

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Table 2-1 Project characteristics for onshore gas treatment facilities

Description	Detail
Location	Ashburton North
Number of LNG trains	5
Total production	25 million tonnes per annum (MTPA)
LNG tank (cryogenic) size	4 x 180 000 m^3
Compression turbines - Process refrigeration power (per train)	33 x LM6000 gas turbines, all equipped with DLE
Power generation turbines	9 x LM6000 gas turbine generators equipped with DLE burners
Flares	Wet / dry flare, marine flare
LNG production rate	23 560 tonnes per day
Condensate tank (ambient) sizes	4 x 60 000 m^3

2.2.1. Construction and Commissioning Phase

The key atmospheric emission of concern during the construction phase of the proposed development is dust. Dust generation will be associated with all the construction activities for the facility, including clearing of vegetation, soil and fill, excavation activities including blasting (should this be required) for site levelling and trenching, loading and dumping of material, wheel-generated dust from all vehicles active on site and wind erosion from exposed surfaces and stockpiles.

Other atmospheric emissions during the construction phase will be associated with marine vessel engines, additional airline flights to and from Onslow and from vehicles and equipment required to support the construction crew at site. Incidental to this will be the increased traffic. These sources will contribute to overall emission levels.

However, the volume and duration of the emissions during construction will not be significant in comparison with emission levels during the operation of the Wheatstone Project. Furthermore, they will not be concentrated in a single location for any extended period of time.

Air dispersion modelling has not been undertaken for the construction phase. The focus of the modelling is on the longer term operational phase impacts.

2.2.2. Operations Phase

The key sources of air emissions during the operations phase include:

- power generation
- process area gas turbines

- flaring of hydrocarbons

The key air emissions of concern from the proposed gas processing facility will be from the combustion of fuel gas in the process and power generation plant gas turbines and by flaring hydrocarbons during routine and non-routine plant operations. The key pollutants from natural gas combustion include CO_2 and NO_X (nitrogen dioxide (NO_2) as a measure of NO_X), together with CO and non-combusted hydrocarbons or VOCs. There will also be smaller amounts of particulate matter and SO_X emitted (sulfur dioxide (SO_2) as a measure of SO_X). The potential contribution of the emission of NO_X and its contribution to the creation of photochemical smog (measured as ground-level O_3) is also of interest.

Atmospheric emissions from the gas processing facility will vary depending on the operating and tanker loading conditions. Non-routine operations such as commissioning, plant start-up and shut-downs have therefore also been modelled.

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3. Air Pollutants and Effects

This section of the report outlines the health and environmental effects of airborne particulate matter, NO_X, SO_2, air toxics (including applicable VOCs) and O_3.

3.1. Overview

The pollutants addressed here are considered the most relevant to the assessment, based on the nature of the works to be undertaken during the overall development and operation of the onshore facilities for the Wheatstone Project and the nature of the receiving environment. These pollutants (with the exception of air toxics) are listed in the National Environment Protection (Ambient Air Quality) Measure (NEPC 1998), and national air standards have been prescribed.

3.2. Oxides of Nitrogen

NO_X is the collective term for nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O). Lightning and the oxidation of ammonia can form NO_X naturally. A major anthropogenic source (the main source) of NO_X is from the combustion of fossil fuels, primarily in urban areas from automobiles and electricity production, and in the Wheatstone Project's case, from the combustion of fuel gas. NO is colourless and odourless but can oxidise in the atmosphere to form NO_2 and NO_3^- (nitrate ions). For most sources, NO_2 accounts for 90% of NO_X with NO contributing the remaining 10%. For brevity, only NO_2 are presented in this study but the full NO_X emissions are included in the modelling.

3.2.1. Human Health Impacts (NO_X)

NO_2 is a pungent, brown, acidic, highly corrosive gas which is known to have significant effects on human health at elevated levels. NO_2 can have detrimental effects on the human respiratory tract, leading to increased susceptibility to and severity of asthma and respiratory infections. NO_3^- oxidises iron in the blood rendering it incapable of carrying oxygen.

3.2.2. Environmental Impacts (NO_X)

Vegetation is adversely affected by exposure to NO_X, in the form of retarded growth rates and reduced crop yields from very high concentrations. N_2O is a greenhouse gas, trapping longwave radiation emitted by the earth and warming the atmosphere. NO_X gases are also some of the main contributors to ozone production and can also contribute to acid rain through the formation of nitrous and/or nitric acid in airborne water droplets.

3.3. Oxides of Sulfur (as Sulfur Dioxide)

SO_2 is a colourless gas produced by combustion of fuels containing sulfur. SO_2 can oxidize to SO_3^{2-}, leading to formation of sulfate aerosols in the atmosphere.

3.3.1. Human Health Impacts (SO_2)

SO_2 has also been linked with the aggravation of existing heart and lung diseases (USEPA 2009). SO_2 can attach itself to small ambient particulates, which can then be inhaled deep into the lungs; this can intensify the health effects of sulfur dioxide with an irritating odour that can contribute to or exacerbate respiratory illnesses (such as asthma or bronchitis), especially in elderly or young people.

3.3.2. Environmental Impacts (SO_2)

SO_2 can also have detrimental effects on the environment. SO_2 can contribute to the formation of acid rain, damaging crops, ecosystems, monuments and historic buildings.

3.4. Airborne Particulate Matter

Airborne or suspended particulate matter can be defined by its size, chemical composition or source. Particles can also be defined by whether they are primary particles (such as a suspension of the fine fraction of soil by wind erosion, sea salt from evaporating sea spray, pollens, soot particles from incomplete combustion) or secondary particles (such as are formed from gas to particle conversion of sulfate and nitrate particles from SO_2 and NO_X).

For the assessment of impacts to human health, particulate matter is characterised by its size (aerodynamic diameter) in microns. The particulate size ranges specified in ambient air criteria are total suspended particulate (TSP), matter less than 10 µm in size (PM_{10}) and particulate matter less than 2.5 µm in size ($PM_{2.5}$).

3.4.1. Human Health Impacts (PM_{10} and $PM_{2.5}$)

The health effect of particulates in the PM_{10} range is the exacerbation of pre-existing respiratory problems. The population that is most susceptible include the elderly, people with existing respiratory and/or cardiovascular problems and children (NEPC 2005). The majority of larger particles greater than 10 µm in aerodynamic diameter do not pass further than the upper respiratory tract (nose and throat).

3.4.2. Environmental Impacts (PM_{10} and $PM_{2.5}$)

PM_{10} can also enhance some chemical reactions in the atmosphere and reduce visibility. The deposition of larger particles (greater than PM_{10}) can have the following consequences: staining and soiling of surfaces; aesthetic or chemical contamination of water bodies or vegetation; and effects on personal comfort, amenity and health.

3.5. Ozone

O_3 is a colourless gas that is naturally found in the upper atmosphere. O_3 is also formed as a secondary pollutant at ground-level by the reaction of NO_2 and sunlight which forms NO and a single oxygen atom (O). This oxygen atom then combines with molecular oxygen (O_2) to form O_3.

Photochemical smog is formed by the reaction of NO_X and VOCs in sunlight. It can form a layer of visible, brown or white haze in the sky. Photochemical smog is a regional, and not localised, phenomenon in that ozone is produced relatively slowly over several hours after exposure to sunlight, allowing sufficient time for the series of reactions to be completed (Carter *et al* 1995). Maximum ozone concentrations therefore tend to occur downwind of the main source areas of precursor emissions, and can become re-circulated within local and regional circulation patterns.

3.5.1. Human Health Impacts (O_3)

The human health effects of exposure to O_3 in the lower atmosphere include irritation of the eyes and exacerbation of respiratory issues such as asthma and bronchitis.

3.5.2. Environmental Impacts (O_3)

O_3 is a strong oxidant and can affect plants, including the retardation of growth and damage to leaf surfaces.

3.6. Air Toxics

Air toxics are gaseous, aerosol or particulate pollutants which are usually present in the air in very low concentrations. All have the potential to be hazardous to human, plant or animal life. The main sources of air toxics are anthropogenic in nature, though emissions also arise from sources such as bushfires and biogenic sources. In Australia, the term “air toxics” is taken to exclude those pollutants covered by the *National Environmental Protection (Ambient Air Quality) Measure* (Ambient Air Quality NEPM) (NEPC 1998) of CO, NO_2, O_3, SO_2, Pb and particulates. Air toxics present significant risk even at low concentrations. Air toxics can be separated into broad pollutant categories:

- metals
- pesticides
- polycyclic aromatic hydrocarbons (PAHs)
- VOCs
- persistent organic pollutants (POPs)
- dioxins and furans
- asbestos.

The air toxics of most interest for the Wheatstone Project are certain VOCs in the context of their contribution to the formation of ground-level ozone.

3.6.1. VOCs

VOCs are a group of carbon-based chemicals with a high vapour pressure at room temperature. Fuels, oil-based paints, solvents, wood preservers, benzene, toluene, ethyl-benzene, xylene(s) and perchloroethylene (the principal dry-cleaning solvent) are all common VOCs. VOCs can react with NO_X in the presence of sunlight to form O_3. A simplified equation is presented as:

- **Equation 3-1**

$$NO_X + VOC \xrightarrow{\text{sunlight}} O_3$$

3.6.2. Human Health Impacts (VOC)

The extent to which individual VOCs can cause health problems depends on their toxicity, concentration and the duration of exposure. Some are known to be carcinogenic, while others can cause reactions such as coughing or eye irritations at very high concentrations.

3.6.3. Environmental Impacts (VOC)

VOCs cover a wide range of compounds and can cause many different environmental impacts at high concentrations, ranging from: death or disfiguration in plants and vegetation; visibility degradation; and photochemical formation of O_3 with associated damage.

4. Air Quality Objectives in Western Australia

This section of the report details air quality objectives (ambient, occupational and deposition) relevant to this assessment.

4.1. Overview

The WA Environmental Protection Authority (EPA) requires that 'all reasonable and practicable means should be used to prevent and minimise the discharge of waste' (EPA 2003). For new proposals the EPA requires an assessment of the best available technologies for minimising the discharge of waste for the processes and justification for the adopted technology.

The EPA has developed a guidance statement for NO_X emissions from gas turbines, with limits for emissions following the AEC/NHMRC National Guidelines (1985). These limits are 0.07 g/m^3 (Standard temperature and pressure, dry and 15% O_2) for 'gaseous fuels' and 0.15 g/m^3 for 'other fuels'. The Guidance Statement states that modern natural gas-fired systems employing NO_X control technology can be expected to achieve lower emissions than 0.07 g/m^3 (EPA 2000).

4.2. Ambient Air Quality Criteria

The WA EPA requires that air pollutants meet the national environment protection standards of the Ambient Air Quality NEPM (NEPC 2005). This measure was created to provide a benchmark by which to ensure that people throughout Australia have protection from the potential health effects of air pollution. The standards were developed by taking into account the most current information available at the time regarding international health-related air pollution research, and the information available on the state of Australia's major airsheds. The final standards represent a high degree of consensus among leading health professionals, varied to reflect what is realistically achievable in Australia within a ten year timeframe.

As NEPM standards are intended to apply to general ambient air in both urban and regional areas, the pollutants of most concern identified for inclusion in the Ambient Air Quality NEPM were determined to be O_3, NO_2, particulates as PM_{10}, CO, SO_2 and lead (Pb). In 2003 the NEPM was extended to include an advisory reporting standard for particulates as $PM_{2.5}$. The pollutants of key interest for the Wheatstone Project are O_3, NO_2 as a measure of NO_X, particulates as PM_{10} and SO_2.

The WA EPA and Department of Environment and Conservation (DEC) routinely apply these NEPM standards and goals in WA. The WA EPA does not have state-wide standards for ambient ground-level concentrations; however, the WA EPA proposes that the NEPM standards be incorporated in an Environmental Protection Policy (EPP) to apply across all areas of WA, excluding industrial areas and residence-free buffer zones (NEPC 2007). As such, and in the absence of other standards relevant to WA, it is considered appropriate to use these standards as the criteria for comparison in this air quality assessment.

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The highest-risk NEPM air pollutants pertinent to the Wheatstone Project are listed in **Table 4-1** along with their associated NEPM standards. These specify maximum concentrations and goals to be achieved within 10 years from the NEPM's commencement. As the NEPM commenced in 1998, 2008 was the aforementioned target date.

Table 4-1 National Environment Protection Standards for the protection of human health used as assessment criteria

Pollutant	Averaging Period	Maximum Concentration	Compliance Goal for exceedances
Nitrogen Dioxide	1 hour	120 ppb	1 day per year
	1 year	30 ppb	None
Photochemical oxidants (as ozone)	1 hour	100 ppb	1 day per year
	4 hours	80 ppb	1 day per year
Sulfur dioxide	1 hour	200 ppb	1 day per year
	1 day	80 ppb	1 day per year
	1 year	20 ppb	None
Particles as PM_{10}	1 day	50 $\mu g/m^3$	5 days per year

4.2.1. Consideration of Other Air Pollutants

Investigation from various emissions estimation techniques (EA 1999a, 1999b, 2003a and 2003b; DEH 2005) has identified other pollutants which would be expected from a development of this type:

- CO
- benzene, toluene and xylenes (BTX)
- formaldehyde, acetaldehyde and PAHs
- $PM_{2.5}$.

Due to the uncertainties that exist at this time regarding the infrastructure and parameters of the Wheatstone Project, only modelling and assessment of the BTX pollutants has been conducted. The monitoring investigation levels for BTX, as stipulated by the NEPC (2004), are presented in **Table 4-2**.

Table 4-2 Monitoring investigation levels for BTEX

Pollutant	Averaging Period	Maximum Concentration (ppb)	Goal
Benzene	Annual	0.3	8-year goal is to gather sufficient data nationally to facilitate development of a standard
Toluene	24 hour	1000	
	Annual	100	
Xylene	24 hour	250	
	Annual	200	

4.3. Criteria for Assessing Impacts on Vegetation

4.3.1. Deposition of Oxides of Nitrogen and Sulfur Dioxide

Acid deposition occurs when SO_2 or NO_X react with water (H_2O), O_2 and other oxidants in the atmosphere to form acidic compounds. These acid compounds precipitate out in rain, snow and fog (wet deposition), or as gases and particles (dry deposition). The SO_2 and NO_X gases, their particulate matter derivatives, sulfate and nitrate aerosols all have the potential to contribute to air quality impacts. The potential impacts include the acidification of lakes and streams, damage to forest ecosystems and acceleration of the decay of building materials (USEPA 2007).

Deposition processes in the study region are expected to be dominated by dry deposition during the dry season and a combination of wet and dry deposition during the wet season. Previous deposition studies undertaken by SKM on the Burrup Peninsula, which is located in the Pilbara region of Western Australia, have indicated that there are large uncertainties associated with the deposition modelling results (SKM 2003a, SKM 2005). Note that while the Burrup Peninsula is a heavily industrialised area in comparison to Onslow, the above studies are the only data available for the region. The uncertainties in the modelled depositions are due to uncertainties in the water, soil and vegetation surface resistances employed in the calculations (Hurley 2005). As such, the deposition quantities provided in this assessment are considered indicative of what may occur.

4.3.2. WHO Guidelines for Air Quality Impacts on Vegetation

The World Health Organisation (WHO) (2000) provides critical loads for deposition of nitrogen and acid. ‘Critical load’ is an estimate of exposure in the form of deposition, below which significant harmful effects on specified sensitive elements of the environment do not occur to the best present knowledge (WHO 2000).

The sulfur critical load is 250–1500 eq/ha/annum (units are ‘acid equivalents’ per hectares per year), depending on the type of soil and ecosystem. The ecosystem example used for sulfur in this assessment is:

- 250–500 eq/ha/annum for fluvial and marine sediment
- 4–8 kg/ha/annum as elemental sulfur
- 8–16 kg/ha/annum as SO_2 (acid).

Since the gas expected to be processed in the Wheatstone facilities only contains small amounts of sulfur containing compounds, emissions of SO_2, combined with very low existing background concentrations, are assumed to be insignificant relative to likely impacts on vegetation, and hence are not considered further in this assessment.

The WHO (2000) nitrogen critical load is 5–35 kg/ha/annum, depending on the type of soil and ecosystem. The ecosystem example used for nitrogen in this assessment is:

- 15–20 kg/ha/annum for heath/shrub lands as elemental nitrogen
- 49–66 kg/ha/annum as NO_2 (acid).

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4.4. Summary of Criteria Used in this Assessment

Based on the preceding discussion, the air pollutant concentrations modelled in this study will be compared against the criteria summarised in **Table 4-3**.

Table 4-3 Summary of the standards used as assessment criteria in this study

Pollutant	Averaging Period	Maximum Concentration	Outcome
Nitrogen Dioxide	1 hour	120 ppb	Protection of human health
	1 year	30 ppb	Protection of human health
	1 year	49–66 kg/ha as NO_2	Protection of vegetation
Sulfur Dioxide	1-hour	200 ppb	Protection of human health
	24-hour	80 ppb	Protection of human health
	Annual	20 ppb	Protection of human health
Photochemical oxidants (as ozone)	1 hour	100 ppb	Protection of human health
	4 hours	80 ppb	Protection of human health
Particles as PM_{10}	1 day	50 µg/m^3	Protection of human health

5. Existing Environment

This section provides a description of environmental characteristics of the project area relevant to the air quality assessment, including the prevailing meteorological conditions influencing the air dispersion, and the meteorological data of the Onslow region used for the air dispersion modelling.

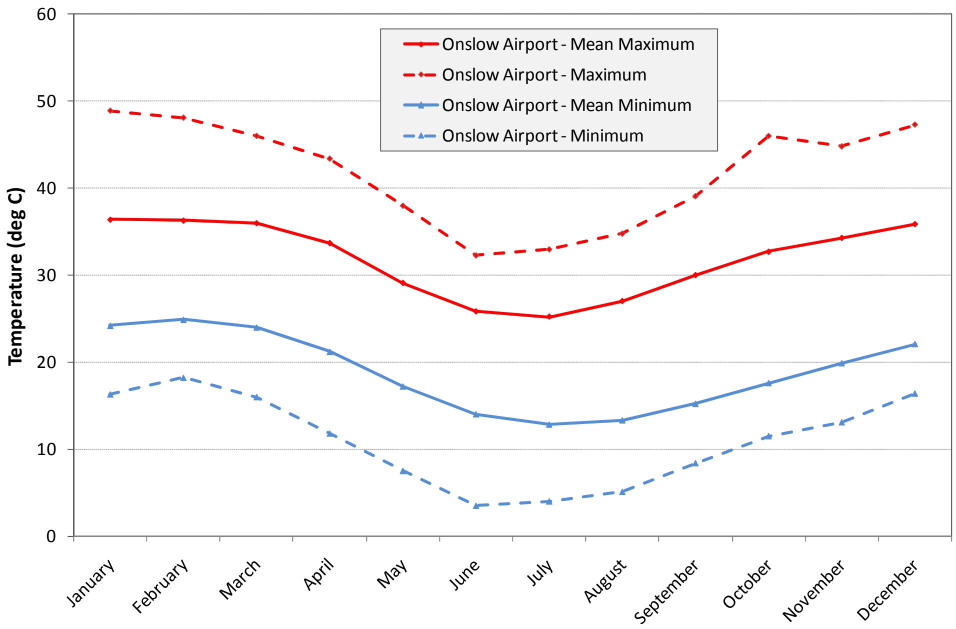
5.1. Climate and Dispersion Modelling

The southern portion of the north-west shelf, including the Onslow region, is characterised by an arid, sub-tropical climate. The wet season occurs from October to March and is characterised by high temperatures, high humidity and predominantly south-west winds (WNI 2003). In contrast, the dry season (June to August) is characterised by clear skies, fine weather and predominantly strong east to south-east winds. The months of April, May and September are considered a transition season during which either the wet or dry weather regime may predominate or conditions may vary between the two (Chevron Australia 2005).

The Australian Bureau of Meteorology (BoM) operates a meteorological station at the Onslow Airport. This station has been operating since 1940 and the data obtained from this station has been used in the following description of meteorological factors.

5.1.1. Temperature

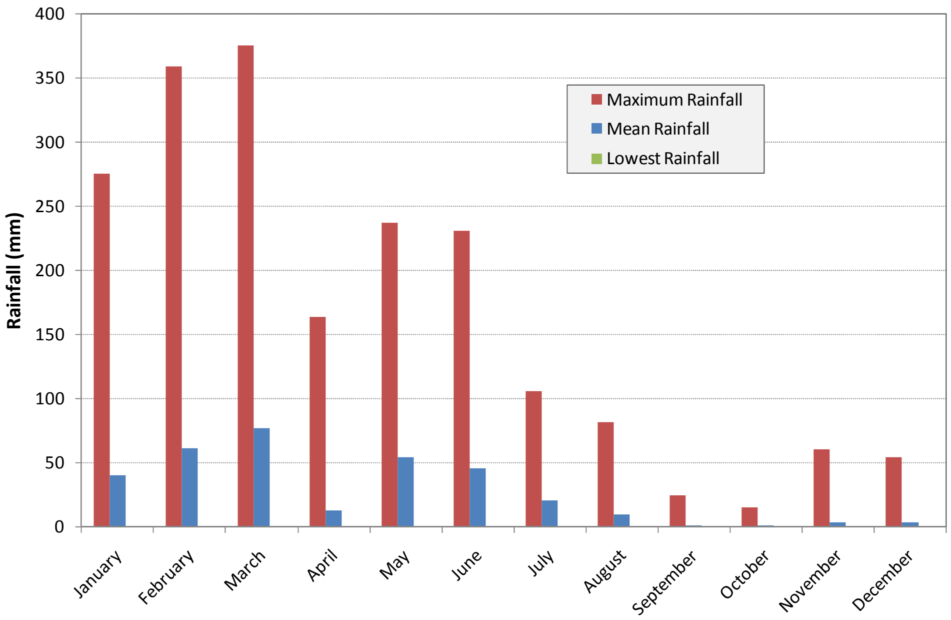
The temperature in the Onslow region can be expected to follow the pattern illustrated by **Figure 5-1**. From this figure it is apparent that Onslow experiences mean daily temperatures during summer ranging from 19 °C to 36 °C with the maximum reaching as high as 49 °C. During winter the mean daily temperatures range between 13 °C and 27 °C with the minimum reaching as low as 3 °C.



- **Figure 5-1 Maximum and minimum monthly temperatures at Onslow Airport from 1940 – 2009 (ºC) (BoM 2009a)**

5.1.2. Rainfall

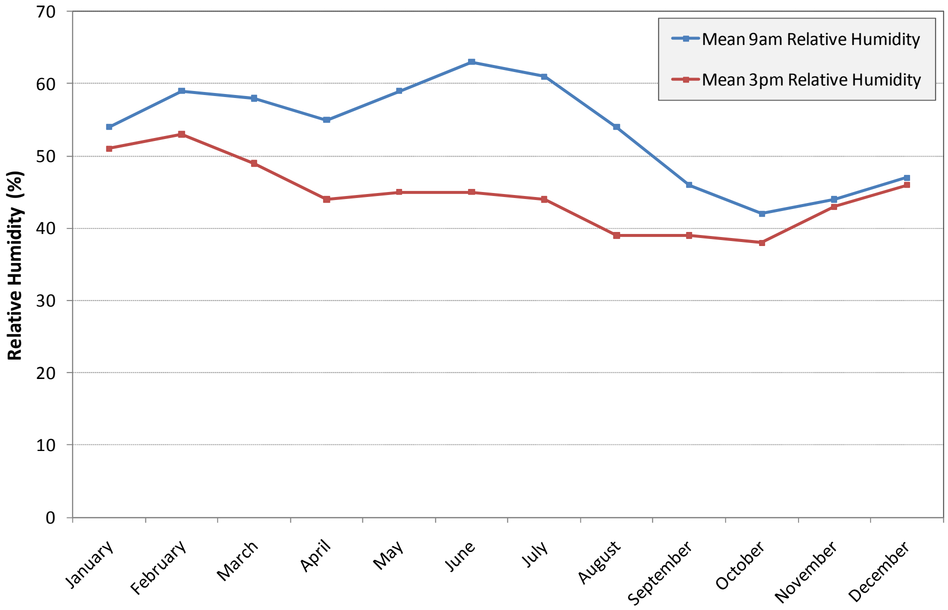
Onslow has an annual average rainfall of 328 mm and the mean monthly rainfall is presented in **Figure 5-2**. From this figure it is evident that the majority of the rain received at Onslow falls between January and June. The rainfall in the region varies significantly from year-to-year and is dependent on rain-bearing low pressure systems, thunderstorm activity and passage of tropical cyclones. Cyclonic events range from storms of 300 mm to milder 30 mm events. Wet years typically receive a large portion of the annual rainfall from tropical cyclones.



- **Figure 5-2 Average monthly rainfall for Onslow Airport from 1940 – 2009 (in mm) (BoM 2009a)**

5.1.3. Relative Humidity

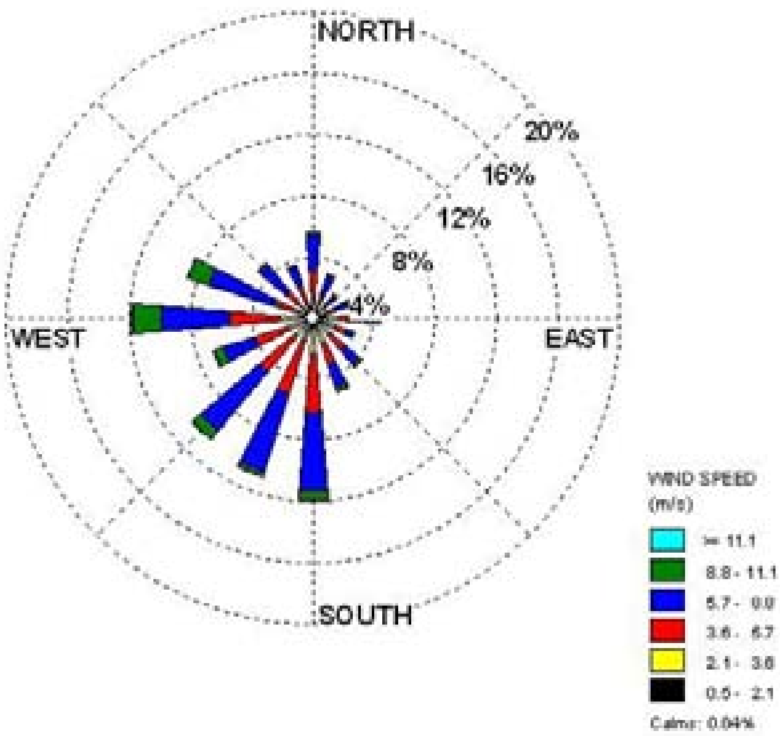
The 9am and 3pm mean relative humidity recorded at the BoM at the Onslow Airport is presented in **Figure 5-3**.



- **Figure 5-3 Relative humidity for Onslow Airport from 1940 – 2009 (%) (BoM 2009a)**

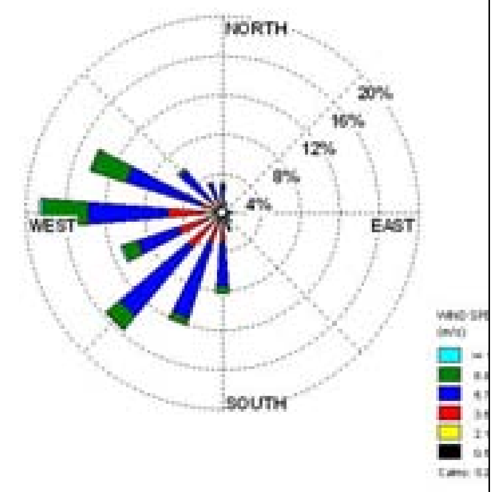
5.1.4. Wind

The annual average wind rose for Onslow Airport is presented in **Figure 5-4**. This figure represents the hourly wind speed and direction from 1998 to 2008 measured at the Onslow airport (BoM 2009a). From this figure it is evident that the dominant wind direction at this locality is from southerly through to westerly winds.

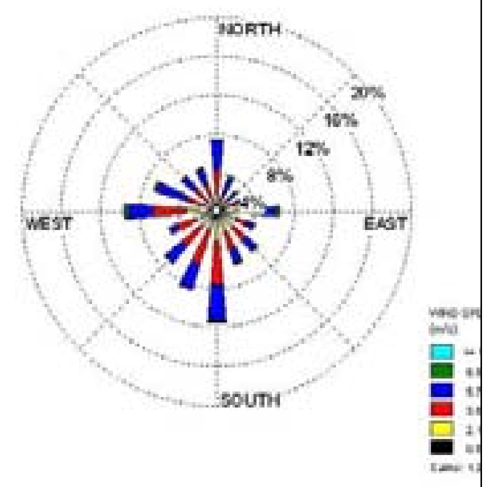


- **Figure 5-4 Annual wind rose for Onslow Airport (1998 – 2008)**

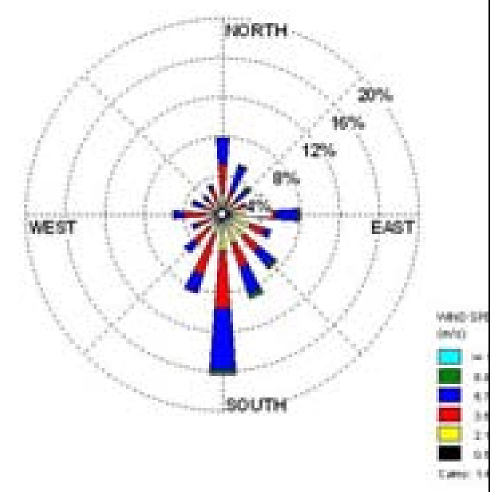
The seasonal wind roses are represented from **Figure 5-5** through to **Figure 5-8**. From these figures it can be seen that the dominant southerly to westerly winds occur primarily during the spring (Sept – Nov) and summer (Dec – Feb) periods. See also **Figure 7-8** which provides further analysis of the wind direction at Onslow Airport. These wind patterns result from high pressure cells which also produce significant periods of wind speeds greater than 10 m/s. During the autumn period (Mar – May) the wind direction is highly variable while winter (Jun – Aug) is dominated by southerly winds (with a degree of variability).



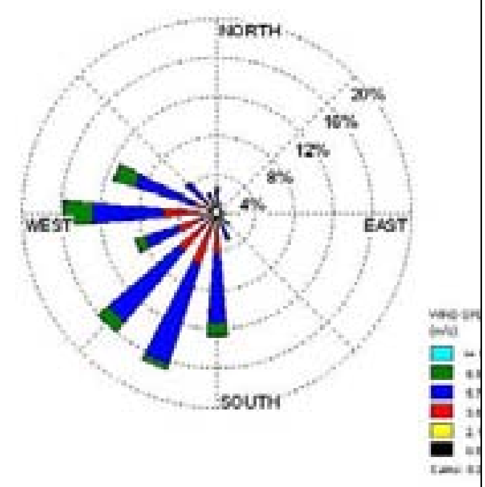
▪ **Figure 5-5 Summer wind rose for Onslow Airport (1998 – 2008)**



▪ **Figure 5-6 Autumn wind rose for Onslow Airport (1998 – 2008)**



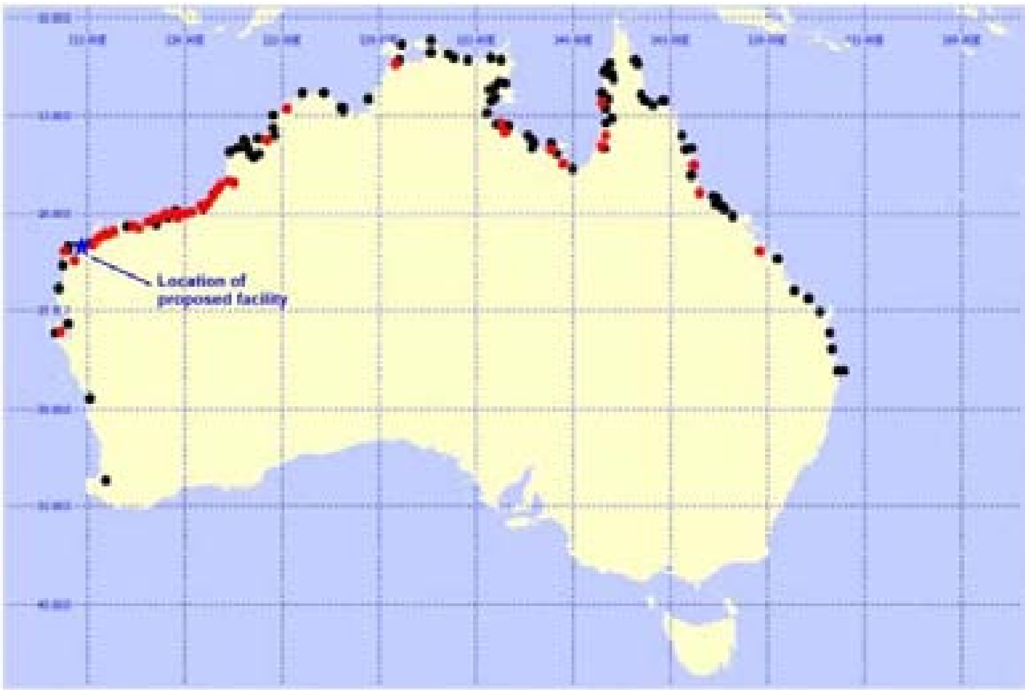
▪ **Figure 5-7 Winter wind rose for Onslow Airport (1998 – 2008)**



▪ **Figure 5-8 Spring wind rose for Onslow Airport (1998 – 2008)**

5.2. Cyclones

A cyclone is an intense low pressure system that is formed in maritime tropical air masses. The cyclone season in Australia starts in November and continues through to April, with the most severe storms occurring later in the season. **Figure 5-9** shows the locations of land-crossings by tropical cyclones from 1970 to 2002. The average number of cyclones to pass through locations in the Southern Indian Ocean and South Pacific Ocean each year is shown in **Figure 5-10**.



- **Figure 5-9 Location of land crossings by tropical cyclones from 1970 to 2002 (BoM 2009c)**

Note: Red dots indicate severe cyclones (category 3-5 on the Bureau of Meteorology's 5-point tropical cyclone scale) and black dots represent non-severe cyclones (below category 3) (BoM 2009c).

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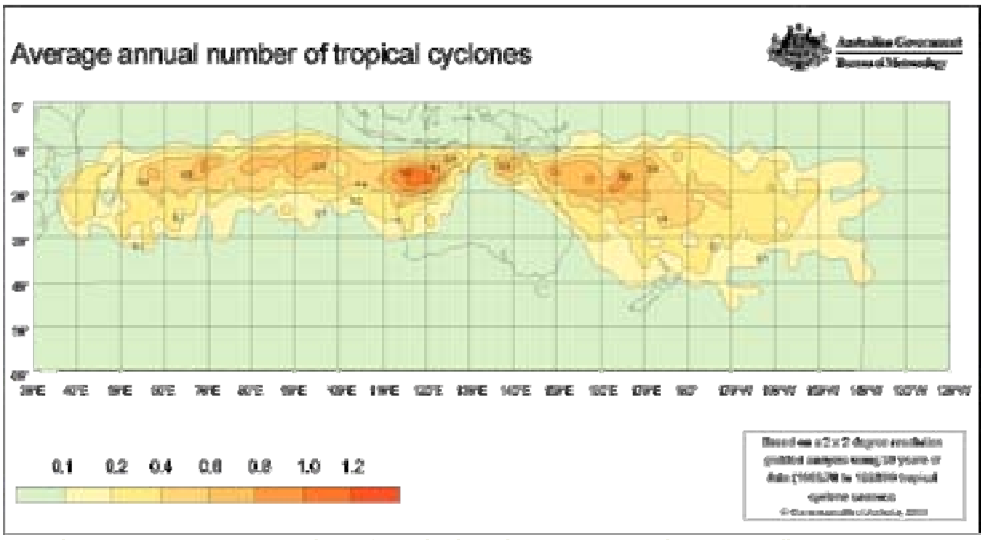


- **Figure 5-10 Average number of tropical cyclones per year (BoM 2009d)**

6. Background Air Quality Assessment

This section describes the results from a desk study estimating the emissions in the local and regional airshed relevant to the project. The desktop study concentrated on biogenic emissions from vegetation and soils (VOC and NO_X).

The amount of vegetation that is burnt each year in the Pilbara region is highly variable and depends on a number of factors including rainfall, previous burn regime and the growth cycle of the dominate plant, Spinifex. The total land area burnt during the 1999/2000 period was estimated by SKM (2003a) to be approximately 27 059 km^2. Bush fires contribute mostly CO and particulates. Bush fires have been excluded from the study due to a number of reasons including:

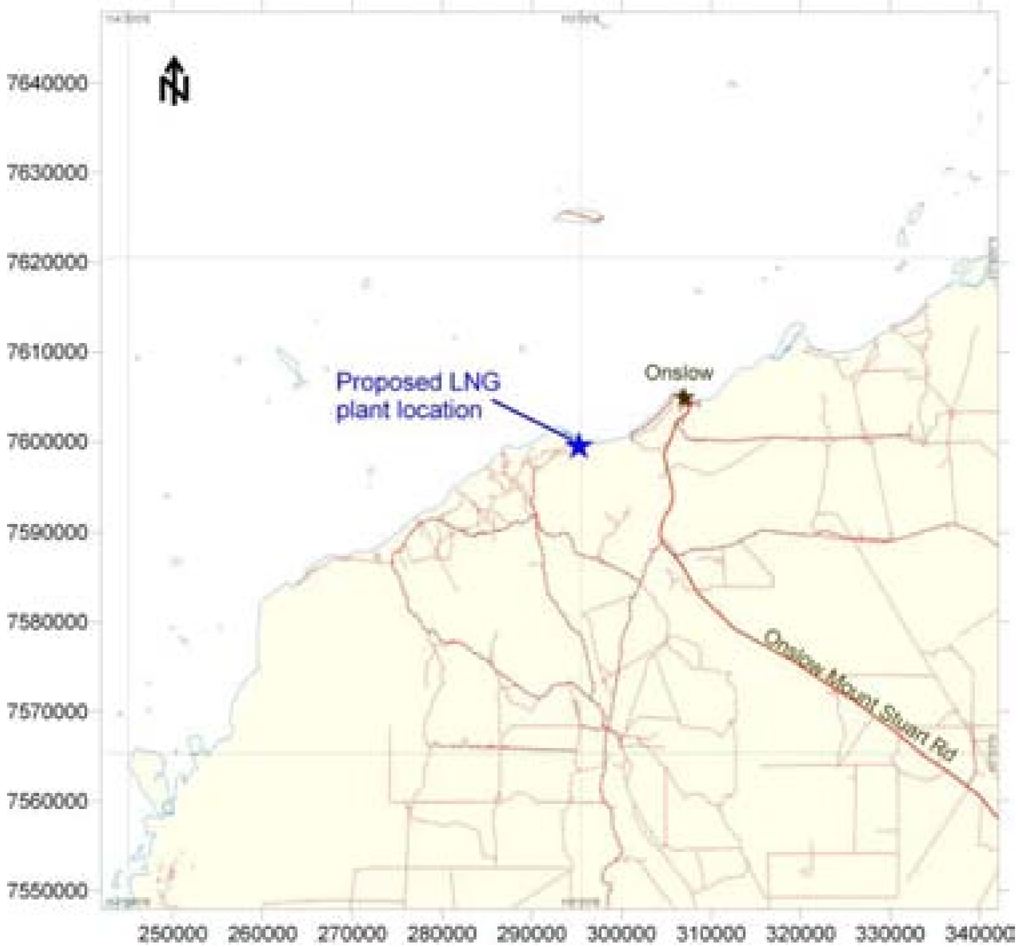
- the complexity of determining emissions from bushfires
- the difficulty in modelling the variable short term impact of fires on an annual basis.

6.1. Overview

Based on the regional setting, ambient air quality around Onslow is expected to be influenced by: ocean sources; biogenic emissions; particulate matter; and regional smoke from bush fires and prescribed burning activities. The study area is shown in **Figure 6-1**.

Although there has been extensive air quality studies conducted in the Pilbara region the majority of these studies have focussed on either the Dampier/Karratha region (CSIRO 2001, SKM 2003b, CSIRO 2006, SKM 2009) or Port Hedland (Physick & Blockley 2001). Information regarding the local ambient air quality experienced in the Onslow region is confined to a study conducted by (SKM in 2003a) which determined the aggregated emissions for the entire Pilbara airshed. The results of this study indicate that the main sources of emissions of VOC and NO_X are from biogenic and burning/wildfire sources.

Due to limited amount of available monitoring data, estimating the emissions in the local and regional airshed has been necessary. This estimation has focused on biogenic emissions from vegetation and soils (VOC and NO_X). The direct health impacts of these pollutants is likely to be negligible, but their calculation is necessary for this assessment, due to their contribution to the formation of secondary ozone.



▪ **Figure 6-1 The extent of the study area for the air quality assessment**

6.2. Biogenic Emissions

Emissions of VOCs and NO_X occur from both anthropogenic (human derived) and biogenic (natural) sources. The main source of biogenic VOCs is vegetation (Lamb et al 1993) while biogenic NO_X sources include soil, biomass burning and lightning (Yienger and Levy 1995). Estimates by Lamb et al (1987) indicate that VOC emissions by vegetation account for half of the estimated total VOC emissions in the USA and two-thirds of the global VOC emissions.

In the presence of sufficient NO_X the oxidation of biogenic VOCs, especially isoprene and monoterpenes, can produce ozone, though if NO_X levels are low these VOCs will react with ozone and therefore reduce the concentrations (Sanderson 2002).

6.2.1. VOCs

It has long been recognised that biogenic VOC emissions contribute a significant amount of the total hydrocarbon emissions into the atmosphere (Guenther *et al* 1993) and that these emissions vary between plant species as well as by temperature, levels of photosynthetically active radiation (PAR; Sanderson 2002) and the physiological activity of plants (Fall 1999). Guenther *et al* (1995) in Geron *et al* (2002) estimated that over 90% of global biogenic isoprene emissions are from vegetation, and Guenther *et al* (1996) in Geron *et al* (2002) showed that approximately 50% of these are derived from tropical ecosystems. This is primarily due to a combination of the large quantities of vegetation and consistently warm temperatures.

As is noted in the process studies, modelling and validation experiments and studies (e.g. BEWA 2000 described in Steinbrecher 2006) the key processes of biogenic VOC emissions are not well understood and this has led to large uncertainties in inventories on both global and regional scales. These uncertainties are a result of:

- variations in emissions caused through source strength, climate and synergistic effects between plant species and emitted species
- land use and distribution
- lack of suitable emission factors for specific endemic species.

6.2.1.1. Data Collection and Information Sources

The methodology adopted for the calculation of VOC emissions from vegetation in the study region is the same as that used in the Aggregated Emission Inventory for the Pilbara Airshed (SKM 2003a). This methodology is based on Lamb *et al* (1987) and estimates the major VOCs emitted (isoprene, 1,8-cineole, and monoterpenes) from vegetation based on a temperature dependant function and a vegetation density index. This methodology is simpler than that adopted for other Australian studies such as Metropolitan Air Quality Study (MAQS) (Carnovale *et al* 1996) and for the Dandenong, Launceston and Port Pirie in the NPI Trial (EPAV 1996). The methodology for these studies requires additional data on biomass density (mass on a dry basis of leaf per unit area of ground) as well as using a more complicated temperature factor and radiation factor that varies with the sun angle.

For this study, given that there is neither biomass density data nor specific VOC measurements for the vegetation types in the study region, the simpler (Lamb *et al* 1987) approach has been deemed most appropriate.

Data required for emission estimates are vegetation types, classification of the vegetation density and meteorological data for the Onslow region. The vegetation type and coverage was obtained from Chevron through URS, who are undertaking detailed vegetation surveys in the area. Temperature data was obtained from the Bureau of Meteorology's automatic weather station at Onslow airport.

6.2.1.2. Emission Estimation

Emissions of VOCs from vegetation were calculated using **Equation 6-1** from Lamb *et al* (1987), as used in SKM (2003a) and EPAV (1996).

- **Equation 6-1**

$$E_j = pq10^r$$

Where:

- E_j is the mass emission flux (g/m^2/hr) of a volatile organic compound j at an ambient temperature of T°C
- p and r are empirical coefficients
- q is the vegetation density index (ranging from 0 to 5)

The empirical constants used in EPAV (1996) are listed in **Table 6-1**.

- **Table 6-1 Empirical constants for Biogenic VOCs from EPAV (1996)**

Pollutant	Time & Temperature	p	r
Isoprene	Day, T<40°C	0.0268	0.0416T – 3.109
	Day, T>40°C	3.52 – 0.064T	-3
	Night	0	n.a.
1,8-Cineole	Day/night	0.0302	0.0416T – 3.109
Monoterpenes	Day/night	0.0133	0.0416T – 3.109

Notes:
1) In this study we have adopted a value of 'p' which is twice the EPAV value.
2) Night was defined as being from 6pm to 6am.

Vegetation densities were assigned (q = 0 to 5) based on the percentage of coverage of trees and percent coverage of grasses. For shrubs and trees with 50% coverage or less, 30% coverage by grasses underneath was assumed. This is approximately mid-range between the maximum grass coverage of 50% and the lower grass coverages. As per EPAV (1996) mangroves were assumed to emit negligible isoprene and cineoles, whilst monoterpenes were assumed to be emitted at approximately the same rate as for other isoprene emitting species. Therefore, as an approximation to estimate total VOCs, emissions of isoprene, cineoles and monoterpenes were reduced by one third. Mangroves were taken to have a biomass density of half that of a forested area. Therefore a q factor of 0.83 was adopted for them. A description of each category is presented in **Table 6-2**.

For areas with 100% grass coverage a value 0.4 mg/m^2/hr has been adopted for the mass emission file from the open savannah measurements of Klinger *et al* (1998). This value is higher than values for temperate grasses used in the US of 0.15 mg/m^2/hr (Carnovale *et* *al* 1996), based on a quoted value of 300 μg/m^2/hr of total non methane hydrocarbons consisting of 50% isoprene). The higher value is considered appropriate as the grasslands consist primarily of Spinifex (known to have high oil content). With no measurements of such grasses in Australia, the African savannah results have been adopted.

- **Table 6-2 Vegetation categories**

Description	Vegetation Index (q)
Mangrove	0.83
Open Woodland	0.44
Sparse Samphire scrubland	Assumed 10% coverage
Tussock grassland	Assumed 30% coverage

Notes
1) Emission rate normalised to 30^0 C and photosynthetically active radiation of 1000 μmol/m^2/s.
2) Grasses and samphire have an emission rate of 0.4 mg/m^2/hr for 100% coverage

Using the methodology outlined above together with a map of vegetation type and coverage typical of the region (obtained from URS), the total VOC emissions were determined on a 1km by 1km grid basis for the entire study region. The breakdown of each vegetation type across the study region is presented in **Appendix B**. The total VOC emissions by each vegetation category are presented in **Table 6-3**. It should be noted that biogenic VOC emissions are derived from vegetation therefore no emissions were assigned to water bodies (oceans/inlets) or bare open areas.

It must be noted that there are large uncertainties associated with biogenic VOC (BVOC) emissions. This includes the assignment to a vegetation type (error in q) and in the emission factors (error in p and r). Typically these BVOC emission estimates only give an order of magnitude assessment.

- **Table 6-3 Total VOC emissions from each vegetation category**

Description	Area (km^2)	VOC Emissions (t/yr)	Contribution (%)
Samphire scrubland	264	93	1.7%
Mangrove	131	1 195	22.6%
Open Forest (with grass)	4	26	0.5%
Tussock grassland	3 780	3 974	75.2
TOTAL	4 179	5 288	100%

6.2.1.3. Comparison to Other Studies

A comparison of the emission estimates from this assessment to emission estimates from other Australian studies is presented in **Table 6-4**. From this table it can be seen that the VOC emissions for the Onslow region are lower than those calculated for other regions within Australia, with the exception of the Dandenong study. This can be attributed to the large expanse of tussock grass land in the Onslow region which has a very low calculated BVOC emission rate.

Table 6-4 VOC emissions from vegetation compared to other Australian studies

Region	VOC ($t/km^2/yr$)
Onslow	1.3
Pilbara[1]	5.5
Dandenong[1]	0.7
Port Pirie[1]	14
Newcastle[1]	5.2
Kalgoorlie[1]	5.1

Source: [1] SKM (2003a)

6.2.2. NO_X Background

One of the principal natural sources of NO_X has been found to be biogenic emissions from soils (Williams *et al* 1987, Guenther *et al* 2000). In rural areas, soil biogenic emissions of NO_X account for a larger fraction of the total NO_X source than anthropogenic emissions (Yienger and Levy 1995).

Natural NO_X emissions are strongly influenced by the landscape. In soil, NO_X emissions result from microbial and chemical processes from both denitrifying bacteria in anaerobic environments and nitrifying bacteria in aerobic environments (Williams *et al* 1987). In water bodies, NO_X emissions result from nitrite photolysis. Guenther *et al* (1996) report that, in general, wetlands and tundra have low NO_X emissions, forests have moderate emissions, and agricultural and grasslands have the highest emission rates. Yienger and Levy (1995) believe that, in general, grassland emissions are an order of magnitude greater than those of forests, while heavily fertilised soils are an order of magnitude greater than those of grasslands.

Biogenic NO_X emission activity can be seen to be a function of both short term and long term effects. Long term effects include soil texture, organic matter content, soil pH and nitrate levels. In the short term, the effects are primarily soil temperature and moisture content. Soil NO_X emission rates generally increase with the application of nitrogen based fertilisers, soil temperature and optimal soil moisture conditions (Guenther *et al* 1996).

6.2.2.1. Data Collection and Information Sources

Previous Australian air pollutant inventories such as the Victorian trial (EPAV 1996), the Kalgoorlie Mining National Pollutant Inventory (NPI) Trial (Coffey 1999) and the MAQS (Carnovale *et al* 1996) have used a temperature dependence of NO_X emissions derived by Williams *et al* (1992), using land use categories as a surrogate for vegetation types.

The approach used in this study is adapted from SKM (2003a) in the Aggregated Emissions Inventory for the Pilbara Airshed and is based on the approach developed by Yienger and Levy (1995). This methodology introduces a concept described as 'pulsing'. When a very dry soil is wetted, a large burst or 'pulse' occurs and then decays rapidly over a period of time. Typically, the flux begins at 10 to 100 times the background-level and decays over a period of a few days to a few weeks, depending on the duration of the dry period and amount of rainfall. Yienger and Levy (1995) believe that the strongest impact of pulsing will be in tropical regions where there are extended dry seasons followed by wet seasons. One of the main features of the model developed by Yienger and Levy (1995) is the inclusion of separate exponential temperature dependence for wet soils and linear dependence for dry soils, and an optimal temperature above which the NO_X emission rate becomes temperature independent.

Emissions of NO_X for the study region in the Onslow region have been estimated using the empirical relationship used by Yienger and Levy (1995) as presented in **Equation 6-2**:

- **Equation 6-2**

$$E_{NOx} = f_{w/d}\text{ (soil temperature, } A_{w/d}) \times P \text{ (precipitation)}$$

Where:

- $f_{w/d}$ is a function with the subscript w/d representing the soil moisture state, either dry or wet
- $A_{w/d}$ is a coefficient used to distinguish between different landscapes
- P is a function of the magnitude and duration of the precipitation, and is a scalar factor which varies between 1 and 15.

A soil is considered dry in the sense that it will pulse when wetted. A dry soil is classified as having received less than 10 mm of precipitation in the previous two weeks.

The function f_w (w, when the soil is wet) is described by three soil temperature intervals: cold-linear (0 to 10 °C), exponential (>10 to 30 °C), and optimal (>30 °C).

- **Equation 6-3**

$$f_w = \begin{cases} 0.28A_wT & 0 < T < 10 \\ A_we^{0.103T} & 10 < T < 30 \\ 21.97A_w & T > 30 \end{cases}$$

Where:

- f_w is measured in kg/km^2/hr
- A_w is estimated at 1.296 x 10^{-3} kg/km^2/hr (the average of 13 grassland/savannah landscapes)
- T is the soil temperature in °C.

Soil temperature (T °C) is approximated by air temperature (T_A°C) after Williams et al (1992) by:

- **Equation 6-4**

$$T = 0.66T_A + 8.8$$

In dry soils, two temperature regimes are defined: cold-linear (0-30°C) and optimal (>30°C):

- **Equation 6-5**

$$f_d = \begin{cases} \dfrac{A_d T}{30} & 0 < T < 30 \\ A_d & T > 30 \end{cases}$$

with A_d estimated at 9.54 x 10^{-3}.

Estimates of P are determined from the rainfall rate and determine the magnitude and duration of the NO_X pulse.

- **Table 6-5 NO_X emission as a function of rainfall**

Rain Rate (mm/day)	Pulse Description	Function
< 1.0	No pulse (assume evaporation)	P = 1.0
1.0 to 5.0	‘sprinkle’, a 3-day pulse with exponential decay starting x5	$P = 11.19e^{-0.805t}$ (1<t<3)
5.0 to 15	‘shower’, 1-week pulse with exponential decay starting x10	$P = 14.68e^{-0.384t}$ (1<t<7)
> 15	‘heavy rain’, 2-week pulse with exponential decay starting x15	$P = 18.46e^{-0.208t}$ (1<t<14)

For water bodies, Yienger and Levy (1995) provide no methodology as they were concerned with estimating a global biogenic inventory. For the purposes of this study, NO_X emissions from water bodies due to nitrite photolysis were calculated using **Equation 6-6**, as used by the Victorian trial (EPAV 1996), the Kalgoorlie Mining NPI Trial (Coffey 1999) and the MAQS study (Carnovale *et al* 1996).

- **Equation 6-6**

$$E_{NOx} = 0.002[10^{(0.049TA - 0.83)}]$$

Where:

- TA is the ambient air temperature.

6.2.2.2. Emission Estimation

Emissions of NO_X for the study region were estimated using the following methodologies:

- Emissions of NO_X over land were estimated using daily rainfall and average daily temperatures from the BoM station at Onslow Airport. These were calculated using the methodology outlined in **Section 6.2.2.1**.
- NO_X emissions over water were estimated using the hourly temperature from the BoM station at Onslow airport and **Equation 6-6**. Hourly temperatures were used as, according to Williams *et al* (1992), water bodies only emit NO_X during daylight hours. For the purpose of this study daylight was taken as being from 6am to 6pm for the entire year.

The calculated emission rates of NO_X for water and land are presented in **Table 6-6**.

- **Table 6-6 Average NO_X emission rates for each region**

Source	Area (km^2)	Total Emission Rate (t/yr)	Average Emission Rate ($kg/km^2/yr$)
Land	4 860	379	78
Water	5 140	195	38
Total	10 000	574	57

6.2.2.3. Comparison to Other Studies

A comparison of the estimated biogenic NO_X emission rates from this study are compared to estimates from other studies within Australia in **Table 6-7**. From this table it is apparent that the calculated biogenic NO_X emissions for the Onslow region are lower than those calculated during the previous Pilbara study (SKM 2003a). This is due to a number of factors including:

- the low rainfall within the Onslow region during 2007
- the high percentage of the study area occurring over water.

Table 6-7 Comparison to other studies

Region	NO_X (kg/km^2/yr)
Onslow	57
Pilbara[1]	112
Dandenong[1]	190
Port Pirie[1]	491
Newcastle[1]	135
Launceston[1]	122
Kalgoorlie[1]	304
Bunbury[1]	609

Source: [1] SKM (2003a)

6.3. Background Particulate (PM_{10}) Concentrations

The semi-arid landscape of the Pilbara is a naturally dusty environment with wind-blown dust being a significant contributor to ambient dust levels within the region. This was highlighted by the aggregated emission study that was conducted by SKM in 2000 (SKM 2003a). This study found that the Pilbara region emitted around 170,000 tonnes of windblown particulate matter in the 1998/1999 financial year. Additional research has also shown that background-levels of dust in the Pilbara region often exceed the NEPM PM_{10} standard of 50 µg/m^3 (CSIRO 2006).

The nearest particulate monitors (TSP, PM_{10} or $PM_{2.5}$) to Onslow, with publically available data, is the Pilbara Iron particulate monitoring network located 210 km to the north east in the Dampier / Karratha region, followed by the Pilbara Iron particulate monitors around Point Samson which is 240 km to the north east. Analysis of the PM_{10} concentrations at the Dampier Primary School indicates that from 2002 to 2006 the annual average was 22.9 µg/m^3 while the monitoring station at Karratha during this same period recorded an annual average of 21.4 µg/m^3 (excluding a high PM_{10} annual average in 2003). The PM_{10} monitoring station at Point Samson recorded an annual average of 21.8 µg/m^3 for the period 2003 – 2006 (SKM 2007).

Based on the above monitoring data this assessment has used a constant PM_{10} background concentration of 22 µg/m^3 for the air quality assessment. Note that Chevron is currently undertaking sampling for ambient particulate concentrations but at the time of writing a full year of data was not available.

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7. Air Quality Model

The following sections describe the meteorological and air dispersion model employed for this project and the modelling methodology. All modelling described in this report has been conducted in accordance with the Air Quality and Air Pollution Modelling Guidance Notes (DOE, 2006).

7.1. Model Selection

For pollutants released in near-coastal environments, the following four dispersion processes are considered important:

1) dispersion under convective conditions when the buoyant plumes can be mixed to ground-level within a short distance of the stacks
2) the influence of the sea breeze with the creation of the Thermal Internal Boundary Layer (TIBL) where onshore winds can lead to complex vertical dispersion
3) the influence of the buildings and structures around facilities that may lead to increased dispersion and reduced plume rise from the stacks
4) the presence of terrain features like hills and ridges in the surrounding area that can impact on dispersion and be subject to elevated concentrations.

Two models accepted for use by the regulator in similar situations in Australia are available to assess all four processes: TAPM and CALPUFF.

CALPUFF (the Californian puff model) is a Lagrangian dispersion model that simulates pollutant releases as a series of continuous releases of puffs. It is the preferred model of the United States Environmental Protection Agency (US EPA) for the long-range transport of pollutants and for complex terrain (TRC 2007). The model differs from traditional Gaussian plume models in that it can model spatially varying wind and turbulence fields that are important in complex terrain, long-range transport and near calm conditions. CALPUFF has the ability to model the effect of the TIBL both through fumigation and plume trapping.

TAPM is a prognostic three-dimensional model designed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) that can be used to predict meteorological and air pollution parameters on an hourly basis (Physick and Blockley 2001). The model predicts flows that are of importance to local-scale air pollution such as sea breezes and terrain induced flows (Hurley 2005). The meteorological parameters predicted by the model have been compared to actual readings recorded during the Kwinana Coastal Fumigation study (Hurley and Luhar 2000) and the Pilbara Air Quality Study (Physick and Blockley 2001). It was found that the model predicts both near-surface parameters and upper parameters well.

For this assessment the CSIRO model TAPM was utilised, primarily due to its usage in previous assessments for gas processing facilities in the region (Hurley, P *et al* 2003a, SKM 2003b, SKM 2005, SKM 2008b, SKM 2009). TAPM was also chosen due to the lack of available meteorological data (particularly upper air data) for the Onslow region.

7.2. Model Setup

The TAPM (ver4) modelling package consists of a model and databases of synoptic meteorology, terrain and land use categories for the Australasian region. For this assessment TAPM was configured as follows:

- Standard four grid domains (30 km, 10 km, 3 km and 1 km) with 31 by 31 cells per domain. The four grid domains are presented from **Figure 7-1** to **Figure 7-4**.
- All grids were centred at 114°59.5'E and 21°42.5'S, which correspond to 292 000E and 7 598 000N in the local grid.
- The TAPM land/sea database was derived from the 9" Digital Elevation Model (DEM) data (Geoscience Australia 2002) and was modified using the 1:100 000 topographical maps for the region (RASC 1974). This involved incorporating the Onslow region into the lower two grid domains within TAPM (3 km and 1 km) and assigning the appropriate soil and vegetation cover.
- Standard 25 vertical levels from 10 m to 8 000 m in height.
- The default sea surface and deep soil temperatures were used. Default sea surface temperatures were checked against the recorded sea surface temperatures from the BoM (2009b). Examples of the sea surface temperatures for January and June are available in **Figure 7-5** and **Figure 7-6** respectively.
- Meteorological runs from 30 December 2006 to 31 December 2007, with the output only after 1 January 2007 being used in the assessment. The 2007 year was chosen for modelling as an analysis of the wind speed (**Figure 7-7**) and direction (**Figure 7-8**) from 1998 to 2008 indicates that 2007 represents a 'typical' year.

The TAPM run-time output file summarising model configuration for the Jan-March run is presented in **Appendix C**.

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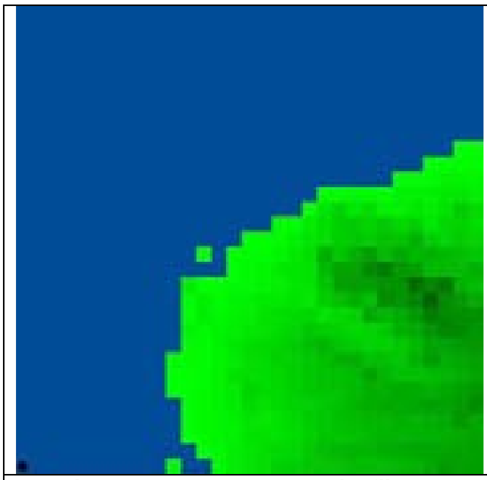
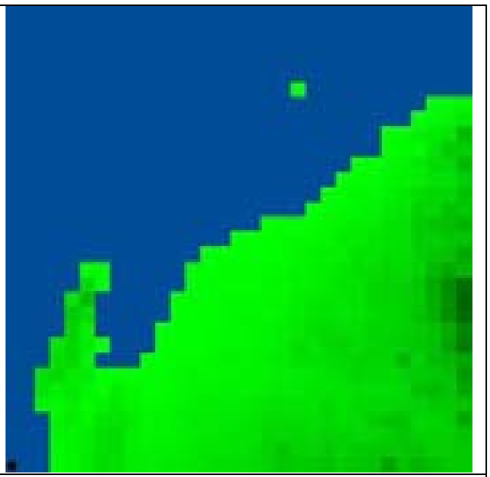
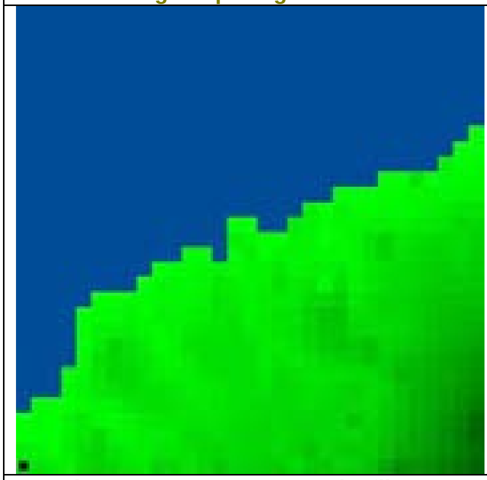


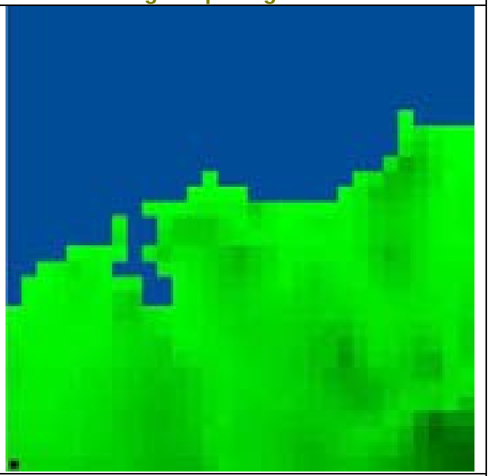
- **Figure 7-1 TAPM topography file at 30 000m grid spacing**



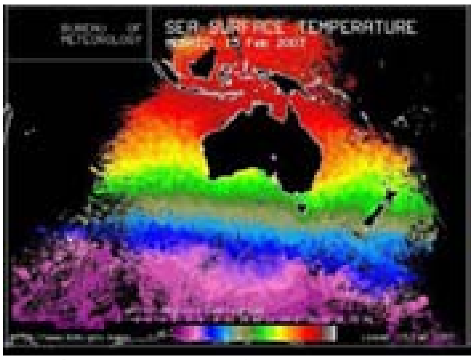
- **Figure 7-2 TAPM topography file at 10 000m grid spacing**



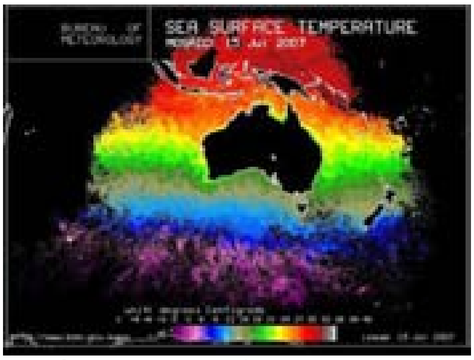
- **Figure 7-3 TAPM topography file at 3 000m grid spacing**



- **Figure 7-4 TAPM topography file at 1 000m grid spacing**



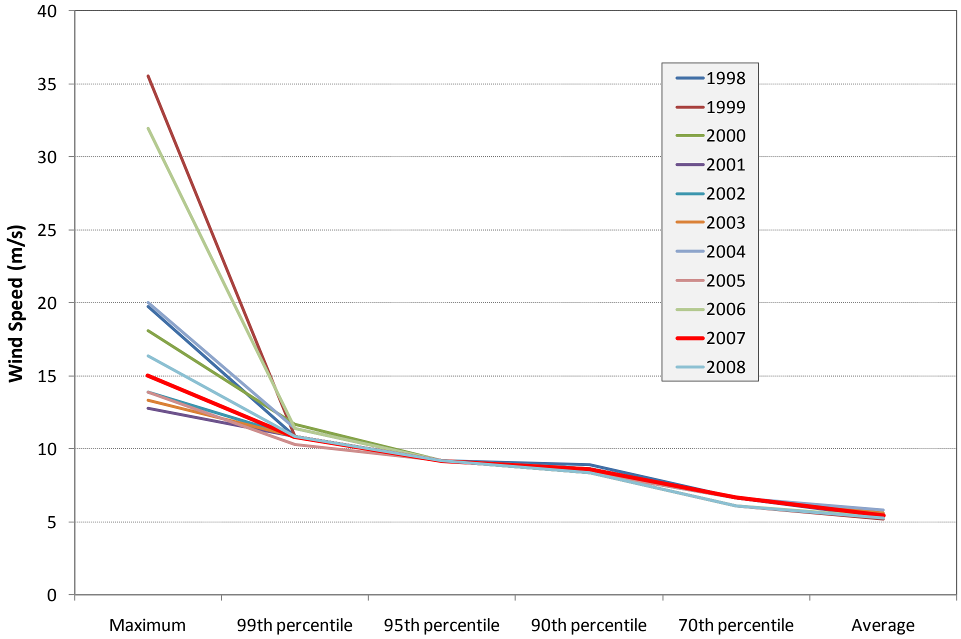
- **Figure 7-5 Sea surface temperature 15/2/2007 (BoM 2009b)**



- **Figure 7-6 Sea surface temperature 15/7/2007 (BoM 2009b)**

For atmospheric modelling of pollutants the following parameters were used:

- regional gridded emission sources (*.gse)
- atmospheric chemistry modelling mode with APM (Airborne Particulate Matter, PM_{10}), NO_X, NO_2, O_3, SO_2 and FPM (Fine Particulate Matter, $PM_{2.5}$)
- background ozone level – 20 ppb (from stratospheric ozone entrainment and global recirculation)
- background Rsmog – 0.2 g/s (Rsmog is the efficiency factor of VOCs to generate smog (refer to Hurley 2005))
- background FPM ($PM_{2.5}$) – 5 µg/m^3 (estimate for clean air)
- pollution grid (inner) – 49 x 49 cells (omitting boundary to reduce 'edge effects'), with resolution of 500 m.



- **Figure 7-7 Analysis of the wind speed at the Onslow airport from 1998 - 2008**

Note: the high wind speeds during 1999 and 2000 are a result of cyclones (Tropical Cyclone Vance in 1999 and Tropical Cyclone Steve in 2000)

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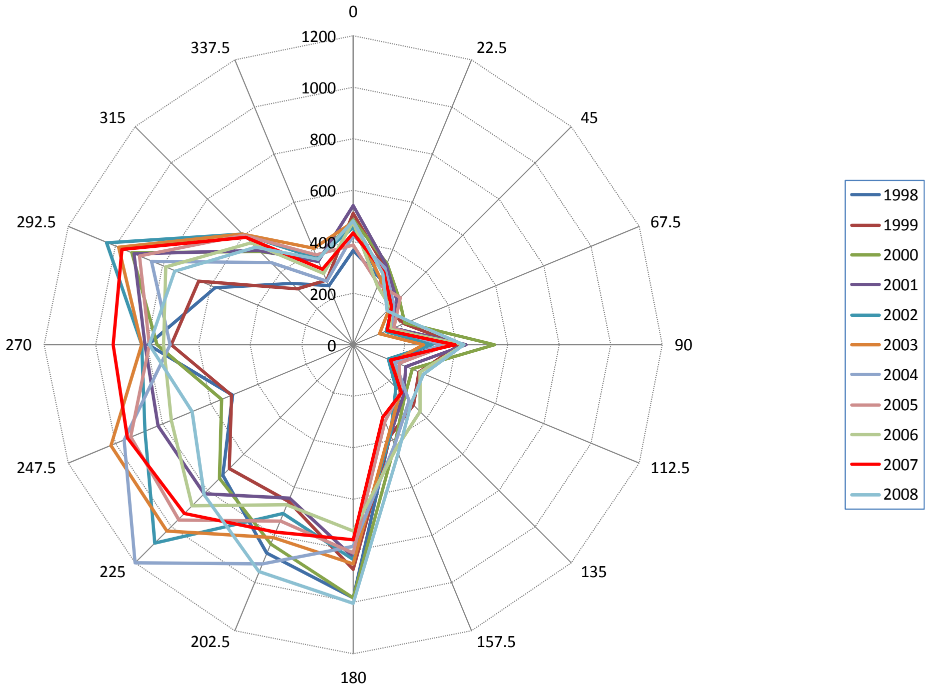
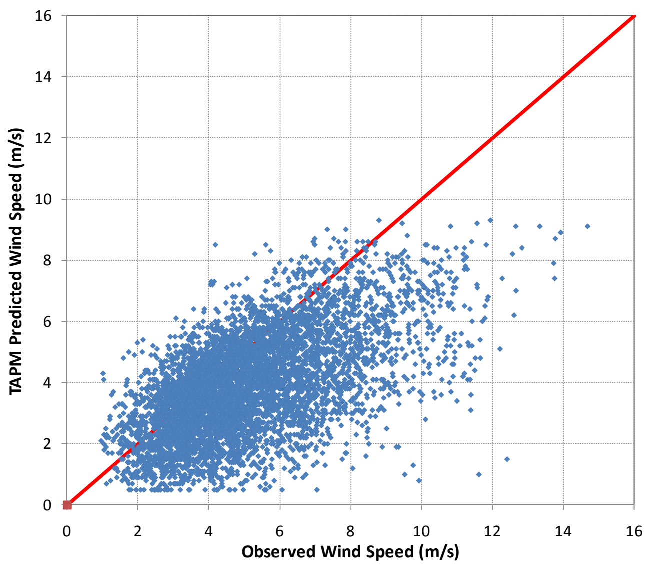


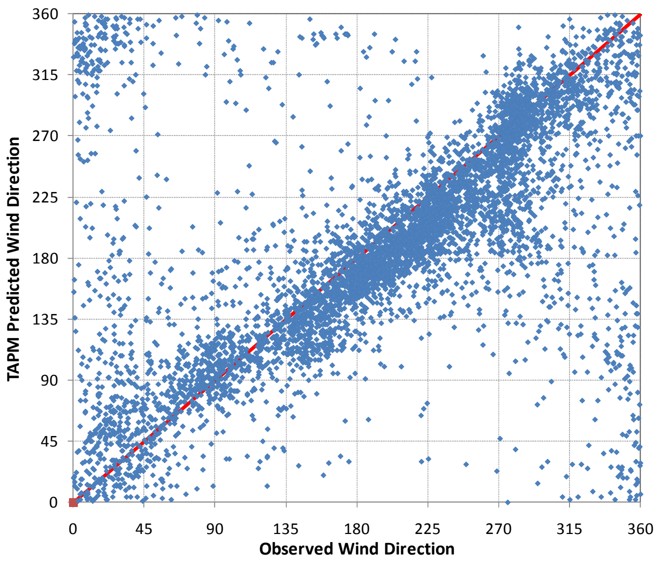
- **Figure 7-8 Analysis of the wind direction at the Onslow airport from 1998 - 2008**

7.3. Comparison of TAPM Predictions to Observations

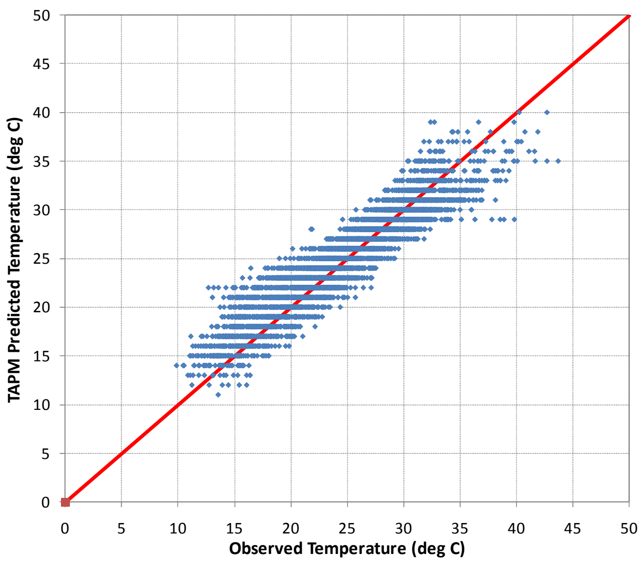
A comparison of the TAPM predicted wind speed to observed wind speed is presented in **Figure 7-9**, while the comparison with the wind direction is presented in **Figure 7-10** and temperature is displayed in **Figure 7-11**. From these figures it is evident that TAPM has a tendency to under predict the high wind speeds that were observed at the Onslow Pier though the wind direction and temperature were generally well predicted.



■ **Figure 7-9 Predicted to observed wind speed at Onslow Pier (2007)**



■ **Figure 7-10 Predicted to observed wind direction at Onslow Pier (2007)**



■ **Figure 7-11 Predicted to observed temperature at Onslow Pier (2007)**

8. Emission Parameters

This section of the report describes the future air pollutant emission sources from the proposed Chevron gas processing and LNG operations at Onslow.

8.1. Overview

Atmospheric emissions from the proposed Wheatstone Project will vary depending on the operation of the plant and tanker loading conditions. These include normal plant operations, shiploading and non-routine operations such as plant start-up, plant shutdown emergency shutdown and LNG carrier cool-down. It is expected, however, that normal conditions will predominate, occurring in excess of 90% of the time. For 30% of this time, plant operations will be accompanied by the loading of product onto LNG tankers. It is anticipated that the level of production may be reduced due to maintenance or operational limitations for four to five days per year, with another 22 days where the plant is shut down for maintenance. Emergency operations may occur for up to ten times during the first year of operation reducing to potentially two or less during a typical operating year. A shutdown will normally result in less than one hour of peak flaring, while start-up will be of approximately six hours duration.

The most significant air pollution emissions from the Wheatstone Project will be from the combustion of fuel gas in the gas turbines and from flaring. The main products of combustion of fuel gas in gas turbines in terms of quantities produced are CO and NO_X. However, the key air pollutants in terms of risk are NO_2 and the subsequent formation of O_3, and PM_{10}.

Small quantities (trace amounts) of other pollutants such as VOCs may also be emitted. BTEX pollutants are among a wide variety of VOCs that typically exist in relatively low concentrations in ambient air. Emissions of BTEX represent a very small percentage of the compounds emitted from the combustion of fossil fuels. A review of Hurley *et al* (2003a and 2003b) regarding atmospheric dispersion modelling of existing and proposed emissions on the Burrup Peninsula indicates that the emission of VOCs is unlikely to cause significant air quality impacts. This was confirmed during the Burrup Peninsula Air Pollution Study (CSIRO 2006) where field monitoring determined that there was little enhancement of benzene adjacent to industrial areas when compared with the background monitoring sites. These findings were also applicable to the other BTEX pollutants including xylene (CSIRO 2006). These findings can be expected to be representative of the Onslow region, where there is currently minimal existing infrastructure contributing to air pollutants. A discussion of the potential cumulative impacts is presented in **Section 8.5.**

For these reasons potential fugitive emission of the BTEX group of compounds from the Wheatstone Project is not considered to be a significant future air pollutant, and thus has not been considered in the future modelling scenarios. It should be noted that point source emissions of VOCs are included in the model as the photochemical precursors (Rsmog).

8.2. Area-based Emission File

An area-based emission file for TAPM was compiled to account for existing diffuse emissions in the Onslow region. The diffuse emissions that could potentially impact on the air quality of the region include:

- NO_X
- VOCs.

These emissions would be derived primarily from biogenic emissions in the region. This section outlines how the diffuse emissions were calculated and incorporated into an area-based emission file for modelling purposes.

Emissions from anthropogenic sources such as motor vehicles and commercial shipping are expected to be negligible given the current low population of Onslow (approximately 573 people (ABS 2006)). Based on this, emissions from these sources were not included in the area emission file.

8.2.1. Biogenic VOC

The methodology to calculate biogenic VOCs is outlined in **Section 6.2.1**. To convert these emission estimates, a smog reactivity (Rsmog) constant of 0.0067 was used as per the recommendation by Hurley (2005) and Physick and Blockley (2001).

8.2.2. Biogenic NO_x

The methodology to calculate biogenic NO_X is addressed in detail in the background air quality assessment (**Section 6.2.2**).

8.3. Normal Operating Condition

Chevron proposes to build a gas processing and LNG facility at Onslow, comprising five LNG trains: two 4.3 MTPA trains and three 5.47 MTPA trains, along with up to 4 Domgas trains. Key characteristics for the 5 LNG trains used for this air quality assessment include:

- power generation:
  - 9 x LM6000 gas turbines with dry low emission (DLE) burners
- gas compressors:
  - 33 x LM6000 gas turbines with DLE burners
- dry and wet gas flare
- marine flare.

The emission rate for the gas turbines was obtained from Bechtel (via email from Chevron to SKM 12/1/2010). The stack parameters for all stacks, including the flares, were also obtained from Bechtel.

The emission rate from the flares was estimated using the emission factors for flare operations listed in the AP-42 (USEPA 1991), together with the following assumptions:

- a flaring rate during normal operations of 0.15% of the total throughput (25 MTPA) (Heede 2006)
- a flaring rate during shiploading operations of 0.20% of the total throughput (25 MTPA) (Heede 2006)
- during an emergency shutdown it was assumed that the entire inventory for one train was flared (491 tonnes).

The stack parameters for flares (dry, wet and marine) were based on the parameters outlined by the Texas Commission on Environmental Quality (TCEQ 2004):

- stack exit velocity of 20 m/s
- stack exit temperature of 1 273 K
- variable stack diameter based on the estimated net heat release (cal/s).

Emissions characteristics for normal routine operations are summarised in **Appendix D.1** and the emission characteristics for shiploading operations are summarised in **Appendix D.2**.

8.3.1. Benzene, Toluene and Xylene

The calculated emission rates of benzene, toluene and xylene was obtained from Bechtel (via email from Chevron to SKM 26/1/2010) and are summarised in **Appendix D.3**.

8.4. Upset Conditions

8.4.1. Overview

Non-routine plant operations include start-up and shutdown. Plant de-inventory may also occur during an emergency event. A non-routine operation may last from several hours to days, with the plant operating under reduced throughput conditions, which could include the flaring of gas. The plant throughput can vary from 15% to 50% depending on the stage of the start-up/shutdown process in place.

In upset condition scenarios, the flares can become a more significant source of air emissions than the gas turbines. For example, all the gas turbines on a single LNG train could be shut down while the flares are operating to full capacity. This would, however, only occur for a very limited time.

Two upset conditions scenarios have been identified for the purposes of this assessment, representing reasonable worst cases. These are associated with the start-up of a single train and the emergency shutdown of one gas train. The following sub-sections detail the emissions characteristics for these scenarios.

8.4.2. Upset Condition 1: Start-up

It is expected that the gas processing plant will be shut down for sufficient time to require a cold start at least once a year. A cold re-start is expected to take approximately six hours, during which time approximately 30% of the normal flow rate of a single LNG train may be directed to the flare as the LNG is brought to product specification.

Emissions characteristics for the first upset condition are summarised in **Appendix D.4**.

8.4.3. Upset Condition 2: Process Emergency Shutdown

The second upset condition scenario is based on a process emergency shutdown. Shutdowns of the gas processing facility will occur for different reasons. They will be required for planned maintenance programs, in which case there will be the opportunity to minimise emissions by reducing the amount of gas directed to the flare system. Alternatively, there could be an unplanned shutdown of one train requiring some flaring. It is anticipated that such circumstances will occur less than ten times in the first year of operation and be of less than one hour peak flaring reducing to six events per year over the next five years.

Emissions characteristics for the second upset condition are summarised in **Appendix D.5**.

8.5. Cumulative Modelling

The location for the proposed Chevron Wheatstone gas processing facility is in the Ashburton North Strategic Industrial Area (SIA). This area is currently being considered as a potential 'processing hub' and as such, there is the potential for an additional gas processing train (operated by Exxon Mobil) with a potential to process approximately 6 MTPA of LNG each year (as originally referred in 2004) and a Domgas plant (operated by BHP Billiton). Both of these proposed facilities would be located immediately to the south of the proposed Chevron facility (refer to **Figure 8-1** for location plan)**.**

The potential emissions from the proposed Exxon Mobil facility have been taken as similar to that of the fifth train at the proposed Wheatstone facility as data on the proposed trains are not currently available. The potential emissions from the BHP Billiton Domgas facility were assumed to be similar to that used in the air quality assessment of the proposed Apache Energy Domgas facility at Devil Creek (SKM 2008a). The emission characteristics for these two additional facilities are summarised in **Appendix D.6**.

It is important to note that this modelling is only conducted to provide an indication of the potential ground-level concentrations of pollutants with these additional gas processing facilities. Further dispersion modelling will have to be conducted by the proponent(s) of these facilities with more detailed emission characteristics as the design of the proposed plant is not yet known.

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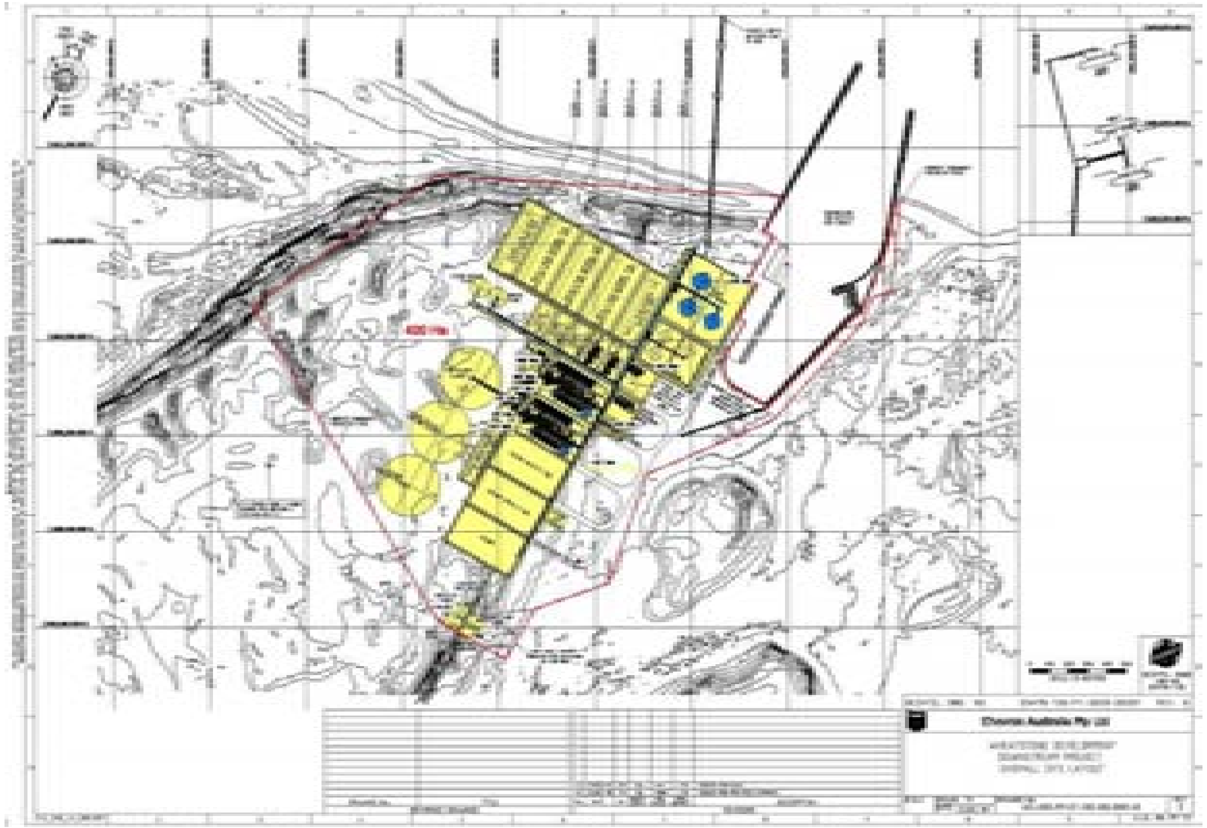

- **Figure 8-1 Potential location of additional gas processing facilities**

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9. Modelling Results

This section presents the results of atmospheric dispersion modelling for the proposed plant under a series of scenarios including:

- the existing air quality (i.e. existing contribution from non-industrial activities and existing industries)
- normal operating conditions (with and without shiploading)
- plant start-up
- emergency shutdown of a single train and
- the cumulative impacts of the Chevron Wheatstone Project and additional gas processing facilities in the proposed Ashburton North Industrial Area..

All modelling results are compared to the relevant assessment criteria discussed in **Section 4**.

As discussed in **Section 3.2**, approximately 90% of NO_X is from NO_2. Thus for simplicity only NO_2 is presented in the modelling results below but the full NO_X component has been used in the modelling. The maximum pollutant concentrations have been compared to the NEPM criteria which are listed in **Table 4-3**.

Note that the town of Onslow is shown on the model results figures and that this location is indicative only; that is, concentrations reported by the model and report text may not align exactly with the isopleths on the figures.

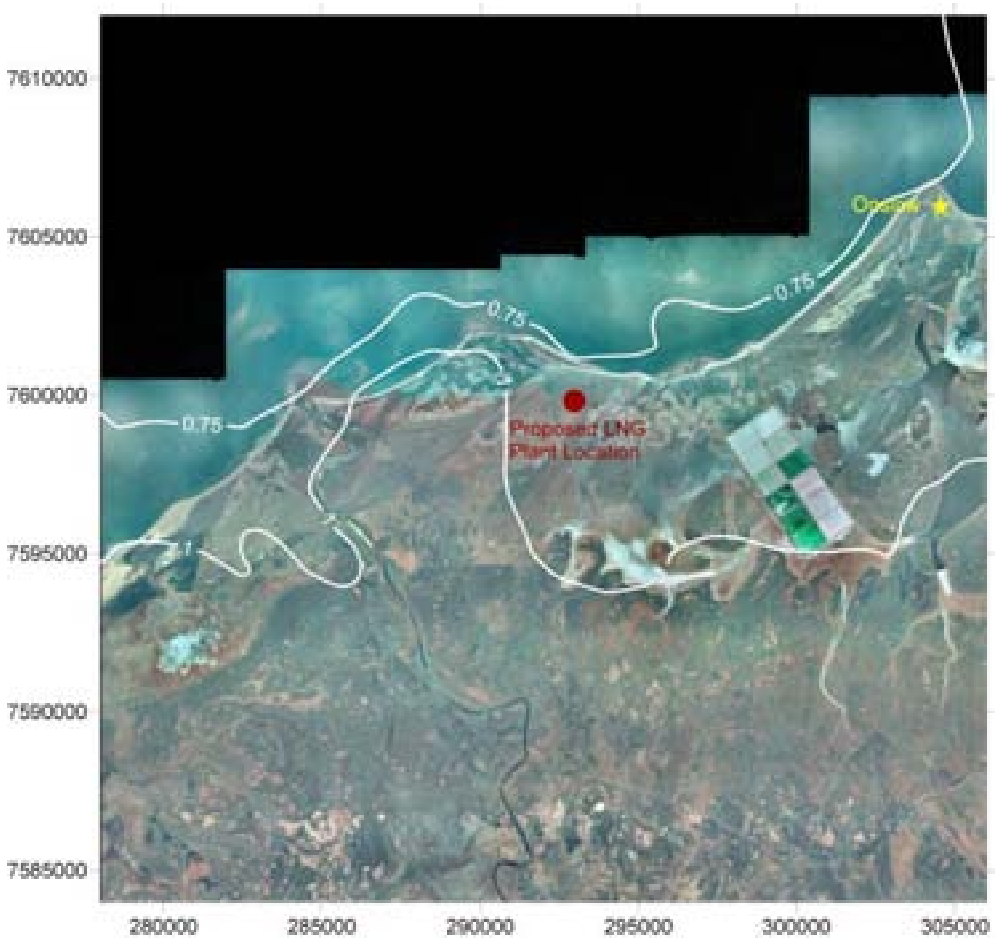
9.1. Existing (Non-industrial) Air Quality Case

The modelling results for the existing (non-industrial) air quality in the Onslow region are presented and discussed in the following sections. The emissions used to model this scenario include:

- BVOC from vegetation (**Section 6.2.1**)
- biogenic NO_X from soil and water (**Section 6.2.2**).

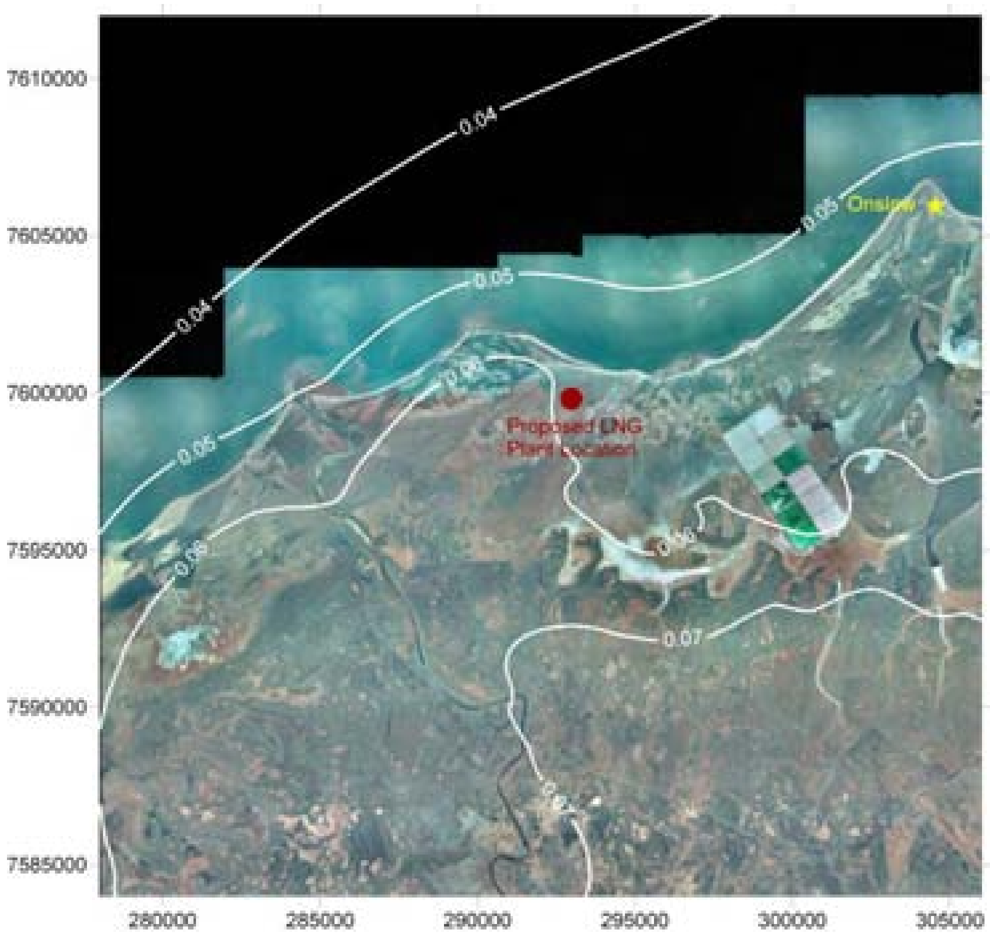
9.1.1. Oxides of Nitrogen (as NO_2)

The maximum predicted 1-hour ground-level concentrations of NO_2 from existing (non-industrial) sources are presented in **Figure 9-1**. This figure shows that the 1-hour predicted ground-level concentrations of NO_2 are relatively low. As shown in **Table 9-1**, the predicted 1-hour maximum concentration of NO_2 is 1.2 ppb. This is 1% of the NEPM criteria, indicating a relatively low concentration of NO_2 in the study area.



▪ **Figure 9-1 Existing (non-industrial) sources - maximum 1-hour NO_2 concentrations (ppb)**

The predicted annual concentration of NO_X for existing (non-industrial) scenario is presented in **Figure 9-2**. This figure shows that the annual average concentrations of NO_2 are relatively low. As summarised in **Table 9-1**, the predicted annual maximum concentration of NO_2 is 0.1 ppb, which is 0.3% of the NEPM criteria.



▪ **Figure 9-2 Existing (non-industrial) sources - annual NO_2 concentrations (ppb)**

9.1.2. SO_2

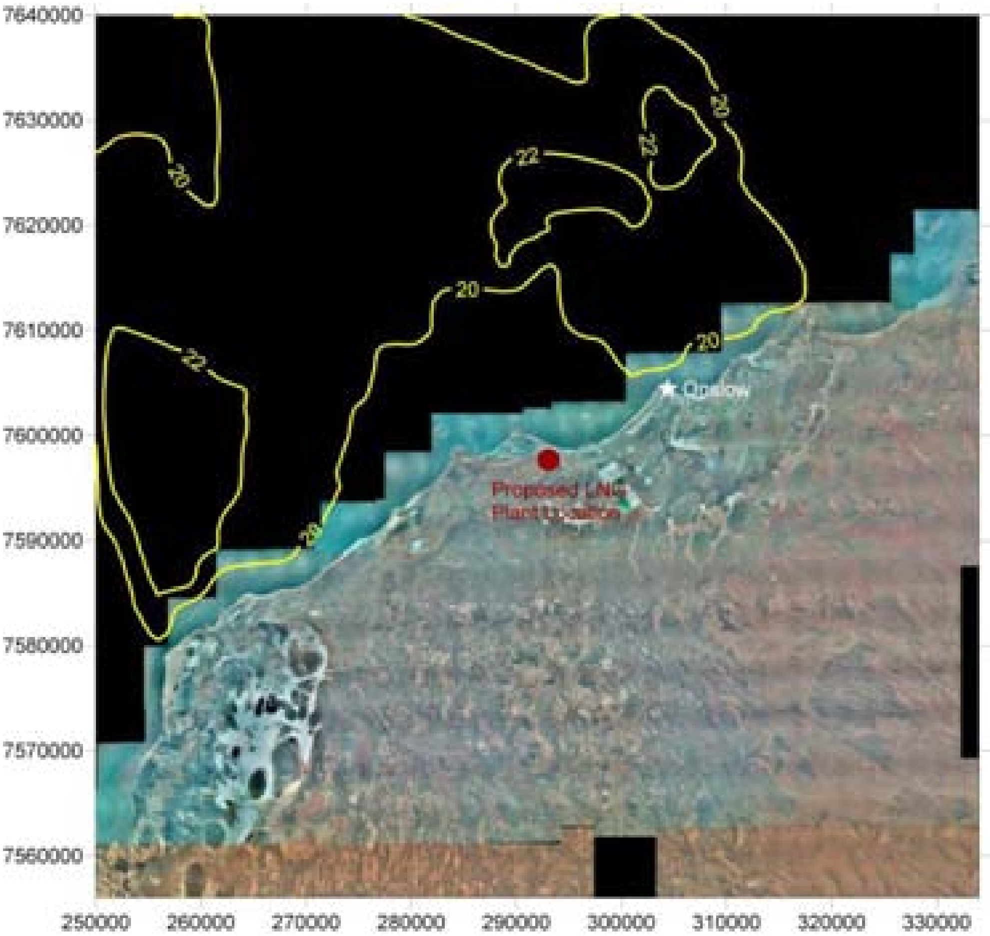
Existing SO_2 emissions have been assumed to be negligible (given the lack of significant existing sources) and have not been reported on.

9.1.3. PM_{10}

Existing PM_{10} emissions within the region are derived primarily from open area erosion and bushfires. These particulate emissions have been excluded from this report due to the complexities of modelling short term events that vary spatially.

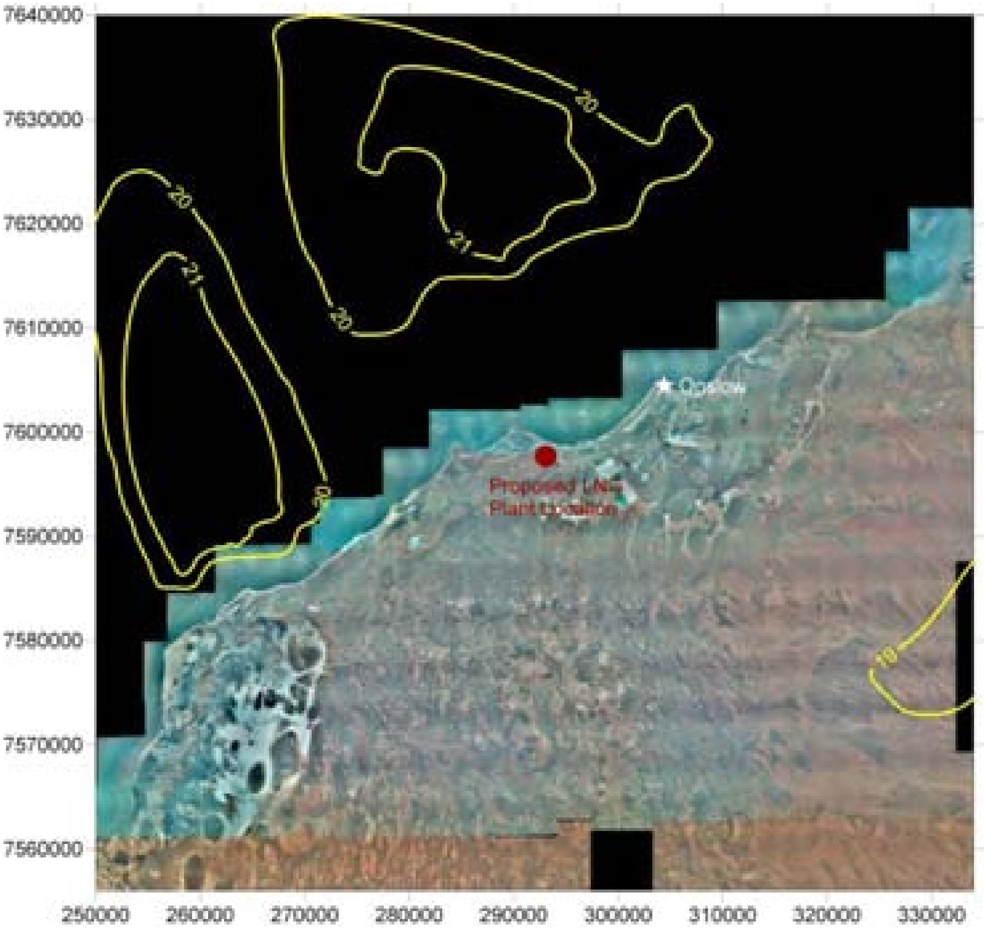
9.1.4. Ozone

The maximum predicted 1-hour ground-level O_3 concentrations for the existing (non-industrial) case are presented in **Figure 9-3.** From this figure it can be seen that the maximum concentrations occur offshore to the north and to the west of Onslow. The maximum predicted 1-hour ground-level concentration for this scenario is 23.8 ppb, which is 23.8% of the NEPM criteria.



- **Figure 9-3 Existing (non-industrial) sources - maximum 1-hour O_3 concentrations (ppb)**

The predicted 4-hour ground-level ozone concentrations are presented in **Figure 9-4**. Maximum concentrations are located in a similar area to those of the 1-hourly ozone concentrations (**Figure 9-3**). The predicted maximum 4-hourly ground-level concentration is 21.8 ppb, which is 27.2% of the NEPM criteria.



■ **Figure 9-4 Existing (non-industrial) sources - maximum 4-hour O_3 concentrations (ppb)**

9.1.5. Maximum on Grid

The maximum predicted ground-level concentrations over various averaging times for O_3 and NO_2 are presented in **Table 9-1**. The NEPM criteria are also presented in this table. Comparison between the criteria and the maximum predicted ground-level concentrations shows that the predicted NO_2 concentrations are well below the criteria. The maximum predicted concentrations of O_3 are also well below the criteria at 23.8% and 27.2% of the applicable NEPM criteria for 1-hour and 4-hour respectively.

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- **Table 9-1 Maximum predicted existing (non-industrial) ground-level concentration on modelled grid**

Pollutant	Modelled Grid	Averaging Period	Unit	NEPM Criteria	Maximum on Grid		Percentage of Criteria	
					On Grid	Onslow	On Grid	Onslow
NO_2	1 km	1-hour	ppb	120	1.2	0.8	1.0%	0.6%
		Annual	ppb	30	0.1	0.1	0.3%	0.2%
O_3	3 km	1-hour	ppb	100	23.8	19.5	23.8%	19.5%
		4-hour	ppb	80	21.8	19.5	27.2%	24.4%

9.2. Future Air Quality – Normal Operations

The modelling for future air quality under normal operating conditions incorporates the emissions used in the existing scenario (**Section 8.2**) as well as those expected from the proposed Chevron Wheatstone gas processing facility (**Section 8.3**). The pollutants taken into consideration in this section include NO_2, SO_2, O_3 and PM_{10}. Additionally, the model results for benzene, toluene and xylene are also presented. The maximum ground-level concentration of each of these pollutants is assessed against the NEPM criteria.

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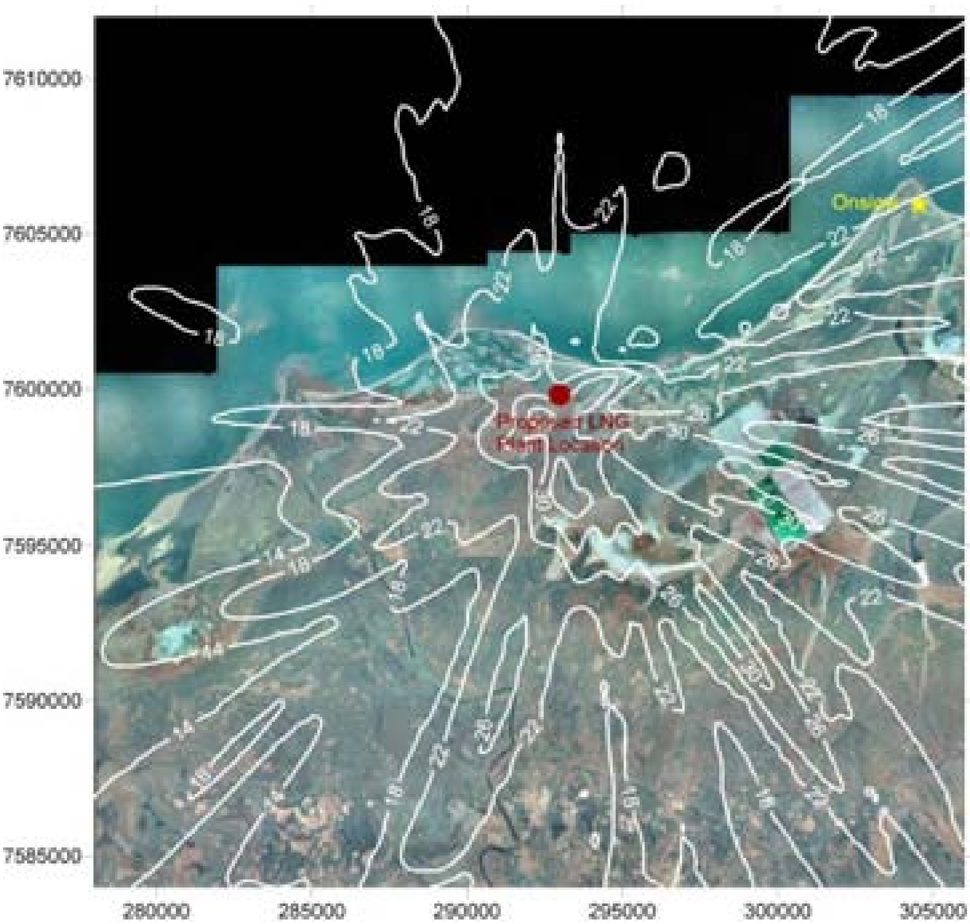
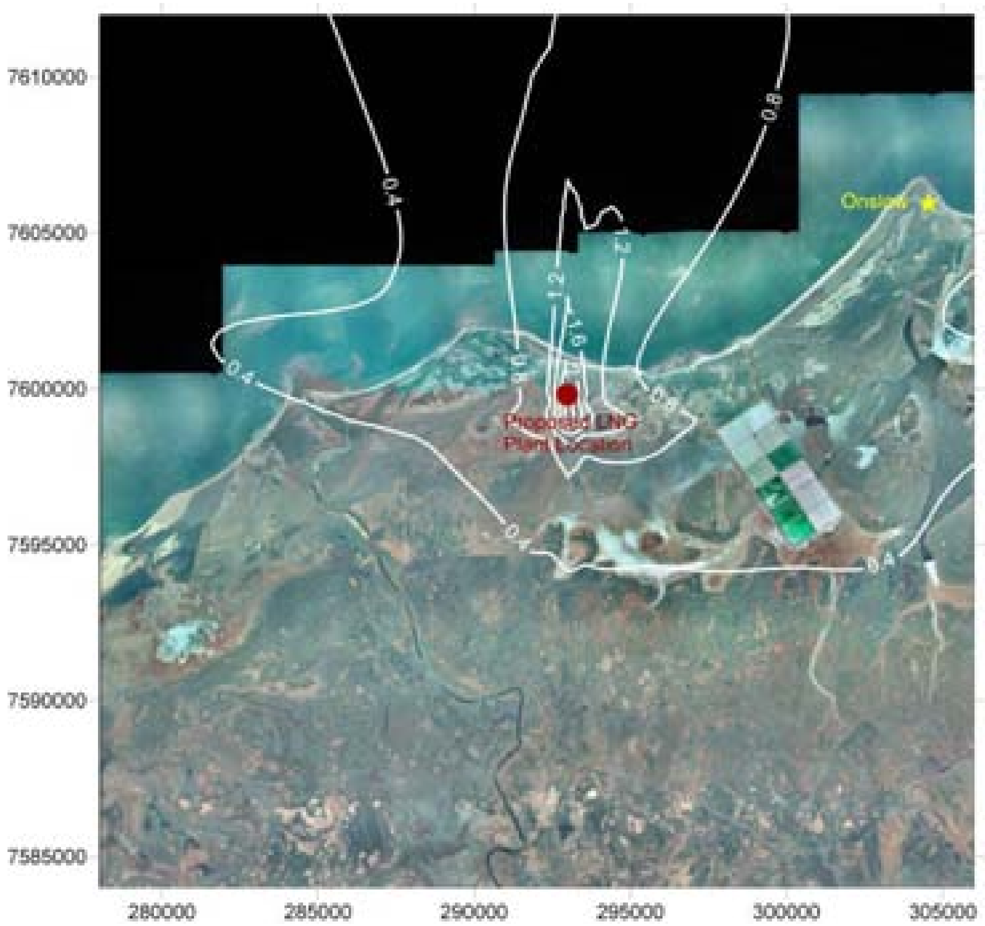
9.2.1. Oxides of Nitrogen (as NO_2)

The maximum 1-hour predicted ground-level NO_2 concentrations are presented in **Figure 9-5**. When the results presented in this figure are compared to that for the existing scenario (**Figure 9-1**), the impact of the proposed Chevron Wheatstone gas processing facility on ground-level concentrations of NO_2 is apparent. The maximum predicted ground-level concentration on the grid is 39 ppb, which represents an increase of 37.4 ppb from that predicted for the existing case (**Table 9-3**), and is 32% of the NEPM criterion (**Table 9-3**). The maximum 1-hour predicted ground-level NO_2 concentration at Onslow is predicted to increase to 24 ppb which is equivalent to 20% of the NEPM criteria.



- **Figure 9-5 Future case (normal operations) - maximum 1-hour NO_2 concentrations (ppb)**

The predicted annual average ground-level NO_2 concentrations are presented in **Figure 9-6**. When the results presented in this figure are compared to that for the existing scenario (**Figure 9-2**), the impact of the proposed Chevron Wheatstone gas processing facility on ground-level concentrations of NO_2 is apparent. The maximum predicted annual ground-level concentration has increased by 2.7 ppb from the existing scenario to 2.8 ppb, and is 9% of the NEPM criterion.



- **Figure 9-6 Future case (normal operations) - annual NO_2 concentrations (ppb)**

9.2.2. Sulfur dioxide

The maximum 1-hour predicted ground-level SO_2 concentrations are presented in **Figure 9-7**. The maximum predicted ground-level concentration on the grid is 3.5 ppb which is equivalent to 1.7% of the NEPM criterion (**Table 9-3**). The maximum 1-hour predicted ground-level SO_2 concentration at Onslow is 0.7 ppb which is equivalent to 0.3% of the NEPM criteria.

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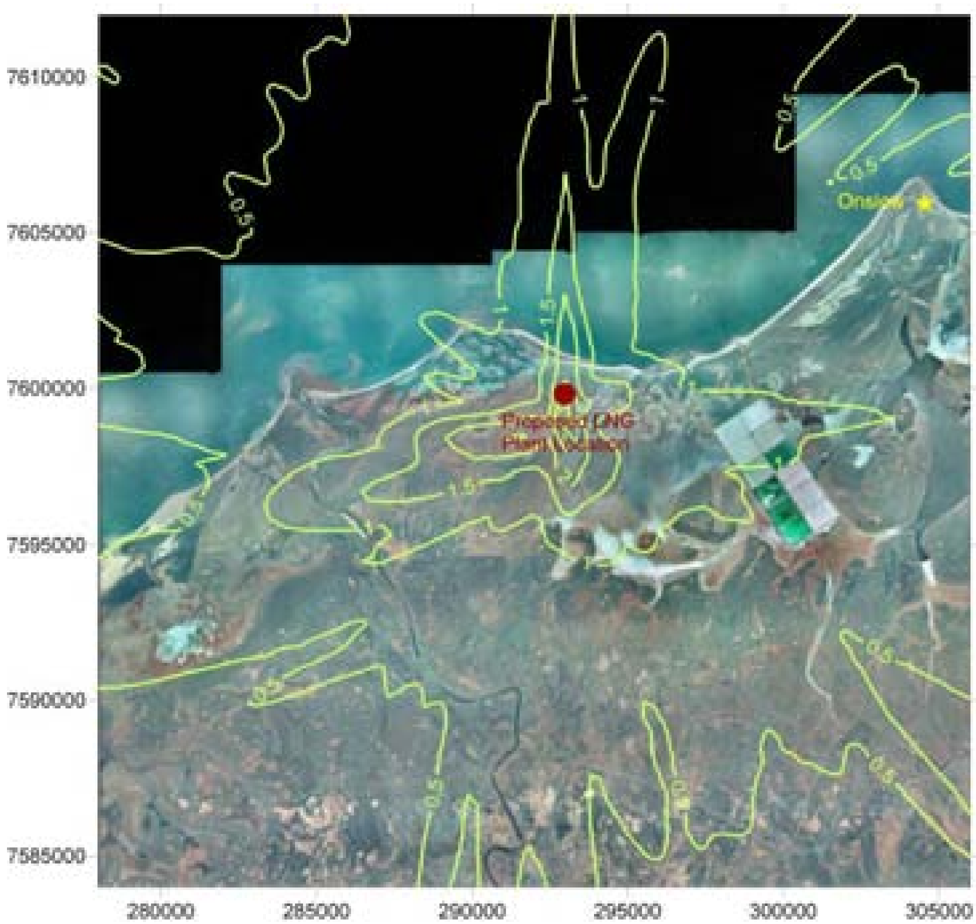
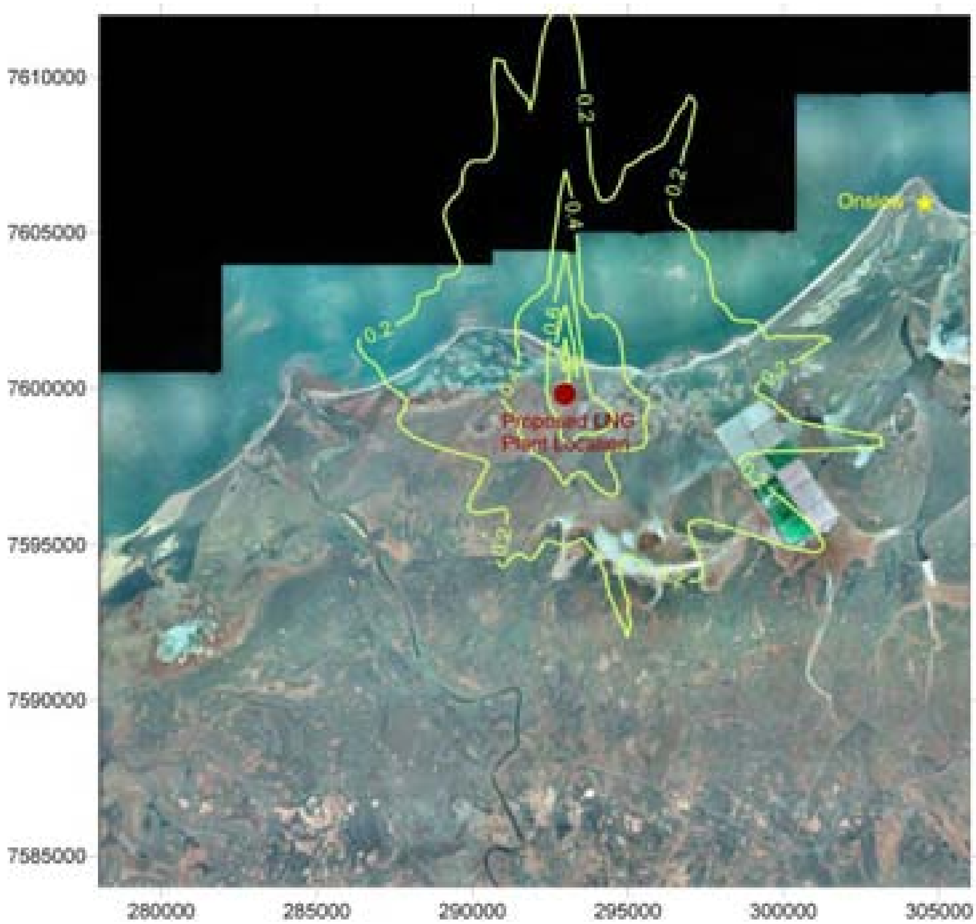


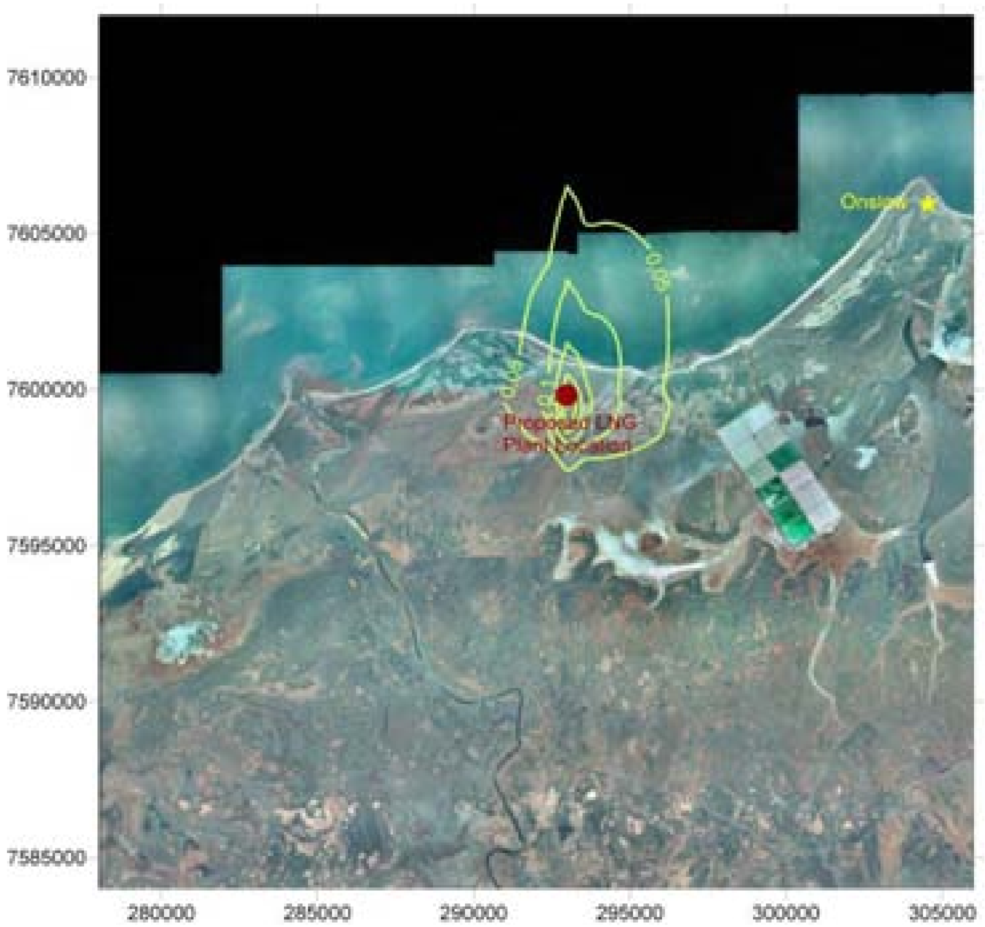
■ **Figure 9-7 Future case (normal operations) - maximum 1-hour SO_2 concentrations (ppb)**

The maximum 24-hour predicted ground-level SO_2 concentrations are presented in **Figure 9-8**. The maximum predicted ground-level concentration on the grid is 1.1 ppb which is equivalent to 1.4% of the NEPM criterion (**Table 9-3**). The maximum 24-hour predicted ground-level SO_2 concentration at Onslow is 0.1 ppb which is equivalent to 0.1% of the NEPM criteria.



- **Figure 9-8 Future case (normal operations) - maximum 24-hour SO_2 concentrations (ppb)**

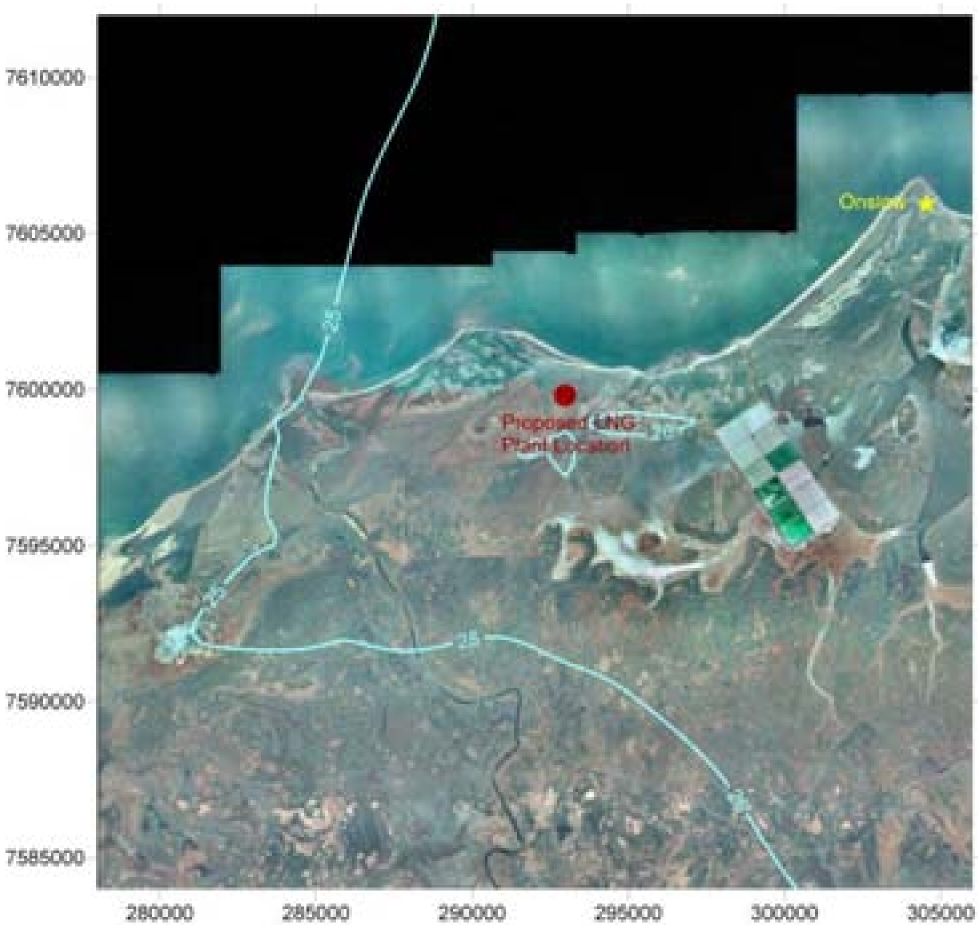
The predicted annual average ground-level SO_2 concentrations are presented in **Figure 9-9**. The maximum predicted annual ground-level concentration is 0.6 ppb which is equivalent to 2.8% of the NEPM criterion.



▪ **Figure 9-9 Future case (normal operations) - annual SO_2 concentrations (ppb)**

9.2.3. Particulates

The maximum 24-hour predicted ground-level PM_{10} concentrations during normal operations are presented in **Figure 9-10**. The maximum predicted ground-level concentration is 27 µg/m^3, which is 53% of the NEPM criteria, shown in **Table 9-3**. The maximum predicted ground-level concentration at Onslow is 25 µg/m^3 which is 50% of the NEPM criteria. These concentrations include a constant background concentration of 22 µg/m^3 as discussed in **Section 6.3**.

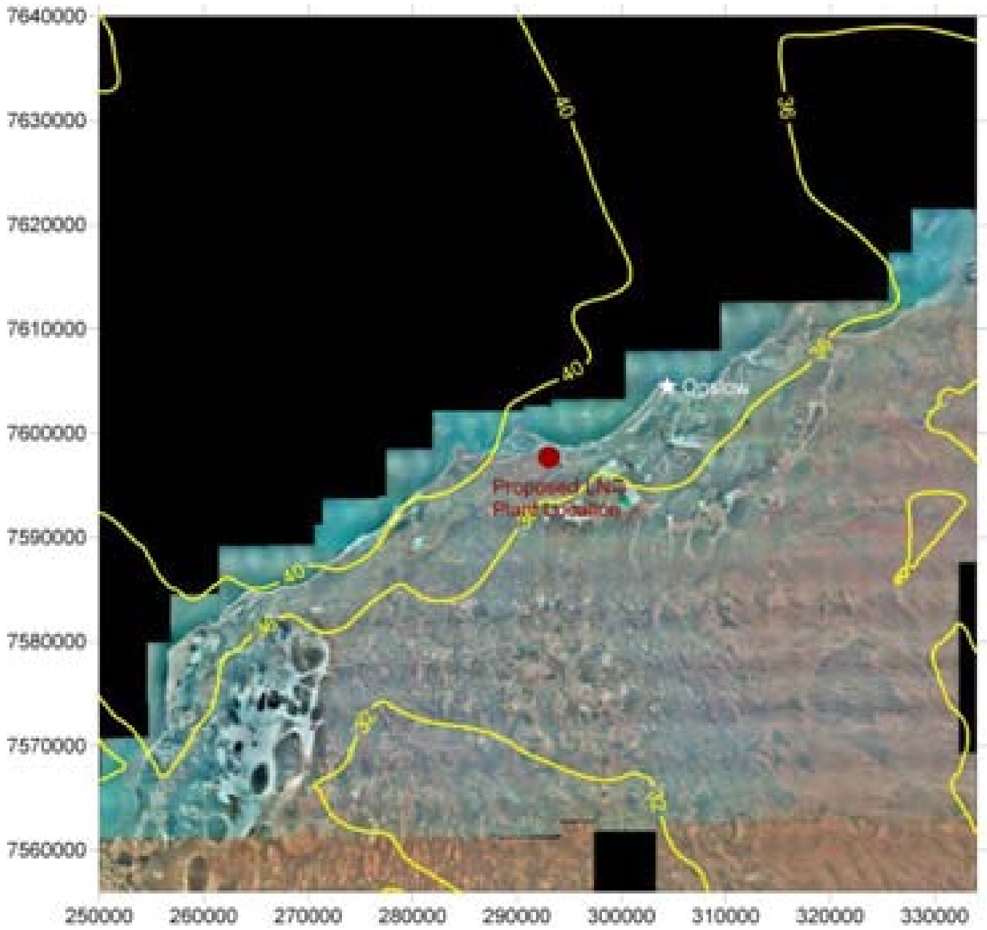


▪ **Figure 9-10 Future case (normal operations) - maximum 24-hour PM_{10} concentrations ($\mu g/m^3$)**

9.2.4. Ozone

The predicted future concentrations of hourly O_3 are presented in **Figure 9-11**. When these concentrations are compared to the existing scenario, it is apparent that the maximum ground-level concentrations are still predicted to occur offshore. The maximum ground-level concentration has increased from 24 ppb in the existing case scenario to 44 ppb, which represents 44% of the NEPM criteria.

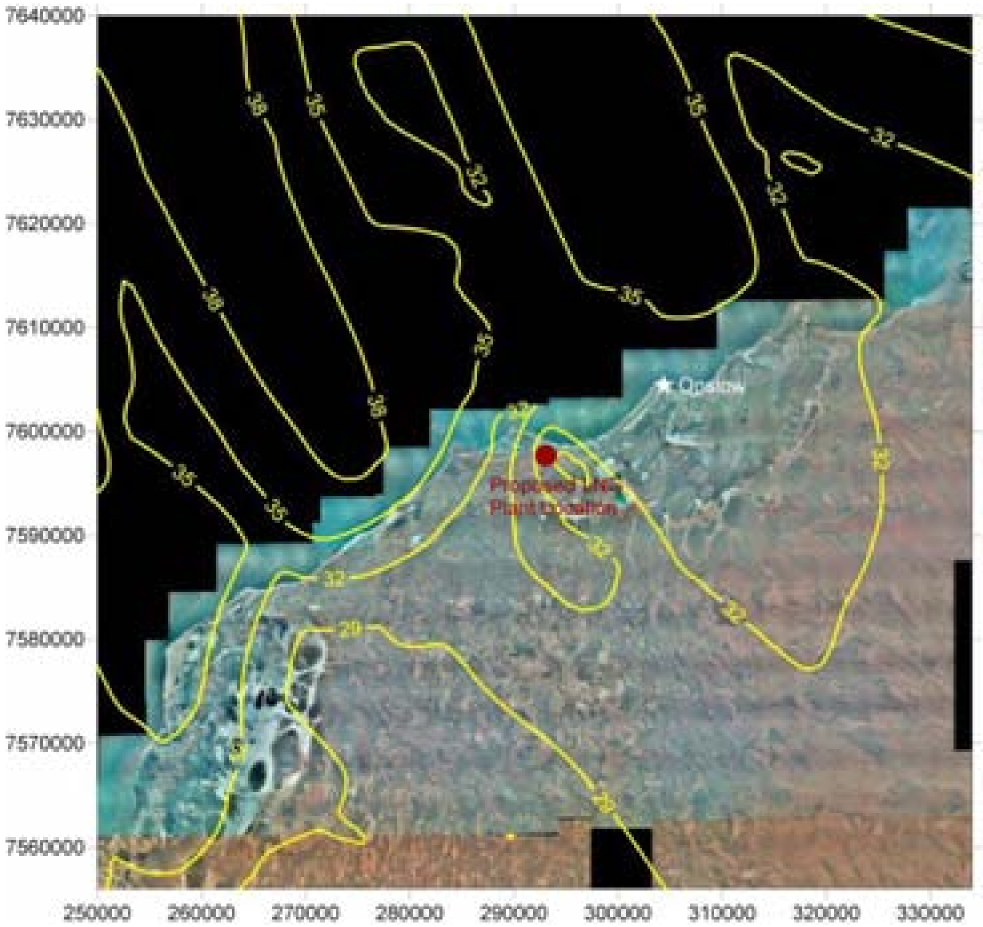
It is important to note that this maximum concentration is predicted to occur offshore. The maximum concentration that is predicted to occur within Onslow is 38 ppb, which represents 38% of the NEPM criterion.



- **Figure 9-11 Future case (normal operations) - maximum 1-hour O_3 concentrations (ppb)**

The predicted future 4-hourly O_3 concentrations are presented in **Figure 9-12** and, as with the 1-hour concentration results, there is little change in the isopleth locations. The maximum ground-level concentration has increased from the existing scenario from 27% up to 50% of the NEPM criterion.

It is important to note that this maximum concentration is predicted to occur offshore. The maximum concentration that is predicted to occur within Onslow has increased from 19 ppb to 34 ppb, which represents 43% of the NEPM criterion.



- **Figure 9-12 Future case (normal operations) - maximum 4-hour O_3 concentrations (ppb)**

9.2.5. Benzene, Toluene and Xylene

The maximum predicted concentrations of benzene, toluene and xylene are presented in **Table 9-3**. From this table it is apparent that the predicted ground level concentrations of BTEX pollutants is very low with benzene having the highest predicted impact on the model grid at 8.4% of the NEPM investigation level.

- **Table 9-2 Maximum predicted future ground-level concentrations for BTX under normal operating conditions**

Pollutant	Modelled Grid	Averaging Period	Unit	NEPM Investigation level (ppb)	Maximum on Grid (ppb)	Percentage of Criteria
Benzene	1 km	Annual	ppb	3	0.3	8.4%
Toluene	1 km	24 hour	ppb	1000	1	0.1%
	1 km	Annual	ppb	100	0.5	0.5%
Xylene	1 km	24 hour	ppb	250	1.3	0.5%
	1 km	Annual	ppb	200	0.6	0.3%

9.2.6. Maximum on Grid

The maximum predicted future ground-level concentrations for NO_2, SO_2, PM_{10} and O_3 are presented in **Table 9-3** below. A comparison between the criteria and the maximum predicted ground-level concentrations shows that all the predicted concentrations for modelled pollutants are below the criterion.

- **Table 9-3 Maximum predicted future ground-level concentrations under normal operating conditions**

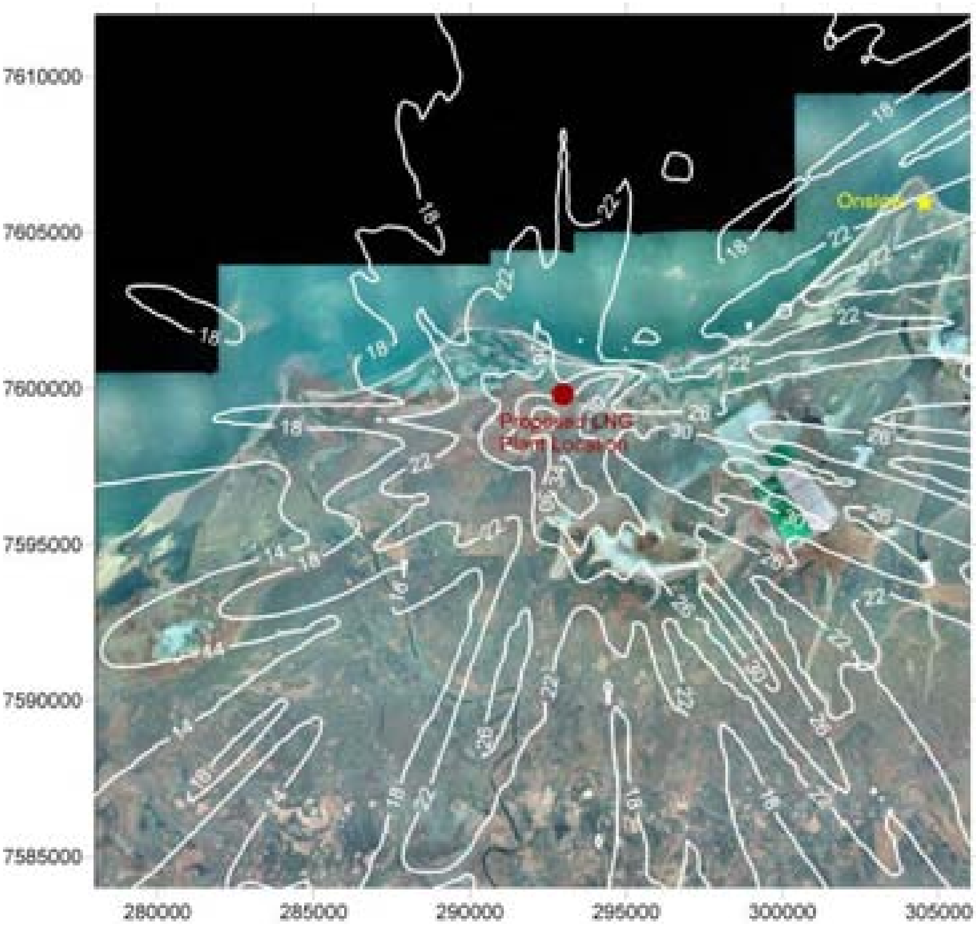
Pollutant	Modelled Grid	Averaging Period	Unit	NEPM Criteria	Maximum on Grid		Percentage of Criteria	
					On Grid	Onslow	On Grid	Onslow
NO_2	1 km	1-hour	ppb	120	39	24	32%	20%
		Annual	ppb	30	2.8	0.4	9%	1%
SO_2	1 km	1-hour	ppb	200	3.5	0.7	1.7%	0.3%
		24-hour	ppb	80	1.1	0.1	1.4%	0.1%
		Annual	ppb	20	0.6	0.0	2.8%	0.1%
PM_{10}	1-km	24-hour	$\mu g/m^3$	50	27	25	53%	50%
O_3	3 km	1-hour	ppb	100	44	38	44%	38%
		4-hour	ppb	80	40	34	50%	43%

9.3. Future Air Quality – During Shiploading Operations

The modelling for future air quality during shiploading operating conditions incorporates the emissions used in the existing scenario (**Section 8.2**) plus those expected from the proposed gas processing facility (**Section 8.3**). The pollutants taken into consideration in this section include NO_2, SO_2, PM_{10} and O_3. The maximum ground-level concentration of each of these pollutants is compared to the NEPM criteria.

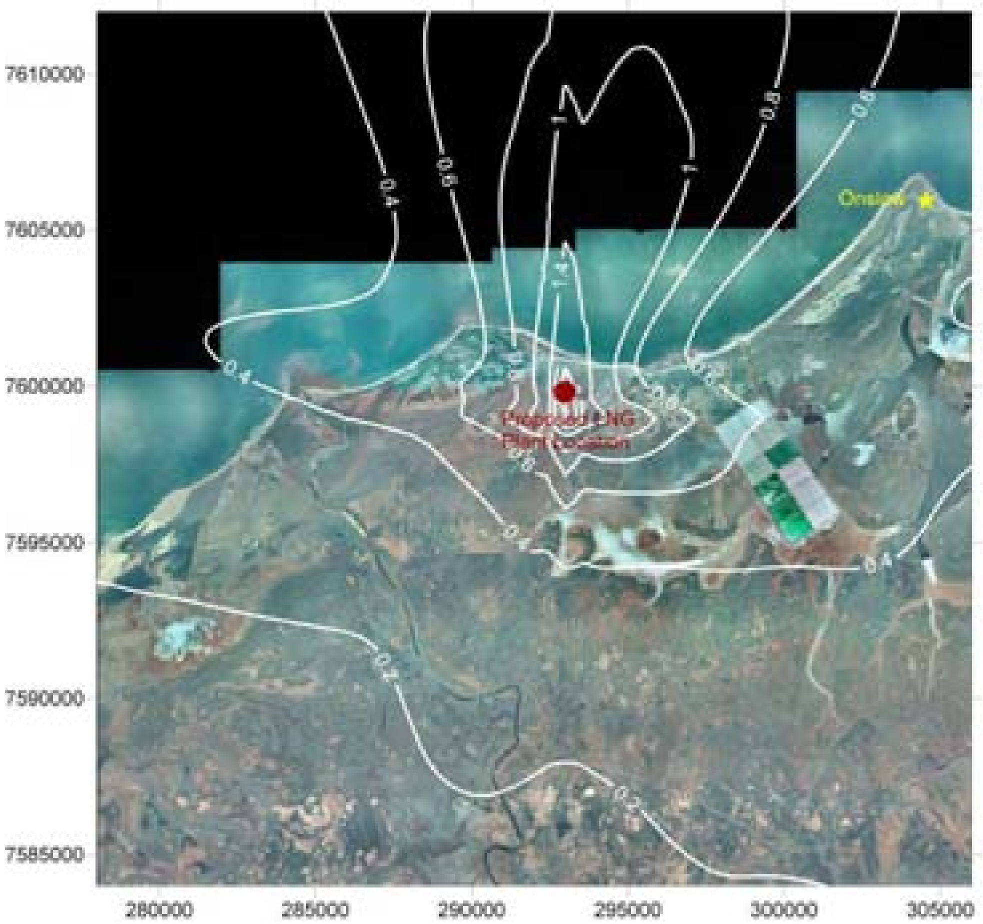
9.3.1. Oxides of Nitrogen (as NO_2)

The maximum 1-hour predicted ground-level NO_2 concentrations are presented in **Figure 9-13**. When the results presented in this figure are compared to that for the normal operating scenario (**Figure 9-5**) it is apparent that the shiploading operations have minimal impact. The maximum predicted ground-level concentration is 39 ppb, which is identical to that predicted for the normal operating scenario case, and is 32% of the NEPM criteria, shown in **Table 9-4**.



- **Figure 9-13 Future case (during shiploading) - maximum 1-hour NO_2 concentrations (ppb)**

The predicted annual average ground-level NO_2 concentrations are presented in **Figure 9-14**. When the results presented in this figure are compared to that for the normal operating scenario (**Figure 9-6**) it is apparent that the shiploading operations do not increase the ground-level concentrations.



■ **Figure 9-14 Future case (during shiploading) - annual NO_2 concentrations (ppb)**

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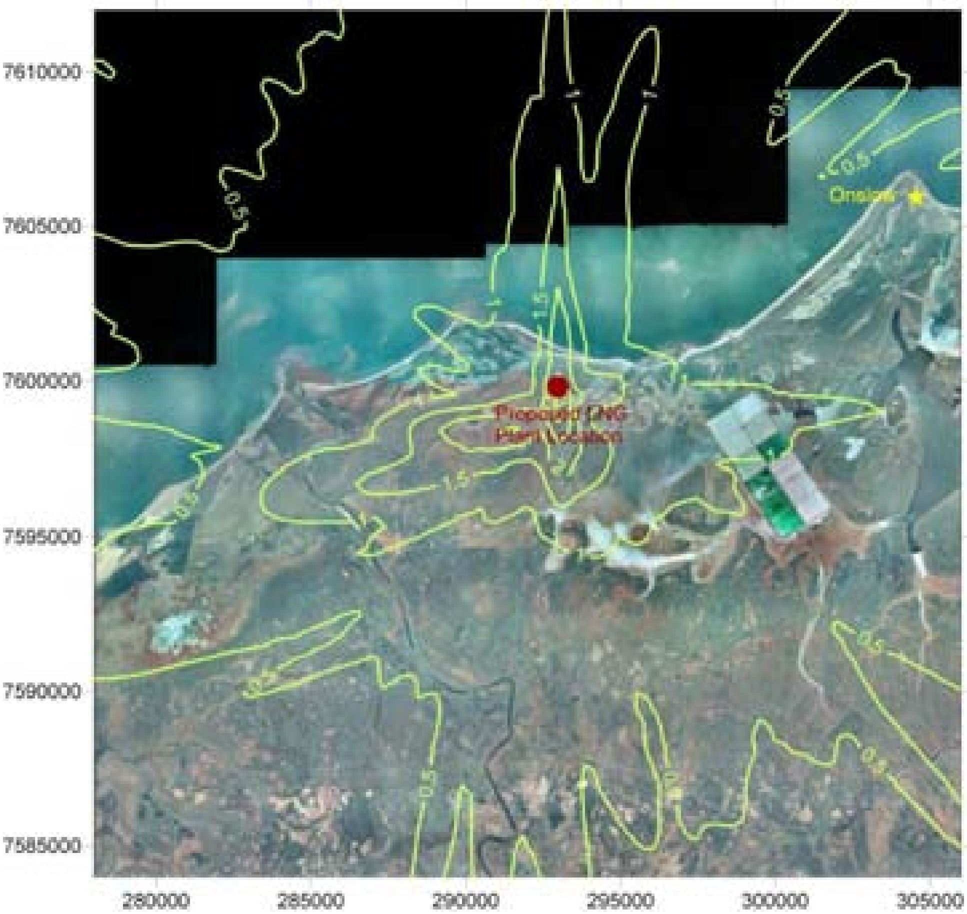
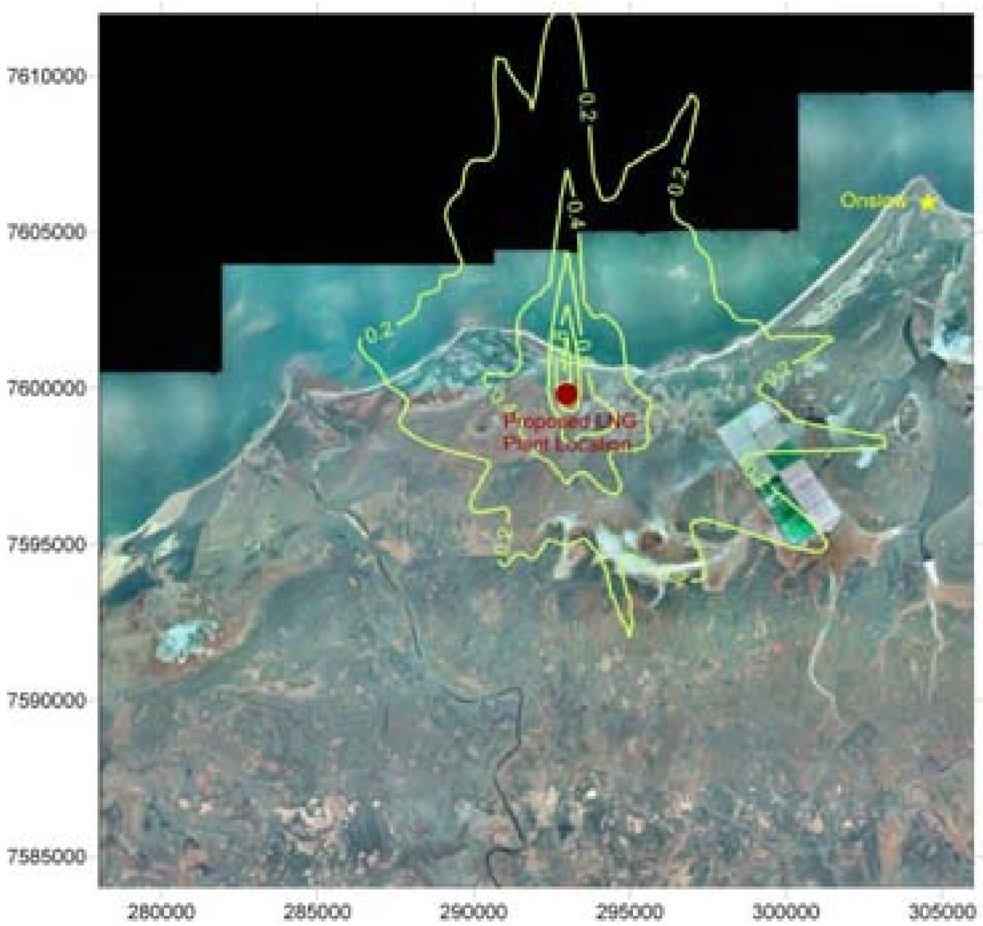
9.3.2. Sulfur dioxide

The maximum 1-hour predicted ground-level SO_2 concentrations are presented in **Figure 9-15**. When the results presented in this figure are compared to that for the normal operating scenario (**Figure 9-7**) it is apparent that the shiploading operations have minimal impact. The maximum predicted ground-level concentration is 3.5 ppb, which is identical to that predicted for the normal operating scenario case, and is 1.7% of the NEPM criteria, shown in **Table 9-4**.



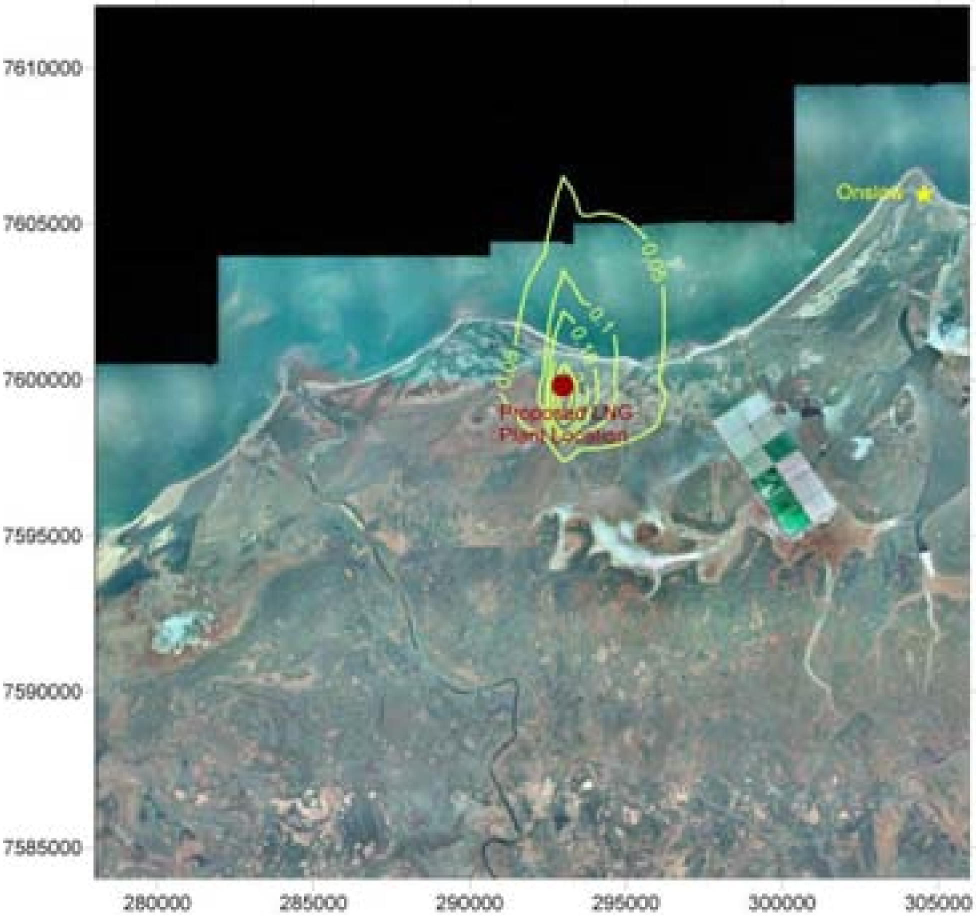
- **Figure 9-15 Future case (during shiploading) - maximum 1-hour SO_2 concentrations (ppb)**

The maximum 24-hour predicted ground-level SO_2 concentrations are presented in **Figure 9-16**. When the results presented in this figure are compared to that for the normal operating scenario (**Figure 9-8**) it is apparent that the shiploading operations have minimal impact. The maximum predicted ground-level concentration is 1.1 ppb, which is identical to that predicted for the normal operating scenario case, and is 1.4% of the NEPM criteria, shown in **Table 9-4**.



- **Figure 9-16 Future case (during shiploading) - maximum 24-hour SO_2 concentrations (ppb)**

The annual average predicted ground-level SO_2 concentrations are presented in **Figure 9-17**. When the results presented in this figure are compared to that for the normal operating scenario (**Figure 9-9**) it is apparent that the shiploading operations have minimal impact. The maximum predicted ground-level concentration is 0.6 ppb, which is identical to that predicted for the normal operating scenario case, and is 2.8% of the NEPM criteria, shown in **Table 9-4**.

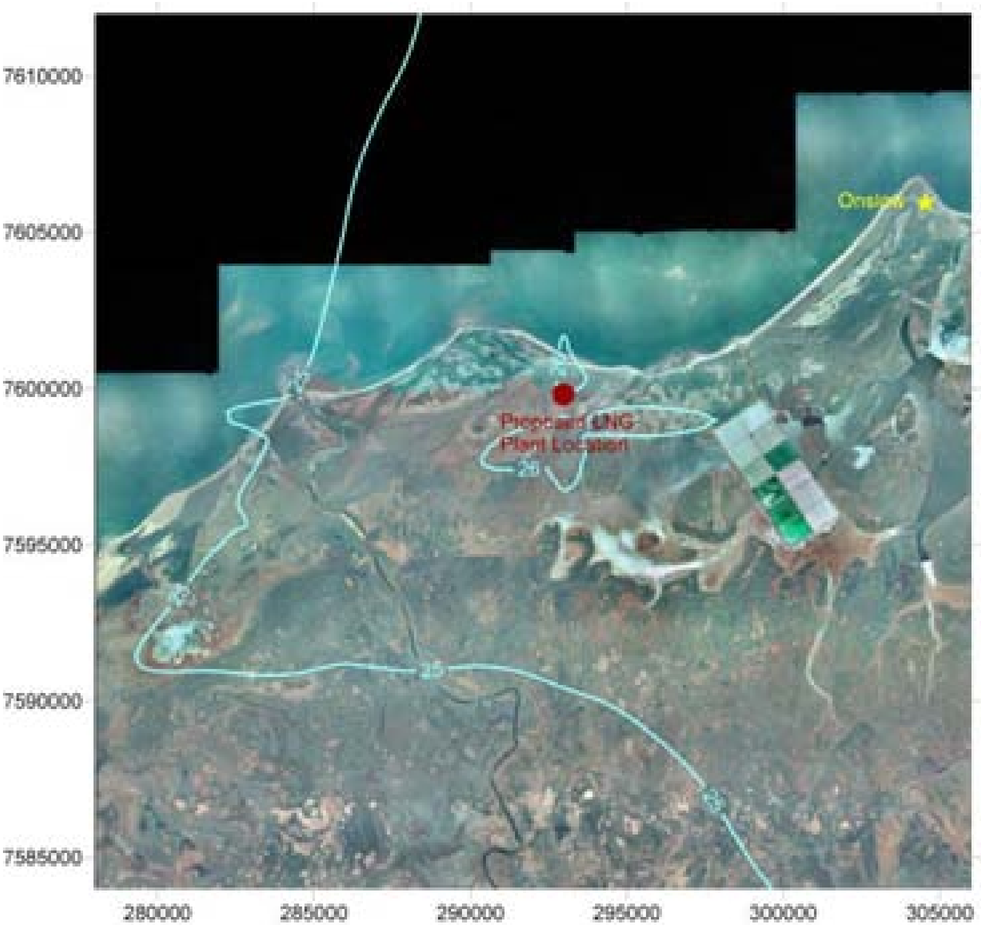


- **Figure 9-17 Future case (during shiploading) - annual NO_2 concentrations (ppb)**

9.3.3. Particulates

The maximum 24-hour predicted ground-level PM_{10} concentrations during shiploading operations are presented in **Figure 9-18**. The maximum predicted ground-level concentration is 27 µg/m^3, which is 54% of the NEPM criteria, shown in **Table 9-4**. The maximum predicted ground-level concentration at Onslow is 25 µg/m^3 which is 50% of the

NEPM criteria. These concentrations include a constant background concentration of 22 µg/m³ as discussed in **Section 6.3**.

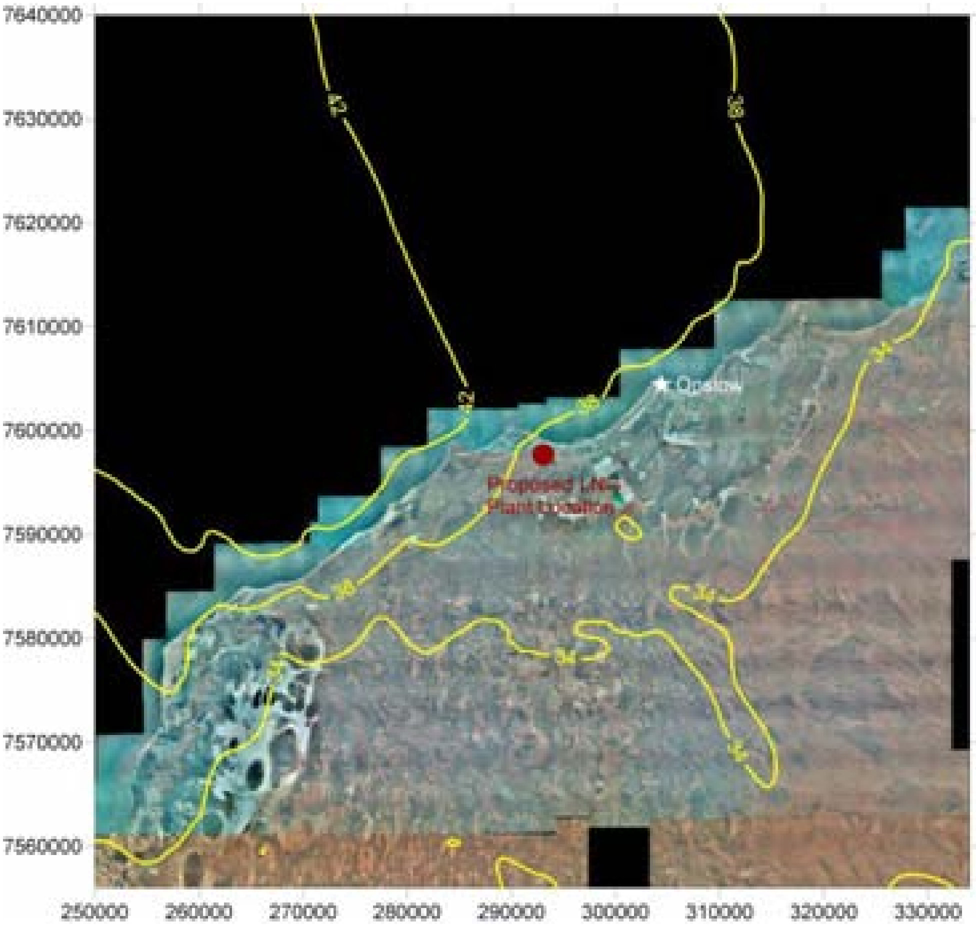


- **Figure 9-18 Future case (during shiploading) - maximum 24-hour PM_{10} concentrations (µg/m³)**

9.3.4. Ozone

The maximum predicted future concentrations of 1-hour ozone are presented in **Figure 9-19**. When these concentrations are compared to the normal operating scenario it is apparent that the maximum ground-level concentrations are still predicted to occur offshore. The maximum ground-level concentration has remained constant at 44 ppb, which represents 44% of the NEPM criteria.

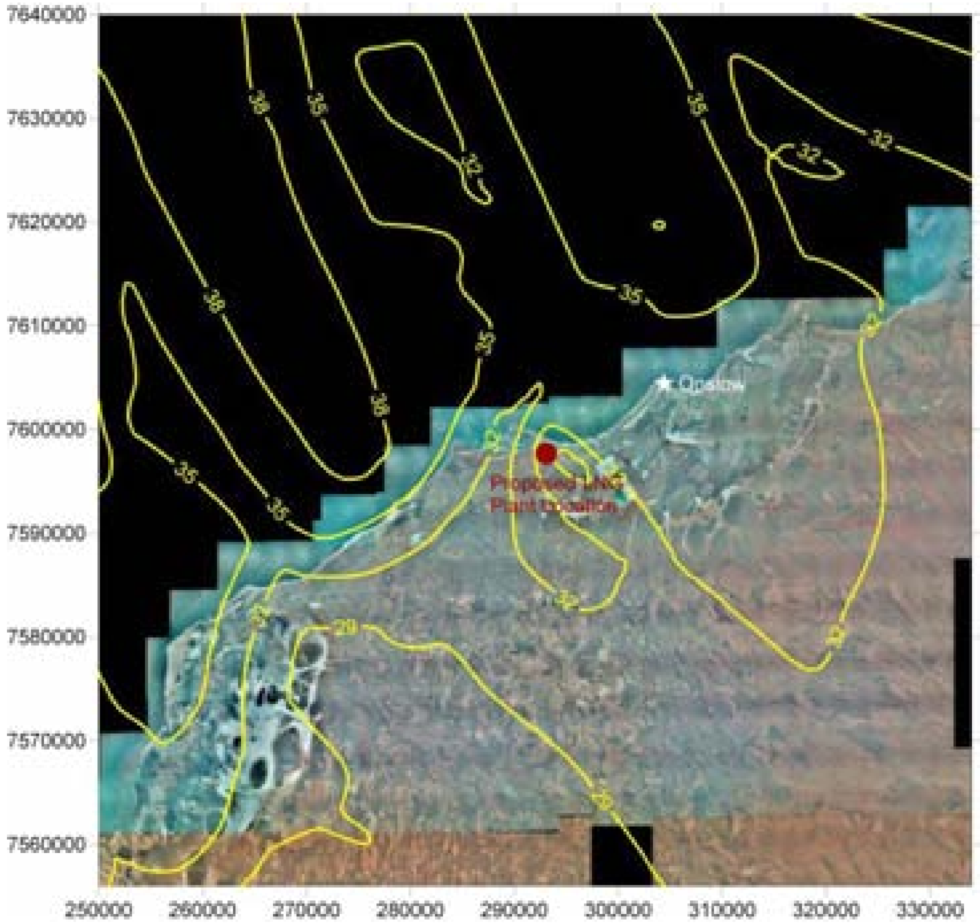
It is important to note that this maximum concentration is predicted to occur offshore and that the maximum concentration that is predicted to occur within Onslow remains unchanged from the normal operations at 38 ppb which represents 38% of the NEPM criteria.



- **Figure 9-19 Future case (during shiploading) - maximum 1-hour O_3 concentrations (ppb)**

The predicted future 4-hourly O_3 concentrations during shiploading operations are presented in **Figure 9-20**, and as with the 1-hour concentration there is little change in the isopleth locations. The maximum predicted ground-level concentration has remained the same as the normal operating scenario at 40 ppb or 50% of the NEPM criteria.

It is important to note that this maximum concentration is predicted to occur offshore. The maximum concentration that is predicted to occur within Onslow has remained at 34 ppb which represents 43% of the NEPM criteria.



- Figure 9-20 Future case (during shiploading) - maximum 4-hour O_3 concentrations (ppb)

9.3.5. Maximum on Grid

The maximum predicted future ground-level concentrations for NO_2, SO_2, PM_{10} and O_3 during shiploading operations are presented in **Table 9-4** below. A comparison between the criteria and the maximum predicted ground-level concentrations shows that all the predicted concentrations for modelled pollutants are below the respective criteria.

Table 9-4 Maximum predicted future ground-level concentration during shiploading operating conditions

Pollutant	Modelled Grid	Averaging Period	Unit	NEPM Criteria	Maximum on Grid		Percentage of Criteria	
					On Grid	Onslow	On Grid	Onslow
NO_2	1 km	1-hour	ppb	120	39	24	32%	20%
		Annual	ppb	30	2.8	0.5	9%	2%
SO_2	1 km	1-hour	ppb	200	3.5	0.7	1.7%	0.3%
		24-hour	ppb	80	1.1	0.1	1.4%	0.1%
		Annual	ppb	20	0.6	0.0	2.8%	0.1%
PM_{10}	1-km	24-hour	µg/m^3	50	27	25	54%(1)	50%
O_3	3 km	1-hour	ppb	100	44	38	44%	38%
		4-hour	ppb	80	40	34	50%	43%

1. In Table 9-2 (normal operations), 27 µg/m^3 is presented as 53% of the assessment criteria. The difference is due to rounding of significant figures and is insignificant in the context of the impact to air quality and human health.

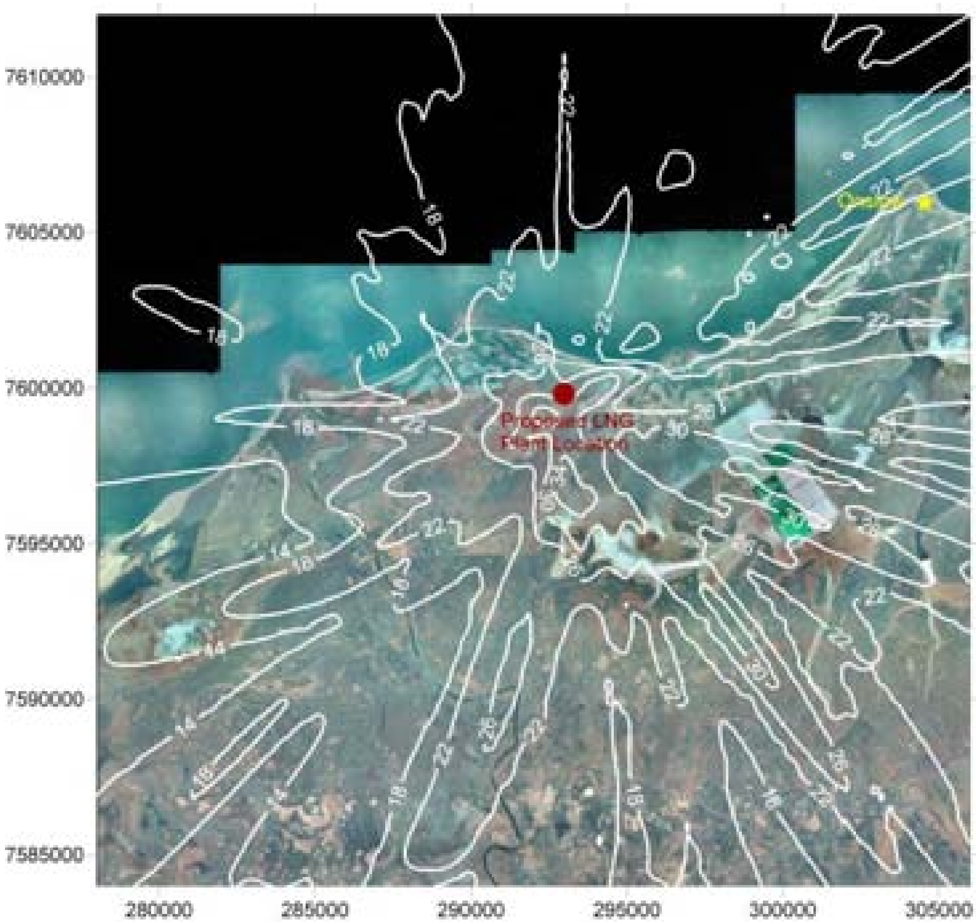
9.4. Future Air Quality – Upset Condition 1 (Start-up)

As outlined in **Section 8.4.2**, the future TAPM modelling results for the proposed Chevron Wheatstone facility under non-routine "Upset 1" conditions are presented here. This upset condition is for a cold start of a single gas processing train. A cold re-start is expected to take approximately six hours, during which time approximately 30% of the normal flow rate of a single LNG train may be directed to the flare as the LNG is brought to product specification.

Given the short duration of this event, results are presented for short-term averages only. The pollutants taken into consideration in this section include NO_2, SO_2, PM_{10} and O_3. The maximum ground-level concentration of each of these pollutants is compared to the NEPM criteria.

9.4.1. Oxides of Nitrogen (as NO_2)

The maximum 1-hour predicted ground-level NO_2 concentrations during upset condition 1 are presented in **Figure 9-21**. The maximum predicted ground-level concentration is 39 ppb, which is identical to that predicted to occur during normal operations (**Table 9-3**) and is 32% of the NEPM criteria, as shown in **Table 9-5**.

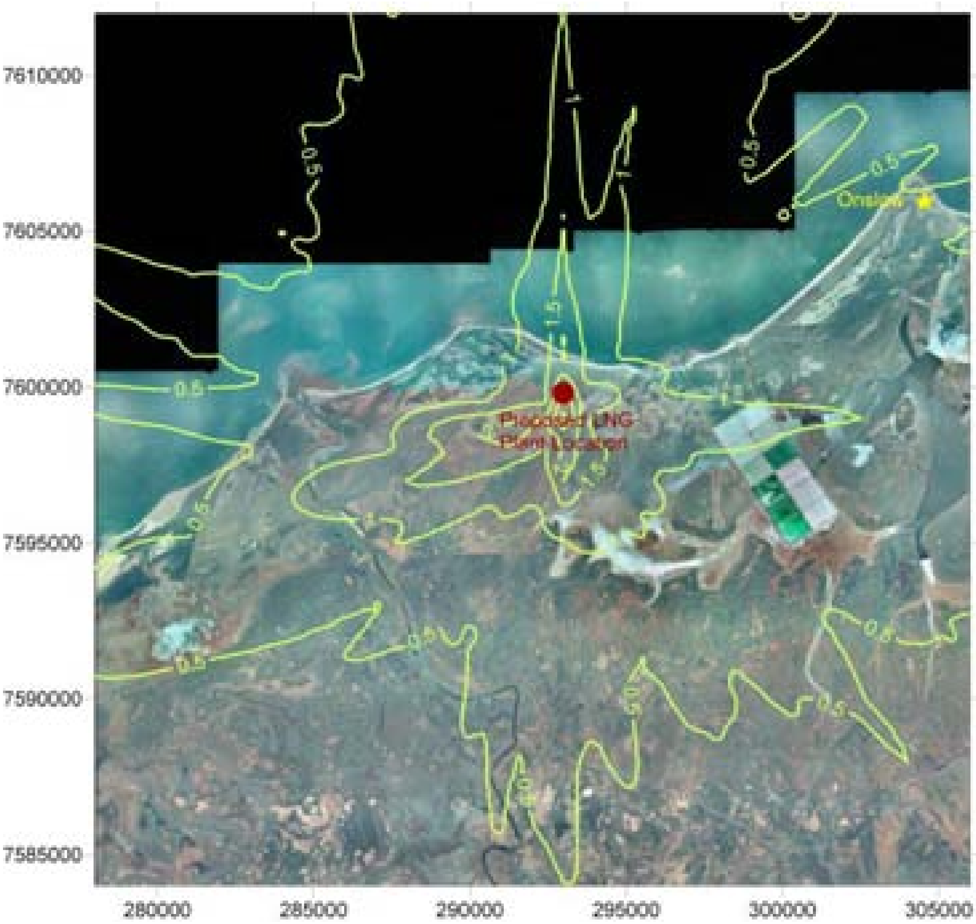


- **Figure 9-21 Future Case - maximum 1-hour ground-level concentrations of NO_2 during Upset Condition 1 (ppb)**

9.4.2. Sulfur dioxide

The maximum 1-hour predicted ground-level SO_2 concentrations during upset condition 1 are presented in **Figure 9-22**. The maximum predicted ground-level concentration is

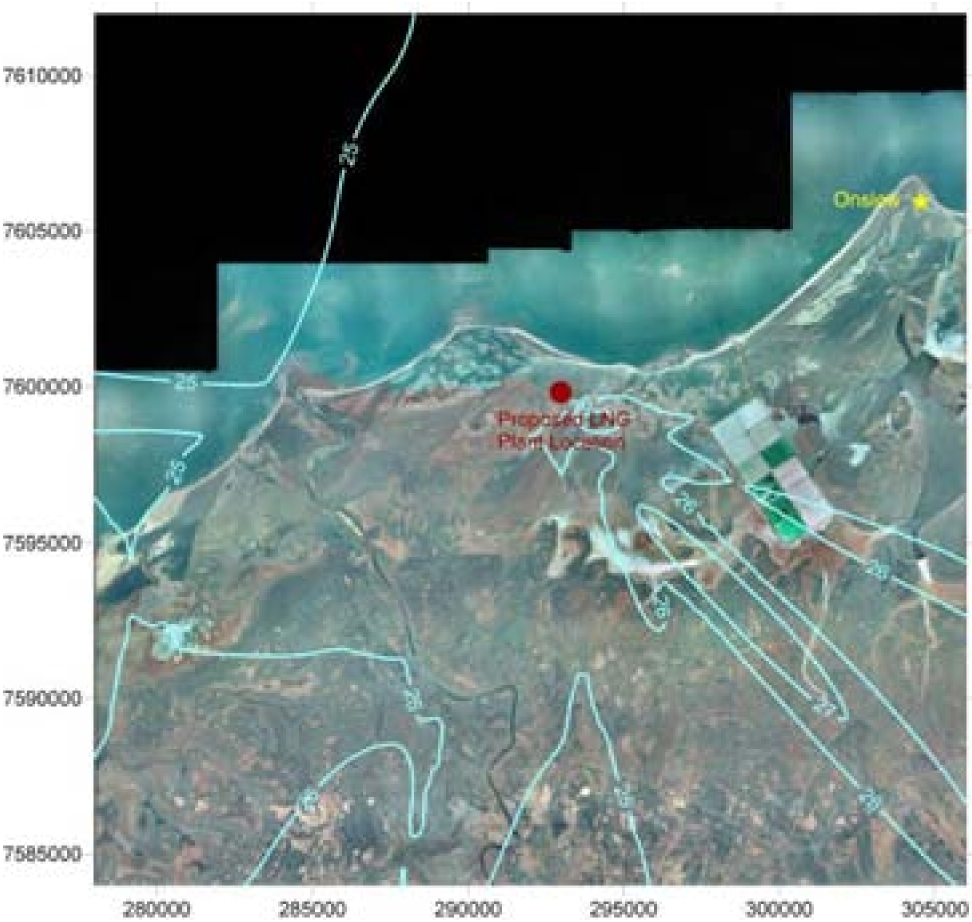
3.3 ppb, which is slightly lower than that predicted to occur during normal operations (**Table 9-3**) and is 1.6% of the NEPM criteria, as shown in **Table 9-5**.



- **Figure 9-22 Future Case - maximum 1-hour ground-level concentrations of SO_2 during Upset Condition 1 (ppb)**

9.4.3. Particulates

The maximum 24-hour predicted ground-level PM_{10} concentrations during upset condition 1 are presented in **Figure 9-23**. The maximum predicted ground-level concentration is 28 $\mu g/m^3$, which is 55% of the NEPM criteria, shown in **Table 9-5**. This maximum concentration is predicted to occur adjacent to the facility. The maximum predicted concentration at Onslow is 25 $\mu g/m^3$ (50% of the applicable NEPM criteria) and is an identical concentration to that predicted to occur during normal operations. These concentrations include a constant background concentration of 22 $\mu g/m^3$ as discussed in **Section 6.3**.



- **Figure 9-23 Future Case - maximum 24-hour ground-level concentrations of PM_{10} during Upset Condition 1**

9.4.4. Ozone

The maximum 1-hour predicted ground-level O_3 concentrations during upset condition 1 are presented in **Figure 9-24**. The maximum predicted ground-level concentration for the 1-hour averaging period is 43 ppb which is slightly lower than that predicted to occur during normal operations (**Table 9-3**).

The maximum predicted 1-hour concentration at Onslow is 38 ppb, equivalent to that predicted to occur during normal operations and represents 38% of the NEPM criteria.

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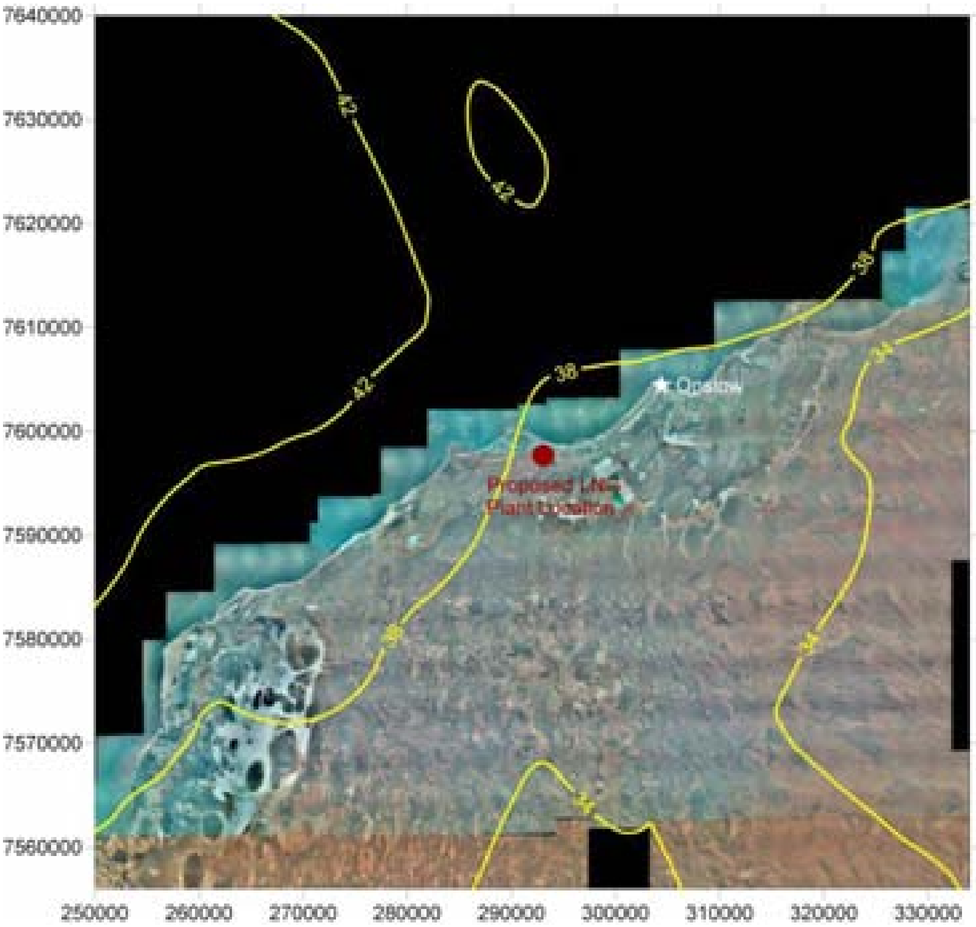

- **Figure 9-24 Future Case - maximum 1-hour ground-level concentrations of O_3 during Upset Condition 1 (ppb)**

9.4.5. Maximum on Grid

The maximum predicted future ground-level concentrations for NO_2, SO_2, PM_{10} and O_3, during upset condition 1 are presented in **Table 9-5** below. A comparison has been made between the maximum predicted future ground-level concentrations and the NEPM criteria, which is also displayed in this table. This table demonstrates that the predicted concentrations for all modelled pollutants are below the assessment criteria.

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- **Table 9-5 Future Case - maximum predicted ground-level concentration under Upset Condition 1**

Pollutant	Modelled Grid	Averaging Period	Unit	NEPM Criteria	Maximum on Grid		Percentage of Criteria	
					On Grid	Onslow	On Grid	Onslow
NO_2	1 km	1-hour	ppb	120	39	24	32%	20%
SO_2	1-km	1-hour	ppb	200	3.3	0.6	1.6%	0.3%
PM_{10}	1-km	24-hour	µg/m^3	50	28	25	55%	50%
O_3	3 km	1-hour	ppb	100	43	38	43%	38%

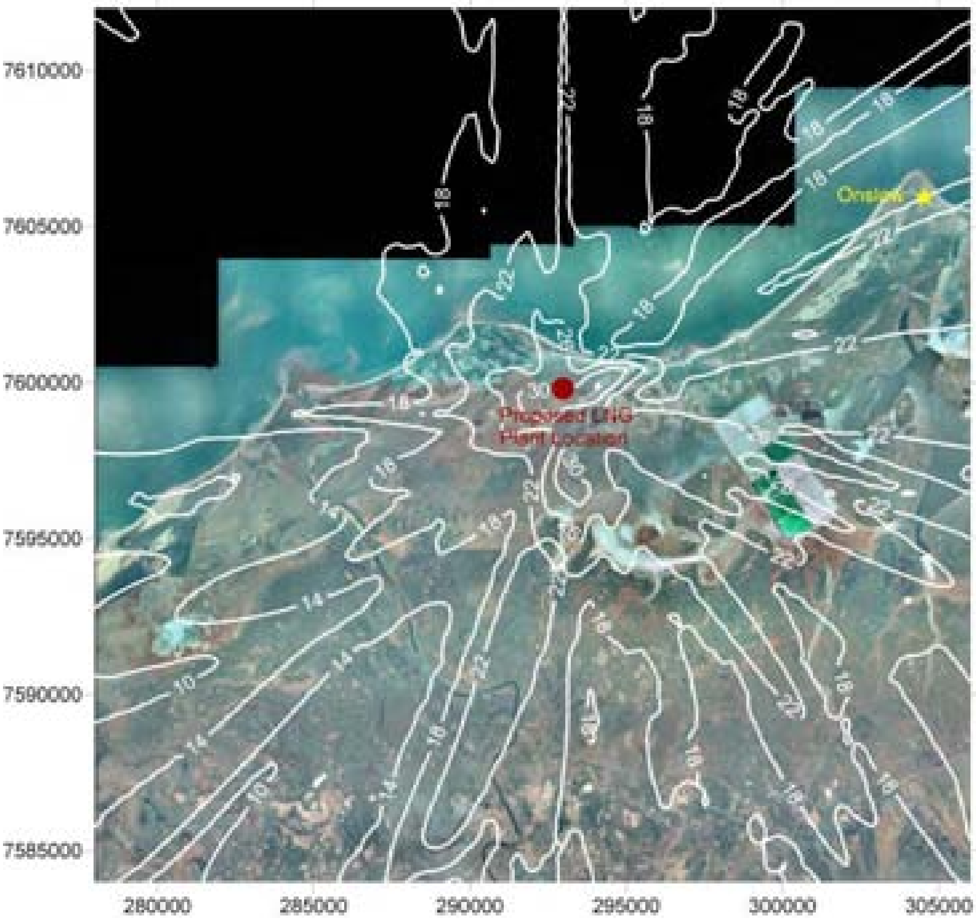
9.5. Future Air Quality – Upset Condition 2

As outlined in **Section 8.4.3** the future TAPM modelling results for the proposed Chevron Wheatstone facility under non-routine "Upset 2" conditions are presented here. This scenario is based on a process emergency shutdown, resulting in peak flaring for approximately 15 minutes. During this type of event, all equipment on one train will be shutdown, while the other trains will continue to operate normally.

Given the short duration of this event, results are presented for short-term averages only. The pollutants taken into consideration in this section include NO_2, SO_2, PM_{10} and O_3. The maximum ground-level concentration of each of these pollutants is compared to the NEPM criteria.

9.5.1. Oxides of Nitrogen (as NO_2)

The maximum 1-hour predicted ground-level NO_2 concentrations during upset condition 2 are presented in **Figure 9-25**. The maximum predicted ground-level concentration is 36 ppb, which represents a decrease of 3 ppb when compared to that predicted to occur during normal operations (**Table 9-3**). This predicted maximum concentration is 30% of the NEPM criteria, as shown in **Table 9-6**. It is important to note that although peak flaring is expected to occur for approximately 15 minutes the modelling has assumed that this flaring rate will occur over an hour and has been modelled to occur over every hour for a full year.



- **Figure 9-25 Future Case - maximum 1-hour ground-level concentrations of NO_2 during Upset Condition 2 (ppb)**

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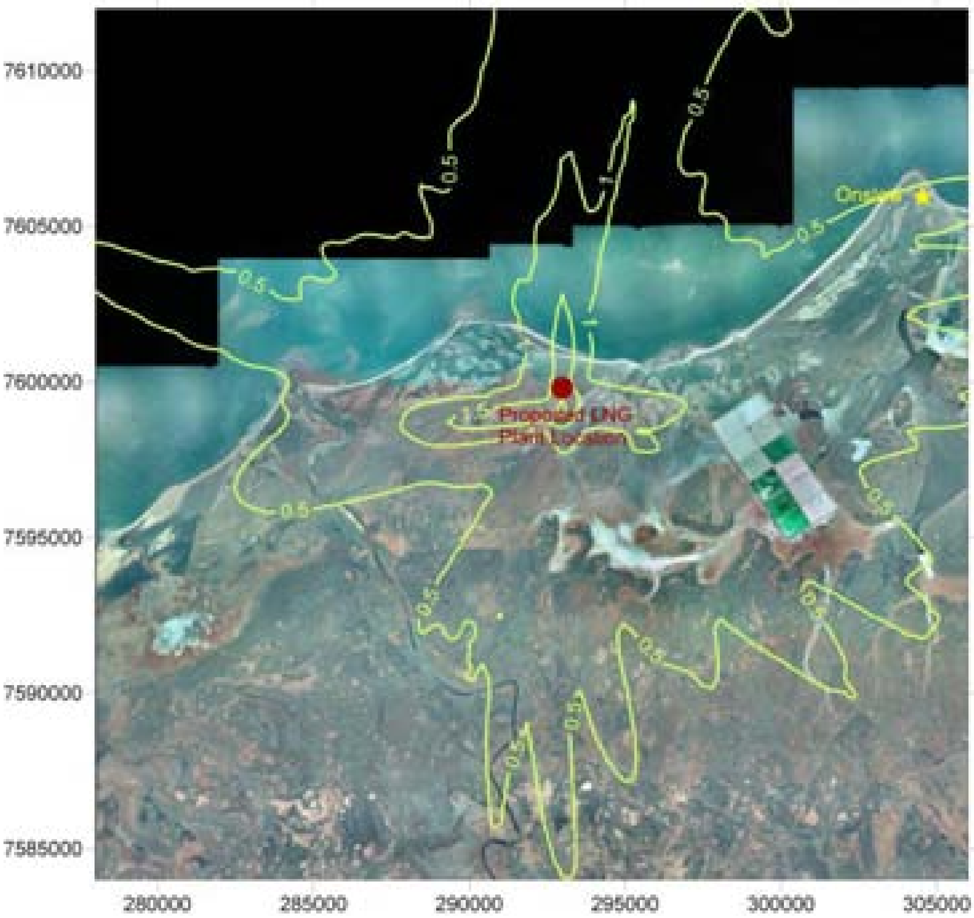
9.5.2. Sulfur dioxide

The maximum 1-hour predicted ground-level SO_2 concentrations during upset condition 2 are presented in **Figure 9-26**. The maximum predicted ground-level concentration is 2.2 ppb, which represents a decrease of 1.3 ppb when compared to that predicted to occur during normal operations (**Table 9-3**). This predicted maximum concentration is 1.1% of the NEPM criteria, as shown in **Table 9-6**.

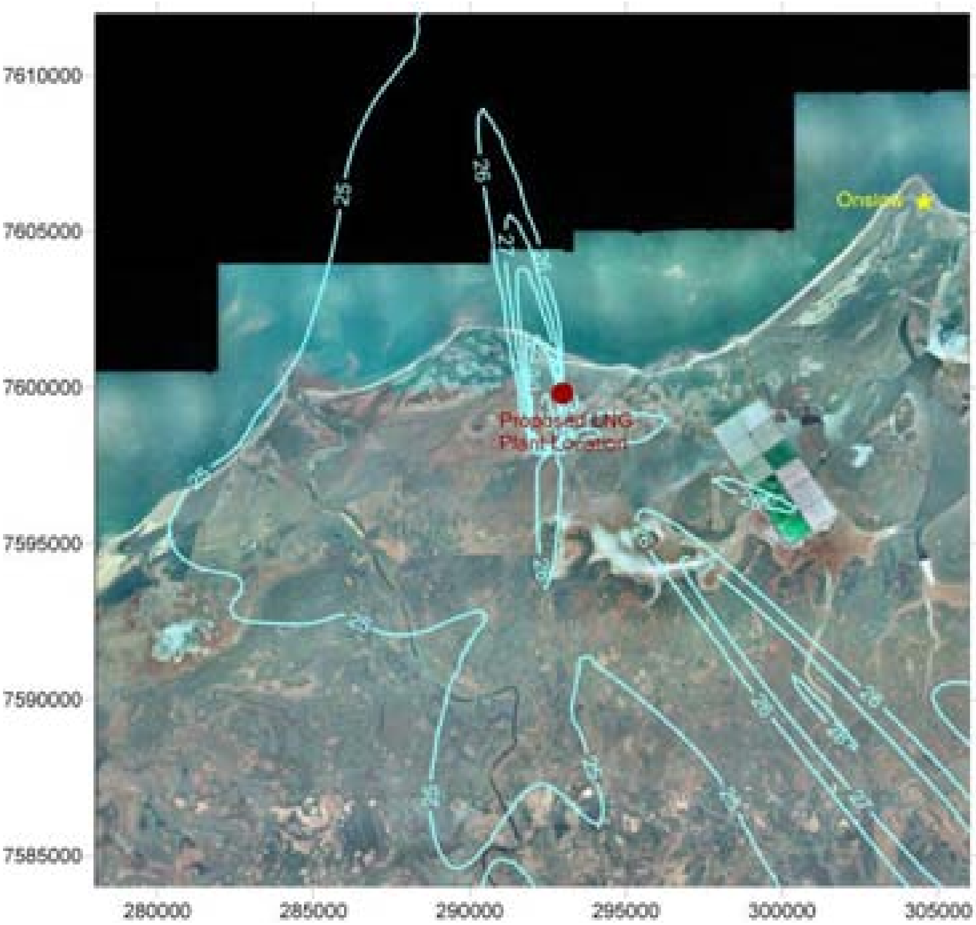


- **Figure 9-26 Future Case - maximum 1-hour ground-level concentrations of SO_2 during Upset Condition 2 (ppb)**

9.5.3. Particulates

The maximum 24-hour predicted ground-level PM_{10} concentrations during upset condition 2 are presented in **Figure 9-27**. The maximum predicted ground-level concentration is 44 $\mu g/m^3$, which is equivalent to 87% of the NEPM criteria, shown in **Table 9-6**, which is predicted to occur adjacent to the proposed facility.

The maximum predicted concentration at Onslow is 25 µg/m³ (50% of the applicable NEPM criteria) and is a similar concentration to that predicted to occur during normal operations. These concentrations include a constant background concentration of 22 µg/m³ as discussed in **Section 6.3**.

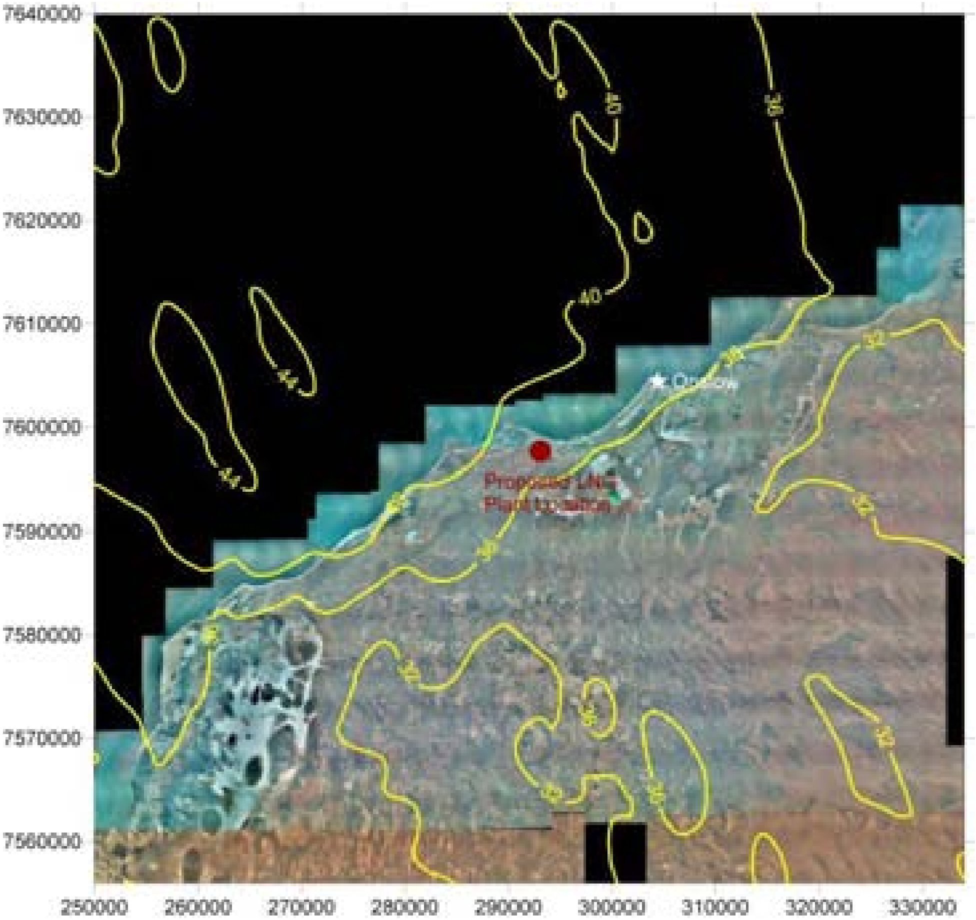


- **Figure 9-27 Future Case - maximum 24-hour ground-level concentrations of PM_{10} during Upset Condition 2 (µg/m³)**

9.5.4. Ozone

The maximum 1-hour predicted ground-level O_3 concentrations during upset condition 2 are presented in **Figure 9-28**. The maximum predicted ground-level concentration is 44 ppb, which is identical (at the level of significance presented) to that predicted to occur during normal operations (**Table 9-3**). As with the predicted concentrations during normal operations, the maximum concentrations during upset condition 2 are predicted to occur offshore.

The maximum predicted concentration at Onslow is 37 ppb which is 1 ppb lower than that predicted to occur during normal operations and represents 37% of the NEPM criteria.



- **Figure 9-28 Future Case - maximum 1-hour ground-level concentrations of O_3 during Upset Condition 2 (ppb)**

9.5.5. Maximum on Grid

The maximum predicted future ground-level concentrations for NO_2, SO_2, PM_{10} and O_3 during upset condition 2 are presented in **Table 9-6** below. A comparison has been made between the maximum predicted future ground-level concentrations and the NEPM criteria, which is also displayed in this table. This table demonstrates that the predicted concentrations for all modelled pollutants are below the assessment criteria.

- **Table 9-6 Future Case - maximum predicted future ground-level concentration under Upset Condition 2**

Pollutant	Modelled Grid	Averaging Period	Unit	NEPM Criteria	Maximum on Grid		Percentage of Criteria	
					On Grid	Onslow	On Grid	Onslow
NO_2	1 km	1-hour	ppb	120	36	23	30%	19%
SO_2	1 km	1-hour	ppb	200	2.2	0.6	1.1%	0.3%
PM_{10}	1-km	24-hour	µg/m^3	50	44	25	87%	50%
O_3	3 km	1-hour	ppb	100	44	37	44%	37%

9.6. Future Air Quality – Potential Cumulative Impact

The modelling for the potential cumulative air quality impacts was conducted assuming normal operating conditions and incorporates the emissions from the Chevron Wheatstone Project (**Section 8.3**) and two additional gas processing facilities located on an adjacent site, immediately to the south of the Chevron Wheatstone facility (**Section 8.5**). The pollutants taken into consideration in this section include NO_2, SO_2, PM_{10} and O_3. The maximum ground-level concentration of each of these pollutants is assessed against the NEPM criteria.

It is important to note that the emissions used in this scenario for the additional gas processing facility and the proposed Domgas plant are only indicative and that additional dispersion modelling will be required once the correct facility layout is determined by the proponents.

9.6.1. Oxides of Nitrogen (as NO_2)

The maximum 1-hour predicted ground-level NO_2 concentrations are presented in **Figure 9-29**. When the results presented in this figure are compared to that for the proposed Chevron Wheatstone facility operating during normal conditions (**Figure 9-5**), the impact of the additional gas processing trains on ground-level concentrations of NO_2 is apparent. The maximum predicted ground-level concentration is 42 ppb (**Table 9-7**), which represents an increase of 3 ppb from that predicted for the normal operating scenario (**Table 9-3**), and is 35% of the NEPM criterion (**Table 9-7**),

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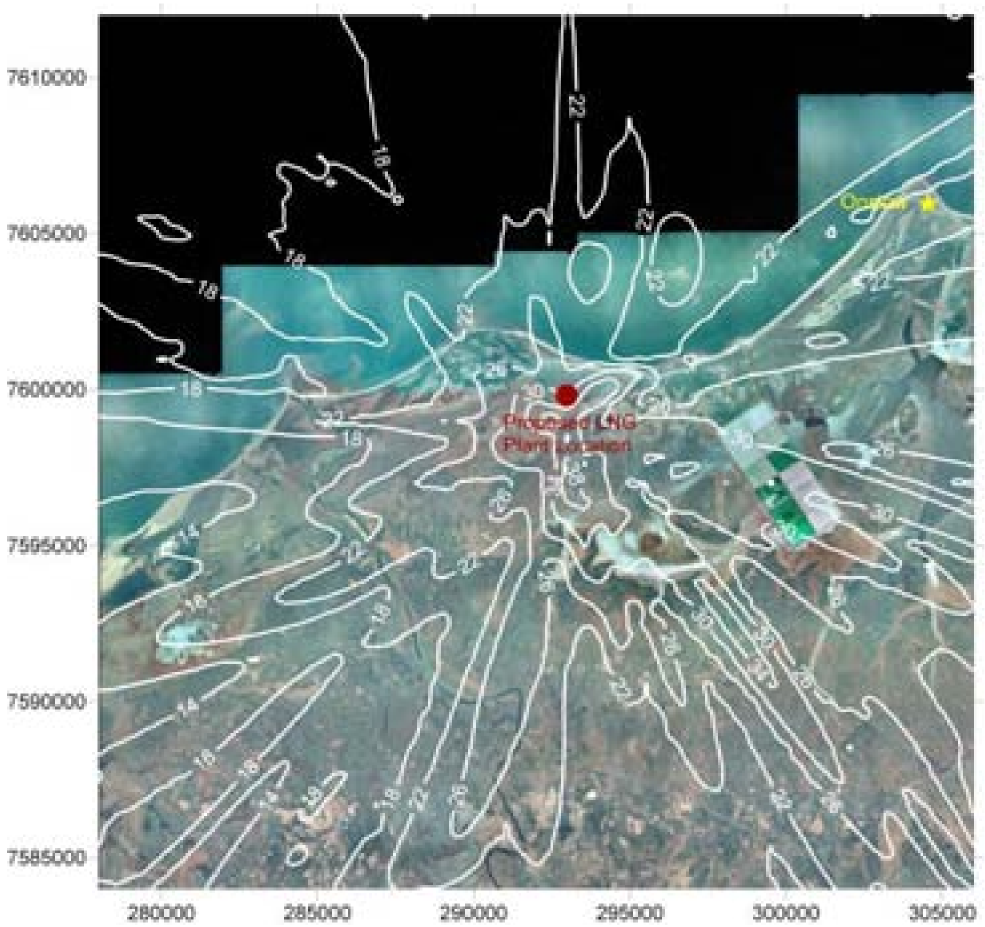
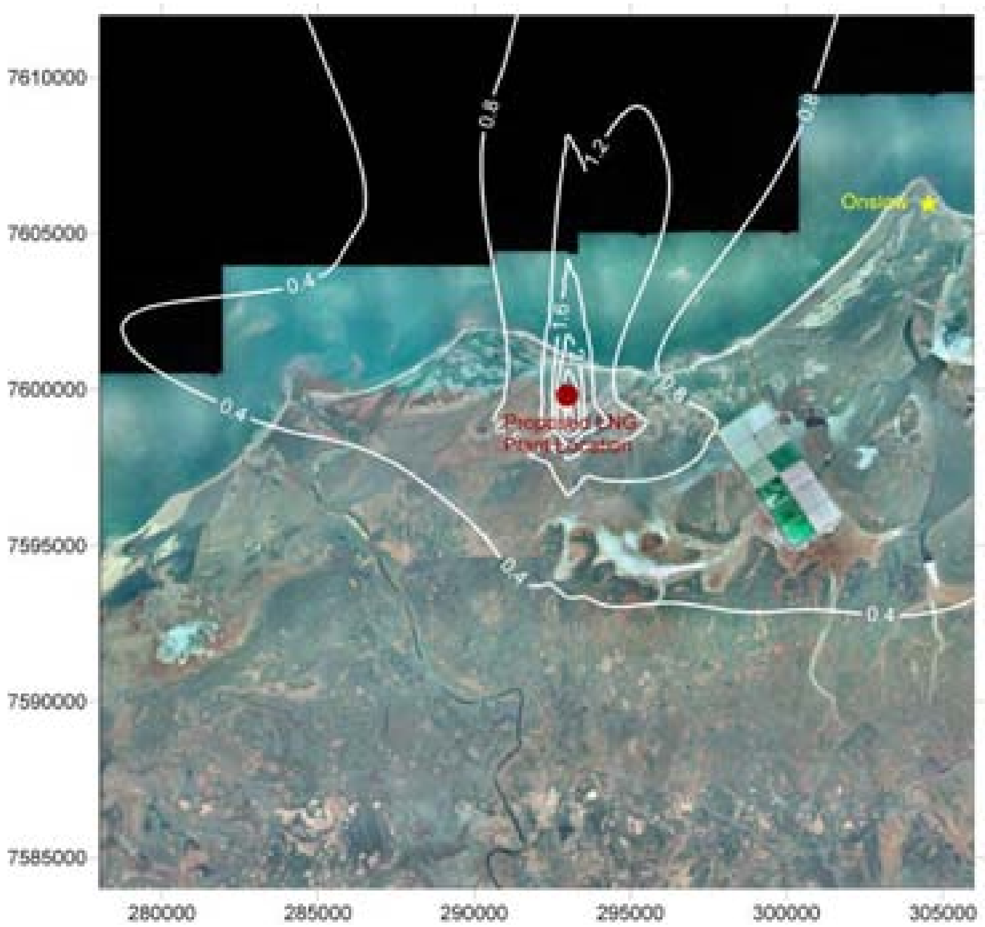


- **Figure 9-29 Cumulative scenario - maximum 1-hour NO_2 concentrations (ppb)**

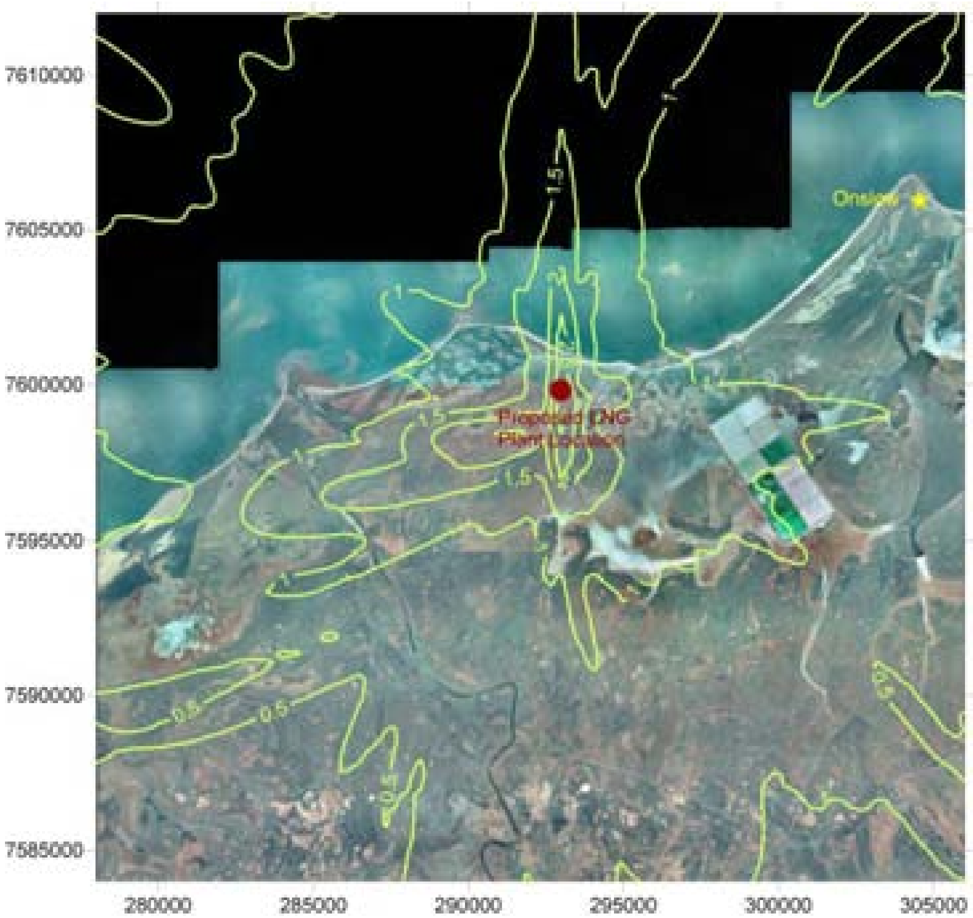
The predicted annual average ground-level NO_2 concentrations are presented in **Figure 9-30**. When the results presented in this figure are compared to that for the proposed Chevron Wheatstone facility during normal operating conditions (**Figure 9-6**), it is apparent that there is little cumulative impact with the introduction of the potential additional gas processing facilities on ground-level concentrations of NO_2. The maximum predicted annual ground-level concentration is predicted to increase from 2.8 ppb to 3.2 ppb, which is 11% of the NEPM criterion.



▪ **Figure 9-30 Cumulative scenario - annual NO_2 concentrations (ppb)**

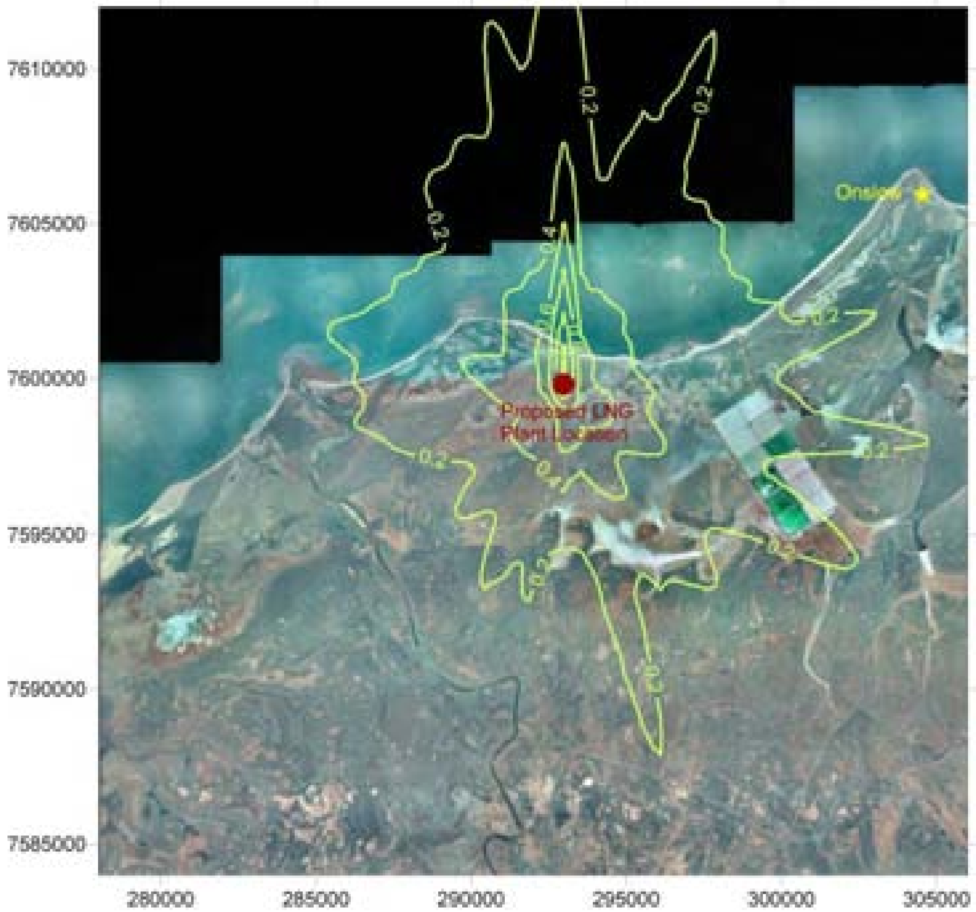
9.6.2. Sulfur dioxide

The maximum 1-hour predicted ground-level SO_2 concentrations are presented in **Figure 9-31**. When the results presented in this figure are compared to that for the proposed Chevron Wheatstone facility operating during normal conditions (**Figure 9-7**), it is apparent that there is little cumulative impact with the introduction of additional gas processing trains on ground-level concentrations of SO_2. The maximum predicted ground-level concentration is 3.5 ppb (**Table 9-7**), which is identical to that predicted for the normal operating scenario (**Table 9-3**), and is 1.8% of the NEPM criterion (**Table 9-7**).



- **Figure 9-31 Cumulative scenario - maximum 1-hour SO_2 concentrations (ppb)**

The maximum 24-hour predicted ground-level SO_2 concentrations are presented in **Figure 9-32**. When the results presented in this figure are compared to that for the proposed Chevron Wheatstone facility operating during normal conditions (**Figure 9-8**), it is apparent that the additional gas processing trains have minimal impact on ground-level concentrations of SO_2. The maximum predicted ground-level concentration is 1.3 ppb (**Table 9-7**), which is slightly higher than that predicted for the normal operating scenario (**Table 9-3**), and is 1.6% of the NEPM criterion (**Table 9-7**).



- **Figure 9-32 Cumulative scenario - maximum 24-hour SO_2 concentrations (ppb)**

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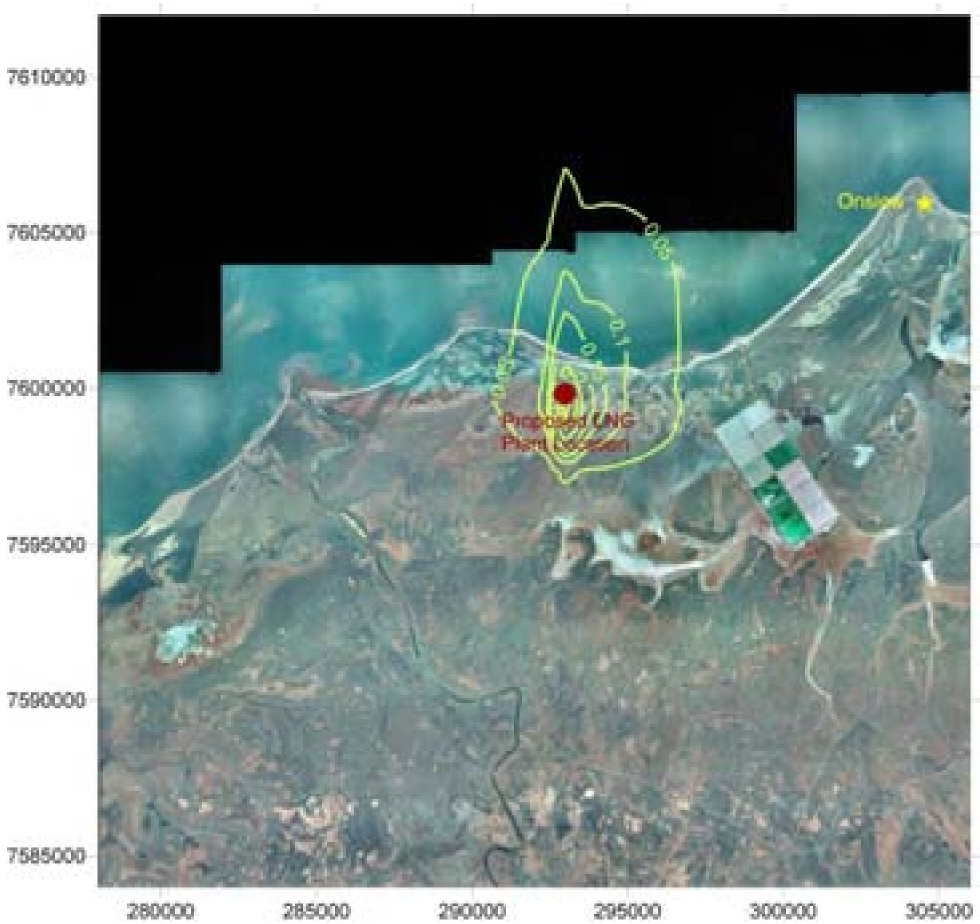
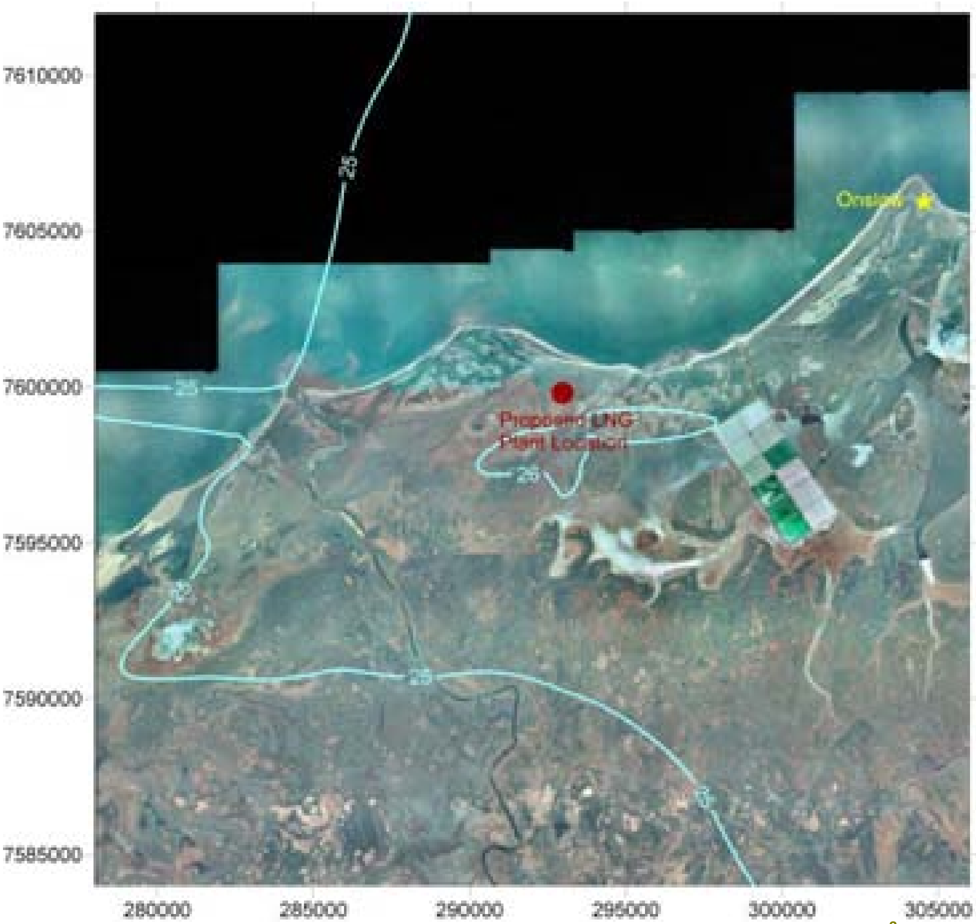
The predicted annual average ground-level SO_2 concentrations are presented in **Figure 9-33**. When the results presented in this figure are compared to that for the proposed Chevron Wheatstone facility during normal operating conditions (**Figure 9-9**), it is apparent that there is little cumulative impact with the introduction of the potential additional gas processing facilities on ground-level concentrations of SO_2. The maximum predicted annual ground-level concentration is 0.6 ppb, and is 3% of the NEPM criterion.



- Figure 9-33 Cumulative scenario - annual SO_2 concentrations (ppb)

9.6.3. Particulates

The maximum 24-hour predicted ground-level PM_{10} concentrations during the potential cumulative scenario are presented in **Figure 9-34**. The maximum predicted ground-level concentration is 27 $\mu g/m^3$, which is 54% of the NEPM criteria, shown in **Table 9-7**. This is similar to that predicted for normal operations, as shown in **Figure 9-10**. The concentrations presented in this figure include a constant background concentration of 22 $\mu g/m^3$ as discussed in **Section 6.3**.



- **Figure 9-34 Cumulative scenario - maximum 24-hour PM_{10} concentrations ($\mu g/m^3$)**

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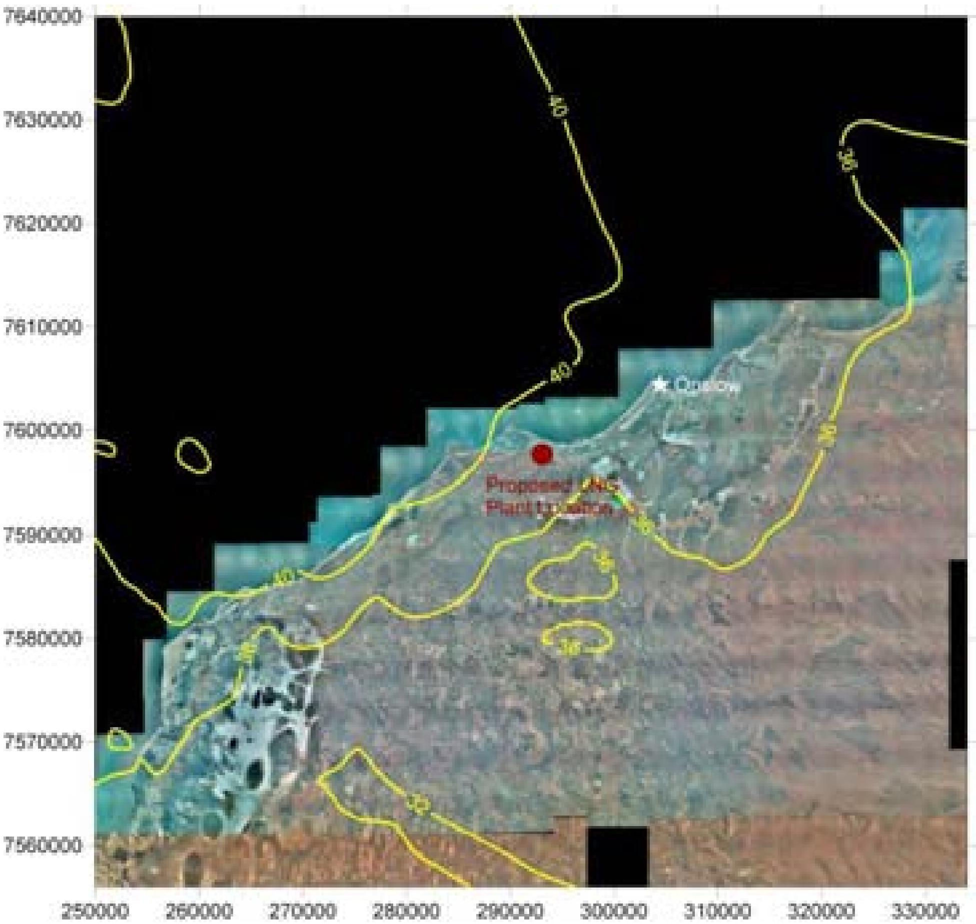
9.6.4. Ozone

The predicted future concentrations of hourly O_3 for the cumulative scenario are presented in **Figure 9-35**. When these concentrations are compared to the current normal operating scenario (**Figure 9-11**), it is apparent that the maximum ground-level concentrations are still predicted to occur offshore. The maximum ground-level concentration has remained at 44 ppb, which represents 44% of the NEPM criteria.

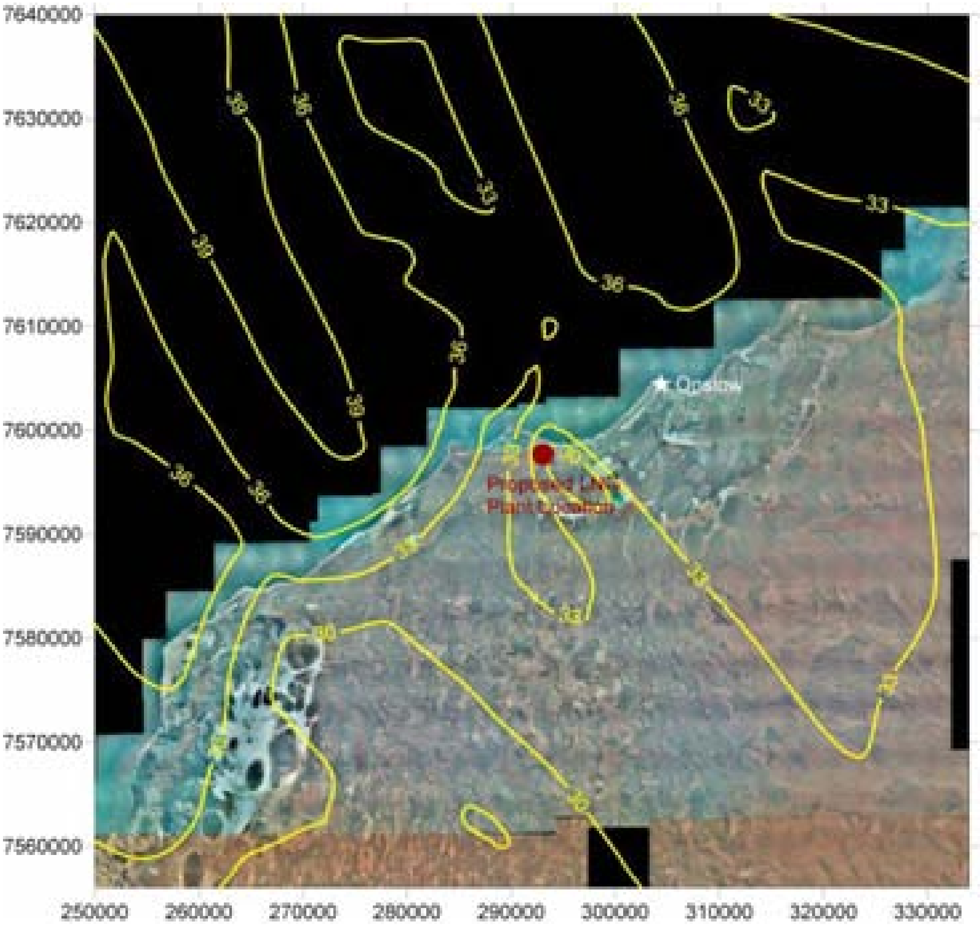
It is important to note that this maximum concentration is predicted to occur offshore. The maximum concentration that is predicted to occur within Onslow is 38 ppb, which represents 38% of the NEPM criterion.



▪ **Figure 9-35 Cumulative scenario - maximum 1-hour O_3 concentrations (ppb)**

The predicted future 4-hourly O_3 concentrations are presented in **Figure 9-36** and, as with the 1-hour concentration, there is little change in the location of the isopleths. The maximum ground-level concentration has increased from the current normal operating scenario from 50% up to 51% of the NEPM criterion.

It is important to note that this maximum concentration is predicted to occur offshore. The maximum concentration that is predicted to occur within Onslow has increased marginally from 34 ppb to 35 ppb, which represents 44% of the NEPM criterion.



■ **Figure 9-36 Cumulative scenario - maximum 4-hour O_3 concentrations (ppb)**

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9.6.5. Maximum on Grid

The maximum predicted future ground-level concentration for NO_2, SO_2, PM_{10} and O_3 are presented in **Table 9-7** below. A comparison between the criteria and the maximum predicted ground-level concentrations shows that all the predicted concentrations for modelled pollutants are below the criterion.

- **Table 9-7 Maximum predicted future ground-level concentration for cumulative impacts under normal operating conditions**

Pollutant	Modelled Grid	Averaging Period	Unit	NEPM Criteria	Maximum on Grid		Percentage of Criteria	
					On Grid	Onslow	On Grid	Onslow
NO_2	1 km	1-hour	ppb	120	42	26	35%	21%
		Annual	ppb	30	3.2	0.5	11%	2%
SO_2	1 km	1-hour	ppb	200	3.5	0.8	1.8%(1)	0.4%
		24-hour	ppb	80	1.3	0.1	1.6%	0.2%
		Annual	ppb	20	0.6	0.0	3.0%(2)	0.1%
PM_{10}	1-km	24-hour	µg/m^3	50	27	25	54%	50%
O_3	3 km	1-hour	ppb	100	44	38	44%	38%
		4-hour	ppb	80	41	35	51%	44%

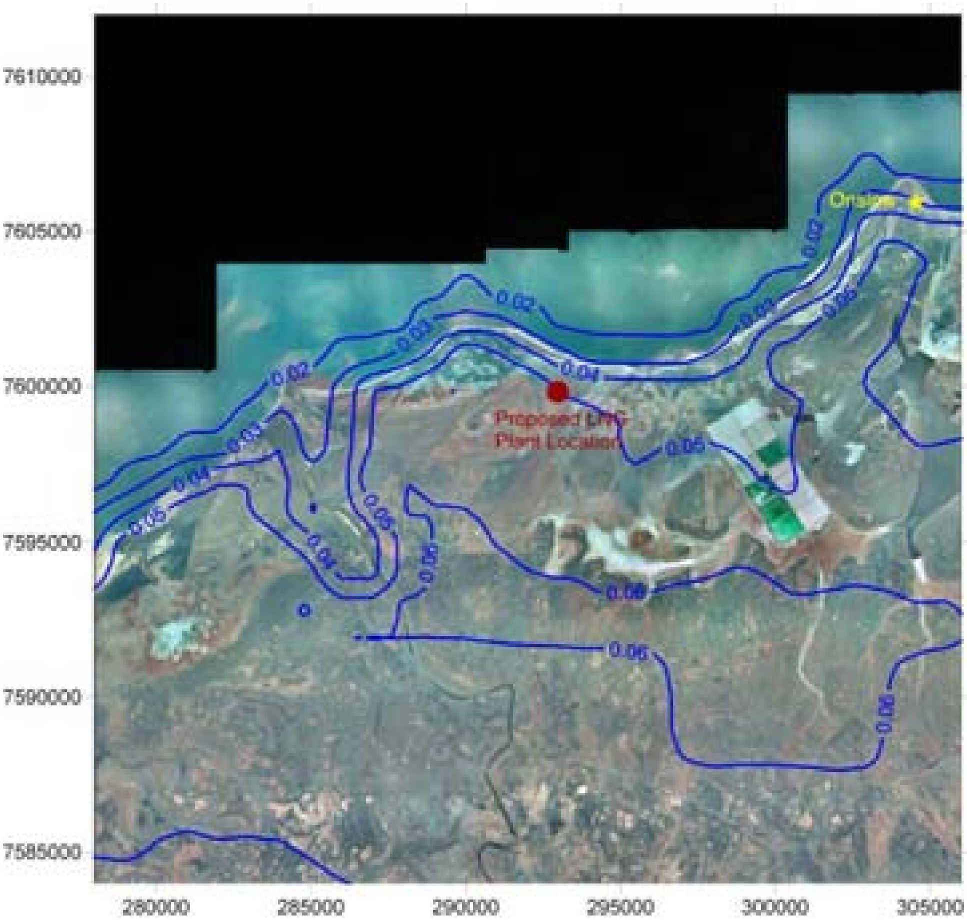
1. In Table 9-2 (normal operations), 3.5 ppb is presented as 1.7% of the assessment criteria. The difference is due to rounding of significant figures and is insignificant in the context of the impact to air quality and human health.
2. In Table 9-2 (normal operations), 0.6 ppb is presented as 2.8% of the assessment criteria. The difference is due to rounding of significant figures and is insignificant in the context of the impact to air quality and human health.

9.7. Impact on Vegetation - Dry Deposition of NO_x

Acid deposition occurs when NO_x reacts with water, oxygen and other oxidants in the atmosphere to form acidic compounds. These acid compounds precipitate in rain, snow and fog, or in dry form as gases and particles. The NO_x gases and their particulate matter derivatives and nitrate aerosols may contribute to air quality impacts, for example, by the acidification of lakes and streams, damage to forest ecosystems and acceleration of the decay of building materials (USEPA 2007). The deposition quantities provided in this assessment are considered indicative of what may occur.

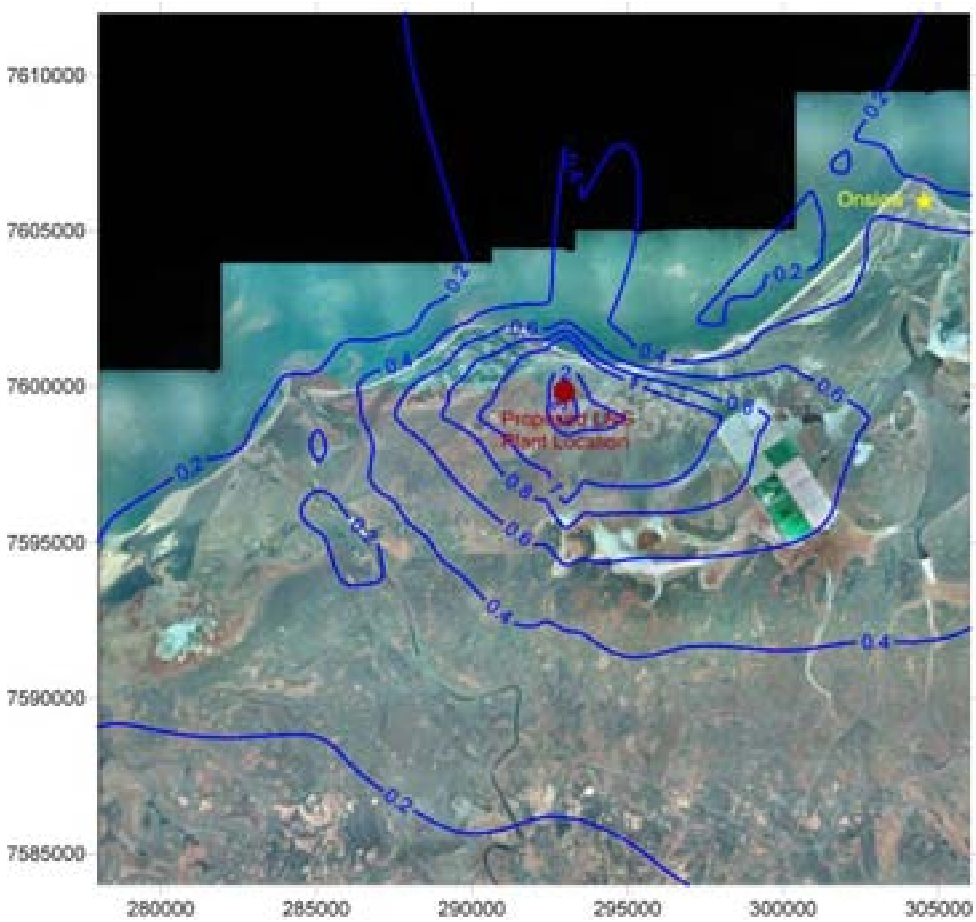
9.7.1. NO_2 Deposition for Chevron Wheatstone in Isolation

The TAPM predictions for the existing NO_2 deposition (kg/ha/annum) results are provided in **Figure 9-37**. The highest predicted NO_2 deposition rate of 0.06 kg/ha/annum is predicted to occur to the south of the proposed facility. It must be noted that the results are strongly dependent on the biogenic emission estimation and the NO_2 solubility used in the calculations.



- **Figure 9-37 Existing Case - Predicted Annual NO_2 Deposition (kg/ha/annum)**

The TAPM predictions for the future NO_2 deposition (kg/ha/annum) results are provided in **Figure 9-38**. The highest NO_2 deposition rate of 3.8 kg/ha/annum is predicted to occur adjacent to the proposed facility. This deposition rate is well within the WHO guidelines (**Section 4.3.2**) and as such NO_2 deposition from the proposed gas processing facility can be considered to be insignificant.



▪ **Figure 9-38 Future Case - Predicted Annual NO_2 Deposition (kg/ha/annum)**

9.8. Summary of Results for Chevron Wheatstone in Isolation

9.8.1. Potential Impact on Human Health

Of the NEPM criteria pollutants (metals, pesticides, PAHs, VOCs, POPs, dioxins and furans and asbestos), the highest risk NEPM ‘criteria air pollutants’ identified for detailed examination in this assessment are NO_2, SO_2, PM_{10} and O_3 with the others being not significant to this project.

Existing (non-industrial) Air Quality Case

Existing (non-industrial) air quality, that is the contribution of emissions from biogenic sources in the region, is predicted to be well below the NEPM criteria for both the predicted 1-hour and 4-hour ground-level ozone concentrations. Maximum concentrations are predicted to occur offshore. The 1-hour and annual ground-level concentrations of NO_2 are also influenced by the non-industrial sources but to a lesser degree (approximately 1% of the NEPM criteria).

Future air quality – normal operations

Atmospheric emissions from the proposed Chevron Wheatstone facility will contribute to a relatively small increase in predicted ground-level concentrations of NO_2, SO_2, PM_{10}, and O_3. Particulate concentrations remain well within the NEPM criteria as well.

This assessment has shown that for NO_2, SO_2, PM_{10} and O_3, no exceedances of the relevant assessment criteria are expected as a result of operating the proposed facility. The highest predicted concentration within the modelled region under normal operating conditions (without shiploading occurring) for any pollutant represented 53% of the NEPM criteria (for the 24-hourly PM_{10} concentration) and is predicted to occur adjacent to the facility. During shiploading, the 24-hourly PM_{10} concentration increases slightly to 54% of the NEPM criteria. The maximum predicted concentration at Onslow, both with and without shiploading, is 50% of the NEPM criteria.

Modelling of the BTEX pollutants indicate that the predicted ground level concentrations is very low with benzene having the highest predicted impact on the model grid at 8.4% of the NEPM investigation level.

Future air quality – upset operations

Atmospheric emissions from the proposed Chevron Wheatstone facility during upset conditions have the potential to result in an increase in the predicted ground-level concentrations of NO_2, SO_2, PM_{10} and O_3.

This assessment has shown that for, NO_2, O_3 and PM_{10}, no exceedances of the relevant assessment criteria are expected from the proposed facility during an upset condition. The highest predicted concentration within the region, for any pollutant, represented 87% of the NEPM criteria (for the 24-hourly PM_{10} concentration during an emergency shutdown of a single gas processing train). Nonetheless, the maximum predicted concentration at Onslow during an emergency shutdown up remains at 50% of the NEPM criteria.

9.8.2. Potential Impact on Vegetation from Deposition

This assessment of deposition of NO_2 for the region surrounding the proposed Chevron Wheatstone facility, incorporating all emissions associated with existing sources and the proposed gas processing facility indicates that 'typical high' NO_2 deposition rates in the region around Onslow are 3.8 kg/ha/annum. These levels are well under WHO (2000) guidelines for assessing the risks of impacts on vegetation; that is, WHO guidelines 49 to 66 kg/ha/annum (NO_2).

10. Conclusion

10.1. Overview

As part of the EIS/ERMP process for the onshore development of the Chevron Wheatstone Project, an air quality assessment was undertaken to determine the predicted air quality impacts from operation of the development. The air quality assessment was carried out in accordance with the Air Quality and Air Pollution Modelling Guidance Notes (DOE, 2006).

The assessment included an analysis and description of existing air quality in the region and an estimate of potential air quality impacts during normal and defined upset operating conditions. The potential ground-level concentrations of NO_2, SO_2, PM_{10} and O_3 from the proposed development were modelled and compared to the relevant assessment criteria.

10.2. Existing Sources of Air Quality Impacts

There is no direct information available on the local ambient air quality experienced in the Onslow region. Based on the regional setting ambient air quality is expected to be influenced by ocean sources, regional smoke from bush fires and prescribed burning activities.

Dispersion modelling predicts that the maximum 1-hour concentration of NO_2 is only 1% of the NEPM criteria. The maximum predicted 4-hour ozone concentration is 22 ppb which is equivalent to 27% of the NEPM criteria. Existing PM_{10} concentrations were not modelled due to the complexities of modelling short term events that vary spatially.

10.3. Wheatstone Air Quality Impacts

With addition of the Wheatstone processing facilities to the existing scenario, concentrations of all pollutants are predicted to increase under normal operating conditions. While the largest impact in terms of percentage of the NEPM under normal operating conditions is for particulates (maximum on the grid is 53% of NEPM), the most significant increase is predicted to occur for ozone. Under normal operating conditions with shiploading, the maximum predicted 4-hour average concentration for ozone, anywhere on the modelled grid, was 40 ppb which is below the relevant NEPM 4-hour average standard (50%). The maximum predicted 4-hour ozone concentration at Onslow is predicted to be even lower at 43% of the NEPM criteria.

Modelling of the BTX pollutants indicate that the predicted ground level concentrations is very low with benzene having the highest predicted impact on the model grid at 8.4% of the applicable NEPM investigation level.

During start-up operations the model is predicting that the maximum 1-hour concentration for O_3, anywhere on the modelled grid will be slightly less to that under normal operating conditions (with shiploading), at 43% of the applicable NEPM criteria. The maximum predicted 1-hour ozone concentration at Onslow is predicted to be 38% of the NEPM criteria.

During an emergency shutdown (Condition 2) event the model is predicting that the maximum 24-hour concentration for PM_{10}, anywhere on the modelled grid, will increase by 1 $\mu g/m^3$ to 28 $\mu g/m^{3,}$ or 55% of the applicable NEPM criteria. The maximum predicted 24-hour PM_{10} concentration at Onslow is predicted to be even lower at 50% of the NEPM criteria.

10.4. Cumulative Air Quality Impacts

Dispersion modelling was also conducted to determine the potential cumulative air quality impacts assuming an additional gas processing facility and a Domgas plant located adjacent and to the south of the proposed Chevron Wheatstone facility. The potential ground-level concentrations resulting from the emissions of these additional gas processing facilities have been modelled utilising the same emission parameters from the fifth LNG train at the proposed Chevron Wheatstone facility while the Domgas facility emissions were taken as identical to that used in the assessment of the Apache Domgas facility at Devils Creek. The results indicate a slight increase in all modelled pollutants though all predicted concentrations are well within the applicable NEPM criteria.

It is important to note that this modelling is only conducted to provide an indication of the potential cumulative impacts of the Chevron Wheatstone facility in combination with potential additional gas processing facilities on adjacent land to the south. Further dispersion modelling will have to be conducted by the proponent/s of these facilities with more detailed emission characteristics.

10.5. Summary of Key Findings

This air quality assessment concludes with the following key findings:

- Normal and non-routine emissions from the proposed Chevron Wheatstone operations are not expected to cause any significant air quality impacts within the study area.
- Throughout the year, no exceedances of the relevant air quality standards are expected for any of the pollutants studied.

Being mindful that further scientific work is required to determine uncertainties for modelling depositions, this assessment has determined that the deposition of NO_2 from the proposed gas processing facility would be insignificant.

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Appendix A Abbreviations and Acronyms

AEC	Australian Environment Council
BoM	Australian Bureau of Meteorology
BTEX	Benzene, toluene, ethylbenzene, and xylene
BEWA 2000	Regional biogenic emissions of reactive volatile organic compounds (BVOC) from forests: Process studies, modelling and validation experiments (Steinbrecher, 2006)
BVOC	Biogenic volatile organic compounds
°C	Degrees Celsius
cal/s	Calories per second
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CO	Carbon monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEC	Western Australian Department of Environment and Conservation
DEWHA	Commonwealth Department of the Environment, Water, Heritage and the Arts
DLE	Dry, Low NO_x
DoE	Western Australian Department of Environment (superseded by the Department of Environment and Conservation)
Domgas	Domestic gas
EA	Environment Australia
EIS/ERMP	Environmental Impact Statement/Environmental Review and Management Programme
EPA	Western Australian Environmental Protection Authority
eq/ha/annum	Acid equivalents per hectare per year
g/m^3	Grams per cubic metre
g/s	Grams per second
H_2O	Water
hPa	Hectopascal
kg	Kilogram
kg/ha	Kilogram per hectare
kg/ha/annum	Kilograms per hectare per year
km	Kilometre
km^2	Square kilometres
LNG	Liquefied natural gas
LPG	Liquid petroleum gas
MAQS	Metropolitan Air Quality Study
$mg/m^2/hr$	Milligrams per square metre per hour
mm	Millimetres
MOF	Material offloading facility
MTPA	Million tonnes per annum
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Centre
NO	Nitric oxide
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide
NO_3^-	Nitrate ion
NOHSC	National Occupational Health and Safety Commission

NO_X	Oxides of nitrogen
NPI	National Pollutant Inventory
O_2	Oxygen molecule
O_3	Ozone
OH^-	Hydroxyl radical
PAH	Polycyclic aromatic hydrocarbon
PAR	Photosynthetically active radiation
Pb	Lead
$PM_{2.5}$	Particulate matter of 2.5 microns or less
PM_{10}	Particulate matter of 10 microns or less
POPs	Persistent organic pollutants
ppb	Parts per billion
ppm	Parts per million
ppmv	Parts per million per volume
SKM	Sinclair Knight Merz
SO_2	Sulfur dioxide
SO_3^{2-}	Sulphate ion
SO_X	Oxides of sulfur
t/yr	Tonnes per year
TAPM	The Air Pollution Model
TIBL	Thermal Internal Boundary Layer
$\mu g/m^2/hr$	Micrograms per square metre per hour
$\mu g/m^3$	Micrograms per cubic metre
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WA	Western Australia
WHO	World Health Organisation

Appendix B Spatial Distribution of Vegetation Types

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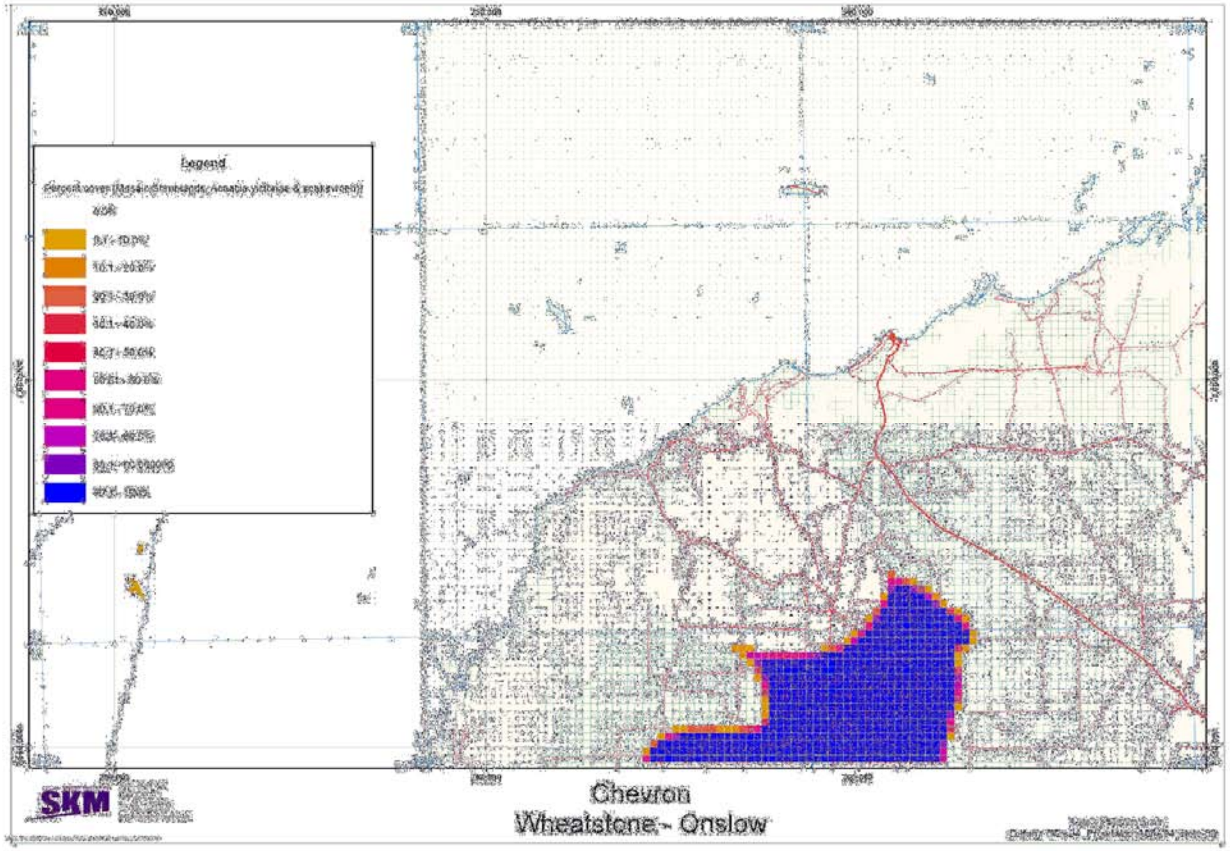


- **Figure B-1 Vegetation density of Acacia Shrubland in the Onslow study region**

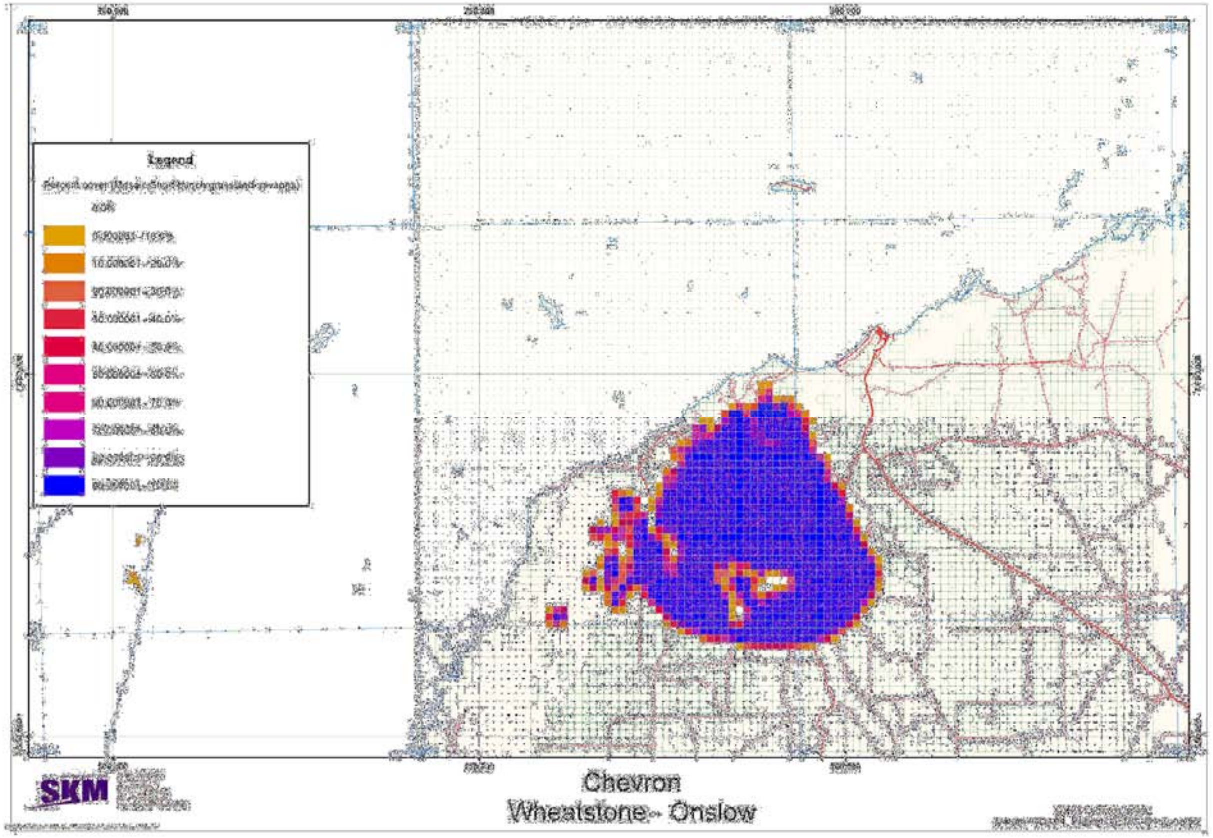
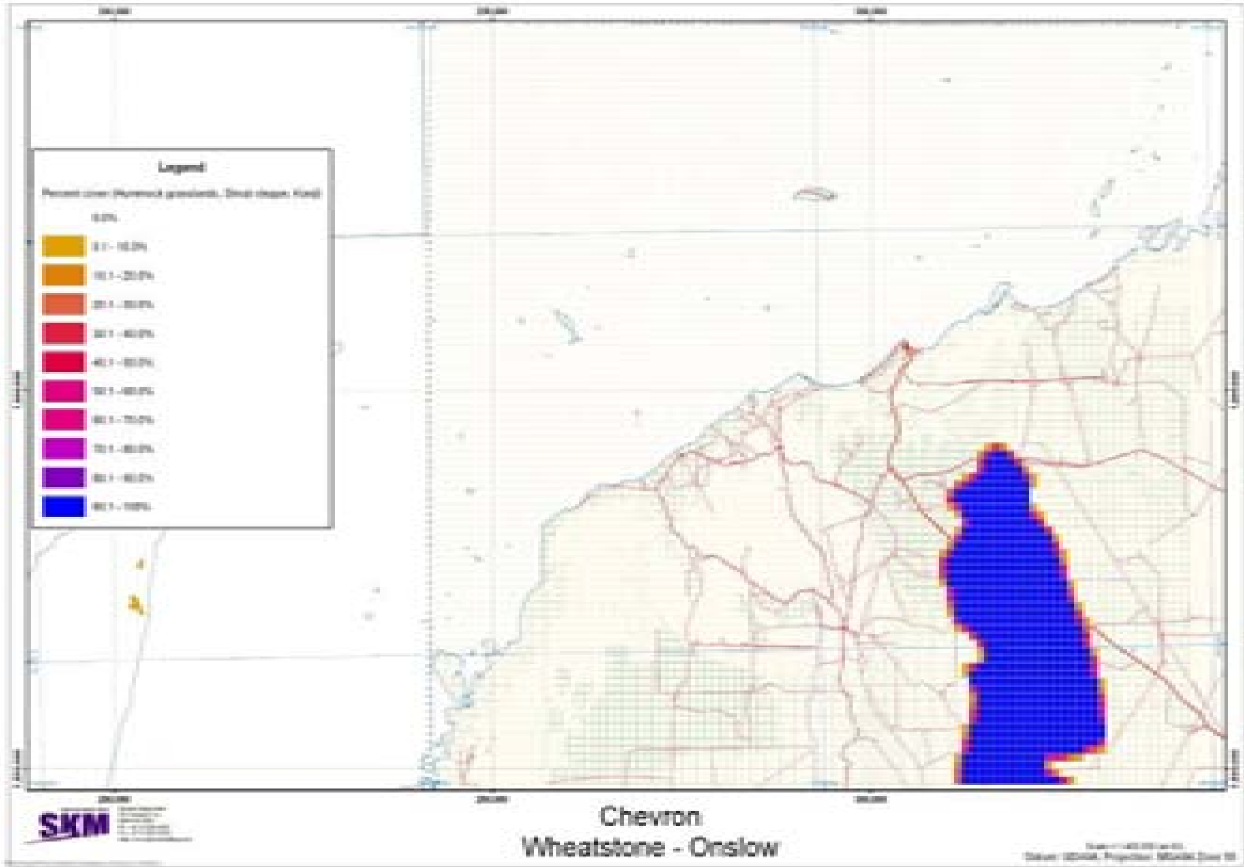
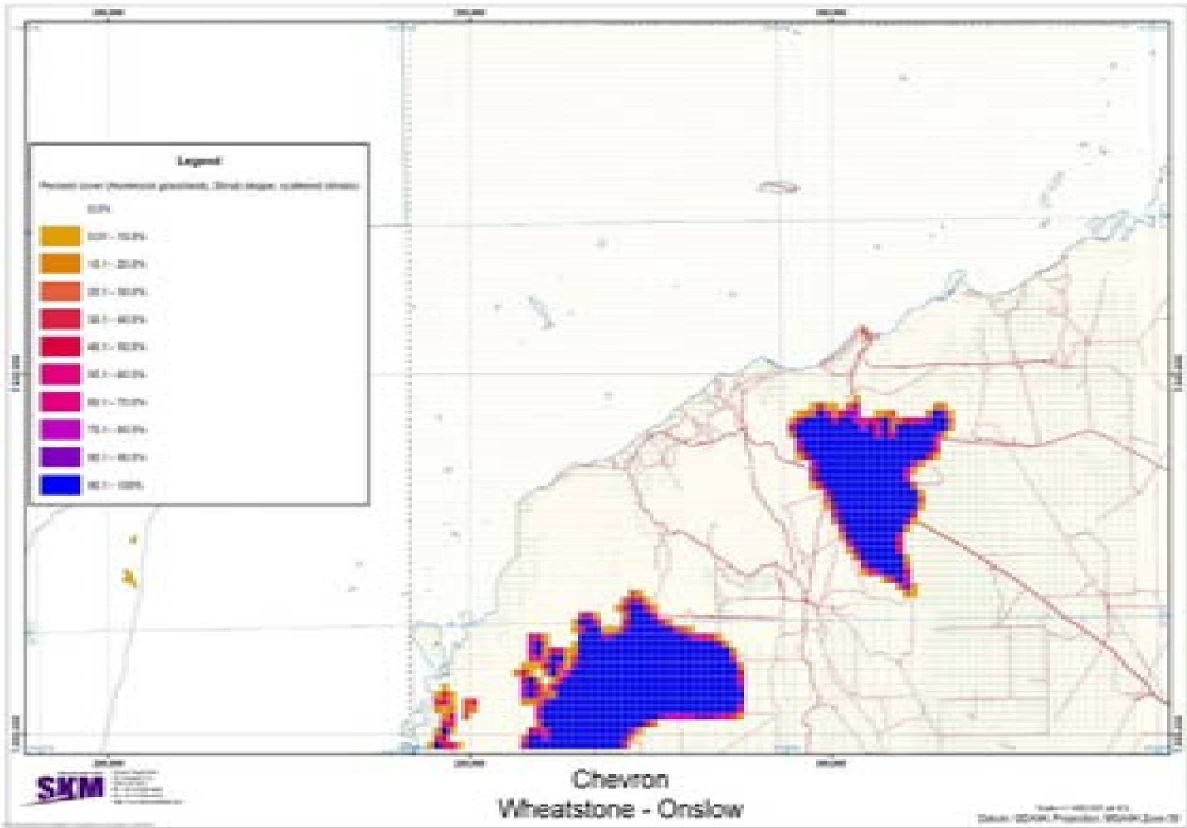


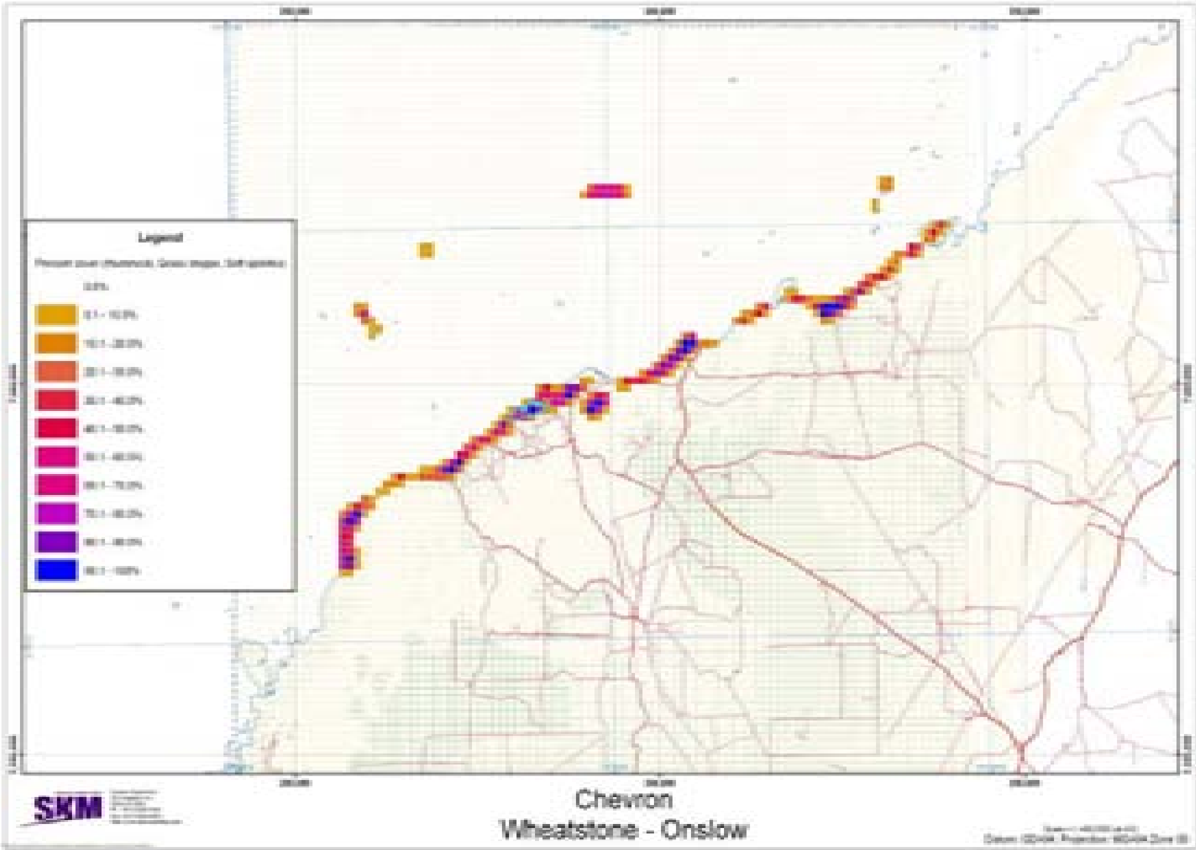
Figure B-2 Vegetation density of Short Bunch Grassland Savannah in the Onslow study region


Legend
Chevron
Wheatstone - Onslow

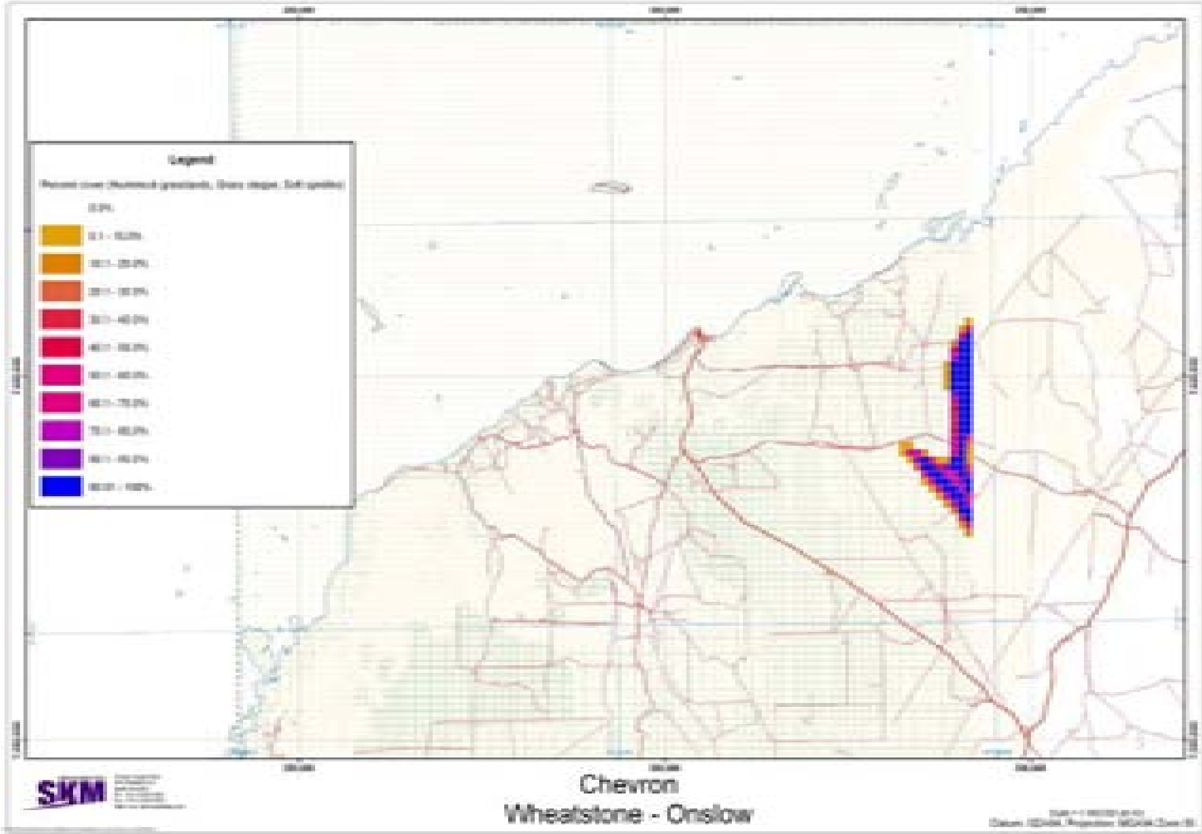
- **Figure B-3 Vegetation density of Hummock Grassland Kanji in the Onslow study region**



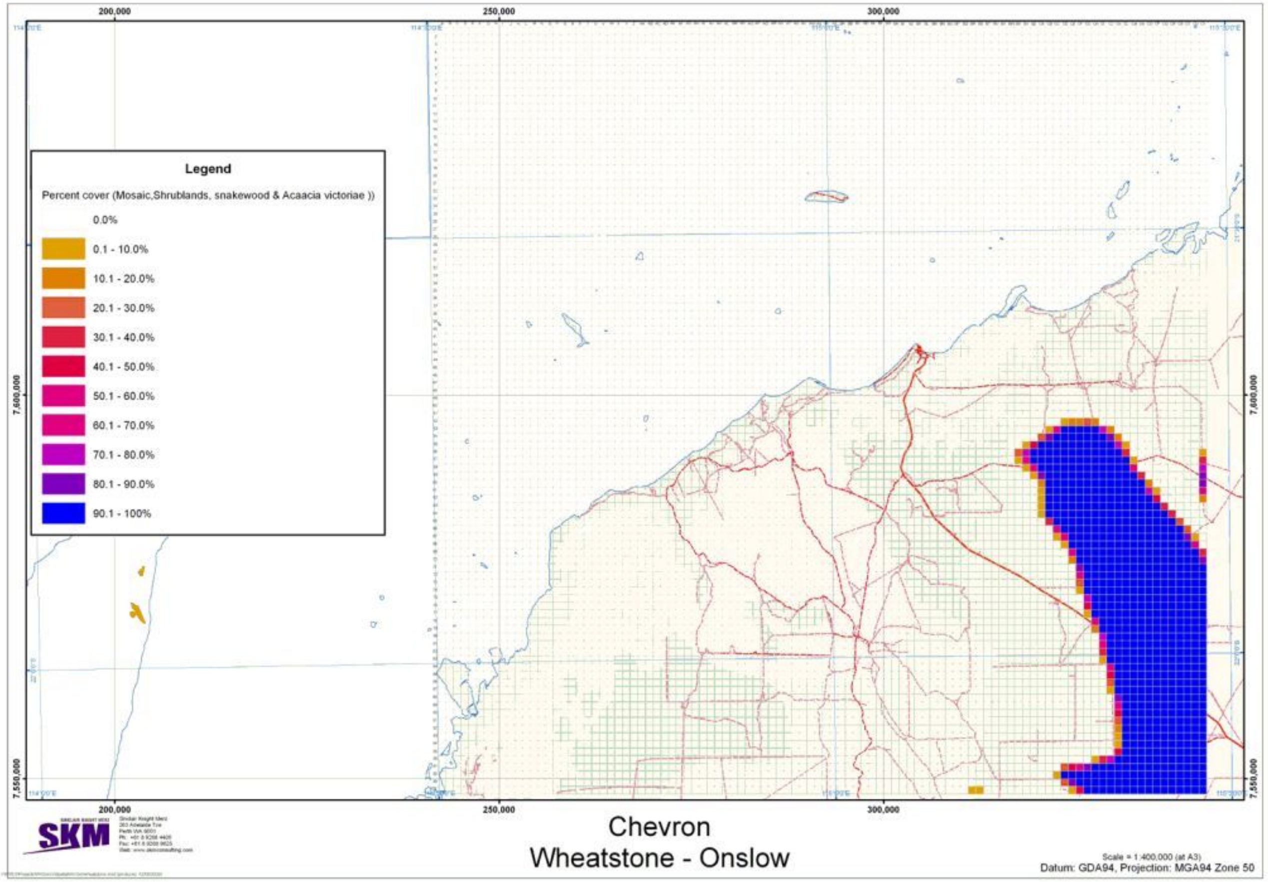
- **Figure B-4 Vegetation density of Hummock Grassland Shrub in the Onslow study region**



- **Figure B-5 Vegetation density of Hummock Grassland Spinifex in the Onslow study region**



■ **Figure B-6 Vegetation density of Hummock Shrubland Spinifex in the Onslow study region**



- **Figure B-7 Vegetation density of Snakewood Shrubland in the Onslow study region**

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Appendix C TAPM *.lis File

```
|---------------------------------------|
| THE AIR POLLUTION MODEL (TAPM V4.0.2). |
| Copyright (C) CSIRO Australia.        |
| All Rights Reserved.                  |
|---------------------------------------|

----------------
RUN INFORMATION:
----------------
NUMBER OF GRIDS=           4
GRID CENTRE (longitude,latitude)=(   114.9917     ,  -21.70833     )
GRID CENTRE (cx,cy)=(      292000 ,     7598000 ) (m)
GRID DIMENSIONS (nx,ny,nz)=(          31 ,          31 ,          25 )
NUMBER OF VERTICAL LEVELS OUTPUT =          15
DATES (START,END)=(    20061230 ,    20070331 )
DATE FROM WHICH OUTPUT BEGINS =    20070101
LOCAL HOUR IS GMT+   7.700000
TIMESTEP SCALING FACTOR =   1.000000
VARY SYNOPTIC WITH 3-D SPACE AND TIME
V4 LAND SURFACE SCHEME
EXCLUDE NON-HYDROSTATIC EFFECTS
INCLUDE PROGNOSTIC RAIN EQUATION
EXCLUDE PROGNOSTIC SNOW EQUATION
TKE-EPS TURBULENCE (PROGNOSTIC TKE + EPS, EDMF)
POLLUTION : CHEMISTRY (APM,NOX,NO2,O3,SO2,FPM)
EXCLUDE POLLUTANT VARIANCE EQUATION
EXCLUDE 3-D POLLUTION OUTPUT (*.C3D)
POLLUTANT GRID DIMENSIONS (nxf,nyf)=(          57 ,          57 )
BACKGROUND APM    =  0.0000000E+00 (ug/m3)
BACKGROUND NOX&NO2=  0.0000000E+00 (ppb)
BACKGROUND O3     =   20.00000     (ppb)
BACKGROUND Rsmog  =  0.2000000     (ppb)
BACKGROUND SO2    =  0.0000000E+00 (ppb)
BACKGROUND FPM    =   5.000000     (ug/m3)
pH of liquid water=   4.500000

---------------------------------
START GRID           1 CWheat300a
METEOROLOGY IS BEING INPUT FROM *.M3D FILES
GRID SPACING (delx,dely)=(       30000 ,       30000 ) (m)
POLLUTANT GRID SPACING (delxf,delyf)=(       15000 ,       15000 ) (m)
NO CONCENTRATION BACKGROUND FILE AVAILABLE
NO BUILDING FILE AVAILABLE
NUMBER OF pse SOURCES=          56
NO lse EMISSION FILE AVAILABLE
NO ase EMISSION FILE AVAILABLE
USING gse EMISSIONS AND MIXING THEM OVER FIRST           1 LEVEL(S)
NO bse EMISSION FILE AVAILABLE
NO whe EMISSION FILE AVAILABLE
NO vpx EMISSION FILE AVAILABLE
NO vdx EMISSION FILE AVAILABLE
```

```
 NO vlx EMISSION FILE AVAILABLE
 NO vpv EMISSION FILE AVAILABLE
 INITIALISE
 LARGE TIMESTEP =   300.0000
 METEOROLOGICAL ADVECTION TIMESTEP =   300.0000     (s)
 POLLUTION ADVECTION TIMESTEP =   300.0000     (s)
 pse KEY :
 is     = Source Number
 ls     = Source Switch (-1=Off,0=EGM,1=EGM+LPM)
 xs,ys = Source Position (m)
 hs     = Source Height (m)
 rs     = Source Radius (m)
 es     = Buoyancy Enhancement Factor
 fs_no = Fraction of NOX Emitted as NO
 fs_fpm= Fraction of APM Emitted as FPM
 INIT_pse
  is,  ls,       xs,       ys,       hs,       rs,       es,    fs_no,
fs_fpm
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0.50,
   2,    0,  293211., 7599460.,    28.30,     1.30,     1.00,     0.90,
0.50,
   3,    0,  293225., 7599456.,    28.30,     1.30,     1.00,     0.90,
0.50,
   4,    0,  293240., 7599452.,    28.30,     1.30,     1.00,     0.90,
0.50,
   5,    0,  293254., 7599448.,    28.30,     1.30,     1.00,     0.90,
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0.50,
   7,    0,  292971., 7599423.,    28.30,     1.30,     1.00,     0.90,
0.50,
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0.50,
   9,    0,  292959., 7599376.,    28.30,     1.30,     1.00,     0.90,
0.50,
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0.50,
  11,    0,  292947., 7599330.,    28.30,     1.30,     1.00,     0.90,
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0.50,
  13,    0,  292677., 7599339.,    87.00,     0.70,     1.00,     0.90,
0.50,
  14,    0,  292677., 7599339.,    87.00,     0.70,     1.00,     0.90,
0.50,
  15,    0,  293069., 7600000.,    13.10,     0.00,     1.00,     0.90,
0.50,
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0.50,
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0.50,
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0.50,
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21,	0,	293181.,	7599233.,	28.30,	1.30,	1.00,	0.90,	0.50,
22,	0,	293195.,	7599229.,	28.30,	1.30,	1.00,	0.90,	0.50,
23,	0,	293210.,	7599225.,	28.30,	1.30,	1.00,	0.90,	0.50,
24,	0,	293437.,	7599756.,	35.00,	0.40,	1.00,	0.90,	0.50,
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26,	0,	293093.,	7599021.,	28.30,	1.30,	1.00,	0.90,	0.50,
27,	0,	293108.,	7599018.,	28.30,	1.30,	1.00,	0.90,	0.50,
28,	0,	293122.,	7599014.,	28.30,	1.30,	1.00,	0.90,	0.50,
29,	0,	293137.,	7599010.,	28.30,	1.30,	1.00,	0.90,	0.50,
30,	0,	293151.,	7599006.,	28.30,	1.30,	1.00,	0.90,	0.50,
31,	0,	292841.,	7598935.,	28.30,	1.30,	1.00,	0.90,	0.50,
32,	0,	292594.,	7599030.,	87.00,	0.80,	1.00,	0.90,	0.50,
33,	0,	292594.,	7599030.,	87.00,	0.80,	1.00,	0.90,	0.50,
34,	0,	293043.,	7599904.,	13.10,	0.00,	1.00,	0.90,	0.50,
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36,	0,	293530.,	7599731.,	35.00,	0.40,	1.00,	0.90,	0.50,
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38,	0,	293034.,	7598802.,	28.30,	1.30,	1.00,	0.90,	0.50,
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41,	0,	293078.,	7598791.,	28.30,	1.30,	1.00,	0.90,	0.50,
42,	0,	293092.,	7598787.,	28.30,	1.30,	1.00,	0.90,	0.50,
43,	0,	292834.,	7598912.,	28.30,	1.30,	1.00,	0.90,	0.50,
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45,	0,	292961.,	7598587.,	28.30,	1.30,	1.00,	0.90,	0.50,

SKM

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0.50,
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0.50,
  50,   0,  293034., 7598567.,    28.30,     1.30,     1.00,     0.90,
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0.50,
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0.50,
  53,   0,  292511., 7598721.,    87.00,     0.60,     1.00,     0.90,
0.50,
  54,   0,  292511., 7598721.,    87.00,     0.60,     1.00,     0.90,
0.50,
  55,   0,  292747., 7598690.,    50.00,     1.30,     1.00,     0.90,
0.50,
  56,   0,  293719., 7599678.,    35.00,     0.40,     1.00,     0.90,
0.50,
 LAGRANGIAN (LPM) MODE IS OFF FOR THIS GRID
 IN_pse
 IN_gse
 DATE=20061230,HOUR= 1
 IN_pse
 REWIND_pse
 IN_gse
 REWIND_gse
 IN_gse
 IN_SYNOPTIC
```

Appendix D Emission Files

D.1 Emissions During Normal Operations without Shiploading

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Train 1										
Compressor LM6000	293197	7599464	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293211	7599461	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293226	7599457	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293240	7599453	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293255	7599449	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293269	7599445	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Power Generator LM6000	292972	7599423	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Power Generator LM6000	292966	7599400	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Dry Gas Flare	292678	7599340	125	0.71	1273	20.0	0.50	0.00	0.31	0.0043
Wet Gas Flare	292678	7599340	125	0.71	1273	20.0	0.50	0.00	0.31	0.0043
Marine Flare	293070	7600001	25	0.00	0	0.0	0.00	0.00	0.00	0.0000
Start up Hot Oil Heater	293005	7599653	50	1.25	0	0.0	0.00	0.00	0.00	0.0000
Domgas Acid Gas Incinerator	293343	7599781	35	0.42	624	13.2	0.00	0.00	0.10	0.0031
Acid Gas Thermal Oxidiser	293085	7599581	35	0.42	624	13.2	0.00	0.26	0.05	0.0000
Train 2										
Compressor LM6000	293137	7599245	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293152	7599241	50	1.33	732	31.0	0.23	0.00	5.50	0.0000

SKM

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Compressor LM6000	293166	7599237	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293181	7599233	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293195	7599229	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293210	7599225	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Power Generator LM6000	293149	7599795	36	1.33	802	31.0	0.13	0.00	4.40	0.0000
Power Generator LM6000	293134	7599769	36	1.33	802	31.0	0.13	0.00	4.40	0.0000
Domgas Acid Gas Incinerator	293437	7599756	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	293026	7599362	35	0.42	624	13.2	0.00	0.26	0.05	0.0000
Train 3										
Compressor LM6000	293079	7599025	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293093	7599021	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293108	7599018	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293122	7599014	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293137	7599010	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293151	7599006	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293166	7599002	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Power Generator LM6000	292841	7598935	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Power Generator LM6000	292826	7598909	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Dry Gas Flare	292594	7599030	125	0.80	1273	20.0	0.63	0.00	0.39	0.0054
Wet Gas Flare	292594	7599030	125	0.80	1273	20.0	0.63	0.00	0.39	0.0054

SKM

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Marine Flare	293043	7599904	25	0.00	1273	20.0	0.00	0.00	0.00	0.0000
Start up Hot Oil Heater	292874	7599165	50	1.25	0	0.0	0.00	0.00	0.00	0.0000
Domgas Acid Gas Incinerator	293530	7599731	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	292967	7599142	35	0.42	624	13.2	0.00	0.26	0.05	0.0000
Train 4										
Compressor LM6000	293020	7598806	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293034	7598802	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293049	7598798	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293063	7598794	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293078	7598791	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293092	7598787	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293106	7598783	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Power Generator LM6000	292834	7598912	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Domgas Acid Gas Incinerator	293625	7599703	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	292967	7599142	35	0.42	624	13.2	0.00	0.26	0.05	0.0000
Train 5										
Compressor LM6000	292961	7598587	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	292976	7598583	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	292990	7598579	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293005	7598575	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293019	7598571	50	1.33	732	31.0	0.23	0.30	5.50	0.0000

Source	Location[1] (east)	Location[1] (north)	Height (m)	Radius (m)	Temp (K)	Exit Vel (m/s)	PM_{10} (g/s)	SO_2 (g/s)	NO_x (g/s)	Rsmog (g/s)
Compressor LM6000	293034	7598567	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293048	7598563	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Power Generator LM6000	292828	7598888	36	1.33	802	31.0	0.13	0.20	4.40	0.0000
Power Generator LM6000	292822	7598865	36	1.33	802	31.0	0.13	0.20	4.40	0.0000
Dry Gas Flare	292511	7598721	125	0.56	1273	20.0	0.32	0.00	0.20	0.0027
Wet Gas Flare	292511	7598721	125	0.56	1273	20.0	0.32	0.00	0.20	0.0027
Start up Hot Oil Heater	292747	7598690	50	1.25	0	0.0	0.00	0.00	0.00	0.0000
Domgas Acid Gas Incinerator	293719	7599678	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	292850	7598704	35	0.42	624	13.2	0.00	0.26	0.05	0.0000

Note [1] Coordinates are in UTM zone 50

D.2 Emissions During Shiploading

Source	Location[1] (east)	Location[1] (north)	Height (m)	Radius (m)	Temp (K)	Exit Vel (m/s)	PM_{10} (g/s)	SO_2 (g/s)	NO_x (g/s)	Rsmog (g/s)
Train 1										
Compressor LM6000	293197	7599464	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293211	7599461	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293226	7599457	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293240	7599453	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293255	7599449	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293269	7599445	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Power Generator LM6000	292972	7599423	36	1.33	802	31.2	0.13	0.00	4.40	0.0000

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Power Generator LM6000	292966	7599400	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Dry Gas Flare	292678	7599340	125	0.71	1273	20.0	0.50	0.00	0.31	0.0043
Wet Gas Flare	292678	7599340	125	0.71	1273	20.0	0.50	0.00	0.31	0.0043
Marine Flare	293070	7600001	25	0.82	1273	20.0	0.66	0.00	0.41	0.0057
Start up Hot Oil Heater	293005	7599653	50	1.25	0	0.0	0.00	0.00	0.00	0.0000
Domgas Acid Gas Incinerator	293343	7599781	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	293085	7599581	35	0.42	624	13.2	0.00	0.26	0.05	0.0000
Train 2										
Compressor LM6000	293137	7599245	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293152	7599241	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293166	7599237	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293181	7599233	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293195	7599229	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293210	7599225	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Power Generator LM6000	293149	7599795	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Power Generator LM6000	293134	7599769	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Domgas Acid Gas Incinerator	293437	7599756	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	293026	7599362	35	0.42	624	13.2	0.00	0.26	0.05	0.0000
Train 3										
Compressor LM6000	293079	7599025	50	1.33	732	31.0	0.23	0.00	5.50	0.0000

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Compressor LM6000	293093	7599021	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293108	7599018	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293122	7599014	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293137	7599010	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293151	7599006	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293166	7599002	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Power Generator LM6000	292841	7598935	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Power Generator LM6000	292826	7598909	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Dry Gas Flare	292594	7599030	125	0.80	1273	20.0	0.63	0.00	0.39	0.0054
Wet Gas Flare	292594	7599030	125	0.80	1273	20.0	0.63	0.00	0.39	0.0054
Marine Flare	293043	7599904	25	0.92	1273	20.0	0.84	0.00	0.41	0.0072
Start up Hot Oil Heater	292874	7599165	50	1.25	0	0.0	0.00	0.00	0.00	0.0000
Domgas Acid Gas Incinerator	293530	7599731	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	292967	7599142	35	0.42	624	13.2	0.00	0.26	0.05	0.0000
Train 4										
Compressor LM6000	293020	7598806	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293034	7598802	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293049	7598798	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293063	7598794	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293078	7598791	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Compressor LM6000	293092	7598787	50	1.33	732	31.0	0.23	0.00	5.50	0.0000

Source	Location[1] (east)	Location[1] (north)	Height (m)	Radius (m)	Temp (K)	Exit Vel (m/s)	PM_{10} (g/s)	SO_2 (g/s)	NO_x (g/s)	Rsmog (g/s)
Compressor LM6000	293106	7598783	50	1.33	732	31.0	0.23	0.00	5.50	0.0000
Power Generator LM6000	292834	7598912	36	1.33	802	31.2	0.13	0.00	4.40	0.0000
Domgas Acid Gas Incinerator	293625	7599703	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	292967	7599142	35	0.42	624	13.2	0.00	0.26	0.05	0.0000
Train 5										
Compressor LM6000	292961	7598587	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	292976	7598583	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	292990	7598579	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293005	7598575	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293019	7598571	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293034	7598567	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293048	7598563	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Power Generator LM6000	292828	7598888	36	1.33	802	31.2	0.13	0.20	4.40	0.0000
Power Generator LM6000	292822	7598865	36	1.33	802	31.2	0.13	0.20	4.40	0.0000
Dry Gas Flare	292511	7598721	125	0.56	1273	20.0	0.32	0.00	0.20	0.0027
Wet Gas Flare	292511	7598721	125	0.56	1273	20.0	0.32	0.00	0.20	0.0027
Start up Hot Oil Heater	292747	7598690	50	1.25	0	0.0	0.00	0.00	0.00	0.0000
Domgas Acid Gas Incinerator	293719	7599678	35	0.42	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	292850	7598704	35	0.42	624	13.2	0.00	0.26	0.05	0.0000

Note [1] Coordinates are in UTM zone 50

D.3 Emissions of Benzene, Toluene, Xylene

Pollutant	AGRU Thermal Oxidisers	AGRU Thermal Oxidisers	Domgas AGRU Thermal Oxidisers	Domgas AGRU Thermal Oxidisers
	Trains 1 & 2	Trains 3-5	Trains 1 & 2	Trains 3-5
	Per train	Per train	1 Domgas for T1 & T2	Per train
	(g/s)	(g/s)	(g/s)	(g/s)
Benzene	0.136	0.165	0.026	0.016
Toluene	0.499	0.606	0.096	0.058
p-xylene	0.121	0.146	0.023	0.014
m-xylene	0.120	0.145	0.023	0.014
o-xylene	0.058	0.071	0.011	0.007

D.4 Emissions During Start Up

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Train 5										
Compressor LM6000	292961	7598587	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	292976	7598583	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	292990	7598579	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293005	7598575	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293019	7598571	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293034	7598567	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Compressor LM6000	293048	7598563	50	1.33	732	31.0	0.23	0.30	5.50	0.0000
Power Generator	292828	7598888	36	1.33	802	31.0	0.13	0.20	4.40	0.0000

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Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
LM6000										
Power Generator LM6000	292822	7598865	36	1.33	802	31.0	0.13	0.20	4.40	0.0000
Dry Gas Flare	292511	7598721	125	10.26	1273	20.0	105.07	0.00	65.36	0.9016
Wet Gas Flare	292511	7598721	125	10.26	1273	20.0	0.00	0.00	0.00	0.0000
Start up Hot Oil Heater	292747	7598690	50	1.25	570	17.0	0.04	0.00	0.59	0.0000
Domgas Acid Gas Incinerator	293719	7599678	35	35.00	624	13.2	0.00	0.00	0.10	0.0000
Acid Gas Thermal Oxidiser	292850	7598704	35	35.00	624	13.2	0.00	0.26	0.05	0.0000

Note [1] Coordinates are in UTM zone 50

D.5 Emissions During Emergency Shut Down

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Train 5										
Compressor LM6000	292961	7598587	50	1.33	732	31.0	0.00	0.00	0.00	0.0000
Compressor LM6000	292976	7598583	50	1.33	732	31.0	0.00	0.00	0.00	0.0000
Compressor LM6000	292990	7598579	50	1.33	732	31.0	0.00	0.00	0.00	0.0000
Compressor LM6000	293005	7598575	50	1.33	732	31.0	0.00	0.00	0.00	0.0000
Compressor LM6000	293019	7598571	50	1.33	732	31.0	0.00	0.00	0.00	0.0000
Compressor LM6000	293034	7598567	50	1.33	732	31.0	0.00	0.00	0.00	0.0000
Compressor LM6000	293048	7598563	50	1.33	732	31.0	0.00	0.00	0.00	0.0000
Power Generator LM6000	292828	7598888	36	1.33	802	31.0	0.00	0.00	0.00	0.0000

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Power Generator LM6000	292822	7598865	36	1.33	802	31.0	0.00	0.00	0.00	0.0000
Dry Gas Flare	292511	7598721	125	14.52	1273	20.0	210.15	0.00	130.72	1.8032
Wet Gas Flare	292511	7598721	125	14.52	1273	20.0	0.00	0.00	0.00	0.0000
Start up Hot Oil Heater	292747	7598690	50	1.25	0	0.0	0.00	0.00	0.00	0.0000
Domgas Acid Gas Incinerator	293719	7599678	35	0.42	624	13.2	0.00	0.00	0.00	0.0000
Acid Gas Thermal Oxidiser	292850	7598704	35	0.42	624	13.2	0.00	0.00	0.00	0.0000

Note [1] Coordinates are in UTM zone 50

D.6 Emissions from Facilities Adjacent to the Wheatstone Project

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
Exxon (6 MTPA)										
Compressor LM6000	292881	7598387	28	1.3	772	23.1	0.56	0.00	3.49	0.0017
Compressor LM6000	292896	7598383	28	1.3	772	23.1	0.56	0.00	3.49	0.0017
Compressor LM6000	292910	7598379	28	1.3	772	23.1	0.56	0.00	3.49	0.0017
Compressor LM6000	292925	7598375	28	1.3	772	23.1	0.56	0.00	3.49	0.0017
Compressor LM6000	292939	7598371	28	1.3	772	23.1	0.56	0.00	3.49	0.0017
Compressor LM6000	292954	7598367	28	1.3	772	23.1	0.56	0.00	3.49	0.0017
Power Generator	292678	7598488	28	1.3	893	31.2	0.56	0.00	2.58	0.0013

Source	Location[1]		Height	Radius	Temp	Exit Vel	PM_{10}	SO_2	NO_x	Rsmog
	(east)	(north)	(m)	(m)	(K)	(m/s)	(g/s)	(g/s)	(g/s)	(g/s)
LM6000										
Power Generator LM6000	292672	7598465	28	1.3	893	31.2	0.56	0.00	2.58	0.0013
Dry Gas Flare	292421	7598471	87	0.6	1273	20.0	0.35	0.00	0.22	0.0027
Wet Gas Flare	292421	7598471	87	0.6	1273	20.0	0.00	0.00	0.00	0.0000
Domgas										
Power Generator 1	292528	7598088	13	0.8	23.5	783	0.00	0.00	0.75	0.0000
Power Generator 2	292522	7598065	13	0.8	23.5	783	0.00	0.00	0.75	0.0000
Compressor 1	292801	7598187	13	0.8	16	633	0.00	0.00	0.75	0.0000
Compressor 2	292816	7598183	13	0.8	16	633	0.00	0.00	0.75	0.0000
Elevated Flare	292331	7598221	48	0.8	20	1273	0.00	0.00	0.77	0.0014
Ground Flare	292331	7598221	20	0.8	20	1273	0.00	0.00	0.77	0.0014

Note [1] Coordinates are in UTM zone 50

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Wheatstone Project Lighting Emissions Study

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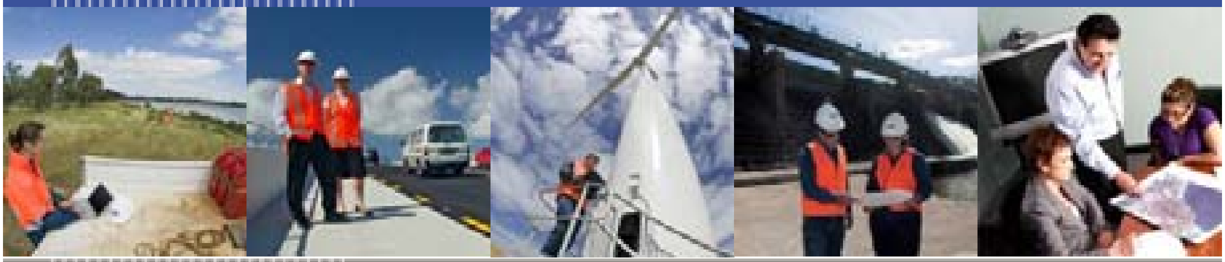

Report

Wheatstone Project Lighting Emissions Study

21 MAY 2010

Prepared for

Chevron Australia Pty Ltd

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42907466

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Introduction

1.1 Wheatstone Project

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.

1.2 Anticipated Lighting Requirements and Regime

It is anticipated that production at the Ashburton North Strategic Industrial Area (Ashburton North SIA) will operate 24 hours per day. Illumination will be required for processes and safe movement of personnel and vehicles. Flares will also contribute to the illumination of the site.

Offshore illumination will include flares and artificial lighting on wellhead platforms, the central processing platform complex, the approach to Materials Offloading Facility (MOF) and Jetty.

1.3 Objectives of the Light Emissions Study

This study aims to provide an overview of light emissions for the Wheatstone project, specifically:

- Light emissions and pollution;
- Potential impacts of lighting on flora and fauna;
- Review of literature relating to impact of light;
- Safety (e.g. requirement for lighting over stairways);
- Visual impact of the lighting equipment;
- Effect of light spillage on surrounding properties;
- Effect of light spillage into the night sky; and
- Interference with adjacent transport routes.

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Light Emission Overview

2.1 Light Theory

Light is part of the electromagnetic spectrum, which is a collection of waves, including visible light, microwaves, radio waves (AM, FM, SW), X-Rays, and Gamma Rays (refer Figure 2-1[a]).

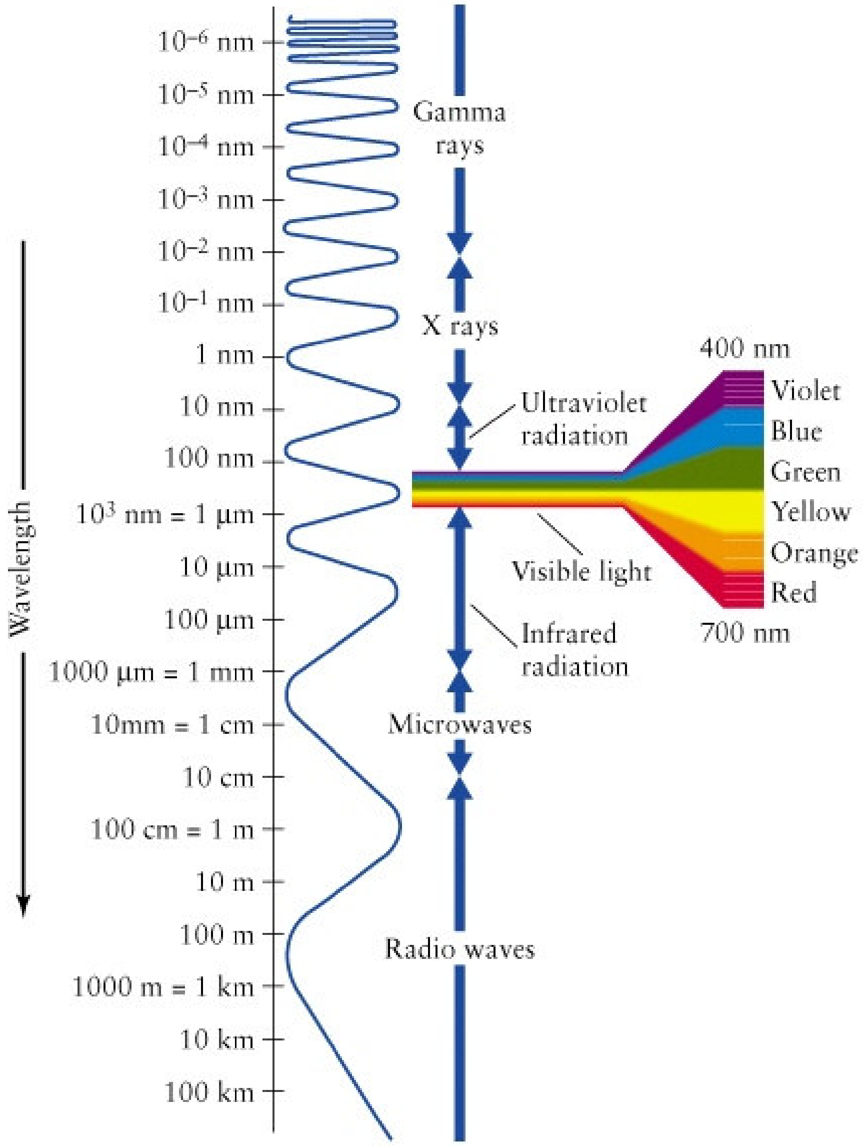


Figure 2-1 Wavelength of Electromagnetic Radiation

[a] http://eosweb.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html

2 Light Emission Overview

Anthropogenic light sources emit in the visible range of the electromagnetic spectrum. Visible light falls between short wavelength ultra-violet (<400 nm[b]) and long wavelength infra-red (>700 nm) radiation in Table 2-1 below. However, the human eye has different sensitivities to light of different wavelengths within the spectrum.

The amount of photopic light falling on a unit of area over a given distance is termed illuminance and is measured in lumens/m^2 or Lux. Lux is a measure of the power of visible light and depends on the sensitivity of the human eye. It is based on the CIE[c] Luminous Efficacy Curve for photopic (light adapted) conditions. The CIE curve has minimal response to light at the ends of the spectrum (400-500 nm and 625-700 nm) and has a peak response at 555 nm. The quantification of irradiance in Lux includes little of the total radiant flux between 400-500 nm and 625-700 nm.

Table 2-1 Spectral wavelengths of visible light

<400nm	400-450nm	450-500nm	500-570nm	570-590nm	590-610nm	610-700nm	>700nm
ultraviolet	violet	blue	green	yellow	orange	red	infra-red

Lights are generally described using a spectral power distribution curve. This is a visual profile of the colour characteristics of a specific light source. A light source emits different amounts of energy at each wavelength across the visual spectrum (380 nm-780 nm).

The maximum reception of light energy occurs at a wavelength of 555 nm (green light) and decreases to a minimum at the two extremes of the visible light spectrum (refer Figure 2-2[d]).

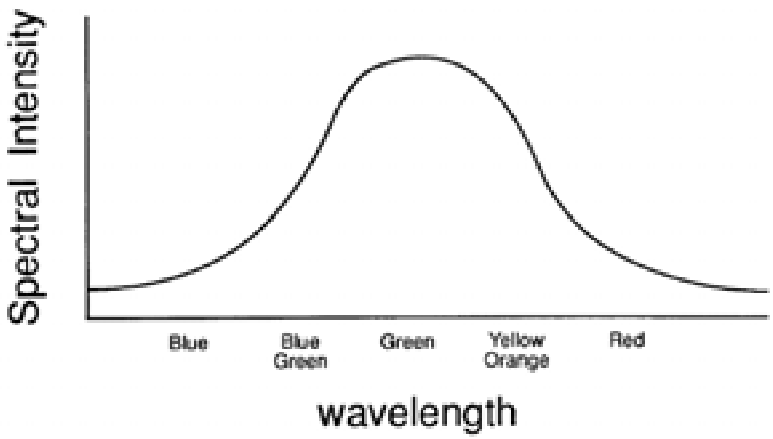


Figure 2-2 Relation between spectral Intensity vs. Wavelength

[b] A nanometre (nm) is a unit of length in the metric system, equal to one billionth of a meter (1×10^{-9} m)
[c] The International Commission on Illumination (usually known as the CIE for its French name *Commission internationale de l'éclairage*), is the international authority on light, illumination, color, and color spaces.
[d] A Comparison of Light Intensity Measurements of Different Light Sources

2 Light Emission Overview

There are many sources of light. The most common light sources are thermal - a body at a given temperature emits a characteristic spectrum of black-body radiation. Examples include sunlight, incandescent light bulbs and glowing solid particles in flames[e].

2.1.1 Lighting fundamentals

The four primary properties of light are:

- **Intensity** - luminous intensity is a measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle, based on the luminosity function, a standardized model of the sensitivity of the human eye. The SI unit of luminous intensity is the candela (cd);
- **Frequency or wavelength** - the **wavelength** of a sinusoidal wave is the spatial period of the wave – the distance over which the wave's shape repeats. Wavelength is inversely proportional to frequency, i.e. waves with higher frequencies have shorter wavelengths, and lower frequencies have longer wavelengths;
- **Polarisation** - polarisation is a property of waves that describes the orientation of their oscillations. By convention, the polarization of light is described by specifying the direction of the wave's electric field. When light travels in free space, in most cases it propagates as a transverse wave—the polarization is perpendicular to the wave's direction of travel.; and
- **Phase** - the fraction of a complete cycle corresponding to an offset in the displacement from a specified reference point at time t = 0. Phase is a frequency domain or Fourier transform domain concept

Light Output

The most common measure of light output (or luminous flux) is the lumen. Light sources are labelled with an output rating in lumens. Most lamp ratings are based on "initial" lumens (i.e., when the lamp has been operated for 100 hours). As lamps and fixtures age, and become dirty, their lumen output decreases (lumen depreciation).

Light Level

Light intensity measured on a plane at a specific location is called illuminance. Lux is the metric unit for illuminance, measured in lumens per square meter

Quality of Illumination[f]

- **Glare -** Perhaps the most important factor with respect to lighting quality is glare. Glare is the sensation, caused by luminances in the visual field that are too bright.
- **Colour Rendition** - The ability to properly see colours is another aspect of lighting quality. Light sources vary in their ability to accurately reflect the true colours of people and objects. The colour rendering index (CRI) scale is used to compare the effect of a light source on the colour appearance of its surroundings. A scale of 0 to 100 defines the CRI. A higher CRI means better colour rendering, or less colour shift. CRIs in the range of 75-100 are considered excellent, while 65-75 are good. The range of 55-65 is fair, and 0-55 is poor. Under higher CRI sources, surface

[e] http://en.wikipedia.org/wiki/Light
[f] http://www.nesllc.com/acrobat/LightingFund.pdf

2 Light Emission Overview

colours appear brighter, improving the aesthetics of the space. Higher CRI sources sometimes create the illusion of higher illuminance levels.

- **Uniformity of Illuminance on Tasks** - The uniformity of illuminance is a quality issue that addresses how evenly light spreads over a task area. Two factors may compromise uniformity:
  - — improper fixture placement based on the luminaire's spacing criteria (ratio of maximum recommended fixture spacing distance to mounting height above task height); and
  - — fixtures that are retrofit with reflectors or louvers that narrow the light distribution.

Efficacy

The efficacy of a lamp refers to the number of lumens leaving the lamp compared to the number of watts required by the lamp (and ballast[9]). It is expressed in lumens per watt. Sources with higher efficacy require less electrical energy to light a space.

Colour Temperature

Colour temperature, is a measurement of "warmth" or "coolness" provided by the lamp. Colour temperature refers to the colour of a blackbody radiator at a given absolute temperature, expressed in Kelvin. A "warm" colour light source actually has a lower colour temperature. For example, a cool-white fluorescent lamp appears bluish in colour with a colour temperature of around 4100 K. A warmer fluorescent lamp appears more yellowish with a colour temperature around 3000 K. Figure 2-3[h] shows the colour temperatures of various artificial light sources.

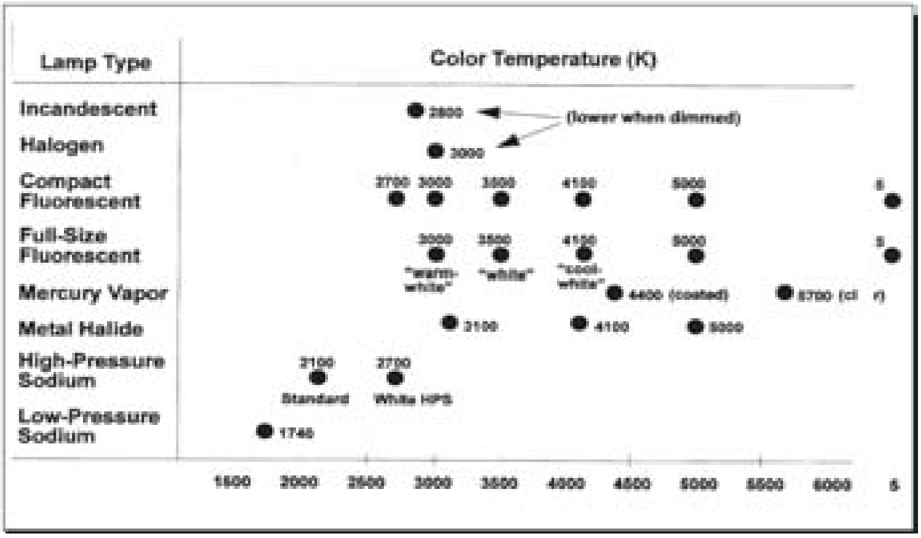


Figure 2-3 Colour temperatures of various light sources

[9] A ballast is a control gear, which is intended to limit the amount of current in an electric circuit.
[h] http://www.nesllc.com/acrobat/LightingFund.pdf

2 Light Emission Overview

The two main sources of light are incandescent and gas discharges. Incandescent sources can be anything that produces light when heated to 1000°K or more. Natural incandescent sources are candle light and the sun. Man made sources are tungsten filament light bulbs (for example, incandescent globes, halogen lamps, etc.).

Passing an electric charge through a gas can also produce light. The colour of the light is a function of the gas used. The intensity of the light is a function of the density of the gas. High pressure light sources will produce a more intense light relative to a low pressure sources (i.e. high pressure sodium vapour vs. low pressure sodium vapour). Common gas discharge sources are sodium vapour, mercury vapour and fluorescent lights.

Table 2-2[i] gives the approximate intensities (surface brightness's) of some natural light sources. Terminology is explained below the table.

Table 2-2 Approximate intensities of some natural light sources

Light Source	Luminance (cd/m^2)	Magnitudes per square	
		Arcsec	Arcmin
Clear daytime sky (at horizon)	3x10^9	-10.7	-19.6
Full Moon	10^4	3	-6
Overcast daytime sky (at horizon)	10^3	5	-4

The magnitude scale measures the brightness both of stars and of the sky. The apparent magnitude (m) of visible stars ranges approximately from m=0 for the brighter stars to m=6 for the fainter naked eye stars.

- Arcsec - Is 1/3600 of a degree and 1/60 of an arcmin. Jupiter usually attains a diameter of 45 to 50 arcsec when closest to Earth.
- Arcmin - This represents 1/60 of a degree. When at its brightest, Jupiter usually displays a diameter near 0.8 arcmin.

2.1.2 Light and distance

The light intensity from a point light source spreads out uniformly in all directions. It is analogous to the surface of an exploding sphere so as you move away from the source, less light reaches you. The intensity at a given distance from the light will be equal to the power output of the light source divided by the surface area of the sphere through which the light has spread (refer Figure 2-4[j]).

[i] Light Pollution: Definition, legislation, measurement, modelling and environmental effects
[j] http://www.pasco.com/file_downloads/experiments/pdf-files/glx/physics/34-Inverse-square-SV.pdf

2 Light Emission Overview

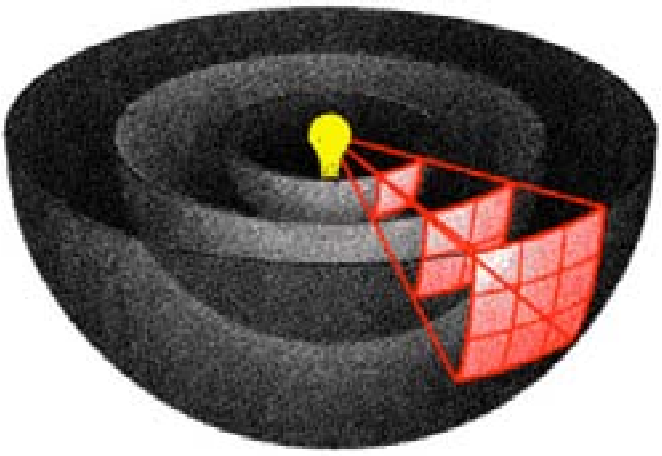


Figure 2-4 Light intensity and distance

The amount of illumination received by a sensor (or eye) varies inversely with the square of the distance from the point source. So if the distance from a point source is doubled the intensity falls off by a factor of four. Tripling the distance decreases the intensity by a factor of nine and so on. As the distance from a point source increases, the intensity of the light that can be detected decreases.

2.1.3 Artificial light sources

White light, such as that produced by electric light sources, consists of a mixture of the different colours of light. Table 2-3[k] lists the characteristics of some of the common artificial light sources.

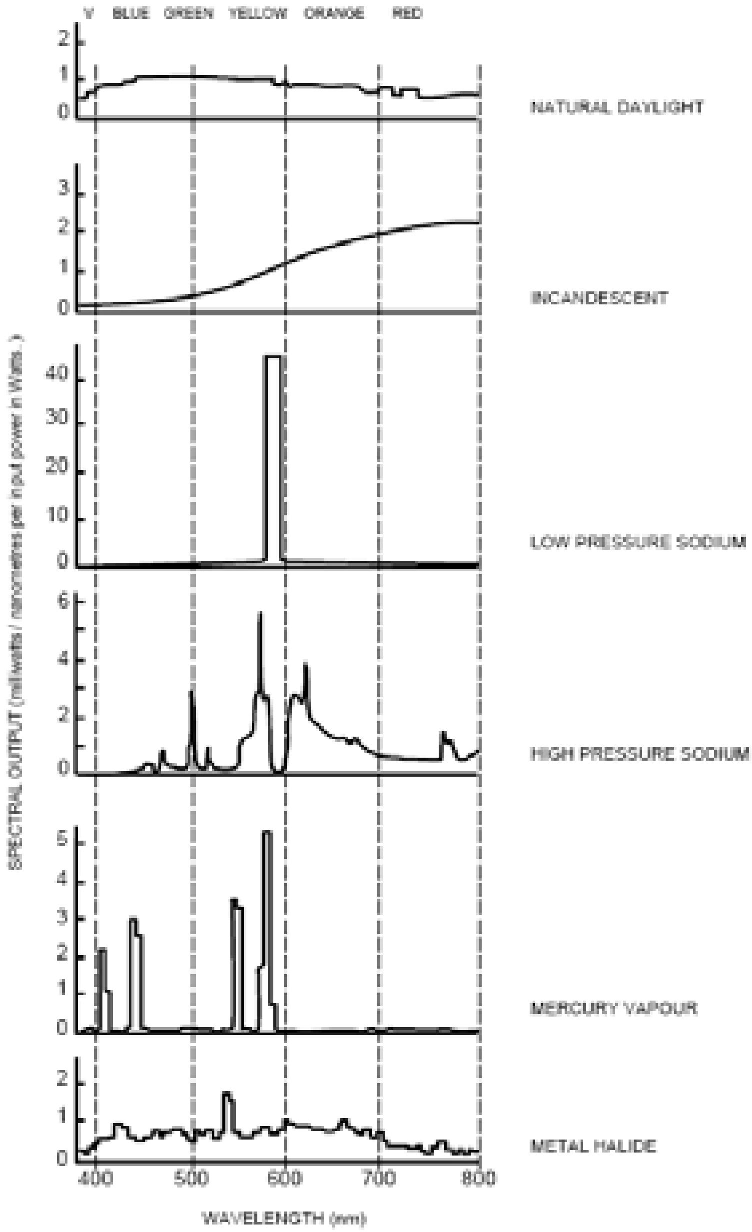
[k] http://www.nesllc.com/acrobat/LightingFund.pdf

2 Light Emission Overview

Table 2-3 Lamp characteristics

	Standard Incandescent	Tungsten-Halogen	Fluorescent	Compact Fluorescent	Mercury Vapor	Metal Halide	High-Pressure Sodium	Low-Pressure Sodium
Wattage	3-1,500	10-1,500	4-215	4-55	40-1,250	32-2,000	35-1,000	18-180
Average System Efficacy (lm/W)	4-24	8-33	49-89	24-68	19-43	38-86	22-115	50-150
Average Rated Life (hrs)	750-2,000	2,000-4,000	7,500-24,000	7,000-20,000	24,000+	6,000-20,000	16,000-24,000	12,000-18,000
CRI	100	100	49-92	82-86	15-50	65-92	21-85	0
Life Cycle Cost	high	high	low	moderate	moderate	moderate	low	low
Fixture Size	compact	compact	extended	compact	compact	compact	compact	extended
Start to Full Brightness	immediate	immediate	0-5 seconds	0-1 min	3-9 min	3-5 min	3-4 min	7-9 min
Restrike Time	immediate	immediate	immediate	immediate	10-20 min	4-20 min	1 min	immediate
Lumen Maintenance	good/excellent	excellent	fair/excellent	good/excellent	poor/fair	good	good/excellent	excellent

2 Light Emission Overview



HISTOGRAMS COMPARING THE TYPICAL SPECTRAL POWER DISTRIBUTION OF THE FIVE ARTIFICIAL LIGHT SOURCES UNDER CONSIDERATION, WITH NATURAL DAYLIGHT

Figure 2-5 Spectral power distribution histograms

2 Light Emission Overview

Figure 2-5 compares the spectral power distribution histograms of five different types of light source with natural daylight. The incandescent, or filament lamp, which includes the tungsten halogen series, offers an output which is particularly rich in the red and orange components, compared with natural daylight, rendering it very “warm”. The incandescent source is compact and requires no control gear. It is available for operation on AC or DC over a wide range of voltages.

The remaining four histograms relate to the outputs of gas discharge lamps. Having no filament, the discharge lamp is more robust than the incandescent source and, for the same reason, has a considerably extended life. Tungsten halogen capsules offer between 25 hours and 2,000 hours life, depending upon type, compared to between five and 10,000 hours for a discharge lamp. The main disadvantage presented by most discharge lamps is the re-start time.

The output from the low pressure sodium lamp is almost exclusively in the yellow components, rendering it unsuitable for most submerged applications. High pressure sodium (HPS) offers a more balanced output but is definitely “warm”, being particularly rich in yellow and having a high orange and red content in relation to natural daylight. Mercury vapour offers a cool output, which is rich in ultra violet radiation. This source is particularly valuable in specialist applications in which the visible light output is absorbed in a filter and the UV is used to cause luminescence in suitable substances.

For the purposes of modelling the light emissions from the Wheatstone Project, it is assumed that 250 W and 400 W HPS lamps are used throughout the site.

2.1.4 High pressure sodium

The HPS is the most efficient lighting source in widespread application. HPS lamps produce light by passing an electrical current through an arc tube filled with vaporized sodium under pressure at high temperature. The light has a colour temperature around 2,000 °K and is a golden yellow. Its physical, electrical and photometric characteristics are different from other high intensity discharge sources.

The shape of HPS lamps is significantly different from mercury vapour and metal halide lamps. HPS lamps have long narrow tube geometry in order to maximize efficiency. The translucent arc tube is made of a ceramic (polycrystalline aluminium oxide) in order to withstand the extremely high temperatures (1,300 °C) generated by the sodium arc.

Advantages of high pressure sodium

HPS lamps have advantages including:

- **Availability** - HPS lamps are manufactured in sizes from 35 to 1,000 watts. In the smaller sizes HPS reflector lamps (PAR 38) can be purchased.
- **Compact Size/High Output** - As with the other HID sources, HPS lamps are a concentrated light source and can be easily controlled.
- **High Efficacy** - Of the widely used lighting sources, HPS lamps have the highest efficacy (70 - 140 lumens/watt).
- **Long Life** - Commercially available HPS lamps have a rated life ranging from 10,000 to 24,000 hours, with the latter being the most prevalent.

Disadvantages of high pressure sodium

HPS lamps exhibit some of the same disadvantages of other HID sources, including:

2 Light Emission Overview

- **Poor Colour Rendering** - While the golden-yellow colour provided by HPS lamps is acceptable for many industrial and outdoor applications, it is not suitable for colour-critical tasks. Colour corrected HPS lamps are now available in limited sizes.
- **Requires Ballast** - Operational characteristics of HPS lamps necessitate special ballasts.
- **Warm-up Period Required**. When a HPS lamp is energized it typically takes about 4 to 6 minutes for it to achieve full lumen output. As with other HID sources, if a momentary power interruption occurs, the lamp must first cool (less than 1 minute) before re-striking.

Figure 2-6[12] shows the spectral distribution of the light produced by a HPS lamp. The lamp shown is rated for 430 W; the actual spectral distribution may vary depending on the globe wattage and the manufacturer.

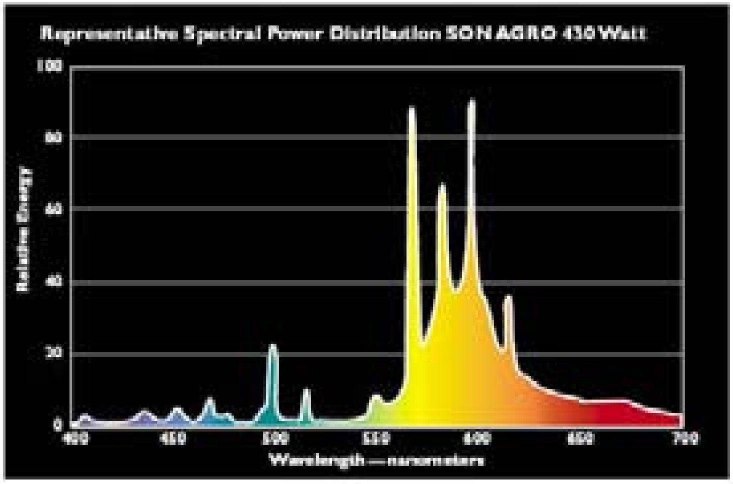


Figure 2-6 Spectral distribution of high pressure sodium light

2.2 Light Pollution

Light pollution, also known as photo-pollution or luminous pollution, encompasses both excessive and misdirected artificial outdoor lighting[13]. Whilst the term "light pollution" has been in use for a number of years, in most circumstances it has referred to the degradation of human views of the night sky (hiding stars). Light pollution is defined as excessive and/or stray artificial light emitted from poorly designed and aimed lighting installations for advertising, business, security and street lighting[14].

The five components of light pollution are often combined and overlapping:

- **Urban sky glow -** the brightening of the night sky over inhabited areas.
- **Light trespass -** light falling where it is not intended, wanted or needed.
- **Glare -** excessive brightness which causes visual discomfort. High levels of glare can decrease visibility.

[12] SON AGRO 430 Watt HPS Lamps
[13] An Introduction to Light Pollution, Hans Vanderknyff
[14] Light Pollution: Definition, legislation, measurement, modelling and environmental effects

2 Light Emission Overview

- **Clutter -** bright, confusing, and excessive groupings of light sources, commonly found in over-lit urban areas. The proliferation of clutter contributes to urban sky glow, trespass, and glare.
- **Over-illumination -** artificial lighting in excess of what is needed for its intended purpose (e.g. safety) is known as over-illumination.

The four negative factors often found with outdoor lighting are sometimes known as GLUT (GLUT = Glare + Light Trespass + Up light + Too Much Light) (refer Figure 2-7[15])

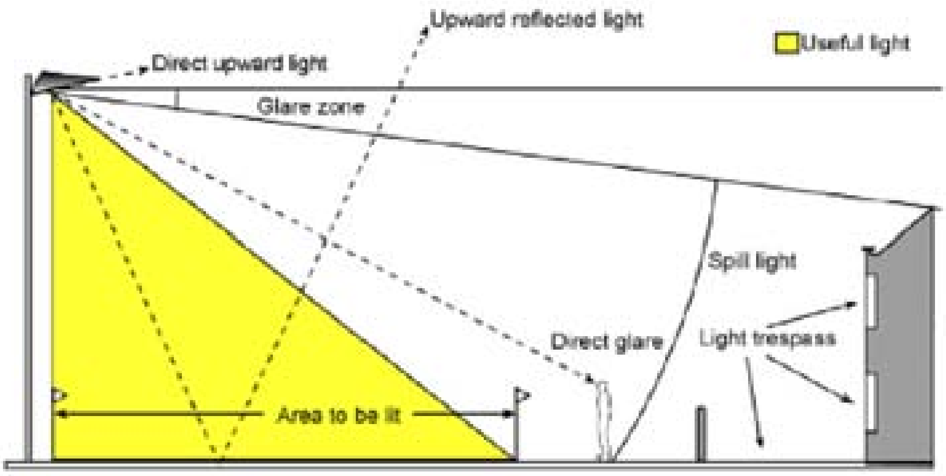


Figure 2-7 Four negative factors found with outdoor lighting

2.2.1 Ecological light pollution

Ecological light pollution is described by Longcore and Rich (2004) as artificial light that alters the natural patterns of light and dark in ecosystems. It comprises direct glare, chronically increased illumination, and unexpected temporary fluctuations in lighting. The sources of ecological light pollution are various and found in nearly every ecosystem in the form of 'sky glow', illuminated buildings and towers, streetlights, fishing vessels, vehicle lights and flares from offshore oil platforms and onshore oil production[16].

2.3 Standards

2.3.1 Criteria for people

The relevant Australian standard for light and spill glare is *AS 4282 – 1997 Control of the Obtrusive Effects of Outdoor Lighting.* This standard provides guidance for development relative to property boundaries of existing buildings and locations of buildings within vacant properties. The standard sets out criteria related to the human experience of light and provides criteria for both pre-curfew hours and post-curfew hours. The criteria for late night (post-curfew which is typically after 2200 or 2300 hours) is

[15] Measurement of light pollution at the Iranian National Observatory
[16] Light Pollution and the Impacts on Biodiversity, Species and their Habitats

considerably more restrictive. The standard nominates the following vertical illuminance criteria for pre-curfew hours:

- 25 lux – at the boundary of commercial and residential areas;
- 10 lux – in residential areas with light surrounds; and
- 10 lux – in residential areas with dark surrounds.

2.3.2 Criteria for Fauna

The threshold value of light onto a beach, which may interfere with the natural progression of fauna is not known. Bright moonlight produces 0.25 lux on the horizontal in the visible spectrum so the assumption could be that there should be less light spill than this value. Another criterion with respect to the travel of hatchlings towards the sea is believed to be the brightness of light sources, that is, the horizon and the moon.

Lighting

The characteristics of light source: colour temperature, colour rendering (R_a), capability and lumen package (quantity of visible light at 1 m) have implications both to the human visual system and the effectiveness of seeing. Colour temperature is the “whiteness” of the light with low colour temperatures being very yellow orange and high colour temperature being “bluish white”. The types of light sources presented in Table 2-4[17] may be installed at the LNG facility.

Table 2-4 Characteristics of light sources

Light Source	Appearance	°K	R_a
Low pressure sodium	Orange	1700	-
High pressure sodium	Yellow	2100	25
Mercury vapour	White	4100	40
Metal halide	White	4200 5500	65 92
Fluorescent colour 54	White	6200	72
Fluorescent colour 86	White	6300	77
Fluorescent colour 33	White	4100	63

Lighting will be used appropriately around the facility with the top of the floodlights being horizontal and the peak intensity being at 60 degrees up from the nadir (downward vertical) minimising unnecessary light spill. However, there will be some instances where floodlights will be aimed upwards a further 30 degrees, which means the peak intensity is aimed horizontally.

With many marine fauna being more sensitive to the blue/green section of the spectrum, mercury vapour, metal halide and fluorescent lamps present the greatest possibility of being disruptive to marine life. Areas such as the beach may be exposed to white light but other areas of the coastline, whilst having the strongest spectra in the orange/red part of the spectrum (due to the concentration of high pressure sodium light sources), will also be exposed to extra spectra in the blue/green wavelength. The relative amounts at any one point vary depending on which light sources are screened and which are visible.

[17] Alcan Grove Alumina Refinery Expansion Project, Environmental Impact Statement

2.4 Bortle Scale

The Bortle Dark-Sky Scale (refer Figure 2-8[18]) is a nine-level numeric scale that measures the brightness of the night sky and stars (naked-eye and stellar limiting magnitude) of a particular location. It quantifies the astronomical observability of celestial objects and the interference caused by light pollution and skyglow.

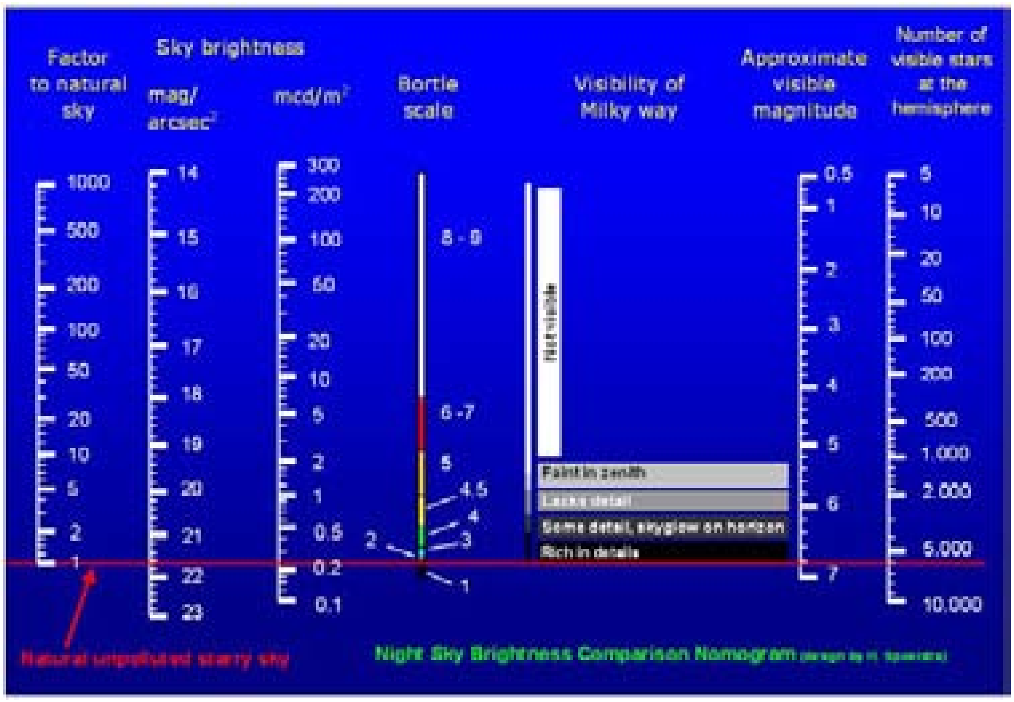


Figure 2-8 Bortle scale

Determining the existing light pollution from the surrounding communities provides some comparison to the expected impact of the LNG facility and gives context to the calculation results presented in Section 3.

2.5 The Transmission of Light through Water

Figure 2-9 depicts the effect of clear oceanic water on a beam of sunlight. A certain amount of incoming light is reflected away when it reaches the ocean surface, depending upon the state of the water itself. If it is calm and smooth, less light will be reflected. If it is turbulent, with many waves, more light will be reflected.

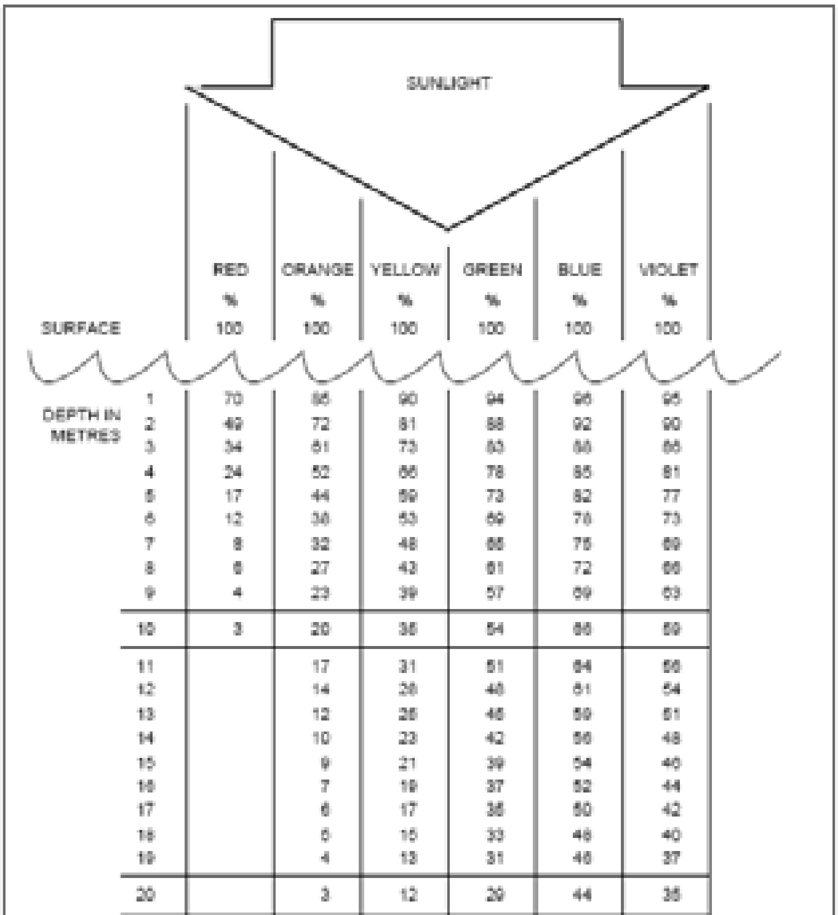
Water selectively scatters and absorbs certain wavelengths of visible light. The red component is largely absorbed at only 10 metres from the surface, orange is down to 20%, yellow to 35%, green to 54%, blue to 66% and violet to 59%. At 20 metres, only the green, blue and violet components are present in significant proportions. Blue penetrates the deepest, which is why deep, clear ocean water

[18] http://www.darkskiesawareness.org/nomogram.php

Lighting Emissions

2 Light Emission Overview

and some tropical water appear to be blue most of the time. Moreover, clearer waters have fewer particles to affect the transmission of light, and scattering by the water itself controls color. Water in shallow coastal areas tends to contain a greater amount of particles that scatter or absorb light wavelengths differently.



	RED %	ORANGE %	YELLOW %	GREEN %	BLUE %	VIOLET %
SURFACE	100	100	100	100	100	100
DEPTH IN METRES 1	70	85	90	94	96	95
2	49	72	81	88	92	90
3	34	61	73	83	88	86
4	24	52	66	78	85	81
5	17	44	59	73	82	77
6	12	38	53	69	78	73
7	8	32	48	65	75	69
8	6	27	43	61	72	66
9	4	23	39	57	69	63
10	3	20	35	54	66	59
11		17	31	51	64	56
12		14	28	48	61	54
13		12	25	45	59	51
14		10	23	42	56	48
15		9	21	39	54	46
16		7	19	37	52	44
17		6	17	35	50	42
18		5	15	33	48	40
19		4	13	31	46	37
20		3	12	29	44	35

THE UNLINEAR ABSORPTION OF NATURAL DAYLIGHT BY CLEAR, OCEANIC WATER
Table shows the % of each component remaining after each metre of transmission from the surface

Figure 2-9 Effect of clear oceanic water on a beam of sunlight

Light Pollution Impact

3.1 Light Sources

The list of sources of light emissions from the main processing plant, the MOF facilities and the offshore platform includes direct and security lighting in the facility and camp, light from the gas flares (wet, marine and dry) and light from vessels. This has the potential to change the coastal environment via emitted light spill, direct light, sky glow and glare. Further, environmental conditions such as dust and particulate matter, and ambient weather conditions (e.g. cloudy day) can affect the absorption or reflection of light, as a result of the changes to the air mass ratio and physiochemical changes to the ambient environment.

Controlled and uncontrolled human presence can also have a bearing on ambient light levels, due to the requirement of minimum light levels, as determined by the Australian lighting standard, AS/NZS 1680.1:2006. Wheatstone Project offshore facilities are not assessed for this study as they are outside the zone of impact for the terrestrial environment.

3.2 Estimation Methodology

Luminance is the measure of the amount and concentration of light flux leaving a surface. The luminance of a surface depends on the direction from which the light strikes the surface, the direction from which the surface is viewed and the reflective properties of the surface. The source of radiation is not an issue and it is the luminance, the producer of light intensity and reflectivity that controls the magnitude of the sensation that is received by the brain. Luminance at a point (refer Figure 2-4) is proportional to the horizontal illumination at that point.

Light levels in compliance with the Australian lighting standard, AS/NZS 1680.1:2006 (refer Table 3-1[s]) were assumed to be the minimum requirements for site illumination. Two basic luminaires with 250 W and 400 W high-pressure sodium (HPS) were considered as the light sources to estimate intensity levels at various locations within the project site for modelling purposes.

Lighting calculations include the light loss factor (maintenance factor) (LLF) and coefficient of utilisation (CU). LLF only considers mounting errors. In reality, there are several factors that affect the LLF such as the time of day, ambient temperature, voltage variations, dirt accumulation on the luminaire surfaces, lamp filament deterioration, maintenance procedures, equipment and ballast variation. Factors beyond the control of the lightning manufactures have not been taken into account in this study, such as: voltage regulation; weather; emission control of the atmosphere; topography; maintenance; aging lamps; position of lamp reflector and refractor; lamp position; pole installation; voltage fluctuation; photodetector response; reliability of illuminaires, etc..

[s] AS/NZS 1680.2.4:1997, Part 2.4 Industrial tasks and processes

3 Light Pollution Impact

Table 3-1 Light levels in compliance with the Australian lighting standard, AS/NZS 1680.1:2006

	Type of interior or activity	Maintenance Illuminance (lx)	Lamp Colour Appearance Group	Lamp Colour Rendering Group	Maximum Glare Index
Assembly Shops and Manufacturing Processes	Rough work e.g. large scale assembly, frame assembly, assembly of heavy machinery	160/240	warm or intermediate	$40 \le R_a < 80$	25
	Medium work e.g. machined parts, main engine assembly, vehicle body assembly	400	warm or intermediate	$60 \le R_a < 80$	22
Building Construction Sites (interior)	Walkways and access areas	40	warm or intermediate	$40 \le R_a < 80$	N/A
	General work areas	160	warm or intermediate	$40 \le R_a < 80$	N/A
Concrete Products	Drying/curing	80	warm or intermediate	$20 \le R_a < 60$	28
	Mixing, casting, cleaning	160	warm or intermediate	$20 \le R_a < 60$	28
Electricity Generating Stations	Normal Operations	160	warm or intermediate	$60 \le R_a < 80$	25
	Maintenance	400	warm, intermediate or cool	$60 \le R_a < 80$	25
	Fuel Supply Plant	40	warm or intermediate	$40 \le R_a < 60$	28
	General movement e.g. walkways and cable tunnels	40	warm or intermediate	$40 \le R_a < 80$	N/A
	Instruments, gauges, valves and similar	160	warm or intermediate	$40 \le R_a < 80$	N/A
Fire Stations	Appliance rooms	160	warm or intermediate	$60 \le R_a < 80$	N/A
Inspection (engineering)	Rough work - rough visual inspection, counting, rough checking of stock parts	160	warm or intermediate	$40 \le R_a < 80$	25
	Medium work - 'Go' and 'No Go' gauges, electronic equipment sub-assemblies	400	warm or intermediate	$60 \le R_a < 80$	19

3 Light Pollution Impact

	Type of interior or activity	Maintenance Illuminance (lx)	Lamp Colour Appearance Group	Lamp Colour Rendering Group	Maximum Glare Index
Laboratories and Testing Areas	General	400	warm or intermediate	$60 \leq R_a < 80$	19
Machine and Fitting Shops	Rough bench and machine work, counting, rough checking of stock parts, etc.	160	warm or intermediate	$40 \leq R_a < 80$	28
	Medium bench and machine work, ordinary automatics machines, rough grinding, medium buffing and polishing	400	warm or intermediate	$60 \leq R_a < 80$	22
Warehouses	Storage of goods of one kind of large unit size	40	warm or intermediate	$20 \leq R_a < 60$	N/A
	Storage of goods of different kinds and search and retrieval tasks	80	warm or intermediate	$40 \leq R_a < 80$	28
	Automatic high-bay storage - Aisles and gangways	20	warm or intermediate	$20 \leq R_a < 60$	N/A

3 Light Pollution Impact

Estimates of lighting levels in the different areas of the processing plants were determined from the illuminance figures by activity type given in AS/NZS 1680.1:2006 (refer Table 3-1). (Note: since the facility will have new lights, the intensity levels will be slightly higher than the maintenance illuminance levels specified in AS/NZS 1680.1:2006). Estimates for lux levels for different areas are presented in Table 3-2.

For the purposes of the estimation, the following assumptions were made:

- Lamp posts for perimeter lighting, jetty and roadway was assumed to be 30 m apart;
- 250 and 400 W HPS globes were assumed to be used throughout the facility;
- Air mass ratio of 1.0; and
- Flare temperature to be 1,000 ℃.

Table 3-2 Estimated lux for plant areas

Area	Lux (lm/m^2)
Roadway, Jetty, Pathway, Perimeter Fence	23.47
Security lighting for Administration Buildings	167.61
LNG Trains, DOMGAS trains	395.2
Condensate and other tanks	234.65
Dry and Wet Flares	1,053

3 Light Pollution Impact

Figure 3-1 Estimated lux levels of the Project

3.2.1 Viewshed estimate

URS estimated the impacts of light pollution at six viewpoints of interest to give a visual representation of light emissions from the LNG facility (refer Figure 3-1). This estimate accounts for the heights of major infrastructure within the onshore development area (e.g. buildings, tanks, flares, etc.) as well as the topography within the catchments of each viewpoint. Allowances were not made for average natural vegetation heights in areas of uncleared bushland.

Figure 3-2 shows the estimated impact of the plant illumination, when viewed from directly above the plant. From the literature review conducted, it is known the intensity of light is inversely proportional to the square of the distance of the viewing point. The figure shows the intensity of light surrounding the different plant areas, with light being the most intense at its source (shown in red) and gradually decreasing in intensity, as it travels farther away from the source (shown in blue).

An air mass ratio of 1.0 is assumed for the purposes of the estimation. In reality, dust and other particulate matter may cause localised reflection, which may slightly impact the visual impact of the plant lighting.

3 Light Pollution Impact

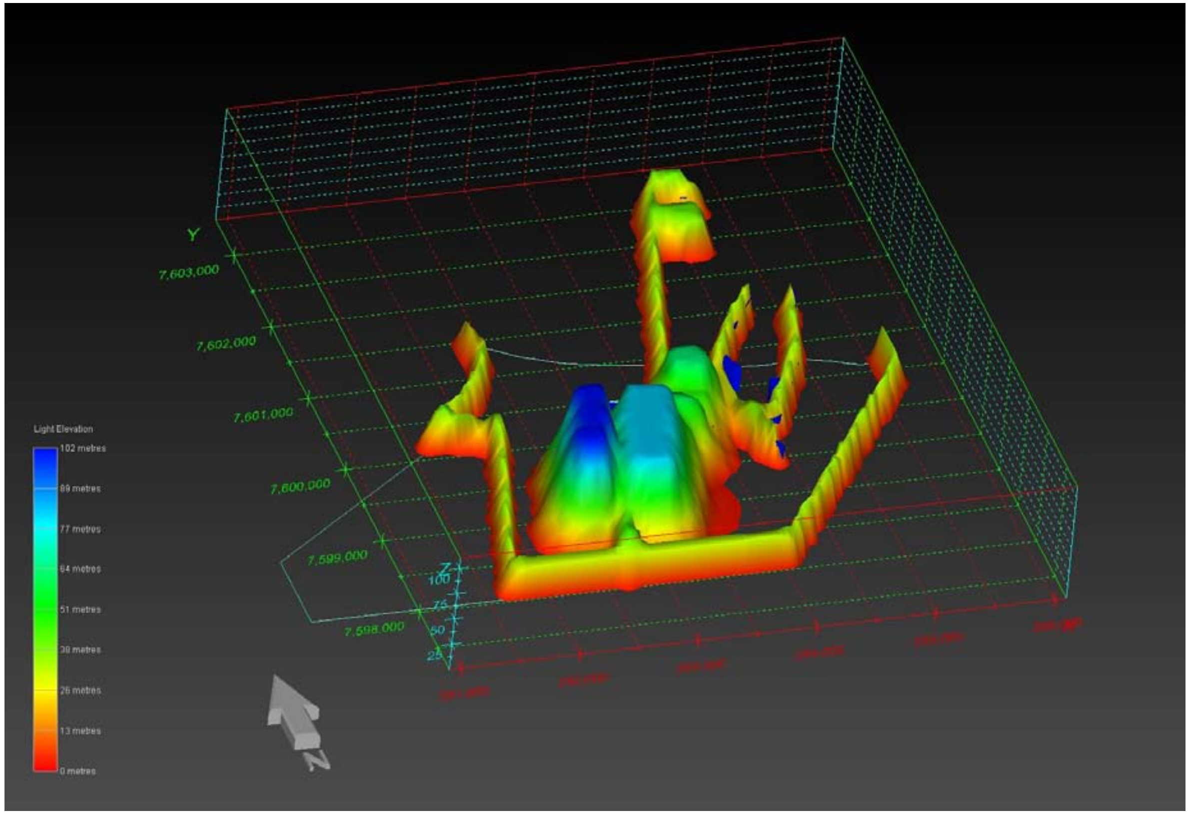


Figure 3-2 Lighting impacts of the Project

3 Light Pollution Impact

3.2.2 Ratings of visual impacts

The visual impacts of light dissipate both laterally (over distance) and longitudinally (increasing height), depending on the viewing location (refer Figure 3-3). Visual impacts at the various viewpoints of interest to the study are reported in Table 3-3.

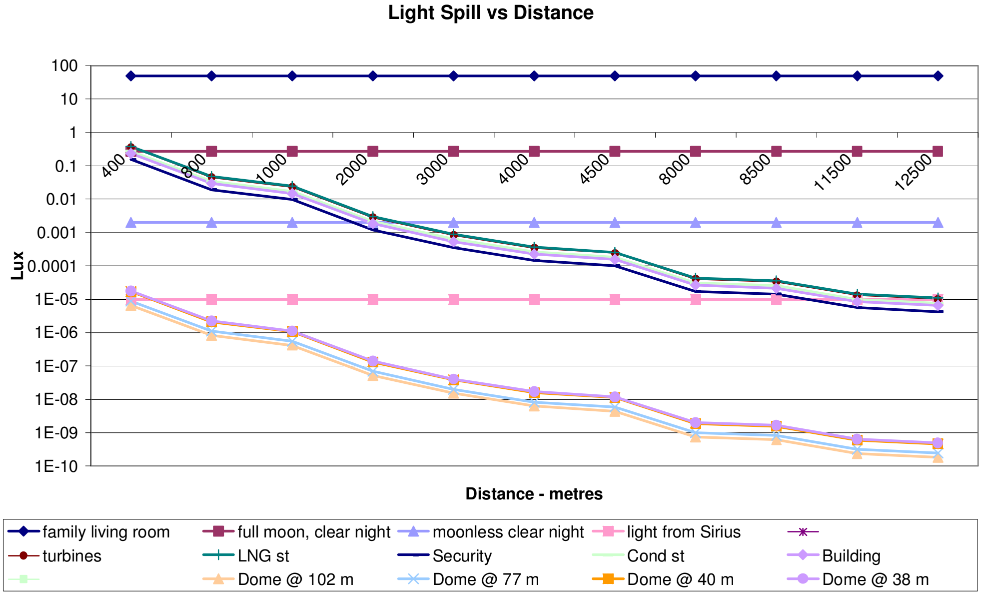


Figure 3-3 Light spill vs. distance

Table 3-3 Viewpoints of interest in the visual impact assessment

Site	Distance (km)	Lighting Levels at viewpoint (lumens)			
		Dome @ 38 m	Dome @ 40 m	Dome @ 77 m	Dome @ 102 m
Offshore	3	4.08E-08	3.88E-08	2.01E-08	1.52E-08
Old Onslow Cemetery	4	1.70E-08	1.61E-08	8.38E-09	6.32E-09
4 Mile Creek Beach	4.5	1.18E-08	1.12E-08	5.84E-09	4.41E-09
Ashburton Island	8	2.01E-09	1.91E-09	9.90E-10	7.47E-10
Ashburton River camping area	8.5	1.66E-09	1.58E-09	8.20E-10	6.19E-10
Ten Mile Dams	11.5	6.44E-10	6.12E-10	3.18E-10	2.40E-10
Simpson Street	12.5	4.95E-10	4.70E-10	2.44E-10	1.84E-10

3 Light Pollution Impact

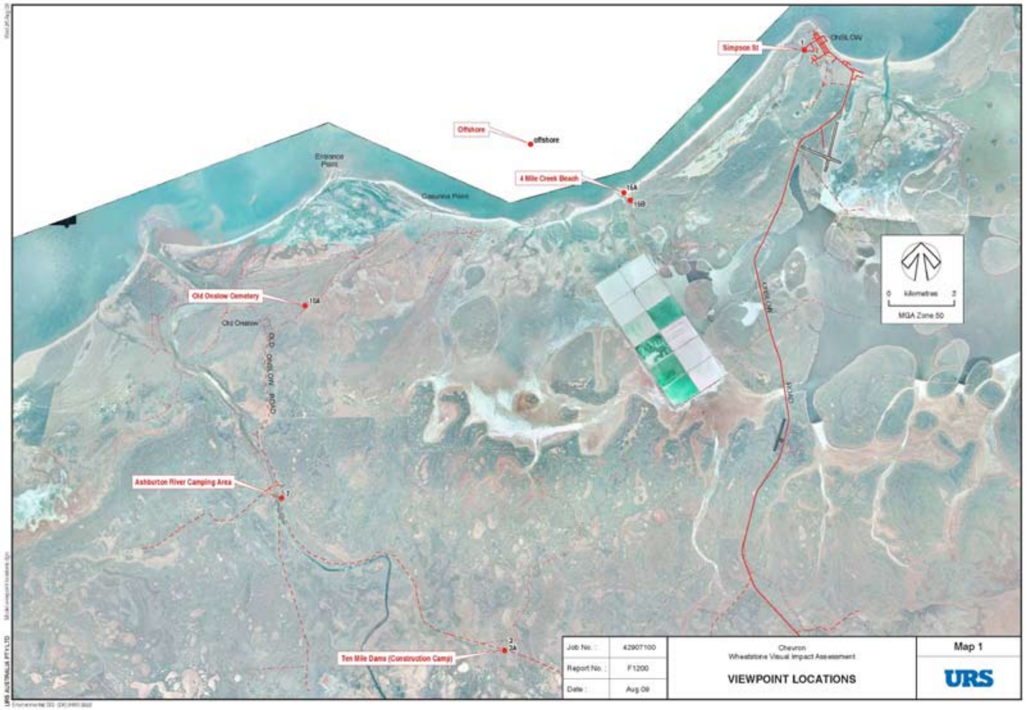


Figure 3-4 Viewpoint locations considered in the visual impact assessment

3.3 Spectral Attenuation with Distance from Source

Figure 3-5 shows the marine flare versus wavelength and Figure 3-6 shows dry and wet flare spectra versus wavelength. From the figures, it is evident that the light in the blue end of the spectrum, i.e. with a shorter wavelength, dissipates a lot quicker as the distance from the source is increased than light at the red end of the spectrum, i.e. longer wavelength.

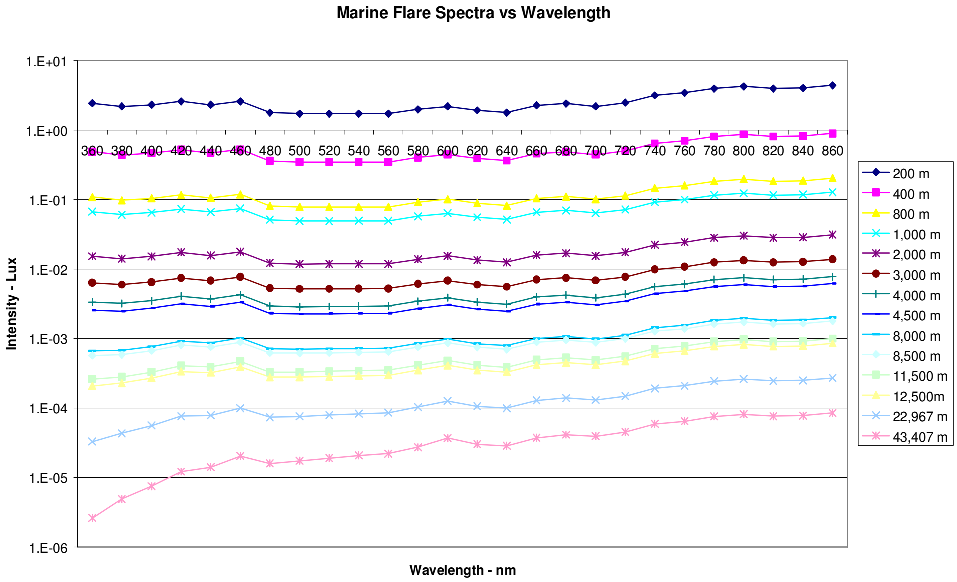


Figure 3-5 Marine flare spectra vs. wavelength

3 Light Pollution Impact

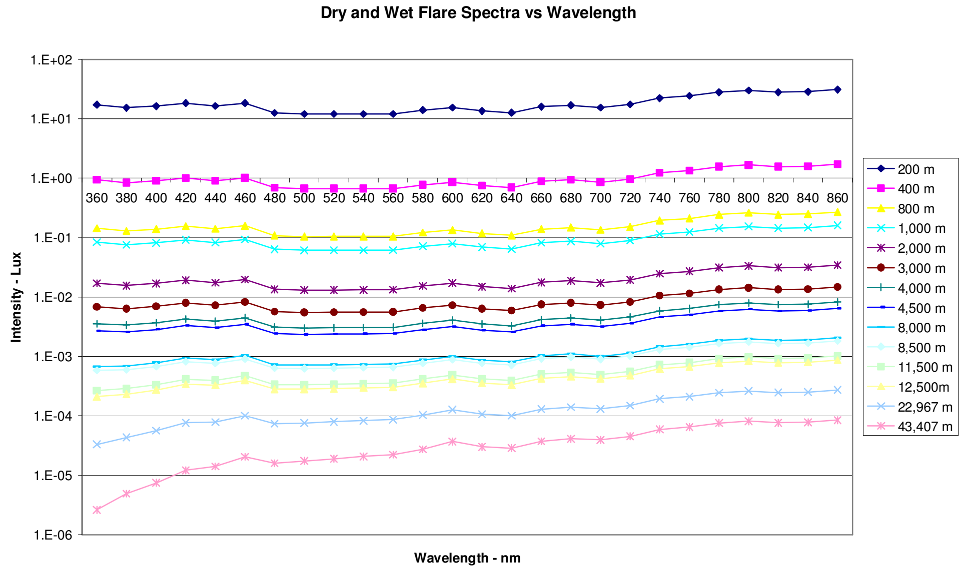


Figure 3-6 Dry and wet flare spectra vs. wavelength

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Glossary

Term	Description
Candela	Unit of luminous intensity, describing the intensity of a light source in a specific direction.
Candlepower	A measure of luminous intensity of a light source in a specific direction, measured in candelas (see above).
Colour Rendering Index (CRI)	A scale of the effect of a light source on the colour appearance of an object compared to its colour appearance under a reference light source. Expressed on a scale of 1 to 100, where 100 indicates no colour shift. A low CRI rating suggests that the colours of objects will appear unnatural under that particular light source.
Colour Temperature	The colour temperature is a specification of the colour appearance of a light source, relating the colour to a reference source heated to a particular temperature, measured by the thermal unit Kelvin. The measurement can also be described as the "warmth" or "coolness" of a light source. Generally, sources below 3200K are considered "warm" while those above 4000K are considered "cool" sources.
Contrast	The relationship between the luminance of an object and its background.
Efficacy	A metric used to compare light output to energy consumption. Efficacy is measured in lumens per watt. Efficacy is similar to efficiency, but is expressed in dissimilar units. For example, if a 100-watt source produces 9000 lumens, then the efficacy is 90 lumens per watt.
Footcandle (FC)	The English unit of measurement of the illuminance (or light level) on a surface. One footcandle is equal to one lumen per square foot.
Glare	The effect of brightness or differences in brightness within the visual field sufficiently high to cause annoyance, discomfort or loss of visual performance.
High Intensity Discharge (HID)	Generic term describing mercury vapour, metal halide, high pressure sodium, and (informally) low pressure sodium light sources and luminaires.
High Pressure Sodium Lamp	A high intensity discharge (HID) lamp whose light is produced by radiation from sodium vapour (and mercury).
Illuminance	A photometric term that quantifies light incident on a surface or plane. Illuminance is commonly called light level. It is expressed as lumens per square foot (footcandles), or lumens per square meter (lux).
Light Emitting Diode (LED)	Consumes low wattage and has a rated life of greater than 80 years.
Light Loss Factor (LLF)	Factors that allow for a lighting system's operation at less than initial conditions. These factors are used to calculate maintained light levels. LLFs are divided into two categories, recoverable and non-recoverable. Examples are lamp lumen depreciation and luminaire surface depreciation.

4 Glossary

Term	Description
Life-Cycle Cost	The total costs associated with purchasing, operating, and maintaining a system over the life of that system.
Low Pressure Sodium	A low-pressure discharge lamp in which light is produced by radiation from sodium vapour. Considered a monochromatic light source (most colours are rendered as gray).
Lumen	A unit of light flow, or luminous flux. The lumen rating of a lamp is a measure of the total light output of the lamp.
Luminaire	A complete lighting unit consisting of a lamp or lamps, along with the parts designed to distribute the light, hold the lamps, and connect the lamps to a power source. Also called a fixture.
Luminaire Efficiency	The ratio of total lumen output of a luminaire and the lumen output of the lamps, expressed as a percentage. For example, if two luminaires use the same lamps, more light will be emitted from the fixture with the higher efficiency.
Luminance	A photometric term that quantifies brightness of a light source or of an illuminated surface that reflects light. It is expressed as footlamberts (English units) or candelas per square meter (Metric units).
Lux	The metric unit of measure for illuminance of a surface. One lux is equal to one lumen per square meter. One lux equals 0.093 footcandles.
Maintained Luminance	Refers to light levels of a space at other than initial or rated conditions. This term considers light loss factors such as lamp lumen depreciation, luminaire dirt depreciation, and room surface dirt depreciation.
Mercury Vapour Lamp	A type of high intensity discharge (HID) lamp in which most of the light is produced by radiation from mercury vapour. Emits a blue-green cast of light. Available in clear and phosphor-coated lamps.
Metal Halide Lamp	A type of high intensity discharge (HID) lamp in which most of the light is produced by radiation of metal halide and mercury vapours in the arc tube. Available in clear and phosphor coated lamps.
Reflectance	The ratio of light reflected from a surface to the light incident on the surface. Reflectances are often used for lighting calculations. The reflectance of a dark carpet is around 20%, and a clean white wall is roughly 50% to 60%.

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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.

This report was prepared between May and 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.

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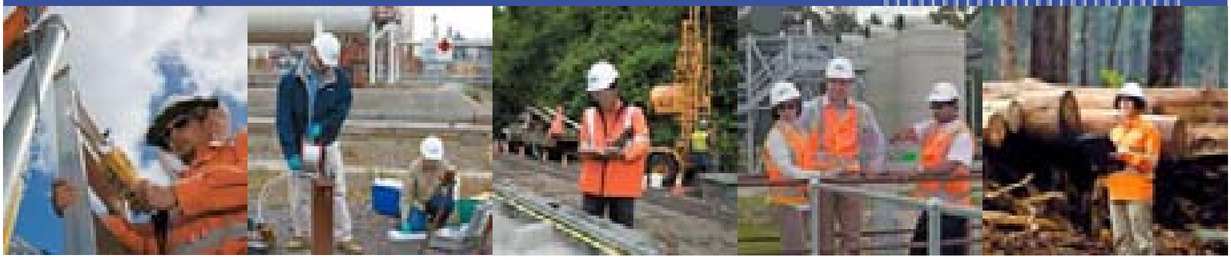

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Appendix E1

Environmental Noise Impact Assessment

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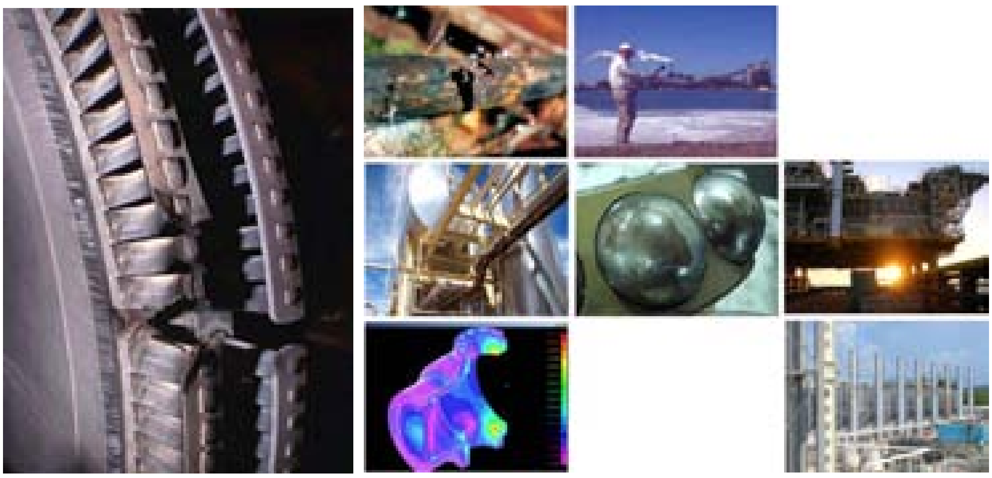
ENVIRONMENTAL NOISE IMPACT ASSESSMENT - CHEVRON WHEATSTONE LNG PLANT



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EXECUTIVE SUMMARY

Introduction

This study presents an assessment of potential noise impacts from the proposed Chevron Wheatstone Liquefied Natural Gas Plant near Onslow in Western Australia on surrounding noise sensitive receptors. Noise emissions from normal plant operations, emergency flaring and piling during construction have been assessed. The study considers airborne noise impacts in relation to humans. Noise impacts on fauna are beyond the scope of this assessment.

Methodology

The assessment methodology follows the procedure outlined in Environmental Protection Authority's (EPA) Draft Guidance No. 8[1] for assessing noise impacts in accordance with the Environmental Protection (Noise) Regulations 1997 which operate under the Environmental Protection Act 1986.

A noise model has been developed and used to predict noise levels associated with normal plant operations, emergency flaring and construction piling at receptors in the vicinity of the plant. Noise contours for the study area have also been prepared. Noise predictions and contours are for worst-case weather conditions for sound propagation.

Ambient noise levels at 5 locations in the vicinity of the proposed development site have been measured to establish current background noise levels prior to construction.

Predicted noise levels have been compared with regulatory noise limits and ambient noise levels to determine noise impacts.

Baseline Conditions

Ambient noise levels have been monitored at five locations in the vicinity of the proposed development site:

- Onslow Town Site (nearest residential area);
- 4 Mile Creek (public access beach and popular fishing and BBQ area);
- 5 Mile Pool (camping area);
- Old Onslow Heritage Site (original site of Onslow);
- 10 Mile Dam (proposed location of workforce accommodation camp)

The noise model has been used to predict noise levels at the same locations as well as at the boundary of Onslow Salt which is the nearest industrial receptor to the proposed plant. These locations are shown in the following figure.

---

[1] EPA Draft Guidance No. 8, May 2007

Monitoring and Prediction Locations

A summary of the ambient noise monitoring data is provided below. The data presented is representative of the quietest background noise levels. The monitored noise levels are very low, particularly at remote inland locations. Monitored levels at coastal locations (Onslow town site and 4 Mile Creek) are slightly higher due to the influence of ocean noise and human activity.

Summary of Ambient Noise Levels

	Underlying Background Noise Level LA90		
	Day time	Evening	Night-time
Onslow Town Site	31	35	28
4 Mile Creek	30	36	32
5 Mile Pool	25	21	<20
Old Onslow (heritage site)	23	22	<20
10 Mile Dam (likely construction camp location)	22	<20	<20

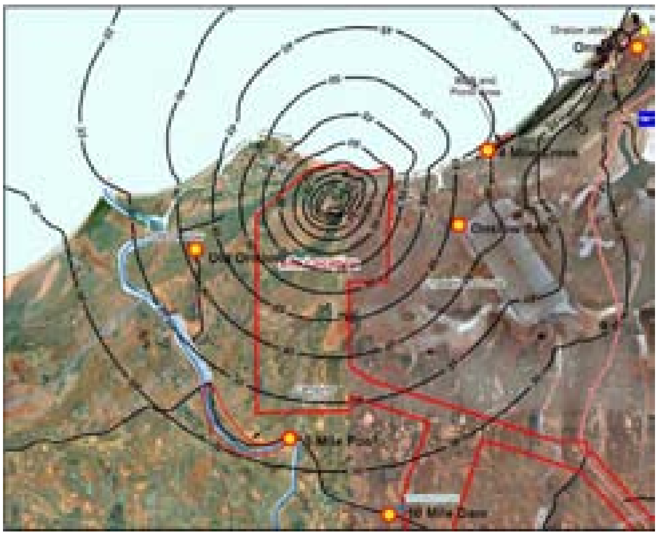
Results

A summary of predicted noise levels for normal plant operations, emergency flaring and pile driving under worst-case sound propagation conditions is presented in the following table and noise contours.

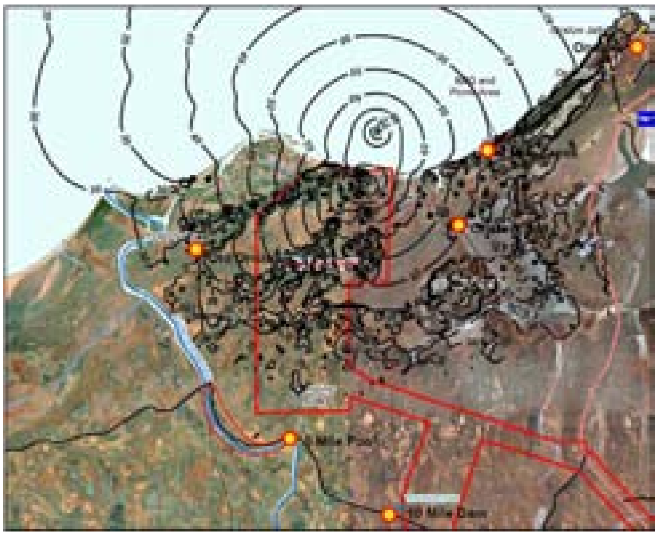
Predicted Noise Levels for Worst-case Sound Propagation Conditions

	Predicted Noise Level – dB(A)		
	Normal Plant Operation	Emergency Flaring	Construction Piling
Onslow Town Site	27	30	31
4 Mile Creek	37	41	48
5 Mile Pool	28	32	26
Old Onslow	36	41	35
10 Mile Dam	24	27	22
Onslow Salt	35	41	41

Noise Contours for Normal Plant Operation



Noise Contours for Emergency Flaring



Noise Contours for Piling During Construction

Conclusion

Predicted noise levels for normal plant operation are compliant with the most stringent night-time assigned noise levels imposed under the Environmental Protection (Noise) regulations 1997 assuming that industry standard noise controls are applied to compressor piping and gas turbines.

The LNG plant is unlikely to be audible above background noise at Onslow town site even under worst-case meteorological conditions for sound propagation.

The proposed location for the workforce accommodation camp is sufficiently distant from the LNG plant site that received noise levels will be significantly below the assigned noise levels.

Predicted noise levels for normal plant operation at the public access areas (4 Mile Creek, 5 Mile Pool and Old Onslow) are higher than underlying background noise. It is possible, therefore, that plant noise may be audible at these locations under worst-case meteorological conditions for sound propagation.

Predicted noise levels from emergency flaring comply with the assigned noise levels.

It is feasible (although unlikely) that noise from piling during construction could exceed assigned noise levels at Onslow if the received noise protrudes sufficiently above background levels to exhibit impulsive characteristics. It is, therefore, recommended that noise monitoring be undertaken during piling so as to determine whether or not noise mitigation measures are warranted.

1. INTRODUCTION

This report provides an assessment of potential airborne noise impacts from the proposed Chevron Wheatstone Liquefied Natural Gas (LNG) plant near Onslow in Western Australia.

1.1 Description of Proposal

Chevron proposes to construct and operate a multi train LNG and domestic gas (domgas) plant on the Pilbara Coast. Gas, condensate and water will enter the main processing plant where the gas and condensate will be processed for export. The key components for processing and export will comprise:

- Separation of gas, liquid and water streams;
- Pre-treatment of the gas stream to remove acid gases, water and other contaminants;
- LNG trains to liquefy the gas;
- LNG storage and loading facilities;
- Domestic gas (domgas) plant;
- Water management;
- Condensate stabilisation and storage;
- LNG and condensate tanks;
- Port facilities including jetties and material offloading facilities.

The current design shows two LNG trains and two domgas plants. (See site layout reproduced in Appendix A.) However, space is provided for future LNG trains and domgas plants. This study assumes 5 operating LNG trains and associated domgas plants.

Construction of the facility will require extensive piling operations which are scheduled to occur 24 hours per day, 7 days per week for approximately 14 months.

1.2 Receptors

The proposed LNG plant is remote from any noise sensitive premises, with the nearest residential area (Onslow Town Site) some 12 km to the north-east of the development site. The nearest industrial receptor is Onslow Salt, approximately 4 km to the east. A workforce accommodation camp is also proposed at location know as 10 Mile Dam approximately 12 km to the south of the development site. The noise model has been used to predict noise levels at these locations.

In addition, noise predictions have also been undertaken for the following public access areas:

- 4 Mile Creek. This is a public access beach approximately 4 km to the east of the development site which is a popular fishing and BBQ area.
- 5 Mile Pool. This area is used for camping and is located approximately 10 km to the south of the development site.
- Old Onslow. This heritage listed area is the site of the original town of Onslow and is approximately 5 km to the west of the development site.

All receptors are shown in the noise contours presented in Appendix B.

1.3 Scope of Study

The following list outlines the major activities undertaken during the course of this study:

- Assessment of existing ambient noise levels in the vicinity of the proposed development;
- Review of documentation provided by URS including a site layout and preliminary noise emission data;
- Development of an acoustic model to represent normal operating conditions and emergency flaring for the LNG plant;
- Plotting of noise contours around the proposed LNG plant for worst case meteorological conditions for sound propagation;
- Prediction of noise levels at the receptors described above (section 1.2);
- Assessment of noise emissions from the plant for compliance with noise limits imposed under the Environmental Protection (Noise) Regulations 1997 at the nearest noise sensitive and industrial receptors;
- Identification of high noise equipment items which significantly contribute received noise levels; and
- Review of construction noise impacts associated with pile driving operations.

2. AMBIENT NOISE ASSESSMENT

Ambient noise levels were measured for 1 – 2 weeks at the following five locations in the vicinity of the proposed Project site:

- Onslow Town Site;
- 4 Mile Creek;
- 5 Mile Pool;
- Old Onslow (heritage site);
- 10 Mile Dam (likely construction camp location).

The noise monitoring equipment was set to continuously record $L_{A\,1}$, $L_{A\,10}$ and $L_{A\,90}$ noise levels at 15-minute intervals, where:

- $L_{A\,1}$ is the noise level exceeded for 1% of the time;
- $L_{A\,10}$ is the noise level exceeded for 10% of the time;
- $L_{A\,90}$ is the noise level exceeded for 90% of the time.

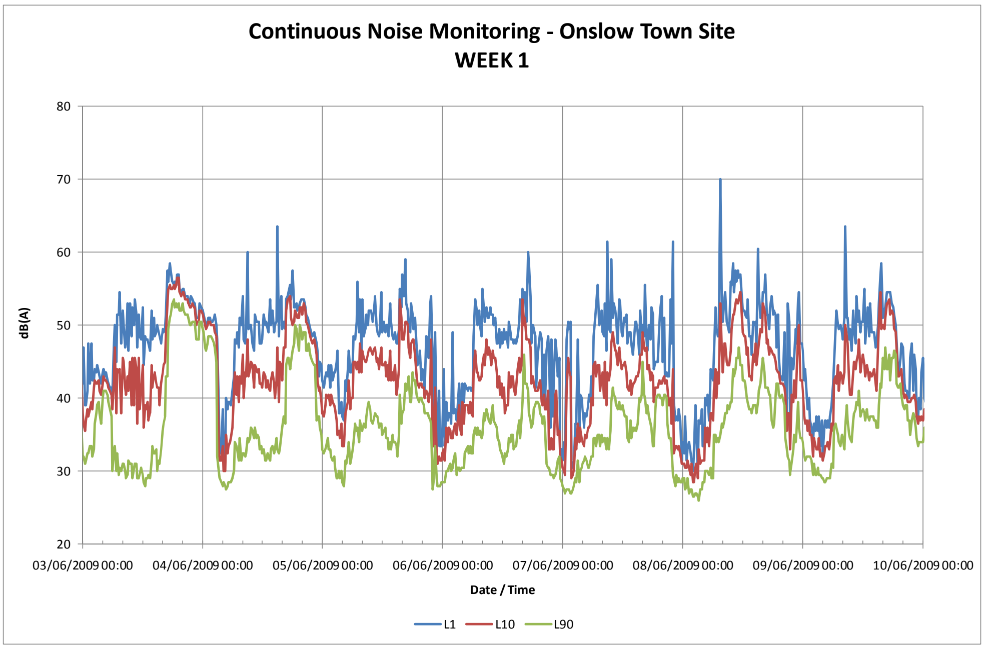
The logging was undertaken from 3 to 17 June 2009.

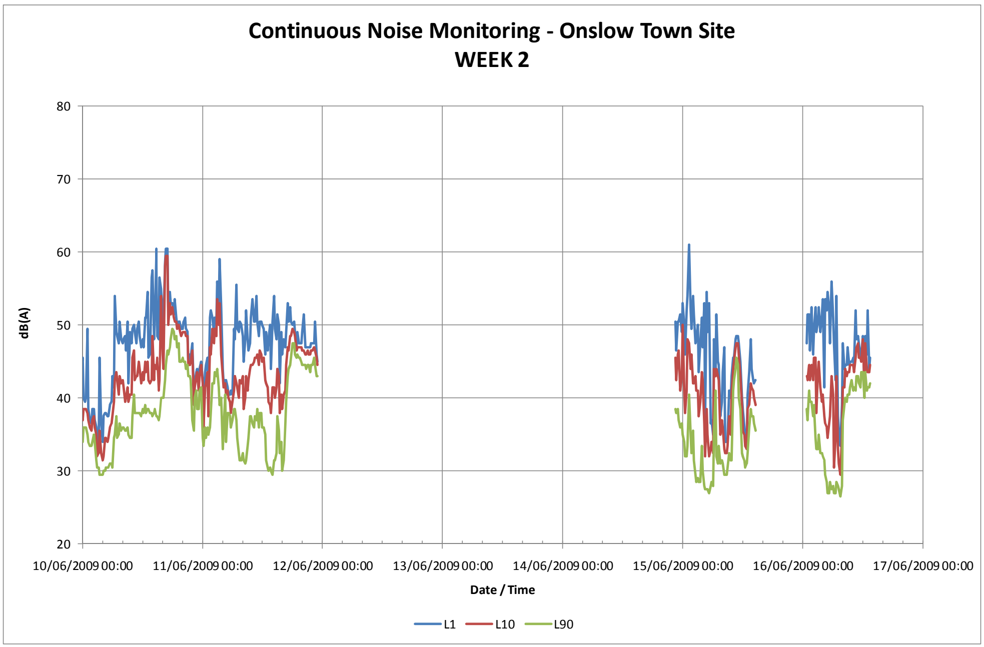
The following sections provide the results of the ambient noise monitoring recorded at each location. Summary tables are provided which include the average $L_{A\,10}$ and $L_{A\,90}$ values collected over the monitoring period during daytime hours, evening hours and night-time hours, and for all periods combined. The standard deviations in the measurement results are also provided. The data have also been analysed to determine the L_{90} (90th percentile) of the $L_{A\,90}$ noise levels for the various time periods. These data provide a good indication of the lowest ambient noise levels. Charts showing the monitored noise data are also presented.

2.1 Onslow Town Site

Table 2-1: Summary of noise logging results for Onslow Town Site

Period	Average $L_{A\,10}$ (dB(A))	Standard deviation in $L_{A\,10}$ (dB)	Average $L_{A\,90}$ (dB(A))	Standard deviation in $L_{A\,90}$ (dB)	L_{90} of $L_{A\,90}$ (dB(A))
Day (0700 to 1900)	44.7	4.7	37.5	5.4	31.0
Evening (1900 to 2200)	44.9	4.9	41.1	5.6	34.5
Night (2200 to 0700)	39.3	5.7	33.7	5.6	28.0
All data	42.6	6.1	36.6	6.1	29.0



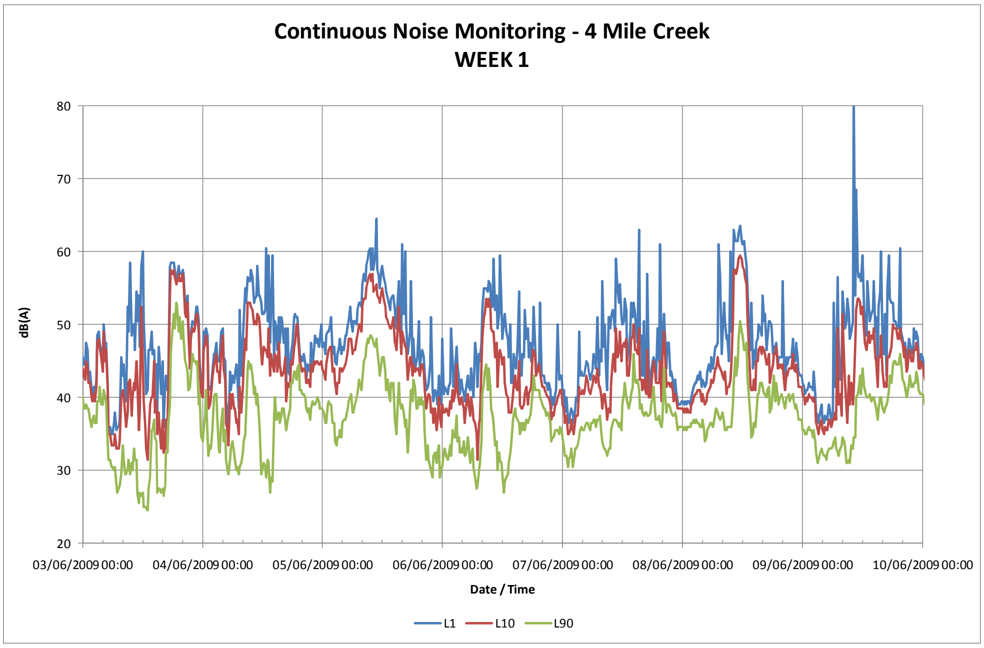


Note that no data was recorded on several occasions during the monitoring period due to low voltages from the solar power supply to the noise monitor.

2.2 4 Mile Creek

Table 2-2: Summary of noise logging results for 4 Mile Creek

Period	Average L_{A10} (dB(A))	Standard deviation in L_{A10} (dB)	Average L_{A90} (dB(A))	Standard deviation in L_{A90} (dB)	L_{90} of L_{A90} (dB(A))
Day (0700 to 1900)	45.7	6.0	37.6	5.9	29.5
Evening (1900 to 2200)	44.8	4.0	39.9	3.8	36.3
Night (2200 to 0700)	41.3	3.7	36.0	3.3	31.8
All data	43.7	5.2	37.4	4.8	31.0

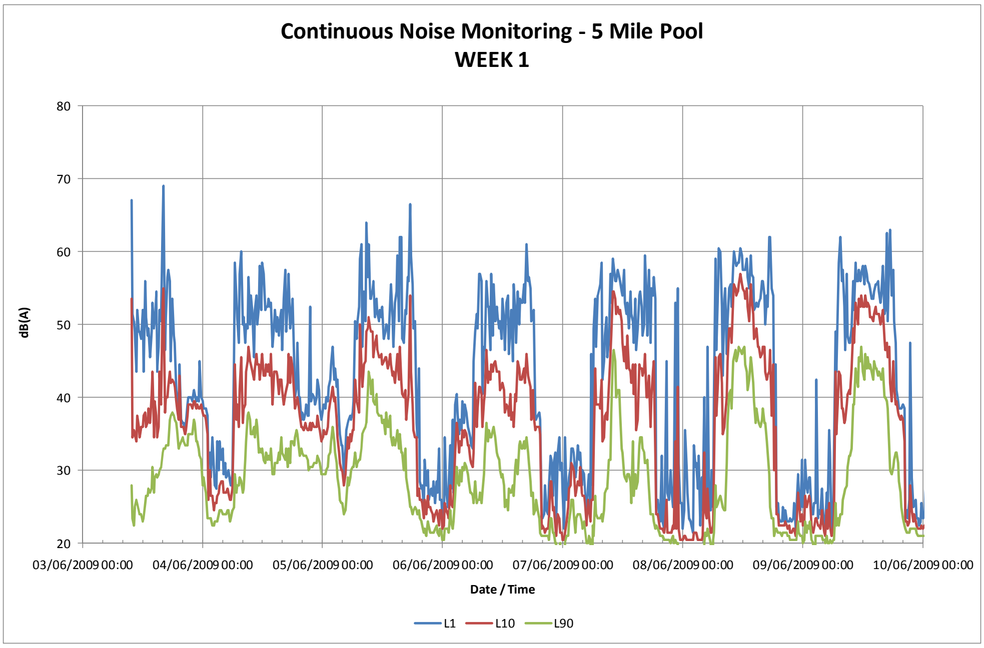


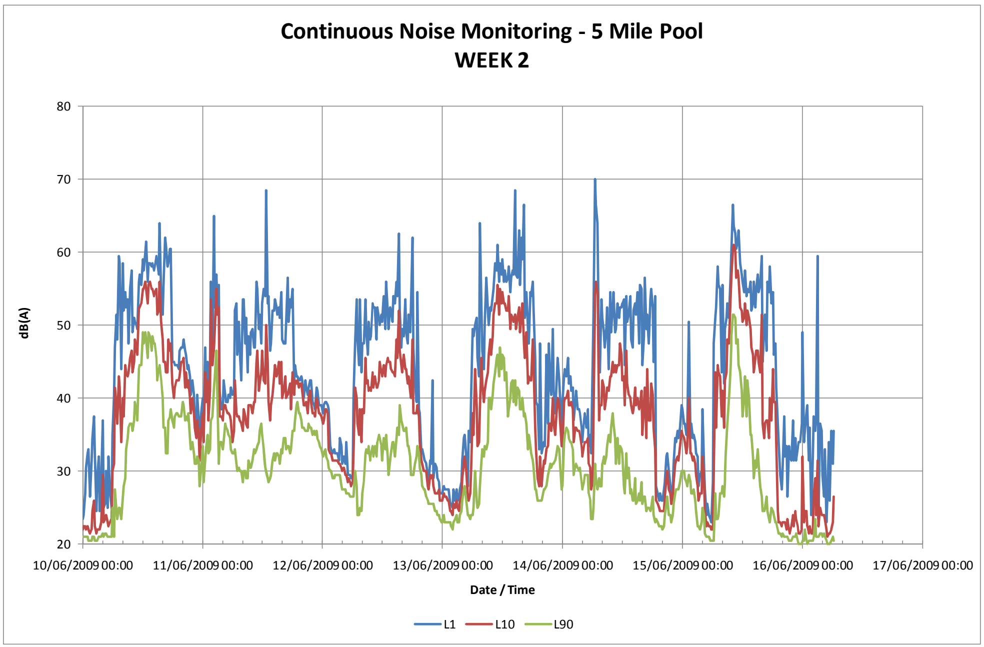
Note that no data was recorded during the second week of the monitoring period due to low voltages from the solar power supply to the noise monitor.

2.3 5 Mile Pool

Table 2-3: Summary of noise logging results for 5 Mile Pool

Period	Average L_{A10} (dB(A))	Standard deviation in L_{A10} (dB)	Average L_{A90} (dB(A))	Standard deviation in L_{A90} (dB)	L_{90} of L_{A90} (dB(A))
Day (0700 to 1900)	44.3	5.8	34.1	6.6	25.0
Evening (1900 to 2200)	34.5	8.8	28.1	6.1	21.0
Night (2200 to 0700)	30.2	7.3	24.5	7.8	<20
All data	36.9	9.5	29.2	8.2	21.0

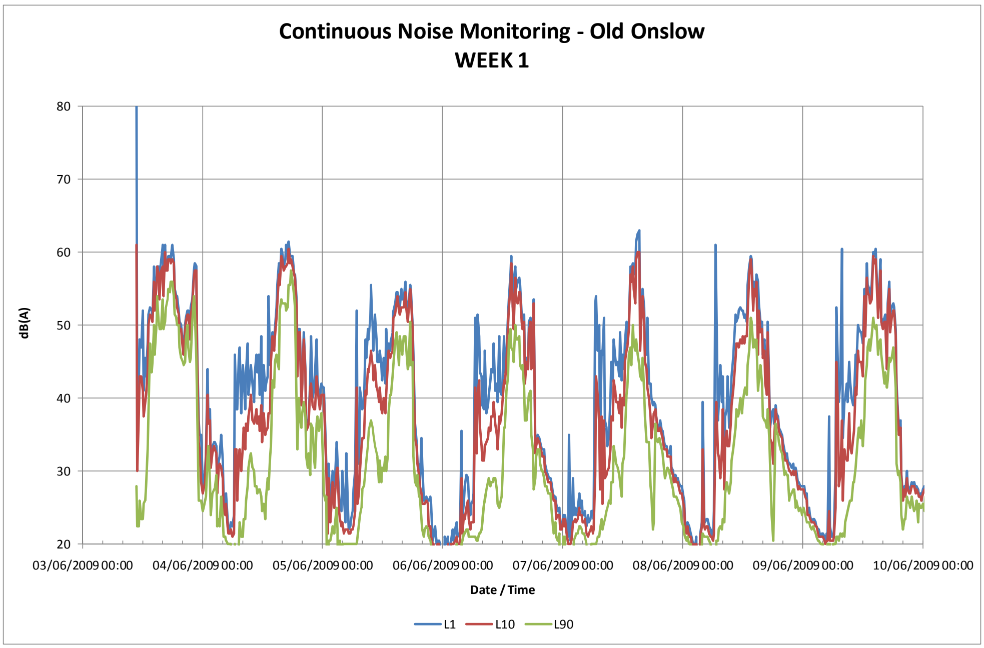


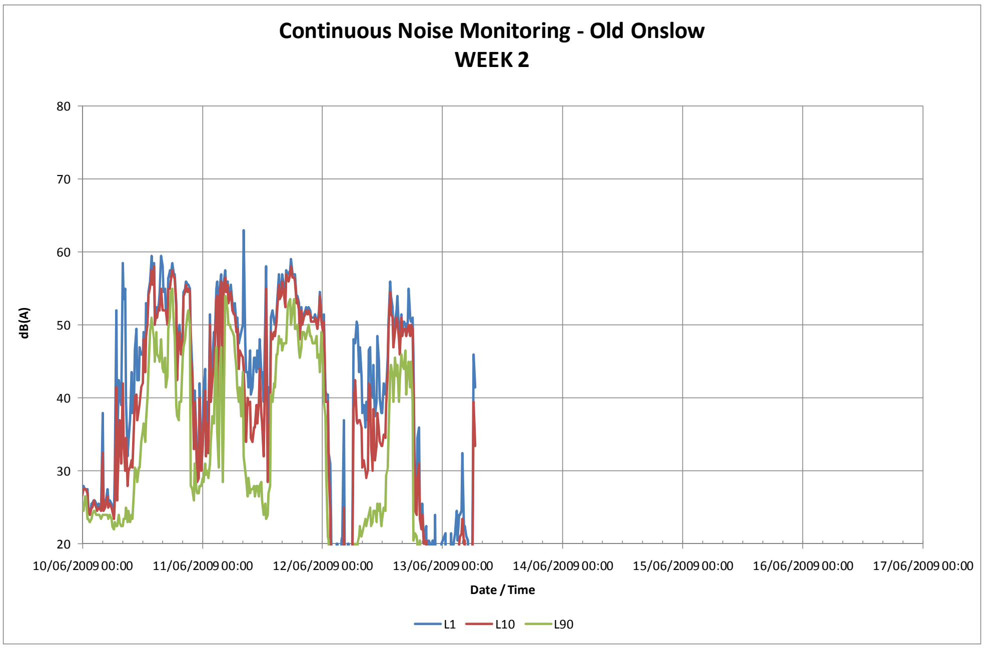


2.4 Old Onslow (Heritage Site)

Table 2-4: Summary of noise logging results for Old Onslow

Period	Average L_{A10} (dB(A))	Standard deviation in L_{A10} (dB)	Average L_{A90} (dB(A))	Standard deviation in L_{A90} (dB)	L_{90} of L_{A90} (dB(A))
Day (0700 to 1900)	44.6	9.1	36.4	10.5	23.0
Evening (1900 to 2200)	38.7	10.6	34.0	9.6	21.9
Night (2200 to 0700)	28.2	9.7	24.6	7.8	<20
All data	37.2	12.2	31.4	10.8	<20



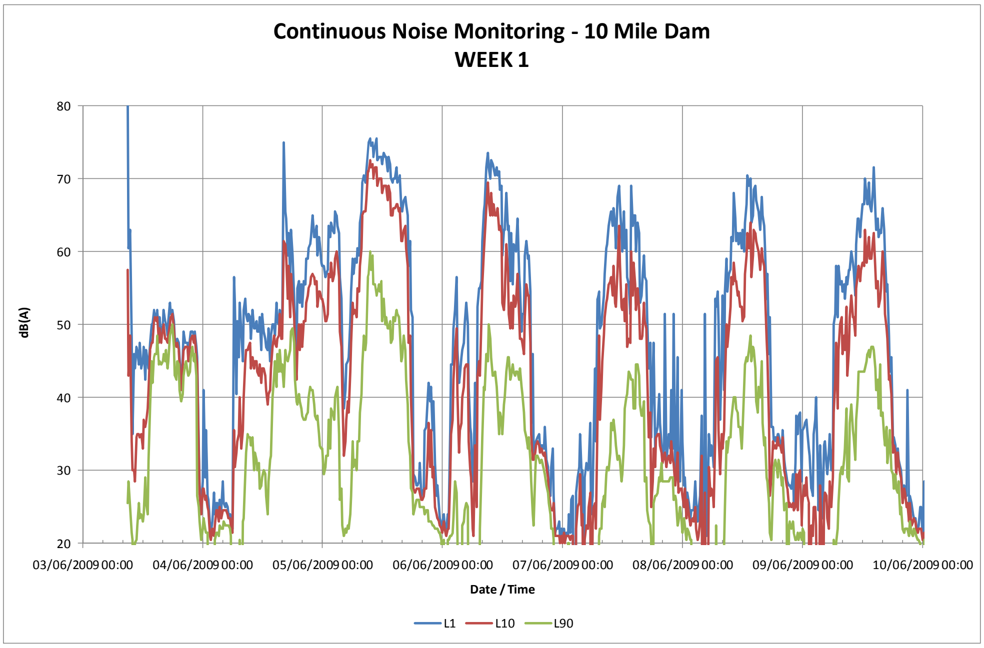


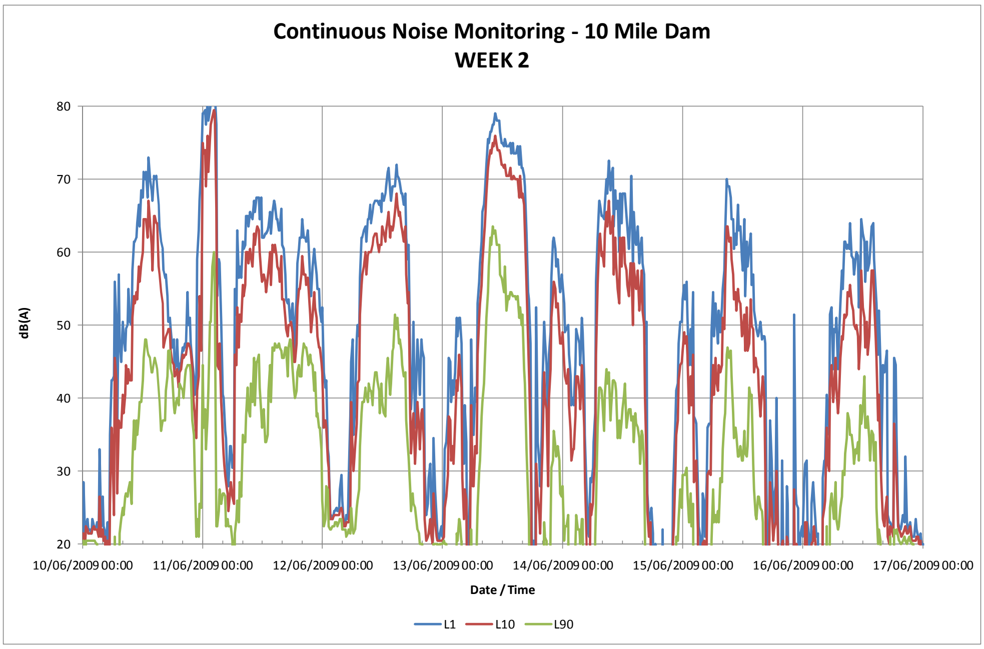
Note that no data was recorded during the second half of the second week of the monitoring period due to low voltages from the solar power supply to the noise monitor.

2.5 10 Mile Dam (Likely Construction Camp Location)

Table 2-5: Summary of noise logging results for 10 Mile Dam

Period	Average L_{A10} (dB(A))	Standard deviation in L_{A10} (dB)	Average L_{A90} (dB(A))	Standard deviation in L_{A90} (dB)	L_{90} of L_{A90} (dB(A))
Day (0700 to 1900)	51.7	12.2	37.5	10.2	22.0
Evening (1900 to 2200)	38.8	14.0	30.3	9.1	<20
Night (2200 to 0700)	32.4	13.1	23.6	6.4	<20
All data	41.8	15.6	30.7	10.7	<20





2.6 Summary

The noise logging data at all locations showed very low underlying background noise levels[2] as would be expected for such a remote area. Background noise levels for inland locations (10 Mile Dam, 5 Mile Pool and Old Onslow) were particularly low. For coastal locations (Onslow town site and 4 Mile Creek), monitored noise levels were higher and are likely to be influenced by ocean noise. Noise levels at Onslow town site are also likely to be significantly influenced by human activity during day-time hours.

[2] Although there were some drop outs in the noise data presented, ample data was collected at each location to reliably assess background noise.

3. NOISE MODELLING

3.1 Methodology

An acoustic model has been produced using the SoundPlan noise modelling program developed by Braunstein & Berndt GmbH. The SoundPlan program calculates sound pressure levels at nominated receiver locations or produces noise contours over a defined area of interest around the noise sources. SoundPlan is a program which has a worldwide clientele including acoustic consultancies, government agencies, industry, and academic institutions. SoundPlan provides a range of prediction algorithms that can be selected by the user. The CONCAWE[3,4] prediction algorithms have been selected for this study. The inputs required are noise source data, ground topographical data, meteorological data and receiver locations. The model produces noise contours or noise levels at specified receiving locations for specific meteorological conditions.

3.2 Input Data and Assumptions

3.2.1 Modelling Scenarios

Noise modelling has been undertaken for the following operating scenarios:

- Normal plant operation assuming 5 LNG trains and associated domgas trains;
- Emergency flaring.

Noise emissions from construction piling have also been considered (see section 6).

3.2.2 Noise Sources and Sound Power Levels

Noise sources associated with the LNG plant have been identified from the following documents which were provided by URS for the study:

- Wheatstone Development Downstream Project overall site layout, drawing no: WS1-0000-PIP-PLT-BEC-000-00001-00 Rev 0 (Reproduced in Appendix A);
- Wheatstone Development Downstream Project LNG Plant – Emissions, Discharges, and Disposal Plan, document no: WS1-0000-HES-PHL-BEC-000-00003-00 Rev A;
- EIS/ERMP Section 8.0 Noise[5]; and
- Email correspondence with URS.

Equipment sound power levels have been developed based on preliminary data provided in the EIS/ERMP Section 8 Noise document (overall levels only) and SVT's in-house data base for similar equipment (spectral composition).

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[3] CONCAWE (Conservation of Clean Air and Water in Europe) was established in 1963 by a group of oil companies to carry out research on environmental issues relevant to the oil industry.

[4] *The propagation of noise from petroleum and petrochemical complexes to neighbouring communities,* CONCAWE Report 4/81, 1981

[5] Extract from document provided by Bechtel and supplied to SVT in hard copy on 11 August 2009

Table 3-1 provides equipment sound power levels for the equipment included in the noise model. The cumulative total sound power level for all equipment in the normal operating scenario is 137 dB(A).

Table 3-1 : Equipment Sound Power Levels

Equipment	Octave band & overall sound power levels – dB(A)									Comment
	63	125	250	500	1000	2000	4000	8000	A-wt	
LNG Train Sources (5 operating trains)										
Air fin coolers	108	115	117	116	117	117	112	101	124	Assuming individual fan sound power level of 99 dB(A)
Methane compressor	75	82	91	100	106	105	96	101	110	2 compressors per train, each comprising LP, MP & HP stages
Ethylene compressor	93	94	97	100	105	108	106	100	113	2 compressors per train, each comprising LP & HP stages
Propane compressor	90	91	94	97	102	105	103	97	109	2 compressors per train, each comprising LP & HP stages
Compressor turbines	80	91	95	102	103	107	106	104	112	6 turbines per train (3 x 2 compressors)
Compressor piping	49	60	99	108	116	113	110	107	119	Distributed as line sources over length of compressor area
Regeneration gas compressor	72	83	93	99	103	102	102	94	108	1 per train
Fuel gas compressor	87	91	96	103	107	106	106	98	112	1 per train
Lean solvent charge pump	80	100	98	103	103	103	100	89	109	1 per train
Lean solvent booster pump	74	94	92	97	97	97	94	83	103	2 per train
LNG transfer pump	80	100	98	103	103	103	100	89	109	1 per train
Feed gas expander	87	91	96	103	107	106	106	98	112	1 per train
Hot oil circulation pump	80	100	98	103	103	103	100	89	109	1 per train
Thermal combustion unit	81	84	92	98	100	98	96	87	105	1 per train
Other Sources										
Gas turbine generator	91	94	98	101	104	108	106	102	112	11 generators operating
Coolers at Domas plant	97	104	105	104	104	104	99	98	112	Assuming individual fan sound power level of 99 dB(A)
Export compressor at Domgas plant	87	91	96	103	107	106	106	98	112	1 per plant
Boil off gas compressor	87	91	92	97	100	108	109	99	112	2 compressors operating
Instrument air compressor	68	78	84	93	99	100	98	93	105	1 compressor operating
Water pumps	71	90	96	99	100	99	95	91	106	Cumulative total for demineralised, service and potable water pumps
Inlet feed gas air coolers	90	97	99	97	97	97	92	82	105	Assuming individual fan sound power level of 99 dB(A)

Equipment	Octave band & overall sound power levels – dB(A)									Comment
	63	125	250	500	1000	2000	4000	8000	A-wt	
Stabiliser overhead compressor	87	91	96	103	107	106	106	98	112	Inlet feed gas area
Elevated flare	111	117	120	124	131	135	133	121	138	3 flares operating at 85 m height (flaring scenario only)
Marine flare	84	90	93	97	104	108	106	94	111	2 flare operating at 13 m height (flaring scenario only)
Pile driver	90	109	117	119	121	117	109	98	125	12 units operating at plant site and 2 at end of jetty (construction scenario only)

3.2.3 Topography, Ground Type and Barriers

Topographical data for the models was provided by URS as ground contours in electronic format. The contours were modified to account for the construction of the materials offloading facility / tug jetty, and the ground height at the LNG plant site was raised to an elevation of 7 m. The modified topography was imported directly into the noise model.

A partially absorptive ground type (ground factor of 0.7) has been used in the model for sound propagation over land. For propagation over water a fully reflective (hard) ground type (ground factor of 0) has been used. Hard ground has also been assumed for the LNG plant site and the evaporation ponds at Onslow Salt.

The noise model does not include noise barriers or buildings[6].

3.2.4 Meteorology

Certain meteorological conditions can increase noise levels at a receiving location by a process known as refraction. When refraction occurs, sound waves that would normally propagate directly outwards from a source can be bent downwards causing an increase in noise levels. Such refraction occurs during temperature inversions and where there is a wind gradient.

The SoundPlan noise model calculates noise levels for user defined meteorological conditions. In particular, temperature, relative humidity, wind speed and direction data, and atmospheric stability are required as input to the models.

The noise model has been used to predict noise levels and prepare noise contours for 3 m/s winds combined with a thermal inversion. These conditions are consistent with the default worst-case conditions for night-time sound propagation specified in Environmental Protection Authority's (EPA) Draft Guidance No. 8[7] for assessing noise impacts. The noise contours for worst-case weather conditions represent the worst-case noise propagation envelopes, i.e., worst-case propagation in all directions simultaneously.

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[6] The large storage tanks at the site will provide shielding for some noise sources. However, due to the preliminary stage of the plant design the barrier effects of the tanks have been excluded from the model. The attenuation achieved by the tanks will strongly depend on the source / barrier / receptor geometry and this is likely to change as the design develops. Hence the model represents a worst-case.

[7] EPA Draft Guidance No. 8, May 2007

3.3 Noise Modelling Results

3.3.1 Normal Plant Operation

Predicted noise levels are presented in Table 3-2 below for normal plant operation and include calm and worst-case weather conditions for sound propagation. Noise contours are presented in Figure 1 in Appendix B for worst-case weather conditions.

Table 3-2 : Predicted Noise Levels – Normal Operations

Receiving Location	Predicted Noise Level dB(A)	
	Calm Conditions	Worst-case Conditions
Onslow Town Site	23	27
4 Mile Creek	32	37
5 Mile Pool	24	28
Old Onslow (Heritage Site)	32	36
10 Mile Dam (Likely Construction Camp Location)	21	24
Onslow Salt	31	35

Air fin coolers are the most significant contributor to received noise levels at all locations.

3.3.2 Emergency Flaring

Predicted noise levels are presented in Table 3-3 below for emergency flaring and include calm and worst-case weather conditions for sound propagation. Noise contours are presented in Figure 2 in Appendix B for worst-case weather conditions.

Table 3-3 : Predicted Noise Levels – Emergency Flaring

Receiving Location	Predicted Noise Level dB(A)	
	Calm Conditions	Worst-case Conditions
Onslow Town Site	26	30
4 Mile Creek	37	41
5 Mile Pool	28	32
Old Onslow (Heritage Site)	38	41
10 Mile Dam (Likely Construction Camp Location)	24	27
Onslow Salt	37	41

4. NOISE LIMIT CRITERIA

4.1 Summary of Legislation

Noise management in Western Australia is implemented through the Environmental Protection (Noise) Regulations 1997 (noise regulations) which operate under the Environmental Protection Act. The Regulations specify maximum noise levels (assigned levels) which are the highest noise levels that can be received at noise-sensitive premises, commercial and industrial premises.

Assigned noise levels have been set differently for noise sensitive premises, commercial premises, and industrial premises. For noise sensitive premises, eg residences, an "influencing factor" is incorporated into the assigned noise levels. The influencing factor depends on land use zonings within circles of 100m and 450m radius from the noise receiver, including:

- the proportion of industrial land use zonings;
- the proportion of commercial zonings; and
- the presence of major roads.

For noise sensitive residences, the time of day also affects the assigned levels.

The regulations define three types of assigned noise level:

- $L_{A\ max}$ assigned noise level means a noise level which is not to be exceeded at any time;
- $L_{A\ 1}$ assigned noise level which is not to be exceeded for more than 1% of the time; and
- $L_{A\ 10}$ assigned noise level which is not to be exceeded for more than 10% of the time.

The L_{A10} noise limit is the most significant for this study since this is representative of continuous noise emissions from the LNG plant.

4.2 Noise Limits

4.2.1 Onslow Town Site

The assigned noise levels at residential premises in Onslow will vary depending on the proximity of particular premises to industrial or commercial areas and also the time of day. The most stringent night-time L_{A10} assigned noise level at residential premises in Onslow is 35 dB(A) for those residences that are greater than 450m from land zoned for industrial or commercial use. This limit has been used for the purposes of this assessment.

4.2.2 Proposed Accommodation Camp at 10 Mile Dam

The EPA's policy on accommodation camps (as defined in EPA draft guidance no 8[8]) is that they should be located and designed so as to achieve compliance with the assigned levels and acceptable standards. Since the proposed camp site is remote from any industrial or commercial

[8] EPA draft guidance no 8, May 2007

activity, the most stringent night-time L_{A10} assigned noise level of 35 dB(A) is deemed to apply and has been used for the purposes of this assessment.

4.2.3 Onslow Salt

Onslow Salt is an industrial site and consequently the L_{A10} assigned noise level is 65 dB(A) at all times of the day and night.

4.2.4 Public Access Areas

Old Onslow, 4 Mile Creek, and 5 Mile Pool are public access areas, but are not considered as premises. Since the noise regulations apply only to noise received at premises, the assigned noise levels do not apply and noise limit criteria are not defined for these locations. The potential for noise impacts at these locations is determined by comparing predicted noise levels with measured background noise levels.

4.3 Intrusive or Dominant Noise Characteristics

Noise levels at receiving premises are subject to penalty corrections if the noise exhibits intrusive or dominant characteristics, i.e. if the noise is impulsive, tonal, or modulated. That is, the measured or predicted noise levels are adjusted and the adjusted noise levels must comply with the assigned noise levels. Regulation 9 sets out objective tests to assess whether the noise is taken to be free of these characteristics.

Based on the large source-receiver distance between the proposed development site and surrounding receptors, and considering the large number of noise emission sources, it is not anticipated that noise from the LNG plant will exhibit impulsive, tonal or modulating characteristics when assessed at the receivers.

Noise emissions from piling during construction may, however, exhibit impulsive characteristics (refer section 6.2).

5. COMPLIANCE ASSESSMENT

5.1 Normal Plant Operation

Table 5-1 presents a comparison of predicted noise levels under worst-case meteorological conditions with applicable noise limits for normal plant operating conditions. It can be seen that compliance is achieved at all locations.

Table 5-1 : Compliance Assessment – Normal Plant Operation

Receiving Location	Noise Limit Criterion	Predicted Noise Level dB(A)
Onslow Town Site	35	27
4 Mile Creek	n/a	37
5 Mile Pool	n/a	28
Old Onslow (Heritage Site)	n/a	36
10 Mile Dam (Likely Construction Camp Location)	35	24
Onslow Salt	65	35

5.2 Emergency Flaring

Table 5-2 presents a comparison of predicted noise levels under worst-case meteorological conditions with applicable noise limits for emergency flaring conditions. It can be seen that compliance is achieved at all locations.

Table 5-2 : Compliance Assessment – Emergency Flaring

Receiving Location	Noise Limit Criterion	Predicted Noise Level dB(A)
Onslow Town Site	35	30
4 Mile Creek	n/a	41
5 Mile Pool	n/a	32
Old Onslow (Heritage Site)	n/a	41
10 Mile Dam (Likely Construction Camp Location)	35	27
Onslow Salt	65	41

5.3 Cumulative Noise Impacts

SVT have been advised (by URS) that there will be two gas plants located immediately to the south and adjacent to the proposed facility. These are:

1) A single train LNG plant;

2) A Domgas plant.

These plants are much smaller than the proposed Chevron facility (which has been assessed assuming 5 operating LNG trains and 5 Domgas units) and thus noise emissions are likely to be significantly lower.

Since the adjacent gas plants are very close to proposed Chevron facility, any increase in noise levels is only likely to affect localised areas in the immediate vicinity of the gas plants. Further afield, noise from the larger Chevron facility will dominate over noise from the adjacent gas plants. Therefore, any increase in noise received at Onslow and 10 Mile Dam will be marginal and will not result in cumulative impacts which exceed the assigned noise levels.

6. CONSTRUCION NOISE

With the exception of pile driving, noise from construction activities is expected to be significantly below noise associated with normal plant operations.

Extensive piling is anticipated during construction using a total of up to 12 impact pile drivers at the plant site and 2 at the jetty. Piling operations are planned to run for 14 months, 24 hours per day, 7 days per week. Noise modelling has been undertaken for a worst-case pile driving scenario assuming 2 pile drivers are operating simultaneously at the end of the jetty (i.e. the worst-case location for sound propagation over water towards Onslow town site) and 12 pile drivers are operating simultaneously at the location of the storage tanks at the plant site.

This is a very conservative approach since it is highly unlikely that all pile drivers will operate simultaneously and that the noise received from each pile driver will arrive at precisely the same time at noise sensitive receiving locations.

6.1 Noise Modelling Results

Predicted noise levels are presented in Table 6-1 below for pile driving and include calm and worst-case weather conditions for sound propagation. Noise contours are presented in Figure 3 in Appendix B for worst-case weather conditions.

Table 6-1 : Predicted Noise Levels – Pile Driving

Receiving Location	Predicted Noise Level dB(A)	
	Calm Conditions	Worst-case Conditions
Onslow Town Site	27	31
4 Mile Creek	42	48
5 Mile Pool	22	26
Old Onslow (Heritage Site)	30	35
10 Mile Dam (Likely Construction Camp Location)	18	22
Onslow Salt	35	41

6.2 Construction Noise Impact Assessment

The noise regulations require an adjustment of 10 dB to be added to predicted noise levels for noise emissions that exhibit impulsive characteristics. Impulsiveness is assessed at the receiving premises and must, therefore, protrude above background noise. If impulsiveness were evident then the adjusted worst-case noise levels for Onslow town site and 10 Mile Dam are as shown in Table 6-2.

Table 6-2 : Predicted Noise Levels for Pile Driving Including Penalty for Impulsiveness

	Predicted Level dB(A)	Penalty for Impulsive Characteristic dB(A)	Adjusted Level Including Penalty for Impulsiveness dB(A)
Onslow Town Site	31	+ 10	41
10 Mile Dam (Likely Construction Camp Location)	22	+ 10	32

For 10 Mile Dam, the adjusted noise levels are below the assigned noise levels for day, evening and night-time periods. However, for Onslow town site, the adjusted noise levels exceed the evening and night-time assigned noise levels and, therefore, a noise management plan may be required. (Refer section 6.3.2 below).

It is noted, however, that the predicted noise levels (before applying penalties for impulsiveness) are only marginally above the lowest background noise levels recorded at both Onslow and 10 Mile Dam. (Refer sections 2.1 and 2.5.). Therefore, the risk of exceeding the assigned noise levels is very low since this would require:

- All pile drivers to be operating;
- Noise from all pile drivers to arrive simultaneously at the noise sensitive premises;
- Worst-case meteorological conditions for sound propagation; and
- Very low background noise (i.e. no extraneous noise) at the receiving premises.

Because of the conservative nature of the assessment undertaken, it is suggested that predicted noise levels are verified during construction and that noise impacts are re-assessed based on the measured levels. In the event that noise emissions exceed the assigned levels then the following noise reduction options may be considered to minimise noise impacts:

- Limit the number of pile drivers operating simultaneously;
- Restrict piling operations during night time hours;
- Restrict night time piling operations under wind conditions which favour sound propagation towards Onslow town site.

Because of the very large distances between the piling operations and receiving locations considered in this assessment, ground borne vibration will be attenuated to such a degree during propagation that there will be no vibration impacts.

6.3 Construction Noise Management Criteria

6.3.1 Daytime Construction Activities

The Environmental Protection Noise Regulations 1997 state that for construction work carried out between 7am and 7pm on any day, which is not a Sunday or public holiday the assigned noise levels do not apply provided that:

- The construction work is carried out in accordance with control of noise practices set out in Section 6 of Australian Standard 2436-1981 "Guide to Noise Control on Construction, Maintenance and Demolition Sites"; and
- The equipment used for the construction is the quietest reasonably available.

The Chief Executive Officer[9] (CEO) may request that a noise management plan be submitted for the construction work at any time.

6.3.2 Night-time Construction Activities

For construction work done outside daytime hours:

- The construction work must be carried out in accordance with control of noise practices set out in Section 6 of Australian Standard 2436-1981 "Guide to Noise Control on Construction, Maintenance and Demolition Sites"; and
- The equipment used for the construction must be the quietest reasonably available.

Furthermore, if noise emissions are likely to exceed the assigned noise levels then:

- The contractor must advise all nearby occupants or other sensitive receptors who are likely to receive noise levels which fail to comply with the standard under Regulation 7, of the work to be done at least 24 hours before it commences;
- The contractor must show that it was reasonably necessary for the work to be done out of hours; and
- The contractor must submit to the CEO a Noise Management Plan at least seven days before the work starts, and the plan must be approved by the CEO. The plan must include details of:
    - Need for the work to be done out of hours;
    - Types of activities which could be noisy;
    - Predictions of the noise levels;
    - Control measures for noise and vibration;
    - Procedures to be adopted for monitoring noise emissions; and
    - Complaint response procedures to be adopted.

[9] The power of the CEO of the Department of Environment and Conservation is delegated under the noise regulations to the CEOs of all local governments in the State of Western Australia.

7. DISCUSSION & CONCLUSIONS

Predicted noise levels for normal plant operation have been shown to be in compliance with the most stringent night-time noise limits imposed under the noise regulations.

Onslow town site is the nearest residential area to the proposed development site. A comparison of predicted noise levels at Onslow with ambient noise levels demonstrates that the LNG plant is unlikely to be audible above background noise even under worst-case meteorological conditions for sound propagation.

The proposed location for the workforce accommodation camp is sufficiently distant from the LNG plant site that received noise levels will be significantly below the assigned noise levels.

Although there are no regulatory criteria for noise received at the public access areas (4 Mile Creek, 5 Mile Pool and Old Onslow), predicted noise levels for normal plant operation are higher at these locations than underlying background noise. It is possible, therefore, that plant noise may be audible at these locations under worst-case meteorological conditions for sound propagation.

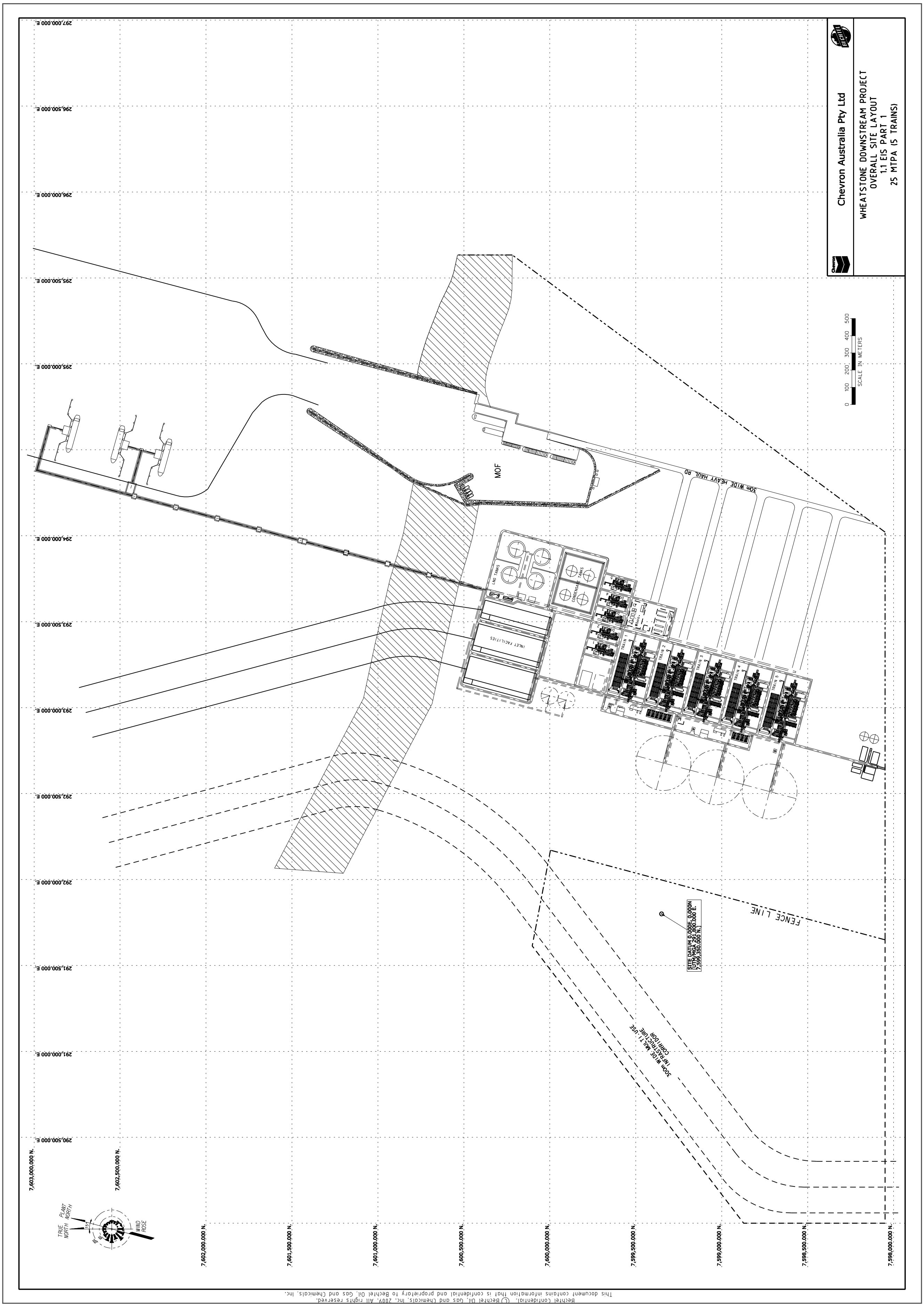
Predicted noise levels from emergency flaring have also been shown to comply with the assigned noise levels.

Noise from piling may potentially impact the town of Onslow. The modelling undertaken demonstrates that under extreme circumstances it is feasible that noise emissions could exceed assigned levels when accounting for impulsiveness. However, it is SVT's opinion that the conditions required to cause an exceedance of the assigned levels would be considered as a very remote possibility. It is, therefore, suggested that noise monitoring be undertaken during piling so as to determine whether or not noise mitigation measures are warranted. Potential noise mitigation options include:

- Limiting the number of pile drivers operating simultaneously;
- Restricting piling operations during night time hours;
- Restricting night time piling operations under wind conditions which favour sound propagation towards Onslow town site.

Measure background noise levels have been shown to be very low, particularly for inland locations.

APPENDIX A : SITE LAYOUT


Chevron Australia Pty Ltd
WHEATSTONE DOWNSTREAM PROJECT
OVERALL SITE LAYOUT
1.1 EIS PART 1
25 MTPA (5 TRAINS)
SCALE IN METERS
MOF
30m WIDE HEAVY HAUL RD
INLET FACILITIES
FENCE LINE
TRUE NORTH
PLANT NORTH
WIND ROSE

APPENDIX B : NOISE CONTOURS

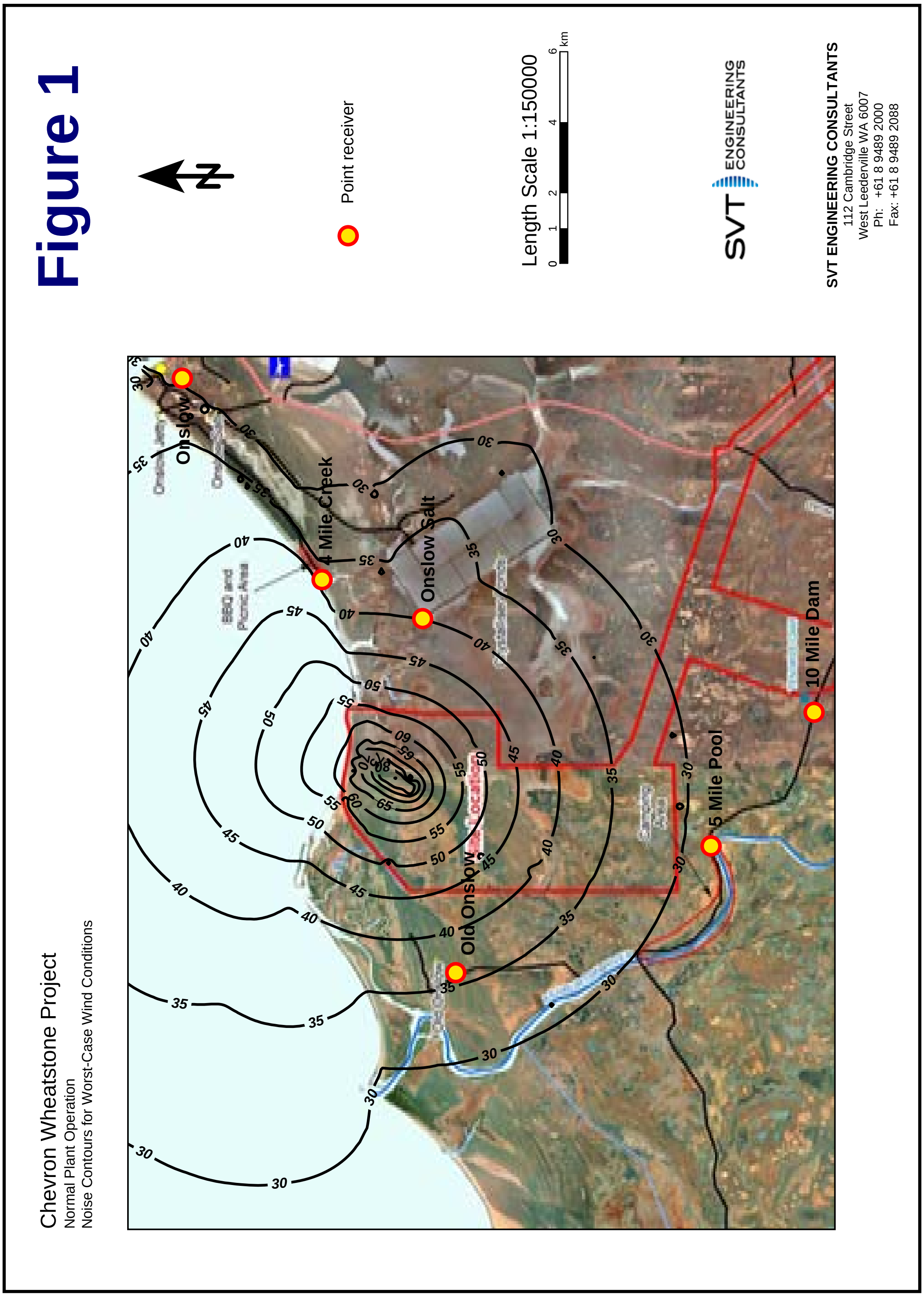


Figure 1
Chevron Wheatstone Project
Normal Plant Operation
Noise Contours for Worst-Case Wind Conditions
N
Point receiver
Length Scale 1:150000
0 1 2 4 6 km
SVT ENGINEERING CONSULTANTS
SVT ENGINEERING CONSULTANTS
112 Cambridge Street
West Leederville WA 6007
Ph: +61 8 9489 2000
Fax: +61 8 9489 2088
Onslow
4 Mile Creek
Onslow Salt
Old Onslow
5 Mile Pool
10 Mile Dam
BBQ and Picnic Area
30
35
40
45
50
55
60
65

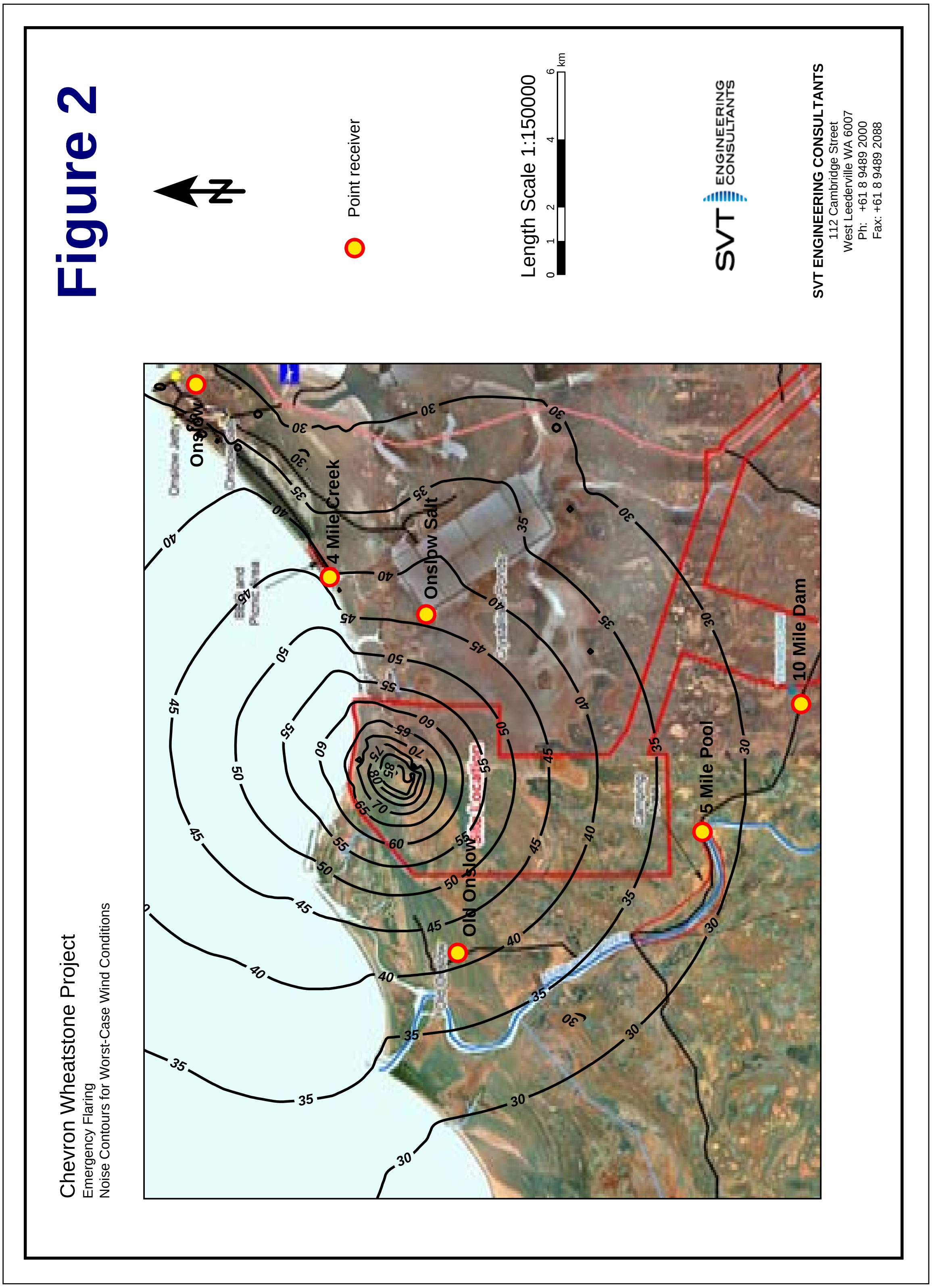


Figure 2
Point receiver
Length Scale 1:150000
0 1 2 4 6 km
SVT ENGINEERING CONSULTANTS
SVT ENGINEERING CONSULTANTS
112 Cambridge Street
West Leederville WA 6007
Ph: +61 8 9489 2000
Fax: +61 8 9489 2088
Chevron Wheatstone Project
Emergency Flaring
Noise Contours for Worst-Case Wind Conditions
Onslow
4 Mile Creek
Onslow Salt
Old Onslow
5 Mile Pool
10 Mile Dam
30
35
40
45
50
55
60
65
70
75
80
85

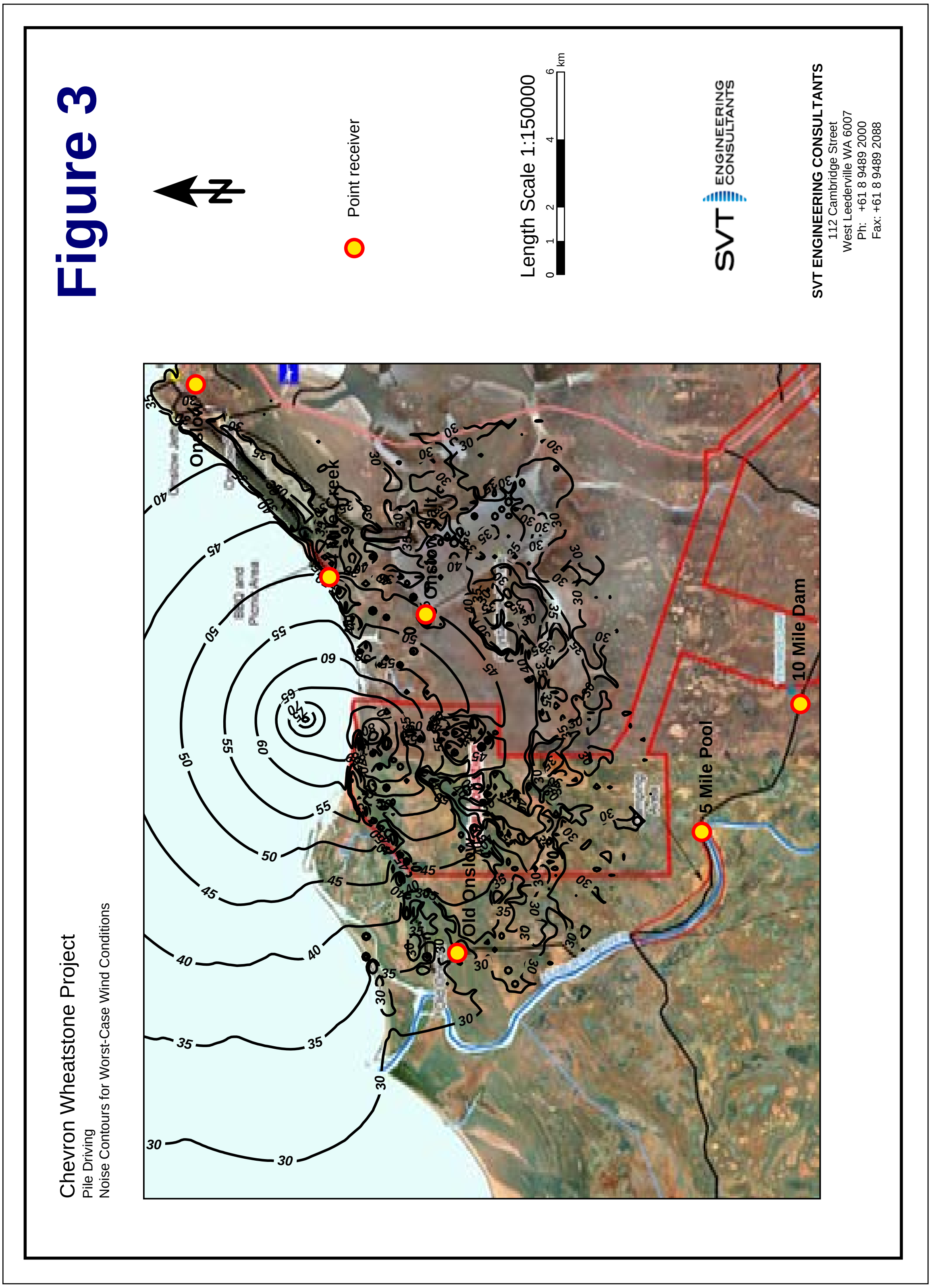


Figure 3
Chevron Wheatstone Project
Pile Driving
Noise Contours for Worst-Case Wind Conditions
Point receiver
Length Scale 1:150000
0 1 2 4 6 km
SVT ENGINEERING CONSULTANTS
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5 Mile Pool
10 Mile Dam
Old Onslow

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Appendix F1

Wheatstone Project Groundwater Studies

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f) 50 Years

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c) 50 Years

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Abbreviations

Abbreviation	**Description**
AHD	Australian Height Datum
approx	Approximately
ARI	Average Recurrence Interval
bgl	Below ground level
BoM	Bureau of Meteorology
DEM	Digital Elevation Map
Domgas	Domestic Gas
DPI	Department for Planning and Infrastructure
DoW	Department of Water
EC	Electrical conductivity
EOH	End of hole
GEMS	Global Environmental Monitoring Systems
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
Mtpa	Million tonnes per annum
mm	Millimetres
mS/cm	MilliSiemens per centimetre
na	Not available
N/A	Not applicable
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	MicroSiemens per centimetre

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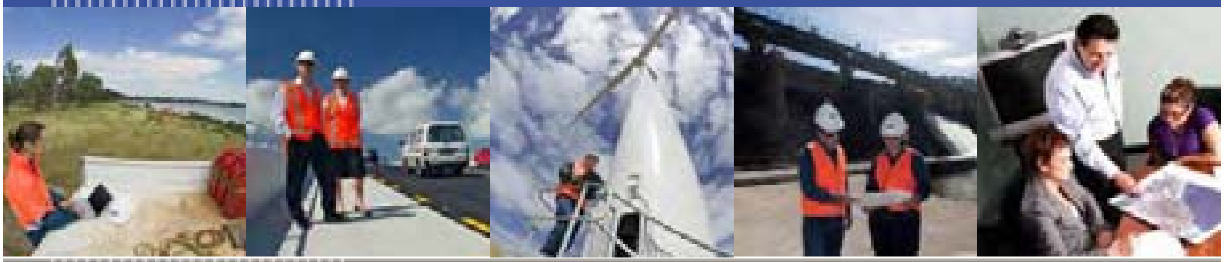

Report

Wheatstone Project Groundwater Studies

20 MAY 2010

Prepared for

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Executive Summary

Chevron Australia Pty Ltd proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and domestic gas (Domgas) plant (Wheatstone Project) at Ashburton North, 12 km southwest of Onslow on the Pilbara Coast. The proposed construction periods for the Wheatstone Project are from 2011 to 2015 and the project has an expected minimum operational life of thirty years.

Due to the potential of flooding and tidal surges, the plant will be located on a constructed 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.

This report describes the hydrogeology of the Project area. The baseline characteristics of the groundwater flow environments at Ashburton North have been determined by interpreting data from site investigations during 2009, which comprised drilling, testing and sampling 69 groundwater monitoring bores and 28 drive point piezometers. Based on the findings of the site investigations it is interpreted that Ashburton North is underlain by a shallow water table, predominantly saline to hypersaline groundwater and is predominantly a groundwater discharge zone associated with regional Carnarvon Basin successions. Local exceptions occur seasonally, when the dunal terrain intercepts and transmits rainfall recharge. All shallow groundwater intercepted by the site investigations appears to be accumulating salt, thus indicating low rates of net recharge and the predominant occurrence of hypersaline groundwater discharge into the water table zone from deeper regional aquifers.

The interpreted hydrostratigraphy and associated hydraulic parameters are based on the local geological profiles intersected during the site investigations, which comprise:

- Dune Sands (typical thickness 3 m; transmissivity 10 to 30 m^2/day).
- Ashburton River Delta alluvium (typical thickness 20 m: transmissivity about 10 m^2/day).
- Ashburton River Delta Clay and Unconformity (typical thickness 5 m; transmissivity 2 m^2/day).
- Trealla Limestone (typical thickness 10 m; transmissivity 50 m^2/day).

Local groundwater flow is influenced by topography and also density effects that characterise the flow dynamics of saline and hypersaline groundwater. Groundwater flows in dune sands; Ashburton River Delta alluvium and Trealla Limestone are strongly influenced by vertical upward hydraulic gradients. Environmental groundwater heads indicate water table mounding beneath the dunes and discharge towards lowlands formed by the supratidal, samphire and tidal flats of the Southwest, Hooley Creek and Ashburton River Mouth Catchments. The vertically upward environmental heads and constructed flow nets indicate groundwater discharge from the underlying regional Carnarvon Basin succession into the water table zone.

Chemical analyses indicate that the local groundwater is brackish to hypersaline, near neutral to slightly alkaline and a sodium-chloride type. The distribution of TDS in the groundwater shows a vertical salinity stratification, with the Trealla Limestone hosting hypersaline (156,000 to 200,000 mg/L TDS) groundwater, with the salinity gradually decreasing upwards (50,000 to 150,000 mg/L in the Ashburton River Delta alluvium; 20,000 to 120,000 mg/L in the Dune Sands) in the shallow hydrostratigraphic units. In many of the monitoring bores, dissolved metal concentrations in the groundwater are above marine ANZECC Guidelines. The comparatively high dissolved metals concentrations are commensurate with the accumulation of salt in the local groundwater environment and the high groundwater salinity.

Executive Summary

The Project developments would alter the local catchments, promote increased recharge and subsequently change water table elevations. There is potential to alter groundwater flow directions, hydraulic gradients and groundwater quality. A groundwater flow model has been developed, calibrated to the baseline water table. Subsequently the model has been adapted and applied to incorporate key elements of the Project infrastructure and to predict the changes to the baseline groundwater environment. The impact assessments and predictive model are predominantly inclusive of the option of onshore emplacement of dredge material. This option provides the largest onshore footprint and presents the worst-case for potential groundwater impacts.

Construction Earthworks – Dredge Material Placement Area

The potential dredge material placement area would be contained by perimeter embankments, except where the dune terrain provides a natural embankment. Up to 10 Mm^3 dredged material and 50 GL of seawater may be hosted within the dredge material placement area. The predictive simulations show:

- The occurrence of mounding of the water table due to loadings from and infiltration of seawater. Initial mounding occurs from vertical infiltration, with saturation of the available storage in the dredge material, dune sands and Ashburton River Delta alluvium beneath the dredge material placement area. Subsequently there is both vertical and lateral flow from the facility.
- The mounded water table is likely to predominantly initially host seawater. The baseline groundwater salinity is typically higher than that of seawater. As such, initial infiltration from the dredge material placement area may typically be of lower salinity than the baseline. Over time, however, the salinity of infiltrates may change and be variable as the salt in storage above the water table is dissolved and mobilised by rainfall infiltration.
- The total seepage from the dredge material placement area peaks at about 2,200 kL/day, with contributions of about 200 kL/day through the facility embankments, up to about 1,900 kL/day that propagates through the base of the facility and manifests as seepage on the embankment perimeters and a variable portion that is increases in storage together with through-flow. Seepage discharge is predicted to predominantly occur on the perimeter of the southern embankment. Substantially smaller scale seepage discharges occur on the perimeter of the western and natural dune sands embankments. Seepage rates rise progressively throughout the dredge campaign, peaking as the campaign ceases. Thereafter, the seepage rates decay to 200 to 400 kL/day over five to ten years. Predicted seepage rates above 1,000 kL/day occur for about one year. Seepage would be manifest as visible groundwater discharge where the rising water table intersects ground surface. Accumulation of salt is expected where the seepage expresses on the ground. Within the Ashburton River Mouth Catchment (on the toe of the dune sands that form a natural embankment for the dredge material placement area) the seepage footprint and 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 intercepted by evaporation and not express as significant surface water flows on the ground surface. Notwithstanding, the seepage potentially imposes environmental risk. As such, the excavation of perimeter drains and provision for interception of the seepage before it discharges beyond the Southwest Catchment would be appropriate. Further, the predicted seepage may be limited by refining the conceptual designs such that internal embankments are constructed of transmissive materials and not beaching the dredge material against the facility embankments.

Presence of the Plant Pad Infrastructure

Mounding of the water table is predicted to initially occur in the vicinity of the dredge material placement area. Ultimately, a comparatively small-scale (about 0.5 to 1.0 m height) local residual steady-state water table mound is predicted.

Operational Spills and Leaks

The interception of leaks and spills is addressed in the spill containment designs. Notwithstanding, infiltration of contaminants may occur. The fate of contaminants would depend on the source and configuration of the water table. Groundwater flow directions from beneath the Plant Pad are predominantly to the north and northeast, into the ocean and Hooley Creek West. Transit times for contaminants in the groundwater environment would be comparatively slow, typically limited to tens of metres per year. Consequently, there would be time to intercept contaminants before the local groundwater enters discharge zones.

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1

Introduction

1.1 Project Description

Chevron Australia Pty Ltd proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km southwest of Onslow (Figure1-1) 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, 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 just behind the coastal dunes on the coastal flood plain and tidal zones that characterise Ashburton North. The construction of the proposed plant will require raising an elevated area of land (Plant Pad) sufficient to accommodate the development of onshore buildings, marine facilities and flood protection measures. 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 completed to support the environmental impact assessment process.

1.1.1 Wheatstone Project Construction and Operation Period

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

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

1.1.2 Wheatstone Plant Development

Ashburton North (Figures 1-2 and 1-3) is located on a local-scale catchment divide between the Hooley Creek Catchment, Southwest Catchment (southwest of the proposed Wheatstone plant pad) and the Ashburton River, each of which are hosted by the coastal delta area of the Ashburton River, termed the Ashburton River Delta. The Ashburton North site is exposed to tidal variation and intense rainfall and storm surges associated with tropical cyclones and monsoonal rain depressions.

The Wheatstone Project comprises the onshore construction of a Plant Pad, Shared Infrastructure Corridor and Accommodation Village. Within the western portion of the footprint of the Plant Pad there may be a dredge material placement area (Figure 1-2). Alternative to the onshore placement would be disposal of all dredge material in offshore domains, resulting in a different onshore Project area footprint (Figure 1-3). Borrow material for construction of elevated platforms is proposed to be sourced from selected pits within the Hooley Creek Catchment. The selected borrow pits (Figure 1-2) occur on islands and foreshore areas of the tidal embayment at Ashburton North.

1 Introduction

Plant Pad

The plant will be located on a raised platform (Plant Pad) constructed to an elevation of approximately 7.5 m AHD. Construction of the platform would be engineered using borrow material and potentially dredge material. The potential dredge material placement area is a discrete facility with embankments forming the western perimeter of the Plant Pad. The proposed Plant Pad is located on the catchment boundary between the Southwest and Hooley Creek Catchments. All plant area permanent structures would be set above the 1:100 Year Average Recurrence Interval (ARI) flood elevation.

Dredge Material Placement Area

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 located within the Plant Pad footprint. The location of the dredge material placement area is shown on Figure 1-2.

The dredge material handling and storage is described as follows:

- During an 18 month near-shore cutter suction dredging program seawater slurry would drain into a discrete embankment area where dredge material solids settle. A decant drains the return water and the suspended fines into slimes ponds for settlement of the fines prior to discharge of the return water.
- Dredger productivity is likely to be up to 200 000 m^3/week of dredge material transported in up to 1 GL/week of seawater. The ratio of dredge material solids to seawater is approximately 1:5.
- The capacity of the dredge material storage facility is estimated to be 20 Mm^3.
- The total volume of dredge material solids to be stored is estimated to be 10.3 Mm^3 (13.3 Mm^3 after bulking).
- Perimeter embankments for the placement area would be constructed along the northern, southern and western boundaries to a crest elevation of approximately +7.5 m AHD at the plant and approximately +6.5 m AHD at the western boundary, with 1 in 5 slopes and 20 percent compaction.
- The potential pathway for the discharge of decanted seawater would be to the shore line in front of Plant Pad.
- Disposal decanted seawater would be subject to a discharge limit of 20 mg/L TSS.

Shared Infrastructure Corridor

The proposed minimum finished elevation for the Shared Infrastructure Corridor from the existing Onslow Road, via the Construction Village to the plant pad is approximately 6.00 m AHD, designed to be above the 1:100 Year ARI storm surge elevation of approximately 4.8 m AHD.

The proposed alignment of the Shared Infrastructure Corridor intersects several drainage lines in the Hooley Creek Catchment. These drainage lines drain local runoff from the Hooley Creek Catchment and periodic Ashburton River flood water after intense rainfall events.

Accommodation Village

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

1.2 Objectives and Scope of Work

The objectives of this study are to:

- Assess the hydrogeology of the existing environment
- Interpret the available data to develop a conceptual hydrogeological model and baseline groundwater conditions at Ashburton North.
- Identify potential impacts of the proposed Wheatstone Project on the groundwater environment. The impact assessments are predominantly inclusive of the option of onshore emplacement of dredge material. This option provides the largest onshore footprint and presents the worst-case for potential groundwater impacts.

Water supplies for the Wheatstone Project are intended to be sourced from seawater. Hence, impacts on the groundwater environment due to groundwater abstraction during construction will be insignificant.

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2

Physical Setting of the Project Area

2.1 Physiography

The Wheatstone Project is located on the Onslow coast, near the mouth of Hooley Creek and about 8 km east of the mouth of the Ashburton River, within the Northern Carnarvon Basin. The regional physiography of the Northern Carnarvon Basin is dominated by wide alluvial valleys and river deltas associated with the drainage basins formed by the Yannarie, Ashburton, Cane, Robe and Fortescue Rivers. Each drainage basin hosts extensive low-relief alluvial plains interspersed with red dune fields. River flows are ephemeral, but semi-permanent water holes can occur locally in the river beds.

The landforms within the area result from periods during the Tertiary when the Carnarvon Basin was a shallow sea bordering continental Australia. After the Eocene Epoch, both Cretaceous and lower-Tertiary successions were exposed to an arid climate, with the associated formation of calcrete duricrusts in the Pliocene and coastal dunes in the Pleistocene.

The vegetation is essentially open to dense shrub land and spinifex grassland. Occasional trees, including large Eucalypts, occur along the nearby Ashburton River. Land use is mainly pastoral with the exception of the Onslow Salt Project, which is located about 3 km from Ashburton North.

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) seasons. 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). The summer season is characterised by hot daytime temperatures, often exceeding 40^{o}C between November and February, and widely variable rainfall. The winter season is 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 winds.

The annual rainfall typically ranges from 230 to 350 mm and mainly occurs during cyclonic activity from January through April. Rainfall patterns vary widely due to the influence of tropical cyclones. Rainfall can be irregular and localised due to thunderstorm activity. Typically, rainfall intensity is highest near the coast and decreases inland. Rainfall from a single monitoring site is seldom representative of the entire local or regional catchment.

Evaporation averages about 3,100 mm/year, measured at Onslow Airport. A nine-year evaporation record from 1966 to 1975 is available at Onslow. The closest station with long-term recorded evaporation rates is 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 Onslow record. Evaporation is strongly seasonal with long-term, mean monthly pan evaporation rates of 370 mm in December and 135 mm in June.

2 Physical Setting of the Project Area

Table 2-1 Average Monthly Climate Statistics

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

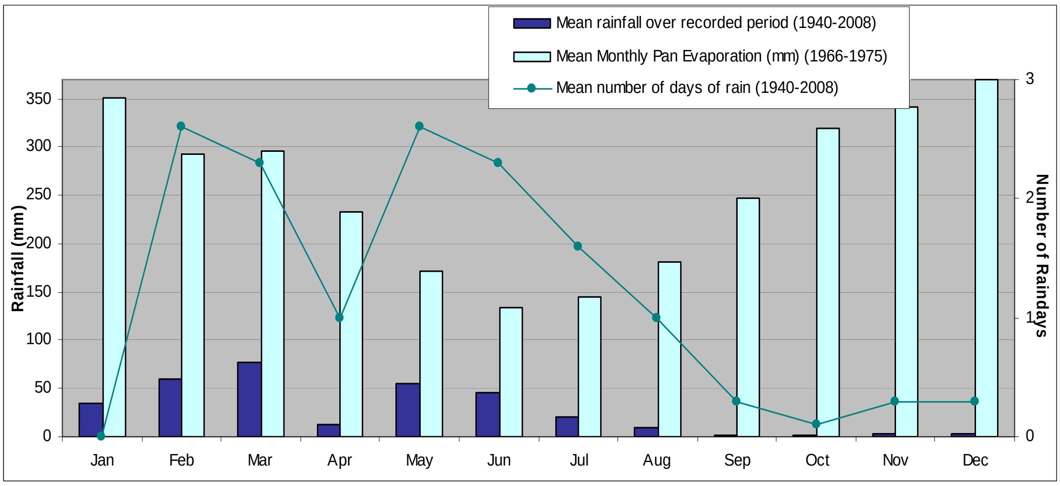

Chart 2-1 Rainfall, Number of Rain Days and Evaporation at Onslow Airport

2 Physical Setting of the Project Area

2.2.1 Tropical Cyclones

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

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 river channel, predominantly resulting from 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 further increases in annual rainfall in the near future.

Notwithstanding the annual rainfall trends at Onslow, it is estimated (Climate Change in Australia - 2007) that: (i) the Pilbara will experience a decrease in annual rainfall of between two and five percent by 2030 and (ii) changes in rainfall patterns will result in an increase in both rainfall intensity (rain per rain-day) and the number of dry days in the future. Therefore in the future, longer dry spells, dispersed by heavier rainfall events, may occur at Ashburton North.

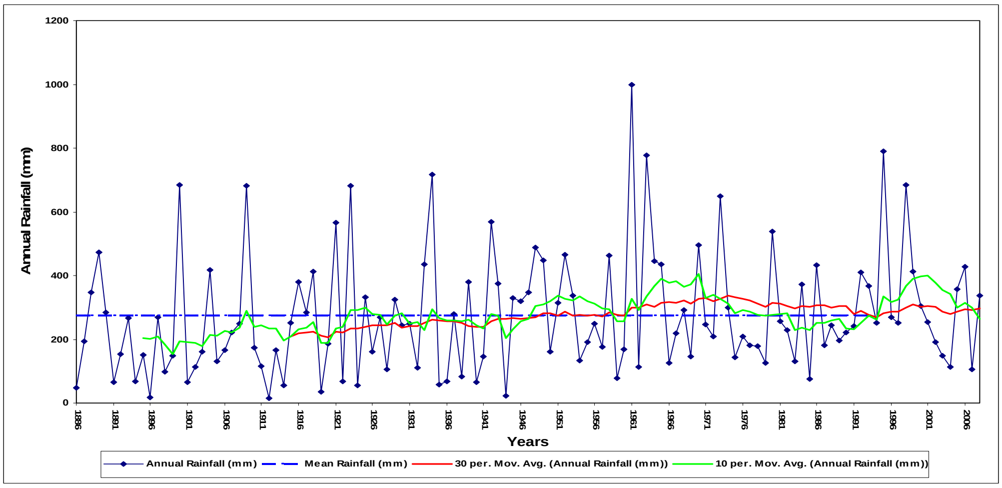

Chart 2-2 Annual and Mean Rainfall at Onslow (BoM Station 005017; 1886 to 2008)

2 Physical Setting of the Project Area

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 pre-1970 data may be less reliable than recent satellite data, these results suggest that the frequency of cyclones is likely to increase in the future.

Contrary to the findings by Qi *et al* (2008), a number of studies (including Climate Change in Australia, 2007), 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.

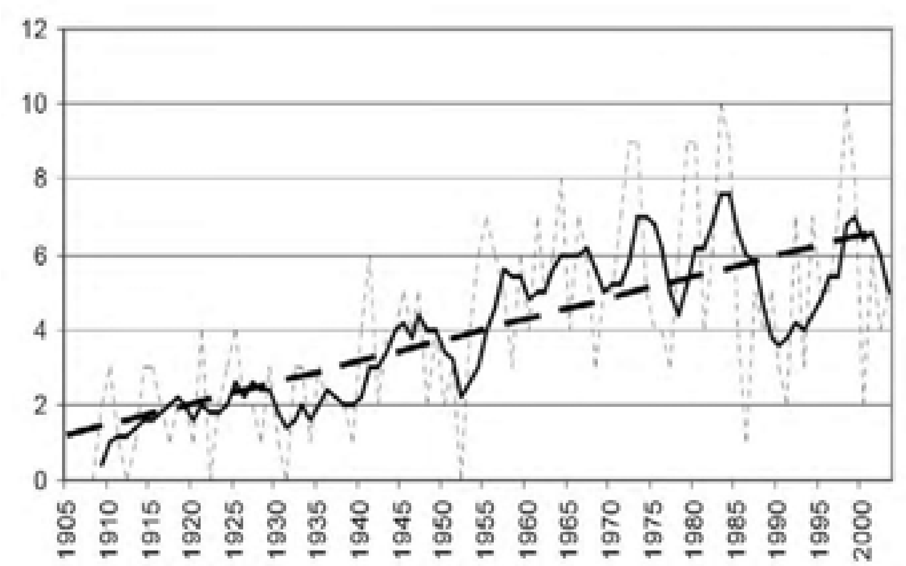

Chart 2-3 Annual Number of Cyclones in WA, Trend Line and 5-Year Moving Average

Evaporation

CSIRO has estimated that temperatures within 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 likely that evaporation rates would increase as a result, although the likely impact is difficult to quantify. Any increase in evaporation rates may be offset by an increase in rainfall intensity.

2.3 Geology

2.3.1 Geological Setting

The Geological Survey of Western Australia (1975) produced a 1:250 000 geological map and report of the regional area around Onslow as Bulletin 133. These geological data and interpretations were substantially updated in publications by Lasky and Mory (1999) and Lasky *et al* (2003).

The Palaeozoic-Recent Northern Carnarvon Basin is a large, mainly offshore, basin on the northwest shelf of Australia. The major basin faults trend north or northeast and define a series of structural highs and sub-basins. Figure 2-3 shows the regional tectonic framework of the Northern Carnarvon Basin.

The Northern Carnarvon Basin developed during four successive periods of extension and thermal subsidence. 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 shelf marls and carbonates dominate the Mid-Cretaceous to Cainozoic successions. The carbonate-rich sediments were deposited as a series of northwest propagating wedges as the region continued to cool and subside. This resulted in deep burial of the underlying Mesozoic source and reservoir sequences in the inboard part of the basin.

Almost all the known hydrocarbon resources in the basin occur in reservoirs within the Upper Triassic, Jurassic and Lower Cretaceous sandstones beneath a regional Early Cretaceous seal formed by the Muderong Shale Formation.

Ashburton North is located on the Peedamullah Shelf within the Northern Carnarvon Basin. Figure 2-4 shows the pre-Cretaceous geology of the Peedamullah Shelf and Onslow Terrace and a cross-section (D-D', Figure 2-5) through Ashburton North. Major structural elements in the region appear to control the thickness of sediments.

2.3.2 Stratigraphy

The local superficial formations are about 25 m thick and predominantly comprise silty and sandy alluvium, with occasional sandy palaeochannel deposits, associated with the Ashburton River Delta.

Underlying the superficial formations is Tertiary limestone and sandstone (Trealla Limestone), with a variable thickness (maximum about 60 m). Beneath the Trealla Limestone is a thick Early-Cretaceous succession of the Winning Group that includes the Gearle Siltstone, Windalia Radiolarite, Muderong Shale, Mardie Greensand and Birdrong Sandstone.

The stratigraphy beneath Ashburton North is summarised in Table 2-2 and described below. The presented data are predominantly interpreted from the Jade 1 petroleum exploration well (Department of Industry and Resources, Western Australia, Information Request for Jade 1, 1993) located in the centre of the Project area. Jade 1 was drilled in 1993 by Pan Pacific Petroleum NL to test the local hydrocarbon potential of the Birdrong Sandstone.

The regional surface geology of the area is shown on Figure 2-6 and the interpreted generic stratigraphy is shown on Figure 2-7.

2 Physical Setting of the Project Area

Table 2-2 Interpreted Regional and Ashburton North Stratigraphy

<table>
<tr><th colspan="2">Formation</th><th>Age</th><th>Lithology</th><th>Typical Depth Interval (m)</th></tr>
<tr><td colspan="2">Superficial Formations Dune Sands</td><td>Recent/Quaternary</td><td>Gravelly sand, calcareous sandstone and sand variably lithified and consolidated.</td><td>0 - 3</td></tr>
<tr><td colspan="2">Superficial Formations Ashburton River Delta Alluvium</td><td>Recent/Quaternary</td><td>Poorly consolidated claystone and minor limestone.</td><td>0 - 25</td></tr>
<tr><td colspan="5">----------Unconformity----------</td></tr>
<tr><td colspan="2">Trealla Limestone</td><td>Tertiary</td><td>Interbedded limestone and claystone with siltstone, sand and limestone at the base.</td><td>25 - 87</td></tr>
<tr><td colspan="5">----------Unconformity----------</td></tr>
<tr><td rowspan="5">Winning Group</td><td>Gearle Siltstone</td><td>Early-Cretaceous</td><td>Argillaceous siltstone, grading to a silty claystone; commonly pyritic, glauconitic and micaceous.</td><td>87 - 318</td></tr>
<tr><td>Windalia Radiolarite</td><td>Early-Cretaceous</td><td>Radiolarian siltstone.</td><td>318 - 382</td></tr>
<tr><td>Muderong Shale</td><td>Early-Cretaceous</td><td>Argillaceous siltstone with thin lenses of siltstone and fine sandstone.</td><td>382 – 476</td></tr>
<tr><td>Mardie Greensand Member</td><td>Early-Cretaceous</td><td>Glauconitic sandstone and minor interbedded claystone, silica cemented.</td><td>476 – 490</td></tr>
<tr><td>Birdrong Sandstone</td><td>Early-Cretaceous</td><td>Glauconitic sandstone with minor interbedded claystone.</td><td>490 – 502</td></tr>
<tr><td colspan="2">Mungaroo Formation</td><td>Triassic</td><td>Quartzose sandstone, siltstone and shale.</td><td>502 - 604</td></tr>
</table>

2 Physical Setting of the Project Area

Recent

SUPERFICIAL FORMATIONS ALLUVIUM (0 to 25 m depth)

Tidal flats comprise: (i) near-surface Quaternary beach and coastal dune systems (unconsolidated quartz calcarenite); or (ii) intertidal flats and mangrove swamps (calcareous clay, silt and sand); and are underlain by claypan-dominant terrain (clay, silt and minor sand).

Inland from the coast, colluvial sediments (clay, silt, sand and gravel) generally overlie clay-pan deposits. Weakly calcretised alluvial sediments (containing clays, silts, sand and gravel) are generally found within major river systems (such as the Cane and Ashburton Rivers) and minor creeks.

Tertiary

TREALLA LIMESTONE (25 to 87 m depth)

The Trealla Limestone can be subdivided into three lithological units: (i) an upper interbedded claystone and limestone unit; (ii) a middle limestone unit; and (iii) a lower unit of interbedded siltstone, sand and limestone.

The upper unit comprises soft, puggy, dispersive claystone (similar to the overlying superficial formations) and limestone made up of predominantly calcilutite and subordinate calcarenite. The middle unit consists of hard and brittle calcilutite and variably dolomitic calcarenite. The lower unit is characterised by generally soft, sticky and dispersive claystone interbedded with unconsolidated sands with a high inferred porosity.

Cretaceous

UPPER GEARLE SILTSTONE (87 to 259 m depth)

Non-calcareous glauconitic siltstone/claystone, strongly pyritic towards the middle of the unit and becoming interbedded with sandstone, calcilutite and dolomite at the base.

LOWER GEARLE SILTSTONE (259 to 318 m depth)

A generally soft, puggy, blocky, non-calcareous siltstone with both glauconite and pyrite in trace amounts. Thin intercalations of sandstone and calcilutite occur, but are rare.

WINDALIA RADIOLARITE (318 to 382 m depth)

Predominantly comprises radiolarite, siltstone, claystone and minor very fine-grained sandstone with white specks of radiolarians and bentonite.

MUDERONG SHALE (382 to 476 m depth)

Interbedded siltstone and claystone, with sandstone and dolomite towards the base. It is the main reservoir rock in the Barrow Island Oil Field. Both the Windalia Radiolarite and the Muderong Shale were deposited in a shallow-marine environment in the initial phase of a transgression.

MARDIE GREENSAND (476 to 490 m depth)

Glauconitic and pyritic sandstone and minor interbedded claystone.

BIRDRONG SANDSTONE (490 to 502 m depth).

Unconsolidated, coarse-grained to granular sand with subordinate interbedded claystone. The upper sand from 490.0 to 492.5 m (2.5 m thick) has a maximum porosity of 25 percent (average 15 percent), while the lower sand from 494.5 to 501.5 m (7 m thick) has a maximum porosity of 33 percent (average 25 percent).

Both sands have sharp bases and fining-upwards log signatures characteristic of low gradient fluvial sands, and show resistivity log separation and mud-cake build-up indicative of a hydraulic conductivity similar to that of sandstone aquifers. The local and regional Birdrong Sandstone is interpreted to form an aquifer.

Triassic

MUNGAROO FORMATION (502 to 604 m depth)

Glauconitic sandstone, locally pyritic and often hosting pyritised fossil fragments. The thicker sand successions (10 to 20 m thick) show the blocky character indicative of a high-energy fluvial deposition environment. The thinner sands beds (5 to 10 m thick), show fining upwards character indicative of a low-energy fluvial deposition environment. Fossil fragments down to 530 m may indicate a shallow marine environment for the shaly interbeds. The lower part of the Mungaroo Formation in Jade 1 may have been deposited in a high-energy fluvial environment and the upper part in a low-energy coastal plain. Porosities range up to 38 percent (average around 25 percent) and showing pronounced mud-cake build-up indicating hydraulic conductivity similar to that of sandstone aquifers.

2.4 Hydrogeology

Outside of the Carnarvon Basin, there are no known major groundwater resources near the coast in the rocks of the Pilbara Craton. Therefore, the description of the regional hydrogeology is limited to the Carnarvon Basin.

2.4.1 Overview and Previous Work

Carnarvon Basin

Hydrogeological assessments of the Carnarvon Basin have been developed from groundwater drilling data and petroleum exploration activities. Many assessments focus on the Birdrong Sandstone (and associated aquifers), as this regional aquifer system has been the predominant source for stock and domestic water supplies since the early-1900s. 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 Physical Setting of the Project Area

In a regional context, an initial study by Playford and Chase (Australian Petroleum Pty. Ltd, 1955) collated geological and hydrogeological data for the Carnarvon Basin from the previous 50 years. A follow-up study (McWhae) was completed in 1958. Allen (1986) interpreted groundwater level data, produced a map of potentiometric groundwater elevations for the Birdrong Sandstone and investigated the consequences of long-term uncontrolled groundwater flows from Birdrong Sandstone artesian bores. In 1996, Skidmore provided an assessment of the groundwater resources hosted by the major catchments of the Pilbara. A regional-scale hydrogeological assessment of the Carnarvon Basin is provided by Wills and Dogramaci (2000) and Hillier *et al* (2002) investigated groundwater recharge and flow using stable and radiocarbon isotopes.

Southern Carnarvon Basin

Site specific, local groundwater studies have been completed in the Southern Carnarvon Basin associated with recharge to reaches of the Wooramel River on Meedo Station (Global Groundwater, 2004) and the Gascoyne River at Carnarvon (Panasiewicz, 1995). Further south, near Shark Bay, the hydrogeology of both the superficial formations and Birdrong Sandstone was investigated for the Coburn Mineral Sand Project (URS, 2005 and 2006).

Northern Carnarvon Basin

Within the Northern Carnarvon Basin, there are comparatively recent hydrogeology studies by Martin (1989), Tomlinson (1994) and Yesertner and Prangley (1997) on alluvial aquifers preferentially developed in high-energy fluvial palaeochannel deposits associated with the Cane and Ashburton rivers.

Alluvial successions and Trealla Limestone, beneath reaches of the Cane River, were investigated by drilling programs reported by Martin (1989). The Cane River is reportedly underlain by about 25 m of alluvium which unconformably overlies the Trealla Limestone. Both successions form aquifers and are hydraulically connected. The alluvium consists of poorly sorted silt, sand and gravel with lenses of palaeochannel sand and gravel limited in thickness to about 5 m.

Tomlinson (1994) developed an estimate of the sustainable yield of Cane River alluvial successions.

Yesertner and Prangley (1997) reported on a Water and Rivers Commission groundwater exploration drilling program in June 1994 to investigate the superficial formations aquifers associated with the Ashburton River. The program focussed on an area about 80 km south of Ashburton North and consisted of nine groundwater exploration bores. The major aquifer identified by the drilling program comprised alluvial gravel and sand deposits of the ancient river bed, which extends 18 km northwest from the Ashburton River at Nanyingee Hill.

In 2008, Haig completed an overview of the groundwater resources potentially hosted in alluvial palaeochannel successions, associated with ancient watercourses of the major rivers, along the Pilbara coast. This study included the Ashburton, Cane, Robe and Fortescue Rivers of the Northern Carnarvon Basin.

2.4.2 Unconfined Aquifers

Groundwater in the regional hinterland of Ashburton North occurs in shallow unconfined aquifers associated with major river channels.

2 Physical Setting of the Project Area

Within the Northern Carnarvon Basin, unconfined aquifers are known to be formed by:

- Alluvial palaeochannel successions associated with ancient watercourses beneath reaches of most major rivers.
- Alluvial successions beneath the wide river valleys and deltas associated with the drainage basins formed by the Yannarie, Ashburton, Cane, Robe and Fortescue Rivers on the coastal plain.

Where saturated, dune beach sands may form local minor aquifers.

Alluvial Palaeochannels

Shallow, brackish groundwater resources along the Pilbara coast occur predominantly in alluvial palaeochannel aquifers associated with the major rivers (Ashburton, Cane, Robe and Fortescue) (Figure 1-1). These aquifers are formed by relict fluvial sand and gravel deposits in ancient watercourses that occur beneath and/or adjacent to the current river beds. Groundwater recharge occurs predominantly from the infiltration of intermittent stream flow. Comparatively low salinity groundwater from alluvial palaeochannel aquifers beneath the Cane, Yule and De Grey rivers is currently used for town water supplies. It is likely that all alluvial palaeochannel aquifers contain saline groundwater near the coast.

The transmissive successions of the Cane River alluvial palaeochannel occur as narrow ribbon deposits sub-parallel to the current river. They have a saturated thickness from about 7 m in the north to 18 m in the south. Significant yields are reported from the contact between the alluvium and the Trealla Limestone. The limestone produces variable yields from bedding-plane partings, fractures and joints. The Lower Cane River alluvial palaeochannel aquifer is the source for the Onslow Water Supply Scheme. Currently 19 production bores are operating for a licensed allocation of 0.35 GL/year. The sustainable yield is about 0.3 GL/yr for the wellfield, which traverses a 3 km length of the river (Tomlinson, 1994). The available yield from the Lower Cane River alluvial palaeochannel is about 0.1 GL/year for each kilometre of river (Hydrogeology Report Series; The Pilbara Coast Water Study; Haig, 2008).

The known alluvial palaeochannel of the Ashburton River consists of sand and gravel deposits up to 37 m thick; with the basal 14 m being saturated. Siltstone and claystone of the Gearle Siltstone or Windalia Radiolarite occur beneath the alluvial successions. Airlift yields from the investigation bores in the alluvial palaeochannel ranged from 15 to 42 kL/day (Yesertener and Prangley, 1997). The Ashburton River alluvial palaeochannel aquifer covers a known area of about 100 km^2 and about 40 km^2 probably contains groundwater of salinity < 2,000 mg/L TDS. By assuming an average saturated thickness of 14 m, and a specific yield of 0.2 (dimensionless) for the alluvial palaeochannel deposits, groundwater storage of about 100 GL is estimated. It is likely that recharge occurs from stream flow along comparatively short reaches of the Ashburton River. Groundwater is a sodium-chloride type and salinity ranges from 2,000 to 8,000 mg/L TDS in the area investigated.

Coastal Plain Alluvium

Regionally, the water table occurs in alluvial successions formed by the superficial formations. Typically, the alluvial successions of the superficial formations beneath the wide river valleys and deltas of the coastal plain are less than 30 m thick. These sediments overlie Tertiary and/or Cretaceous limestone, siltstone and claystone successions of the Trealla Limestone, Gearle Siltstone or Windalia Radiolarite. Groundwater levels are typically less than 10 m below ground in inland areas and within a few metres of (or at) ground surface near the coast. Groundwater flow is to the northwest, towards the coast, and discharges into river deltas and the ocean. Beneath the coastal plain, pastoral supplies of brackish to saline groundwater are abstracted from low-yielding bores and wells.

Groundwater salinity is generally adequate for stock watering, only if sourced from the water table zone. Groundwater yields from the superficial formations are moderate to small.

2.4.3 Confined Aquifers

Groundwater in the regional hinterland of Ashburton North also occurs in confined aquifers in the deeper Carnarvon Basin successions.

Confined aquifers are known to occur in the Trealla Limestone (semi-confined by the superficial formations), and Birdrong Sandstone (confined by the Gearle Siltstone and Muderong Shale).

The Windalia Radiolarite has an anisotropic permeability distribution and may be only a minor confined aquifer (Wills and Dogramaci, 2000) or an aquitard (Lasky, 2003).

Trealla Limestone

The Trealla Limestone occurs predominantly beneath the coastal plain from the Ashburton River to the Lower Robe River. It has a poorly defined distribution and outcrops only in small, isolated patches. In Jade 1, Trealla Limestone is intersected at 25 m and has a thickness of 62 m. The local succession consists of limestone, sand, siltstone and claystone interbeds. Limestone is the predominant lithology in the form of calcarenite and calcilutite. Groundwater recharge occurs by leakage from the overlying alluvial successions (Skidmore, 1996). There is limited information on yields from bores completed in the Trealla Limestone. At the Robe River, yields of 980 kL/day have been reported where fissured limestone is in contact with the overlying alluvial sediments. In the Lower Cane River area, yields of up to 300 kL/day have been reported where the limestone is fractured, but most yields are less than 100 kL/day (Skidmore, 1996).

Birdrong Sandstone

The Birdrong Sandstone predominantly comprises poorly sorted glauconitic sandstone, with minor siltstone and conglomerate. At the inland margin of the Carnarvon Basin, the Birdrong Sandstone is unconfined where the overlying Muderong Shale is absent; groundwater recharge occurs in this area. The recharge is interpreted to be predominantly sourced from the infiltration of stream flow where the Birdrong Sandstone is unconfined. Nominally, the recharge rates are 0.5 (Wills and Dogramaci, 2000) to 10.0 (Department of Environment, 2004) mm/year, thus representing <1 to 4 percent of annual average rainfall. Based on groundwater isotope data, Hiller *et al*. (2002) suggest recharge rates of about 1.5 to 2 mm/yr in the Carnarvon Basin. DoE (2004) suggests that the annual total recharge to groundwater in the Carnarvon Basin is approximately 17 GL.

In Jade 1, the Birdrong Sandstone was intersected at 490 m, with a thickness of 11.5 m. Regionally, the Birdrong Sandstone has consistently high porosity and hydraulic conductivity (Crostella and Lasky, 1997), with porosities of 25 to 33 percent. Pan Pacific Petroleum NL (Department of Industry and Resources 1993, Information Request for Jade 1) reported the Birdrong Sandstone in Jade 1 as having good reservoir characteristics (average porosity 25 percent). Petrophysical analyses indicate that the entire succession is probably an aquifer.

The interpreted potentiometric surface of the Birdrong Sandstone (URS, 2007) is a few metres above sea level in the vicinity of Onslow. Groundwater flow is to the northwest, towards the coast, with natural discharge occurring offshore via faults into overlying sediments and ultimately to the sea. Groundwater salinity increases from brackish (5,000 mg/L TDS) along the eastern margin to saline (>10,000 mg/L TDS) nearer the coast. Estimated groundwater salinity in the Birdrong Sandstone in Jade 1, is about 6,050 mg/L[1] TDS. The temperature of groundwater in the Birdrong Sandstone ranges from around 30 ^{o}C inland to 45 to 60 ^{o}C along much of the coast, depending on the depth.

2.5 Hydrological Characteristics of the Ashburton River

Ashburton North is located in the Ashburton River Catchment. The Ashburton River is one of the major rivers of the Pilbara with a catchment area of approximately 79,000 km^2 (Figure 2-8). Stream flow is ephemeral, occurring in response to significant local and regional rainfall events. Runoff is preferentially generated 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, the lower reaches of which are frequently inundated by the sea. Major flows occur in the Ashburton River every one to three years. River flows predominantly occur during the cyclone season and are typically ephemeral.

At a local scale, Ashburton North is located within the Ashburton River Delta, the near-coastal expression of the Ashburton River Catchment. The catchment area of the Ashburton River Delta comprises the Ashburton River Mouth, Southwest, Hooley Creek and Northeast Catchments (Figure 2-9). The proposed Plant Pad 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 area well outside the tidal zone, but the alignment of the Shared Infrastructure Corridor crosses a number of drainage lines within the catchment.

2.5.1 Ashburton River - Historical Flows and Flood Events

Flow in the lower reaches of the Ashburton River (Chart 2-4) has been monitored since 1972 at the DoW gauging station at the Nanutarra Bridge, approximately 100 km inland from the river mouth. The annual flow volumes in the Ashburton River vary significantly, ranging from 3 GL in 2007 to 4,500 GL in 1997.

[1] Using the 16" (R_{16}=7 ohm.m) and 64" (R_{64}=7 ohm.m) resistivity normals after Archie's law (Archie, 1942) with F as the Formation factor with a porosity of 25 percent in the following formula:

$$R_T = \frac{R_{64} \times R_{64}}{R_{16}} = \frac{8.5 \times 8.5}{7} = 10.7 \ ohm.m; \ TDS = \frac{5,300}{\left(\frac{R_T}{F}\right)} = \frac{5,300}{\left(\frac{10.7}{12.21}\right)} = 6,048 \ mg/L$$

2 Physical Setting of the Project Area

The maximum flow rates on the Ashburton River (Chart 2-5) were obtained for every year; using the average daily maximum stream flow values.

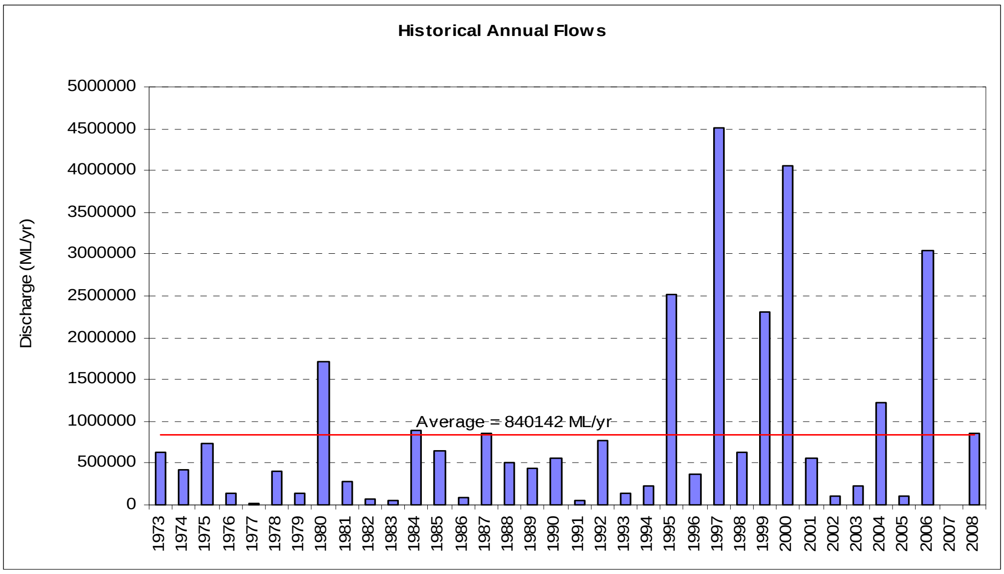

Chart 2-4 Ashburton River - Annual Flow Volumes (1973 to 2008)

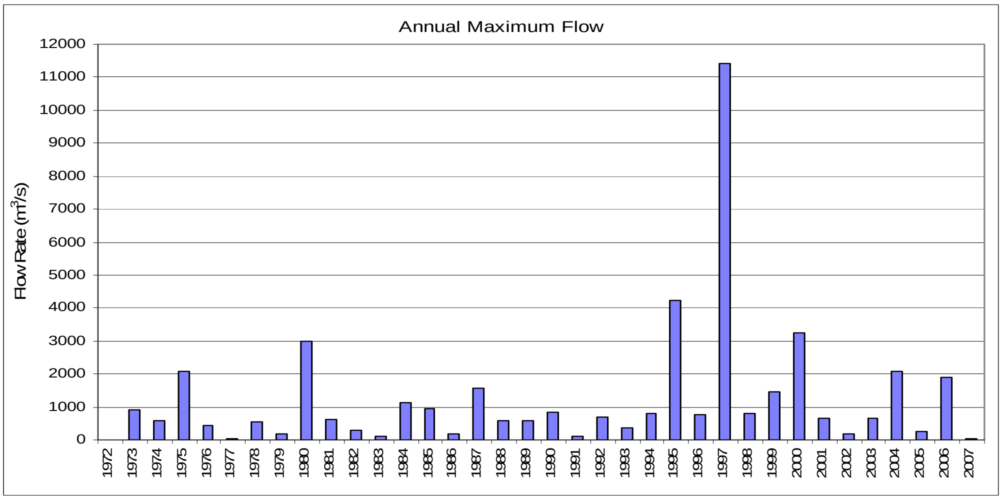

Chart 2-5 Ashburton River - Annual Maximum Flow Rates (1973 to 2008)

2.5.2 Ashburton River - Frequency of Flooding

A flood frequency assessment of the Ashburton River was performed using Log-Pearson Type III Analysis to obtain the magnitude and frequency of stream flow on the Ashburton River. Interpreted flows for selected ARI events are shown in Table 2-3.

Table 2-3 Ashburton River - Flood Frequency Using Log-Pearson Analysis III

Average Recurrence Interval (years)	Discharge (m^3/s)
1	5
2	700
5	2000
10	3150
25	4500
50	6000
100	7000
200	8000
500	9000
1000	11 000

A flood frequency analysis (Chart 2-6) was prepared for the Ashburton River, based on flows recorded at the Nanutarra Bridge. The flow event in February 2009, resulting from Cyclone Dominic, recorded a peak flow at the Nanutarra Bridge of 411 m3/s. This flow event has a recurrence interval of less than two years (Chart 2-6).

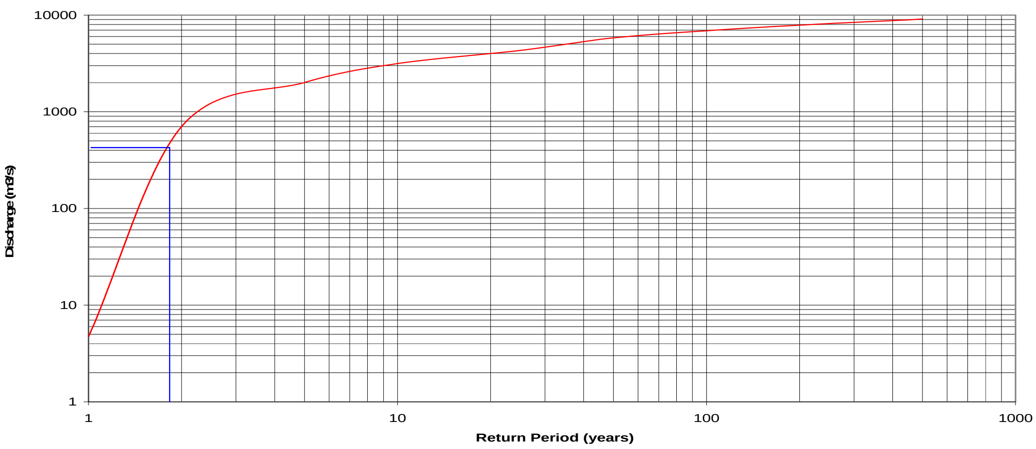

Chart 2-6 Ashburton River - Flood Frequency Analysis

2.5.3 Ashburton River - Water Quality

The Ashburton River flow is generally fresh, with a salinity of about 130 mg/L TDS (Ruprecht & Ivanescu, 2000). Water salinity in others rivers in the Pilbara is similar, typically in the range of 50 to 1,000 mg/L. Salinity in the Ashburton River generally decreases with increasing flow, becoming more saline during times of low flow.

When in flow, the Ashburton River mobilises sediment. The total average sediment load has been calculated to be 1.3 Mtpa (URS, Ashburton River Flow and Sediment Study, May 2009). Annually, this load varies widely, depending on river flow. The total estimated 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 Mt (in 1997 during a major flood event). Total Suspended Solids (TSS) and turbidity in the flow of the Ashburton River are generally low, but increase as flows increase. 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. The flow weighted turbidity for the Ashburton River is 1,705 NTU, which is higher than other Pilbara rivers, which range from 10 to 587 NTU (Ruprecht & Ivanescu, 2000). There is a correlation between TSS and turbidity, which is site-specific and can be determined for individual systems. In general, both TSS and turbidity increase with increased flows. For average flow rates, the turbidity in the Ashburton River is comparatively low. In flood events, however, comparatively high turbidity has been observed, suggesting active erosion in the catchment during high rainfall events.

2.5.4 Ashburton River Delta Catchment

The Ashburton River Delta Catchment has an area of 190 km^2 (Figure 2-9). The Ashburton River Delta Catchment comprises the Ashburton River Mouth, Southwest, Hooley Creek and Northeast catchments. None of these catchments is gauged.

The Ashburton River Delta Catchment is characterised by:

- A comparatively small catchment area.
- Ephemeral runoff estimated to vary significantly, depending on local and regional rainfall.
- Five main watercourses (Ashburton River, Hooley Creek West, Hooley Creek East, Eastern Creek and Four Mile Creek) discharging into the ocean.

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

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

These three components are not discreet and independent. Catchment divides between the Ashburton River, Southwest Catchment and Hooley Creek Catchment have a low topographical relief (Figure 2-10). As such, the catchment divides are over-topped with stream flow from the Ashburton River during larger flood events and the catchments become temporarily combined. Consequently, the Ashburton River in flood may affect flood levels and stream flow in both the Southwest and Hooley Creek Catchments. Baseline flood assessments for 5, 10, 25, and 100-year ARI rainfall events indicate the Ashburton River overflows its banks during all four events. These ‘breakouts’ promote flows into low-lying areas of the Southwest and Hooley Creek Catchments. The areas and depths of inundation may be extensive over Ashburton North. Baseline assessments indicate flows from the Ashburton River may cause flooding in the vicinity of Ashburton North at recurrence intervals of less than two years.

At ARIs of less than two years, the local catchments predominantly function independently, with surface water flow directions controlled by local topography (Figure 2-11). The effects of local flooding are demonstrated 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 2-12) to be widespread across both the Southwest and Hooley Creek Catchments, but not propagating across the local catchment divides. Comparative volumes of stream flow are provided on Figure 2-13 for the Ashburton River Delta, Southwest, Hooley Creek and Northeast Catchments. The Hooley Creek Catchment stream flows are substantially (up to two orders) larger than those in the adjoining catchments.

The abandoned site of Old Onslow is located west of the Project area, within the Southwest Catchment. Salt crystallisation ponds operated by the Onslow Salt Project are located to the east of the Project area, within the Hooley Creek Catchment.

2.6 Tides

2.6.1 Tidal Influence

Onslow is one of the national standard port tidal reference stations (62470), with a tide gauge located in Beadon Creek and maintained by the WA Department of Transport. Along the Onslow coast, a mesotidal setting hosts mixed, mainly semi-diurnal tides with a spring tide range of 1.9 m. Tidal variations and ranges (Table 2-4) 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) on the Onslow coast 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, Operations Division.

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

Table 2-4 Summary of Tidal Planes (Australian 'National Tide Tables') – Onslow

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

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

- 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 relative timing means that high sea level events (>1.0 m AHD) can occur over the majority of the year. The relative timing of the tidal and mean sea level peaks provides increased potential for high sea 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 actions. Tidal fluctuations affect expressions of inundation in the lower reaches of the Ashburton River Mouth, Southwest Catchment and Hooley Creek Catchments. Downstream reaches of the Ashburton River and Hooley Creek are daily and temporally inundated by seawater. Figures 2-14 and 2-15 show mean sea level and areas inundated by typical high tides. Figure 2-16 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 sea level (‘the storm tide’) is a combination of the storm surge and tidal variation. The storm surge may rise above the HAT. For example, a 1:25-year ARI storm surge exceeds the inundation caused by the HAT.

Onslow 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) in the Onslow area (Global Environmental Modelling Systems (GEMS), 2000), which was in the order of a 45 to 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. GEMS estimated a 1:100-year ARI storm surge of 4.7 m AHD in the vicinity of the Ashburton River mouth. Figure 2-17 shows the simulated land submergence caused by a 1:100-year ARI storm surge.

2.7 Geomorphology

Semeniuk (1993) characterised the Pilbara coast as “a riverine coastal plain in a tropical arid setting”. The western portion of the Pilbara coast, near Onslow, is part of the Carnarvon Basin. The hinterland of the Onslow coast (the Onslow Plain) is low-lying with vast areas of high tidal mud flats and supra-tidal salt flats. This is a dynamic coastline that is characterised by an exposed, sandy shore with both constructional and erosional processes ongoing.

2 Physical Setting of the Project Area

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:

- Alluvial sediments discharged by the Ashburton River.
- Erosion of dunes and rocky shores by near-shore processes.
- Erosion of salt flats and mudflats by fluvial run-off and tidal creeks after flooding and tidal inundation.
- Bio-production and reworking of material from the inner continental shelf.

At a local scale, tidal creeks play a role in exchanging sediment between the terrestrial and marine environments. Inundation of the coastal wetlands by runoff during floods reinforces ebb currents and may contribute to erosional scour of the wetland margins 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 determining factor in controlling 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.

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 (Figure 2-18). The aeolian and alluvial depositional landscape comprises north-south trending dunes, unconsolidated and undulating sand plains, clay pans and incised watercourses. A simplified coastal geomorphology and distribution of the intertidal habitats and adjacent supratidal areas is shown on Figure 2-19.

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. 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 to extend 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. Generally, 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 and 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 - bioturbated mudflats with samphire communities and algal mats.

The **Hooley Creek–Four Mile Creek Tidal Embayment** is a 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.

2.8 Environmental Receptors

Ashburton North occurs in the transition zones from terrestrial to marine environments. For groundwater, the transition zones and potential receptors (Figure 2-19, after URS 2010a) occur within the tidal embayments and foreshore areas, including mangroves, samphire, bioturbated high tide mud flats, algal mat covered high tide flats, supratidal flats, salt flats and local beaches. Upstream of the tidal range there are clay pans and non-perennial pools that may form groundwater receptors. URS (2010a) defines the baseline intertidal habitats at Ashburton North.

Within the intertidal zone, shallow saline and hypersaline groundwater occurs as a result of tidal inundation, groundwater discharge and evaporation effects associated with shallow water table settings. The groundwater salinity in mangrove and mud flats areas is closely linked to the relative influence of tidal inundation (as determined by tidal elevation and evaporation). A natural salinity gradient occurs across the tidal flat in response to differences in tidal inundation patterns (Semeniuk, 1983). Mangroves in the vicinity of Ashburton North occupy the section of the intertidal gradient that is approximately between mean sea level (0 m AHD) and an elevation of approximately 0.7 m AHD, between mean high water neaps (0.4 m AHD) and mean high water springs (1.0 m AHD). Inundation by seawater during flood tides is the main recharge mechanism that regulates the intertidal zone; lower salinities occur in mangrove areas of lower elevation. The salinity gradients influence the occurrence of the different mangrove species (due to differing salinity tolerance), the mangrove community structure and zones of mangrove associations as shown on Figure 2-20 (after URS, 2010a).

Variations to the mangrove association occur in the eastern Ashburton River Delta where the presence of cheniers and dune sands may provide localised brackish to saline seepage at their margins and a calcareous sands substrate (Figure 2-21, after URS, 2010a). Fresh, brackish and saline input from flood events and groundwater seepage may locally be important in reducing salinities and delivering nutrients to the mangroves in this setting (Semeniuk, 1983).

The importance of fresh and brackish water input in maintaining mangrove systems generally decreases with increasing aridity (Semeniuk 1983; Gordon 1988). The intertidal mudflats in the chenier-mangrove association within the Ashburton River Delta are interpreted to be a typical arid zone mangrove system, with limited freshwater or brackish groundwater flow from the hinterland. Therefore, it is the tidal exchange and associated groundwater discharge function that regulates salinities and predominantly provides for the maintenance of the mangrove zone.

Biota (2010) considers that none of the terrestrial vegetation units mapped at Ashburton North are likely to comprise ecosystems entirely dependant on groundwater, with most species sourcing their water requirements from the unsaturated zone of the soil profile.

3

Site Investigations

Site investigations were conducted in two phases; Phase 1 and Phase 2 Environmental Drilling Programs.

The objectives of the Phase 1 Environmental Drilling Program were to install groundwater monitoring bores for subterranean fauna sampling, provide data for preliminary conceptualisation of the baseline hydrogeology and provide raw data to support initial design decisions for the site infrastructure and water supply. The program design was predominantly framed based on easy access considerations together with providing an appropriate network for investigation of subterranean fauna and initial groundwater sampling.

Guidelines for the sampling of subterranean fauna were obtained from:

- Environmental Protection Authority, Draft Guideline Statement No. 54; Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia, December 2003.
- Environmental Protection Authority, Draft Guideline Statement No. 54 (No.54a); Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia, August 2007, Draft.

These guidelines were used in the design of groundwater monitoring bores.

The Phase 2 Environmental Drilling Program objectives were predominantly to expand the coverage areas, determine the hydraulic characteristics of the shallow groundwater systems and provide additional data to support assessments of the baseline groundwater environments.

3.1 Phase 1 and Phase 2 Environmental Drilling Programs

The Phase 1 Environmental Drilling Program was undertaken by Hagstrom Drilling between 25 March and 5 May 2009. The program comprised 20 drilling sites (E001 to E021, excluding EO14) at which the following bores were installed:

- A dedicated subterranean fauna monitoring bore network, nominally intersecting and sampling the water table zone and upper 15 m of the saturated profile.
- Varying combinations of shallow, intermediate and deep groundwater monitoring bores, with nominal depths of investigation of 5, 15 and 35 m. Individual shallow, intermediate and deep monitoring bores were screened over 2 to 5 m intervals, enabling discrete assessments of the groundwater environments at different depths.

Ultimately, the program was reduced to 18 sites. Site E001 was abandoned because it was located outside of the approved access zone. Site E020 was drilled but not constructed because the site is within the tidal zone, with limited access.

The Phase 2 Environmental Drilling Program was undertaken by Hagstrom Drilling between 5 April and 28 September 2009, and again between 14 and 27 October 2009 within the Shared Infrastructure Corridor.

The total program comprised 33 drilling sites (E014, EO22 to E033, E034 to E048 and E052 to E056) at which the following groundwater activities were completed:

- A dedicated subterranean fauna monitoring bore at EO14, nominally intersecting and sampling the water table zone and upper 15 m of the saturated profile.
- At most sites varying combinations of shallow, intermediate and deep groundwater monitoring bores, with depths of investigation up to about 70 m.

- A shallow test production bore (E022), with screen interval limited to the upper 5 m of the water table zone beneath the dunal terrain.
- An additional 16 sites (E034 to E045 and E053 to E056) for the construction of drive point piezometers, intended to host a deep and shallow standpipes, with nominal depths of 1 m and 2.5 m.
- An aquifer test in E022.

3.1.1 Drilling Methods

A diamond core rotary rig was used to undertake the drilling, with 122.6 mm (PQ) diameter drilled in most holes. Reaming occurred in holes with wall stability difficulties to enlarge the diameter to 160 mm (PWT) and enable monitoring bore construction. Core was recovered from the PQ drilling on the deepest bore at each site, enabling lithological and geotechnical logging and testing. All remaining holes on each site were drilled using mud-rotary methods and a 122.6 mm blade bit.

3.1.2 Monitoring Bore Construction

The completed monitoring bores (standpipe piezometers) were cased with 65 mm Class 18 uPVC. In the reamed drill-holes, the uPVC casing was installed within the drill-string, to limit the impacts of hole-sidewall instability, with the drill-string subsequently being withdrawn. Slotted casing was installed at selected depth intervals in each monitoring bore. Subterranean fauna monitoring bores were slotted from 1 m below ground level (m bgl) to the bottom of the drill-hole. The groundwater monitoring bores have 2 to 6 m slotted casing intervals at the bottom of the drill-hole. The slotted uPVC has a horizontal slot pattern with a 3 mm slot aperture.

Once cased, the annulus around the casing in each monitoring bore was gravel packed. The gravel comprised 6 to 10 mm graded quartz and ironstone, typically backfilling the annulus to 0.2 to 1 m above the slotted interval. A bentonite clay seal was subsequently placed above the gravel pack. The bentonite clay acts to limit the hydraulic connection between the slotted interval and adjoining formation groundwater. Above the bentonite clay, each monitoring bore was backfilled to the ground surface with drill cuttings.

Steel risers with a lockable protective cap were installed around each standpipe at ground surface.

A summary of the monitoring bores constructed during the programs is shown in Table 3-1 and Table 3-2. Bore names/numbers were determined by (in order) site name, purpose and depth. Bore purpose is represented by a prefixed F or G, indicating a subterranean fauna (F) or groundwater (G) monitoring bore. Depths are represented by S, I or D, indicating shallow (S), intermediate (I) and deep (D) groundwater monitoring bores.

Locations of the completed monitoring bore sites are shown on Figure 3-1. Details of each monitoring bore and the associated bore construction diagrams are summarised in Appendix A. These diagrams include lithological logs and field records of airlift yields, measured depths to the water table and Electrical Conductivity (EC) data.

3.1.3 Test Production Bore Construction

The test production bore (E022) was drilled using mud-rotary methods and a 255 mm diameter blade bit to a depth of 10 m. The bore was constructed with 125 mm diameter uPVC casing, slotted between 3 and 7 m.

Table 3-1 Phase 1 Drilling Program – Summary of Monitoring Bore Construction

Site No.	Monitoring Bore	Description	Location		Date		Depth Drilled (m)	Cased Depth (m)	Slotted Casing		Collar Height (m)	Airlift Yield (L/sec)	Airlift Duration (mins)	Field Groundwater Quality		Groundwater Level	
			Northing (mN)	Easting (mE)	Started	Completed			Depth Interval (m bgl)	Length (m)				EC (mS/cm)	pH	(m btc)	(m bgl)
1	E001	Site is beyond the approved access zone. Drilling has been abandoned.															
2	E002G-D	Deep	291,158	7,595,091	25/03/2009	30/03/2009	33.1	33.1	30.1 – 33.1	3.0	0.37	2.0	35	187.6	7.7	3.86	3.49
	E002G-S	Shallow	291,156	7,595,091	30/03/2009	31/03/2009	5.0	4.6	0.6 – 4.6	4.0	0.64	0.3	21	65.0	8.0	2.97	2.33
	E002F	Subterranean	291,153	7,595,088	31/03/2009	1/04/2009	15.0	14.2	0.3 -14.2	13.9	0.50	0.5	30	117.9	7.8	2.86	2.36
3	E003F	Subterranean	291,105	7,595,517	29/03/2009	1/04/2009	20.6	20.6	1.0 – 20.6	19.6	1.06	0.9	40	101.1	7.72	5.44	4.38
4	E004F	Subterranean	291,243	7,595,540	25/03/2009	29/03/2009	21.1	21.1	1.0 – 21.1	20.1	0.97	0.8	40	102.9	7.65	6.90	5.93
5	E005G-D	Deep	291,482	7,596,954	1/04/2009	3/04/2009	33.2	33.2	29.5 – 33.2	3.7	0.1	0.7	20	103.0	7.6	2.83	2.73
	E005G-I	Intermediate	291,484	7,596,954	4/04/2009	4/04/2009	12.2	11.9	10.0 – 11.9	1.9	0.12	0.2	15	96.0	7.9	2.3	2.18
	E005G-S	Shallow	291,484	7,596,954	5/04/2009	5/04/2009	3.3	3.3	0.7 – 3.3	2.6	0.2	0.1	30	12.7	8.9	2.3	2.10
	E005F	Subterranean	291,482	7,596,953	5/04/2009	6/04/2009	13.7	13.7	1.0 – 13.7	12.7	0.14	0.3	40	83.0	7.9	2.25	2.11
6	E006F	Subterranean	292,538	7,598,296	6/04/2009	7/04/2009	15.3	15.3	0.6 – 15.3	14.7	0.07	0.5	40	128.8	7.5	1.17	1.10
7	E007G-D	Deep	292,711	7,598,613	8/04/2009	11/04/2009	32.2	31.2	28.2 – 31.2	3.0	0.1	2.0	20	176.2	6.87	2.13	2.03
	E007G-I	Intermediate	292,712	7,598,613	11/04/2009	12/04/2009	12.5	12.5	9.5 – 12.5	3.0	0.09	0.7	40	135	7.5	1.68	1.59
	E007G-S	Shallow	292,712	7,598,611	12/04/2009	12/04/2009	4.5	4.5	2.5 – 4.5	2.0	0.1	0.9	20	73.1	7.65	1.73	1.63
	E007F	Subterranean	292,716	7,598,612	13/04/2009	13/04/2009	18.5	18.5	1.0 – 18.5	17.5	0.05	1.0	45	135.9	7.71	1.67	1.62
8	E008F	Subterranean	293,243	7,599,460	18/04/2009	19/04/2009	16.0	16.0	0.5 – 16.0	15.5	0.05	1.0	40	124.4	7.37	5.07	5.02
9	E009F	Subterranean	243,256	7,599,398	19/04/2009	20/04/2009	16.0	16.0	0.5 – 16.0	15.5	0.09	1.5	45	128.8	7.44	4.75	4.66
10	E010G-I	Intermediate	293,462	7,599,684	14/04/2009	16/04/2009	20.0	19.5	17.5 – 19.5	2.0	-0.25	3.0	30	na	6.98	1.98	2.23
	E010G-S	Shallow	293,463	7,599,683	17/04/2009	17/04/2009	5.0	5.0	3.0 – 5.0	2.0	0.11	0.5	30	90.8	7.1	2.05	1.94
	E010F	Subterranean	293,465	7,599,682	17/04/2009	18/04/2009	20.0	20.0	0.5 – 20.0	19.5	0.09	1.5	40	124	7.27	2.08	1.99
11	E011F	Subterranean	294,123	7,600,692	12/04/2009	14/04/2009	18.0	17.5	0.4 – 17.5	17.1	0.6	1.6	30	77.3	7.85	1.46	0.86
12	E012F	Subterranean	294,958	7,600,445	21/04/2009	22/04/2009	16.6	16.6	1.3 – 16.6	15.3	0	1.7	40	111.7	7.32	0.79	0.79
13	E013F	Subterranean	295,014	7,600,692	10/04/2009	11/04/2009	19.5	19.5	0.7 – 19.5	18.8	0.14	1.2	28	91.6	7.7	1.14	1.00
14	E014	Drilling of this site has now been incorporated within the Phase 2 Environmental Drilling Program.															
15	E015F	Subterranean	290,894	7,596,347	8/04/2009	9/04/2009	20.0	17.5	0.6 – 17.5	16.9	0.52	0.5	45	104.2	7.7	4.36	3.84
16	E016G-D	Deep	290,313	7,596,335	3/04/2009	6/04/2009	33.0	33.0	30.0 – 33.0	3.0	0.09	2.5	25	155.9	7.3	3.78	3.69
	E016G-S	Shallow	290,313	7,596,335	6/04/2009	6/04/2009	5.0	5.0	1.0 - 5.0	4.0	0.01	na		44.0	8.1	3.11	3.10
	E016F	Subterranean	290,313	7,596,330	6/04/2009	7/04/2009	15.0	15.0	0.6 – 15.0	14.4	0.06	0.1	25	96.3	7.8	3.17	3.11
17	E017F	Subterranean	290,022	7,596,324	1/04/2009	3/04/2009	20.0	18.6	14.7 – 18.6	3.9	0.8	2.0	45	107.8	7.5	1.87	1.07
18	E018G-D	Deep	293,920	7,600,287	14/04/2009	17/04/2009	34.0	32.0	29.0 – 32.0	3.0	0.35	2.5	10	na	7.03	2.66	2.31
	E018G-I	Intermediate	293,926	7,600,288	17/04/2009	18/04/2009	18.5	18.5	15.5 – 18.5	3.0	0.33	1.0	20	101.8	7.31	2.18	1.85
	E018G-S	Shallow	293,925	7,600,292	19/04/2009	19/04/2009	7.5	7.5	1.5 – 7.5	6.0	0.45	0.5	20	61.3	7.2	1.95	1.50
	E018F	Subterranean	293,917	7,600,300	19/04/2009	20/04/2009	15.0	14.5	1.0 – 14.5	13.5	0.23	0.5	10	25.1	7.58	1.8	1.57
19	E019G-D	Deep	293,685	7,600,754	29/04/2009	3/05/2009	34.0	33.5	30.5 – 33.5	3.0	0.66	2	35	161.9	6.36	2.73	2.07
	E019G-S	Shallow	293,688	7,600,753	4/05/2009	4/05/2009	5.5	5.5	1.0 – 5.5	4.5	0.6	0.5	40	34.5	7.42	1.64	1.04
	E019F	Subterranean	293,691	7,600,753	4/05/2009	5/05/2009	15.5	15.0	0.5 – 15.0	14.5	0.59	0.5	15	97.5	6.97	1.71	1.12
20	E020	This site was drilled but not constructed. Site is within the tidal zone, with limited access.															
21	E021F	Subterranean	293,984	7,600,707	20/04/2009	21/04/2009	15.0	14.0	0.0 – 14.0	14.0	0.74	1.0	43	85.5	7.85	1.74	1.00

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Table 3-2 Phase 2 Drilling Program – Summary of Monitoring Bore Construction

Site No.	Monitoring Bore	Description	Location		Date		Depth Drilled (m)	Cased Depth (m)	Slotted Casing		Collar Height (m)	Airlift Yield (L/sec)	Airlift Duration (mins)	Field Groundwater Quality		Static Groundwater Level	
			Northing (mN)	Easting (mE)	Started	Completed			Depth Interval (m)	Length (m)				EC (mS/cm)	pH	(m btc)	(m bgl)
14	E014F	Subterranean	291,024.13	7,599,362.53	23/05/2009	24/05/2009	15.5	15.0	1.0 - 15.0	14.0	0.09	0.5	40	105.6	7.47	3.19	2.64
	E014G-I	Intermediate	291,023.87	7,599,360.48	24/05/2009	25/05/2009	15.5	15.0	12.0 - 15.0	3.0	0.11	1	20	107.5	7.28	3.20	2.62
	E014G-S	Shallow	291,023.67	7,599,358.53	26/05/2009	26/05/2009	7.0	7.0	1.0 - 7.0	6.0	0.95	0.2	80	67.6	7.89	3.20	2.61
22	EO22	Shallow	293,464	7,599,690	16/09/2009	16/09/2009	10	10	3.0-7.0	4	0.47	2	30	111	7.45	2.93	2.46
23	E023FG-D	Deep	292,463.25	7,600,535.22	27/05/2009	29/05/2009	34.0	34.0	31.0 - 34.0	3.0	0.14	2.5	20	162.7	7.01	5	4.86
	E023FG-S	Shallow	removed		29/05/2009	30/05/2009	5.0	5.0	0.5 - 5.0	4.5	0.15	Dry	N/A	N/A	N/A	N/A	N/A
	E023FG-S	Shallow	292,465.73	7,600,538.44	18/06/2009	18/06/2009	6.2	6.2	0.7 - 6.2	5.5	0.66	0.06	70	33.4	8.2	4.54	3.88
24	E024FG-I	Intermediate	291,590.03	7,599,721.78	26/05/2009	27/05/2009	15.0	8.0	6.0 - 8.0	2.0	0.18	1.5	20	73.8	7.7	2.13	1.95
	E024FG-S	Shallow	291,591.54	7,599,723.82	27/05/2009	27/05/2009	5.0	5.0	4.0 - 5.0	1.0	0.26	0.1	30	101.2	8.18	2.19	1.93
25	E025FG-D	Intermediate/Deep	291,797.16	7,600,222.21	5/04/2009	6/04/2009	13.5	13.5	10.5 - 13.5	3.0	0.21	2	20	72.7	7.16	7.43	6.70
	E025FG-I	Intermediate	291,797.82	7,600,221.84	7/06/2009	7/06/2009	9.0	9.0	6.0 - 9.0	3.0	0.18	0.06	30	6.4	8.58	7.31	6.65
	E025FG-S	Shallow	291,799.17	7,600,221.06	7/06/2009	7/06/2009	5.0	5.0	4.0 - 5.0	1.0	0.1	0	20	N/A	N/A	Dry	N/A
26	E026FG-D	Deep	292,032.47	7,599,731.04	8/06/2009	17/06/2009	34.5	34.5	31.5 - 34.5	3.0	0.09	0.9	15	169.6	6.89	5.09	5.00
	E026FG-S	Shallow	292,030.31	7,599,731.38	17/06/2009	17/06/2009	7.5	7.5	1.5 - 7.5	6.0	0.25	0.1	45	42.8	7.72	4.30	4.05
27	E027FG-I	Intermediate	293,131.63	7,598,678.91	12/05/2009	13/05/2009	18.0	18.0	16.0 - 18.0	2.0	0.16	0.5	45	198.5	6.65	2.06	1.90
	E027FG-S	Shallow	293,133.91	7,598,677.49	13/05/2009	13/05/2009	6.0	6.0	5.5 - 6.0	0.5	0.1	0.3	45	172.4	7.39	1.79	1.69
	E027FG-D	Deep	293,135.82	7,598,676.44	14/05/2009	17/05/2009	40.5	40.0	37.0 - 40.0	3.0	0.91	2	30	250	7.21	3.13	2.22
28	E028G-I	Intermediate	290,045	7,595,657	4/08/2009	5/08/2009	15.0	15.0	12.0 - 15.0	3.0	0.14	0.83	33	72.0	6.80	3.13	2.99
	E028G-S	Shallow	290,042	7,595,647	5/08/09	5/08/2009	8.0	8.0	2.0 – 8.0	6.0	0.58	0.2	26	60.1	7.33	3.35	2.77
29	EO29G-D	Deep	290,734	7,597,191	26/06/2009	28/06/2009	30.0	30.0	27.0 - 30.0	3.0	0.54	0.3	65	112.5	6.73	2.18	1.64
	EO29G-S	Shallow	290,736	7,597,189	28/06/2009	4/07/2009	6.0	6.0	0.5 - 6.0	5.5	0.65	0.3	90	93.8	6.88	2.04	1.39
	EO29G-I	Intermediate	290,736	7,597,188	4/07/2009	5/07/2009	16.3	16.0	13.0 - 16.0	3.0	0.63	0.2	64	79.8	6.77	2.29	1.66
30	EO30G-D	Deep	292,209	7,596,336	12/07/2009	14/07/2009	33.1	33.1	30.6 - 33.6	3.0	0.72	0.3	23	171.1	6.78	9.2	8.35
	EO30G-I	Intermediate	292,210	7,596,337	14/07/2009	14/07/2009	12.2	12.2	9.8 - 12.8	3.0	0.815	0.2	43	90.1	7.17	8.54	7.77
	EO30G-S	Shallow	292,211	7,596,338	14/07/2009	14/07/2009	5.2	5.2	1.9 - 5.9	4.0	0.955	Dry	N/A	N/A	N/A	Dry	N/A
31	E031FG-D	Deep	292,856	7,597,525	15/07/2009	20/07/2009	67.5	67.5	55.5 - 67.5	12.0	0.92	2	15	117.3	7.04	2.50	1.58
	E031FG-S	Shallow	292,855	7,597,525	20/07/2009	20/07/2009	7.5	7.5	1.5 - 7.5	6.0	0.89	0.1	45	44.8	7.72	2.95	2.06
32	E032FG-D	Deep	294,582.72	7,600,425.02	7/05/2009	9/05/2009	21.0	21.0	19.0 - 21.0	2.0	0.16	0.3	45	139.9	7.54	2.18	2.02
	E032FG-I	Intermediate	294,583.17	7,600,422.32	9/05/2009	10/05/2009	7.2	7.0	6.5 - 7.0	0.5	0.2	0.3	40	77.4	7.58	1.93	1.73
	E032FG-S	Shallow	294,583.64	7,600,420.11	11/05/2009	11/05/2009	4.0	4.0	0.5 - 4.0	3.5	0.19	0.2	40	52.5	8.25	1.75	1.56
33	E033FG-D	Deep	293,169.25	7,600,363.76	17/05/2009	21/05/2009	41.0	40.0	37.0 - 40.0	3.0	0.15	2	10	175.5	7.21	3.04	2.89
	E033FG-I	Intermediate	293,169.00	7,600,361.71	21/05/2009	21/05/2009	18.0	14.0	11.0 - 14.0	3.0	0.14	2	25	92	7.26	2.13	1.99
	E033FG-S	Shallow	293,168.66	7,600,359.65	22/05/2009	23/05/2009	7.0	6.5	1.0 - 6.5	5.5	0.08	0.2	45	13.63	7.66	2.73	1.94
46	E046FG-I	intermediate/aquitard	293,199	7,593,723	14/10/2009	17/10/2009	14.2	14.2	11.2-14.2	3	0.66	0.5	15	77.1	7.26	2.98	2.32
	E046FG-S	shallow	293,201	7,593,720	17/10/2009	17/10/2009	6	6	1.0-6.0	5	0.65	0.25	37	83.5	7.54	2.73	2.08
47	E047FG-D	Deep	294,209	7,592,313	18/10/2009	22/10/2009	57	56	44.0-56.0	12	0.71	0.5	15	78	7.5	2.72	2.01
	E047FG-I	Intermediate	294,209	7,592,311	22/10/2009	22/10/2009	13	12	9.0-12.0	3	0.73	0.25	15	126.5	7.19	2.11	1.38
	E047FG-S	Shallow	294,209	7,592,309	23/10/2009	23/10/2009	6.2	6	1.0-6.0	5	0.79	0.2	20	57.9	7.96	2.03	1.24
48	E048FG-I	intermediate	296,274	7,591,599	23/10/2009	26/10/2009	15	13	10.0-13.0	3	0.80	2	15	91.2	7.37	3.64	2.84
	E048FG-S	shallow	296,274	7,591,598	27/10/2009	27/10/2009	6	6	1.0-6.0	5	0.79	0.1	25	50.7	7.67	4.17	3.38
49	Drilling of this site has been postponed until heritage clearance in proposed Accommodation Village area is obtained																
50	Drilling of this site has been postponed until heritage clearance in proposed Accommodation Village area is obtained																
51	Drilling of this site has been postponed until heritage clearance in proposed Accommodation Village area is obtained																
52	E052FG-D	Deep	300,285	7,590,245	23/10/2009	27/10/2009	36	35	32.0-35.0	3	0.75	0.4	15	175.7	7.13	2.87	2.12
	E052FG-S	Shallow	300,290	7,590,244	27/10/2009	27/10/2009	5	5	1.0-5.0	4	0.69	0.25	25	92.8	7.27	1.91	1.22

3.1.4 Monitoring Bore Development

Each monitoring bore was developed by airlifting. The airlifting displaces the water column in the monitoring bore using compressed air, promoting groundwater flow into the standpipe and subsequent removal of drilling fluids and sediment. Airlift development times ranged from 10 to 80 minutes, depending on the drilling fluid and sediment contents of the abstracted groundwater.

Groundwater yields, EC and pH measurements were taken at five minute intervals during development. A groundwater sample was collected at the completion of airlift development. Each sample was submitted to ALS Laboratory Group for analysis.

3.1.5 Drive Point Piezometer Construction

Solinst Model 615 Drive Point Piezometers (Chart 3-1) were used to investigate and sample shallow groundwater profiles. Model 615 is comprised of a stainless steel cylindrical screen housed within a 20 mm diameter stainless steel drive point body. The leading edge of the drive point body hosts a solid drive point. Individual drive point piezometers were installed using a heavy-wall slide hammer.

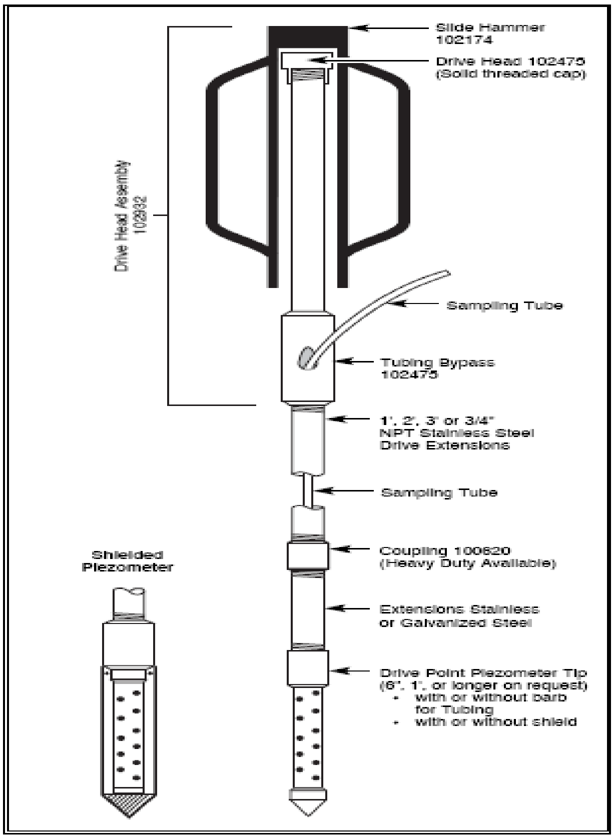

Chart 3-1 Solinst Model 615 Drive Point Piezometer (Solinst, 2006)

Twenty-seven (27) drive point piezometers were constructed at 16 sites. A summary of the drive point piezometers constructed during the program is shown in Table 3-3. Typically, the drive point piezometer construction at individual sites included:

- Shallow (approximately 0.50 m).
- Deep (approximately 2 m).

Bore names are depicted by (in order) site name, purpose and depth. The prefix G indicates a groundwater monitoring bore. Depths are represented by S or D, indicating shallow and deep settings. Locations of the drive point piezometer sites are shown on Figure 3-2.

Information on each drive point piezometer and the associated construction diagrams are summarised in Appendix B.

3.2 Hydrogeological Data Collection

The constructed monitoring bores, test production bore and drive point piezometers have been used to source hydrogeological data, including:

- Groundwater levels.
- Hydraulic characteristics, through pumping tests and slug tests.
- Groundwater quality, through EC profiles, sampling and analysis.

Groundwater levels have been measured in each of the monitoring bores and drive point piezometers using an electronic water level meter.

EC profiles were completed in the monitoring bores, including those for subterranean fauna monitoring, using an *in situ* 'Aquatroll' logger.

3.2.1 Aquifer Tests

Following bore completion, aquifer tests were completed in most of the monitoring bores and drive point piezometers to enable interpretations of local hydrogeological parameters.

Pumping Tests

Short-term constant-rate pumping tests were conducted in the shallow, intermediate and deep monitoring bores using a 12-volt Hurricane submersible pump. Pumping tests involved the abstraction of groundwater from individual bores at a constant discharge rate, with the change in hydraulic head monitored using an automated data logger recording the groundwater level at 2 second intervals. The discharge rates during the tests were typically between 0.05 and 0.1 L/s.

The monitoring bore pumping tests are summarised in Table 3-4 and locations are shown on Figure 3-3. Additional pumping test records are provided in Appendix C.

Table 3-3 Phase 2 Drilling Program – Summary of Drive Point Piezometer Construction

Site No.	Drive Point Piezometer	Description	Location		Date		Casing		Collar Height (m)	Groundwater Level	
			Easting (mE)	Northing (mN)	Started	Completed	Blank (m)	Slotted (m)		(m btc)	(m bgl)
E034	EO34G-S	Shallow	294,517	7,600,206	9/07/2009	9/07/2009	0-0.53	0.53-0.82	0.39	0.97	0.55
	EO34G-D	Deep	294,517	7,600,207	9/07/2009	9/07/2009	0-2.73	2.73-3.02	0.26	0.96	0.7
E035	E035G-S	Shallow	294,136	7,600,046	23/07/2009	23/07/2009	0-0.8	0.80-1.10	0.41	1.22	0.81
	E035G-D	Deep	294,136	7,600,045	23/07/2009	23/07/2009	0-2.84	2.84-3.10	0.17	0.89	0.72
E036	E036G-S	Shallow	293,399	7,599,407	23/07/2009	23/07/2009	0-0.84	0.84-1.15	0.16	0.64	0.48
	E036G-D	Deep	293,399	7,599,406	23/07/2009	23/07/2009	0-2.70	2.70-3.00	0.26	0.79	0.53
E037	E037G-D	Deep	292,883	7,597,561	24/07/2009	24/07/2009	0-0.78	0.78-1.10	0.21	N/A	N/A
E038	E038G-S	Shallow	292,625	7,597,597	24/07/2009	24/07/2009	0-0.90	0.90-1.10	0.09	N/A	N/A
	E038G-D	Deep	292,623	7,597,505	23/07/2009	23/07/2009	0-3.00	3.00-3.39	0.13	N/A	N/A
E039	E039G-S	Shallow	N/A	N/A	9/07/2009	N/A	N/A	N/A	0.58	N/A	N/A
	E039G-D	Deep	N/A	N/A	9/07/2009	N/A	N/A	N/A	0.43	N/A	N/A
E040	E040G-S	Shallow	292,981	7,599,709	14/07/2009	14/07/2009	0-0.74	0.74-0.94	0.19	1.23	1.04
	E040G-D	Deep	292,981	7,599,708	14/07/2009	14/07/2009	0-2.33	2.33-2.93	0.67	1.66	1.03
E041	E041G-S	Shallow	292,508	7,598,328	22/07/2009	22/07/2009	0-0.54	0.54-0.84	0.4	dry	
	E041G-D	Deep	292,507	7,598,328	22/07/2009	22/07/2009	0-1.67	1.67-2.27	0.59	1.28	0.69
E042	EO42G-S	Shallow	290,856	7,599,137	10/07/2009	10/07/2009	N/A	N/A	0.41	dry	
	E042G-D	Deep	290,857	7,599,138	14/07/2009	14/07/2009	0-2.21	2.21-2.50	0.46	0.64	0.18
E043	E043G-S	Shallow	290,545	7,599,160	24/07/2009	24/07/2009	0-0.71	0.71-1.05	0.28	1.08	0.8
	E043G-D	Deep	290,545	7,599,159	23/07/2009	24/07/2009	0-2.27	2.27-2.57	0.71	1.52	0.81
E044	E044G-S	Shallow	293,188	7,598,659	22/07/2009	22/07/2009	0-0.70	0.70-1.00	0.48	dry	
	E044G-D	Deep	293,189	7,598,659	22/07/2009	22/07/2009	0-2.40	2.40-2.53	0.1	0.7	0.6
E045	EO45G-S	Shallow	290,653	7,597,644	15/07/2009	15/07/2009	0-1.23	1.23-1.88	0.14	N/A	N/A
	E045G-D	Deep	290,755	7,597,213	25/07/2009	25/07/2009	0-1.86	1.86-2.05	0.1	0.86	0.76
E053	EO53G-S	Shallow	290,048	7,596,453	28/07/2009	29/07/2009	0-1.73	1.73-2.20	0.27	N/A	N/A
E054	EO54G-D	Deep	294,618	7,598,350	28/07/2009	29/07/2009	0-1.83	1.83-2.05	0.17	0.48	0.31
E055	E055G-S	Shallow	292,626	7,598,246	29/07/2009	29/07/2009	0-0.90	0.90-1.10	0.1	dry	
E056	E056G-S	Shallow	292,157	7,599,634	24/07/2009	24/07/2009	0-1.46	1.46-1.85	0.1	1.22	1.12
	E056G-D	Deep	292,157	7,599,632	23/07/2009	23/07/2009	0-2.88	2.88-3.05	0.12	1.2	1.08

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3 Site Investigations

Table 3-4 Summary of Monitoring Bore Aquifer Tests

Monitoring Bore	Screened Unit	Screen Length (m)	Test Duration (mins)	Groundwater Level (m bgl)	Discharge Rate (L/s)	Maximum Drawdown (m)
Superficial Formations - Dune Sands						
E005G-S	Gravelly Sand, Calcareous Sandstone	2.6	23	2.43	0.08	0.40
E007G-S	Sandstone and Silty Sand	2.0	6	2.31	0.07	0.02
E010G-S	Sandstone and Sand	2.0	24	2.24	0.1	0.35
E016G-S	Silty and Gravelly Clay and Sandstone	4.0	43	3.34	0.1	0.20
E019G-S	Sandstone/Sand/Clayey Sand	4.5	20	1.06	0.09	0.20
E019G-S	Sandstone/Sand/Clayey Sand	4.5	20	0.81	0.1	0.33
E014G-S	Gravel and Sand, clay horizons	6.0	16.2	2.57	0.1	0.20
E023FG-S	Sand	5.5	20.6	3.91	0.1	0.43
E026G-S	Sand	6.0	20.2	4.07	0.1	0.32
E027FG-S	Interbedded Sand and Clayey Sand	0.5	21.7	1.90	0.1	0.75
E029G-S	Sand and Clayey Sand	5.5	23.9	1.41	0.1	0.32
E031G-S	Sand and Gravel	6.0	21.5	2.09	0.1	0.26
E032FG-S	Sand	3.5	29.4	1.67	0.1	0.40
Superficial Formations - Ashburton River Delta Alluvium						
E007G-I	Sandy Gravel and Clayey Sand	3.0	30	1.75	0.08	0.70
E010G-I	Silty Sand and Paleochannel Deposits	2.0	20	2.29	0.1	0.20
E018G-I	Silty Clay, Silty Sand and Claystone	3.0	48	2.10	0.1	0.80
E014G-I	Clay and Claystone, some sandstone	3.0	18	2.58	0.1	0.45
E024FG-S	Sandy Clay and Gravelly Clay	1.0	21.6	2.03	0.1	NA
E024FG-I	Sandy Clay	2.0	18.6	2.04	0.1	NA
E025FG-I	Calcarenite	3.0	2.8	6.67	0.1	0.99
E025FG-D	Sand, with Palaeochannel Deposits	3.0	22.6	6.73	0.1	0.17
E027FG-I	Clay and Sandstone	2.0	27.8	2.00	0.1	3.90
E028G-S	Sandy Clay and Gravelly Clay	6.0	10.4	3.32	0.1	0.90
E028G-I	Sandy Clay and Clay	3.0	105.8	2.98	0.1	NA
E029G-I	Sandstone	3.0	24.1	1.30	0.1	1.40
E030G-I	Silty Sand and Sand	3.0	21.2	7.75	0.1	0.20
E032FG-I	Sand	0.5	21.5	1.83	0.1	0.80
E032FG-D	Sandstone and Clayey Sand	2.0	18.6	2.03	0.1	2.30
E033FG-S	Clay, Sand and Oolitic Limestone	5.5	25.6	1.86	0.1	0.55
E033FG-I	Mostly Sand with some Clay	3.0	22	2.14	0.1	0.03
E046FG-S	Silty Sand and Clayey Sand	5.0	25	2.13	0.1	1.12
E046FG-I	Calcarenite	3.0	50	2.43	0.1	1.26
E047FG-S	Mainly Clay Some Sand	5.0	52	1.24	0.1	1.44
E047FG-I	Sandy Clay and Clay	3.0	51.67	1.17	0.1	1.52
E048FG-S	Silty Clayey Sand and Calcarenite	5.0	72	2.44	0.1	0.88
E048FG-I	Sand	3.0	72	2.43	0.1	0.09
E052FG-S	Clayey Silty Sand and Silty Clayey Sand	4.0	27	1.17	0.1	0.56
Superficial Formations - Ashburton River Delta Clay						
E005G-I	Clay (aquitard)	1.9	14	2.56	0.1	2.20
Trealla Limestone						
E002G-D	Limestone, vuggy	3.0	16	3.794	0.2	0.87
E005G-D	Limestone,	3.7	20	3.08	0.13	2.00
E007G-D	Limestone, with cavities	3.0	70	2.12	0.08	0.10
E016G-D	Limestone	3.0	246	3.63	0.07	0.45
E018G-D	Clay then Limestone	3.0	56	2.69	0.09	0.25
E019G-D	Limestone, very weathered	3.0	105	2.12	0.1	0.04
E019G-D	Limestone	3.0	30.4	1.68	0.1	0.09
E023FG-D	Limestone and Limestone Breccia,	3.0	28.6	5.12	0.1	0.15
E026G-D	Limestone	3.0	29.5	5	0.1	0.44
E027FG-D	Limestone and Conglomerate	3.0	31.6	2.63	0.1	4.80
E029G-D	Limestone	3.0	43	1.47	0.1	2.20
E030G-D	Sand and Limestone	3.0	21	8.07	0.1	2.10
E031G-D	Mainly Limestone and some Silty Sand	12.0	62.7	1.35	0.1	3.60
E033FG-D	Mainly Limestone, some Breccia sandstone	3.0	39.4	3.01	0.1	0.90
E047FG-D	Limestone, Calcarenite and Silty Clay	12.0	50.3	2.01	0.1	6.52
E052FG-D	Limestone	3.0	64.6	1.96	0.1	0.32

48 Hour Pumping Test in Test Production Bore E022

Aquifer testing was completed in E022 from 18 to 22 September 2009. Details of the aquifer testing program are shown in Table 3–5. The testing was designed to determine bore characteristics and estimate the aquifer parameters of the dune sands. An electro-submersible pump powered by a portable generator was used to abstract groundwater from the test production bore. During pumping, discharge rates were controlled with a valve and measured using a flowmeter. Abstracted groundwater was directed, using a lay-flat pipeline, to a point approximately 500 m east of E022.

Two types of tests were completed in the bore. The first, a step-drawdown test, comprised three discharge rate steps, each of 30 minutes duration, that were used to determine the efficiency of the test production bore and the most suitable discharge rate for the subsequent constant-rate aquifer test. The discharge rates for the step-drawdown test ranged from 0.4 to 1.25 L/s. Subsequently, a 48-hour constant-rate aquifer test was conducted at a flow rate of 1.0 L/s. Groundwater level measurements during the aquifer test enabled aquifer parameters to be interpreted by defining the groundwater-level response to pumping. Groundwater levels were measured in E022 and the nearest monitoring bores (E010F, E010G-I and E010G-S) using electronic water level probes and data loggers. These bores are between 7.3 and 8.6 m from E022. Groundwater level recovery was measured for 90 minutes following completion of the constant-rate test.

Groundwater samples were collected at the beginning and end of the constant-rate test and submitted to ALS Laboratory Group for analysis. Field measurements of groundwater pH and EC were taken at regular intervals (5 minutes to 2 hours) during the constant-rate test.

Table 3-5 Test Production Bore E022 Aquifer Test Details

Bore	Test Type	Observation Bore	Groundwater Level (m btoc)[1]	Discharge Rate		Duration (mins)	Final Drawdown (m)
				(L/s)	(kL/day)		
E022	Step 1	E022	2.99	0.40	35	30	0.90
	Step 2	E022	2.99	0.80	69	30	1.86
	Step 3	E022	2.99	1.25	108	30	2.81
	Constant	E022	3.01	1.00	86	2,880	2.59
	Constant	E010F	2.86	1.00	86	2,880	0.50
	Constant	E010G-I	3.00	1.00	86	2,880	0.12
	Constant	E010G-S	2.80	1.00	86	2,880	0.37
	Recovery	E022	3.01	(1.00)	(86)	90	0.14
	Recovery	E010F	2.86	(1.00)	(86)	90	0.14
	Recovery	E010G-I	3.00	(1.00)	(86)	90	0.03
	Recovery	E010G-S	2.80	(1.00)	(86)	90	0.21

Slug (Falling Head) Tests

Slug tests were also completed in the (deeper) monitoring bores and drive point piezometers. During the slug tests a measured volume of water (5 to 10 L), was quickly poured into the monitoring bore and drive point piezometer standpipes. The change in hydraulic head was monitored using an *in situ* 'Aquatroll' data logger programmed to record groundwater levels at 2 second intervals. Slug tests were not completed in the subterranean fauna or shallow monitoring bores.

The slug tests in the monitoring bores and drive point piezometers are summarised in Tables 3-6 and 3-7 and locations shown on Figure 3-4. Additional slug test records are provided in Appendix D.

Table 3-6 Summary of Slug Tests in Monitoring Bores

Monitoring Bore	Screened Unit	Groundwater Level (m bgl)	Slug Volume (L)	Maximum Displacement (m)
Superficial Formations - Ashburton River Delta Alluvium				
E007G-I	Sandy Gravel and Clayey Sand	1.891	10	-
E010G-I	Silty sand and Palaeochannel Deposits	2.289	10	1.511
E018G-I	Silty Clay, Silty Sand and Claystone	2.1	10	1.566
E014G-I	Clay and Claystone, some Sandstone	2.584	10	2.512
E024FG-I	Sandy Clay	2.041	10	1.341
E025FG-I	Calcarenite	6.667	10	0.086
E025FG-D	Sand, with Palaeochannel Deposits	6.728	10	0.086
E027FG-I	Clay and Sandstone	2	10	2.384
E028G-I	Sandy Clay and Clay	2.98	10	2.488
E029G-I	Sandstone	1.3	10	6.134
E030G-I	Silty Sand and Sand	7.75	5	4.25
E032FG-I	Sand	1.829	10	1.782
E032FG-D	Sandstone and Clayey Sand	2.034	10	1.998
E033FG-I	Mostly Sand, part Clay	2.138	10	0.62
E046FG-I	Calarenite	2.32	10	2.570
E047FG-I	Sandy Clay and Clay	1.38	10	1.980
E048FG-I	Sand	2.43	10	2.281
Superficial Formations - Ashburton River Delta Clay				
E005G-I	Clay (aquitard)	2.847	10	1.343
Trealla Limestone				
E002G-D	Limestone, vuggy	3.794	10	2.701
E005G-D	Limestone, notes ad good aquifer	3.086	10	
E007G-D	Limestone, with cavities	2.456	10	2.456
E016G-D	Limestone	3.997	10	2.452
E018G-D	Clay then Limestone		10	NA
E019G-D	Limestone, very weathered		10	
E027FG-D	Limestone and Conglomerate	2.63	10	2.013
E029G-D	Limestone	1.47	10	1.955
E030G-D	Sand and Limestone	8.075	10	5.854
E031G-D	Mainly Limestone and some Silty Sand	1.35	10	7.005
E033FG-D	Mainly Limestone, some Breccia and Sandstone	3.012	10	2.474
E047FG-D	Limestone, Calcarenite and Silty Clay	2.01	10	1.893
E052FG-D	Weathered Limestone	2.12	10	2.444

Table 3-7 Summary of Slug Tests in Drive Point Piezometers

Drive Point Piezometer	Screened Unit	Screened Length (m)	Groundwater Level (m bgl)	Slug Volume (L)	Maximum Displacement (m)
EO34G-S	Saturated Sands and Clays: Intertidal zone	0.3	0.63	1.00	0.77
E036G-S	Superficial Sands	0.3	0.72	0.50	0.70
E040G-S	Sandy claypan	0.2	0.94	0.50	0.66
E041G-S	Sandy Clay	0.3	0.59	1.00	0.76
E043G-S	Sandy Clay	0.6	0.55	0.75	0.80
E044G-S	Sandy Clay	0.3	0.48	1.00	0.92
E056G-S	Sandy Clay	0.4	0.97	1.00	2.77
E034G-D	Saturated Sands and Clays: Intertidal zone	0.3	0.64	1.00	0.77
E036G-D	Superficial Sands	0.3	0.82	0.50	NA
E040G-D	Sandy Claypan	0.6	0.93	1.00	0.93
E041G-D	Sandy Clay	0.6	0.53	1.00	1.10
E042G-D	Sandy Claypan	0.3	0.95	1.00	2.16
E043G-D	Sandy Clay	0.5	0.56	1.00	1.08
E044G-D	Sandy Clay	0.1	1.31	1.00	1.16
E045G-D	Saturated Claypan	0.2	0.56	0.50	0.72
E056G-D	Sandy Clay	0.2	0.93	1.00	3.45

3.2.2 Groundwater Quality

Field EC and pH of the groundwater being discharged from each monitoring bore were recorded during airlift development. At the completion of airlift development, a groundwater sample was taken from each bore and submitted to ALS Laboratory Group for analysis. Laboratory certificates of these analyses are provided in Appendix E.

Subsequently EC profiles were measured in the completed monitoring bores. Plots of the EC profiles are provided in Appendix F.

Groundwater analyses were completed to determine pH, TDS, EC, major dissolved ions (hydroxide, alkalinity, carbonate alkalinity, bicarbonate alkalinity, total alkalinity, sulphate as sulphur, elemental sulphur, chloride, calcium, magnesium, sodium, potassium) and total metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc, mercury).

3.3 Infiltration Tests

Infiltration tests were completed at 15 sites at Ashburton North. Details of the infiltration test sites are outlined in Table 3-8 and locations of the test sites are shown on Figure 3-5. The sites were selected to represent the different geomorphology units at Ashburton North.

The methodology involved the placement of two 0.5 m lengths of uPVC casing (one inside the other) at the selected locations. The inner and outer casings were 50 and 125 mm nominal diameter. Both lengths of casing were driven about 0.15 m into the ground. Fresh, clear water was poured into the inner and outer ring to wet the underlying strata. Subsequently, the inner and outer rings were filled to the top of the casing and the fall in head was measured at selected time intervals.

Data and results from the infiltration tests are provided in Appendix G.

Table 3-8 Infiltration Test Sites

Name of Test	Location of Test
Claypan-E029	Border of claypan 40 m from E029
Claypan#2-E029	Middle of claypan
Claypan#3-Dune8	Border of claypan
Claypan#4-Dune8	Middle of claypan
Tidal Flat Test 1	Tidal flat
Tidal Flat Test 2	Tidal flat
Tidal Flat 1	Close to estuary
Red Sand E026	Spinifex and red sand close to E026
Beach E019	Beach, 20 m southeast of E019
Spinifex Sand #1	Spinifex and sand next to E027
Spinifex Sand #2	Spinifex and sand approximately 50 m from E032
Main Dune Test 1 E008	Mid height of dune, 50 m south of E008
Main Dune Test 2	Top of main dune
Beach Test 1	Beach
Beach Test 2	Beach

3.4 Barometric Pressure and Tidal Measurements

Both barometric pressure and tidal fluctuations may influence groundwater level measurements in near-coastal settings. Therefore, site investigations included the collection of tidal and barometric data (Table 3-9) to enable the assessment of the influence of barometric pressure and tidal forces on measured groundwater levels.

Tidal measurements were obtained from the Government of Western Australia – Department of Planning and Infrastructure (DPI, reference http://www.dpi.wa.gov.au/imarine/19102.asp). Barometric pressures and groundwater level data were recorded using *in situ* 'Baratroll' and 'Aquatroll' loggers.

Table 3-9 Data Collection to Assess Tidal and Barometric Efficiency

Monitoring Site	Periods of Data Collection		
	Tidal Data	**Barometric Pressure**	**Groundwater Levels**
DPI Website	17 – 18 April 2009		
	3 – 10 August 2009		
E005G-S			17 – 27 April 2009
E005G-I			17 – 18 April 2009
E005G-D			17 – 22 April 2009
E007G-S			3 – 10 August 2009
E024G-S			3 – 9 August 2009
E025G-S			3 – 9 August 2009
E026G-S			3 – 9 August 2009
E027G-S			3 – 7 August 2009
E027G-I		4 – 10 August 2009	4 – 10 August 2009
E027G-D			3 – 10 August 2009

4

Interpreted Baseline Groundwater Environment

4.1 Hydrostratigraphy

The interpreted hydrostratigraphy of Ashburton North is based on the local lithological profiles intersected during the Environmental Drilling Programs. Depths of investigation were predominantly up to 30 m, with a few holes extending to 80 m. The interpreted hydrostatigraphy is broad-scale and limited to the depths of investigation. The interpreted hydrostatigraphy is summarised in Table 4-1 and shown in cross-sections on Figure 4-1 (plan view of cross-section lines) and Figures 4-2, 4-3 and 4-4 (cross- sections).

Table 4-1 Interpreted Hydrostratigraphy

Hydrostratigraphic Unit	Potential Aquifer Description		Typical Saturated Thickness (m)
	Storage Characteristics	Broad Lithology	
Quaternary/Recent Superficial Formations			
Dune Sands	Unconfined	Sands and Sandstones	3
Ashburton River Delta Alluvium	Semi-Confined and Confined	Silty and Sandy Clays, interbedded sand and clay	20
Ashburton River Delta Clay and Unconformity	Confining Layer and Aquitard	Clay and Claystone	5
Tertiary Successions - Carnarvon Basin			
Trealla Limestone	Confined	Limestone	30

4.2 Interpreted Aquifer Parameters

Aquifer parameters have been interpreted from the pumping, slug and infiltration test data. The interpretations have been aligned with the defined hydrostratigraphy. As such, the individual monitoring bores and drive point piezometers were grouped, depending on the screened hydrostratigraphic unit, as follows:

- **Dune Sands -** All shallow 'S' monitoring bores are screened in the dune sands, with the exception of E024FG-S, E033FG-S, E046FG-S to E048FG-S and E052FG-S.
- **Ashburton River Delta Alluvium -** All intermediate 'I' monitoring bores (with the exception of E005G-I, E024FG-S, E033FG-S, E046FG-S to E048FG-S, E052FG-S, E025FG-D and E032FG-D) are screened in the Ashburton River Delta alluvium.
- **Ashburton River Delta Clay and Unconformity -** E005G-I is the only monitoring bore screened in the claystone, basal, and unconformity units for which aquifer test data are available.
- **Trealla Limestone -** The deep 'D' monitoring bore are screened in the Trealla Limestone (except E025FG-D and E032FG-D).

4.2.1 Methods of Aquifer Test Analysis

Pumping test data were analysed using the Theis (type curve) and Cooper-Jacob (straight-line) methods to estimate transmissivity. Hydraulic conductivity was subsequently calculated from:

$$k = \frac{T}{b}$$

Where: k is hydraulic conductivity (m/day).

T is transmissivity (m^2/day).

b is aquifer thickness (m), assumed to be the equivalent of the screened interval in each individual monitoring bore. This assumption is considered valid, because the short tests and low pumping rates nature of the tests would limit vertical flow in the aquifer.

Slug test data were analysed using the Bouwer and Rice Method.

Infiltration tests were used to derive vertical hydraulic conductivity values using the Bouwer and Rice Method.

4.2.2 Interpretation of Hydraulic Conductivity from Aquifer Tests

Step-Test Analysis for E022

The step-drawdown test data are presented on Figure 4-5.

Groundwater level drawdown in a pumping bore has two components - drawdown associated with the aquifer (formation loss) and drawdown associated with turbulent flow, friction and intake velocity through the screens/gravel pack (well losses). The Bierschenk and Wilson method allows the determination of formation and well losses, utilising the following equation:

$S_w = BQ + CQ^2$

where:

S_w is the specific drawdown at a certain time (30 minutes in this case).

Q is the discharge rate in kL/day.

B is the formation loss factor in m/m^3/day.

C is the well loss factor in m/(m^3/day)^2.

The data are plotted as specific drawdown versus flow rate (Figure 4-5) and a best fit straight line has a gradient (equivalent to *C)* and a Y intercept *(*equivalent to B*).*

The analysis indicates that the test production bore has a high efficiency.

E022 Well Efficiency (at 69 kL/day) $= (BQ/S_w) \times 100$

$=(0.0275 \times 69/ 2.26) \times 100$

$= 84$ *percent*

Similar calculations were performed at discharge rates of 35 and 108 kL/day, resulting in well efficiencies of 93 percent and 80 percent respectively. Well efficiency decreases as discharge rate increases.

Constant-Rate Test Analysis for E022

The constant-rate test data are shown on Figure 4-6.

Constant-rate test data were analysed using the Theis (type curve) and Cooper-Jacob (straight-line) methods to estimate aquifer parameters. Aquifer thickness, for calculating the hydraulic conductivity, has been determined as 4 m for E022, as this is the thickness from the water table to the base of the dune sands at the site.

Analysis of the constant-rate test indicates aquifer transmissivity of the dune sands to be between 16 and 26 m^2/day (E010G-S and E022, respectively), with the corresponding hydraulic conductivity values between 4 and 6.6 m/day. These values are within the range shown in Table 4-2 obtained from short-term pumping tests, but above the average of 2 m/day.

The response of E010G-I during the test suggests the transmissivity of the Ashburton River Delta alluvium is about 60 m^2/day, with a corresponding hydraulic conductivity of 4 m/day.

Storativity values were estimated to be between 0.00006 and 0.001 for both the Dune Sands and Ashburton River Delta Alluvium.

Following the completion of the 48-hour constant-rate test, recovering groundwater levels were measured over a 90 minute period. The groundwater level within the bore recovered to within 0.14 m of the static level after 90 minutes. Results of the recovery test are shown on Figure 4-7.

Short Term Test Analysis for Monitoring Bores and Drive Point Piezometers

Tables 4-2 and 4-3 summarise hydraulic conductivity values determined from short-term pumping tests and slug tests in monitoring bores and drive point piezometers.

4 Interpreted Baseline Groundwater Environment

Table 4-2 Hydraulic Conductivity Interpreted from Short-Term Pumping Tests

Hydrostratigraphic Unit	Data Sets Analysed[1]	Interpreted Hydraulic Conductivity (m/day)			
		Range	Average	Median	Outliers[2]
Quaternary/Recent Superficial Formations					
Dune Sands[3]	12	0.8 – 8	2	2	50 (E007G-S)
Ashburton River Delta Alluvium	13	0.2 – 1	0.5	0.4	6.9 (E010G-I) 20 (E033FG-I)
Ashburton River Delta Clay and Unconformity	1	0.3	-	-	-
Tertiary Successions - Carnarvon Basin					
Trealla Limestone	14	0.1 – 10	3	0.8	-

1. Selected data were not analysed due to comparatively poor quality.

2. Outlying values are not included in range or calculation of average and median values. The high outlier hydraulic conductivity value for E007G-S is compatible with a comparatively high airlift yield and small drawdown during the pumping test. The aquifer is screened in sandstone. The high outlier hydraulic conductivity value in E033FG-I corresponds with sand beds within the Ashburton River Delta alluvium. The sand beds appear small-scale and localised, typically being of insufficient thickness, continuity and extent to significantly influence the effective transmissivity of the Ashburton River Delta alluvium.

3. An average of the Theis and Cooper Jacob hydraulic conductivity values was taken.

Table 4-3 Hydraulic Conductivity Interpreted from Slug Test Data

Hydrostratigraphic Unit	Data Sets Analysed[1]		Interpreted Hydraulic Conductivity (m/day)			
	Drive Point Piezometers	Monitoring Bores	Typical Range	Average	Median	Outliers[2]
Quaternary/Recent Superficial Formations						
Ashburton River Delta Alluvium - Clay Pans	7	-	0.01 – 0.2	0.05	0.02	-
Ashburton River Delta Alluvium	-	14	0.1 – 7	2	2	0.002 (E030G-I) 22 (E010G-I)
Ashburton River Delta Clay and Unconformity	-	1	1	-	-	-
Tertiary Successions - Carnarvon Basin						
Trealla Limestone	-	9	0.01 - 7	2	0.4	-

1. Selected data were not analysed due to comparatively poor quality.

2. Outlying values are not included in range or calculation of average and median values. The high outlier hydraulic conductivity in E010G-I corresponds with palaeochannel sand deposits within the Ashburton River Delta alluvium. It is interpreted that the palaeochannel sand deposits are small-scale and localised, typically being of insufficient thickness, continuity and extent to significantly influence the effective transmissivity of the Ashburton River Delta alluvium.

4.2.3 Interpretation of Vertical Hydraulic Conductivity from Infiltration Tests

Table 4-4 summarises the vertical hydraulic conductivities interpreted from infiltration tests. Table 4-5 provides a consolidated summary of these results.

Table 4-4 Interpreted Vertical Hydraulic Conductivity – Infiltration Tests

Hydrostratigraphic Unit	Name of Test	Vertical Hydraulic Conductivity (m/day)
Quaternary/Recent Superficial Formations		
Dune Sands	Red Sand E026	1
	Beach E019	24
	Spinifex Sand #1	0.1
	Spinifex Sand #2	0.5
	Main Dune test 1 E008	0.4
	Main Dune test 2	4
	Beach Test 1	5
	Beach Test 2	6
Ashburton River Delta Alluvium	Claypan-E029	0.1
	Claypan#2-E029	0.003
	Claypan#3-Dune8	0.1
	Claypan#4-Dune8	0.03
	Tidal Flat test 1	1
	Tidal Flat test 2	0.4
	Tidal Flat 1	no infiltration

Table 4-5 Summarised Vertical Hydraulic Conductivity – Infiltration Tests

Hydrostratigraphic Units	Number of Tests	Vertical Hydraulic Conductivity (m/day)	
		Range	Average
Quaternary/Recent Superficial Formations			
Dune Sands - Beach	3	3.5 – 24	9
Dune Sands	5	0.6 - 4	1
Ashburton River Delta Alluvium - Claypan and Tidal Flats	7	0.003 - 1	0.2

4.2.4 Interpretation of Effective Transmissivity

Effective transmissivity for each stratigraphic unit was calculated by assuming an average thickness for each unit.

The hydraulic parameters assigned to individual hydrostratigraphic units (derived from short-term pumping, slug and infiltration tests) are presented in Table 4-6. These parameters represent the estimated effective characteristics of the discrete hydrostratigraphic units and were used as initial hydraulic parameters for the numerical model.

Table 4-6 Interpreted Effective Hydraulic Parameters

Hydrostratigraphic Unit	Average Saturated Thickness (m)	Hydraulic Conductivity (m/day)		Effective Transmissivity (m^2/day)
		Horizontal	Vertical	
Quaternary/Recent Superficial Formations				
Dune Sands	3	4 – 8	4	12 - 24
Ashburton River Delta Alluvium	20	0.5	0.05	10
Ashburton River Delta Clay and Unconformity	5	0.3	0.03	2
Tertiary Successions - Carnarvon Basin				
Trealla Limestone	10[1]	5.0	5.0	50

1. The monitoring bores typically do not fully penetrate the Trealla Limestone.

4.3 Groundwater Flow

4.3.1 Relationship of Groundwater Levels and Topography

An assessment of the relationship between topography and measured shallow groundwater levels is shown on Figure 4-8 and demonstrates topographic control on the water table elevation. Groundwater flow is a reflection of the surface water catchments, with the dune systems hosting catchment divides. In the deeper profiles of the Ashburton River Delta alluvium and Trealla Limestone, the influence of the local topography remains evident but subdued and increasingly masked by regional influences and density effects.

4.3.2 Groundwater Level Trends

Figure 4-9 (a to j) shows hydrographs for all those monitoring bores in which multiple groundwater level measurements. Monthly monitoring of groundwater levels was undertaken from June to October 2009, however, the discontinuous nature of the drilling program resulted in selected bores being monitored less frequently.

The hydrographs show a decrease in groundwater level over the period. This is most likely a result of seasonal climatic influences. Decreases in groundwater level over the monitoring period range from 0.1 to 0.5 m, and are generally about 0.2 m. Groundwater level decreases appear to be similar in all three hydrostratigraphic units.

A slight increase in groundwater levels was noted between late-July and early-August in monitoring bores at several sites (E002, E012, E014, E018, E019, E021, E029, E031, E032 and E033). This is probably a response to increased rainfall during June and July 2009, when 43 and 5 mm fell (Onslow Airport Station 005017, BoM 2009). In the months before and after this period, <5 mm of rainfall fell at Onslow Airport.

The hydrographs show significantly fluctuating groundwater levels in monitoring bores E002, E029, E030, E032 and E033, and then a return to a typical range.

4.3.3 Environmental Heads

The local shallow groundwater has a widely variable salinity. The dune sands, Ashburton River Delta alluvium and Trealla Limestone contain brackish, saline and hypersaline groundwater. Therefore, the groundwater hydraulics is coupled to density effects that characterise saline and hypersaline groundwater flow dynamics. Determining potentiometric heads, hydraulic gradients and groundwater flow directions in successions that contain saline and hypersaline groundwater requires the interpretation of environmental heads. The environmental heads compensate for and equilibrate vertical density stratification due to groundwater salinity.

Freshwater has a density of 0.99 g/cm^3. Locally beneath the Project area, TDS concentrations of 5,000 to about 200,000 mg/L have been measured, with commensurate groundwater density ranging from 1.00 to 1.16 g/cm^3. The relationship between fresh and saline groundwater heads was investigated by Luscynski (1961) and used to interpret environmental heads.

The depth and groundwater TDS concentration in each monitoring bore has been used to determine the density of the water column and equivalent height of a freshwater column (freshwater equivalent heads, Chart 4-1). Subsequently, the freshwater equivalent heads were determined by considering the densities and freshwater heads of the successions overlying the monitoring bore screen interval, to establish environmental heads.

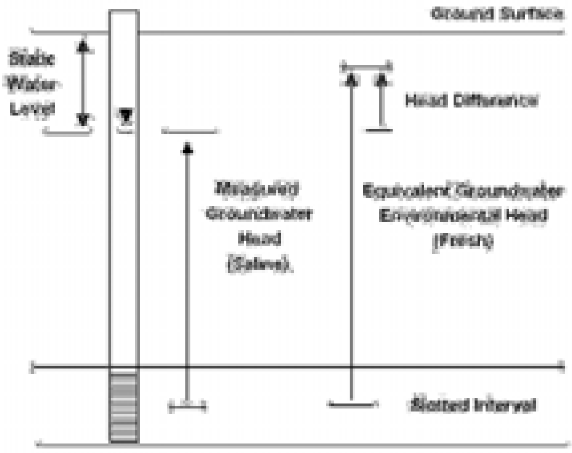

Chart 4-1 Fresh Water Equivalent Environmental Water Heads

4.3.4 Horizontal Groundwater Flow Dynamics

Groundwater level contour maps have been derived for the water table (Figure 4-10) and the predominant hydrostratigraphic units formed by the dune sands (Figure 4-11), Ashburton River Delta alluvium (Figure 4-12) and Trealla Limestone (Figure 4-13).

The water table elevation (m AHD) is based on the physical expression of the water table, as measured in monitoring bore and drive point piezometer standpipes, together with the assumption that the directions of groundwater flow would closely conform to the topography. As such, the interpreted water table elevations peak beneath the dunes, with flow lines perpendicular to the dune crests towards lowlands formed by the supratidal, samphire and tidal flats of the Southwest, Hooley Creek and Ashburton River Delta Catchments; and flow eventually northwards into the sea. Groundwater levels are highest in the southern portion of the Shared Infrastructure Corridor and indicate a northerly groundwater flow direction.

The interpreted groundwater contour maps for the dune sands, Ashburton River Delta alluvium and Trealla Limestone are based on environmental heads. These maps are directly comparable and provide an understanding of the potential vertical flow dynamics between the shallow hydrostratigraphic units. The interpreted environmental heads show broad conformance with the topography, with mounds beneath the dunes, regional flow to the north and vertically upward flow from the Trealla Limestone into the overlying successions. That is, the environmental heads are highest (typically 1.0 to 2.5 m AHD) in the Trealla Limestone and progressively decline (typically 0.75 to 1.0 m AHD) throughout the Ashburton River Delta alluvium and are lowest (typically 0.25 to 0.75 m AHD) within the dune sands.

4.3.5 Vertical Groundwater Flow Dynamics

Figures 4-14, 4-15 and 4-16 illustrate the interpreted vertical distribution of environmental heads on selected cross-sections aligned along groundwater flow paths. These figures illustrate the broad conformance of the environmental heads with topography, with mounds beneath the dunes and vertically upward flow from the Trealla Limestone into the overlying successions. The upward flow gradients occur within the entire domain, but the cross-sections illustrate predominant upward flow to the lowlands formed by the supratidal, samphire and tidal flats.

The interpreted vertically upward flow dominates the cross-sections and characterises the project area as a regional groundwater discharge zone.

4.4 Barometric Efficiency

Groundwater levels in confined aquifers respond to changes in barometric pressure. A reduction in barometric pressure results in a rise in confined aquifer groundwater levels. The ratio of concurrent change between barometric pressure and groundwater level fluctuation is termed the barometric efficiency of an aquifer. Usually, highly confined aquifers have high (approaching 1.0, dimensionless) barometric efficiency, whereas unconfined water table aquifers have a barometric efficiency which approaches zero. Barometric pressures measured at Ashburton North during August 2009 are shown on Chart 4-2.

4 Interpreted Baseline Groundwater Environment

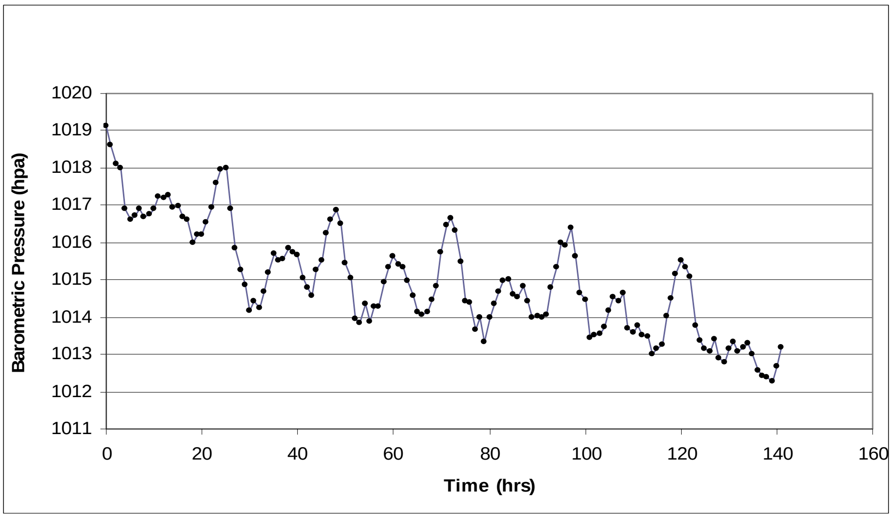

Chart 4-2 Measured Barometric Pressure (4 to 10 August 2009)

These data have been used to assess and correct groundwater level fluctuations in monitoring bores E007G-S and E027G-D during the corresponding period. The corrected groundwater levels are shown on Chart 4-3. Both corrected data sets show trends linked to other water balance factors. The ratio of groundwater level fluctuations compared to barometric pressure changes indicates a mean barometric efficiency of 0.4 (dimensionless) for E027G-D. For E007G-S, the barometric efficiency is inconsistent, suggesting any groundwater level fluctuations caused by barometric pressure changes were masked by the other water balance factors.

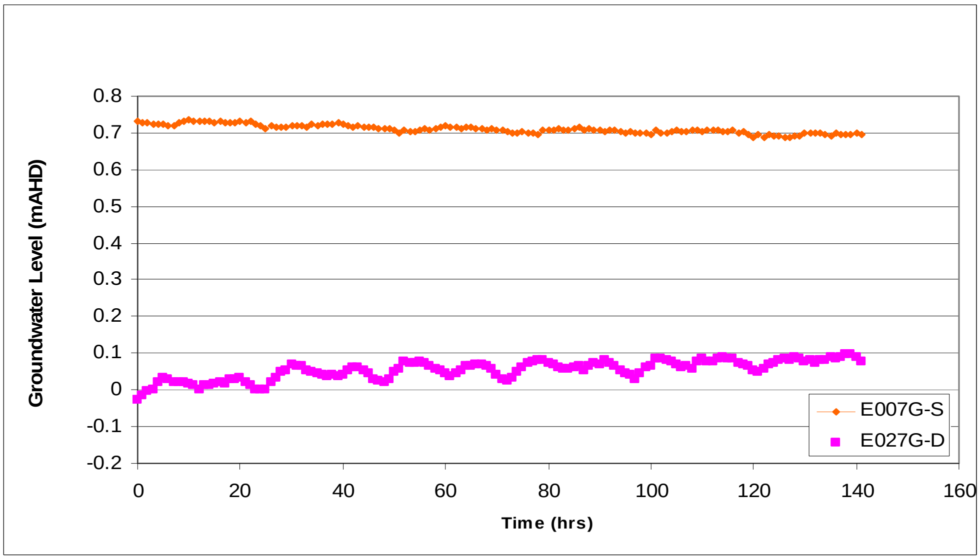

Chart 4-3 Selected Groundwater Levels Corrected for Barometric Pressure (4 to 10 August 2009)

4.5 Tidal Efficiency and Influence

Groundwater levels may respond to tidal fluctuations. A rise in sea level may be accompanied by a rise in groundwater levels. The ratio of concurrent change between tidal amplitude and groundwater level fluctuations is termed the tidal efficiency of an aquifer. Usually, highly confined aquifers have low tidal efficiency (not impacted by tidal actions), whereas unconfined water table aquifers may have a tidal efficiency approaching 1.0 (dimensionless).

The amplitudes of tidal fluctuations from 22 to 23 June and 4 to 10 August 2009 were compared to groundwater levels measured concurrently in E011F and E013F (on the beach); E007F (Southwest Catchment); and E027G-D (Hooley Creek Catchment) - (Charts 4-4 and 4-5). The available data indicate low tidal efficiency, typically less than 0.1 (dimensionless).

The low tidal efficiency indicates that the local groundwater environments are predominantly independent of and isolated from tidal influences. Measured TDS concentrations and associated groundwater densities, combined with the vertically upward hydraulic gradients, appear to locally limit seawater intrusion into the shallow water table zones. Presumably, the interface between groundwater and seawater occurs further offshore.

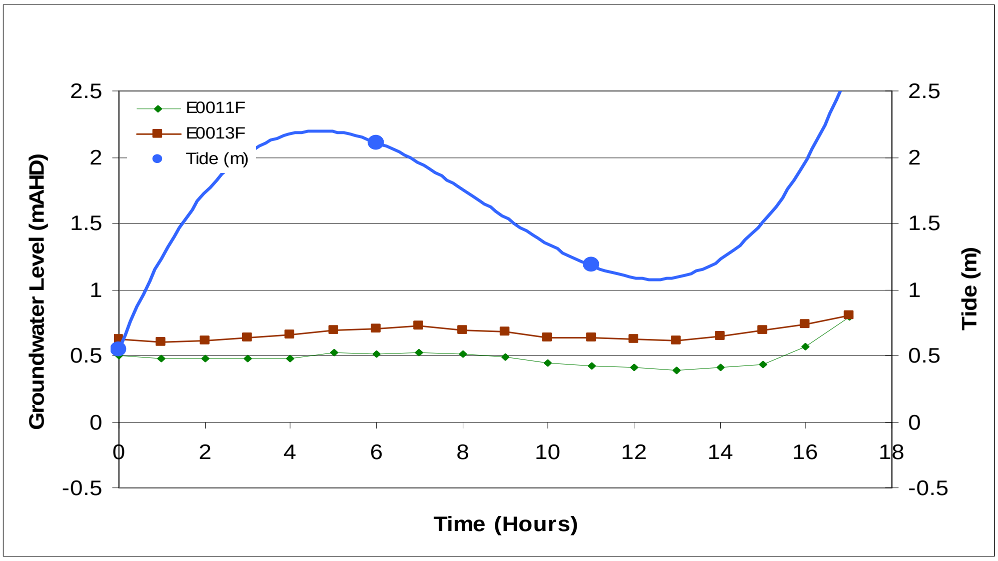

Chart 4-4 Tidal Fluctuations and Groundwater Levels (E011F and E013F) - 22 to 23 June 2009

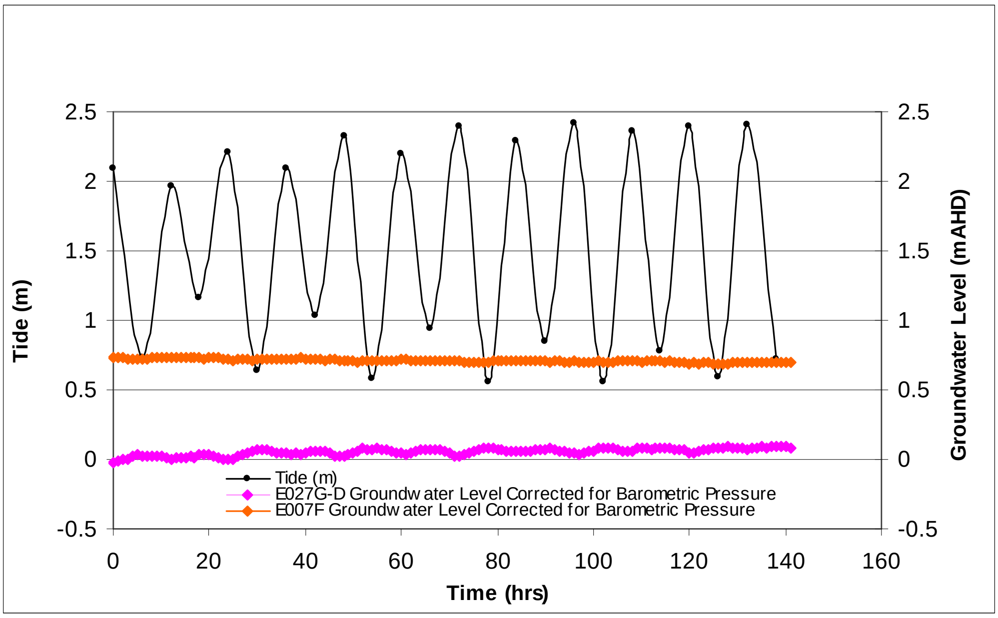

Chart 4-5 Tidal Fluctuations and Groundwater Levels (E007F and E027G-D) - 4 to 10 August 2009

4.6 Groundwater Quality

The available water quality data indicate that the local groundwater, at all depths, is brackish to hypersaline, near neutral to slightly alkaline and a sodium-chloride type - similar to seawater (Figure 4-17). Ionic balance was out of the acceptable 5 percent limit due to analytes not quantified in the sample, most probably nitrate. TDS concentrations range from 3,560 to 204,000 mg/L, typically being higher in the Trealla Limestone. This aspect is supported by the Electrical Conductivity (EC) measurements, with values ranging from 12.7 to 187.6 mS/cm and being greatest in the Trealla Limestone. The groundwater quality data are summarised in Table 4-7.

The measured TDS concentrations have been differentiated for the dune sands, Ashburton River Delta alluvium and Trealla Limestone (Figures 4-18, 4-19 and 4-20). These maps are directly comparable and provide an understanding of the potential regional source of accumulated salt within the deeper Carnarvon Basin successions being transmitted to the superficial formations predominantly formed by the Ashburton River Delta alluvium.

Seawater salinity is about 33,000 mg/L TDS. The measured TDS distributions show vertical salinity stratification in the groundwater. The Trealla Limestone contains hypersaline (156,000 to 200,000 mg/L TDS) groundwater. Groundwater salinity gradually decreases (typically 50,000 to 150,000 mg/L in the Ashburton River Delta alluvium and 20,000 to 120,000 mg/L in the dune sands) in the shallower successions.

4 Interpreted Baseline Groundwater Environment

The vertical distribution of groundwater salinity is shown on selected cross-sections (Figures 4-21, 4-22 and 4-23). Typically, the groundwater salinity is less in the dune sands, beneath comparatively broad expanses of transmissive dunes that may preferentially intercept and transmit rainfall recharge. Brackish groundwater locally occurs in the dune sands, but the distribution is irregular.

In principle, the lateral and vertical distributions of TDS concentrations are expected by be strongly aligned with the interpreted environmental heads.

Table 4-7 Groundwater Quality Data

Monitoring Bore	pH	EC @ 25°C	TDS @180°C	Hydroxide Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Bicarbonate Alkalinity as $CaCO_3$	Total Alkalinity as $CaCO_3$	Sulphate $(SO4)^{2-}$	Sulphur as S	Cl	Ca	Mg	Na	K	As	Cd	Cr	Cu	Pb	Ni	Zn	Hg
		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
E002F	7.36	89,700	83,600	<1	<1	188	188	5,740	1,910	38,700	1,240	2,420	23,300	920	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E002G-D	7.10	177,000	188,000	<1	<1	174	174	11,200	3,750	118,000	3,000	6,440	52,900	2,110	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E002G-D	6.82	172,000	185,000	<1	<1	200	200	6,220	2,070	97,000	1,800	6,140	62,900	1,460	<0.052	<0.0052	<0.052	<0.052	<0.052	0.191	0.521	<0.0001
E002G-S	7.5	63,200	49,400	<1	<1	304	304	1,350	450	26,400	770	1,350	14,700	500	<0.052	<0.0052	<0.052	<0.052	<0.052	0.193	0.117	<0.0001
E002G-S	7.47	63,200	56,000	<1	<1	396	396	4,040	1,350	25,800	790	1,400	15,200	500	<0.052	<0.0052	<0.052	<0.052	<0.052	0.118	<0.052	<0.0001
E003F	7.58	69,200	54,700	<1	<1	291	291	4,060	1,350	25,100	815	1,900	15,900	617	NA	NA	NA	NA	NA	NA	NA	NA
E004F	7.56	59,700	49,800	<1	<1	269	269	2,720	906	24,400	687	1,370	15,700	438	<0.052	<0.0052	<0.052	<0.052	<0.052	0.24	0.058	<0.0001
E005F	7.94	39,700	29,200	<1	<1	388	388	1,430	477	15,800	350	770	8,170	260	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E005G-D	7.03	148,000	155,000	<1	<1	182	182	4,760	1,590	74,900	2,800	4,530	43,800	1,700	<0.052	<0.0052	<0.052	0.061	<0.052	0.417	0.405	<0.0001
E005G-I	7.43	52,800	39,100	<1	<1	98	98	2,520	841	22,200	748	1,360	11,800	284	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E005G-S	8.41	11,400	6,470	<1	31	545	576	480	160	3,450	48	161	2,680	113	<0.052	<0.0052	<0.052	<0.052	<0.052	0.071	<0.052	<0.0001
E006F	7.41	80,500	72,100	<1	<1	177	177	5,650	1,880	39,600	1,010	2,120	18,200	1,010	<0.010	0.0013	0.057	0.031	<0.010	0.024	0.028	<0.0001
E007G-D	7	165,000	200,000	<1	<1	233	233	10,000	3,350	98,200	1,330	6,120	49,100	2,020	<0.052	0.0059	0.055	0.237	<0.052	0.063	0.077	<0.0001
E007G-I	7.11	127,000	134,000	<1	<1	171	171	9,300	3,100	64,300	1,300	4,280	31,400	1,360	<0.052	<0.0052	0.116	0.181	<0.052	0.096	0.064	<0.0001
E007G-S	7.68	61,300	49,000	<1	<1	286	286	4,470	1,490	25,100	582	1,470	12,300	651	<0.021	0.0022	0.074	0.033	<0.021	0.03	0.031	<0.0001
E007F	7.46	101,000	96,400	<1	<1	257	257	4,570	1,520	35,000	723	1,930	15,900	736	<0.021	<0.0021	0.057	0.098	<0.021	0.037	0.04	<0.0001
E008F	7.29	110,000	113,000	<1	<1	210	210	1,080	359	7,470	168	499	3,880	197	<0.021	<0.0021	0.059	0.033	<0.021	0.036	0.035	<0.0001
E009F	7.18	108,000	101,000	<1	<1	257	257	7,450	2,480	49,300	1,140	3,480	26,200	1,170	NA	NA	NA	NA	NA	NA	NA	NA
E010-F	6.75	119,000	114,000	<1	<1	178	178	7,700	2,560	51,900	1,170	3,100	27,100	1,050	<0.052	<0.0052	<0.052	<0.052	<0.052	0.084	<0.052	<0.0001
E010-F	6.89	116,000	119,000	<1	<1	187	187	7,070	2,360	52,200	1,210	3,180	26,700	1,080	<0.052	<0.0052	<0.052	<0.052	<0.052	0.163	<0.052	<0.0001
E010G-S	7.17	77,100	72,000	<1	<1	184	184	4,760	1,580	32,900	1,030	1,740	16,600	628	<0.052	<0.0052	<0.052	<0.052	<0.052	0.207	<0.052	<0.0001
E010G-I	6.88	121,000	133,000	<1	<1	190	190	8,710	2,900	54,900	1,410	3,980	33,400	1,310	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E010G-S	7.3	77,500	71,000	<1	<1	176	176	6,160	2,050	31,800	1,280	2,100	20,900	877	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E011F	7.89	40,500	30,700	<1	<1	219	219	2,210	737	14,100	356	1,040	7,580	374	NA	NA	NA	NA	NA	NA	NA	NA
E012F	7.24	77,400	70,300	<1	<1	259	259	5,620	1,870	36,600	832	2,260	17,700	904	<0.001	0.0001	<0.001	0.039	<0.001	0.005	<0.005	<0.0001
E013F	8.19	23,700	16,700	<1	<1	288	288	1,440	480	8,270	257	703	5,570	278	<0.001	<0.0001	<0.001	0.009	<0.001	0.003	<0.005	<0.0001
E013-C	7.93	47,400	36,000	<1	<1	222	222	3,140	1,050	17,100	427	1,440	10,000	482	NA	NA	NA	NA	NA	NA	NA	NA
E015F	7.35	76,800	76,800	<1	<1	236	236	3,950	1,320	37,900	1,410	2,430	15,700	572	<0.010	<0.0010	0.032	0.039	<0.010	0.031	0.022	<0.0001
E016G-D	6.67	156,000	182,000	<1	<1	389	389	6,190	2,060	86,700	1,850	5,030	42,100	1,500	<0.052	<0.0052	0.17	0.42	<0.052	0.175	0.102	<0.0001
E016-F	7.2	60,600	56,100	<1	<1	162	162	3,740	1,250	22,500	1,150	2,170	14,700	680	NA	NA	NA	NA	NA	NA	NA	NA
E016G-S	7.75	36,500	33,500	<1	<1	128	128	934	311	15,000	550	1,020	7,230	297	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	0.318	<0.0001
E017F	7.34	96,600	93,400	<1	<1	171	171	5,880	1,960	46,500	1,340	2,970	22,100	1,020	<0.021	<0.0021	0.1	0.04	<0.021	0.05	0.036	<0.0001
E018G-I	8	32,300	26,400	<1	<1	219	219	1,840	614	9,930	286	849	6,620	346	NA	NA	NA	NA	NA	NA	NA	NA
E018-F	7.12	74,200	65,400	<1	<1	310	310	12,600	4,210	27,800	1,290	3,180	18,900	728	NA	NA	NA	NA	NA	NA	NA	NA
E018G-D	6.79	156,000	156,000	<1	<1	185	185	16,900	5,620	77,800	1,720	6,810	53,800	2,870	NA	NA	NA	NA	NA	NA	NA	NA
E018G-I	6.82	119,000	119,000	<1	<1	220	220	14,400	4,790	53,200	1,530	4,670	34,300	1,540	NA	NA	NA	NA	NA	NA	NA	NA
E018G-S	7.2	58,700	51,900	<1	<1	369	369	11,200	3,720	21,100	1,090	2,600	1,4900	498	NA	NA	NA	NA	NA	NA	NA	NA

Monitoring Bore	pH	EC @ 25°C	TDS @180°C	Hydroxide Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Bicarbonate Alkalinity as $CaCO_3$	Total Alkalinity as $CaCO_3$	Sulphate $(SO4)^{2-}$	Sulphur as S	Cl	Ca	Mg	Na	K	As	Cd	Cr	Cu	Pb	Ni	Zn	Hg
		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
E019G-D	7.09	157,000	168,000	<1	<1	228	228	10,200	3,400	75,600	1,310	5,720	42,800	1,880	<0.021	<0.0021	0.055	0.069	<0.021	0.035	0.024	<0.0001
E019G-D	7.37	154,000	169,000	<1	<1	217	217	10,200	3,400	82,400	1,260	5,430	41,500	1,790	<0.001	<0.0001	0.001	0.012	<0.001	0.003	<0.005	<0.0001
E019G-S	7.87	34,400	27,200	<1	<1	214	214	1,910	637	12,900	295	884	6,900	349	<0.001	<0.0001	0.001	0.012	<0.001	0.003	<0.005	<0.0001
E019F	7.62	82,600	79,600	<1	<1	153	153	6,290	2,100	41,100	779	2,700	18,100	862	<0.005	<0.0005	0.075	0.016	<0.005	0.033	0.01	<0.0001
E019G-D	6.95	148,000	175,000	<1	<1	170	170	11,200	3,740	71,200	1,610	5,560	46,600	2,030	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E019G-F	7.57	62,900	55,800	<1	<1	152	152	4,620	1,540	26,300	676	2,060	16,800	538	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E019G-S	7.68	33,500	27,400	<1	<1	172	172	1,890	630	10,900	265	785	7,600	274	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E021F	7.7	84,000	84,200	<1	<1	232	232	6,680	2,220	40,300	1,040	2,830	18,900	923	NA	NA	NA	NA	NA	NA	NA	NA
E021F	7.86	32,300	24,800	<1	<1	207	207	3,170	1,060	11,900	452	1,020	6,920	286	0.012	<0.0010	<0.010	0.012	<0.010	0.021	0.011	<0.0001
E014G-F	7.48	66,500	57,800	<1	<1	280	280	3,850	1,280	29,000	757	2,010	17,400	553	<0.010	<0.0010	<0.010	0.025	<0.010	0.018	0.012	<0.0001
E014G-I	7.24	94,700	79,200	<1	<1	234	234	5,870	1,960	39,800	980	2,920	22,100	1,130	<0.010	<0.0010	<0.010	0.049	<0.010	0.022	<0.010	<0.0001
E014G-S	7.97	45,500	34,600	<1	<1	430	430	2,520	839	18,200	317	965	10,800	423	<0.010	<0.0010	<0.010	<0.010	<0.010	0.018	<0.010	<0.0001
E023FG-D	6.9	153,000	168,000	<1	<1	265	265	9,400	3,130	74,200	1,440	5,230	44,600	2,380	<0.010	<0.0010	<0.010	0.08	<0.010	0.028	0.016	<0.0001
E023FG-S	7.87	28,600	22,500	<1	<1	252	252	1,430	477	10,700	300	790	5,020	220	<0.010	<0.0010	<0.010	0.02	<0.010	0.026	<0.010	<0.0001
E024FG-I	7.54	61,500	50,200	<1	<1	235	235	4,630	1,540	25,600	635	1,830	14,600	815	0.012	<0.0010	<0.010	0.028	<0.010	0.021	<0.010	<0.0001
E024FG-S	7.75	48,700	36,400	<1	<1	243	243	2,770	922	19,500	527	1,320	11,800	411	<0.010	<0.0010	<0.010	0.022	<0.010	0.014	0.022	<0.0001
E025FG-D	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.010	<0.0010	<0.010	0.027	<0.010	0.016	<0.010	<0.0001
E025FG-I	8.2	8,460	5,820	<1	<1	274	274	324	108	2,090	83	163	1,580	95	<0.010	<0.0010	<0.010	0.022	<0.010	0.019	0.016	<0.0001
E026G-D	6.76	152,000	165,000	<1	<1	161	161	7,860	2,620	73,600	1,200	4,400	37,100	1,450	<0.010	<0.0010	<0.010	0.101	<0.010	0.024	<0.010	<0.0001
E026G-S	7.69	41,800	30,600	<1	<1	222	222	2,420	805	13,600	372	1,010	9,490	351	<0.010	<0.0010	0.014	0.01	<0.010	0.018	<0.010	<0.0001
E027FG-D	6.53	161,000	185,000	<1	<1	145	145	9,430	3,140	87,300	1,450	6,160	58,000	1,890	<0.010	<0.0010	<0.010	0.089	<0.010	0.027	<0.010	<0.0001
E027FG-I	6.99	141,000	155,000	<1	<1	143	143	9,890	3,300	71,300	1,510	5,120	42,500	2,280	<0.010	<0.0010	<0.010	0.083	<0.010	0.037	<0.010	<0.0001
E027FG-S	7.11	119,000	127,000	<1	<1	176	176	9,660	3,220	55,500	1,450	4,350	39,400	1,450	0.012	<0.0010	0.116	0.128	0.025	0.062	0.082	<0.0001
E028G-I	7.33	102,000	70,000	<1	<1	138	138	5,180	1,730	43,000	1,100	2,680	23,700	1,110	<0.010	<0.0010	<0.010	0.054	<0.010	0.022	<0.010	<0.0001
E028G-S	7.57	74,700	49,000	<1	<1	172	172	3,160	1,050	30,100	700	1,690	15,500	680	<0.010	<0.0010	<0.010	0.036	<0.010	0.024	0.018	<0.0001
E029G-D	6.81	136,000	160,000	<1	<1	169	169	9,550	3,180	67,600	1,400	4,920	39,300	1,540	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E029G-I	6.8	128,000	135,000	<1	<1	147	147	6,070	2,020	60,100	1,420	3,670	27,800	1,040	<0.052	<0.0052	<0.052	0.086	<0.052	<0.052	0.062	<0.0001
E029G-S	6.79	93,300	99,300	<1	<1	261	261	4,840	1,610	42,000	1,430	3,280	22,600	777	<0.052	<0.0052	<0.052	0.06	<0.052	0.329	0.109	<0.0001
E030G-D	6.57	160,000	185,000	<1	<1	213	213	8,160	2,720	90,600	1,670	5,530	52,400	2,560	0.018	<0.0010	<0.010	0.118	<0.010	0.048	0.022	<0.0001
E030G-I	7.32	88,500	78,400	<1	<1	203	203	3,730	1,240	36,100	930	1,920	19,600	950	0.011	<0.0010	<0.010	0.058	<0.010	0.031	<0.010	<0.0001
E030G-S	7.21	119,000	108,000	<1	<1	143	143	7,900	2,640	50,300	1,130	3,960	33,200	1,380	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E031G-D	7.27	146,000	156,000	<1	<1	234	234	4,710	1,570	68,700	1,660	4,150	35,300	1,040	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E031G-S	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA
E032FG-D	7.12	119,000	127,000	<1	<1	161	161	7,670	2,560	53,000	1,230	3,680	30,000	1,610	0.014	0.0029	0.01	0.071	0.012	0.043	0.015	<0.0001
E032FG-I	7.57	66,700	59,600	<1	<1	318	318	6,020	2,000	26,800	845	1,950	14,800	590	0.014	<0.0010	<0.010	0.029	<0.010	0.016	<0.010	<0.0001
E032FG-S	7.6	46,400	38,500	<1	<1	302	302	4,630	1,540	18,500	772	1,590	11,200	441	NA	NA	NA	NA	NA	NA	NA	NA
E033FG-D	6.72	150,000	176,000	<1	<1	145	145	11,800	3,930	72,800	1,540	5,880	49,000	2,140	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E033FG-I	7.17	82,400	79,400	<1	<1	175	175	5,500	1,840	35,900	898	2,300	17,000	570	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001
E033FG-S	7.96	22,000	17,700	<1	<1	368	368	2,530	844	6,900	237	722	3,950	115	<0.052	<0.0052	<0.052	<0.052	<0.052	<0.052	<0.052	<0.0001

Monitoring Bore	pH	EC @ 25°C	TDS @180°C	Hydroxide Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Bicarbonate Alkalinity as $CaCO_3$	Total Alkalinity as $CaCO_3$	Sulphate $(SO4)^{2-}$	Sulphur as S	Cl	Ca	Mg	Na	K	As	Cd	Cr	Cu	Pb	Ni	Zn	Hg
		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EO46FG-S	7.57	65,900	47,400	<1	<1	165	165	1,870	N/A	25,400	657	1,390	13,500	351	<0.010	<0.0010	<0.010	0.026	<0.010	0.011	<0.052	<0.0001
EO46FG-I	7.19	131,000	126,000	<1	<1	118	118	5,340	N/A	55,200	1,660	3,320	27,500	957	<0.021	<0.0021	<0.021	0.050	<0.021	<0.021	<0.105	<0.0001
EO47FG-D	6.64	194,000	226,000	<1	<1	120	120	5,140	N/A	99,600	2,140	5,820	41,900	1,380	<0.021	0.0024	<0.021	0.104	<0.021	<0.021	<0.105	<0.0001
EO47FG-I	7.05	137,000	135,000	<1	<1	146	146	5,150	N/A	59,300	2,270	3,770	29,300	1,050	<0.021	0.0026	<0.021	0.046	<0.021	<0.021	<0.105	<0.0001
EO47FG-S	7.26	104,000	91,900	<1	<1	90	90	4,820	N/A	41,500	1,960	2,750	21,000	552	<0.021	<0.0021	<0.021	0.036	<0.021	<0.021	<0.105	<0.0001
EO48FG-I	6.81	124,000	130,000	<1	<1	144	144	3,020	N/A	53,700	3,610	4,570	22,400	537	<0.021	0.0024	<0.021	0.074	<0.021	<0.021	<0.105	<0.0001
EO48FG-S	7.19	88,800	82,300	<1	<1	48	48	2,710	N/A	35,800	2,370	2,620	14,900	312	<0.021	<0.0021	<0.021	0.035	<0.021	<0.021	<0.105	<0.0001
EO52FG-D	6.64	204,000	259,000	<1	<1	126	126	7,260	N/A	114,000	1,320	7,790	46,000	1,700	<0.021	0.0023	0.084	0.107	0.029	<0.021	<0.105	<0.0001
EO52FG-S	7.28	102,000	93,100	<1	<1	143	143	2,280	N/A	40,800	1,670	2,610	19,800	647	<0.021	<0.0021	<0.021	0.054	<0.021	<0.021	<0.105	<0.0001
Production Bore																						
E022 48hr Pumping Test Start (16/09/09)	7.03	112,000	88,600	<1	<1	133	133	8000	2660	44100	1570	2970	24000	1420	0.03	0.0028	0.014	0.028	0.025	0.017	0.111	<0.0001
E022 48hr Pumping Test End (21/09/09)	7.08	110,000	87,600	<1	<1	134	134	7900	2630	42700	1550	2990	24800	1430	0.022	<0.0010	<0.010	0.018	<0.010	<0.010	<0.052	<0.0001

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4 Interpreted Baseline Groundwater Environment

Heavy metals were detected in groundwater from most monitoring bores, with chromium, copper, nickel and zinc detected in the highest concentrations (Table 4-8). The limit for reporting for the heavy metals was raised in several samples due to the high EC of these samples. Heavy metal concentrations occur above the marine Australian and New Zealand Environment and Conservation Council (ANZECC, 2000) Guidelines in groundwater from many of the monitoring bores. The marine ANZECC Guidelines are used as a reference due to the high concentrations of salt in the groundwater. The application of the guidelines is only relevant if the groundwater discharges at the surface and does not undergo any chemical alteration, such as precipitation, that might affect heavy metals concentrations.

Table 4-8 Heavy Metal Concentrations in Monitoring Bores

Heavy Metal	Concentrations (mg/L)		Number of Samples with Metal Detected	ANZECC Guideline Trigger Value for Maine Water with 95% Level of Protection
	Highest	Lowest		
Arsenic	0.045	0.011	10	No value
Cadmium	0.059	0.0001	6	0.005
Chromium	0.747	0.001	20	0.027
Copper	0.42	0.009	41	0.0013
Lead	0.07	0.012	7	0.004
Nickel	1.18	0.003	52	0.07
Zinc	0.564	0.01	32	0.015
Mercury	<0.0001	<0.0001	0	0.0004

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5

Conceptual Hydrogeology Model

Ashburton North is underlain by a shallow water table, predominantly saline to hypersaline groundwater and is a groundwater discharge zone associated with regional Carnarvon Basin successions. Local exceptions occur seasonally, when the dunal terrain intercepts and transmits rainfall recharge. Interpreted seasonal recharge zones are shown on Figure 5-1. All shallow groundwater intercepted by the site investigations appears to be accumulating salt, thus indicating low rates of net recharge and the predominant occurrence of hypersaline groundwater discharge into the shallow sediments from the underlying Trealla Limestone.

Local groundwater flow is influenced by topography. Within the dune sands, the influence of topography on groundwater flow is more apparent (Figure 5-2) than for the underlying successions. This reflects the occurrence of a lateral flow component from crests to lowlands, driven in part by seasonal recharge.

Local groundwater flow is also influenced by density effects that characterise the flow dynamics of saline and hypersaline groundwater. Groundwater flows in dune sands, Ashburton River Delta alluvium and Trealla Limestone are strongly influenced by vertical upward hydraulic gradients. Environmental groundwater heads indicate mounding beneath the dunes and discharge towards lowlands formed by the supratidal, samphire and tidal flats of the Southwest, Hooley Creek and Ashburton River Mouth Catchments. The vertically upward environmental heads and constructed flow net (Figure 5-3) indicate groundwater discharge from the underlying regional Carnarvon Basin succession into the overlying sediments. This results in the potential for mixing of both (deeper) regional and (shallow) local groundwaters, particularly within the Ashburton River Delta alluvium and dune sands successions. Such mixing would contribute to the accumulation of salt in the groundwater of the shallower successions.

The interpreted hydraulic characteristics of the discrete hydrostratigraphic units are summarised in Table 5-1 and are based on the site investigation data. While the vertical hydraulic conductivity values are approximate only, they indicate the potential for hypersaline groundwater in the Trealla Limestone to discharge into the overlying shallow sediments.

Table 5-1 Interpreted Hydraulic Parameters

Hydrostratigraphic Unit	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Effective Transmissivity (m^2/day)
Dune Sands	4 - 8	4	12 - 24
Ashburton River Delta Alluvium	0.5	0.05	10
Ashburton River Delta Clay and Unconformity	0.3	0.03	2
Trealla Limestone	5.0	5.0	50

The distribution of salinity in the shallow groundwater controls the density-coupled flow dynamics and environmental heads. The TDS distribution in groundwater shows vertical salinity stratification, with Trealla Limestone containing hypersaline groundwater and groundwater salinity progressively reducing in the shallower sediments. The dune sand contains brackish to saline groundwater.

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6

Groundwater Impacts Assessments

6.1 Potential Groundwater Impacts

Construction of the Plant Pad, Shared Infrastructure Corridor and Accommodation Village would alter natural drainage lines, water balance and salt balance. This impact would commence during construction, be local on scale and permanent. The large volumes of fill material being brought into the Project area and the placement methods would alter local landforms and potentially impact the groundwater environment. Changes to the landforms would alter the local catchments, promote increased recharge and subsequently change water table elevations. There is potential to alter groundwater flow directions, hydraulic gradients and groundwater quality.

The potential groundwater impacts may be linked to different aspects and stages of the Project development, such as:

- Construction earthworks – dredge material placement area: The Project considers onshore placement of the dredge material. Seawater pumped ashore with the dredge cuttings may infiltrate to and mound the water table beneath the dredge material placement area. Seawater that infiltrates to the water table would be transported within the groundwater environment. Potential impacts may be linked to:
  - Mounding of the local water table due to the infiltration of seawater within the placement area.
  - Increased salt loadings to the water table. The shallow local groundwater quality may change to reflect the seawater infiltration. The dredge material is assumed to be inert, thus seawater infiltration from the placement area may only influence the local groundwater salinity. The placement area and surrounds host brackish to hypersaline groundwater in shallow water table settings beneath dune, supratidal and tidal settings.
  - Seepage of seawater beneath perimeter bunds, expressing as groundwater discharge on the ground surface on the outside perimeter of the dredge material placement area.
- Presence of the Plant Pad infrastructure – mounding of the water table: The large volumes of fill material imported into the Project area would alter the local landforms and may impose impacts on the groundwater environment. Changes to the landforms, particularly the Plant Pad and dredge material placement area would alter the local catchments, promote increased recharge and subsequently change the water table elevations. There is potential that the changed landforms would promote mounding of the water table and consequent alteration of local groundwater flow directions and hydraulic gradients.
- Operations – spills and leaks. Spills or leaks of contaminants that infiltrate the dune sands beneath the Plant Pad may enter the water table zone and be transmitted by groundwater flow to local terrestrial and marine receptors.

The methodology for the assessment of impacts on the groundwater focuses on the differences between the interpreted baseline groundwater levels and groundwater quality and any altered groundwater environments linked to developments at Ashburton North. The potential impacts are identified and assessed according to the proposed infrastructure (Plant Pad, Shared Infrastructure Corridor and Accommodation Village) of the Project. For the impact assessments, the infrastructure predominantly includes the option of onshore dredge material emplacement as this presents a potential worst-case groundwater impact. In the absence of onshore dredge material emplacement, the Project footprint would be reduced, with commensurate reduction of potential groundwater impacts.

6 Groundwater Impacts Assessments

Potential impacts on groundwater levels have been assessed based on the interpretation of baseline data and simulation of the aspects of the Project that may influence the groundwater environment. Potential impacts on groundwater quality have been assessed based on baseline quality data and application of the ANZECC Guidelines for Fresh and Marine Water Quality (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 6-1.

Further, the potential impacts to the groundwater 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 (LEP) 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 6-1 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 trigger values for salinity and turbidity which should not be exceeded, in order to protect the local groundwater environment and associated ecosystems. These trigger values are provided in Table 6-2.

Table 6-2 Baseline Groundwater Trigger Values

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

6.2 Groundwater Flow Model Development

A groundwater flow model has been developed to simulate the interpreted baseline groundwater environment.

6.2.1 Model Code

MODFLOW-Surfact (Hydrogeologic Inc 1996) is used as the model code for the numerical simulations using Visual MODFLOW 2009.1 as the pre-processor. MODFLOW is a 3D block-centred finite difference code developed by the United States Geological Survey to simulate groundwater flow.

6.2.2 Model Domain and Layering

The model domain covers an area of 52 km^2 and consists of six layers. The coordinates (in GDA 94, zone 50) of the model corners are shown in Table 6-3.

Table 6-3 Model Domain

Easting (mE)	Northing (mN)
287,000	7,595,000
287,000	7,602,500
296,000	7,595,000
296,000	7,602,500

The cell size within the model varies from 50 x 50 m over the Plant Pad to 100 x 100 m close to the model boundaries. The model domain and grid are shown on Figure 6-1; the domain incorporates the Hooley Creek, Southwest and Ashburton River Mouth Catchments.

The numerical model has been developed to be compatible with the conceptual hydrogeological model. The top of the model represents the natural and altered ground surface, interpolated from a 5 m raster dataset. Hydrostratigraphic units are represented in the numerical model as discrete layers (Figure 6-2). The representation of hydrostratigraphic units in the numerical model is based on the stratigraphy interpreted from site investigation data.

All model layers are continuous. Layer 1 hosts the dredge material placement area and associated embankments. Layer 1 and Layer 2 represent the dune sands, with a thickness of 1 to 5 m. The simulated dune sands extend beneath the Hooley Creek, Southwest and Ashburton River Mouth Catchments at a minimum thickness of 1 m. The Ashburton River Delta alluvium ranges in thickness from 15 to 19 m and is represented as layer 3 and 4. Ashburton River Delta clay has a thickness of approximately 6 m and is represented as layer 5. The Trealla Limestone (layer 6) is simulated with a nominal thickness of 7 m, since it was not intended to integrate the full thickness of this limestone into the model. The representation of the hydrostratigraphic units in the numerical model is summarised in Table 6-4 and shown on west-east and south-north cross-sections on Figures 6-3 and 6-4.

Table 6-4 Representation of Hydrogeological Units in the Numerical Model

Hydrogeological Unit	Model Layer
Dredge Material Placement Area, Embankments and Dune Sands	1
Dune Sands and Clay Pans	2
Ashburton River Delta Alluvium	3 and 4
Ashburton River Delta Clay	5
Trealla Limestone	6

6.2.3 Boundary Conditions

No-flow conditions are assigned to the western and eastern model boundaries that approximately are aligned along groundwater flow lines. The seaward boundary of the model is represented as a constant-head condition at mean sea level. Interpreted tidal efficiencies are low and consequently, no tidal fluctuations are simulated. In the Trealla Limestone, layer a general-head boundary condition is assigned to the southern and northern boundaries of the model. A general-head boundary condition allows a flux based on an assigned head and conductance. The conductance parameter represents the resistance to flow between the prescribed head value and the model boundary.

The model also includes recharge to contribute to the water balance and enabling simulation of a representative water table. Groundwater discharge at the land surface is removed from the model domain via evaporation or stream flow.

Since the model domain is located in an area where variable groundwater densities occur, the measured groundwater levels have been transformed into environmental heads and these have been used to define boundary heads.

6 Groundwater Impacts Assessments

6.2.4 Steady-State Calibration

For the steady-state (a flow condition that does not change with time) calibration, the model is calibrated to interpreted July and August 2009 environmental heads. A reasonable calibration result is achieved (Chart 6-1). The overall Root Mean Square (RMS) error of the model calibration is 11 percent, with the monitoring bores in the Trealla Limestone showing the widest variation between simulated and interpreted environmental heads.

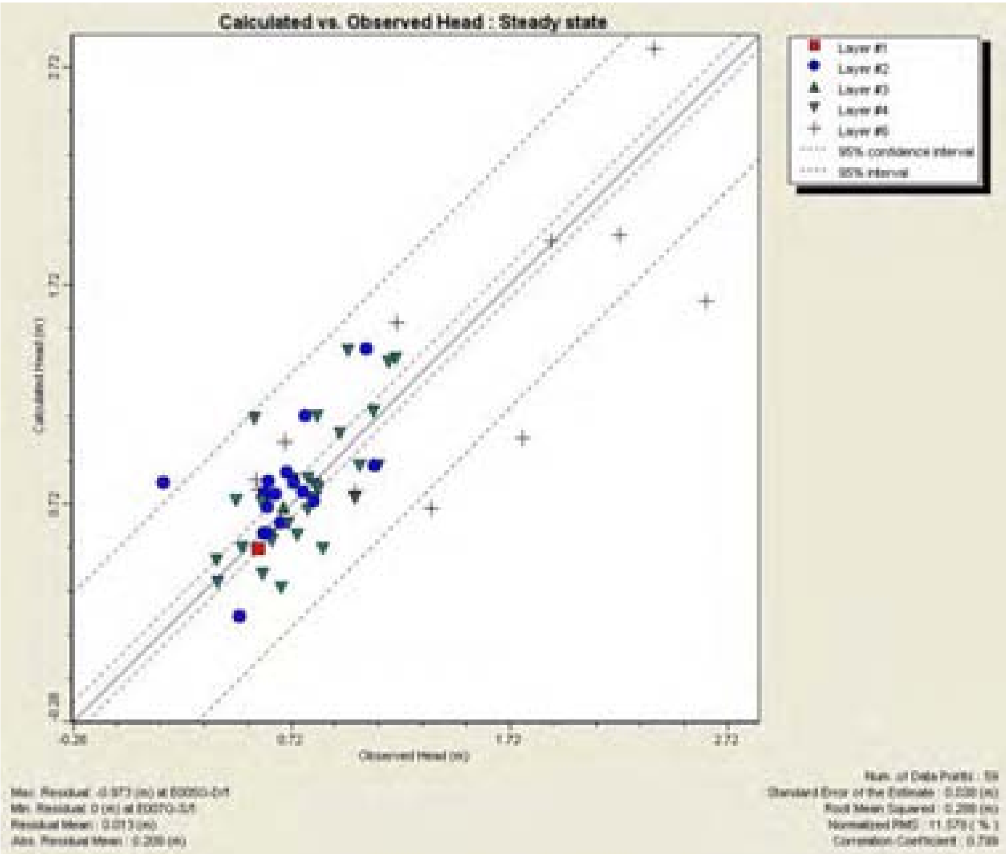

Chart 6-1 Observed and Simulated Environmental Heads

The calibration results indicate the developed groundwater flow model is a broad representation of the local groundwater environments. Figure 6-5 shows the simulated water table, indicating lateral flow from comparatively high water table elevations beneath the dune sands towards the low-lying catchment areas. In the calibrated model, vertical flow gradients (west-east and south-north cross-sections shown on Figures 6-6 and 6-7) between the Trealla Limestone and the Ashburton River Delta alluvium are maintained by applying comparatively low vertical hydraulic conductivities to layer 5; the Ashburton River Delta clay. A comparatively high hydraulic conductivity in the southern half of the Ashburton River Delta alluvium is required to obtain a satisfactory calibration error. The hydraulic parameters derived from the calibrated model are presented in Table 6-5. The calibrated model also hosts recharge of 5 mm/year to enable the simulated water table beneath the dunes to reflect the ground surface topography.

Table 6-5 Calibrated Model Parameterisation

Material Type	Hydraulic Conductivity (m/day)		Storage	
	Horizontal	Vertical	Specific Storage (1/m)	Specific Yield (dimensionless)
Dune Sands	2	0.1	0.0002	0.15
Ashburton River Delta Clay Pan	0.4	0.004	0.0002	0.15
Ashburton River Delta Alluvium (North)	0.4	0.004	0.0002	0.03
Ashburton River Delta Alluvium (South)	2	0.2	0.0002	0.03
Ashburton River Delta Clay	0.2	5×10^{-5}	0.001	0.01
Trealla Limestone	5	0.5	0.00001	0.05

The clay pans in Layer 2 are assigned the same hydraulic properties as the Ashburton River Delta alluvium.

The overall mass balance error of the steady-state calibration is 0.02 percent. The mass balance summary for the model boundaries is shown in Table 6-6.

Table 6-6 Steady-State Model Mass Balance Summary

Model Boundaries	Rate (kL/day)	
	Inflow	Outflow
Recharge	702	0
Surface Ponding (evaporation/stream flow)	0	1,377
Constant Head	406	67
Head Dependent Boundary	337	0
Totals	1,445	1,444

6.3 Predictive Groundwater Model Impacts Assessments

The calibrated groundwater flow model has been adapted to incorporate key elements of the Project infrastructure (predominantly the dredge material placement area). Subsequently the model has been applied to predict the changes to the baseline groundwater environment that would be imposed by the Project.

The modelling predictions and assessments are framed based on the potential impacts imposed by:

- Construction earthworks – dredge material placement area.
- Presence of the Plant Pad infrastructure – mounding of the water table.
- Operations – spills and leaks.

6.3.1 Construction Earthworks – Dredge Material Placement Area

The potential onshore placement of dredge material may involve dredged cuttings being transported hydraulically and disposed through a pipeline into a purpose-built placement area located within western domain of the Plant Pad (Figure 6-1). Typically, the dredging operations will produce seawater slurry with solids to water ratio of about 1:5. The onshore placement of dredge material is characterised as follows:

- Up to 10 Mm^3 dredged material disposed to land in seawater slurry.
- Approximately 50 GL of seawater temporarily disposed to land.

The dredge material placement area would be contained by perimeter embankments, except where the dune terrain provides a natural embankment. Internally, the dredge material placement area would be sub-divided into three cells. Two of these cells are intended to contain dredge material; the third forms a sediment trap and sump (Figure 6-8).The perimeter embankments would be constructed using suitable fill and compacted materials.

Consolidation and dewatering of the disposed dredge material will occur within the placement area. The processes of consolidation and dewatering will occur through the decanting of supernatant seawater, seepage of seawater into the groundwater environment and evaporation. Seawater slurries would drain from the two cells containing disposed dredge material through weir boxes, into the sump.

6 Groundwater Impacts Assessments

The heights of the weir boxes would be variable:

- Enabling retention of sediment fines on the upstream side.
- Limiting the depth of upstream water ponds against the embankments.
- Limiting the sediment ingress into the sump.

Within the sump, there would be storage and retention of decanted seawater which allows settlement of sediment fines prior to disposal. Seawater disposal to an ocean outfall in front of the Plant Pad is proposed during the dredging campaign. Subsequently, seawater disposal and runoff would be initially intercepted by the sump, then released into the Southwest Catchment through a weir box in the external embankment (Figure 6-8). The sump and weir box would enable retention and settling of sediment fines, thus limiting release their release into the catchment.

To simulate the dredge material placement, layer 1 of the groundwater flow model has been adapted to represent the facility embankments, depositional cells and sump as shown on Figure 6-8. Subsequently, concepts and schedules for the placement of dredge materials have been developed and applied to the model. These model, concepts and schedules host several assumptions, including:

- The perimeter and internal embankments are formed of inert dry fill, emplaced and compacted to peak elevations of about 6.5 m AHD.
- Embankments are characterised by lateral and vertical hydraulic conductivity of 0.2 m/day.
- The embankments do not host geotextile fabrics or liners.
- The base of the dredge material placement area is the natural ground surface, typically at an elevation of about 1.5 m AHD.
- Peak dredge material beach elevation is 6.0 m AHD, thus providing a typical 4.5 m height for dredge material placement.
- Emplaced dredge material slurries would form a backfill profile with beach angles of about one percent.
- Emplaced dredge material may not be trafficable for several months after deposition.
- Dredge material deposition occurs over a period of about 18 months.
- Dredge material placement would occur at a typical rate of 0.56 Mm^3/month.
- The deposition of the dredge material conceptually occurs sequentially, in three stages:
  - Stage 1: Given the assumed heights of dredge material placement and beach angles, the initial emplacement stage would form a wedge with crest height of 4.5 m and toe of the beach about 450 m from the crest. The unit cross-section volume of the initial beach is about 1,000 m^3/linear metre. The rate of beach advance would be 550 m/month. The Stage 1 beaches would have crests on the perimeter of the facility embankments.
  - Stage 2: Return beaches that on-lap the Stage 1 emplaced dredge materials, thus with the same crest elevations but shorter beach lengths. The unit cross-section volume of the initial beach is about 500 m^3/linear metre and the rate of beach advance would be 1,100 m/month.
  - Stage 3: Final pass, capping Stage 1 and Stage 2 emplaced dredge materials to an elevation of 6.0 m AHD. The unit cross-section volume of the initial beach is about 515 m^3/linear metre and the rate of beach advance would be 1,080 m/month.
- The stages deposition sequences have been applied to the design depositional cells (Figure 6-8) to formulate depositional schedules. The conceptual depositional schedules are shown on Figure 6-9 (a to c).
- The dredge material has an isotropic hydraulic conductivity of 1 m/day.

- The dredge material has a specific yield of 0.15 (dimensionless).
- The sump hosted within the southern dredge material placement area is pumped, at least during the dredging campaign, with simulated water levels maintained at 1.5 m AHD.

Once adapted, the groundwater model has been applied to predict the impacts of the dredge material placement area on the local groundwater environment. The initial groundwater levels at the commencement of dredge material placement are those obtained from the steady-state groundwater flow model. In the predictive simulations, the period of the dredge campaign is 485 days, about 16 months. Results of the predictive simulations during the dredge campaign and subsequently are outlined below in context with:

- Mounding of the water table.
- Increased salt loadings to the water table.
- Seepage of seawater.

Mounding of the Water Table

Mounding of the water table is predicted to occur due to the infiltration of seawater from the dredge material placement area. The predictive simulations show the occurrence of mounding of the water table due to loadings from and infiltration of seawater within the dredge material placement area. This initially occurs as vertical infiltration, with saturation of the available storage in the dredge material, dune sands and Ashburton River Delta alluvium. Subsequently there is both vertical and lateral flow within the dune sands and Ashburton River Delta alluvium beneath the placement areas embankment perimeters.

Outputs from the predictive model have been interrogated to provide snapshots of changes to the local groundwater environment at times 100, 301 and 485 days after commencement of dredge material placement. Each snapshot is represented on Figure 6-10 (a to d), Figure 6-11 (a to d) and Figure 6-12 (a to d), illustrating:

- Predicted water table elevations.
- Magnitude of the water table mound above baseline elevations.
- West-East Cross-Section Flow Net.
- South-North Cross-Section Flow Net.

The predictive simulations show:

- The simulated water table is locally mounded beneath the dredge material placement area in the short-term after commencement of dredge material placement.
- The simulated maximum mound elevation is about 6.0 m AHD, compatible with the top elevation of the emplaced dredge material.
- The mounding of the water table is predominantly constrained to the vicinity of the dredge material placement area, embankments and adjacent dune terrain.
- The mounding preferentially occurs in the dune sands, a reflection of the available storage above the baseline water table and effective transmissivity of the saturated profiles.
- The mounded water table radiates from the dredge material placement area.
- Outside of the dredge material placement area, residual heads typically occur up to 0.5 m above the baseline water table elevation.
- The mounding of the water table leads to subtle changes in groundwater flow directions and zones of discharge.

6 Groundwater Impacts Assessments

Increased Salt Loadings to the Water Table

The baseline salinity of the shallow groundwater beneath the placement area is saline to hypersaline, being typically:

- 50,000 to 150,000 mg/L TDS in the Ashburton River Delta alluvium.
- 20,000 to 120,000 mg/L TDS in the dune sands.

Successions of Ashburton River Delta alluvium predominantly underlie the dredge material placement area.

The mounded water table in the immediate vicinity of the dredge material placement area is likely to predominantly initially host seawater. The salinity of seawater is about 33,000 mg/L TDS. Thus the expectation is that the initial infiltration from the dredge material placement area may typically be of lower salinity than that of the baseline groundwater environment. Over time, however, depending on the concentration effects of evaporation, rates of consolidation of the emplaced dredge material rates of rainfall infiltration, the salinity of infiltrates may change and be variable. It is anticipated that the consolidated dredge material may contain about 40,000 tonnes of salt residual after dewatering and evaporation of available pore water in the dredge material. The salt in storage above the water table may eventually be dissolved and mobilised by rainfall infiltration, enter the water table and be transmitted within the local groundwater environment. Dissolved salts in the infiltrating rain would mix with the local groundwater. The mixing with the groundwater and ultimate flow paths would be controlled by the salinity (density) of the infiltrates compared with those of the shallow groundwater.

The infiltration of seawater from the dredge material placement area may alter the local salinity profiles within the shallow water table zones of the dune sands and Ashburton River Delta alluvium. Potential impacts on salt loadings to and salinity concentration of the shallow groundwater from the infiltration of seawater and salt would be reduced by enabling rapid consolidation and dewatering of the emplaced dredge material. The rapid lowering of the mounded water table within the dredge material placement area would reduce the concentration effects of evaporation, thus reducing both the potential salt loadings and concentrations of infiltrates.

Seepage of Seawater

During and after the cessation of the dredge material disposal, the mounding of the water table progressively decays. The decay occurs in response to dewatering and consolidation of the disposed dredge material and associated seawater losses to vertical and radial groundwater flow and evaporation. The vertical and lateral groundwater flows from the dredge material placement area manifest as seepage on the perimeter of and through the facility embankments. The seepage expresses at the water table and on the ground surface outside of the dredge material placement area.

6 Groundwater Impacts Assessments

The groundwater flow model has been used to predict the locations and rates of seepage from the dredge material placement area. The seepage fronts are closely linked with the areas of mounded water tables and vary over time as the mounded water tables decay. The predicted locations and rates of seepage have been interpreted using:

- Simulated synthetic monitoring bores located on the outside perimeter of the dredge material placement area (Figure 6-13) and associated hydrographs (Figure 6-14 (a to g). The predictive hydrographs illustrate the ground elevation and transient magnitude of the mounded water table at the selected sites on the perimeter of the dredge material placement area embankments.
- Water budget zones that quantify lateral and vertical groundwater flow both in and out of selected domains within the groundwater flow model. Plan and cross-section views of the water budget zones used to quantify seepage locations and rates are shown on Figure 6-15 and Figure 6-16. Findings from the predicted water budgets have been consolidated to show:
  - Seepage from the dredge material placement area embankments (Figure 6-17).
  - Seepage through the base of the dredge material placement area (Figure 6-18).
  - Seepage to the water table on the outside perimeter of the dredge material placement area embankments (Figure 6-19, a and b).
- Changes in groundwater intercepted by evaporation in the model due to the mounded water table propagating to the ground surface. These changes predict the visible seepage zones in perimeter area of the dredge material placement area at different times. Snapshots of the predicted seepage zones at times of 100, 301 and 485 days and five, ten and 50 years after commencement of the dredge material emplacement are shown on Figure 6-20 (a to f).

The predictive simulations show total seepage from the dredge material placement area peaks at a rate of about 2,200 kL/day (Figure 6-19a). Contributions to the total seepage (Table 6-7 and Table 6-8) include a peak of about 200 kL/day through the facility embankments and up to about 1,900 kL/day that propagates through the base of the facility, predominantly into the Ashburton River Delta alluvium and to a lesser extent into the dune sands and manifests as seepage on the embankment perimeters. A variable portion of the seepage is also manifest as changes (increases) in storage beneath the mounded water table and increased groundwater through-flow in the water table zone and at depth linked to higher local hydraulic gradients. The seepage through the base of the facility predominantly manifests as surface expressions of the water table within the South and West water budget zones shown on Figure 6-15. In these areas, the water table expresses on the ground surface due to seepage from the dredge material placement area. 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.

6 Groundwater Impacts Assessments

Table 6-7 Predicted Transient Total Seawater Seepage

Time	Simulated Seawater Seepage (kL/day)		
	Water Budget Zone		
	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 predicted seepage would be manifest as visible groundwater discharge where the rising water table intersects ground surface. Seepage discharge from the dredge material placement area is predicted to predominantly occur on the perimeter of the southern embankment. Substantially smaller scale seepage discharges occur on the perimeter of the western and natural dune sands embankments. 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 perimeter toe of the dune sands that form a natural embankment for the dredge material placement area) the predicted seepage footprint (Figure 6-20, a to f) 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.

6 Groundwater Impacts Assessments

The simulated seepage rates are sufficiently low that they may be intercepted by evaporation and not express as significant surface water flows on the ground surface. Notwithstanding, the excavation of perimeter drains and provision for interception and collection of the seepage before it discharges beyond the Southwest Catchment would be appropriate.

Table 6-8 Predicted Distribution of Seawater Seepage

Time	Simulated Seawater Seepage (kL/day)									
	Water Budget Zone									
	Embankments					Outside Perimeter of Embankments				
	South	West	North West Dune	North	East	South	West	North West Dune	North	East
30	2	-	-	6	8	165	8	17	52	47
60	2	-	-	6	16	173	8	17	41	88
101	6	-	-	6	27	307	8	17	32	137
209	3	-	-	6	17	273	8	43	57	122
301	8	20	4	4	12	391	114	77	65	121
398	23	12	22	13	53	771	82	192	94	257
485	44	44	29	9	39	1,017	217	190	66	206
666	9	20	24	5	25	509	129	177	42	171
786	6	14	23	4	20	430	111	175	33	155
1,031	4	11	5	3	13	353	37	94	21	124
5 years	2	2	2	1	4	254	4	52	7	65
10 years	29	1	1	-	1	214	1	26	3	31
50 years	2	1	-	-	-	188	2	4	-	9

6.3.2 Seepage Prediction Uncertainties

The groundwater flow model hosts several assumptions that may influence the predictive outcomes, particularly in the context of seepage rates. Therefore, several sensitivity simulations have been completed to quantify the uncertainty in the predicted seepage rates.

The potential occurrence of seepage is linked to several factors including:

- Perimeter embankment designs and characteristics, particularly related to water retention and throughflow characteristics.
- Approach to dredge cuttings deposition, with beach-head locations and beach angles.
- Effective hydraulic conductivity of the emplaced dredge materials.
- Effective vertical hydraulic conductivity transmissivity of the dune sands and Ashburton River Delta alluvium beneath the placement area.

- Effective transmissivity of the dune sands and Ashburton River Delta alluvium in areas adjoining the dredge material placement area.
- Rates and extinction depth of evaporation from the beached dredge material.
- Lengths of flow paths from recharge sources to discharge zones.

Table 6-9 outlines the selected sensitivity parameters applied to the seepage simulations. Summarised results of the sensitivity simulations are shown in Table 6-10. The findings of the sensitivity analyses show a limited range of seepage rates.

Table 6-9 Sensitivity Parameters

Model Parameter	Parameterisation	
	Base Case	Sensitivity Case
Dune Sands Lateral Hydraulic Conductivity (m/day)	2	4
Embankment Lateral Hydraulic Conductivity (m/day)	0.2	2
Ashburton River Delta Alluvium Lateral Hydraulic Conductivity (m/day)	0.4	2
Clay Pan Lateral Hydraulic Conductivity (m/day)	0.4	2

Table 6-10 Comparative Peak Seepage Rate Predictions

Simulated Peak Seawater Seepage (kL/day)											
Water Budget Zone											
Embankments						Outside Perimeter of Embankments					
South	West	North West Dune	North	East	Total	South	West	North West Dune	North	East	Total
Base Case											
111	154	77	29	55	426	1,107	217	192	94	257	1,895
Dune Sands Lateral Hydraulic Conductivity 4 m/day											
111	154	77	29	55	426	1,015	259	311	150	311	1,840
Embankment Lateral Hydraulic Conductivity 2 m/day											
363	570	287	29	202	1,451	1,002	212	199	106	298	1,642
Ashburton River Delta Alluvium and Clay Pan Lateral Hydraulic Conductivity 2 m/day											
111	154	77	29	55	426	522	292	278	106	710	1,557

6.3.3 Presence of the Plant Pad Infrastructure

Construction of the Plant Pad, including the dredge material placement area, would alter the natural drainage lines and water balance. Mounding of the water table is predicted to initially occur due to the dredge material placement area. This occurrence may mask initial mounding linked to the presence of the Plant Pad. Potential changes to the water table due to presence of the Plant Pad and associated altered landforms include:

- Raised landforms promoting increased recharge and consequent localised mounding of the water table.
- Changes in local hydraulic gradients and groundwater flow directions.

The water table mound elevation is expected to be highest at the end of the dredge material disposal campaign and thereafter progressively decay.

The groundwater flow model has been applied to simulate the long-term revised water balance linked to the presence of the Plant Pad infrastructure inclusive of the dredge material placement area. Predictive simulations provide longer-term snapshots of the water table elevation and mounding at times five, ten and 50 years after commencement of the dredge material placement. The predictive snapshots of water table elevations and mounding are shown on Figure 21 (a to c) and Figure 22(a to c). Ultimately, a comparatively small-scale residual steady-state water table mound is predicted to occur beneath the dredge material placement area. After 50 years, the water table is predicted to have decayed to a steady-state with subtle (about 0.5 to 1.0 m height) local mounding above the baseline water table elevations.

In the absence of the onshore dredge material placement area, a comparatively small water table mound (less that 0.5 m height) may develop beneath the Plant Pad. This mound would tend to conform to the topography of the elevated platform of the Plant Pad and closely mimic the baseline groundwater flow directions.

6.3.4 Operational Spills and Leaks

Leaks and spills may occur during the construction, commissioning, operations and decommissioning phases of the Project. 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. The interception of leaks and spills is addressed in the spill containment design for the Plant Pad.

Infiltration of hydrocarbons and other contaminants into the groundwater environment would have an adverse impact on local groundwater quality beneath the Plant Pad. Where contaminants enter the groundwater environment, subsequent transport to local groundwater discharge zones (both in terrestrial and marine settings) may occur. Contaminants from leaks and spills may enter the groundwater environment via:

- Infiltration of runoff hosting contaminants.
- Direct infiltration of contaminants to the water table during and after rainfall events.

The fate of contaminants that enter the water table will be dependent on the location of the source and local mounded configuration of the water table beneath the Plant Pad. Predicted water table elevations are shown on Figure 22 (a to c). Groundwater flow directions from beneath the Plant Pad are predominantly to the north and northeast, into the ocean and Hooley Creek West. Should onshore emplacement of dredge material occur, mounding of the water table in proximity to the dredge material placement area constrains flow to the Southwest Catchment. In the absence of the dredge material placement area, the constraints to groundwater flow and discharge within the Southwest Catchment would not occur.

Transit times for contaminants in the groundwater environment would be comparatively slow, typically limited to tens of metres per year. Consequently, there would be time to intercept contaminants before the local groundwater enters discharge zones.

7

Conclusions

7.1 Baseline Groundwater Environment

7.1.1 Hydrostratigraphy and Hydraulic Parameters

The hydrostratigraphy and hydraulic parameters of the groundwater flow systems at Ashburton North have been determined by interpreting data collected during site investigations during 2009, which comprised drilling, testing and sampling 69 groundwater monitoring bores and 28 drive point piezometers.

The interpreted hydrostratigraphy and associated hydraulic parameters (Table 7-1) are based on the local geological profiles intersected during the site investigations, which comprise:

- Dune Sands (typical thickness 3 m; transmissivity 10 to 30 m2/day).
- Ashburton River Delta Alluvium (typical thickness 20 m: transmissivity about 10 m2/day).
- Ashburton River Delta Clay and Unconformity ((typical thickness 5 m; transmissivity 2 m2/day).
- Trealla Limestone (typical thickness 10 m; transmissivity 50 m2/day).

Table 7-1 Summary of Hydrostratigraphy and Hydraulic Parameters

Hydrostratigraphic Unit	Aquifer Description		Effective Transmissivity (m^2/day)
	Broad Lithology	Thickness (m)	
Quaternary/Recent Superficial Formations			
Dune Sands	Sands and Sandstones	3	12 - 24
Ashburton River Delta Alluvium	Silty and Sandy Clays, interbedded sand and clay	20	10
Ashburton River Delta Clay and Unconformity	Clay and Claystone	5	2
Tertiary Successions - Carnarvon Basin			
Trealla Limestone	Limestone	30	50

7.1.2 Groundwater Levels and Flow

The water table elevation in the area is closely linked to topography, and groundwater flow directions are therefore a reflection of the surface water catchments. The highest water table elevation occurs beneath the dunes, with groundwater flow perpendicular to the dune crests towards the lowlands of the adjoining catchments. On the seaward side of the beach dunes, groundwater flows northwards, directly into the sea. In the deeper sections of the Ashburton River Delta alluvium and Trealla Limestone, the influence of the local topography remains evident but is increasingly masked by regional groundwater flow and density effects.

The local groundwater environment is predominantly independent of and isolated from tidal influences; however, groundwater levels in the confined aquifer formed by the Trealla Limestone are responsive to changes in barometric pressure.

7 Conclusions

Ashburton North is predominantly a groundwater discharge zone associated with the regional Carnarvon Basin successions. All shallow soils and sediments intercepted during the site investigations are interpreted to be accumulating salt, thus indicating low rates of net recharge and the predominant occurrence of groundwater discharge.

Because of the saline to hypersaline groundwater in the area, measured groundwater levels need to be converted to environmental heads in order to compensate for vertical density stratification caused by differences in groundwater salinity. The interpreted environmental heads confirm that groundwater levels are sub-parallel to topography, with higher groundwater elevations (mounds) beneath the dunes, and vertically upward groundwater flow from the Trealla Limestone into the overlying sediments.

High groundwater salinities and densities, combined with the vertically upward hydraulic gradients, appear to locally limit seawater intrusion into the shallow water table zones. Presumably, the seawater/groundwater interface occurs further offshore.

7.1.3 Groundwater Quality

Groundwater analyses indicate that the local groundwater is brackish to hypersaline, near neutral to slightly alkaline and a sodium-chloride type. The distribution of TDS in the groundwater shows a vertical salinity stratification, with the Trealla Limestone containing hypersaline (156,000 to 200,000 mg/L TDS) groundwater and salinity gradually reducing upwards (50,000 to 150,000 mg/L in the Ashburton River Delta alluvium; 20,000 to 120,000 mg/L in the dune sands) in the shallow hydrostratigraphic units.

Dissolved metals also occur in groundwater from most monitoring bores, with chromium, copper, nickel and zinc detected at the highest concentrations. In many of the monitoring bores, dissolved metal concentrations in the groundwater are above the marine ANZECC Guidelines. The comparatively high dissolved metals concentrations are commensurate with the accumulation of salt in the local groundwater environment and the high groundwater salinity.

7.2 Groundwater Impacts Assessment

Construction of the Plant Pad, Shared Infrastructure Corridor and Accommodation Village would alter the local catchments, promote increased recharge and subsequently change water table elevations. There is potential to alter groundwater flow directions, hydraulic gradients and groundwater quality.

The potential groundwater impacts may be linked to different aspects and stages of the Project development, including:

- Construction earthworks – dredge material placement area.
- Presence of the Plant Pad infrastructure – mounding of the water table.
- Operations – spills and leaks.

The methodology for the assessment of impacts on the groundwater focuses on the differences between the interpreted baseline groundwater levels and groundwater quality and any altered groundwater environments linked to developments at Ashburton North. For the impact assessments, the infrastructure predominantly includes the option of onshore dredge material emplacement as this presents a potential worst-case groundwater impact.

7 Conclusions

Potential impacts on groundwater levels have been assessed based on the interpretation of baseline data and simulation of the aspects of the Project that may influence the groundwater environment. A groundwater flow model has been developed, calibrated to the baseline water table and subsequently adapted to incorporate key elements of the Project infrastructure (predominantly the dredge material placement area). Subsequently, the model has been applied to predict the changes to the baseline groundwater environment that would be imposed by the Project.

7.2.1 Construction Earthworks – Dredge Material Placement Area

The potential dredge material placement area would be contained by perimeter embankments, except where the dune terrain provides a natural embankment. Up to 10 Mm^3 dredged material and 50 GL of seawater may be hosted within the dredge material placement area. The perimeter embankments would be constructed using suitable fill and compacted materials. Notwithstanding, the dredge material placement area is predicted to impose changes on the baseline groundwater environment, including:

- Mounding of the water table.
- Increased salt loadings to the water table.
- Seepage of seawater.

Mounding of the Water Table

The predictive simulations show the occurrence of mounding of the water table due to loadings from and infiltration of seawater. Initial mounding occurs from vertical infiltration, with saturation of the available storage in the dredge material, dune sands and Ashburton River Delta alluvium beneath the dredge material placement area. Subsequently there is both vertical and lateral flow within the dune sands and Ashburton River Delta alluvium beneath the placement areas embankment perimeters.

The predictive simulations show:

- The simulated water table is locally mounded beneath the dredge material placement area in the short-term after commencement of dredge material placement.
- The simulated maximum mound elevation is about 6.0 m AHD, compatible with the top elevation of the emplaced dredge material.
- The mounding of the water table is predominantly constrained to the vicinity of the dredge material placement area, embankments and adjacent dune terrain.
- The mounding preferentially occurs in the dune sands, a reflection of the available storage above the baseline water table and effective transmissivity of the saturated profiles.
- The mounded water table radiates from the dredge material placement area.
- Outside of the dredge material placement area, residual heads typically occur up to 0.5 m above the baseline water table elevation.
- The mounding of the water table leads to subtle changes in groundwater flow directions and zones of discharge.

7 Conclusions

Increased Salt Loadings to the Water Table

The mounded water table in the immediate vicinity of the dredge material placement area is likely to predominantly initially host seawater. The salinity of seawater is about 33,000 mg/L TDS. The baseline salinity of the shallow groundwater beneath the placement area is saline to hypersaline, ranging from 20,000 to 150,000 mg/L. As such, it is estimated that the initial infiltration from the dredge material placement area may typically be of lower salinity than that of the baseline groundwater environment. Over time, however, depending on the concentration effects of evaporation, rates of consolidation of the emplaced dredge material and rates of rainfall infiltration, the salinity of infiltrates may change and be variable as the salt in storage above the water table is dissolved and mobilised by rainfall infiltration.

Seepage of Seawater

The vertical and lateral groundwater flows from the dredge material placement area manifest as seepage through and on the perimeter of the facility embankments. The seepage expresses at the water table and on the ground surface outside of the dredge material placement area. The predictive simulations show total seepage from the dredge material placement area peaks at a rate of about 2,200 kL/day, with contributions including:

- About 200 kL/day through the facility embankments (Table 7-2).
- Up to about 1,900 kL/day that propagates through the base of the facility, predominantly into the Ashburton River Delta alluvium and to a lesser extent into the dune sands and manifests as seepage on the embankment perimeters (Table 7-2).
- A variable portion of the seepage manifest as changes (increases) in storage beneath the mounded water table and increased groundwater through-flow in the water table zone and at depth linked to higher local hydraulic gradients.

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 7-2 Simulated Peak Seawater Seepage

Simulated Peak Seawater Seepage (kL/day)											
Water Budget Zone											
Embankments						Outside Perimeter of Embankments					
South	West	North West Dune	North	East	Total	South	West	North West Dune	North	East	Total
44	44	29	13	53	163	1,107	217	192	94	257	1,895

7 Conclusions

The predicted seepage would be manifest as visible groundwater discharge where the rising water table intersects ground surface. Seepage discharge is predicted to predominantly occur on the perimeter of the southern embankment. Substantially smaller scale seepage discharges occur on the perimeter of the western and natural dune sands embankments. 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 perimeter toe of the dune sands that form a natural embankment for the dredge material placement area) the predicted seepage footprint (Figure 6-20) 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.

7.2.2 Presence of the Plant Pad Infrastructure

Predictive simulations provide snapshots of the water table elevation and mounding at times five, ten and 50 years after commencement of the dredge material placement. Mounding of the water table is predicted to initially occur due to the dredge material placement area. Ultimately, a comparatively small-scale (about 0.5 to 1.0 m height) local residual steady-state water table mound is predicted to occur beneath the dredge material placement area. This residual mound is likely due to the lengthy and radial flow paths for seawater contained within the dredge material placement area.

In the absence of the onshore dredge material placement area, a comparatively small water table mound (less that 0.5 m height) may develop beneath the Plant Pad.

7.2.3 Operational Spills and Leaks

The interception of leaks and spills is addressed in the spill containment design for the Plant Pad. Notwithstanding, contaminants from leaks and spills may enter the groundwater environment via:

- Infiltration of runoff hosting contaminants.
- Direct infiltration of contaminants to the water table during and after rainfall events.

The fate of contaminants that enter the water table will be dependent on the location of the source and local mounded configuration of the water table beneath the Plant Pad Groundwater flow directions from beneath the Plant Pad are predominantly to the north and northeast, into the ocean and Hooley Creek West. Transit times for contaminants in the groundwater environment would be comparatively slow, typically limited to tens of metres per year. Consequently, there would be time to intercept contaminants before the local groundwater enters discharge zones.

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8

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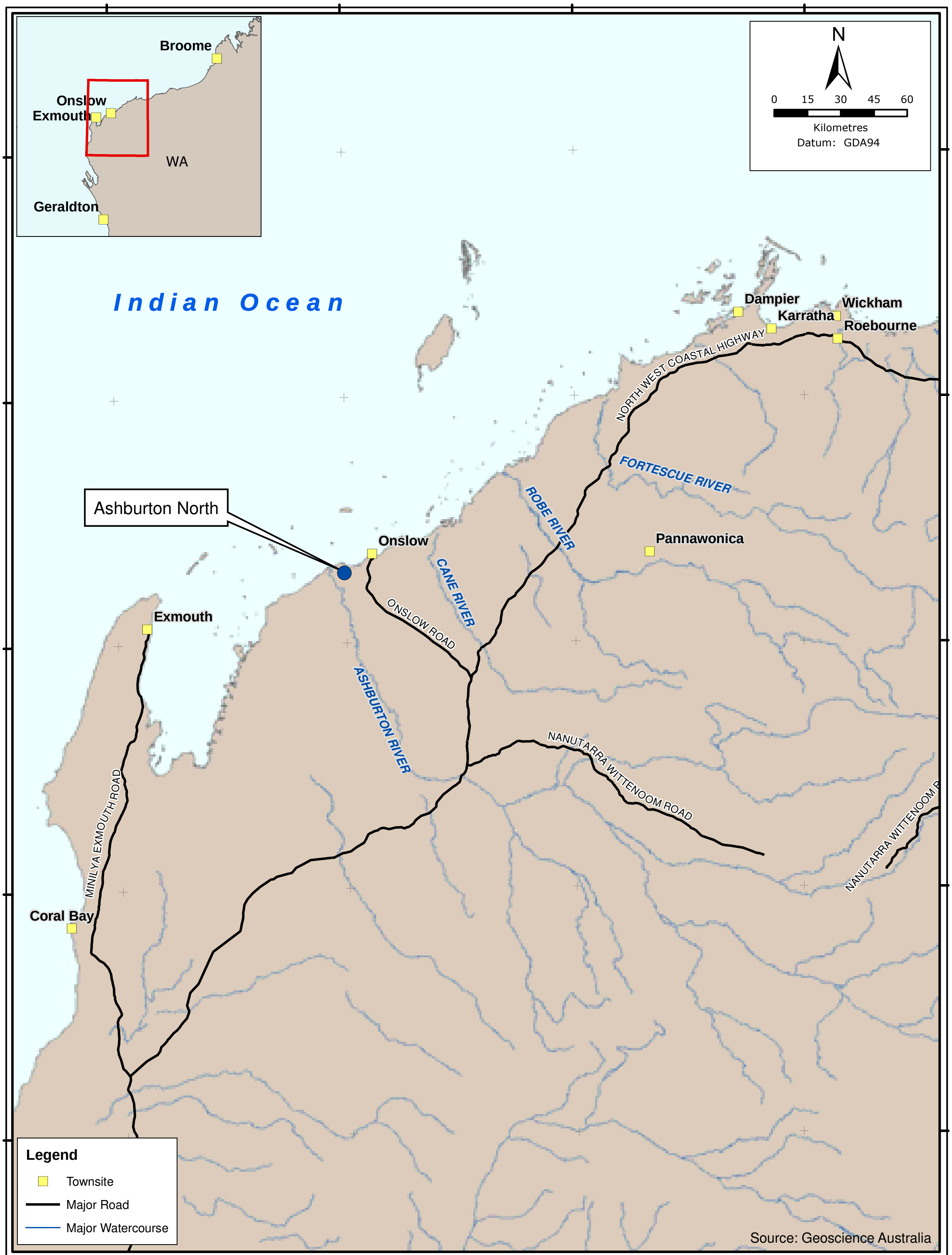

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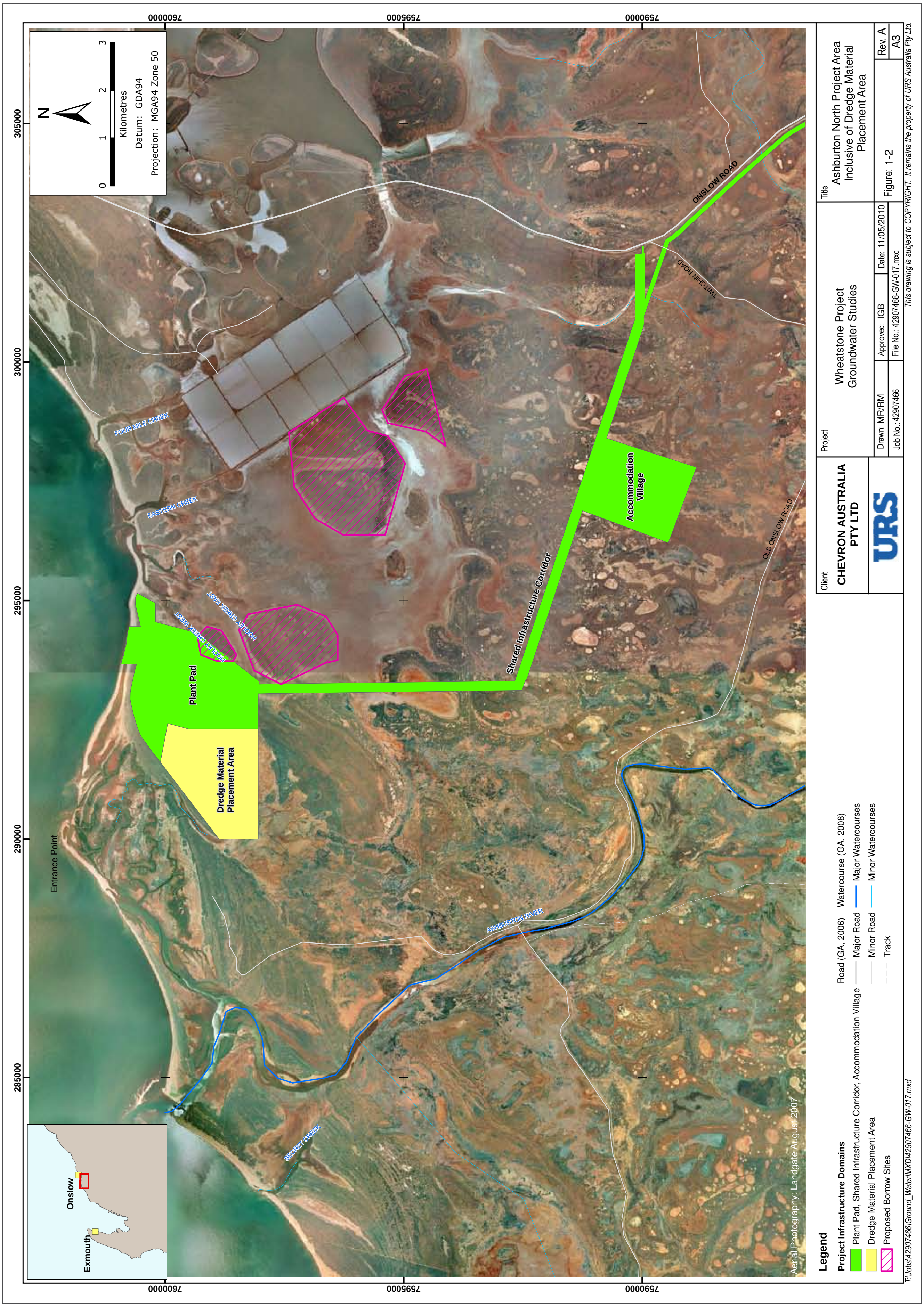
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EASTERN CREEK
HOOLEY CREEK EAST
HOOLEY CREEK WEST
ONSLOW ROAD
TWITCHIN ROAD
OLD ONSLOW ROAD
ASHBURTON RIVER
SECRET CREEK
Plant Pad
Dredge Material Placement Area
Shared Infrastructure Corridor
Accommodation Village
Onslow
Exmouth
Aerial Photography: Landgate August 2007
Legend
Project Infrastructure Domains
Plant Pad, Shared Infrastructure Corridor, Accommodation Village
Dredge Material Placement Area
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 Groundwater Studies
Title
Ashburton North Project Area Inclusive of Dredge Material Placement Area
Drawn: MR/RM
Approved: IGB
Date: 11/05/2010
Rev. A
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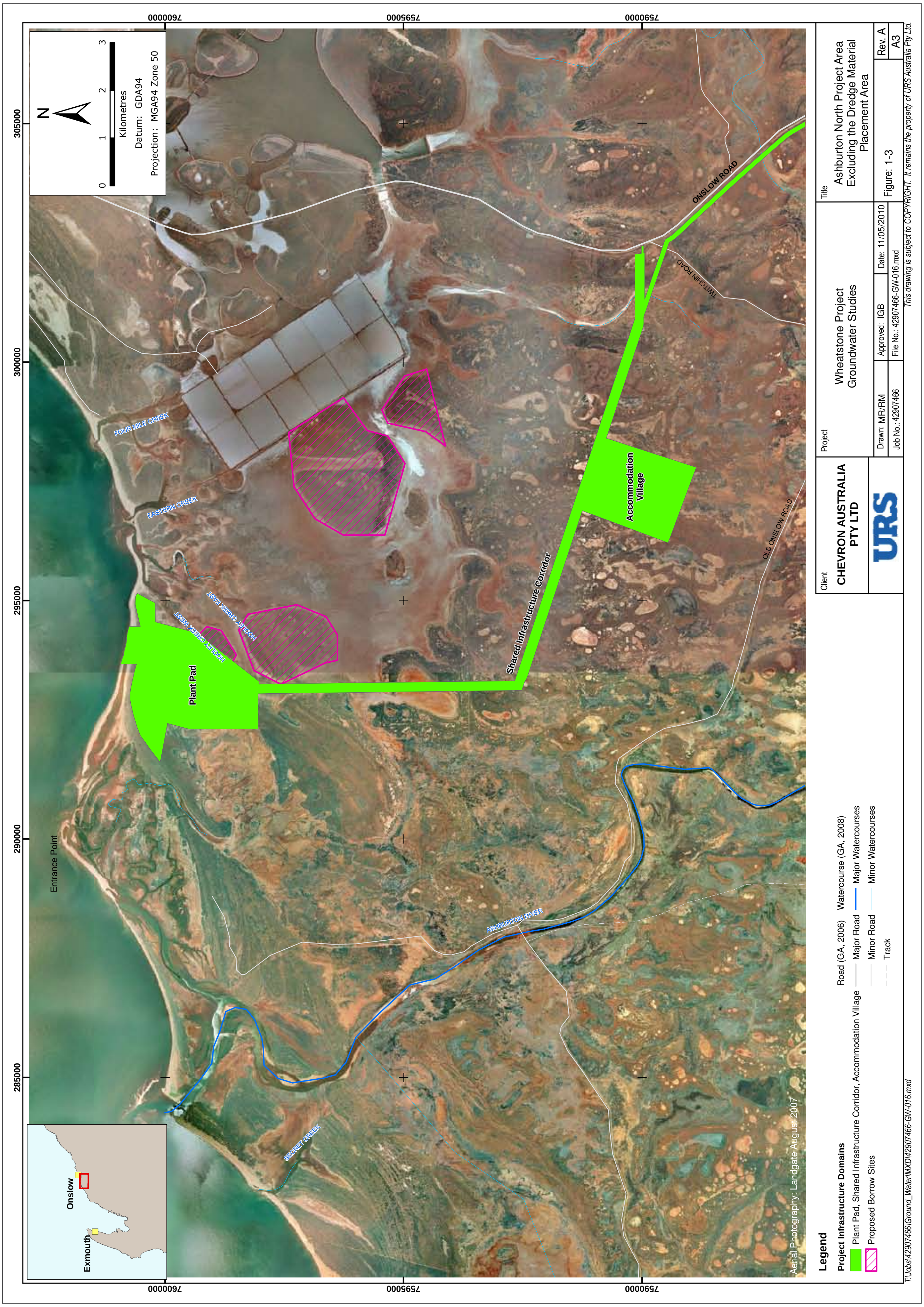

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Onslow
Exmouth
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EASTERN CREEK
HOOLEY CREEK EAST
HOOLEY CREEK WEST
ASHBURTON RIVER
SECRET CREEK
ONSLOW ROAD
TWITCHIN ROAD
OLD ONSLOW ROAD
Plant Pad
Shared Infrastructure Corridor
Accommodation Village
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
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Wheatstone Project Groundwater Studies
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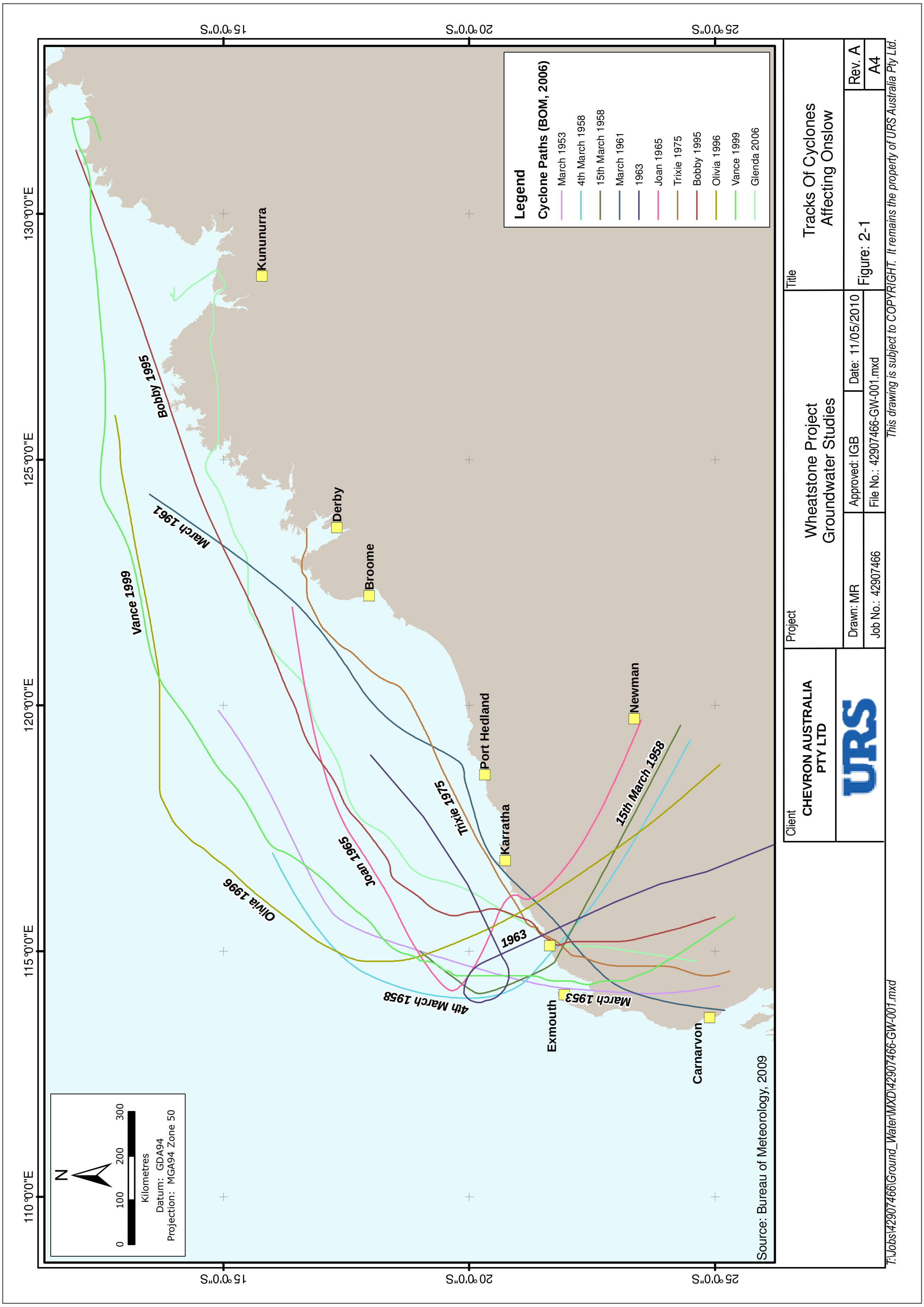
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4th March 1958
15th March 1958
March 1961
1963
Joan 1965
Trixie 1975
Bobby 1995
Olivia 1996
Vance 1999
Glenda 2006
Kununurra
Derby
Broome
Port Hedland
Karratha
Newman
Exmouth
Carnarvon
Bobby 1995
March 1961
Vance 1999
Olivia 1996
Joan 1965
Trixie 1975
1963
4th March 1958
March 1953
15th March 1958
15°0'0"S
20°0'0"S
25°0'0"S
110°0'0"E
115°0'0"E
120°0'0"E
125°0'0"E
130°0'0"E
N
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100
200
300
Kilometres
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Source: Bureau of Meteorology, 2009
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URS
Project
Wheatstone Project Groundwater Studies
Title
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Approved: IGB
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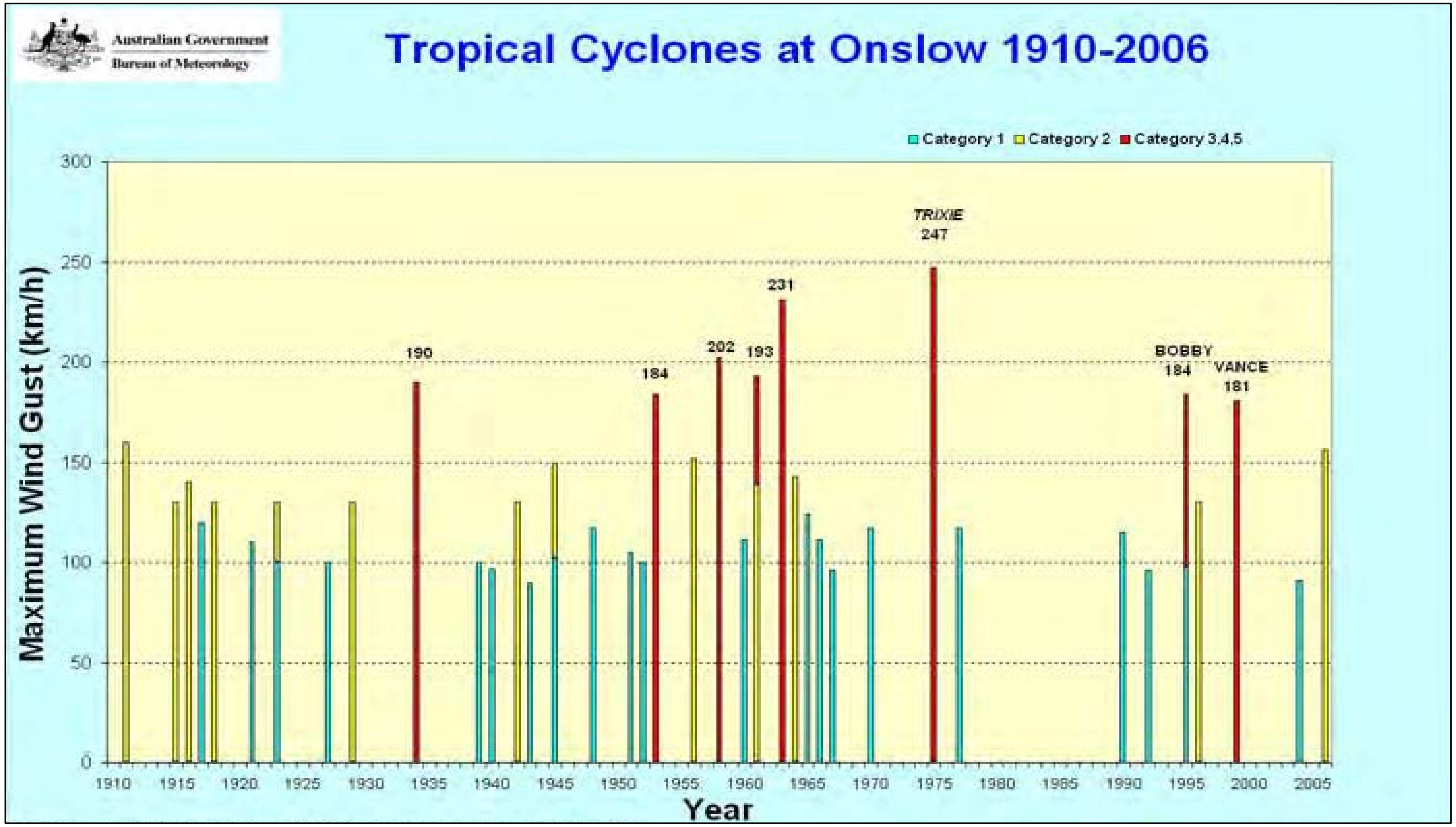

Note: Category relates to the impact at the town not to the intensity of the cyclone.
Wind instrumentation and official sites have changed over the years.
The accuracy of wind gust values early in the record are usually less reliable than those in more recent times.

Source: Bureau of Meteorology Website, 2009.

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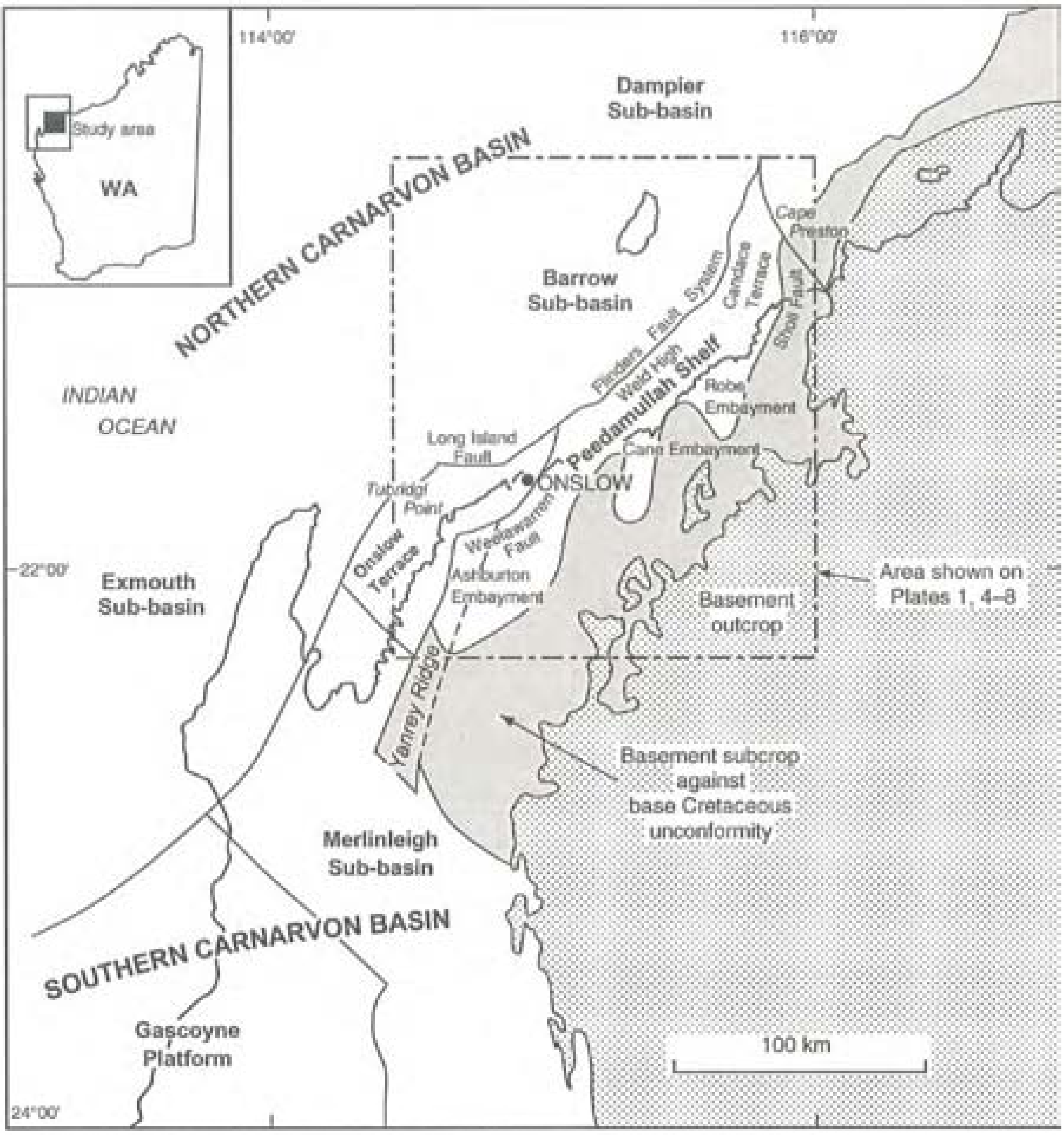

Source: Geological Survey of Western Australia, 2000

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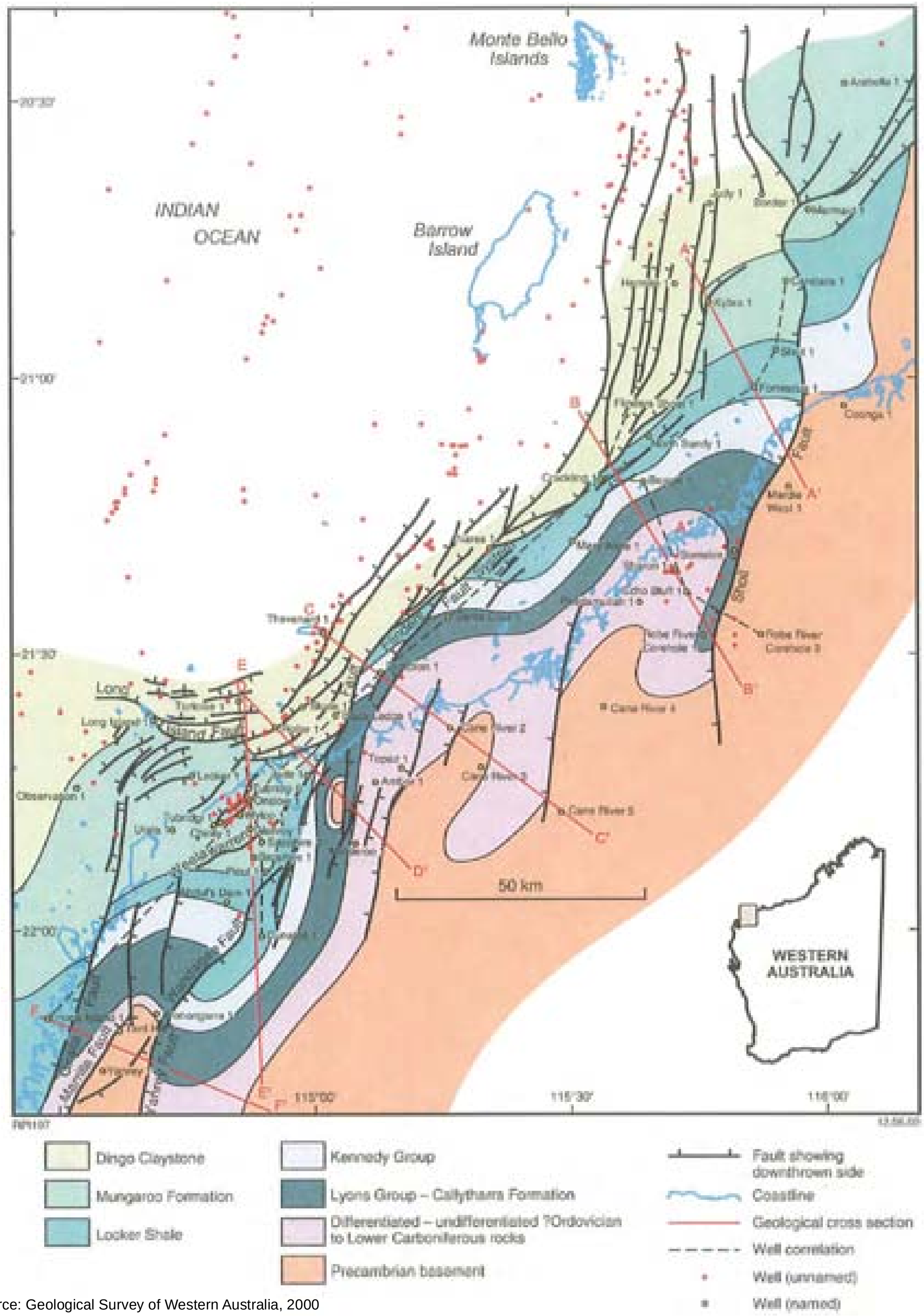

Source: Geological Survey of Western Australia, 2000

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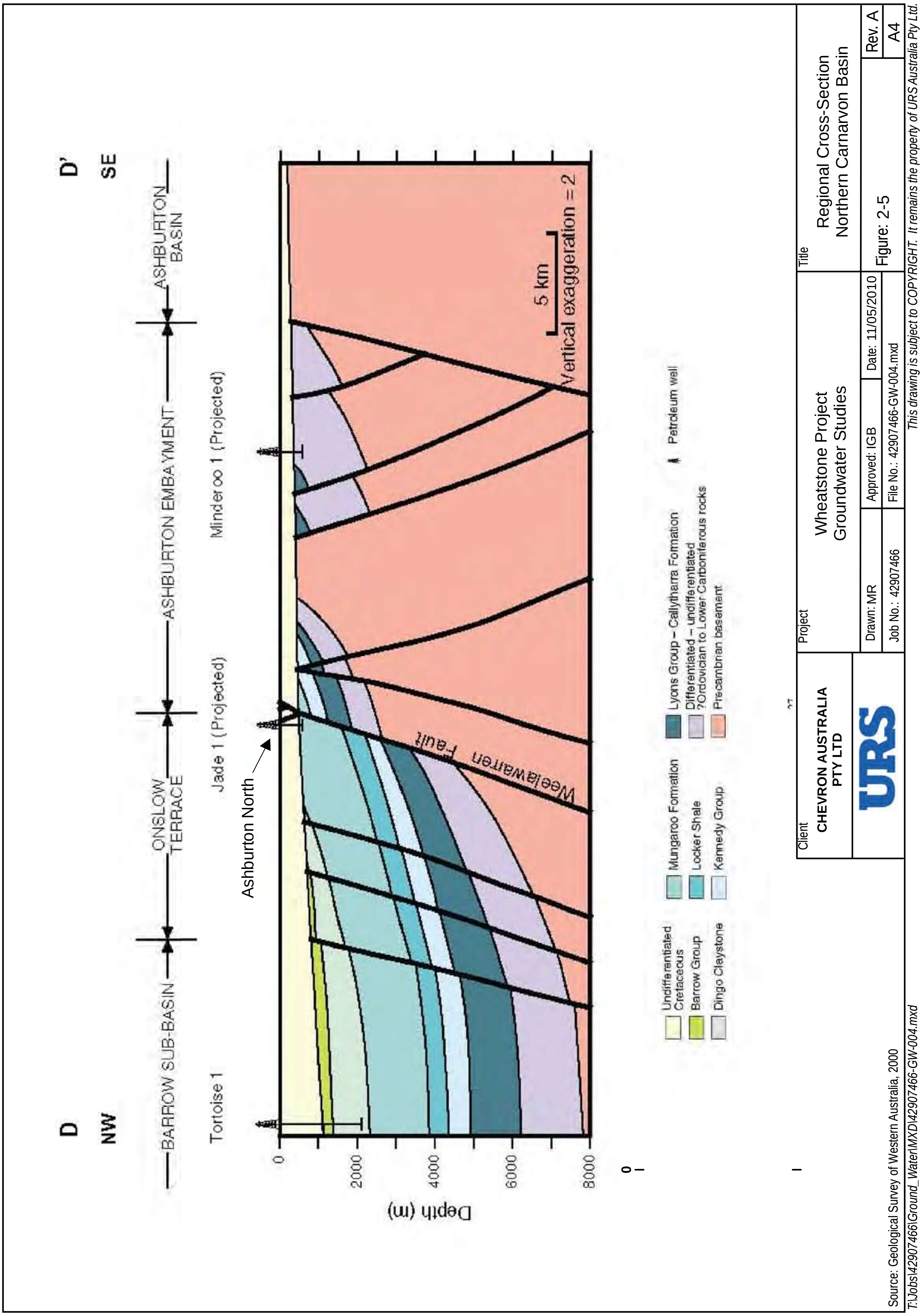
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NW
D'
SE
BARROW SUB-BASIN
ONSLOW TERRACE
ASHBURTON EMBAYMENT
ASHBURTON BASIN
Tortoise 1
Jade 1 (Projected)
Minderoo 1 (Projected)
Ashburton North
Depth (m)
0
2000
4000
6000
8000
Weelawarren Fault
5 km
Vertical exaggeration = 2
Undifferentiated Cretaceous
Barrow Group
Dingo Claystone
Mungaroo Formation
Locker Shale
Kennedy Group
Lyons Group – Callytharra Formation
Differentiated – undifferentiated ?Ordovician to Lower Carboniferous rocks
Precambrian basement
Petroleum well
Client
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URS
Project
Wheatstone Project
Groundwater Studies
Title
Regional Cross-Section
Northern Carnarvon Basin
Drawn: MR
Approved: IGB
Date: 11/05/2010
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Legend

Townsite

Indicative Terrestrial Project 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

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 flood and deflatation; includes minor laterite exposed
Czp Claypan-dominant terrain - claypans with longitudinal and net dunes, and/or flat deflation-lag surfaces; clay, silt, sand and gravel

Source: Geological Survey of Western Australia, 2000

Client	Project	Title	
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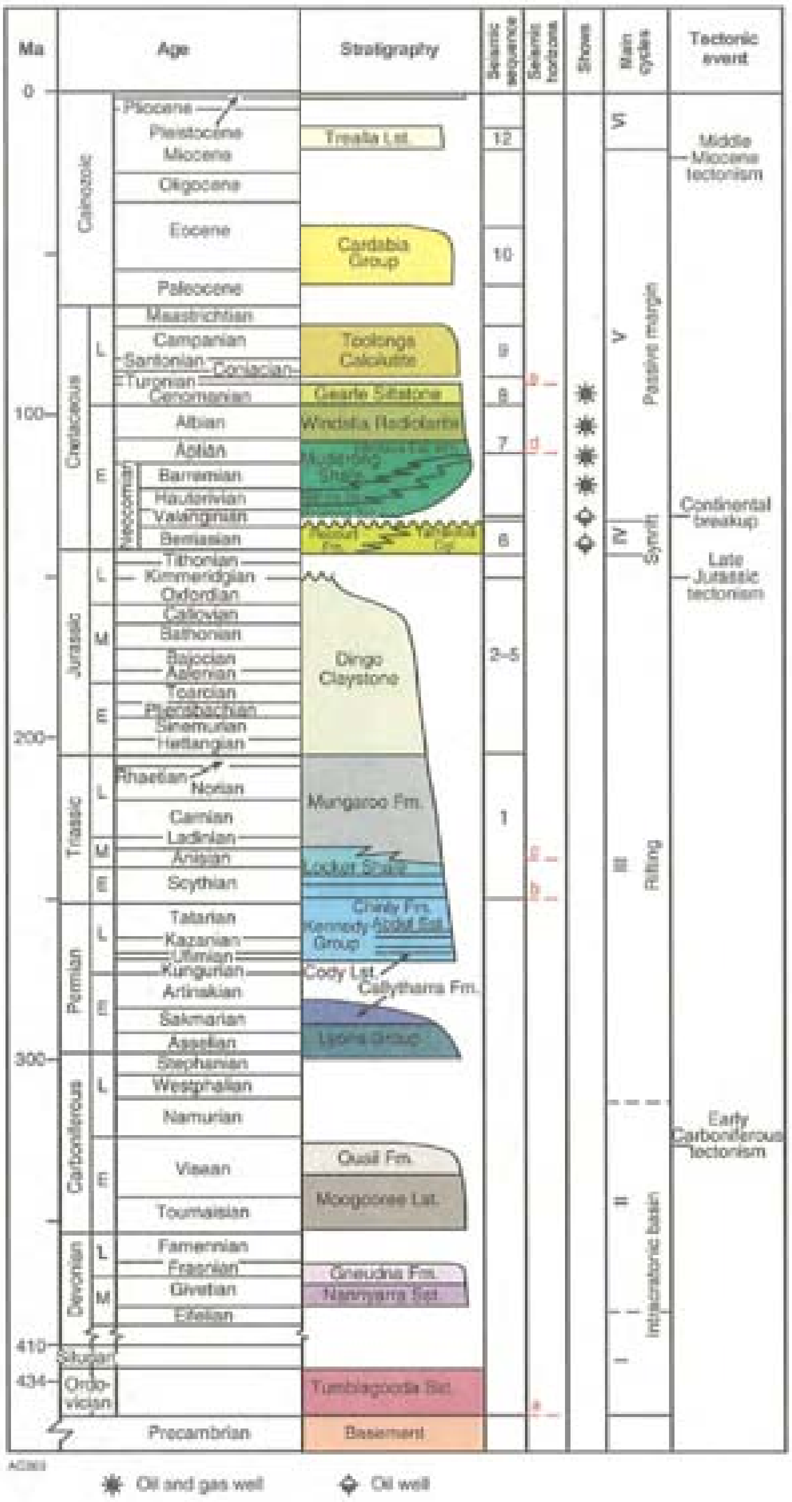

Source: Crostella et al., 2000

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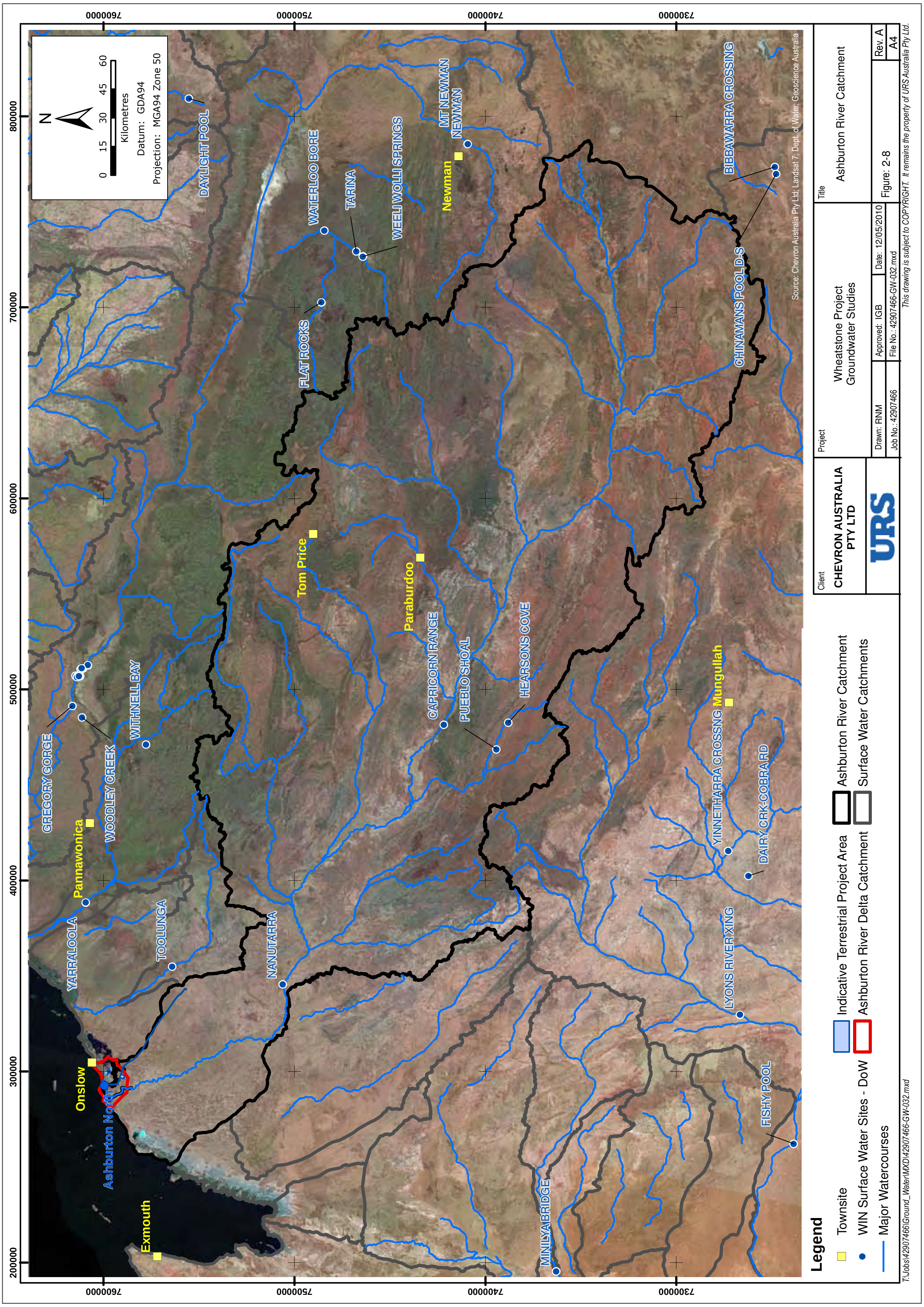

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WIN Surface Water Sites - DoW
Major Watercourses
Indicative Terrestrial Project Area
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Ashburton River Catchment
Surface Water Catchments
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project
Groundwater Studies
Title
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Kilometres
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Projection: MGA94 Zone 50
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Exmouth
Pannawonica
Tom Price
Paraburdoo
Newman
Mungullah
Ashburton North
DAYLIGHT POOL
WATERLOO BORE
TARINA
WEELI WOLLI SPRINGS
MT NEWMAN
NEWMAN
BIBBAWARRA CROSSING
CHINAMANS POOL D-S
FLAT ROCKS
GREGORY GORGE
WOODLEY CREEK
WITHNELL BAY
CAPRICORN RANGE
PUEBLO SHOAL
HEARSONS COVE
YINNETHARRA CROSSNG
DAIRY CRK-COBRA RD
YARRALOOLA
TOOLUNGA
NANUTARRA
LYONS RIVER XING
FISHY POOL
MINILYA BRIDGE
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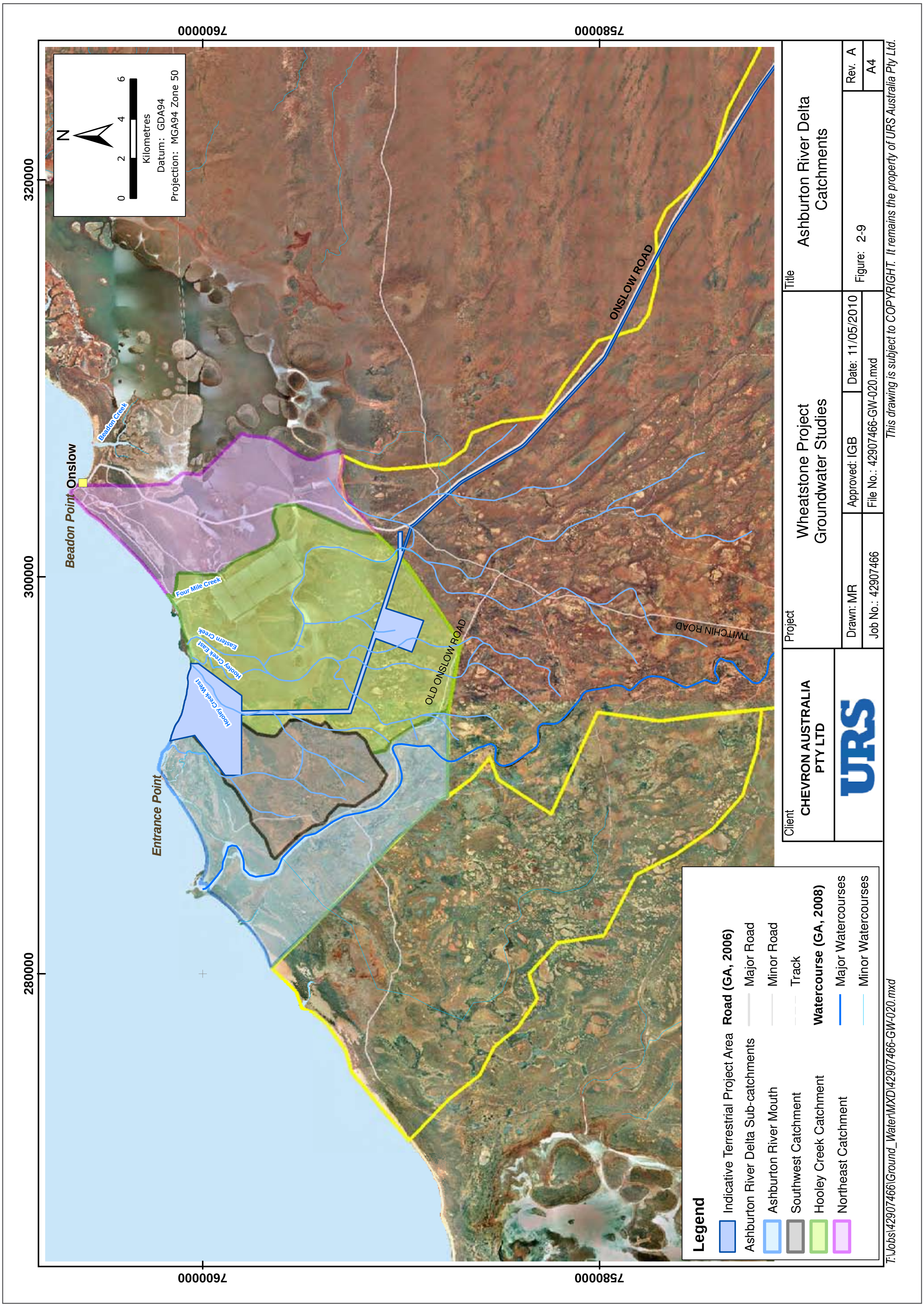
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Indicative Terrestrial Project Area
Ashburton River Delta Sub-catchments
Ashburton River Mouth
Southwest Catchment
Hooley Creek Catchment
Northeast Catchment
Road (GA, 2006)
Major Road
Minor Road
Track
Watercourse (GA, 2008)
Major Watercourses
Minor Watercourses
N
0 2 4 6
Kilometres
Datum: GDA94
Projection: MGA94 Zone 50
Onslow
Beadon Point
Beadon Creek
Entrance Point
Four Mile Creek
Eastern Creek
Hooley Creek East
Hooley Creek West
ONSLOW ROAD
OLD ONSLOW ROAD
TWITCHIN ROAD
7600000
7580000
280000
300000
320000
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project Groundwater Studies
Title
Ashburton River Delta Catchments
Drawn: MR
Approved: IGB
Date: 11/05/2010
Rev. A
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Figure: 2-9
A4
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Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Local Topography
URS	Drawn: RNM / Approved: IGB / Date: 12/05/2010	Figure: 2-10 / Rev. A
	Job No.: 42907466 / File No.: 42907466-GW-025.mxd	A4

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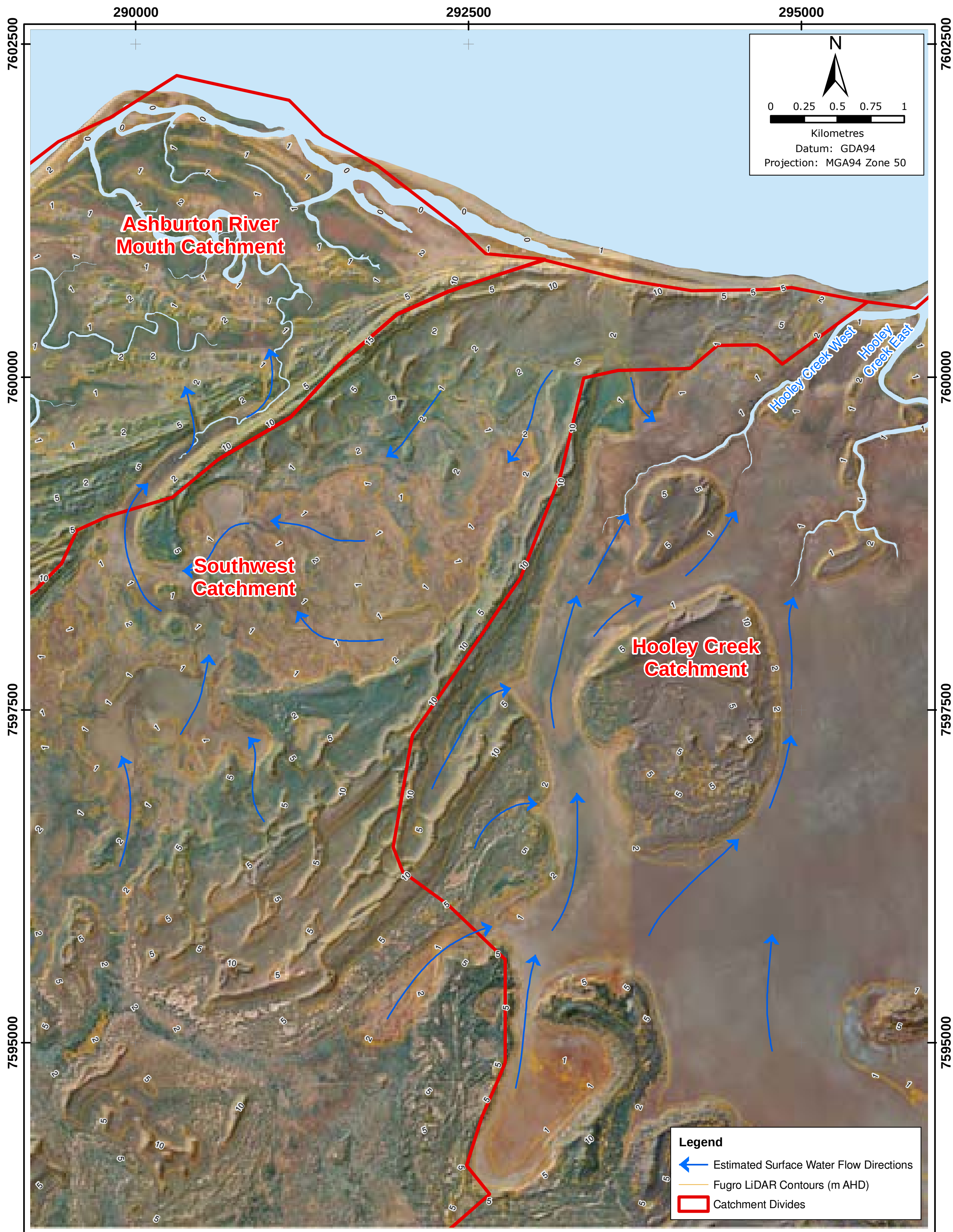

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Local Catchment Divides and Surface Water Flow Directions

URS	Drawn: MR	Approved: IGB	Date: 11/05/2010	Figure: 2-11	Rev. A
	Job No.: 42907466	File No.: 42907466-GW-021.mxd			A4

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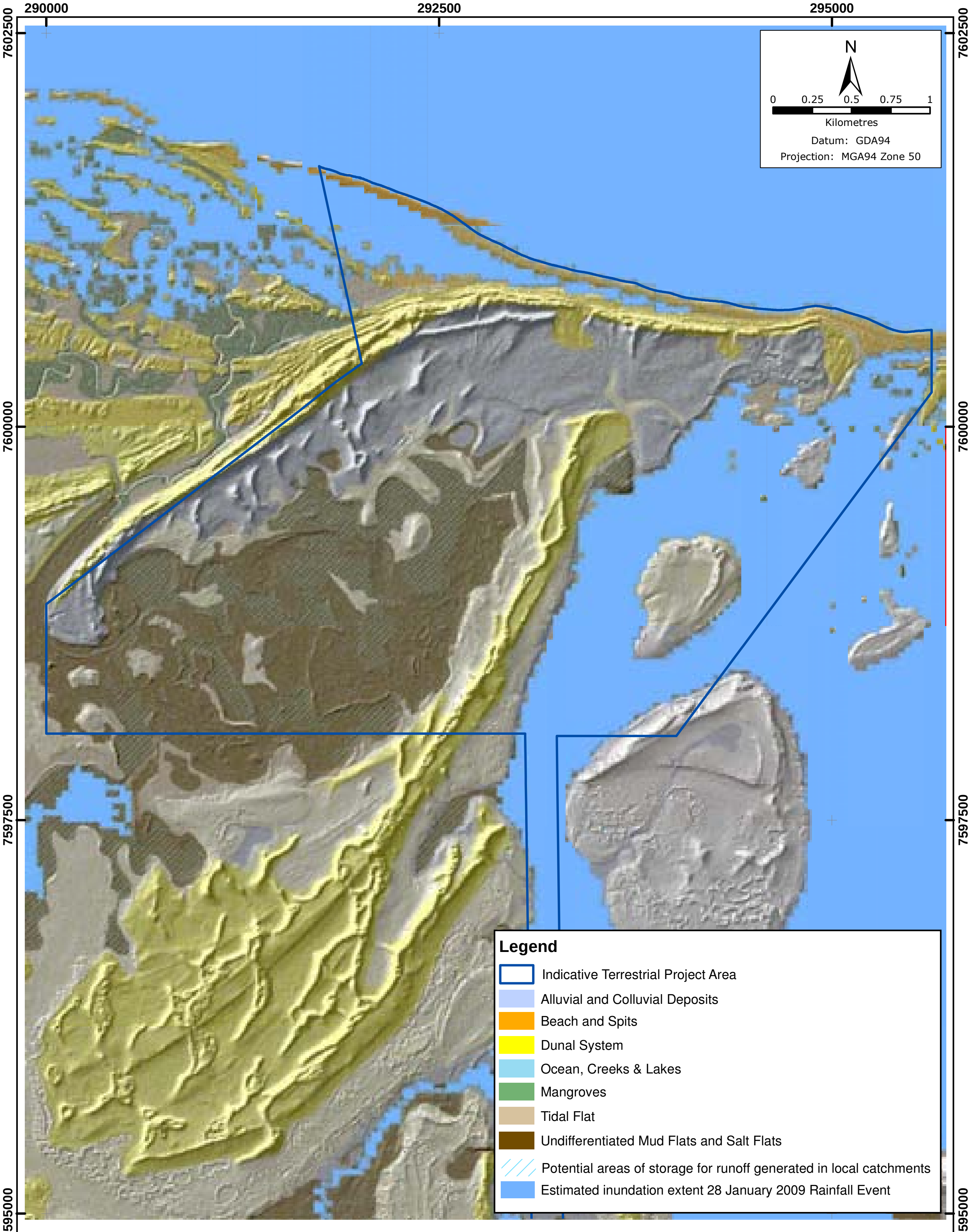

Client CHEVRON AUSTRALIA PTY LTD	Project Wheatstone Project Grounwater Studies		Title Estimated Flooding from 28/01/09 1:2 Year ARI Rainfall Event with Tidal Record	
URS	Drawn: MR	Approved: IGB	Date: 11/05/2010	Rev. A
	Job No.: 42907466	File No.: 42907466-GW-006.mxd	Figure: 2-12	A4

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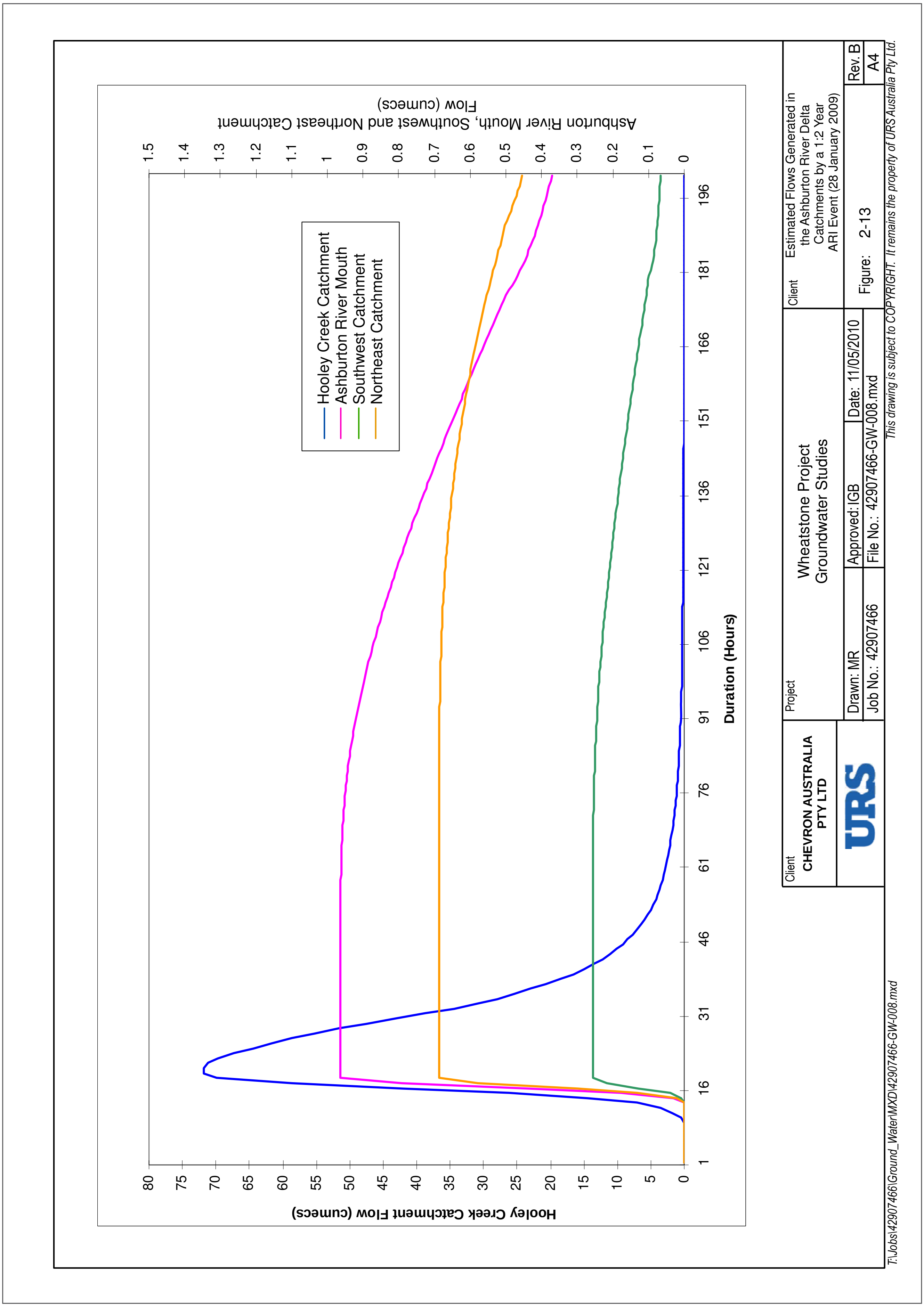
Hooley Creek Catchment
Ashburton River Mouth
Southwest Catchment
Northeast Catchment
Hooley Creek Catchment Flow (cumecs)
Ashburton River Mouth, Southwest and Northeast Catchment Flow (cumecs)
Duration (Hours)
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project Groundwater Studies
Client
Estimated Flows Generated in the Ashburton River Delta Catchments by a 1:2 Year ARI Event (28 January 2009)
Drawn: MR
Approved: IGB
Date: 11/05/2010
Rev. B
Job No.: 42907466
File No.: 42907466-GW-008.mxd
Figure: 2-13
A4
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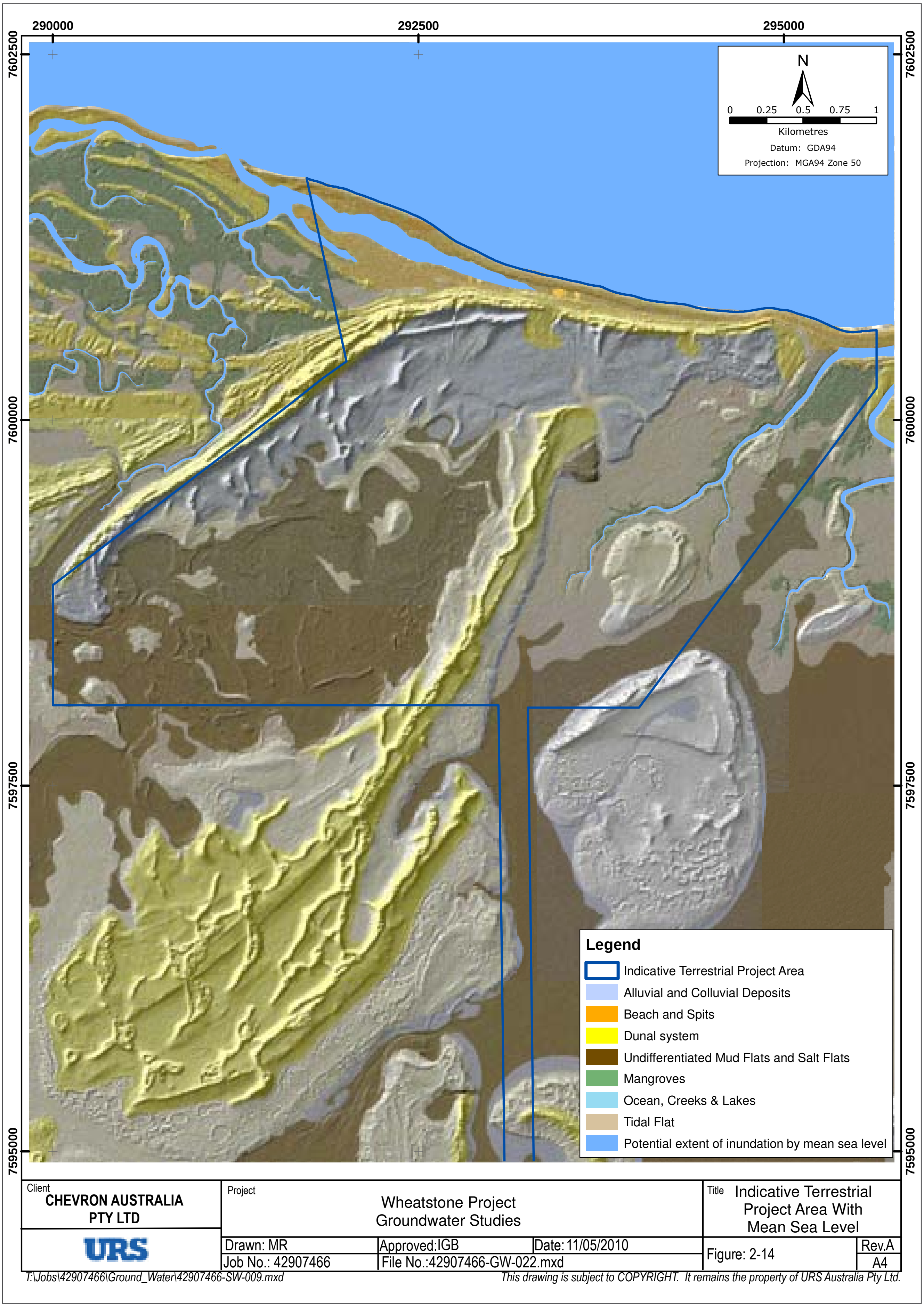

290000
292500
295000
7602500
7600000
7597500
7595000
N
0 0.25 0.5 0.75 1
Kilometres
Datum: GDA94
Projection: MGA94 Zone 50
Legend
Indicative Terrestrial Project Area
Alluvial and Colluvial Deposits
Beach and Spits
Dunal system
Undifferentiated Mud Flats and Salt Flats
Mangroves
Ocean, Creeks & Lakes
Tidal Flat
Potential extent of inundation by mean sea level
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project Groundwater Studies
Title
Indicative Terrestrial Project Area With Mean Sea Level
Drawn: MR
Approved:IGB
Date: 11/05/2010
Job No.: 42907466
File No.:42907466-GW-022.mxd
Figure: 2-14
Rev.A
A4
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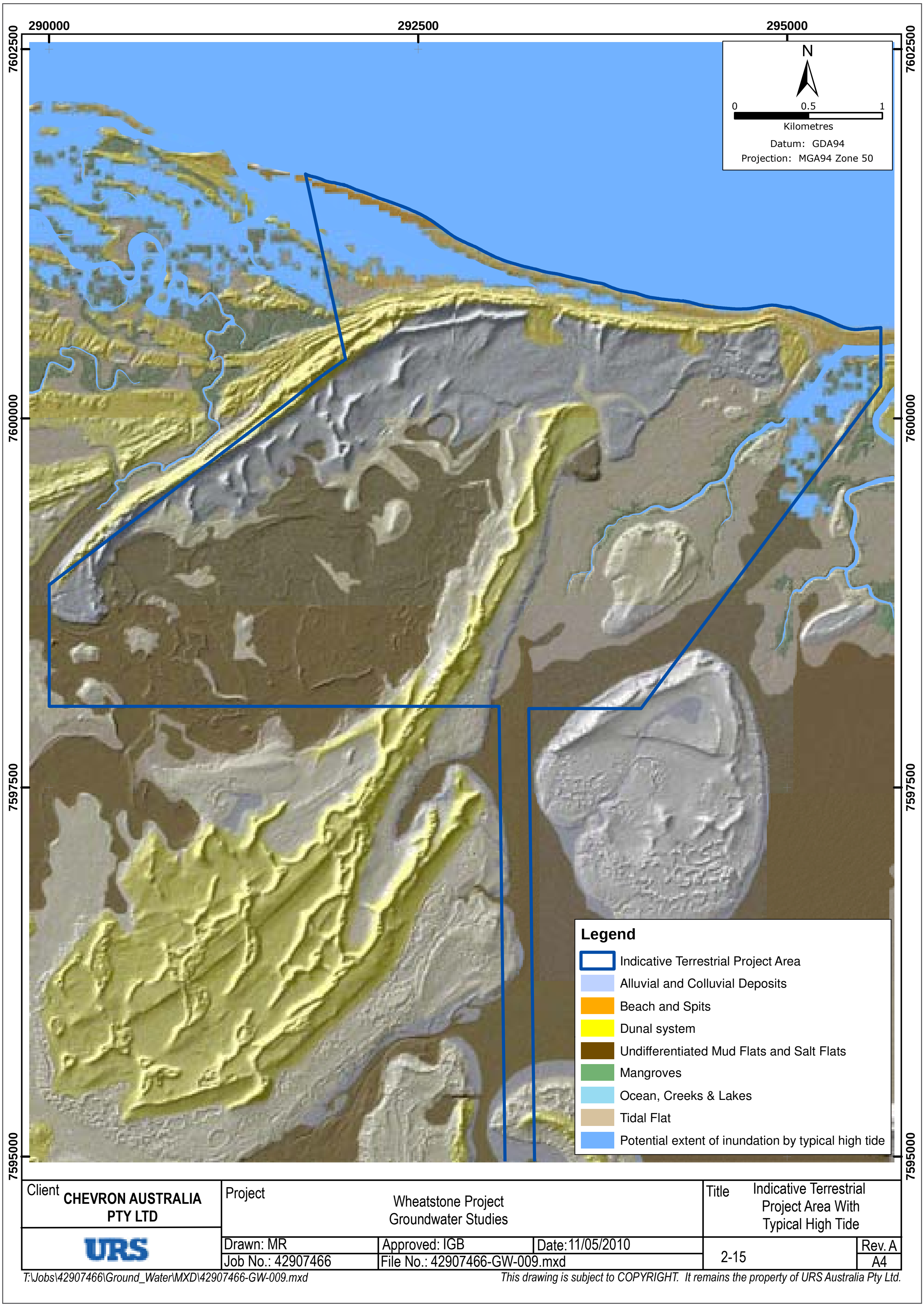
290000
292500
295000
7602500
7600000
7597500
7595000
N
0
0.5
1
Kilometres
Datum: GDA94
Projection: MGA94 Zone 50
Legend
Indicative Terrestrial Project Area
Alluvial and Colluvial Deposits
Beach and Spits
Dunal system
Undifferentiated Mud Flats and Salt Flats
Mangroves
Ocean, Creeks & Lakes
Tidal Flat
Potential extent of inundation by typical high tide
Client CHEVRON AUSTRALIA PTY LTD
URS
Project Wheatstone Project Groundwater Studies
Title Indicative Terrestrial Project Area With Typical High Tide
Drawn: MR
Approved: IGB
Date: 11/05/2010
Job No.: 42907466
File No.: 42907466-GW-009.mxd
2-15
Rev. A
A4
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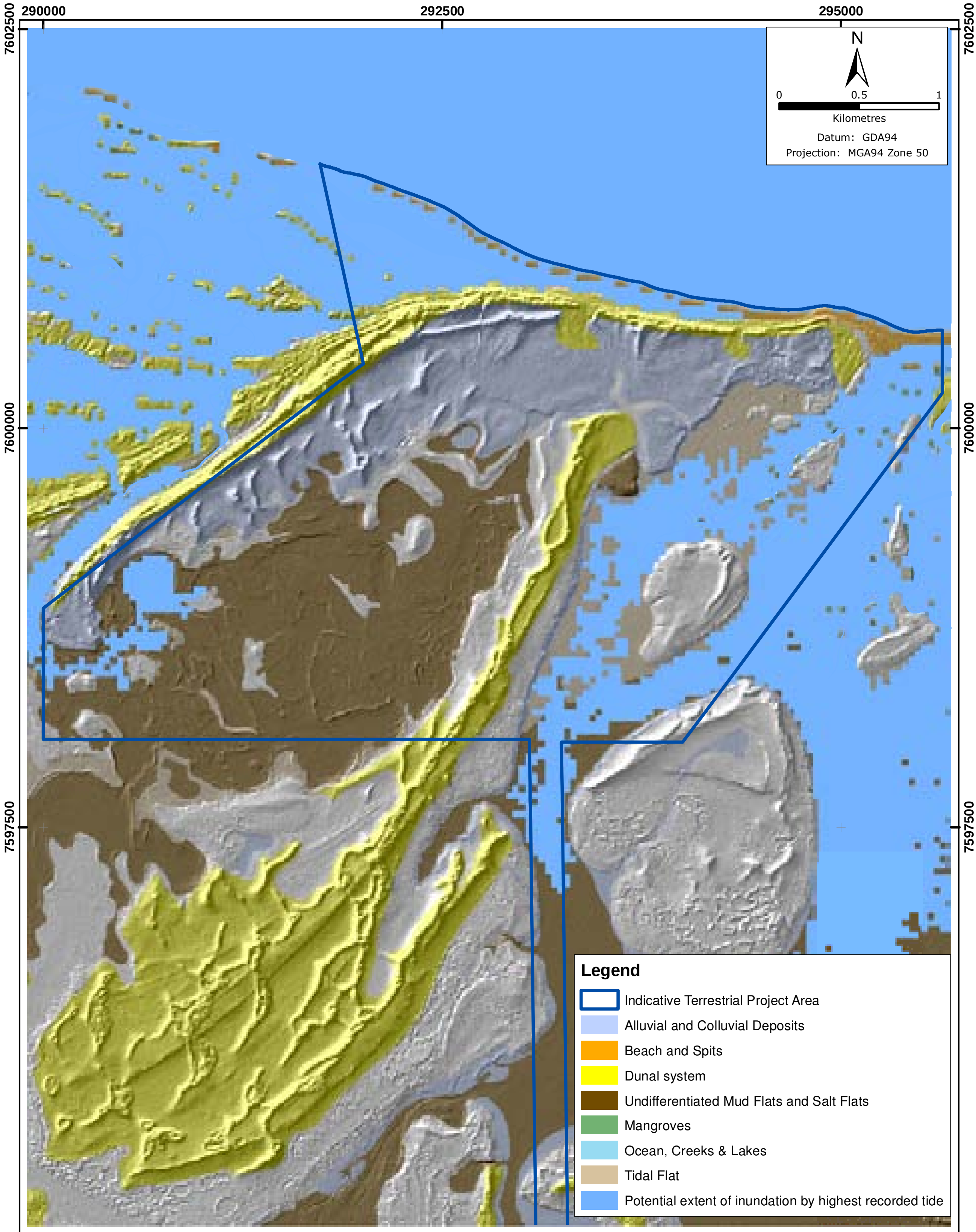

Client CHEVRON AUSTRALIA PTY LTD	Project Wheatstone Project Groundwater Studies		Title Indicative Terrestrial Project Area With Highest Recorded Tide	
URS	Drawn: MR	Approved: IGB	Date: 11/05/2010	Figure: 2-16	Rev.A
	Job No.: 42907466	File No.: 42907466-GW-010.mxd			A4

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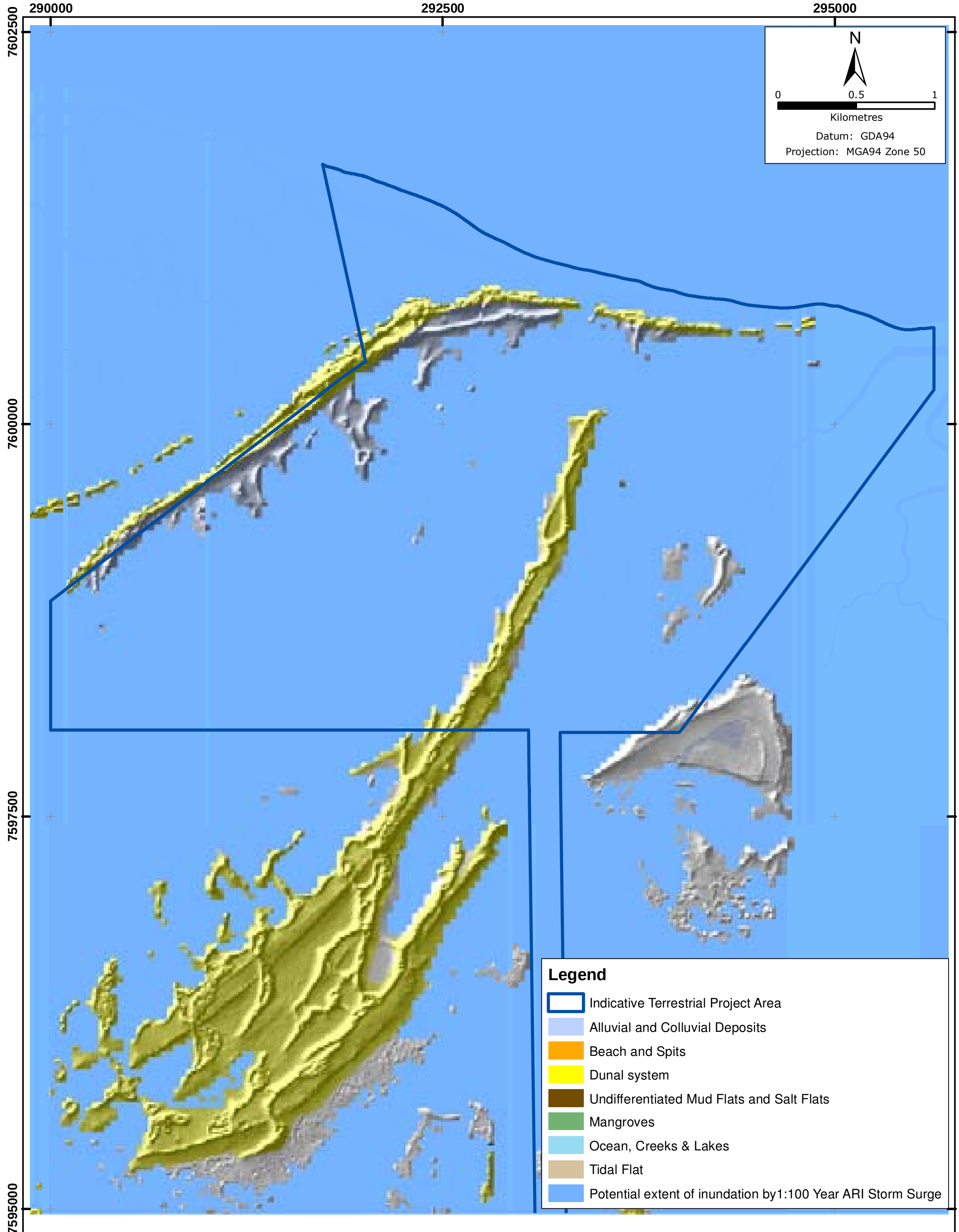

Client CHEVRON AUSTRALIA PTY LTD	Project Wheatstone Project Groundwater Studies			Title Indicative Terrestrial Project Area With 1:100 Year ARI Storm Surge	
URS	Drawn: MR	Approved: IGB	Date: 11/05/2010	Figure: 2-17	Rev. A
	Job No.: 42907466	File No.: 42907466-GW-011.mxd			A4

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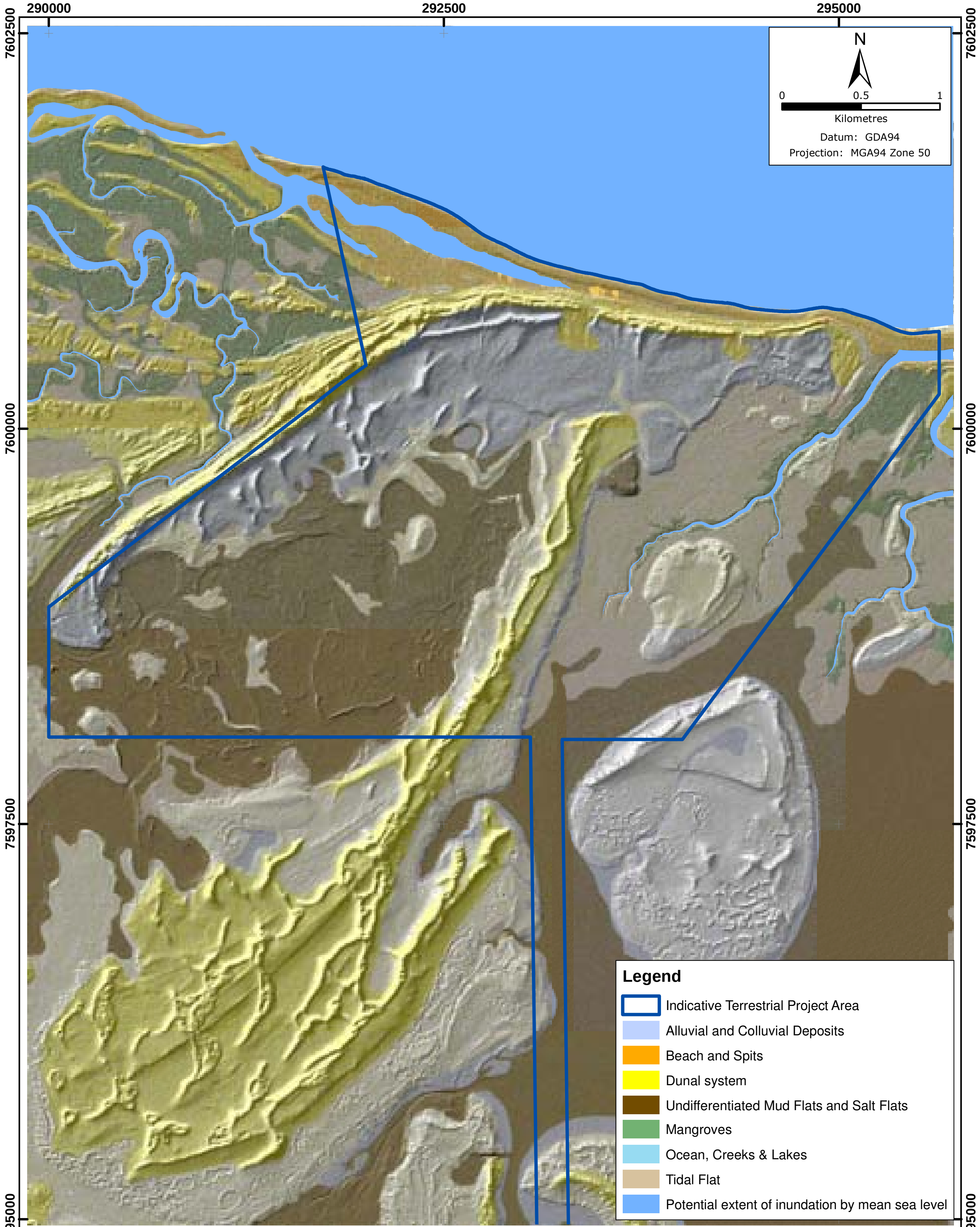

Client CHEVRON AUSTRALIA PTY LTD	Project Wheatstone Project Groundwater Studies		Title Simplified Coastal Geomorphology	
URS	Drawn: MR	Approved: IGB	Date: 11/05/2010	Figure: 2-18	Rev.A
	Job No.: 42907466	File No.: 42907466-GW-012.mxd			A4

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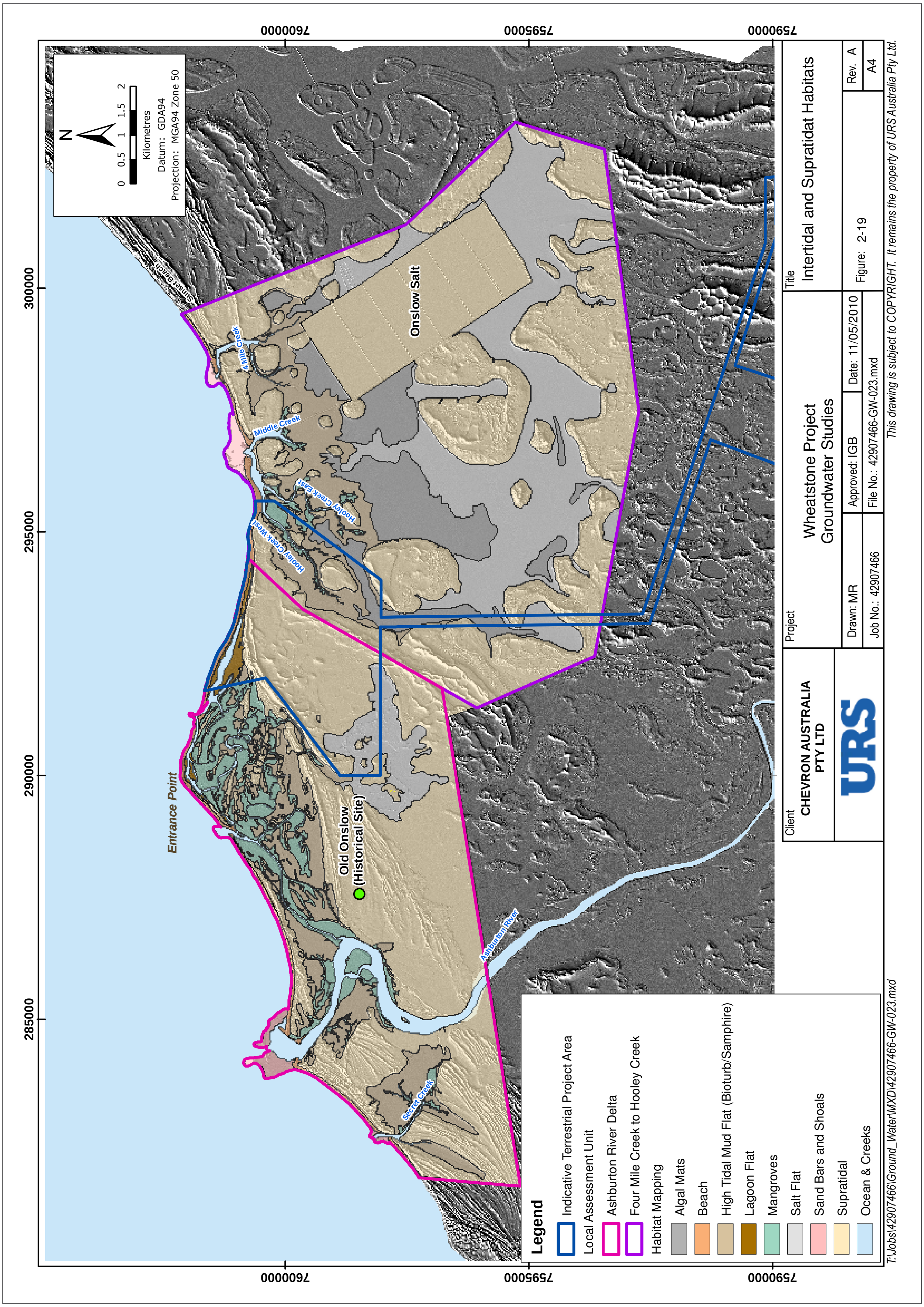
Intertidal and Supratidal Habitats
Wheatstone Project
Groundwater Studies
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Title
Drawn: MR
Approved: IGB
Date: 11/05/2010
Figure: 2-19
Rev. A
A4
Job No.: 42907466
File No.: 42907466-GW-023.mxd
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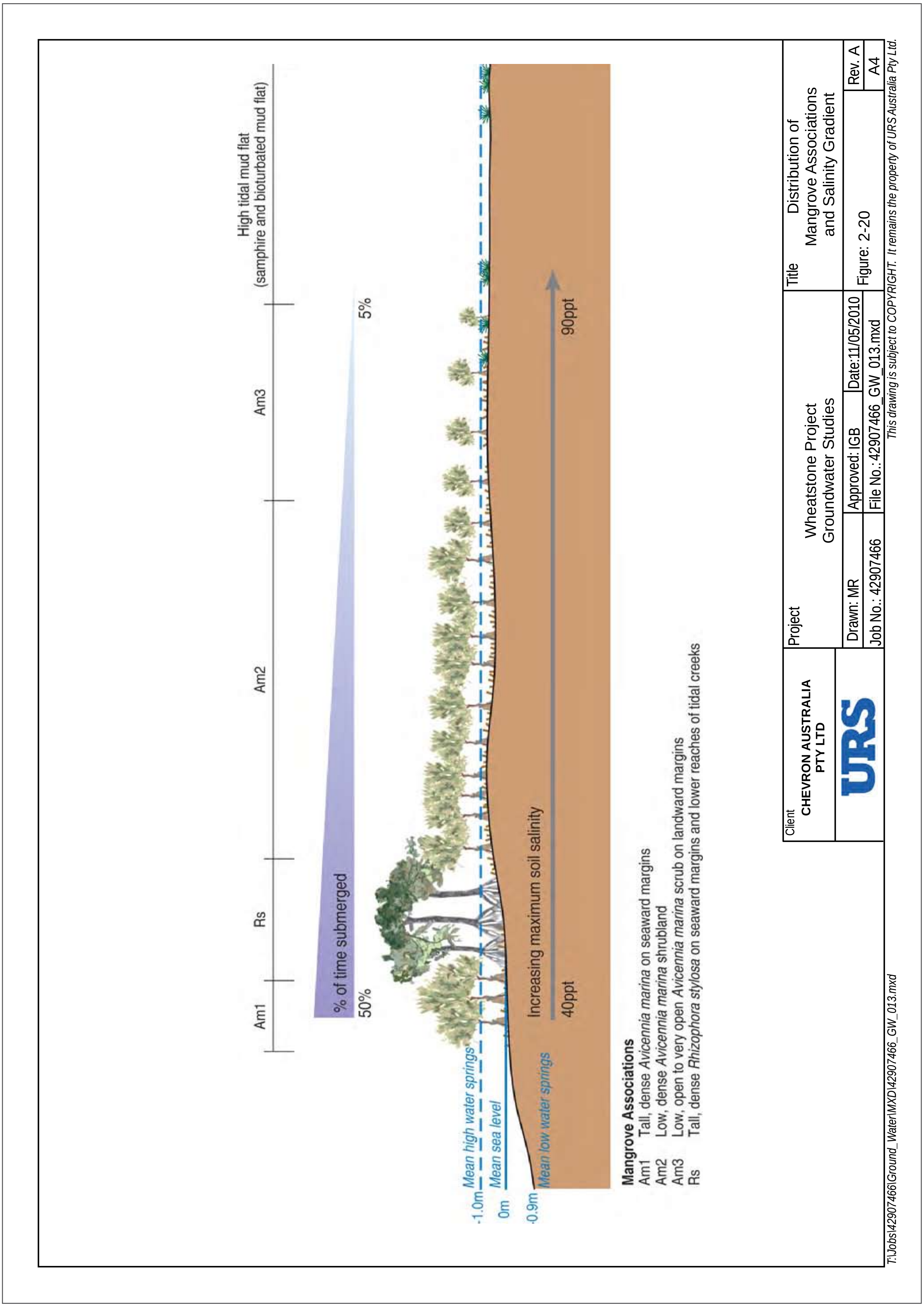
Legend
Indicative Terrestrial Project Area
Local Assessment Unit
Ashburton River Delta
Four Mile Creek to Hooley Creek
Habitat Mapping
Algal Mats
Beach
High Tidal Mud Flat (Bioturb/Samphire)
Lagoon Flat
Mangroves
Salt Flat
Sand Bars and Shoals
Supratidal
Ocean & Creeks
N
Kilometres
0 0.5 1 1.5 2
Datum: GDA94
Projection: MGA94 Zone 50
Onslow Salt
Old Onslow (Historical Site)
Entrance Point
Sunset Beach
4 Mile Creek
Middle Creek
Hooley Creek East
Hooley Creek West
Ashburton River
Secret Creek
285000
290000
295000
300000
7590000
7595000
7600000


Am1
Rs
Am2
Am3
High tidal mud flat
(samphire and bioturbated mud flat)
% of time submerged
50%
5%
-1.0m
Mean high water springs
0m
Mean sea level
-0.9m
Mean low water springs
Increasing maximum soil salinity
40ppt
90ppt
Mangrove Associations
Am1 Tall, dense Avicennia marina on seaward margins
Am2 Low, dense Avicennia marina shrubland
Am3 Low, open to very open Avicennia marina scrub on landward margins
Rs Tall, dense Rhizophora stylosa on seaward margins and lower reaches of tidal creeks
Client
CHEVRON AUSTRALIA PTY LTD
Project
Wheatstone Project Groundwater Studies
Title
Distribution of Mangrove Associations and Salinity Gradient
Drawn: MR
Approved: IGB
Date:11/05/2010
Figure: 2-20
Rev. A
Job No.: 42907466
File No.: 42907466_GW_013.mxd
A4
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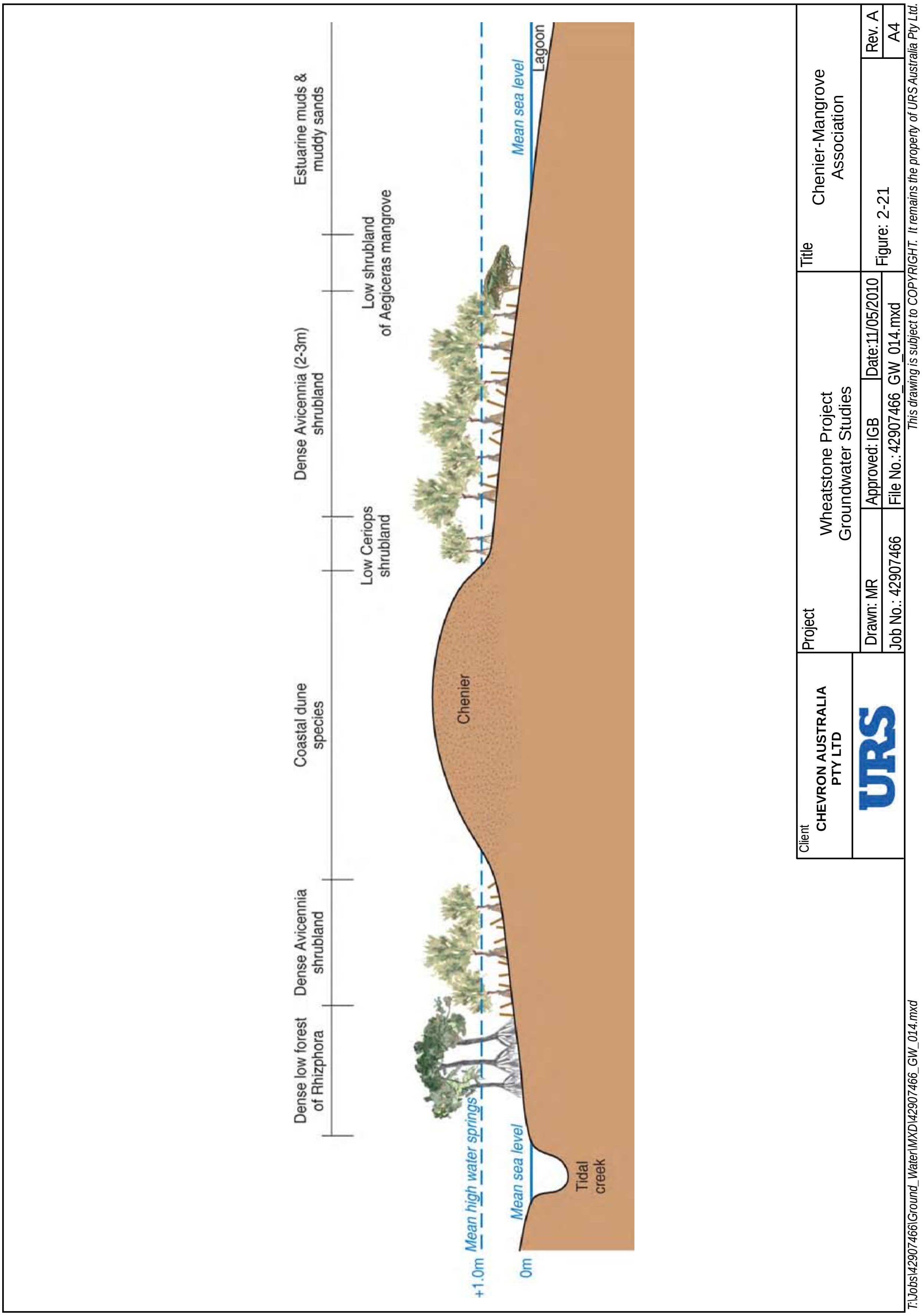
Dense low forest of Rhizphora
Dense Avicennia shrubland
Coastal dune species
Low Ceriops shrubland
Dense Avicennia (2-3m) shrubland
Low shrubland of Aegiceras mangrove
Estuarine muds & muddy sands
+1.0m
Mean high water springs
0m
Mean sea level
Tidal creek
Chenier
Mean sea level
Lagoon
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project Groundwater Studies
Title
Chenier-Mangrove Association
Drawn: MR
Approved: IGB
Date:11/05/2010
Figure: 2-21
Rev. A
Job No.: 42907466
File No.: 42907466_GW_014.mxd
A4
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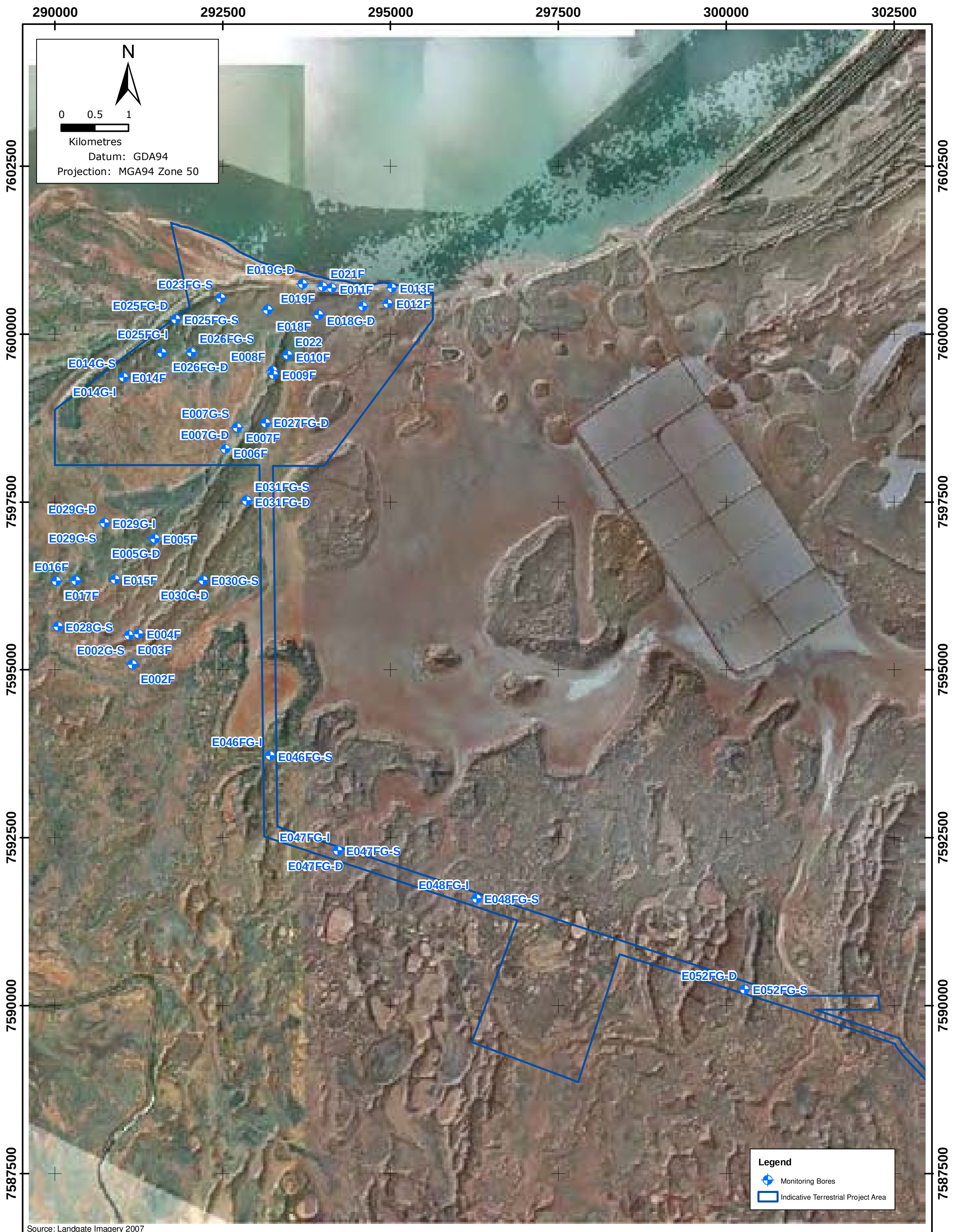

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Environmental Monitoring Bore Sites	
URS	Drawn: RNM / Approved: IGB / Date: 12/05/2010	Figure: 3-1	Rev. A
	Job No.: 42907466 / File No.: 42907466-GW-027.mxd		A4

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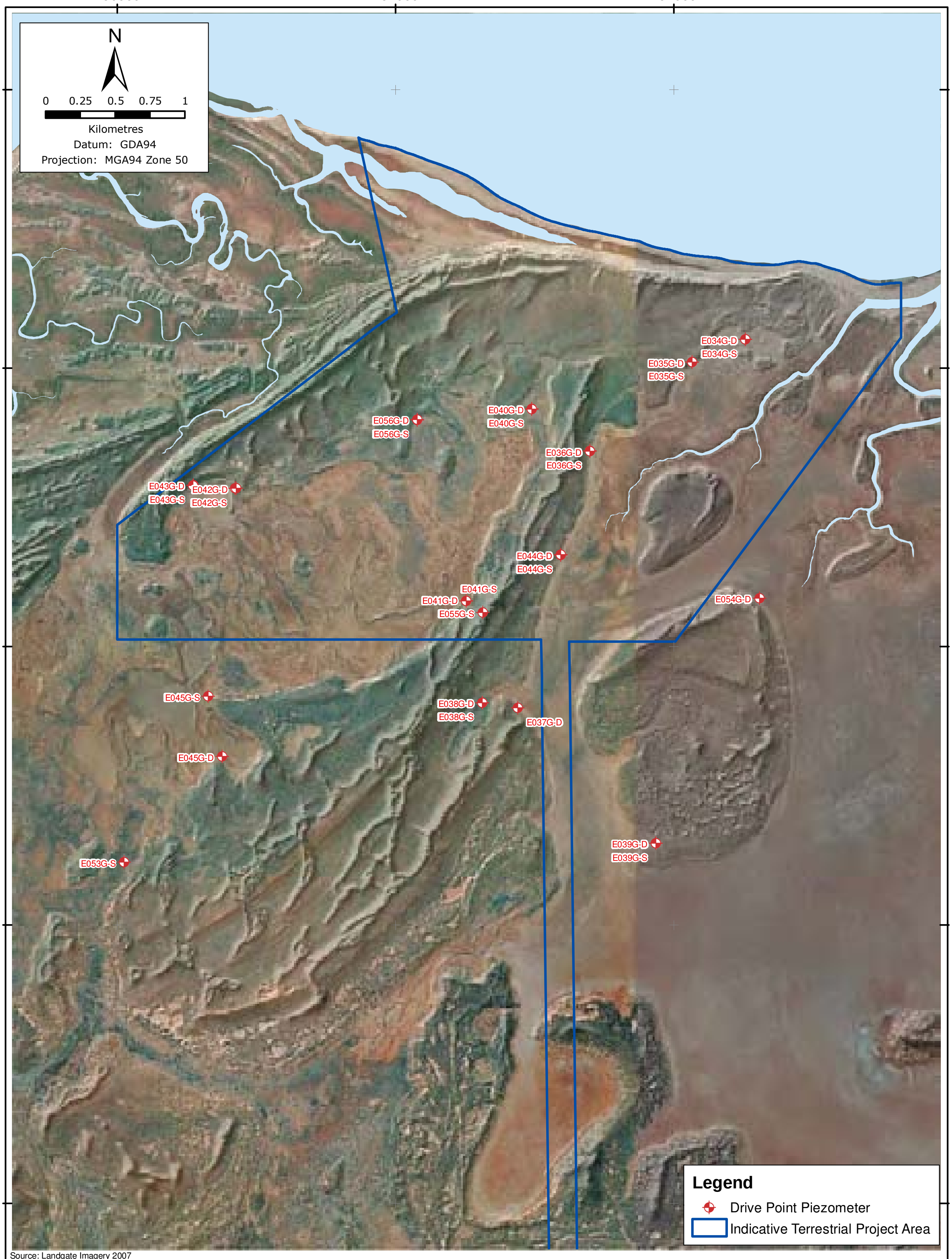

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Drive Point Piezometer Locations	
URS	Drawn: RNM / Approved: IGB / Date: 11/05/2010	Figure: 3-2	Rev. A
	Job No.: 42907466 / File No.: 42907466-GW-024.mxd		A4

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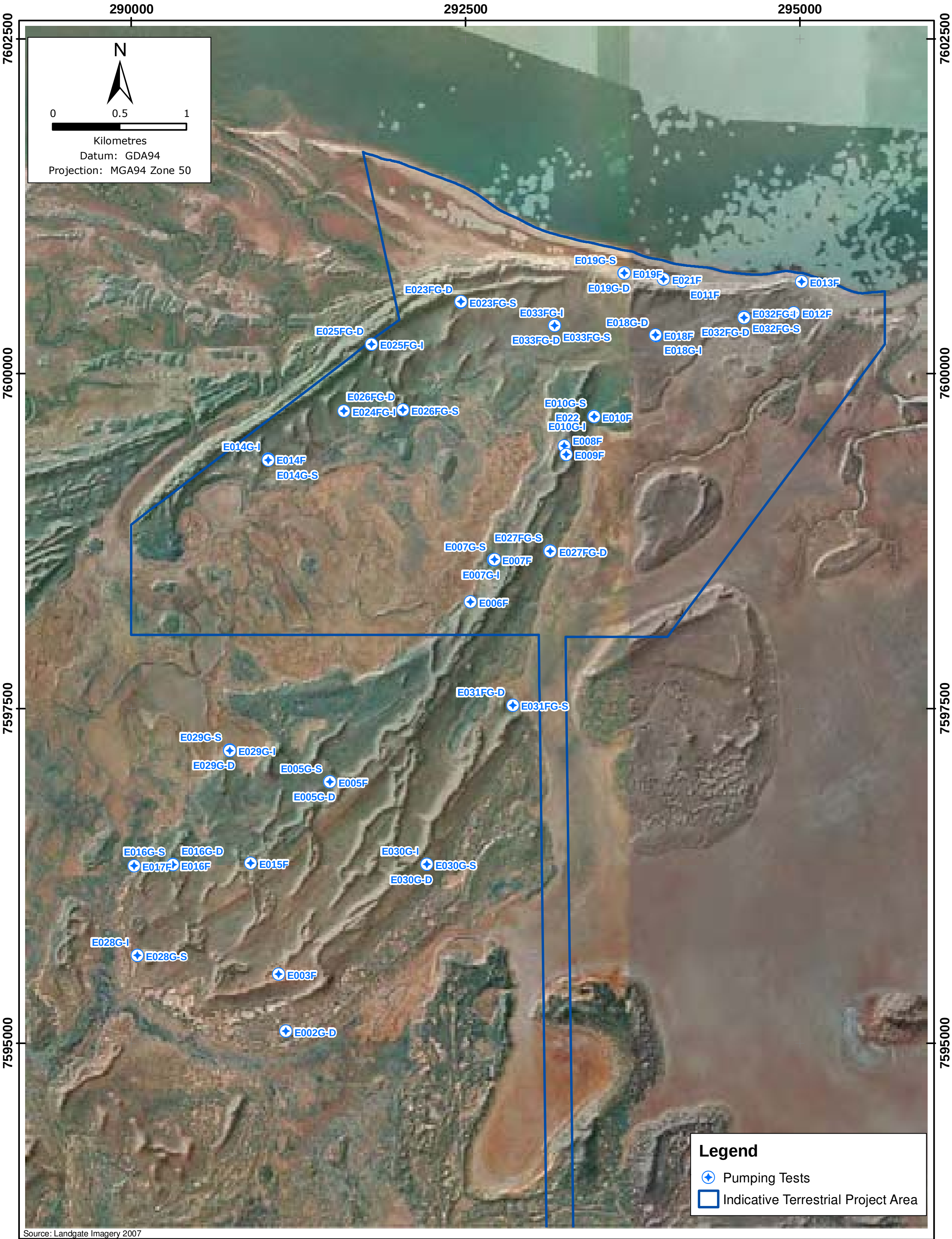

Source: Landgate Imagery 2007

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Pumping Test Sites	
URS	Drawn: MR / Approved: IGB / Date: 11/05/2010	Figure: 3-3	Rev. A
	Job No.: 42907466 / File No.: 42907466-GW-015.mxd		A4

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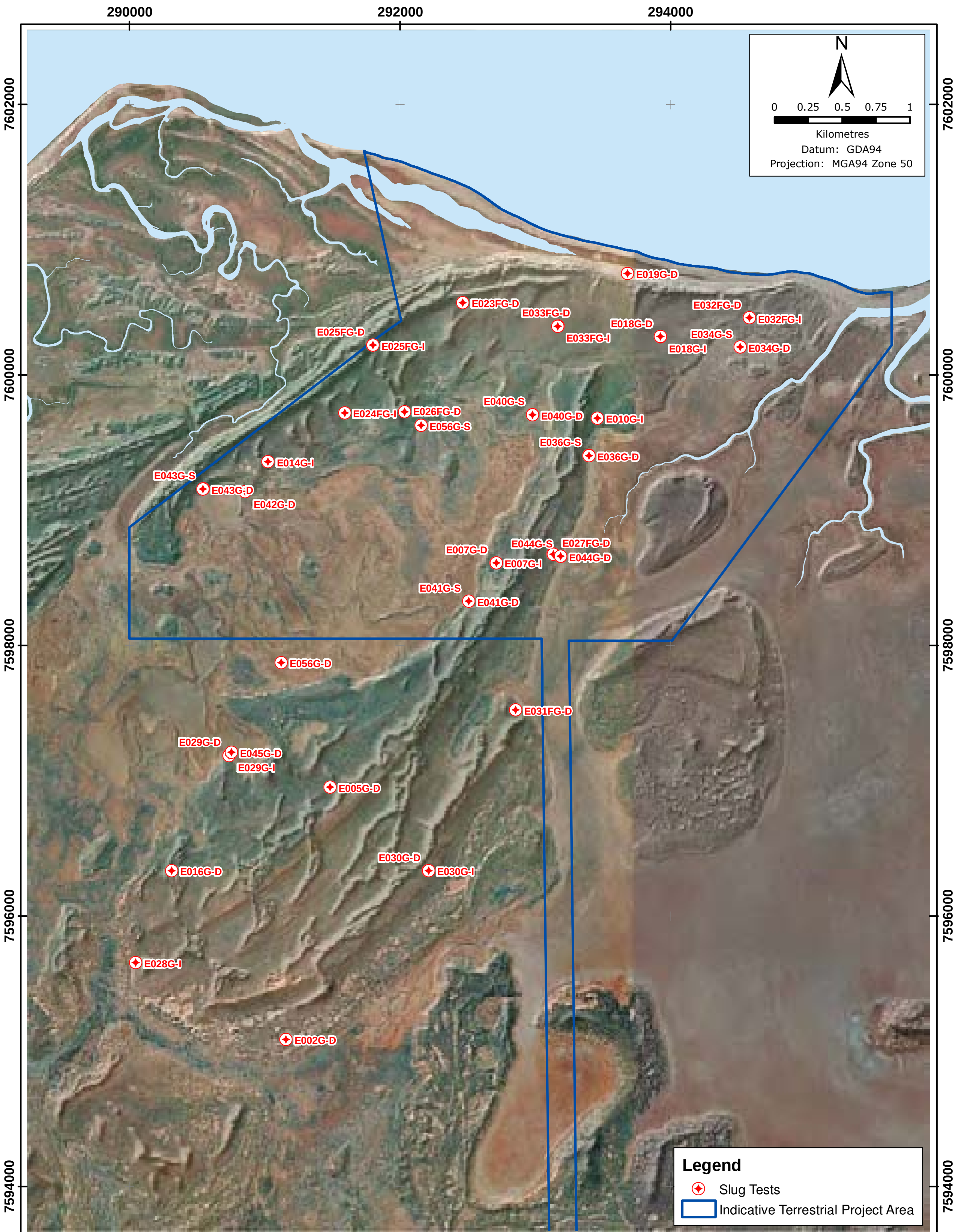

Source: Landgate Imagery 2007

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Slug Test Sites
URS	Drawn: MR / Approved: IGB / Date: 11/05/2010	Figure: 3-4 / Rev. A
	Job No.: 42907100 / File No.: 42907466-GW-026.mxd	A4

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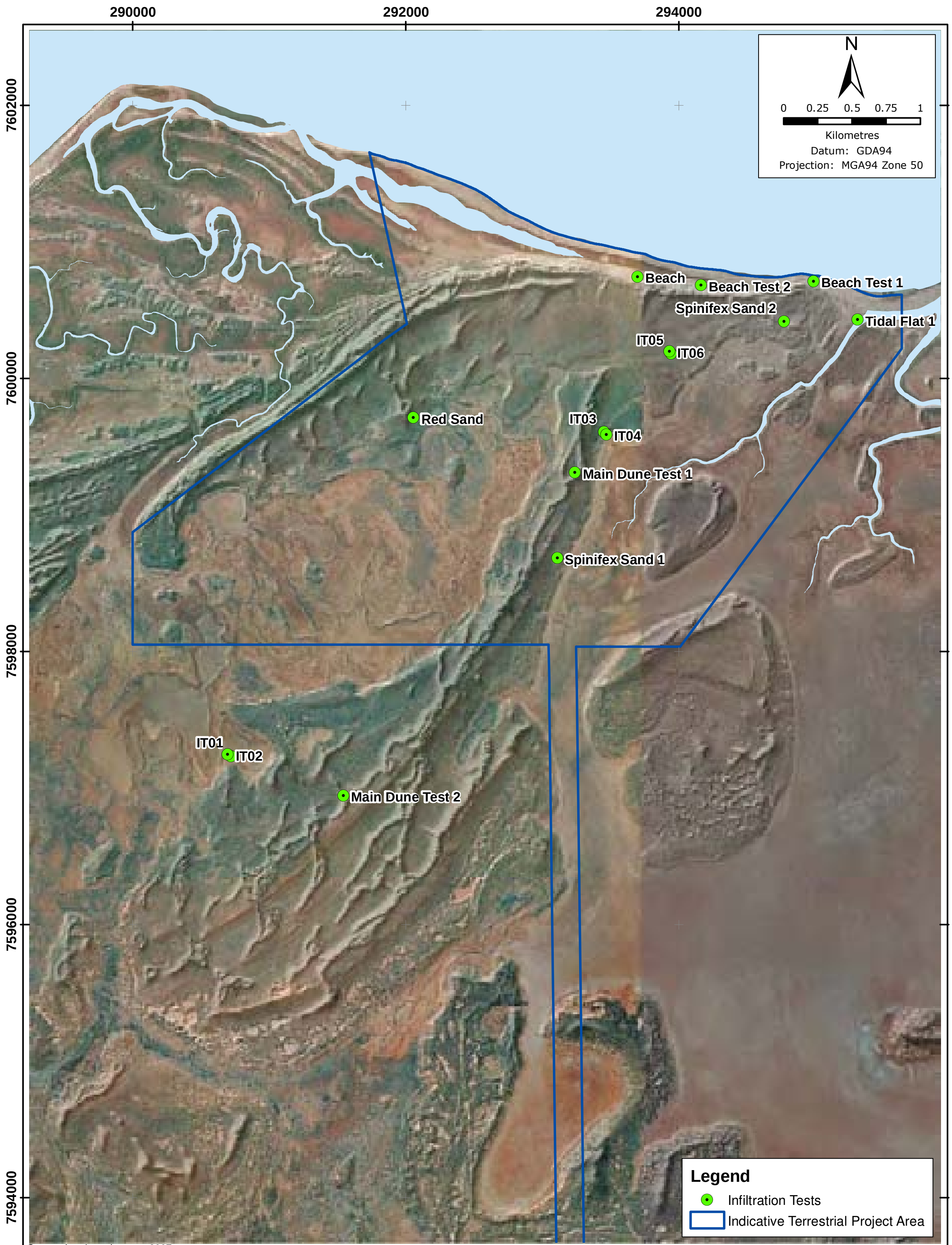

Source: Landgate Imagery 2007

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Infiltration Test Sites
URS	Drawn: MR; Approved: IGB; Date: 11/05/2010; Job No.: 42907100; File No.: 42907466-GW-028.mxd	Figure: 3-5; Rev. A; A4

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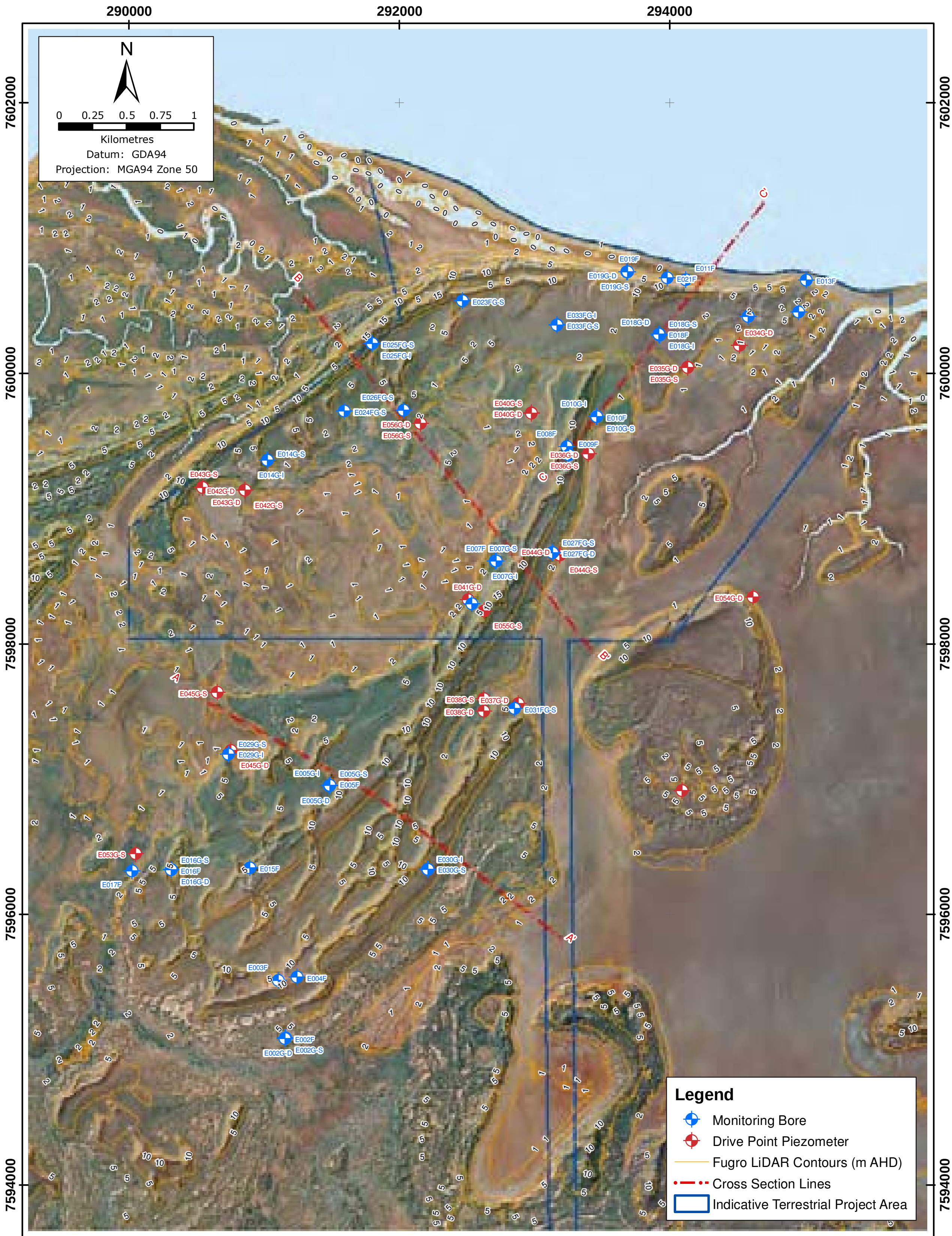

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Locations of Hydrostratigraphic Cross-Sections	
URS	Drawn: MR / Approved: IGB / Date: 11/05/2010	Figure: 4-1	Rev. A
	Job No.: 42907466 / File No.: 42907466-GW-018.mxd		A4

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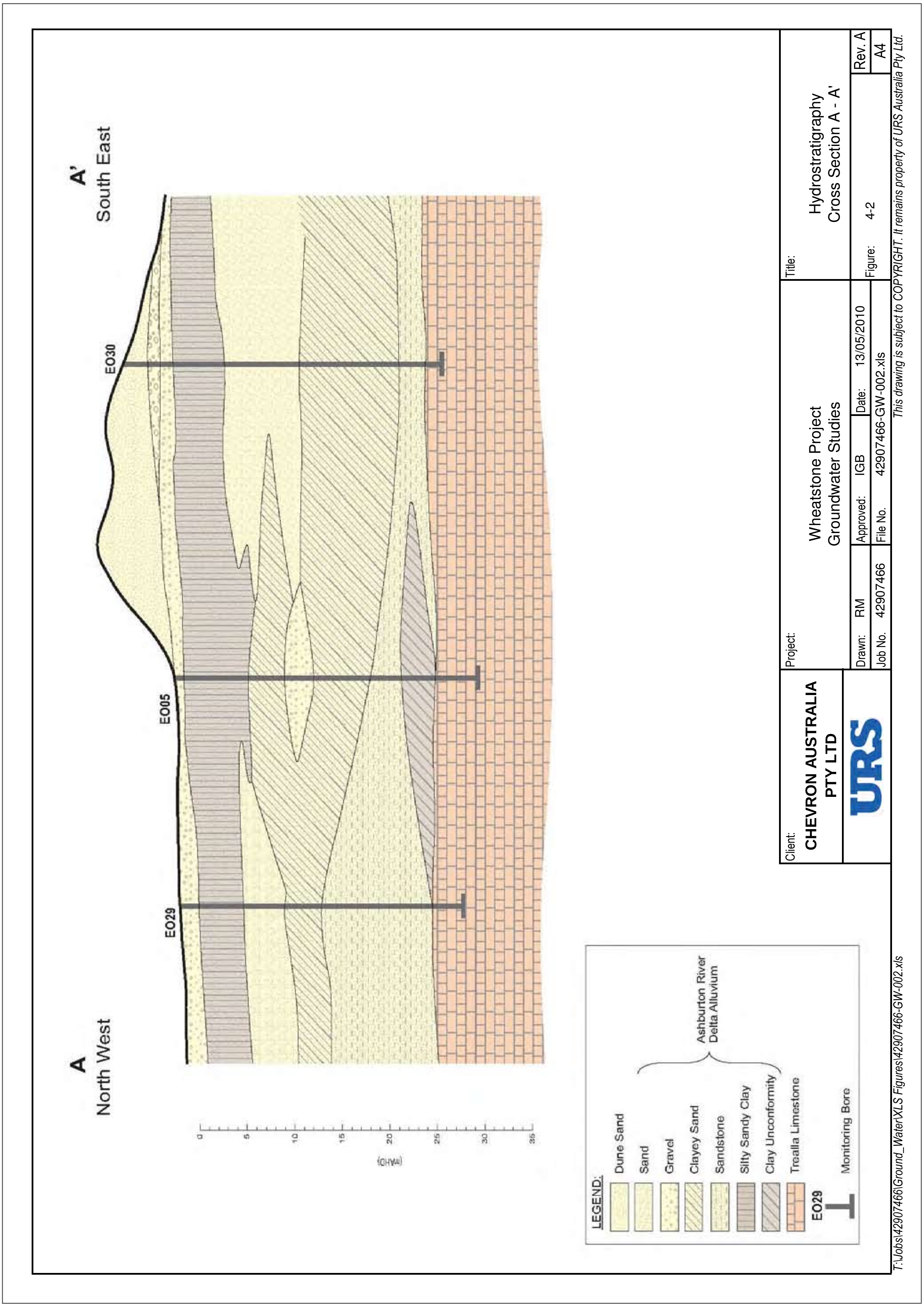
A
North West
A'
South East
EO29
EO05
EO30
(mAHD)
0
5
10
15
20
25
30
35
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Trealla Limestone
Ashburton River Delta Alluvium
EO29
Monitoring Bore
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Hydrostratigraphy Cross Section A - A'
Drawn: RM
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-002.xls
Figure: 4-2
Rev. A
A4
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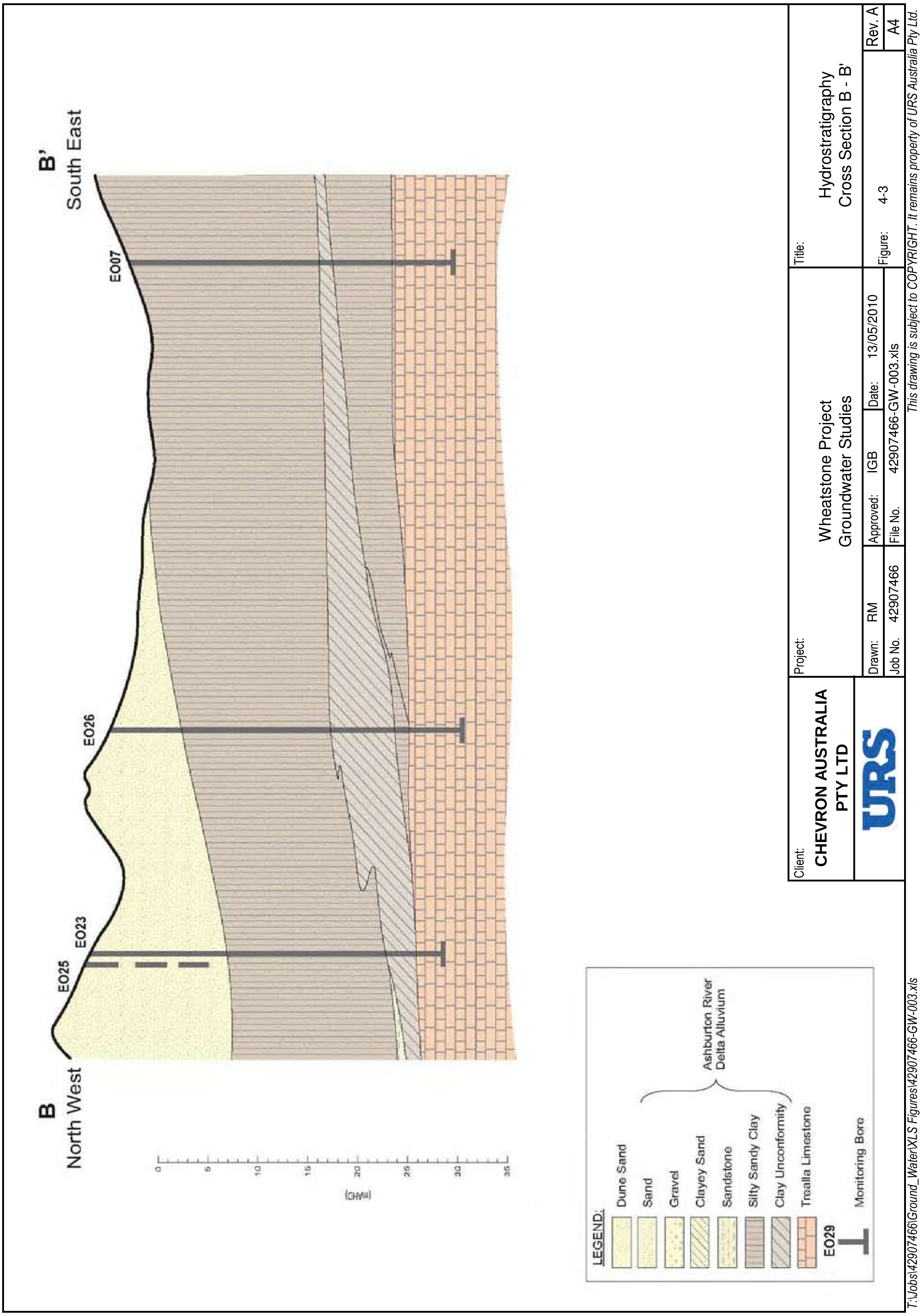
B
North West
B'
South East
EO25
EO23
EO26
EO07
(mAHD)
0
5
10
15
20
25
30
35
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Trealla Limestone
Ashburton River Delta Alluvium
EO29
Monitoring Bore
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
Hydrostratigraphy
Cross Section B - B'
Drawn: RM
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-003.xls
Figure: 4-3
Rev. A
A4
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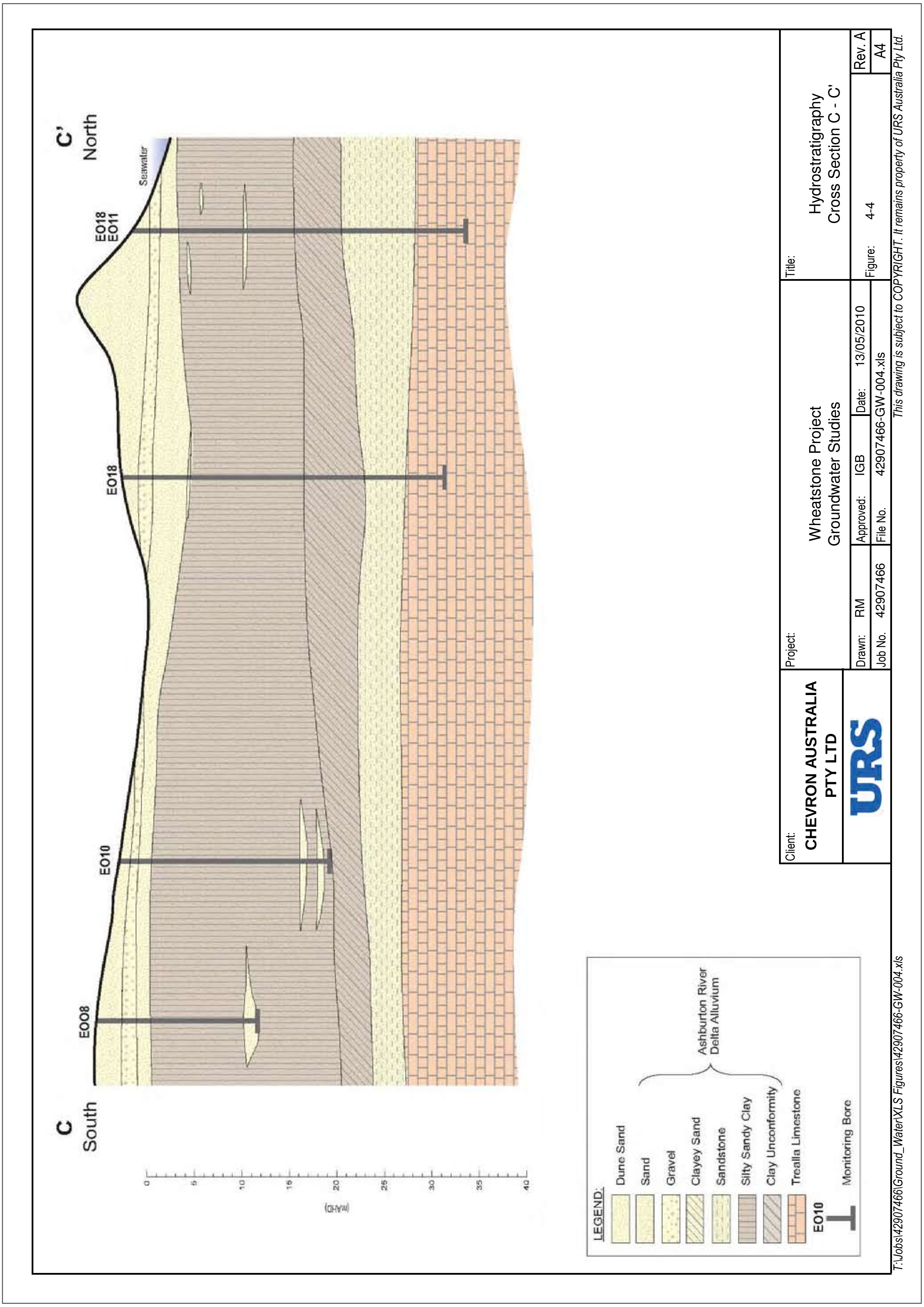
C
South
C'
North
EO08
EO10
EO18
EO18
EO11
Seawater
(mAHD)
0
5
10
15
20
25
30
35
40
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Trealla Limestone
Ashburton River Delta Alluvium
EO10
Monitoring Bore
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Hydrostratigraphy Cross Section C - C'
Drawn: RM
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-004.xls
Figure: 4-4
Rev. A
A4
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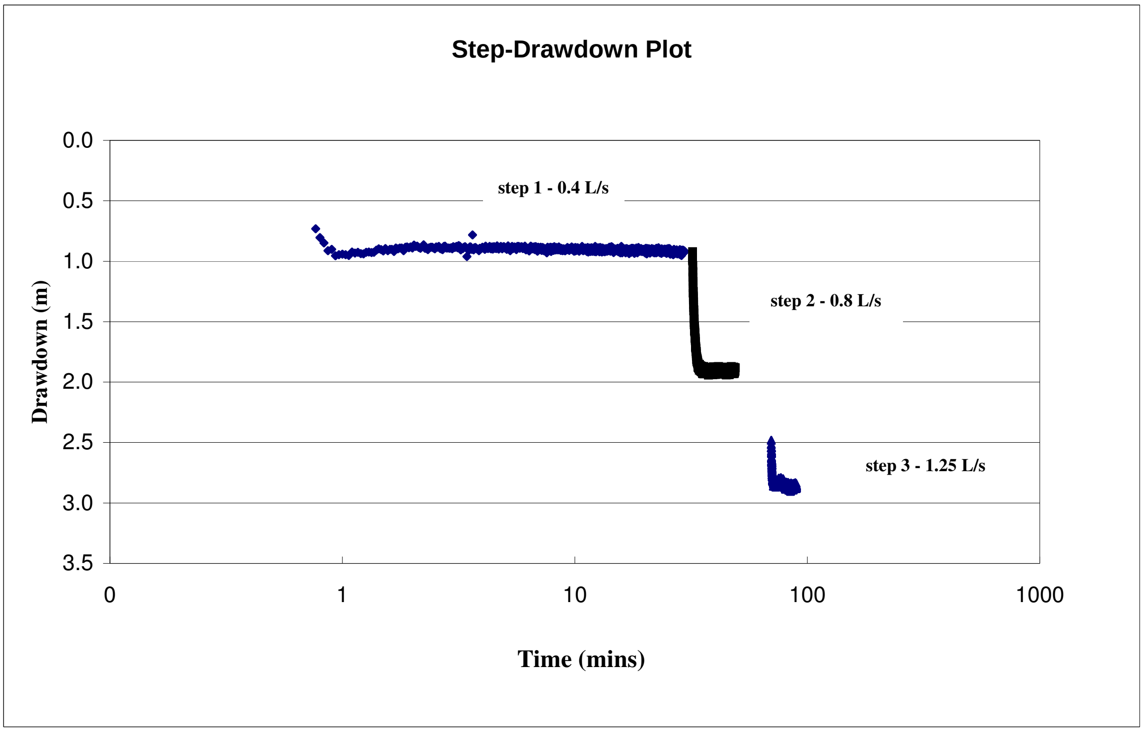

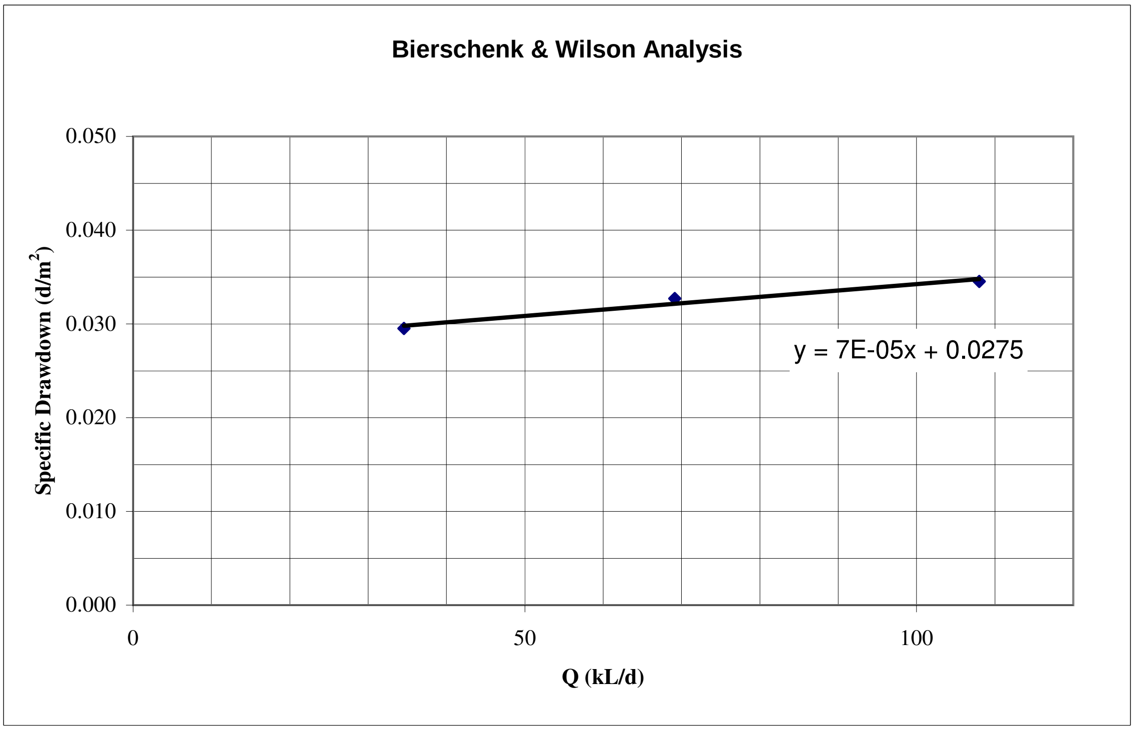

Client:	Project:		Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies		E022 Step-Drawdown Test Bierschenk & Wilson Analysis	
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010	Figure: 4-5	Rev. A
	Job No. 42907466	File No. 42907466-GW-012.xls			A4

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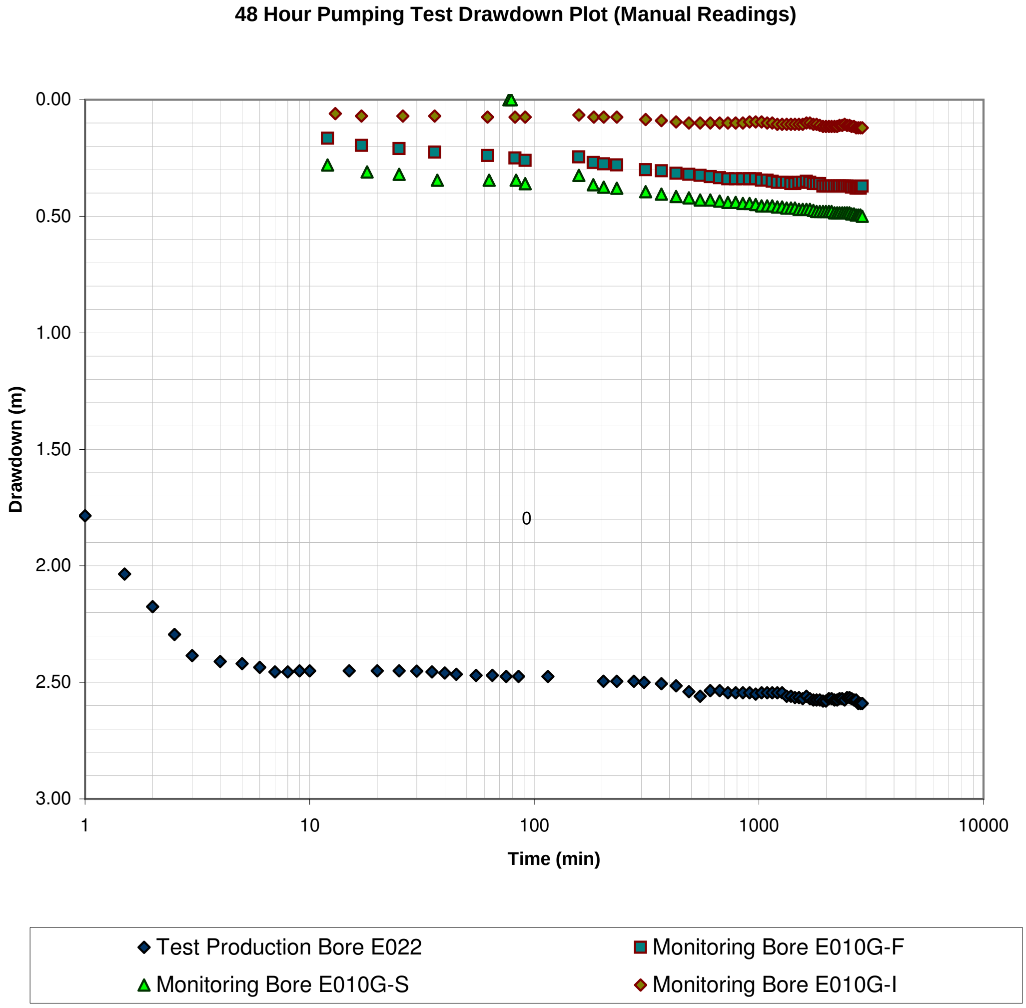

Client:	Project:	Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	E022 Constant Rate Test Drawdown Data	
URS	Drawn: RM · Approved: IGB · Date: 13/05/2010	Figure: 4-6	Rev. A
	Job No. 42907466 · File No. 42907466-GW-013.xls		A4

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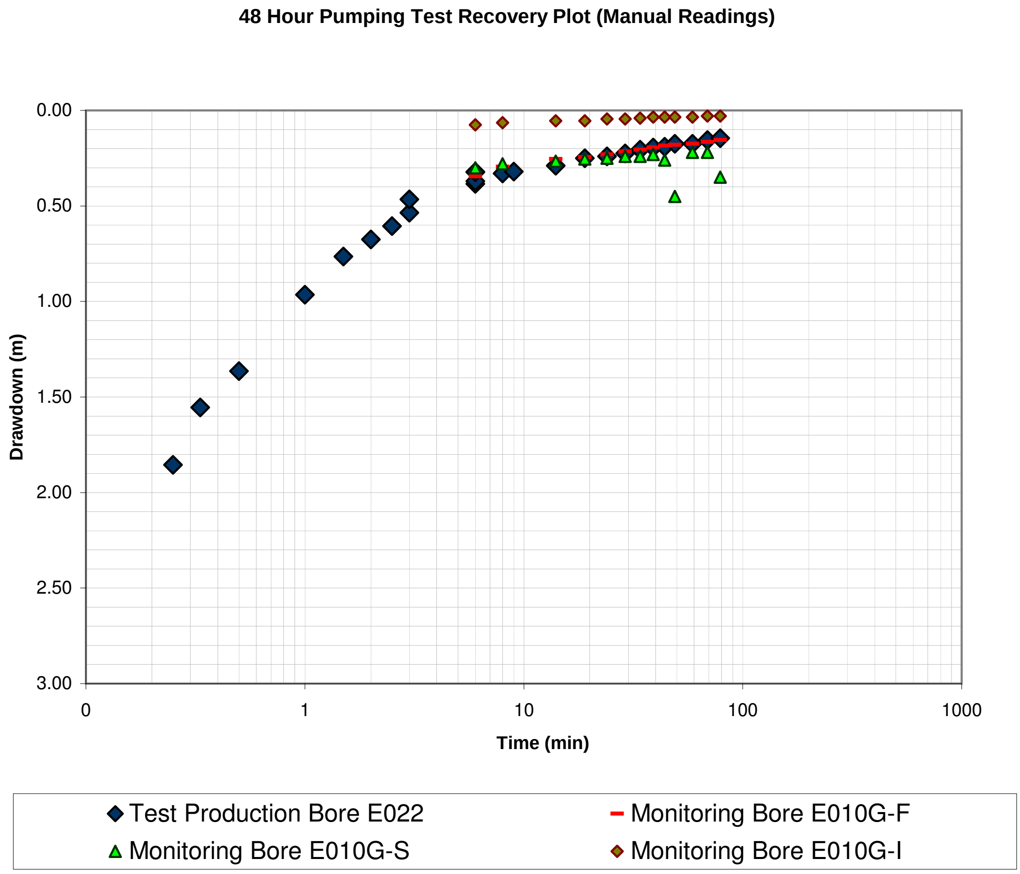

Client:	Project:			Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies			E022 Constant Rate Test Recovery Data	
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010	Figure: 4-7	Rev. A
	Job No. 42907466	File No. 42907466-GW-014.xls			A4

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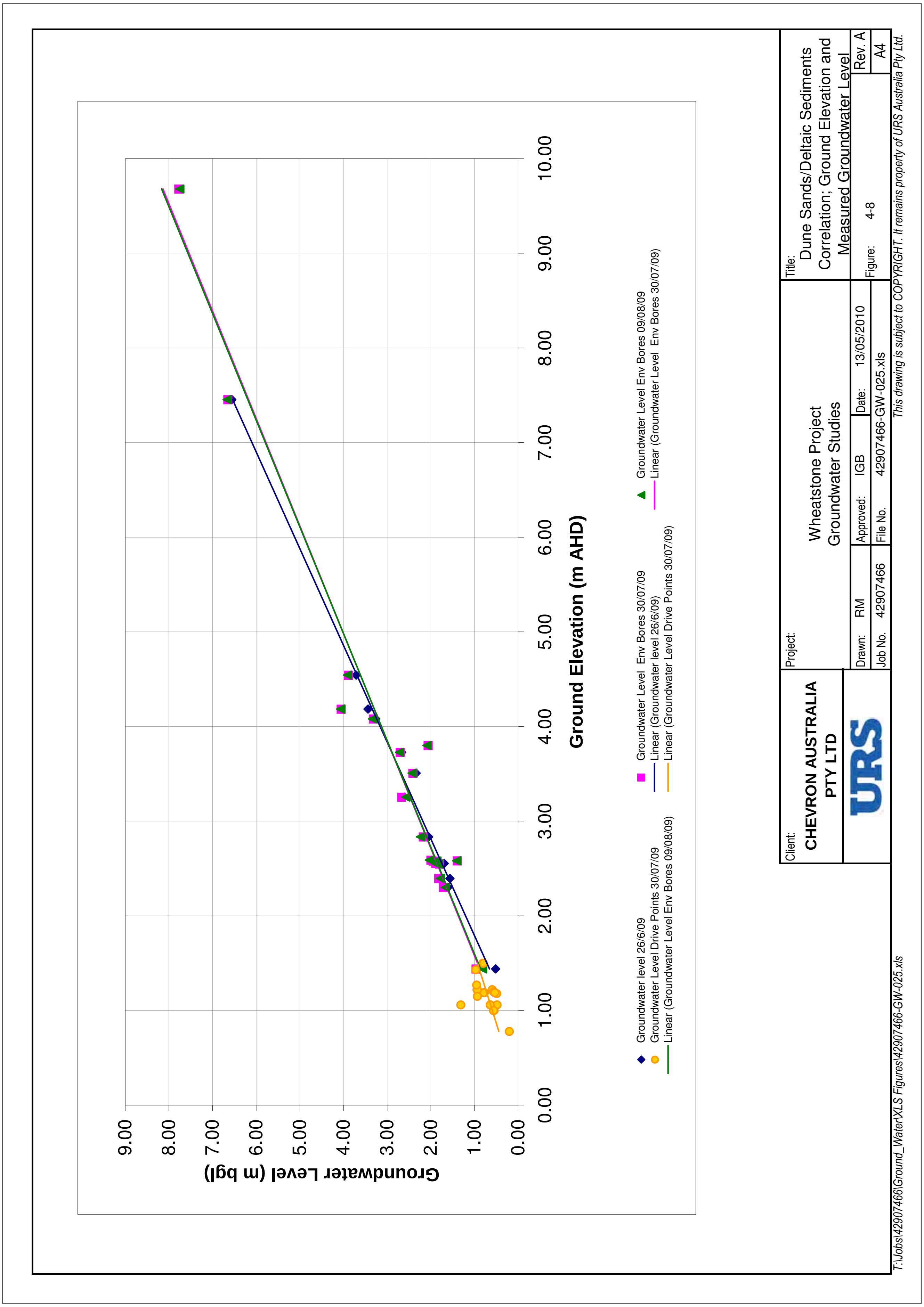
Groundwater Level (m bgl)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Ground Elevation (m AHD)
Groundwater level 26/6/09
Groundwater Level Drive Points 30/07/09
Linear (Groundwater Level Env Bores 09/08/09)
Groundwater Level Env Bores 30/07/09
Linear (Groundwater level 26/6/09)
Linear (Groundwater Level Drive Points 30/07/09)
Groundwater Level Env Bores 09/08/09
Linear (Groundwater Level Env Bores 30/07/09)
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project
Groundwater Studies
Title:
Dune Sands/Deltaic Sediments
Correlation; Ground Elevation and
Measured Groundwater Level
Drawn: RM
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-025.xls
Figure: 4-8
A4
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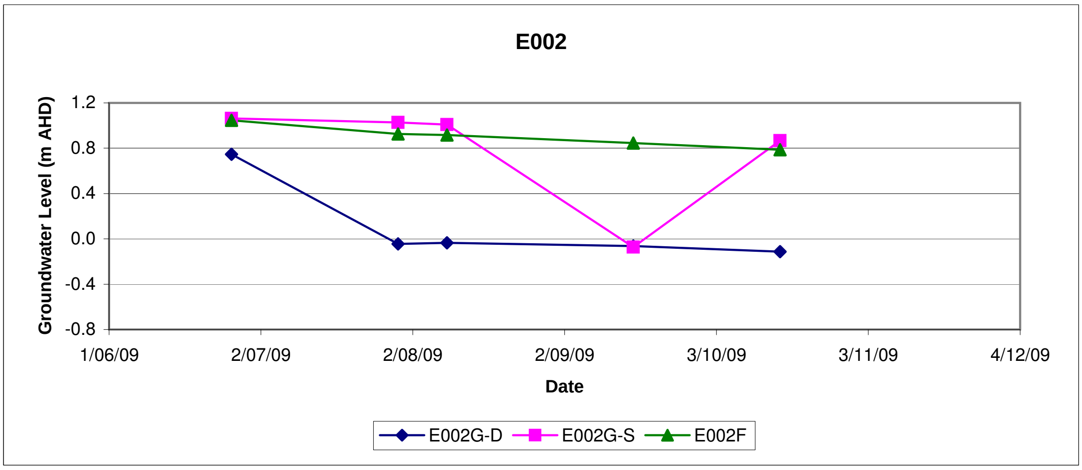

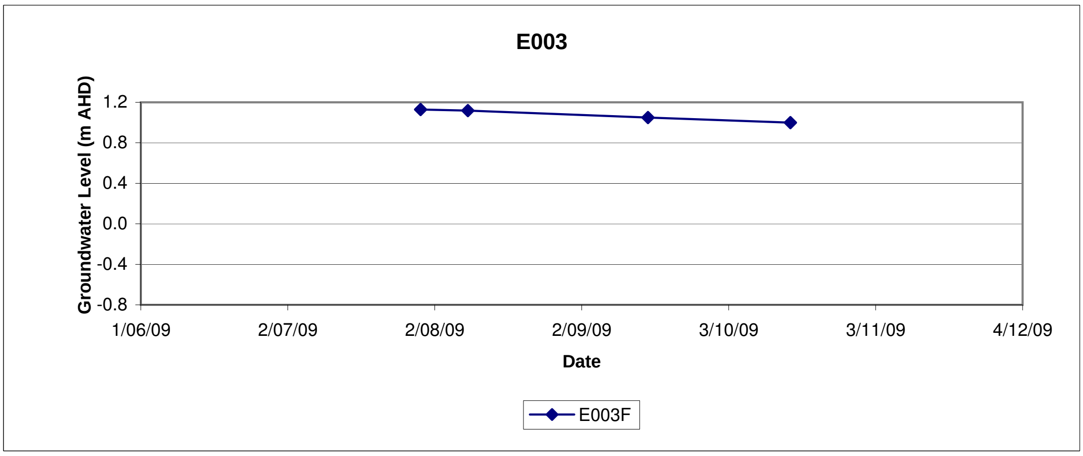

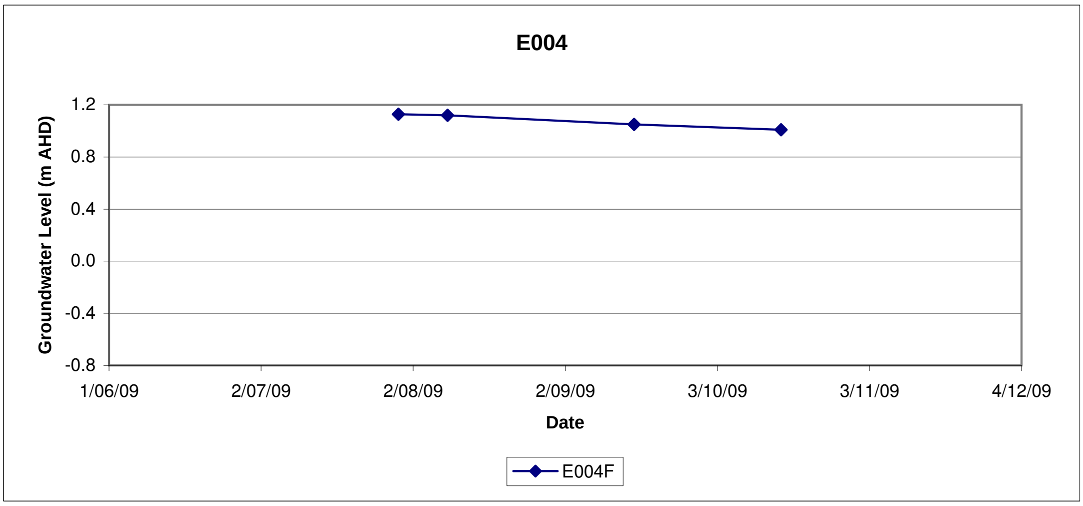

Client:	Project:				Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies				Monitoring Bore Hydrographs	
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010		Figure: 4-9a	Rev. A
	Job No. 42907466	File No. 42907466-GW-015.xls				A4

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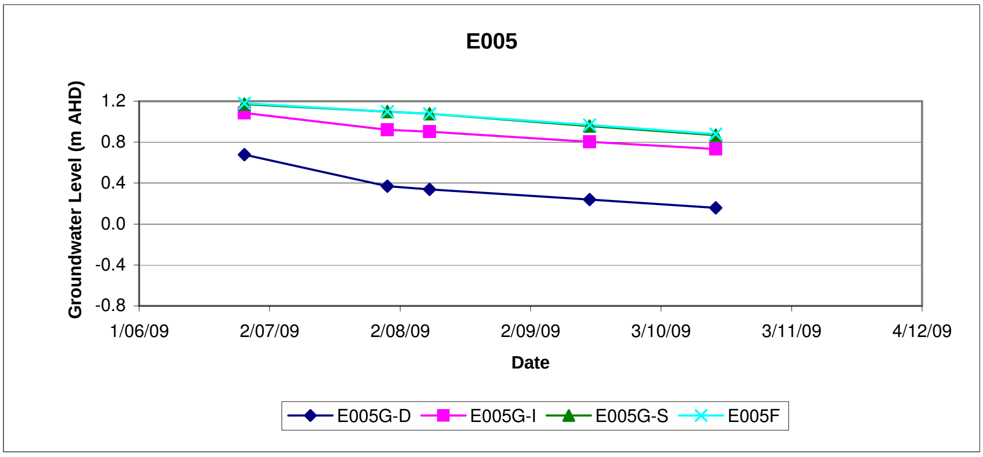

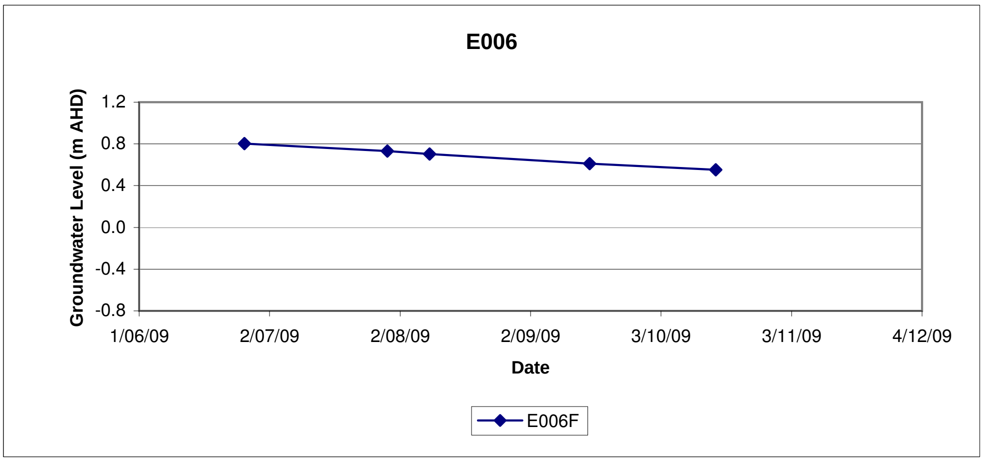

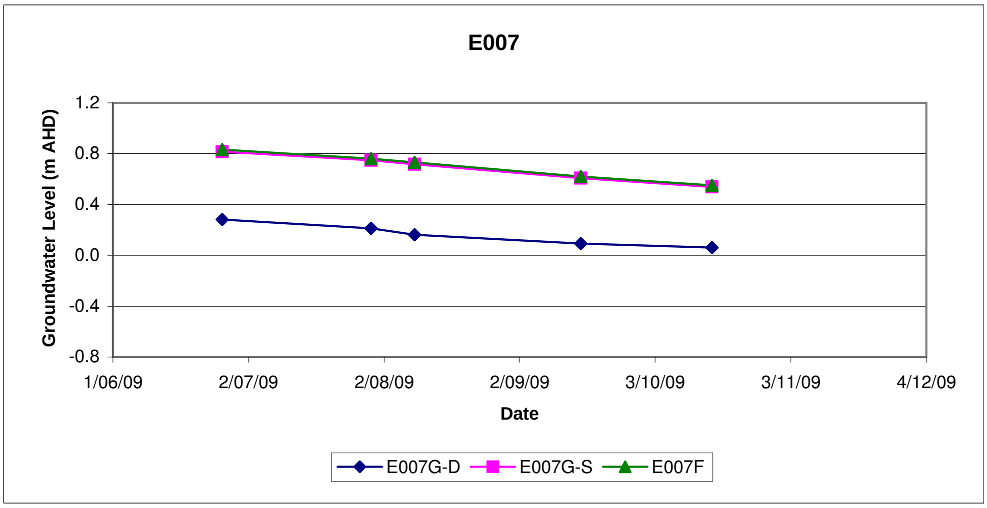

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies		Title: Monitoring Bore Hydrographs
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010
	Job No. 42907466	File No. 42907466-GW-016.xls	Figure: 4-9b — Rev. A — A4

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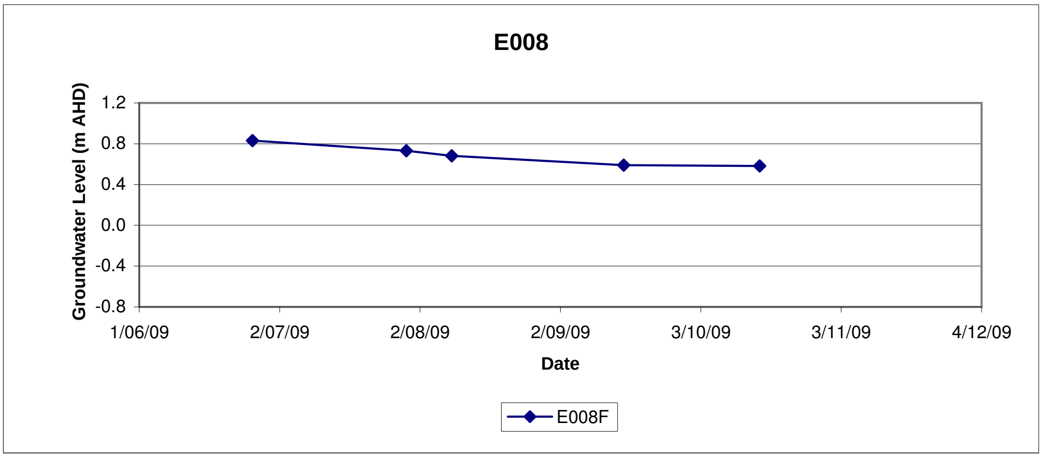

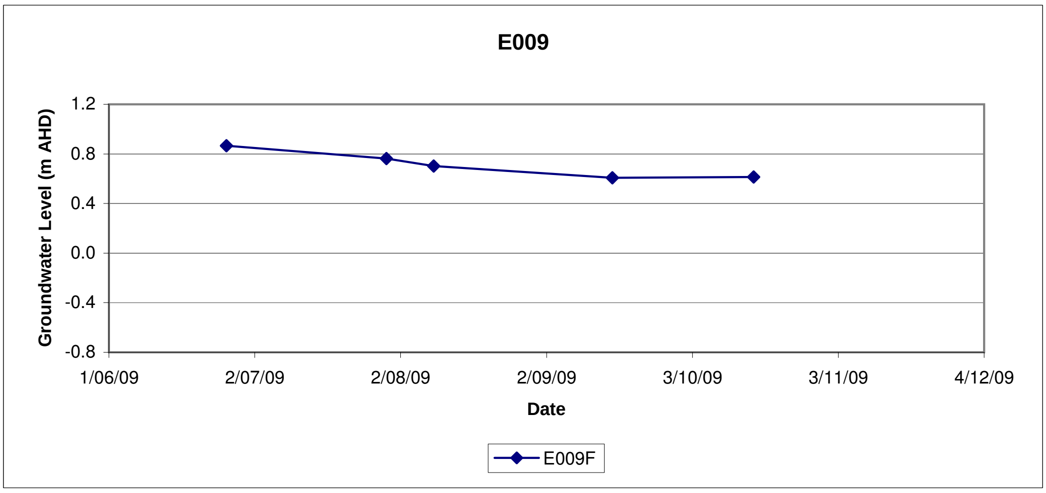

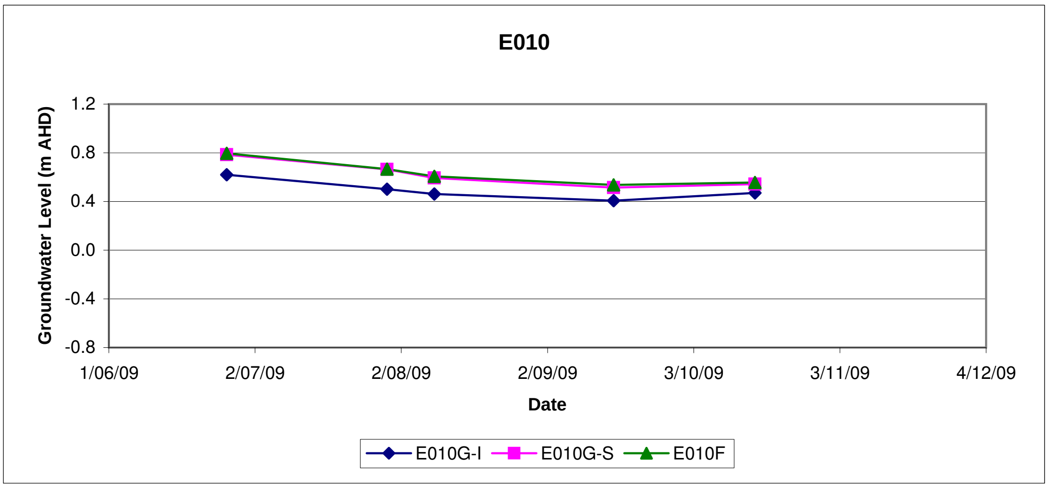

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies			Title: Monitoring Bore Hydrographs
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010	Figure: 4-9c — Rev. A
	Job No. 42907466	File No. 42907466-GW-017.xls		A4

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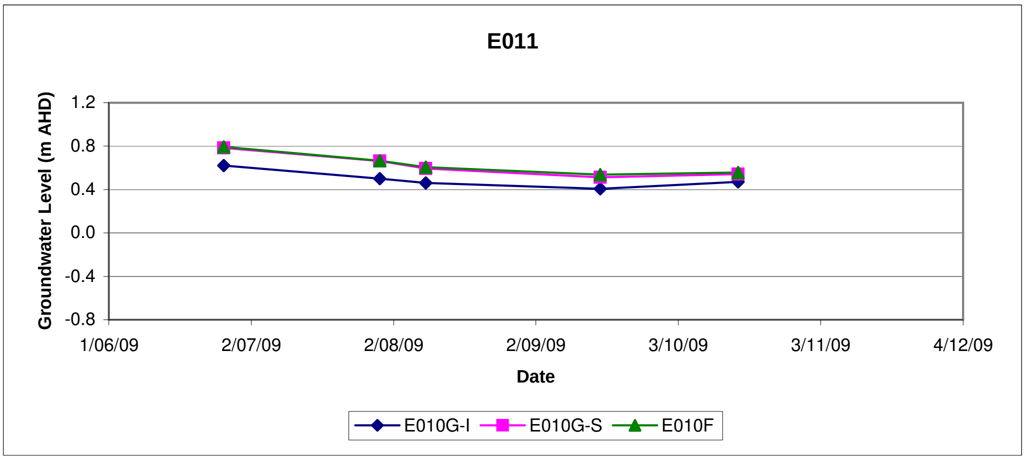

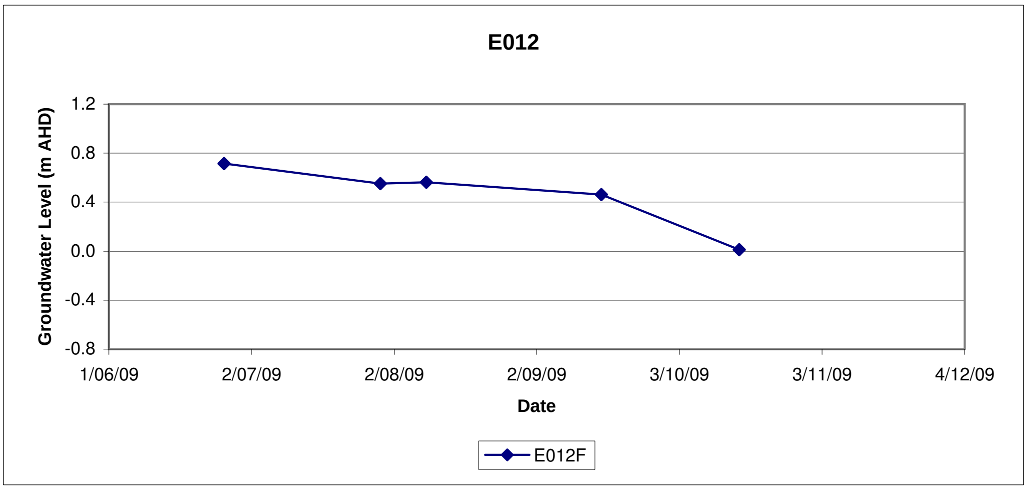

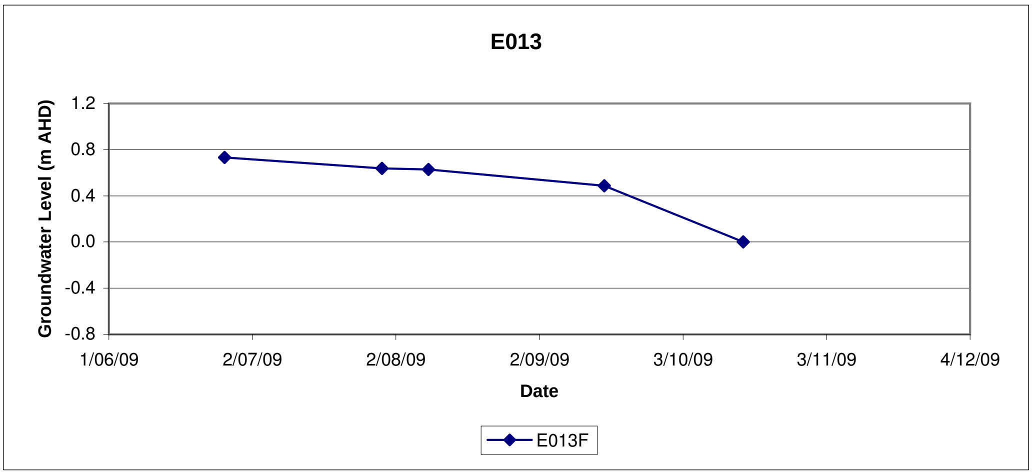

Client:	Project:	Title:
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Monitoring Bore Hydrographs
URS	Drawn: RM; Approved: IGB; Date: 13/05/2010	Figure: 4-9d; Rev. A
	Job No. 42907466; File No. 42907466-GW-018.xls	A4

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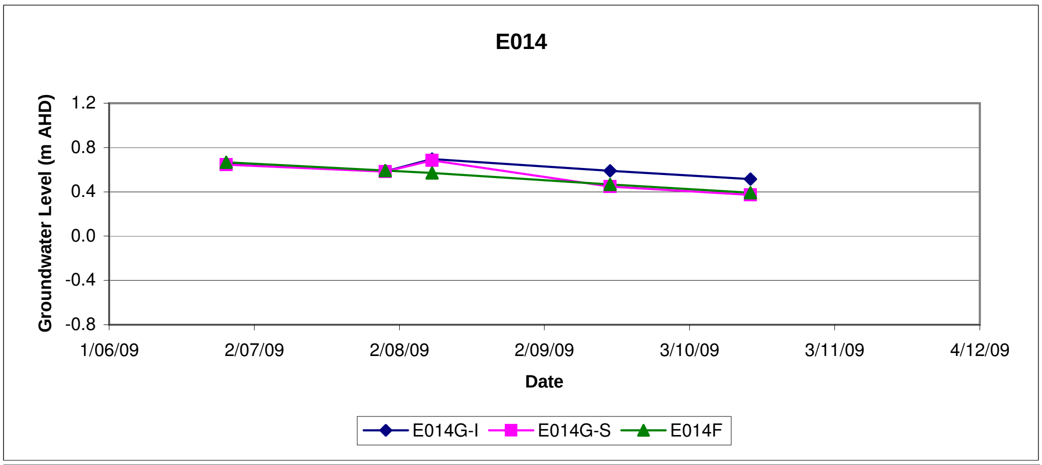

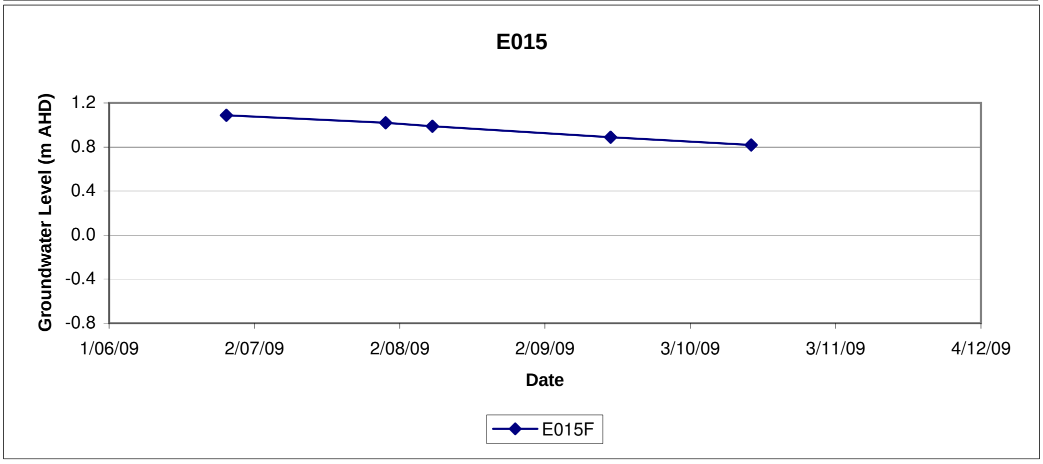

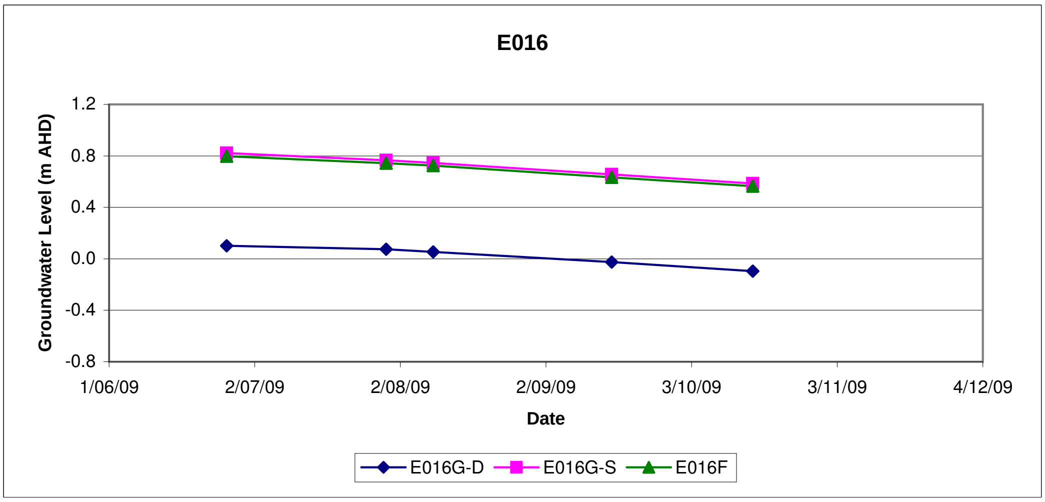

Client: **CHEVRON AUSTRALIA PTY LTD**

URS

Project: Wheatstone Project Groundwater Studies

Title: Monitoring Bore Hydrographs

Drawn: RM | Approved: IGB | Date: 13/05/2010

Job No. 42907466 | File No. 42907466-GW-019.xls

Figure: 4-9e | Rev. A | A4

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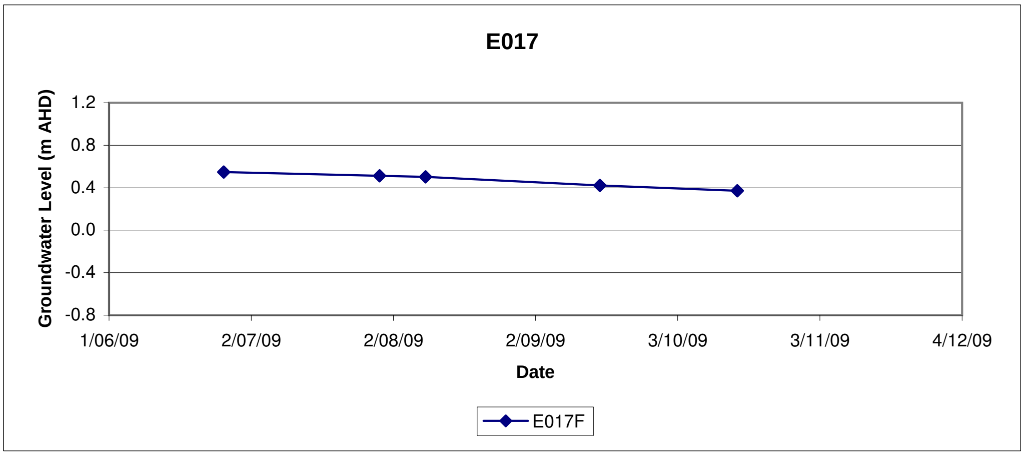

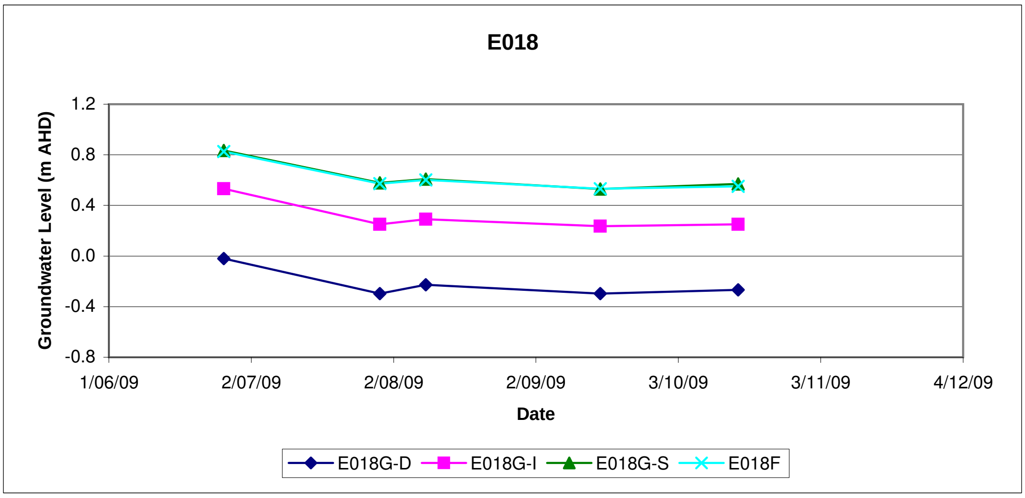

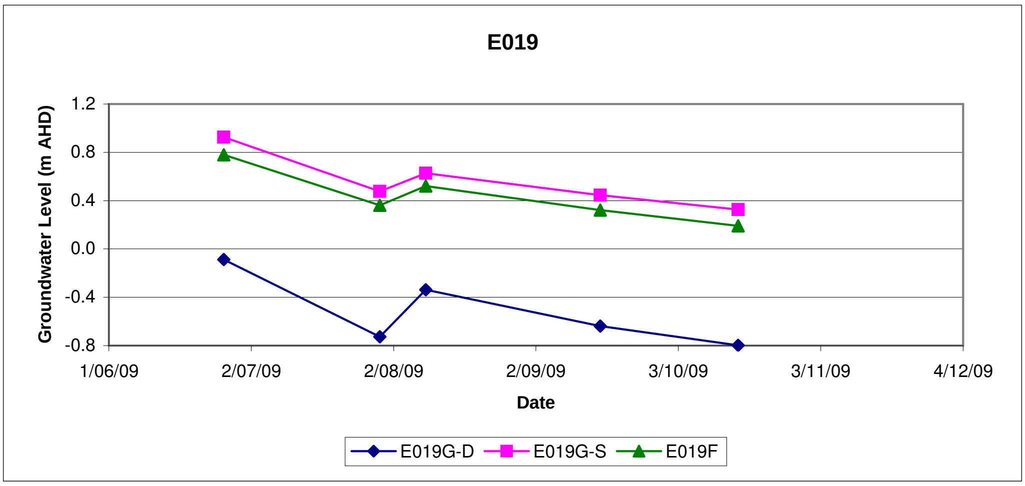

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies			Title: Monitoring Bore Hydrographs	
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010	Figure: 4-9f	Rev. A
	Job No. 42907466	File No. 42907466-GW-020.xls			A4

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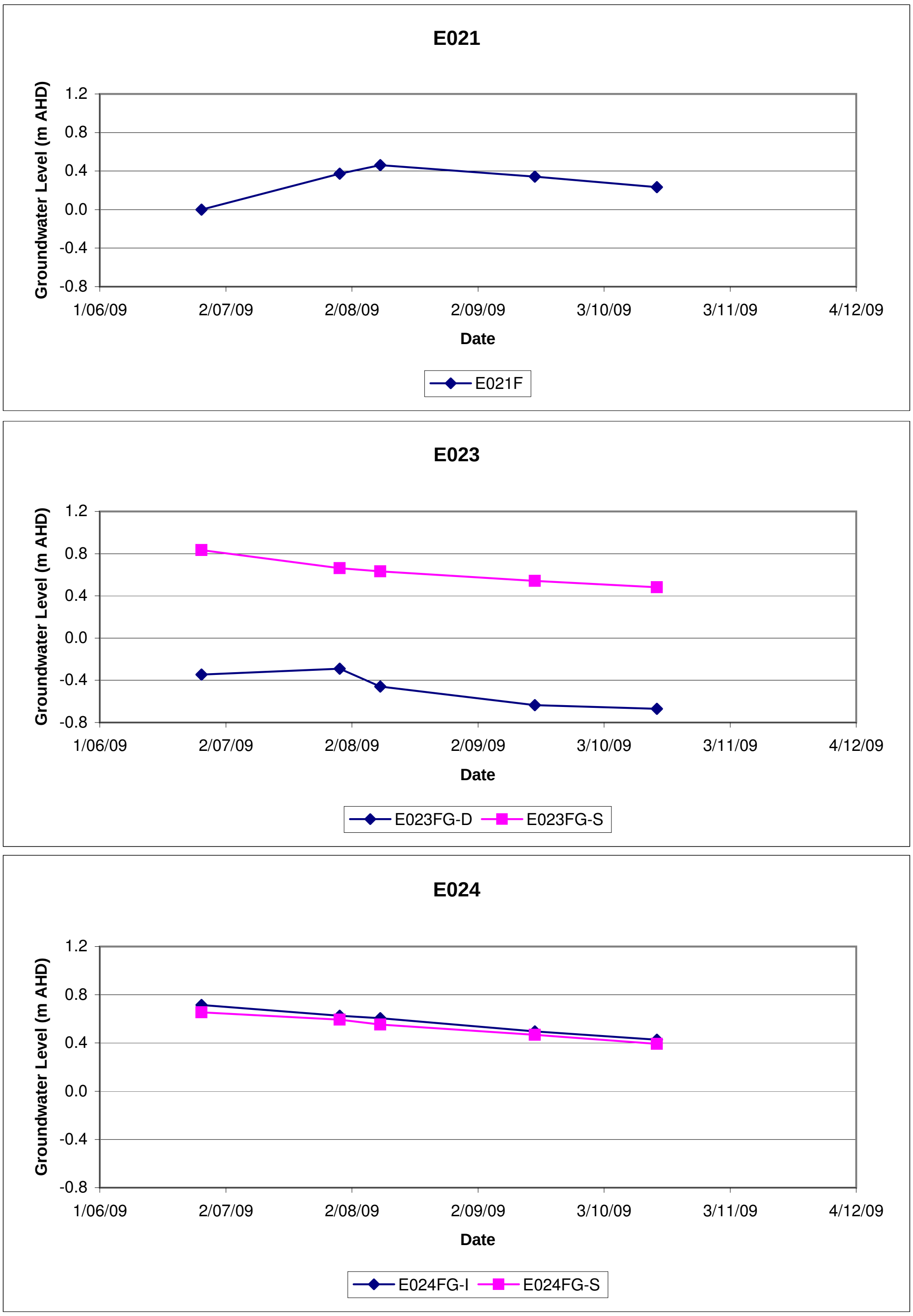

Client:	Project:	Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Monitoring Bore Hydrographs	
URS	Drawn: RM / Approved: IGB / Date: 13/05/2010	Figure: 4-9g	Rev. A
	Job No. 42907466 / File No. 42907466-GW-021.xls		A4

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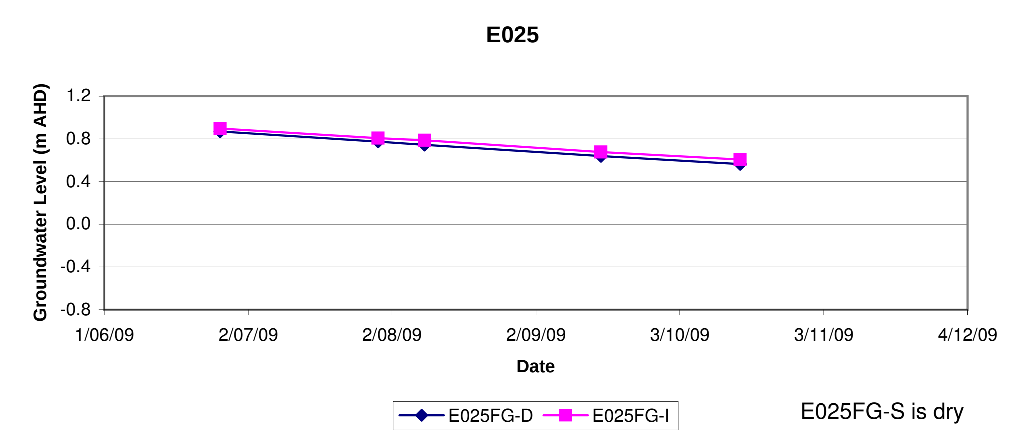

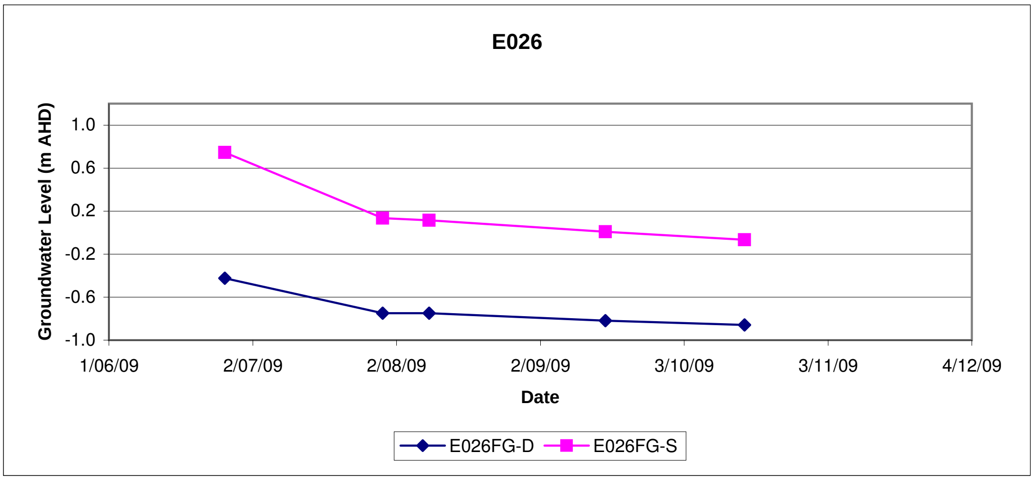

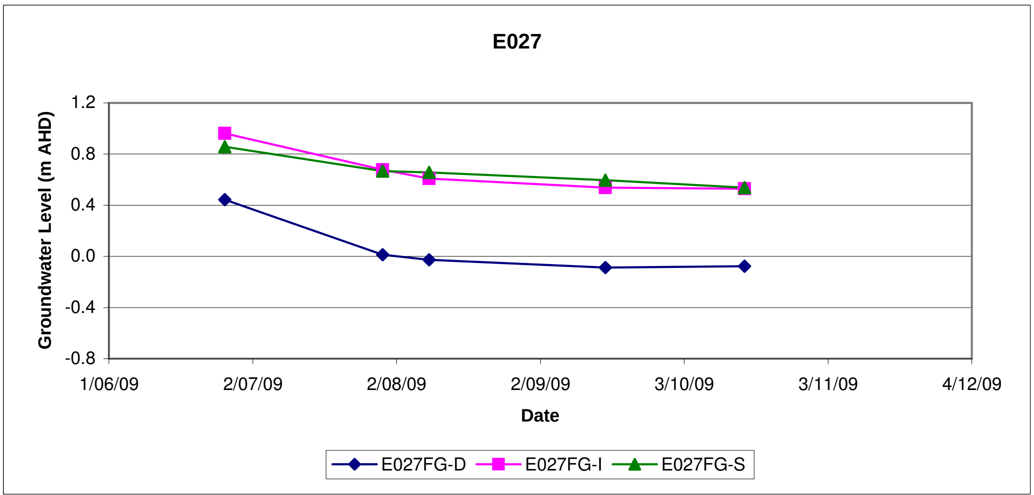

Client:	Project:		Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies		Monitoring Bore Hydrographs	
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010	Figure: 4-9h	Rev. A
	Job No. 42907466	File No. 42907466-GW-022.xls			A4

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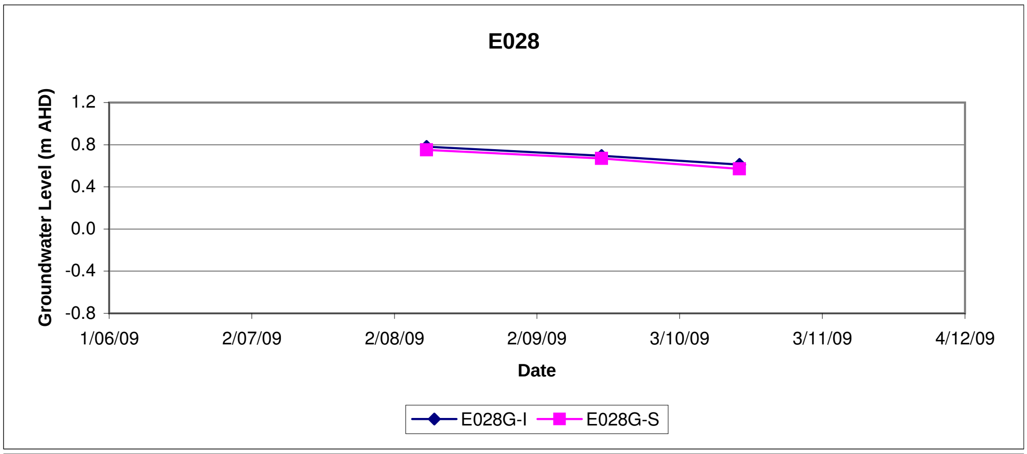

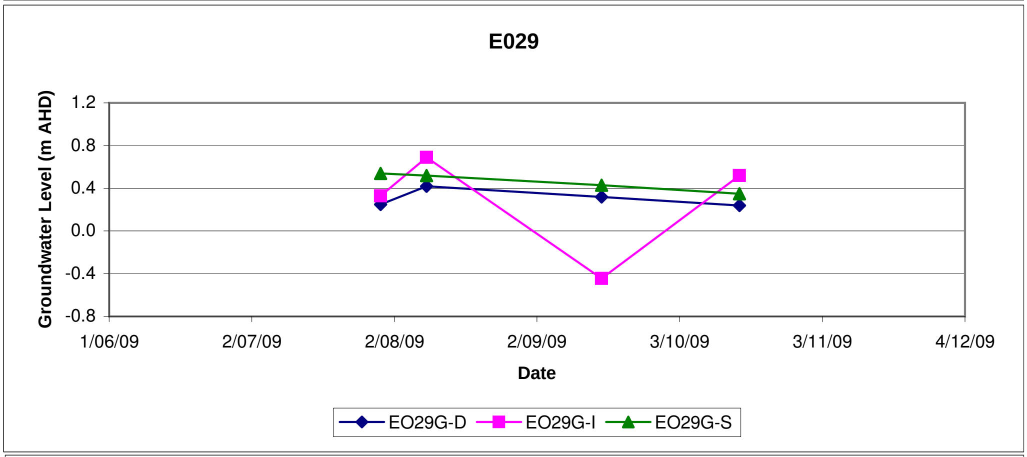

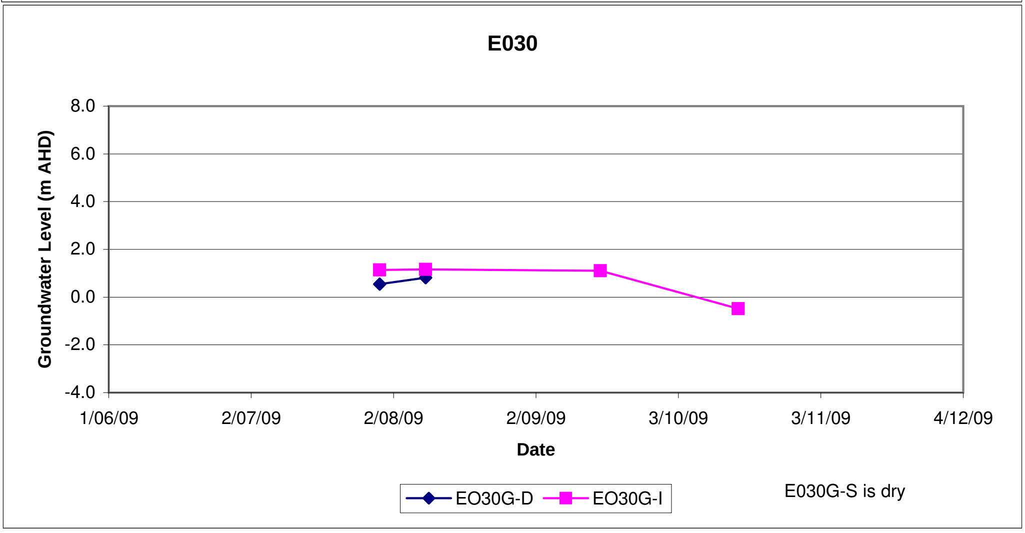

Client:	Project:		Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies		Monitoring Bore Hydrographs	
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010	Figure: 4-9i	Rev. A
	Job No. 42907466	File No. 42907466-GW-023.xls			A4

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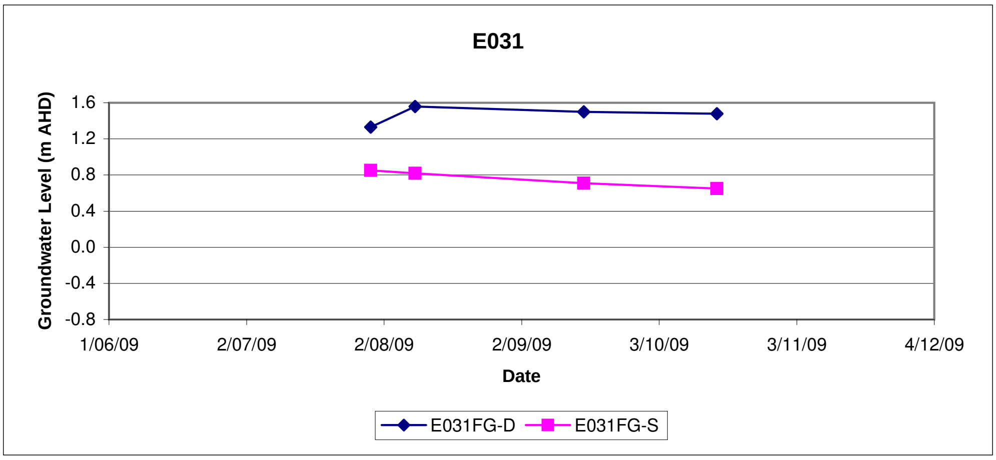

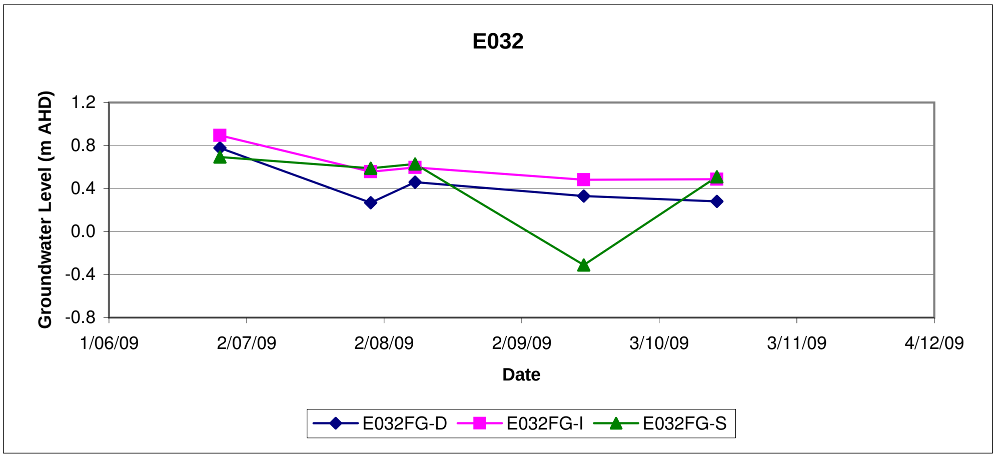

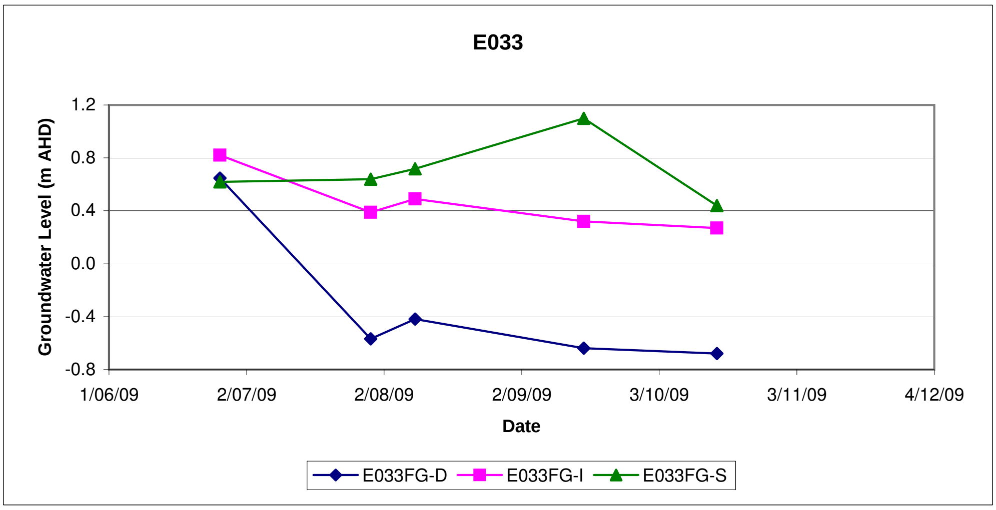

Client:	Project:		Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies		Monitoring Bore Hydrographs	
URS	Drawn: RM	Approved: IGB	Date: 13/05/2010	Figure: 4-9j	Rev. A
	Job No. 42907466	File No. 42907466-GW-024.xls			A4

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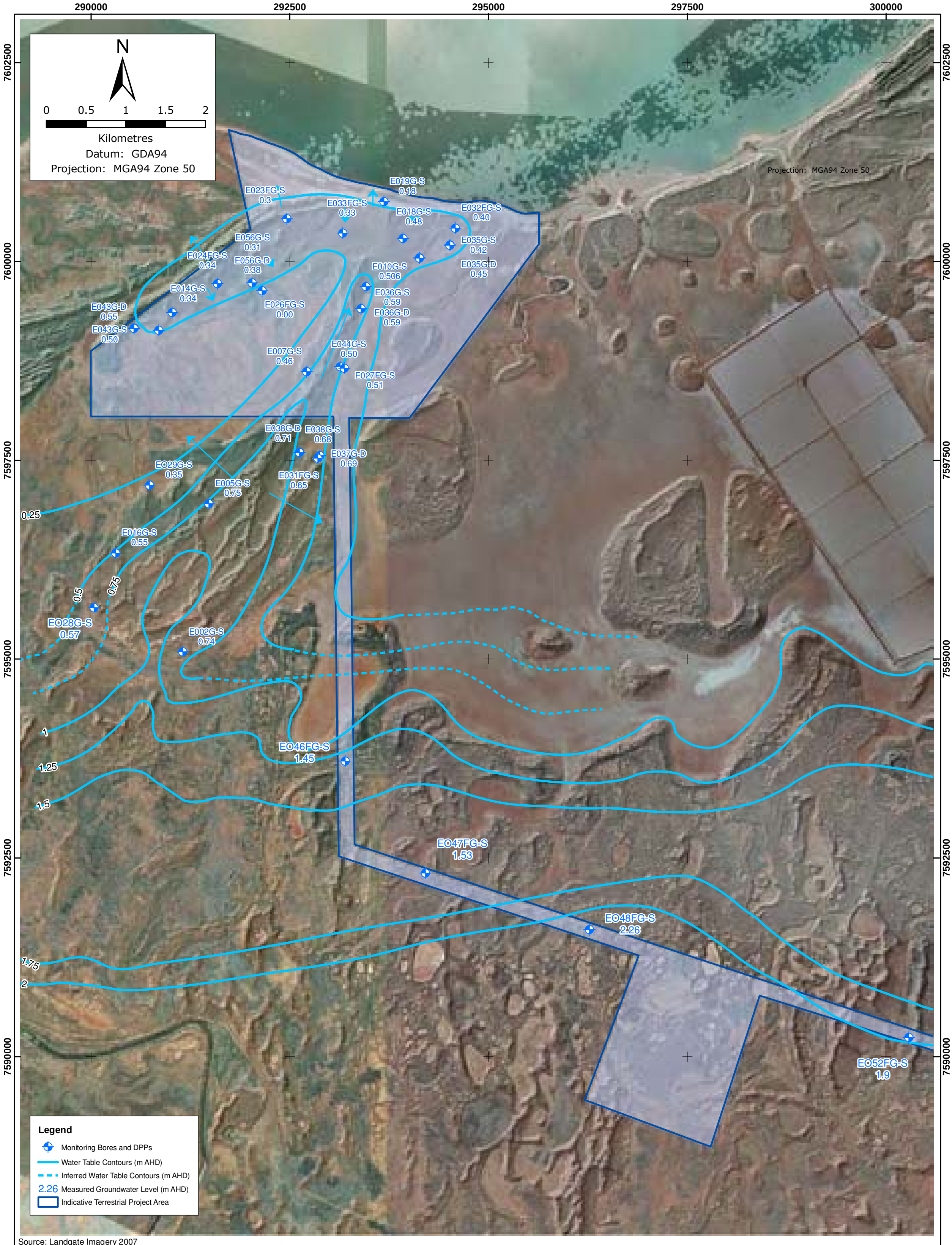

Client	Project		Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies		Water Table Elevation (October 2009)	
URS	Drawn: IGB	Approved: IGB	Date: 12/05/2010	Figure: 4-10	Rev. A
	Job No.: 42907466	File No.: 42907466-GW-030.mxd			A3

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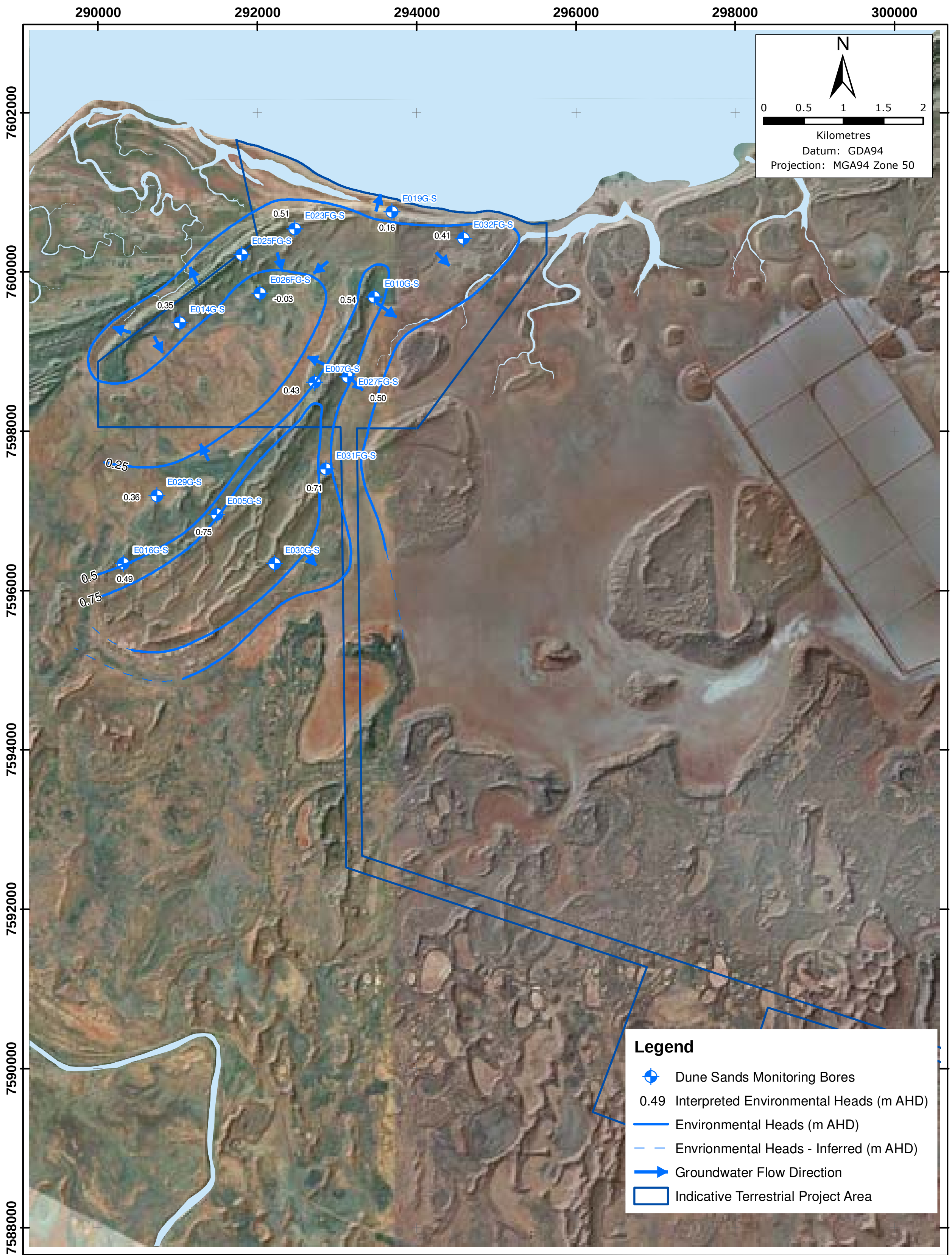

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Environmental Heads in Dune Sands (October 2009)	
URS	Drawn: IGB/MR · Approved: IGB · Date: 11/05/2010	Figure: 4-11	Rev. A
	Job No.: 42907466 · File No.: 42907466-GW-033.mxd		A4

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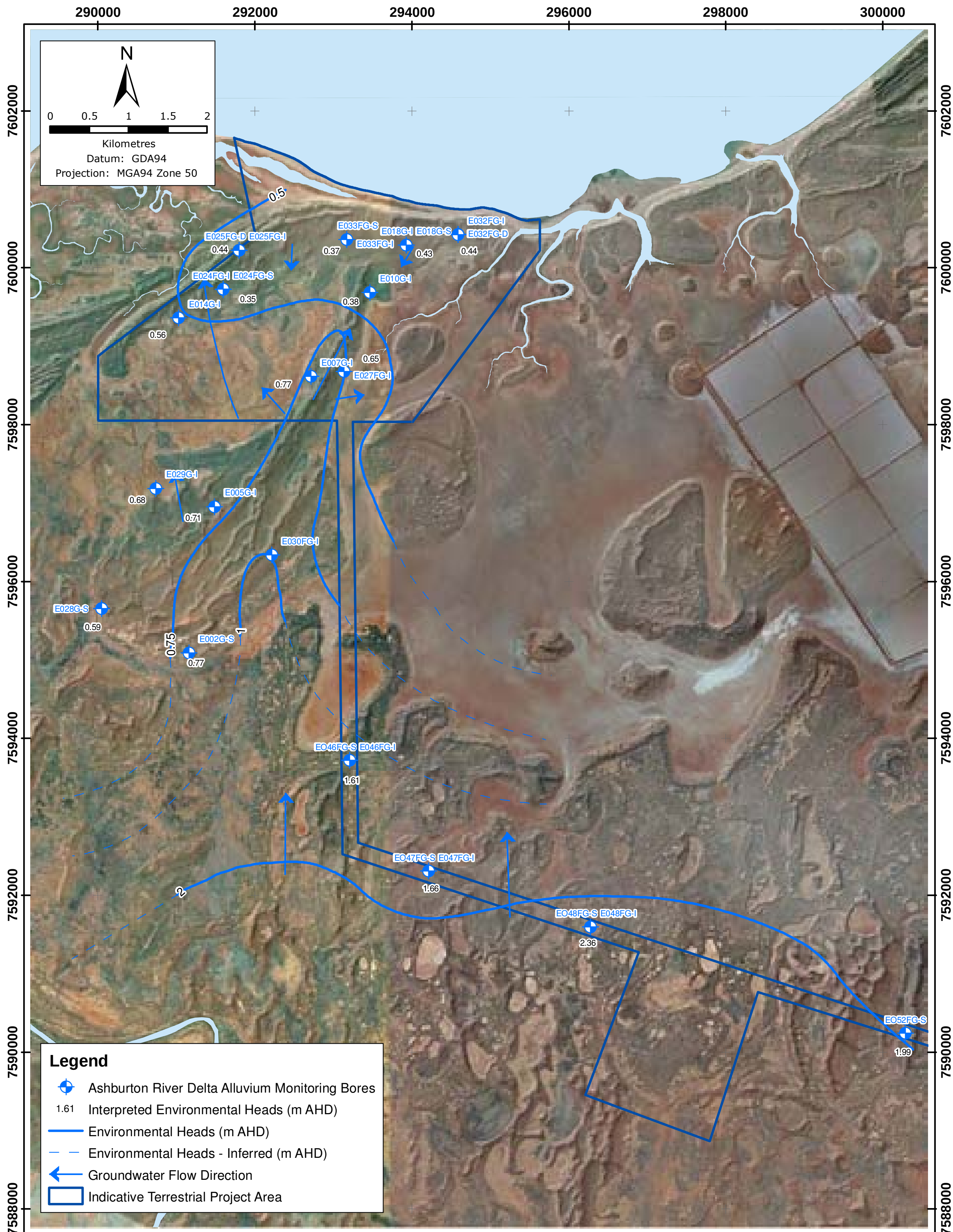

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Environmental Heads in Ashburton River Delta Alluvium (October 2009)
URS	Drawn: IGB/MR; Approved: MR; Date: 11/05/2010; Job No.: 42907466; File No.: 42907466-GW-036.mxd	Figure: 4-12; Rev. A; A4

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290000
292000
294000
296000
298000
300000
7602000
7600000
7598000
7596000
7594000
7592000
7590000
7588000
N
0 0.5 1 1.5 2
Kilometres
Datum: GDA94
Projection: MGA94 Zone 50
E019G-D
0.43
E023FG-D
E033FG-D
E018G-D
2.44
1.19
0.42
E026FG-D
1.16
E007G-D
E027FG-D
1.5
0.49
E031FG-D
2.79
E029G-D
0.96
E005G-D
2.22
E016G-D
E030FG-D
1
1.5
1.60
2
E002G-D
2.20
2.5
E047FG-D
2.94
3
4
E052FG-D
4.73
Legend
Trealla Limestone Monitoring Bores
2.22 Interpreted Environmental Heads (m AHD)
Environmental Heads (m AHD)
Environmental Heads - Inferred (m AHD)
Groundwater Flow Direction
Indicative Terrestrial Project Area
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project
Groundwater Studies
Drawn: IGB\MR
Approved: IGB
Date: 11/05/2010
Job No.: 42907466
File No.: 42907466-GW-038.mxd
Title
Environmental Heads in
Trealla Limestone
(October 2009)
Figure: 4-13
Rev. A
A4
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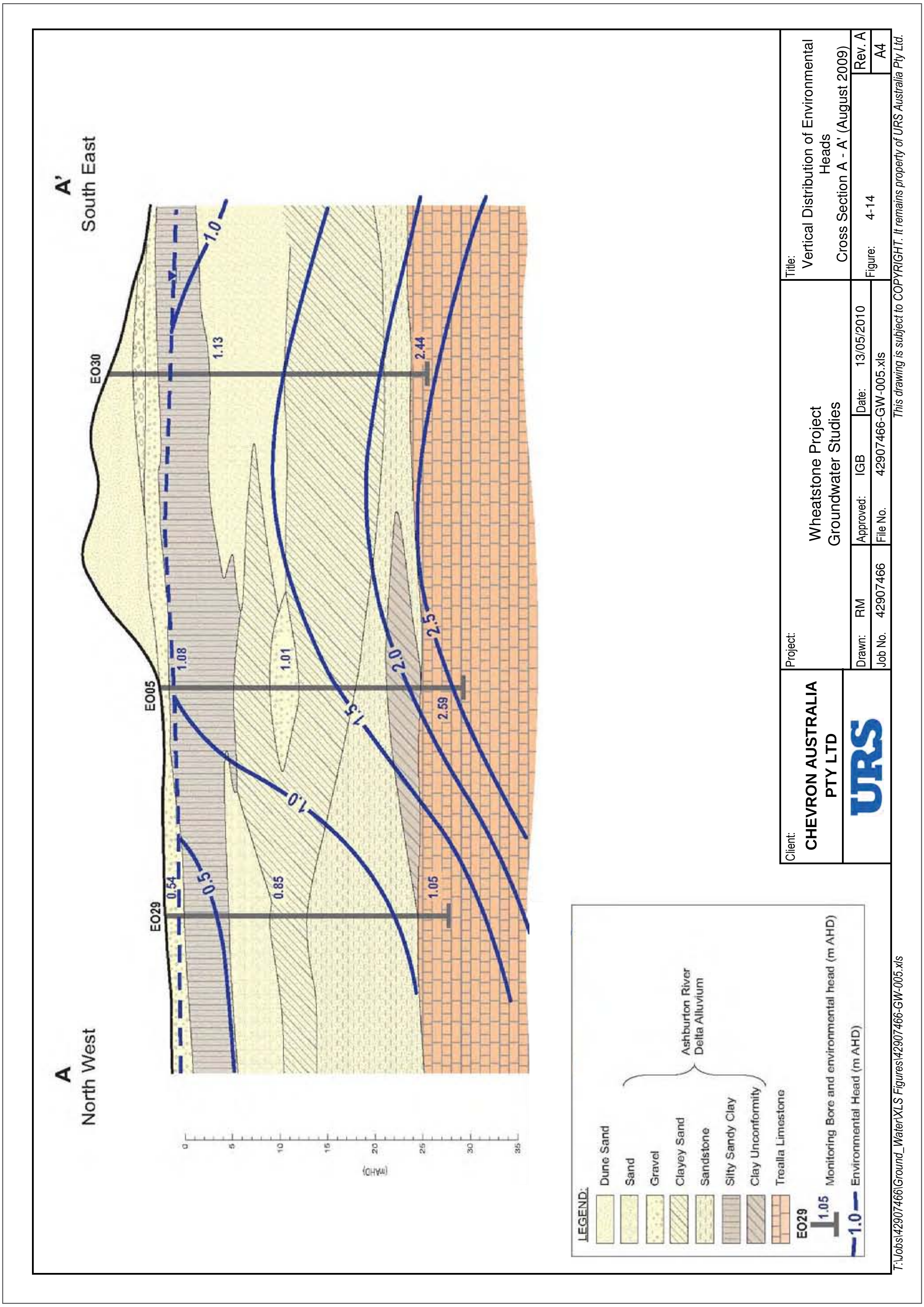
A
North West
A'
South East
EO29
EO05
EO30
0.54
0.5
0.85
1.05
1.08
1.01
1.0
1.5
2.0
2.5
2.59
1.13
2.44
1.0
(mAHD)
0
5
10
15
20
25
30
35
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Ashburton River Delta Alluvium
Trealla Limestone
EO29 1.05 Monitoring Bore and environmental head (m AHD)
1.0 Environmental Head (m AHD)
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project
Groundwater Studies
Title:
Vertical Distribution of Environmental Heads
Cross Section A - A' (August 2009)
Drawn: RM
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-005.xls
Figure: 4-14
A4
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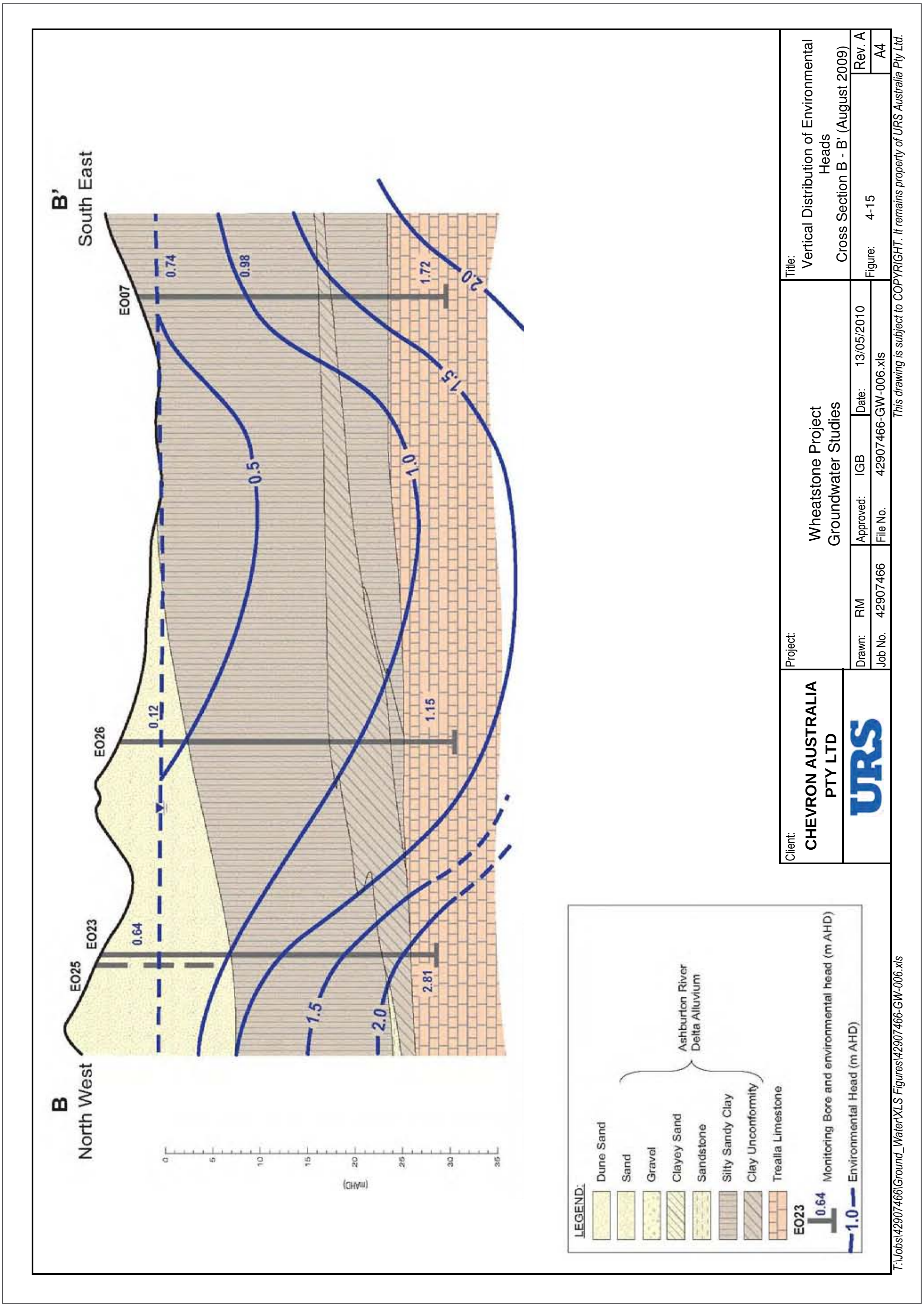
B
North West
B'
South East
EO25
EO23
EO26
EO07
0.64
0.12
0.74
0.98
1.72
2.81
1.15
0.5
1.0
1.5
2.0
0
5
10
15
20
25
30
35
(mAHD)
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Ashburton River Delta Alluvium
Trealla Limestone
EO23 0.64 Monitoring Bore and environmental head (m AHD)
1.0 Environmental Head (m AHD)
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Drawn: RM
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-006.xls
Title:
Vertical Distribution of Environmental Heads
Cross Section B - B' (August 2009)
Figure: 4-15
Rev. A
A4
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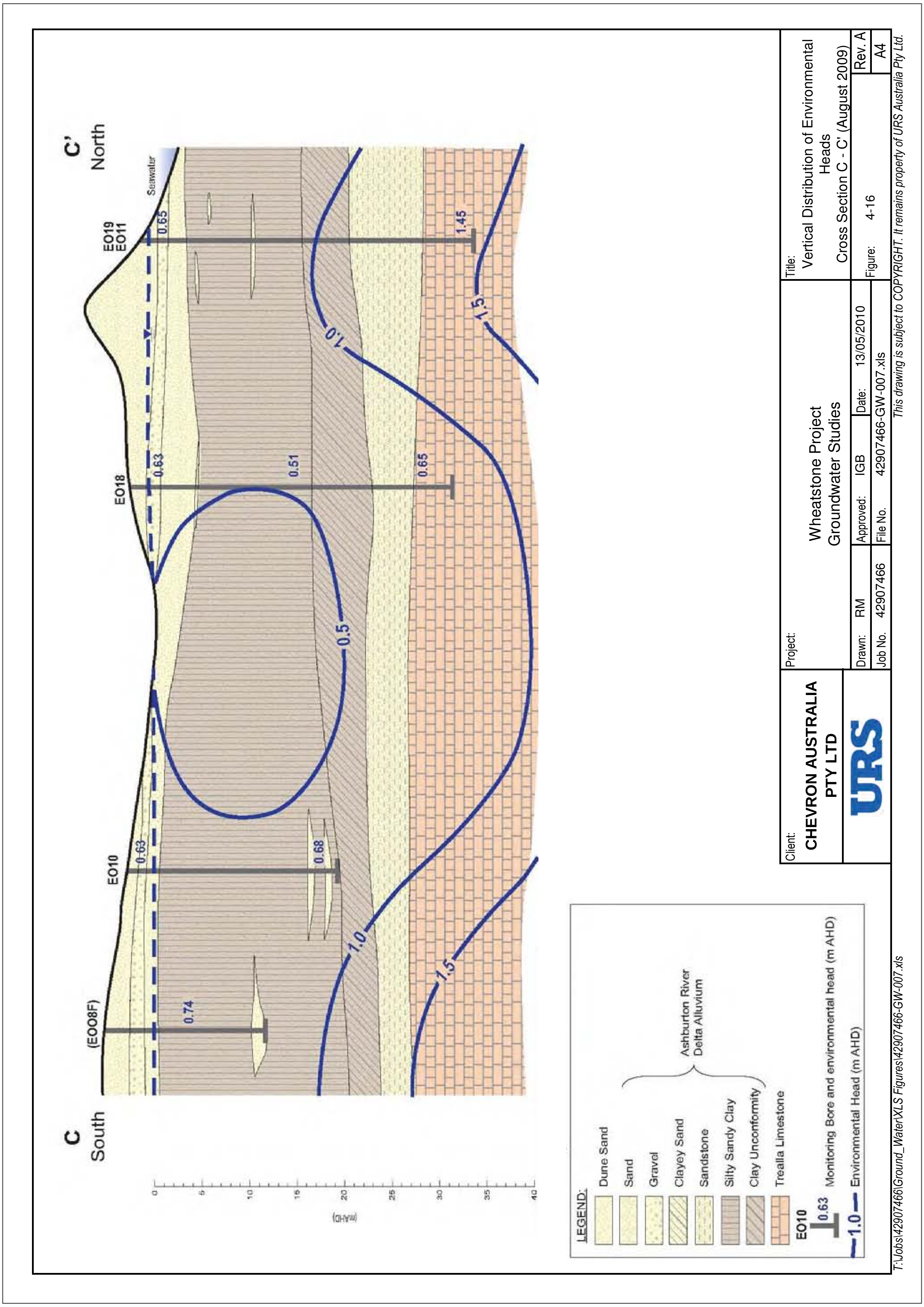
C
South
C'
North
(EO08F)
EO10
EO18
EO19
EO11
Seawater
0.74
0.63
0.68
0.63
0.51
0.65
0.65
1.45
1.0
1.5
0.5
(mAHD)
0
5
10
15
20
25
30
35
40
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Trealla Limestone
Ashburton River Delta Alluvium
Monitoring Bore and environmental head (m AHD)
Environmental Head (m AHD)
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project
Groundwater Studies
Title:
Vertical Distribution of Environmental Heads
Cross Section C - C' (August 2009)
Drawn: RM
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-007.xls
Figure: 4-16
A4
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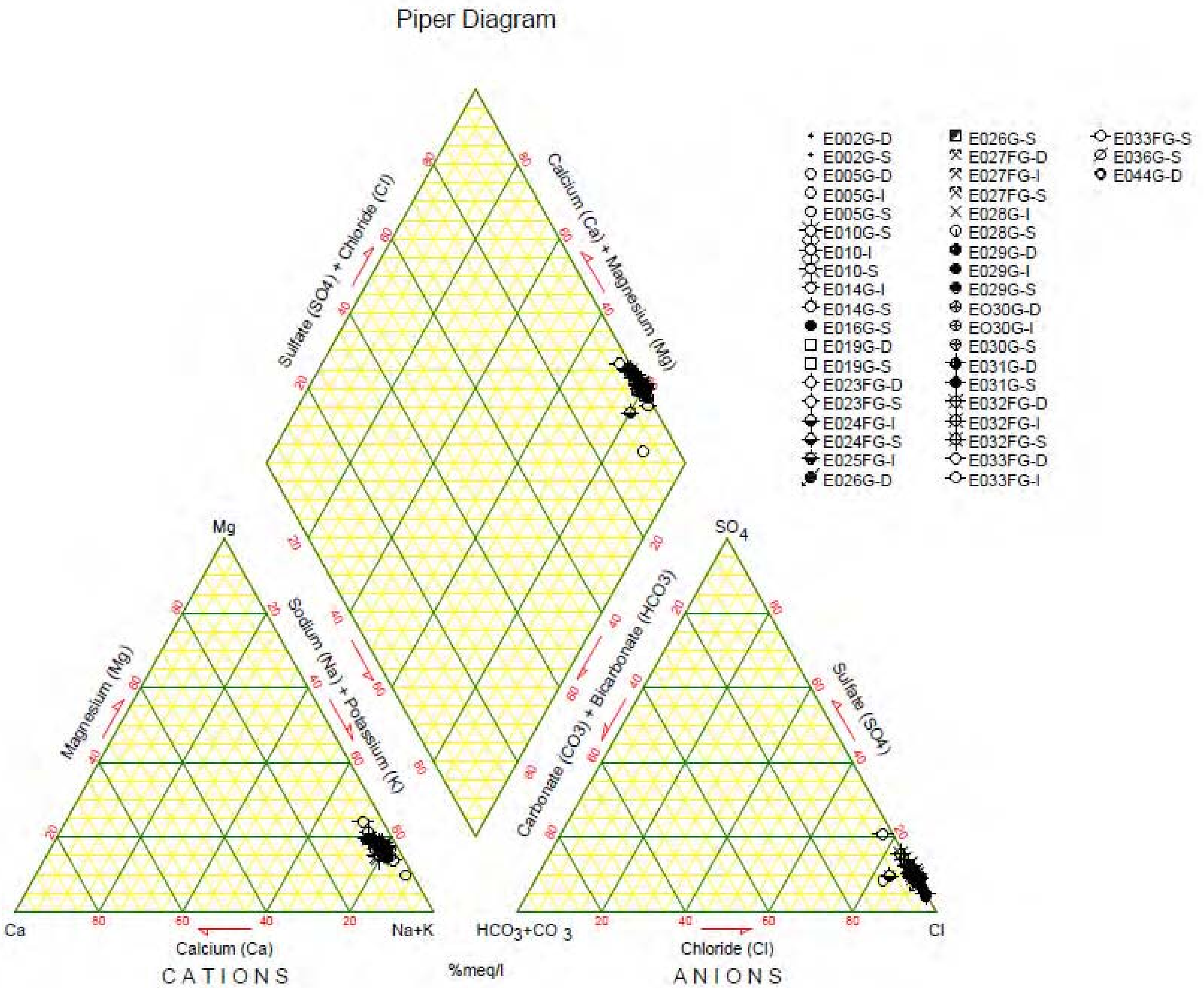

Client: **CHEVRON AUSTRALIA PTY LTD**

URS

Project: Wheatstone Project Groundwater Studies

Title: Groundwater Quality Piper Diagram

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

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

Figure: 4-17 | Rev. A | A4

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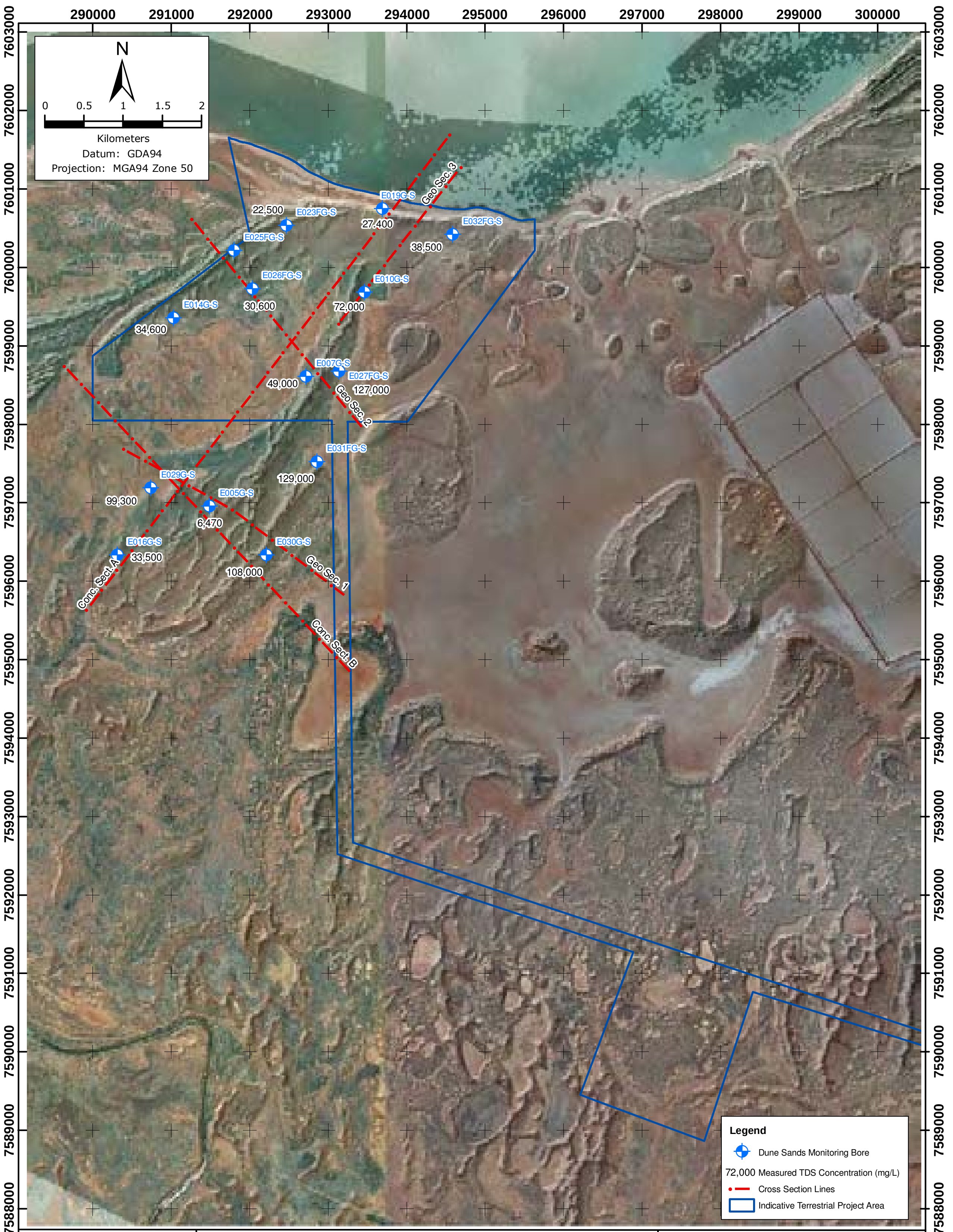

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Groundwater TDS in Dune Sands (June to November 2009)	
URS	Drawn: IGB · Approved: IGB · Date: 12/05/2010	Figure: 4-18	Rev. A
	Job No.: 42907466 · File No.: 42907466-GW-034.mxd		A4

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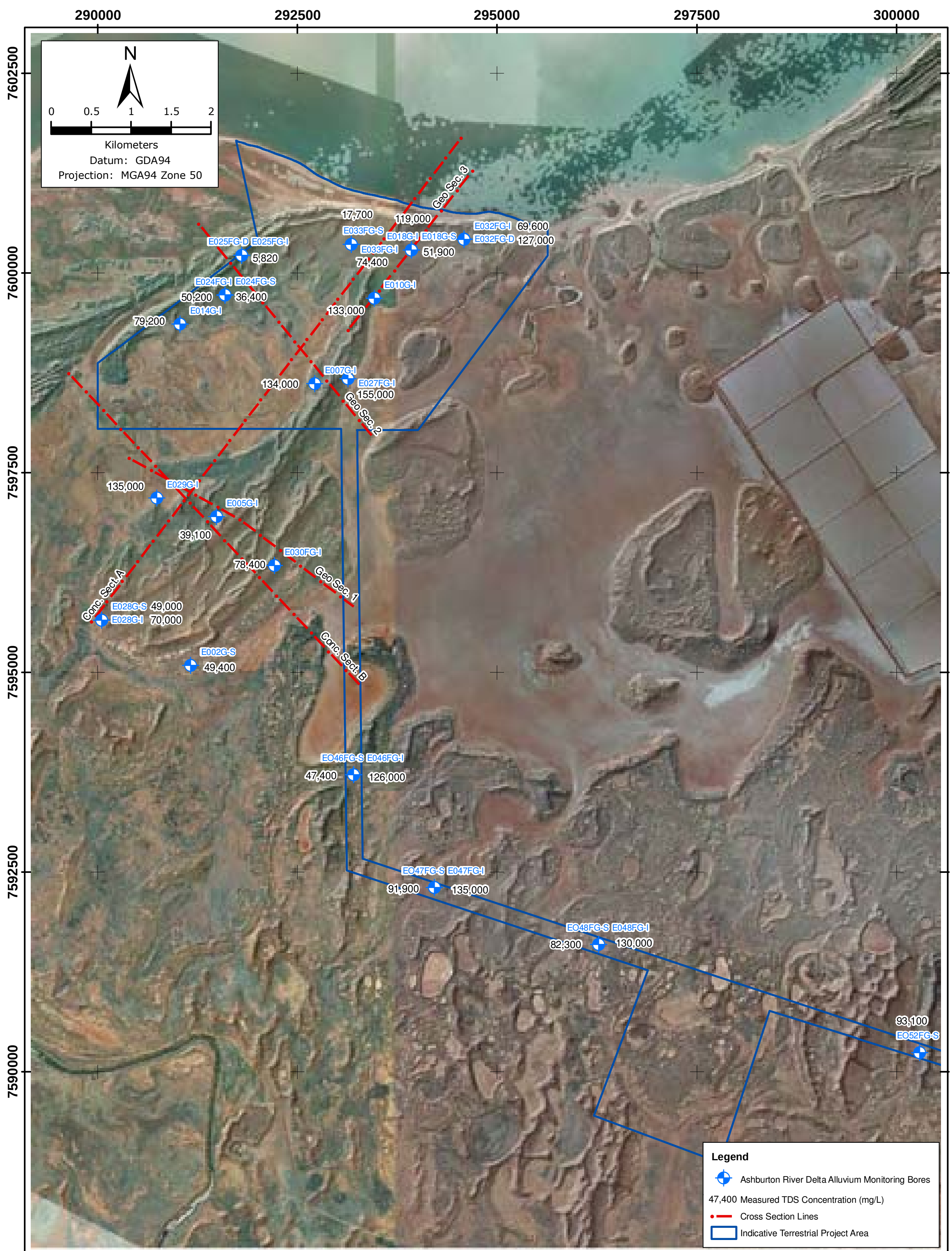

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Groundwater TDS in Ashburton River Delta Alluvium (June to November 2009)	
URS	Drawn: IGB / Approved: IGB / Date: 12/05/2010	Figure: 4-19	Rev. A
	Job No.: 42907466 / File No.: 42907466-GW-035.mxd		A4

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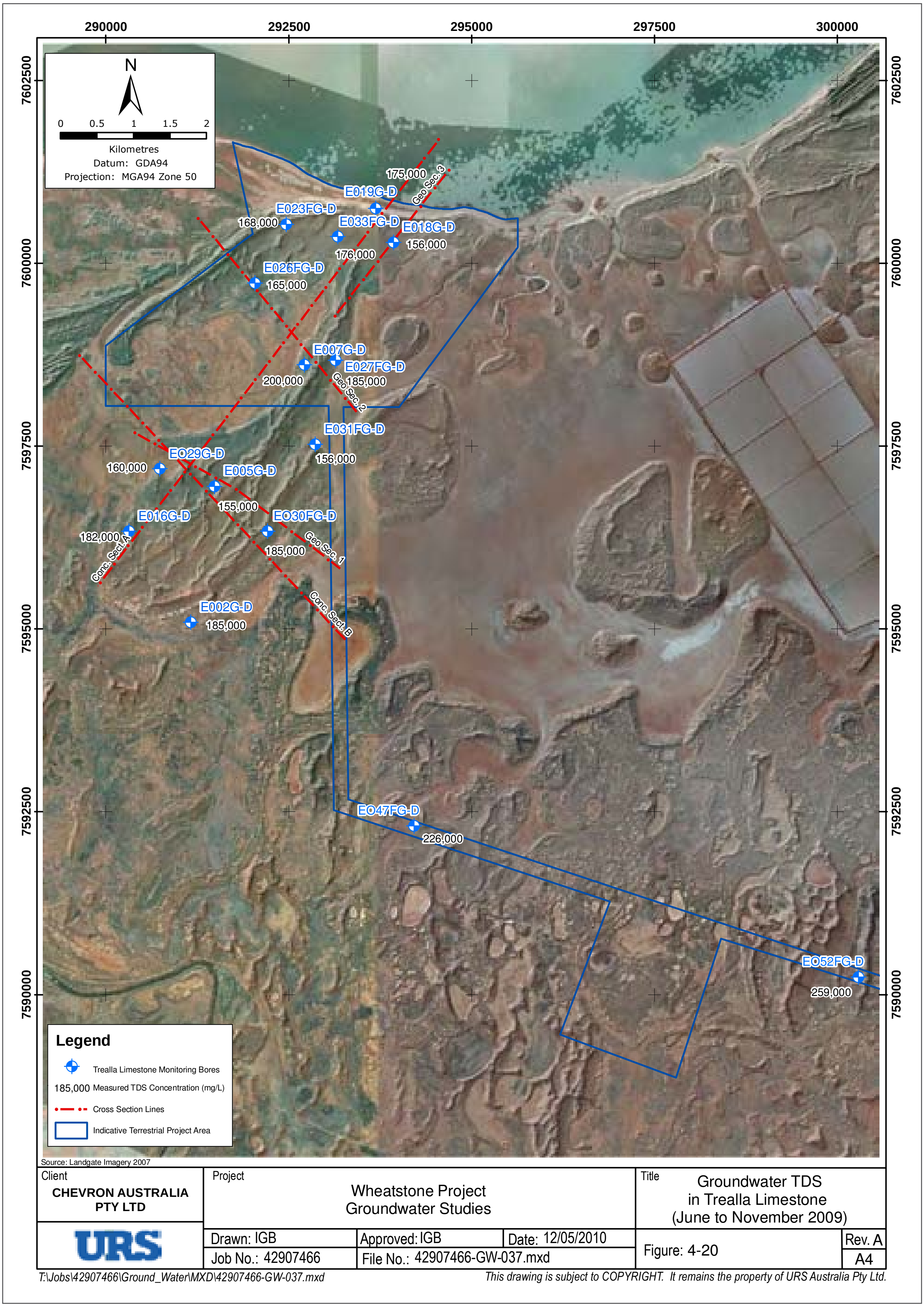

290000
292500
295000
297500
300000
7602500
7600000
7597500
7595000
7592500
7590000
N
0 0.5 1 1.5 2
Kilometres
Datum: GDA94
Projection: MGA94 Zone 50
E019G-D
175,000
E023FG-D
168,000
E033FG-D
176,000
E018G-D
156,000
E026FG-D
165,000
E007G-D
200,000
E027FG-D
185,000
E031FG-D
156,000
E029G-D
160,000
E005G-D
155,000
E016G-D
182,000
E030FG-D
185,000
E002G-D
185,000
E047FG-D
226,000
E052FG-D
259,000
Geo Sec. 1
Geo Sec. 2
Geo Sec. 3
Conc. Sect A
Conc. Sect B
Legend
Trealla Limestone Monitoring Bores
185,000 Measured TDS Concentration (mg/L)
Cross Section Lines
Indicative Terrestrial Project Area
Source: Landgate Imagery 2007
Client
CHEVRON AUSTRALIA PTY LTD
URS
Project
Wheatstone Project
Groundwater Studies
Title
Groundwater TDS
in Trealla Limestone
(June to November 2009)
Drawn: IGB
Approved: IGB
Date: 12/05/2010
Job No.: 42907466
File No.: 42907466-GW-037.mxd
Figure: 4-20
Rev. A
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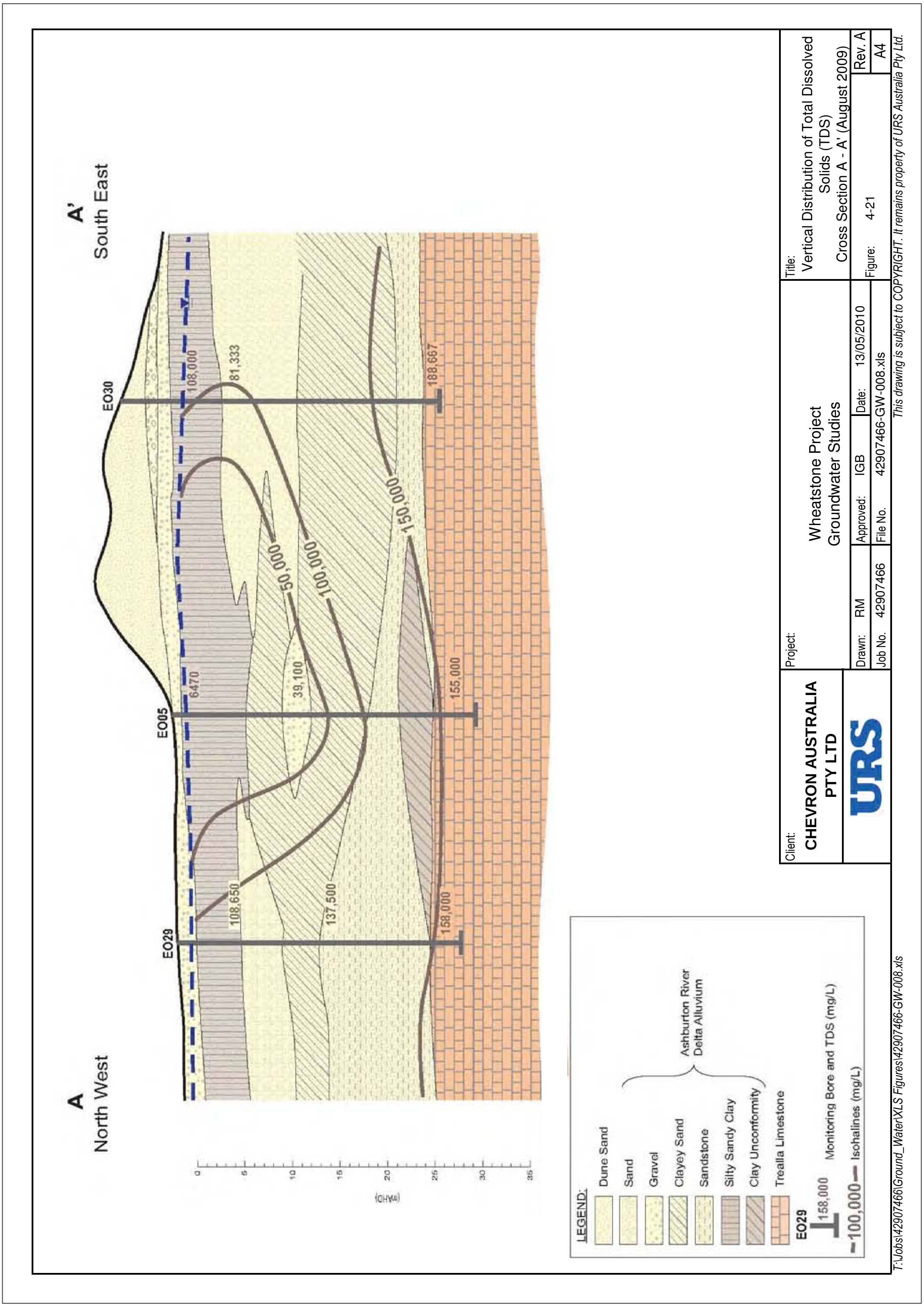
A
North West
A'
South East
EO29
EO05
EO30
108,650
137,500
158,000
6470
39,100
155,000
108,000
81,333
188,667
50,000
100,000
150,000
(mAHD)
0
5
10
15
20
25
30
35
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Trealla Limestone
Ashburton River Delta Alluvium
EO29 158,000 Monitoring Bore and TDS (mg/L)
100,000 Isohalines (mg/L)
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
Vertical Distribution of Total Dissolved Solids (TDS)
Cross Section A - A' (August 2009)
Drawn: RM
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-008.xls
Figure: 4-21
A4
T:\Jobs\42907466\Ground_Water\XLS Figures\42907466-GW-008.xls
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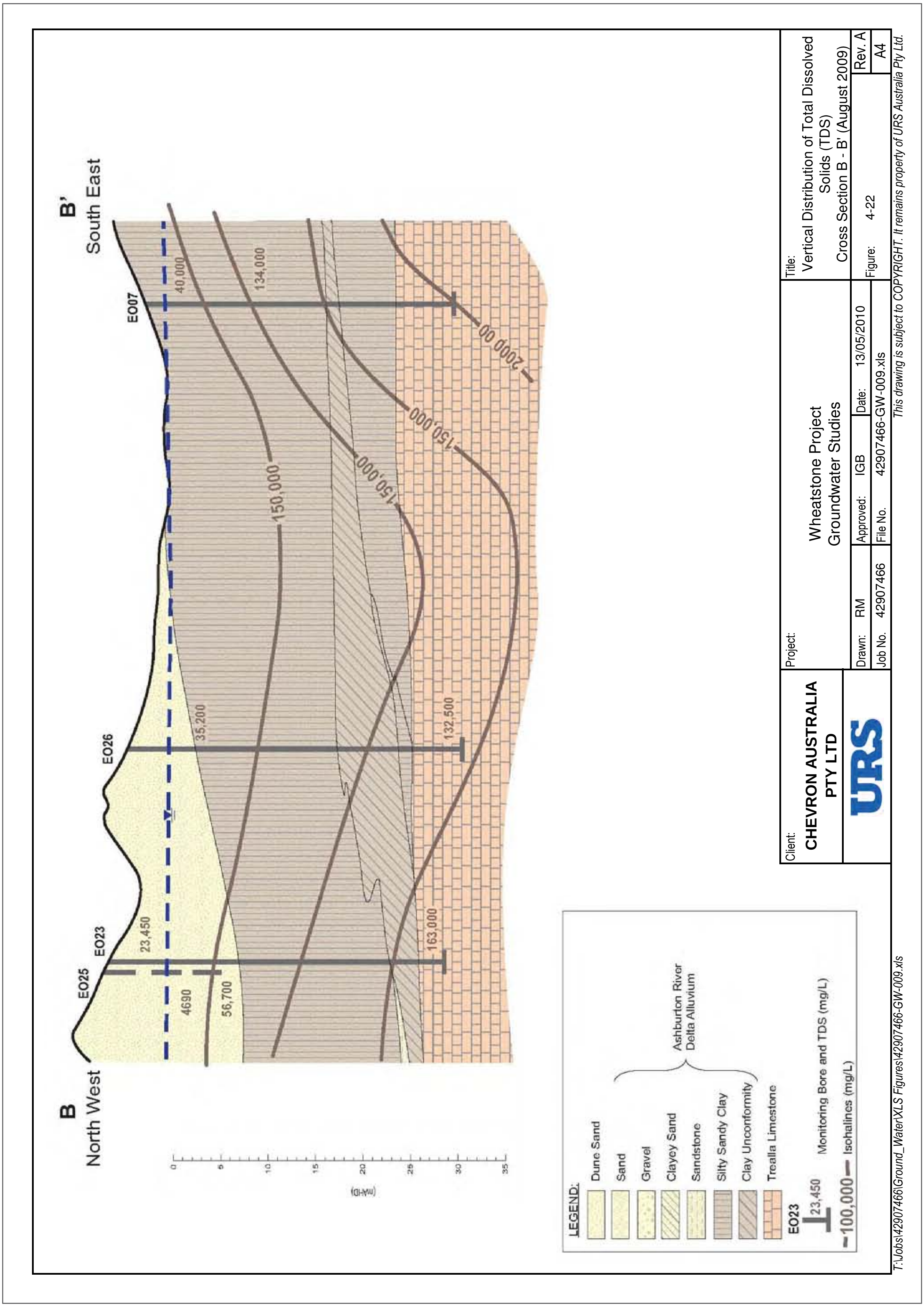
B
North West
B'
South East
EO25
EO23
EO26
EO07
4690
56,700
23,450
163,000
35,200
132,500
150,000
150,000
150,000
40,000
134,000
2000 00
(mAHD)
0
5
10
15
20
25
30
35
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Trealla Limestone
Ashburton River Delta Alluvium
EO23
23,450
Monitoring Bore and TDS (mg/L)
100,000 Isohalines (mg/L)
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
Vertical Distribution of Total Dissolved Solids (TDS)
Cross Section B - B' (August 2009)
Drawn: RM
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-009.xls
Figure: 4-22
A4
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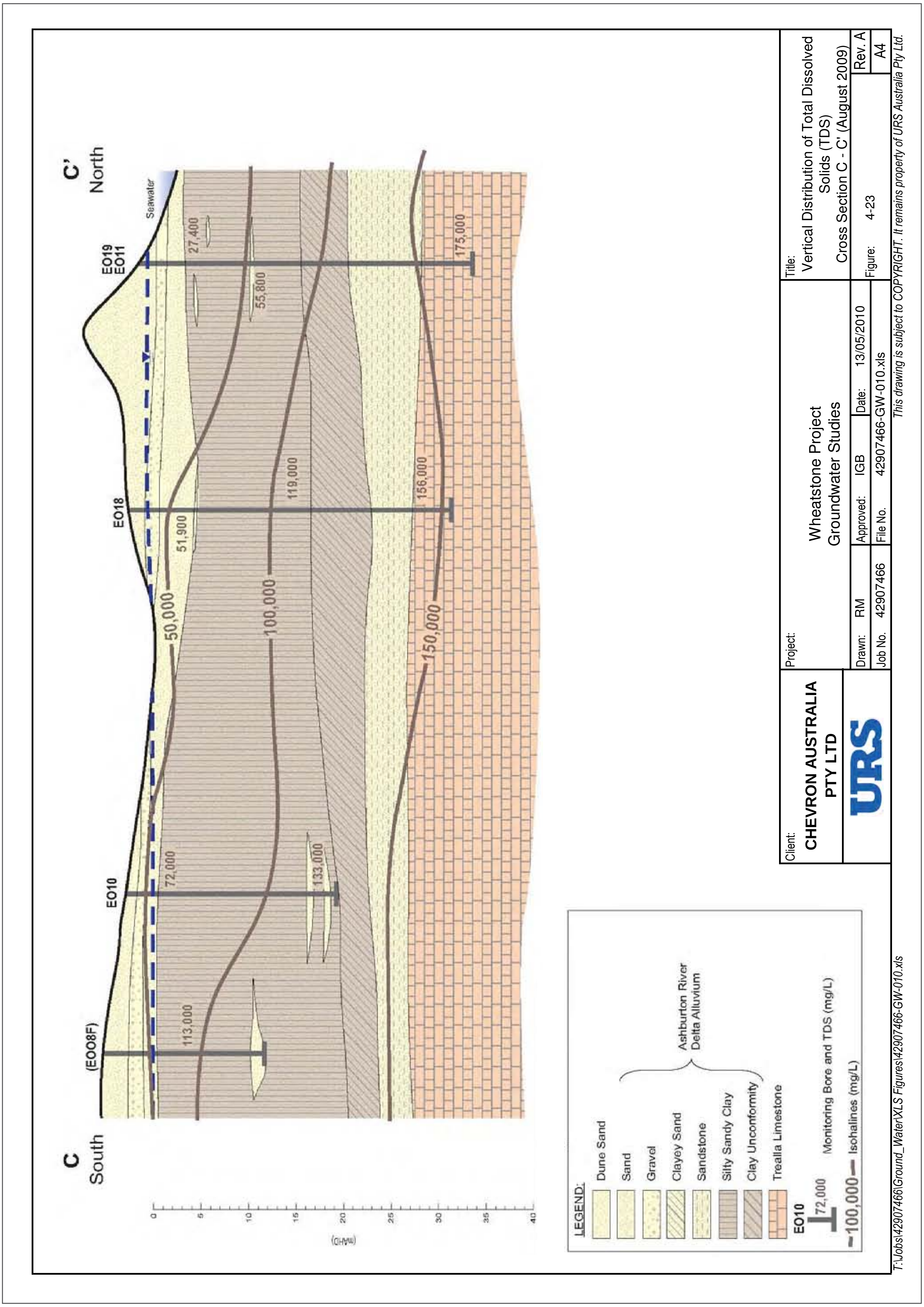
C
South
C'
North
(EO08F)
EO10
EO18
EO19
EO11
Seawater
113,000
72,000
133,000
50,000
51,900
100,000
119,000
150,000
156,000
27,400
55,800
175,000
(mAHD)
0
5
10
15
20
25
30
35
40
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Trealla Limestone
Ashburton River Delta Alluvium
EO10 72,000 Monitoring Bore and TDS (mg/L)
100,000 Isohalines (mg/L)
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project Groundwater Studies
Title:
Vertical Distribution of Total Dissolved Solids (TDS) Cross Section C - C' (August 2009)
Drawn: RM
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-010.xls
Figure: 4-23
Rev. A
A4
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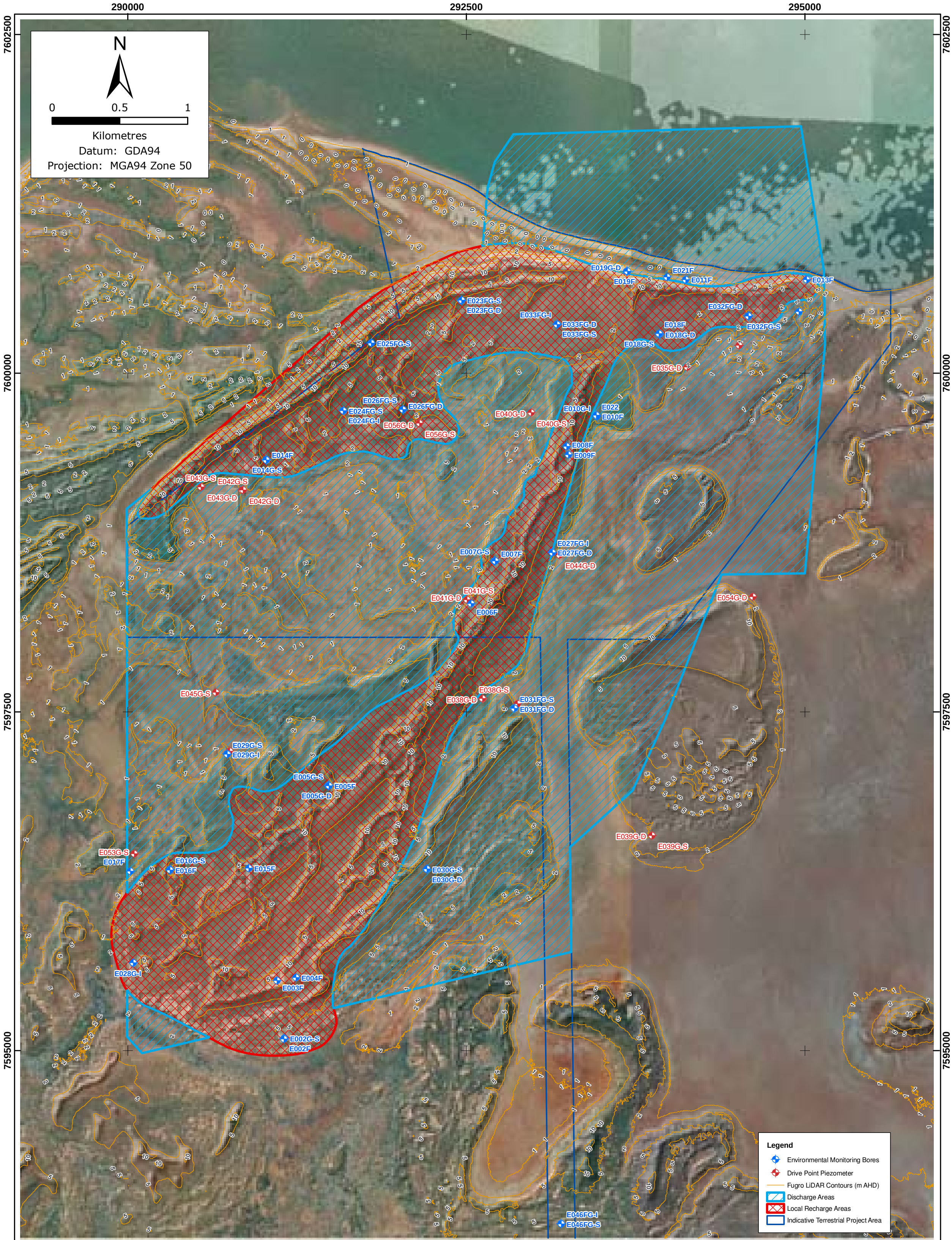

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Seasonal Groundwater Recharge and Discharge Areas	
URS	Drawn: JD / Approved: IGB / Date: 12/05/2010	Figure: 5-1	Rev. A
	Job No.: 42907466 / File No.: 42907466-GW-029.mxd		A3

T:\Jobs\42907466\Ground_Water\MXD\42907466-GW-029.mxd

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Groundwater Divides	
URS	Drawn: RNM / Approved: IGB / Date: 12/05/2010	Figure: 5-2	Rev. A
	Job No.: 42907466 / File No.: 42907466-GW-031.mxd		A4

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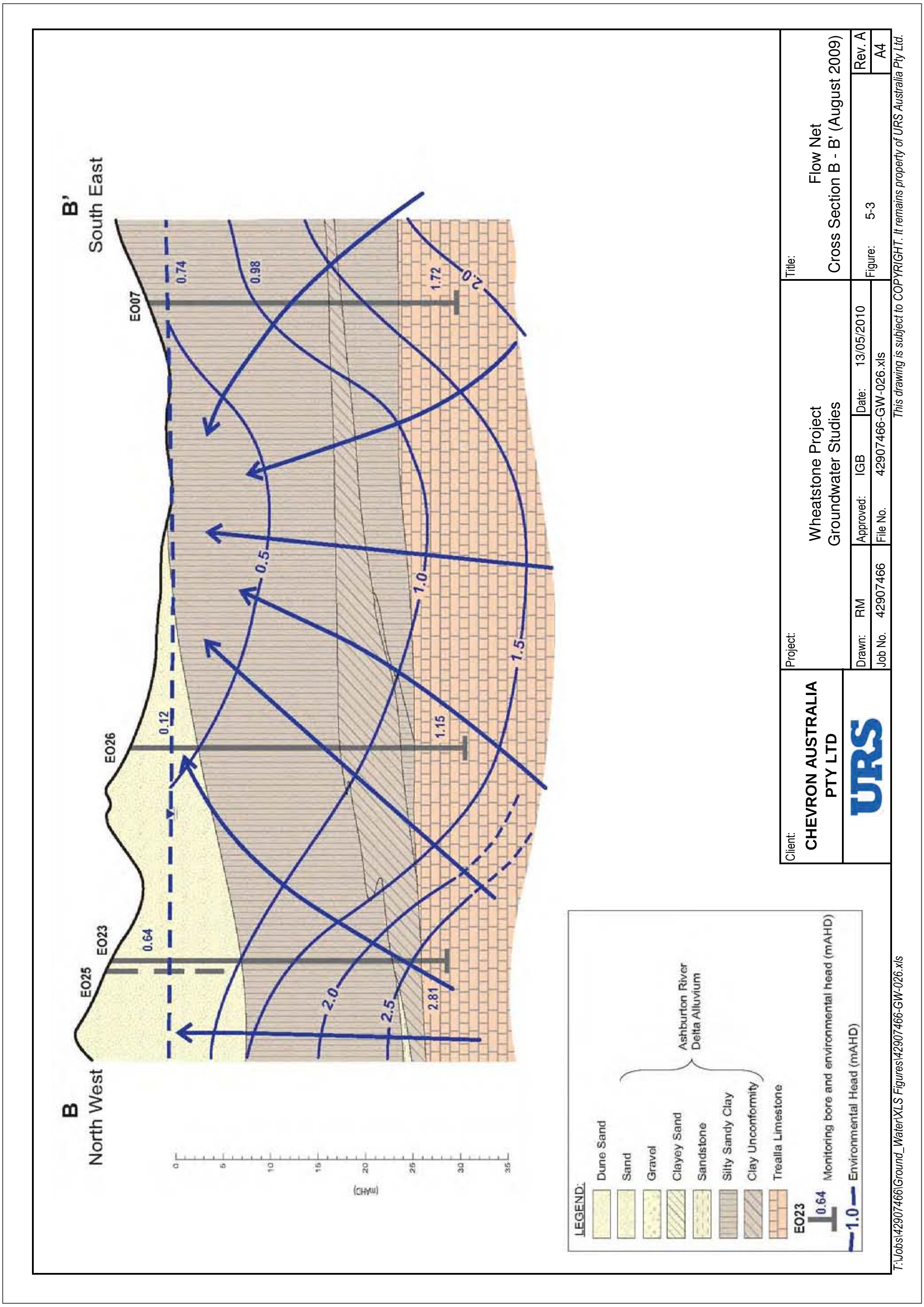
B North West
B' South East
EO25
EO23
EO26
EO07
0.64
0.12
0.74
0.98
1.72
2.0
1.15
2.81
2.0
2.5
0.5
1.0
1.5
0 5 10 15 20 25 30 35
(mAHD)
LEGEND:
Dune Sand
Sand
Gravel
Clayey Sand
Sandstone
Silty Sandy Clay
Clay Unconformity
Trealla Limestone
Ashburton River Delta Alluvium
EO23 0.64 Monitoring bore and environmental head (mAHD)
1.0 Environmental Head (mAHD)
Client: CHEVRON AUSTRALIA PTY LTD
Project: Wheatstone Project Groundwater Studies
Title: Flow Net Cross Section B - B' (August 2009)
Drawn: RM
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-026.xls
Figure: 5-3
Rev. A
A4
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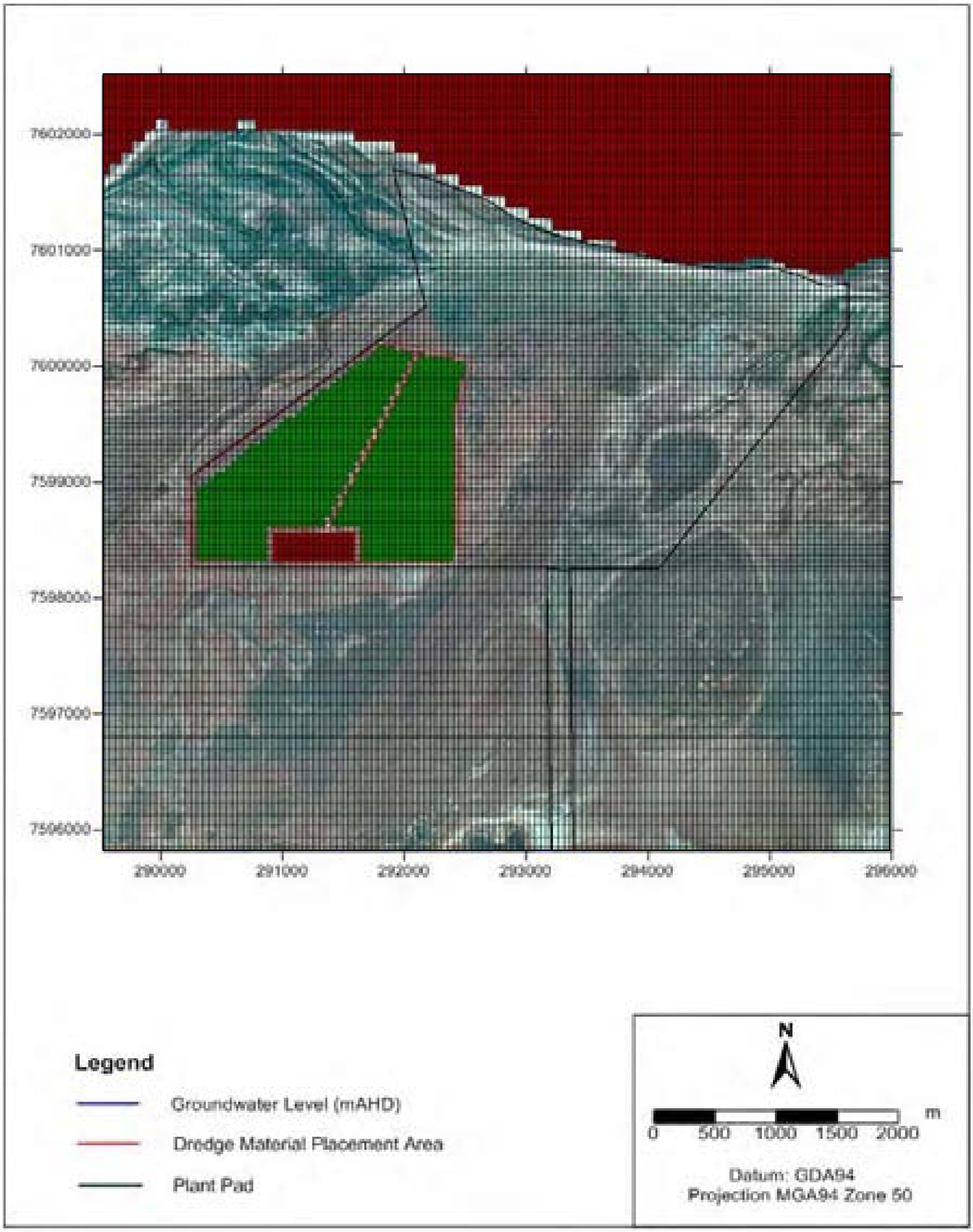

Client:	Project:		Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies		Model Domain and Grid	
URS	Drawn: WY	Approved: IGB	Date: 20/05/2010	Figure: 6-1	Rev. A
	Job No. 42907466	File No. 42907466-GW-056.xls			A4

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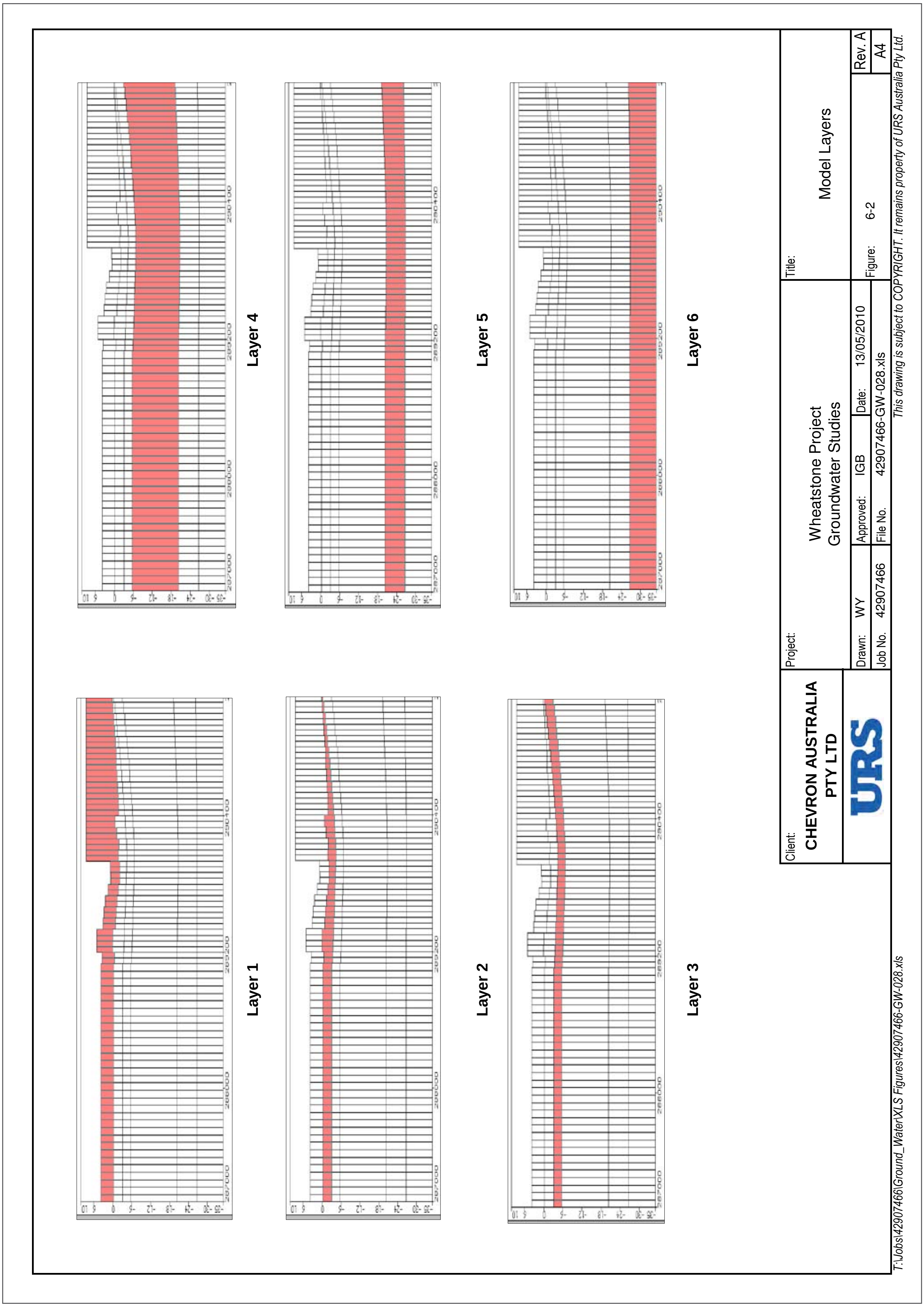
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Model Layers
Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-028.xls
Figure: 6-2
Rev. A
A4
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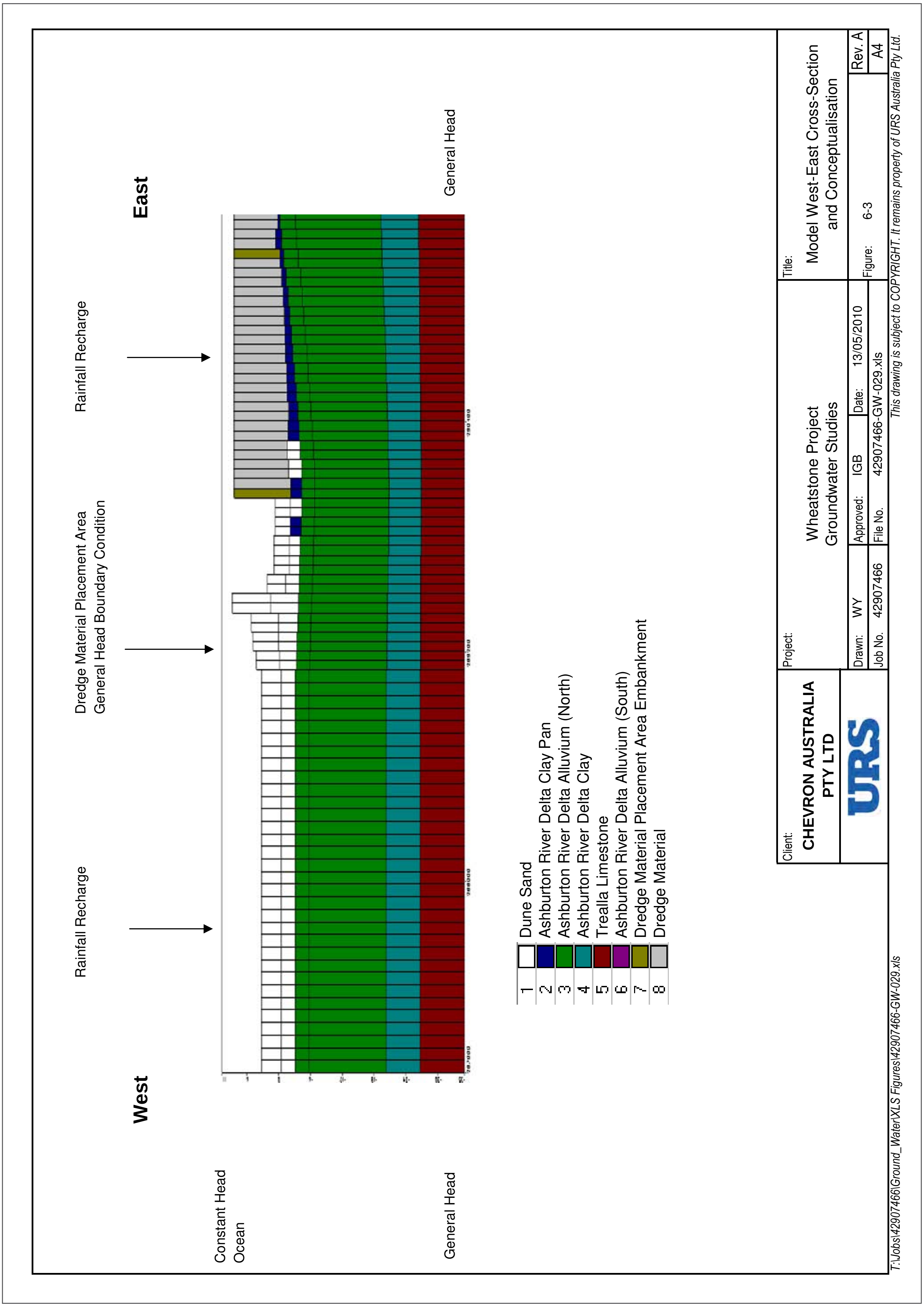
West
East
Rainfall Recharge
Dredge Material Placement Area
General Head Boundary Condition
Rainfall Recharge
Constant Head
Ocean
General Head
General Head
1 Dune Sand
2 Ashburton River Delta Clay Pan
3 Ashburton River Delta Alluvium (North)
4 Ashburton River Delta Clay
5 Trealla Limestone
6 Ashburton River Delta Alluvium (South)
7 Dredge Material Placement Area Embankment
8 Dredge Material
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Model West-East Cross-Section and Conceptualisation
Drawn: WY
Approved: IGB
Date: 13/05/2010
Figure: 6-3
Rev. A
Job No. 42907466
File No. 42907466-GW-029.xls
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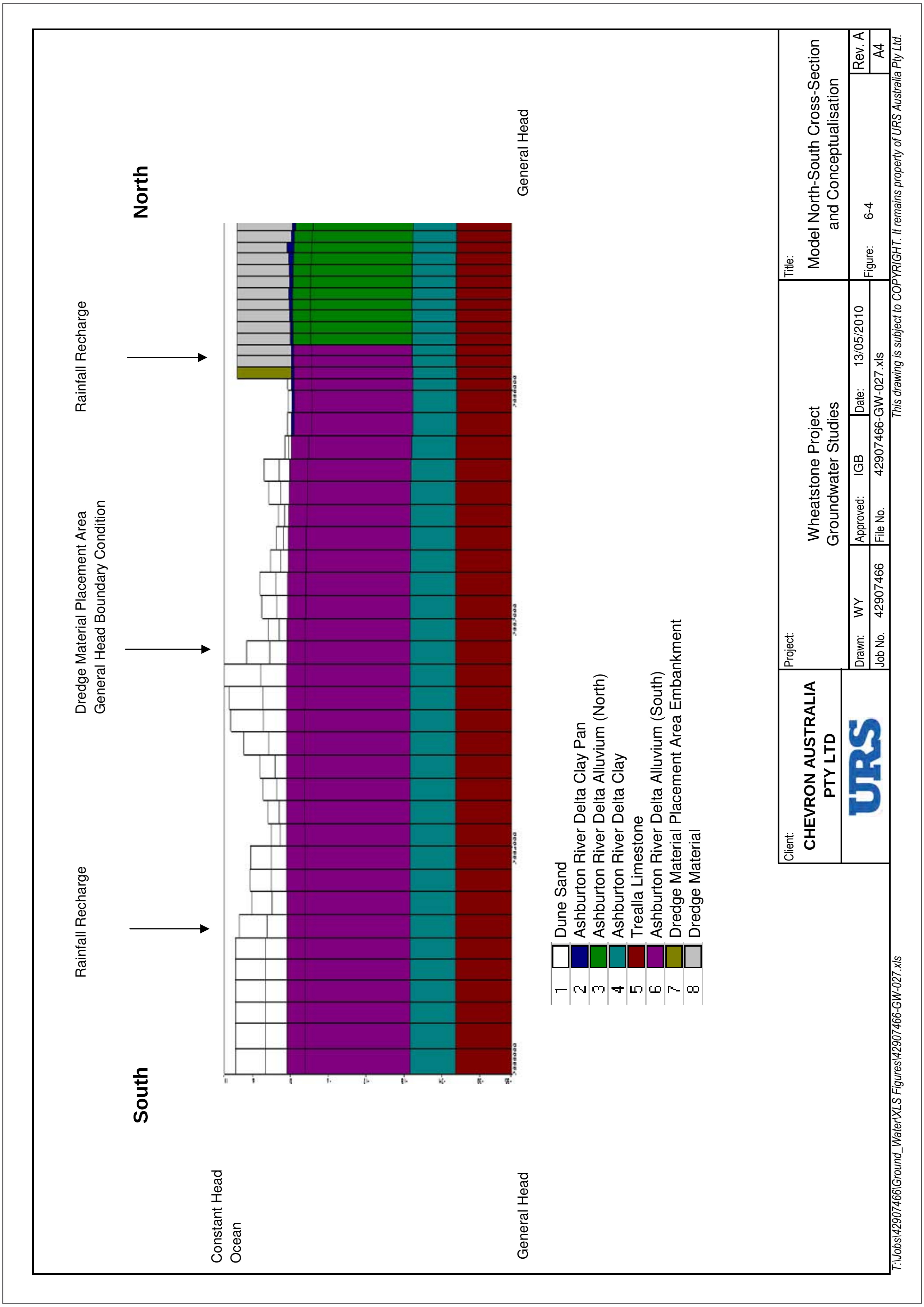

South
North
Constant Head
Ocean
General Head
Rainfall Recharge
Dredge Material Placement Area
General Head Boundary Condition
Rainfall Recharge
General Head
1 Dune Sand
2 Ashburton River Delta Clay Pan
3 Ashburton River Delta Alluvium (North)
4 Ashburton River Delta Clay
5 Trealla Limestone
6 Ashburton River Delta Alluvium (South)
7 Dredge Material Placement Area Embankment
8 Dredge Material
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-027.xls
Title:
Model North-South Cross-Section and Conceptualisation
Figure: 6-4
Rev. A
A4
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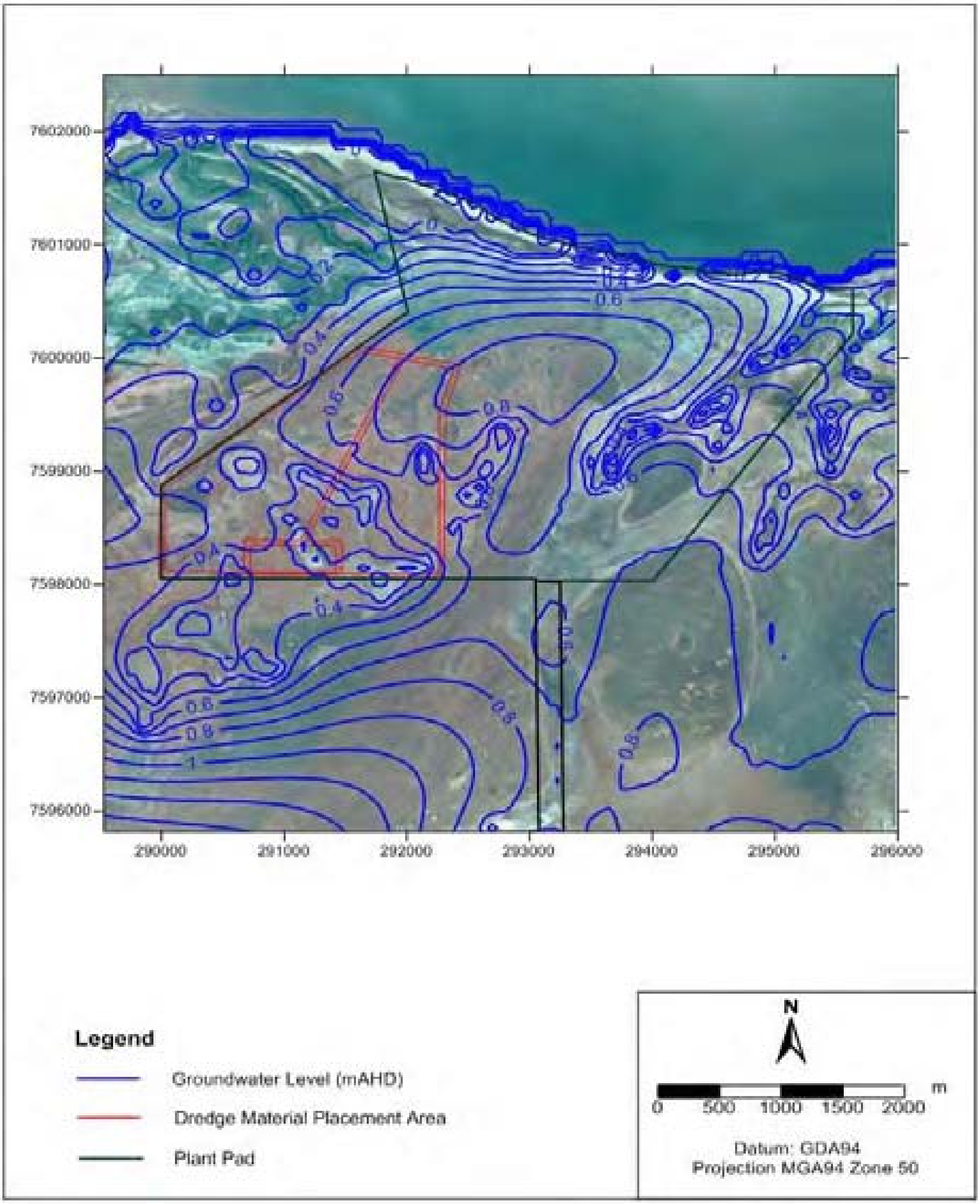

Client:	Project:			Title:	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies			Calibrated Model Steady-State Water Table (m AHD)	
URS	Drawn: WY	Approved: IGB	Date: 20/05/2010	Figure: 6-5	Rev. A
	Job No. 42907466	File No. 42907466-GW-057.xls			A4

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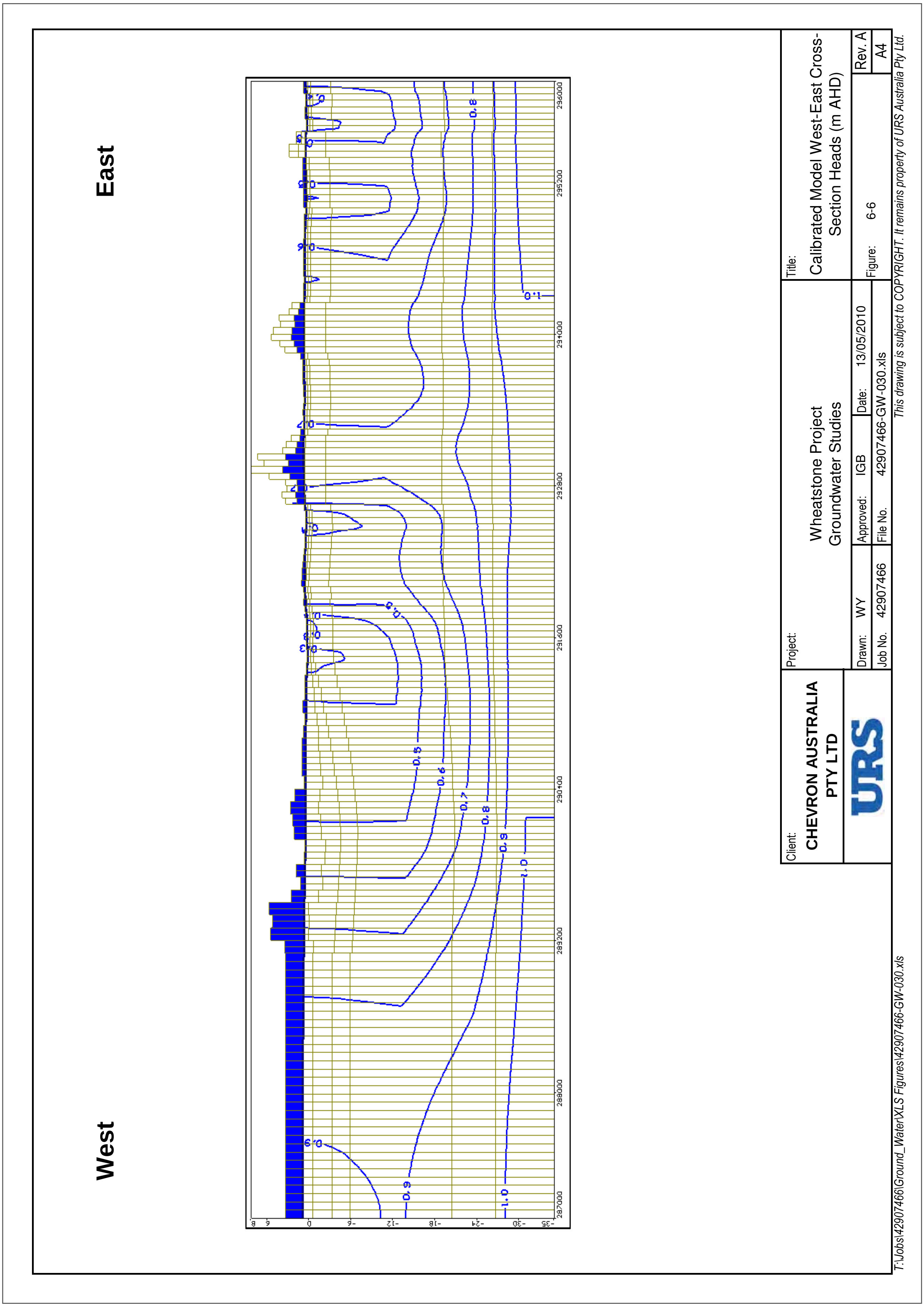

East
West
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project Groundwater Studies
Title:
Calibrated Model West-East Cross-Section Heads (m AHD)
Drawn: WY
Approved: IGB
Date: 13/05/2010
Figure: 6-6
Rev. A
A4
Job No. 42907466
File No. 42907466-GW-030.xls
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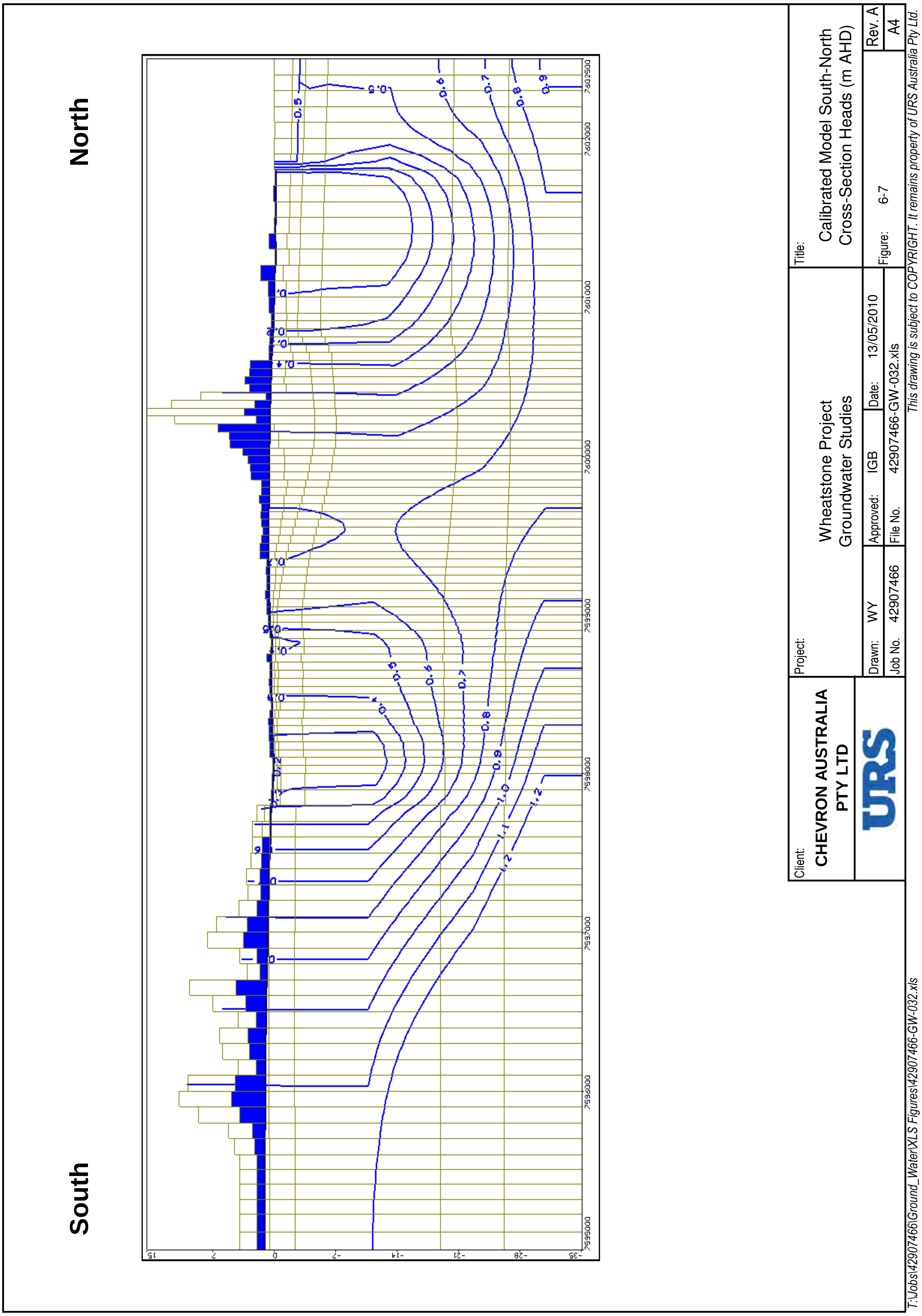
North
South
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Calibrated Model South-North Cross-Section Heads (m AHD)
Drawn: WY
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-032.xls
Figure: 6-7
A4
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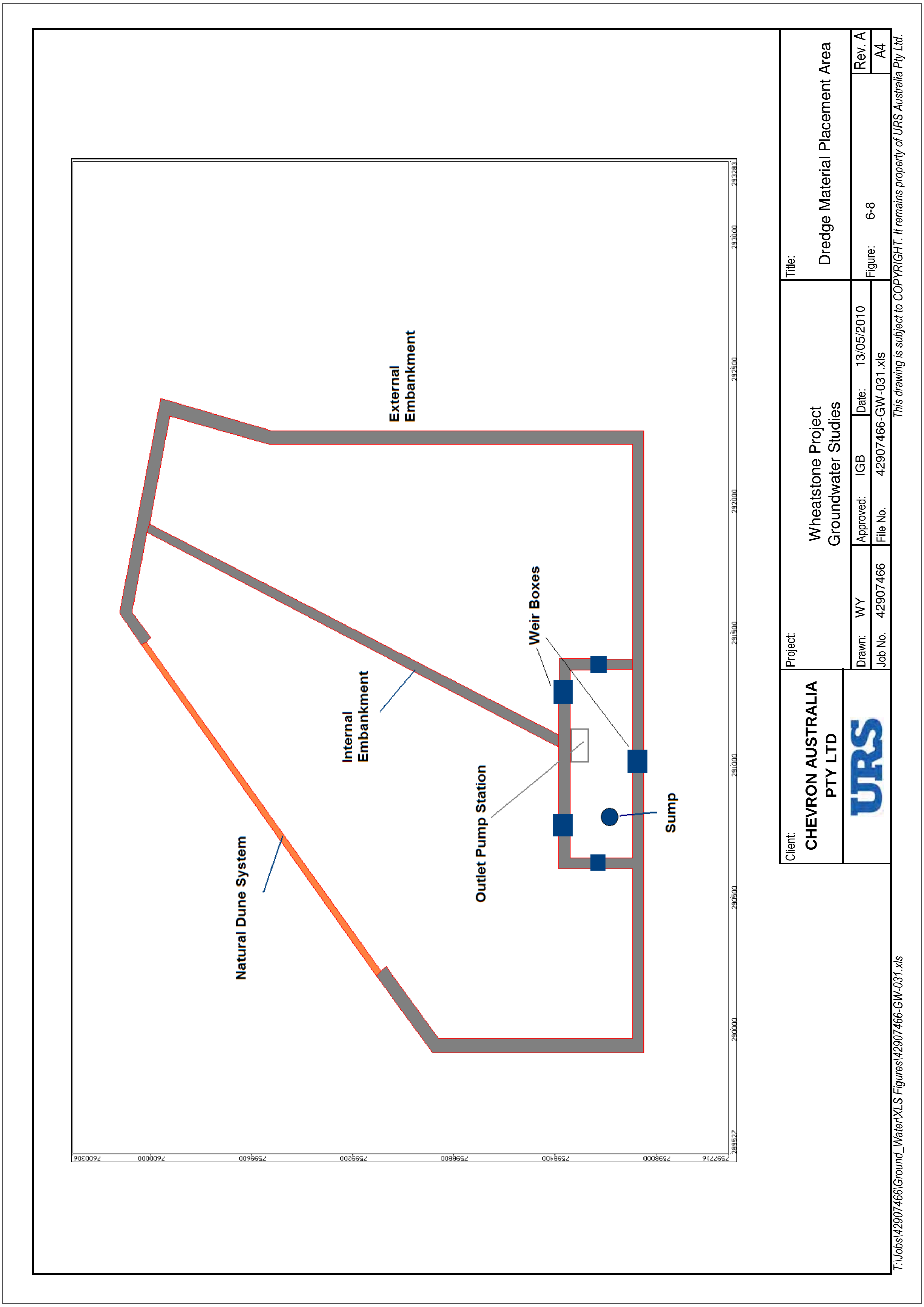
External Embankment
Weir Boxes
Internal Embankment
Outlet Pump Station
Sump
Natural Dune System
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Dredge Material Placement Area
Drawn: WY
Approved: IGB
Date: 13/05/2010
Figure: 6-8
Rev. A
A4
Job No. 42907466
File No. 42907466-GW-031.xls
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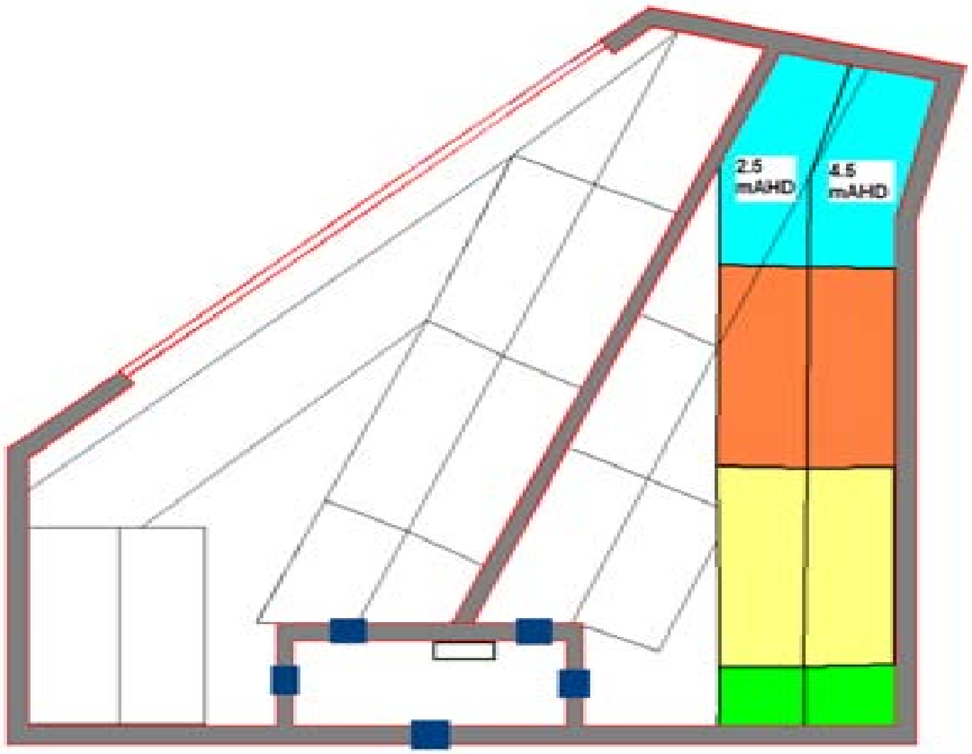

Dredge Material Placement	Stage	Period	Days	Entrained Water Level 1 (mAHD)	Entrained Water Level 2 (mAHD)
	1	1	30	4.5	2.5
	1	2	30	4.5	2.5
	1	3	30	4.5	2.5
	1	4	10	4.5	2.5

Embankment
Sand Dune

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: Conceptual Dredge Material Placement Schedule 1
URS	Drawn: WY / Approved: IGB / Date: 13/05/2010	Figure: 6-9a / Rev. A
	Job No. 42907466 / File No. 42907466-GW-033.xls	A4

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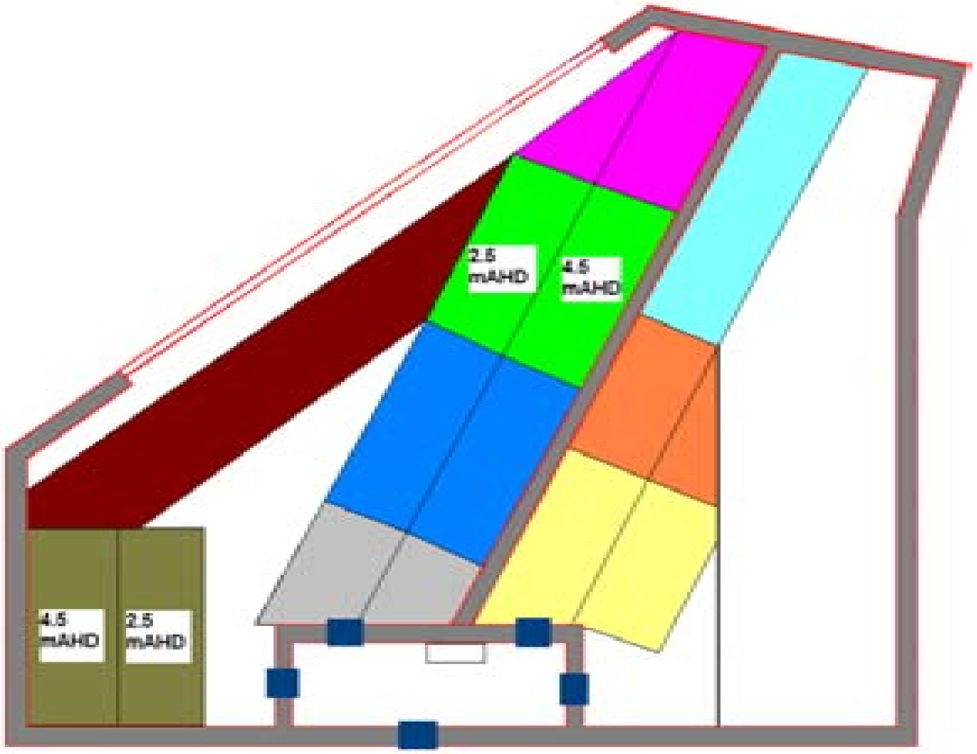

Dredge Material Placement	Stage	Period	Days	Entrained Water Level 1 (mAHD)	Entrained Water Level 2 (mAHD)
(cyan)	2	5	22	4.5	N/A
(orange)	2	6	12	4.5	2.5
(yellow)	2	7	30	4.5	2.5
(magenta)	3	8	15	3.5	2.0
(green)	3	9	30	4.5	2.5
(blue)	3	10	30	4.5	2.5
(grey)	3	11	10	4.5	2.5
(olive)	4	12	30	4.5	2.5
(dark red)	4	13	22	2.5	N/A

Embankment
Sand Dune

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies		Title: Conceptual Dredge Material Placement Schedule 2	
URS	Drawn: WY	Approved: IGB / Date: 13/05/2010	Figure: 6-9b	Rev. A
	Job No. 42907466	File No. 42907466-GW-034.xls		A4

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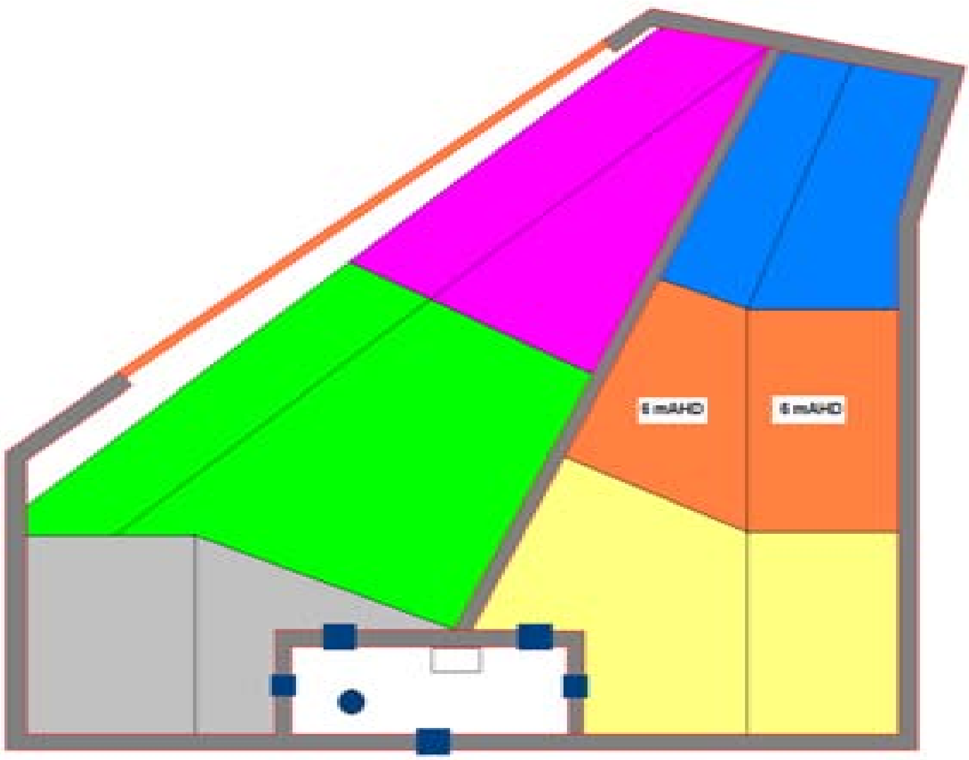

Dredge Material Placement	Stage	Period	Days	Entrained Water Level 1 (mAHD)	Entrained Water Level 2 (mAHD)
	5	14	22	6.0	6.0
	5	15	16	6.0	6.0
	5	16	34	6.0	6.0
	6	17	25	6.0	6.0
	6	18	55	6.0	6.0
	6	19	32	6.0	6.0

Embankment

Sand Dune

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies			Title: Conceptual Dredge Material Placement Schedule 3	
URS	Drawn: WY	Approved: IGB	Date: 13/05/2010	Figure: 6-9c	Rev. A
	Job No. 42907466	File No. 42907466-GW-035.xls			A4

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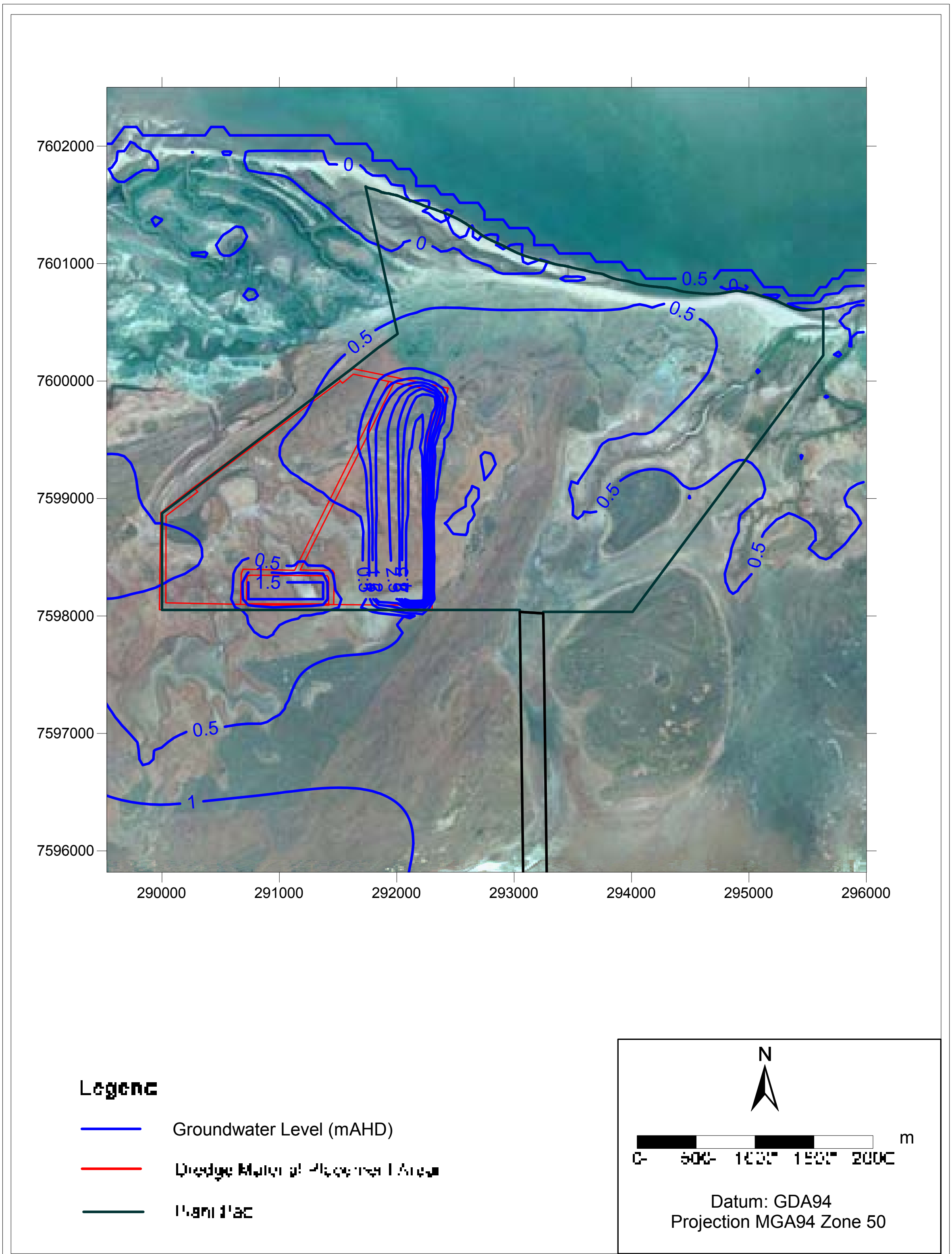

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Predicted Water Table Contours (m AHD) 100 Days after Commencement of Dredge Material Placement
URS	Drawn: / Approved: / Date: / Job No: / File No:	Figure: / Rev 0 / A4

J:\Jobs\42907466\Deliv\GRW\Figures\Figures_All

Groundwater Mounding (m)

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: Predicted Water Table Mounding 100 Days after Commencement of Dredge Material Placement
URS	Drawn: / Approved: / Date: / Job No: / File No:	Figure: / Rev 0 / A4

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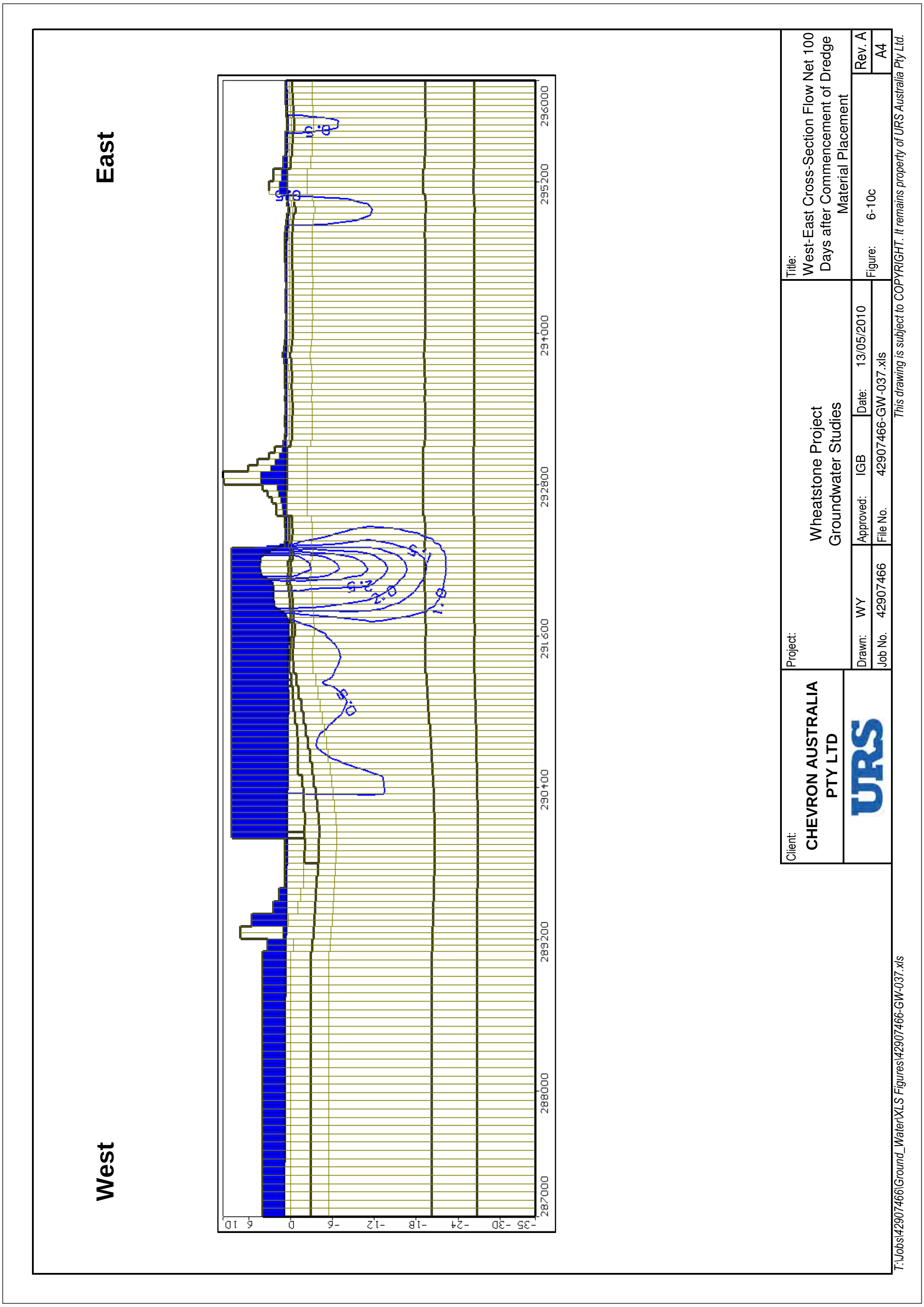
West
East
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
West-East Cross-Section Flow Net 100 Days after Commencement of Dredge Material Placement
Drawn: WY
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-037.xls
Figure: 6-10c
A4
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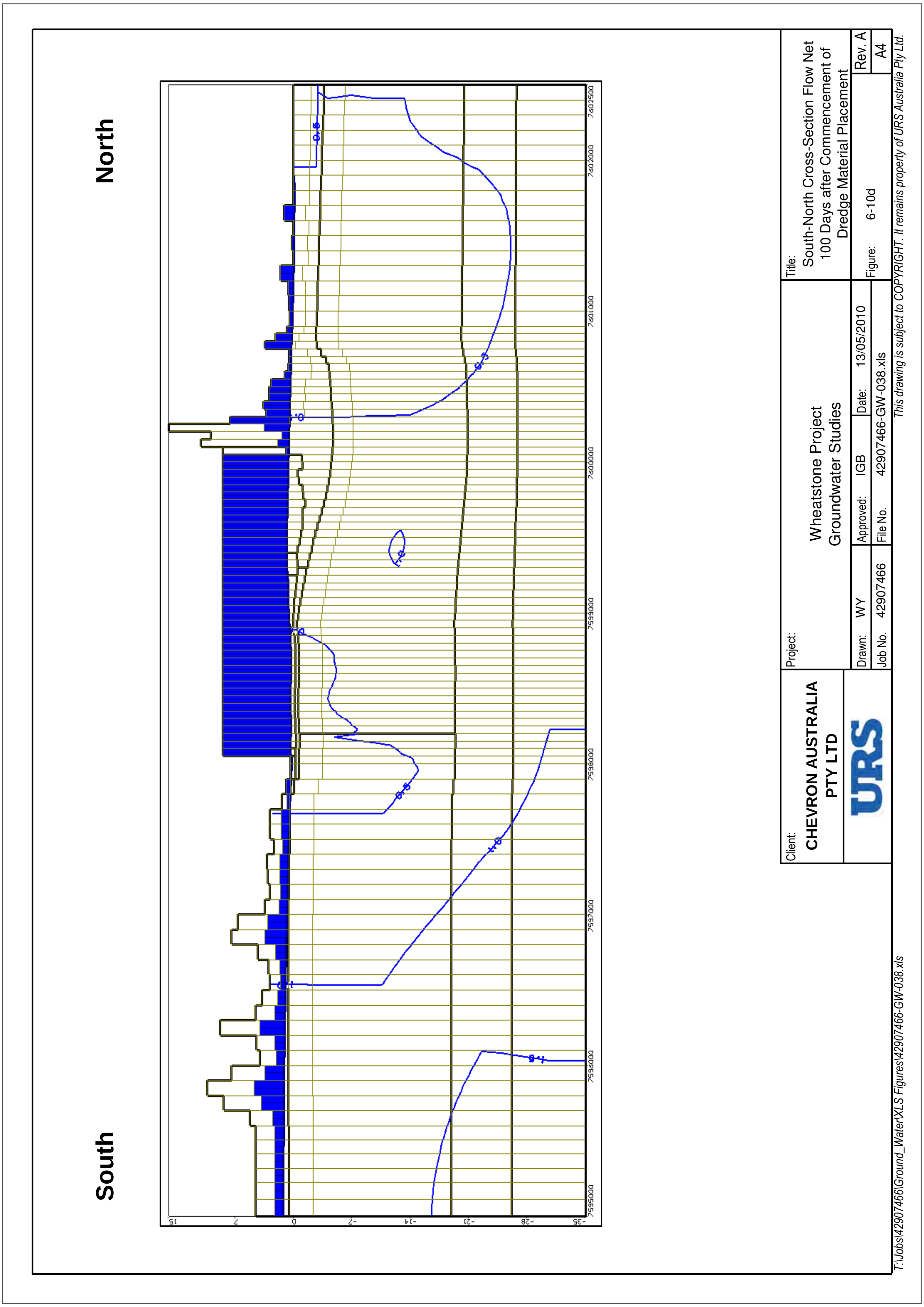

North
South
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
South-North Cross-Section Flow Net
100 Days after Commencement of
Dredge Material Placement
Drawn: WY
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-038.xls
Figure: 6-10d
A4
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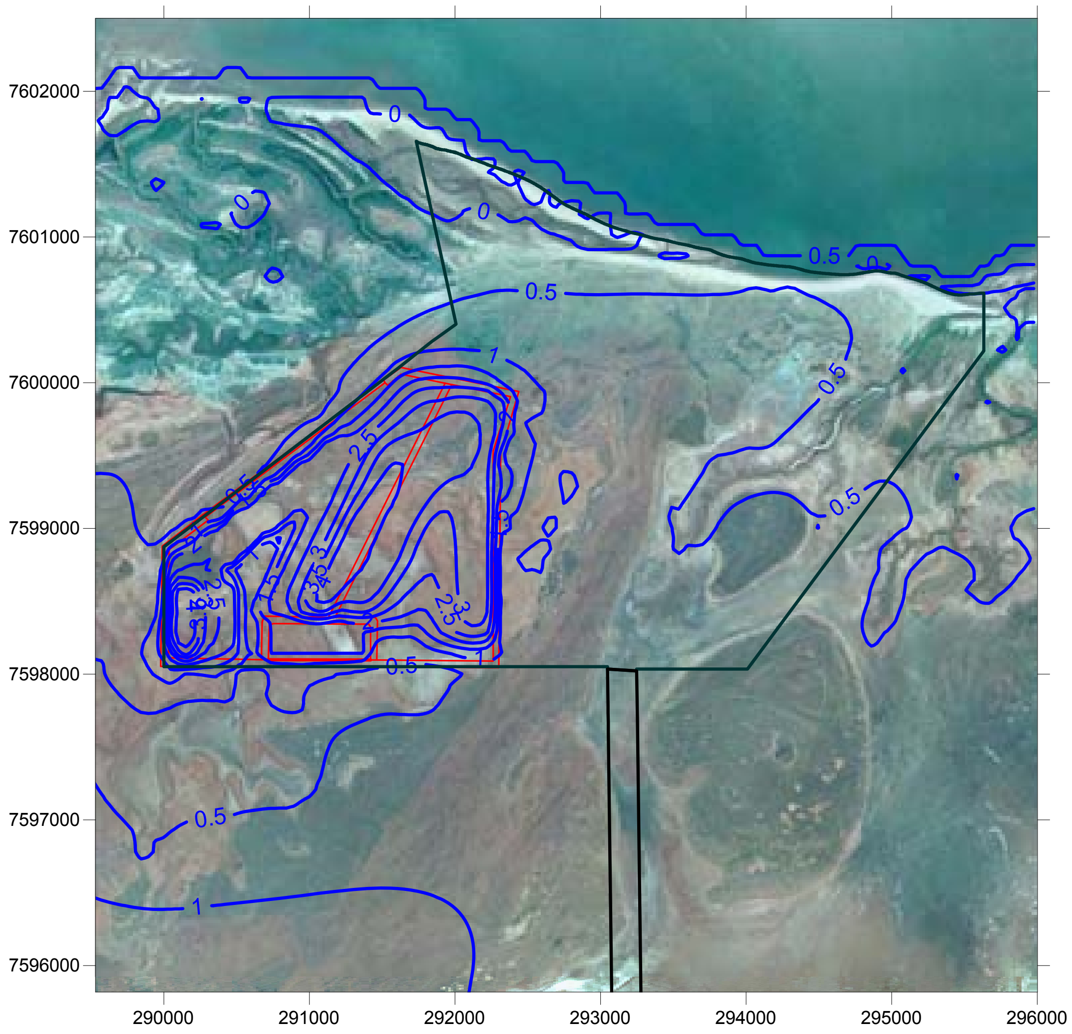

Legend

Groundwater Level (m AHD)

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: Predicted Water Table Contours (m AHD) 301 Days after Commencement of Dredge Material Placement	
URS	Drawn: / Approved: / Date:	Figure:	Rev 0
	Job No: / File No:		A4

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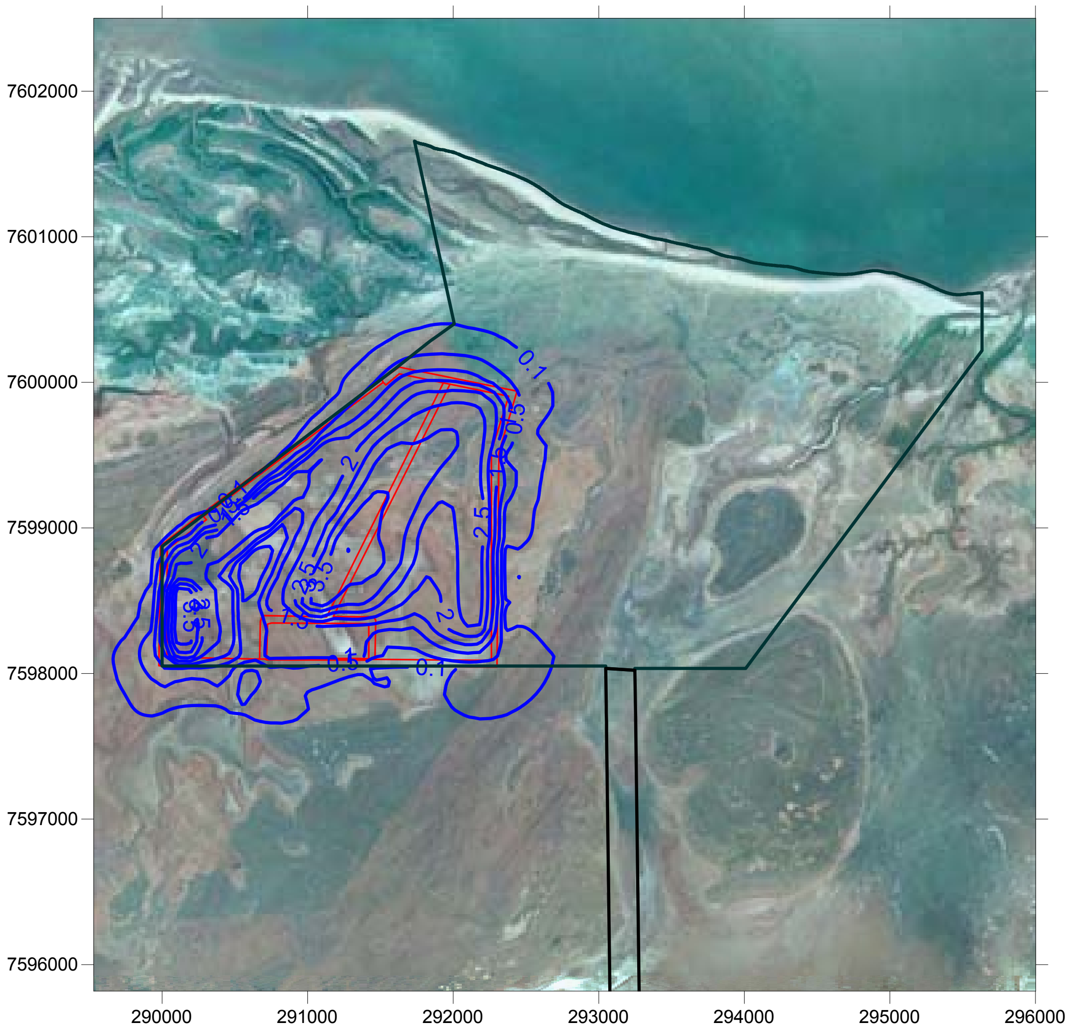

Legend

Groundwater Mounding

[illegible]

[illegible]

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies		Title: Predicted Water Mounding 301 Days after Commencement of Dredge Material Placement	
URS	Drawn: [illegible]	Approved: [illegible] Date: [illegible]	Figure: [illegible]	Rev 0
	Job No: [illegible]	File No: [illegible]		A4

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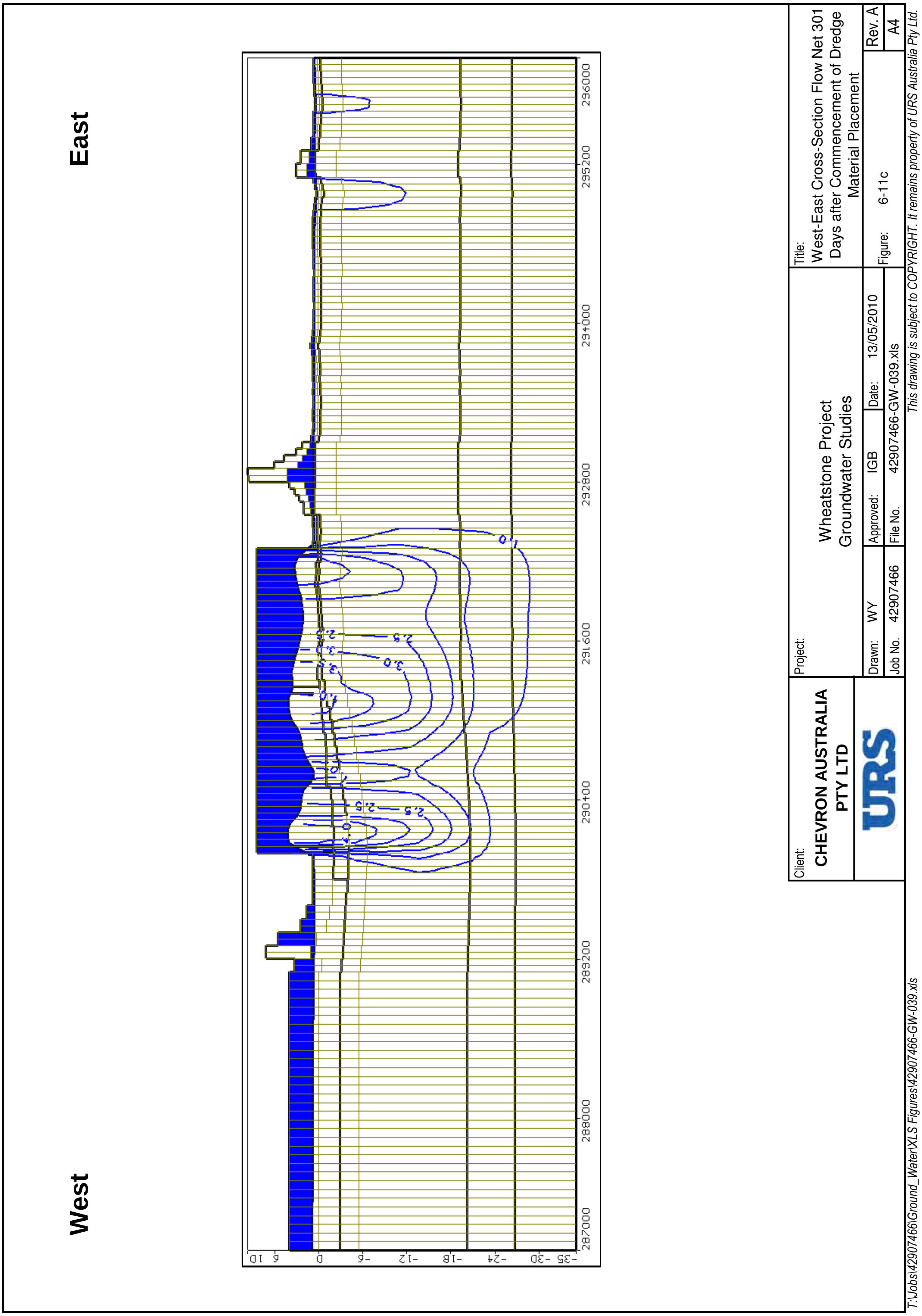
West
East
287000
288000
289200
290400
291600
292800
294000
295200
296000
6 10
0
-6
-12
-18
-24
-30 -35
1.0
2.5
3.0
3.5
4.0
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
West-East Cross-Section Flow Net 301 Days after Commencement of Dredge Material Placement
Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-039.xls
Figure: 6-11c
Rev. A
A4
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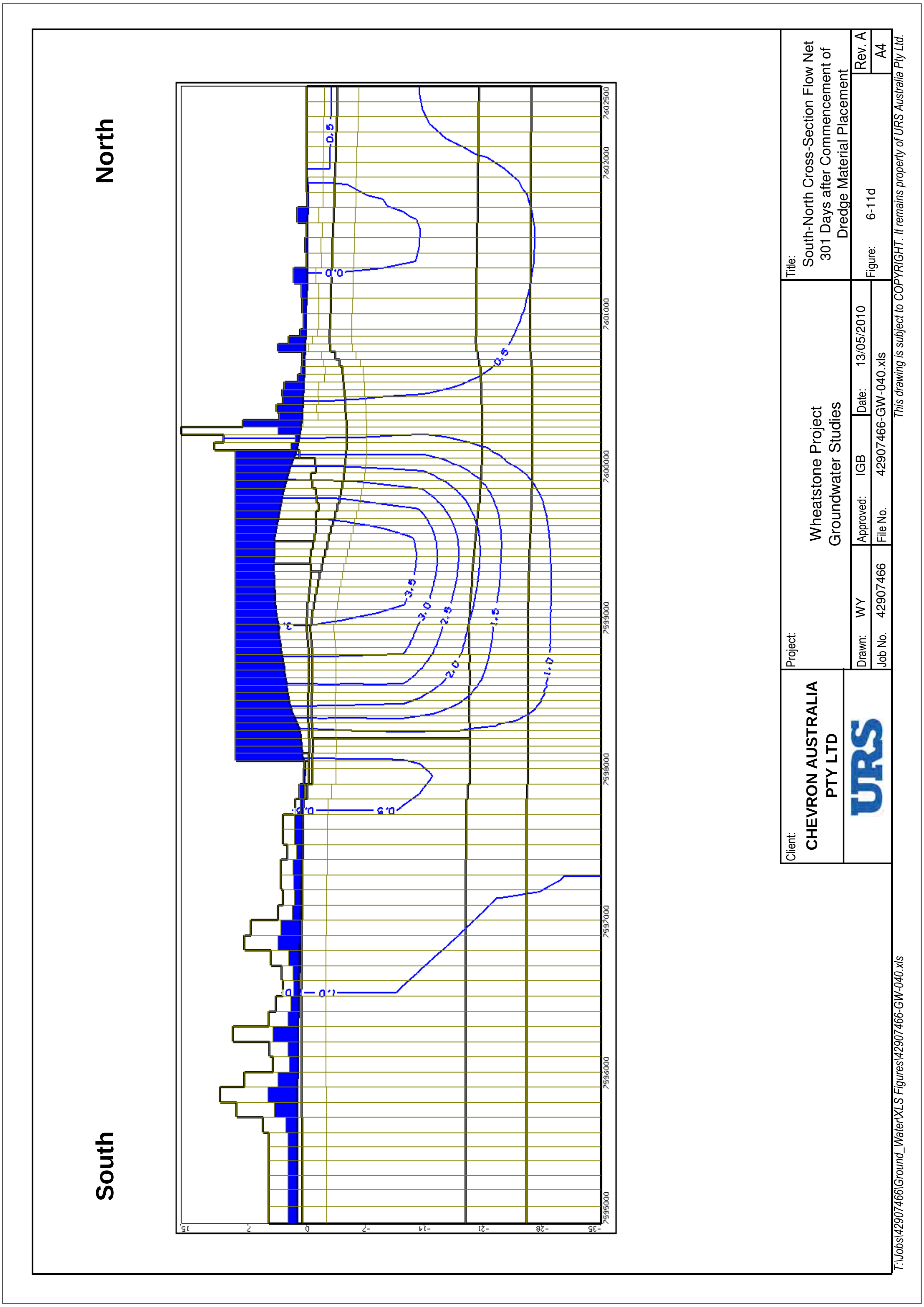
North
South
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
South-North Cross-Section Flow Net
301 Days after Commencement of
Dredge Material Placement
Drawn: WY
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-040.xls
Figure: 6-11d
A4
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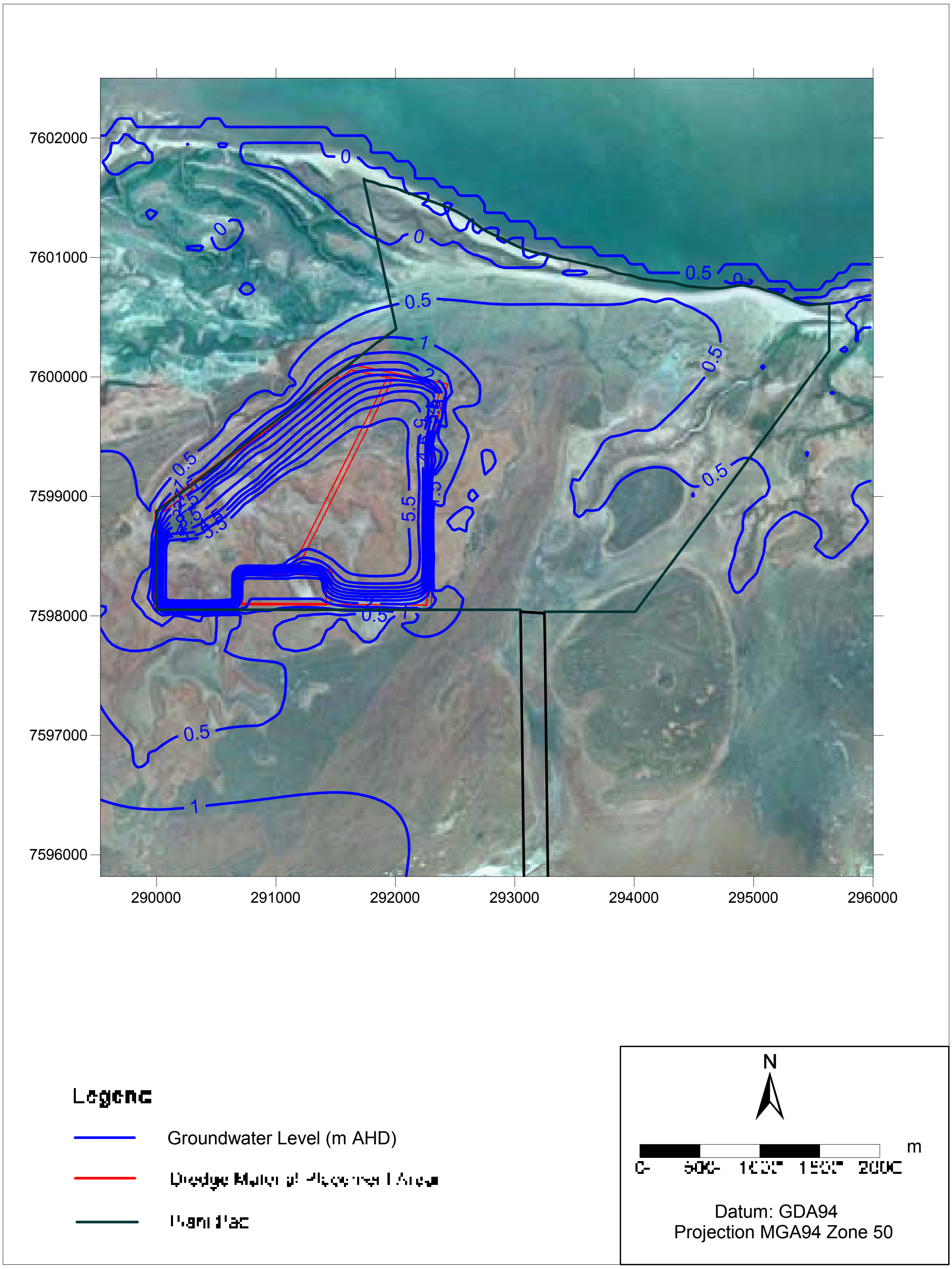

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Predicted Water Table Contours (m AHD) 485 Days after Commencement of Dredge Material Placement
URS	Drawn: / Job No:	Approved: / File No:	Date:	Figure:	Rev 0 / A4

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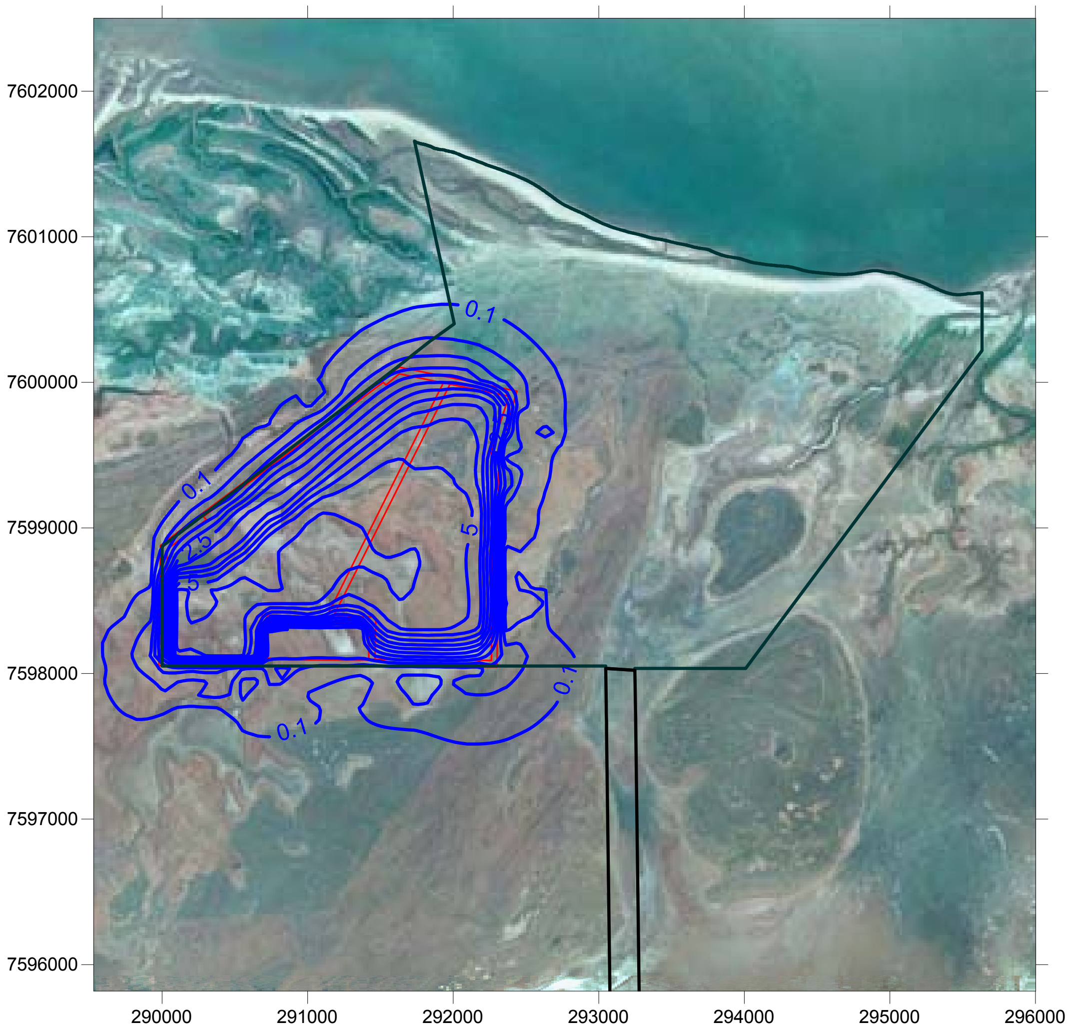


Legend

- Groundwater Mounding

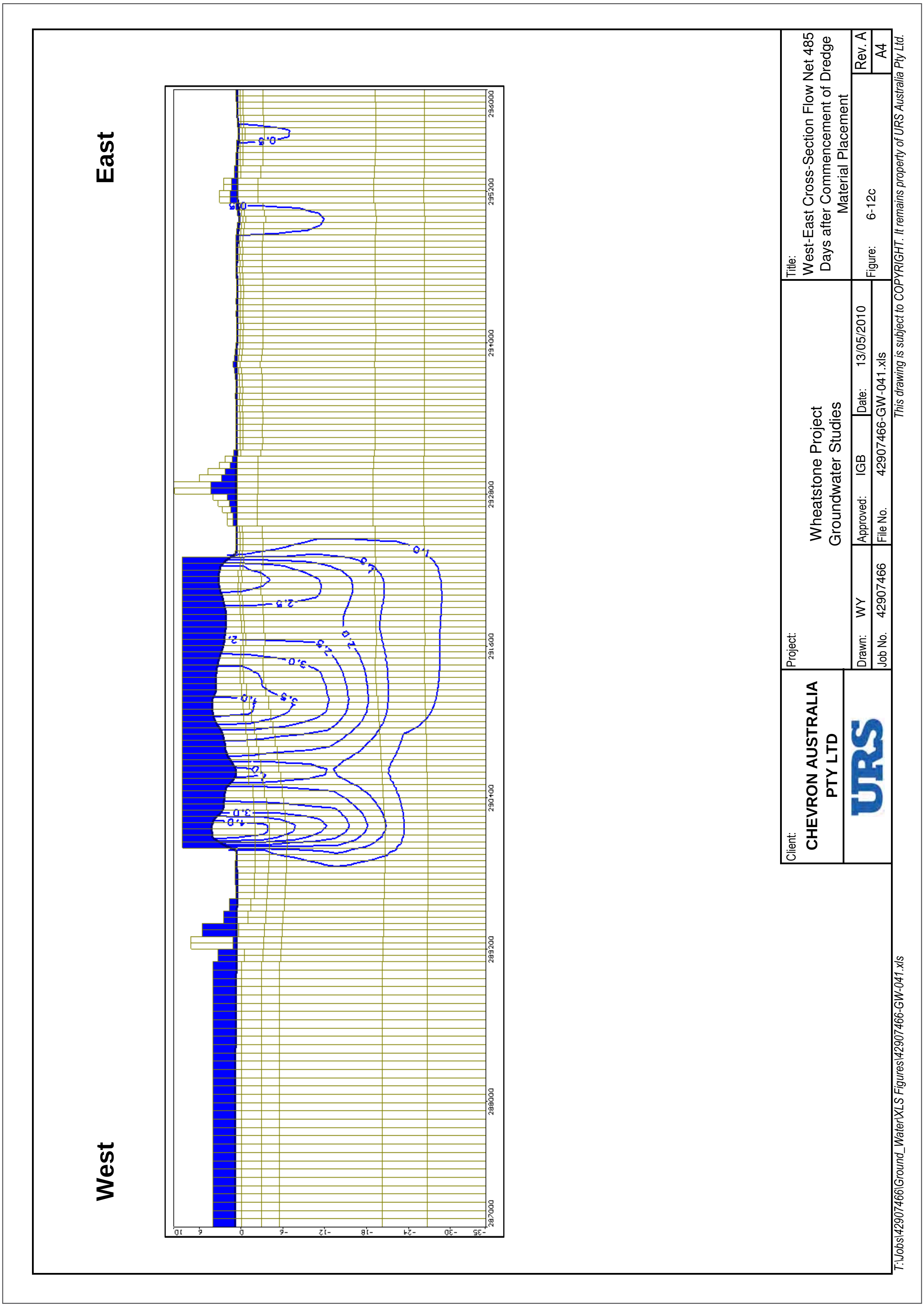
N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: Predicted Water Table Mounding 485 Days after Commencement of Dredge Material Placement	
URS	Drawn: / Approved: / Date: / Job No: / File No:	Figure:	Rev 0 / A4

J:\Jobs\42907466\Deliv\GRW\Figures\Figures_All


West
East
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project
Groundwater Studies
Title:
West-East Cross-Section Flow Net 485 Days after Commencement of Dredge Material Placement
Drawn: WY
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-041.xls
Figure: 6-12c
A4
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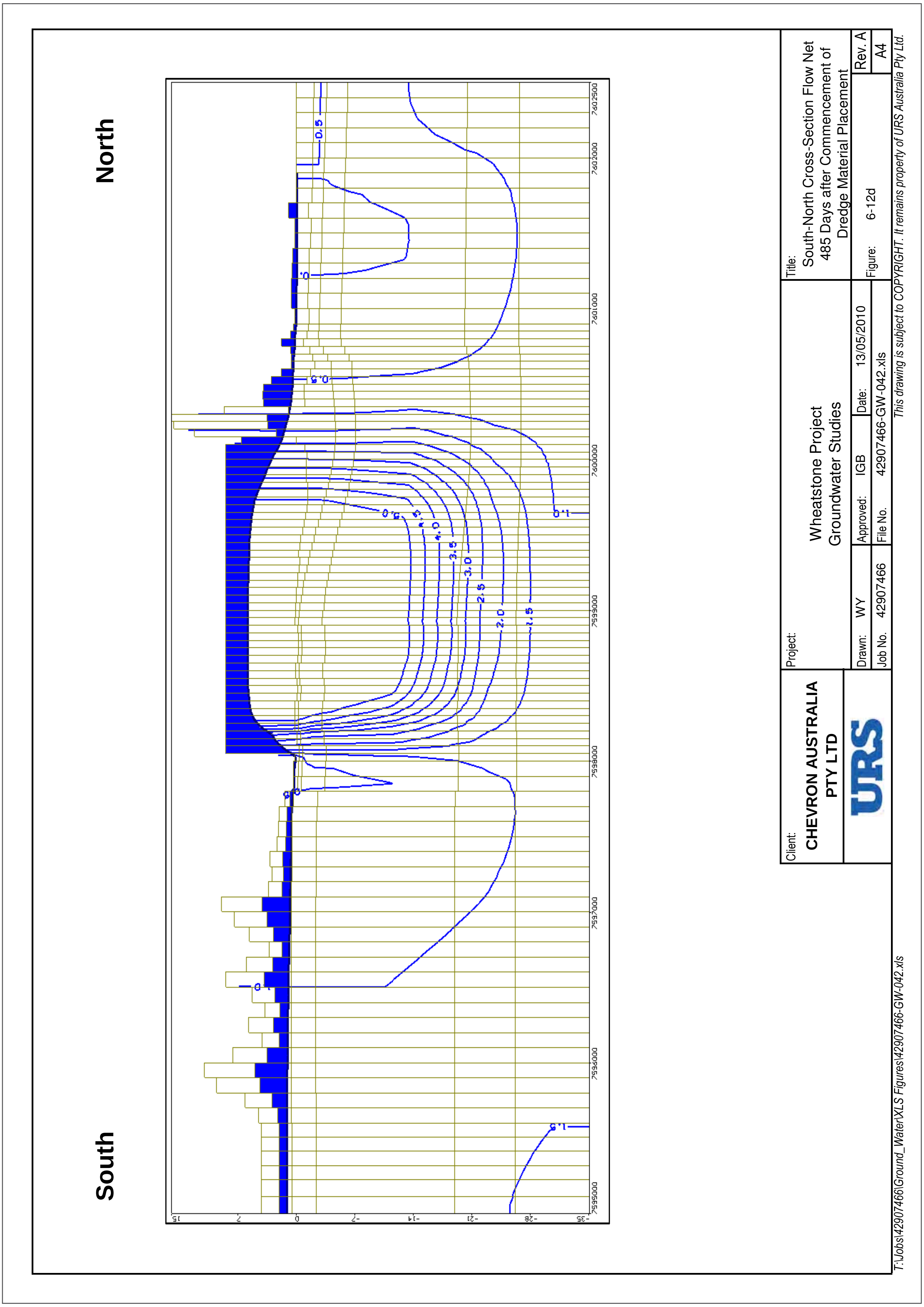
South
North
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
South-North Cross-Section Flow Net
485 Days after Commencement of
Dredge Material Placement
Drawn: WY
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-042.xls
Figure: 6-12d
A4
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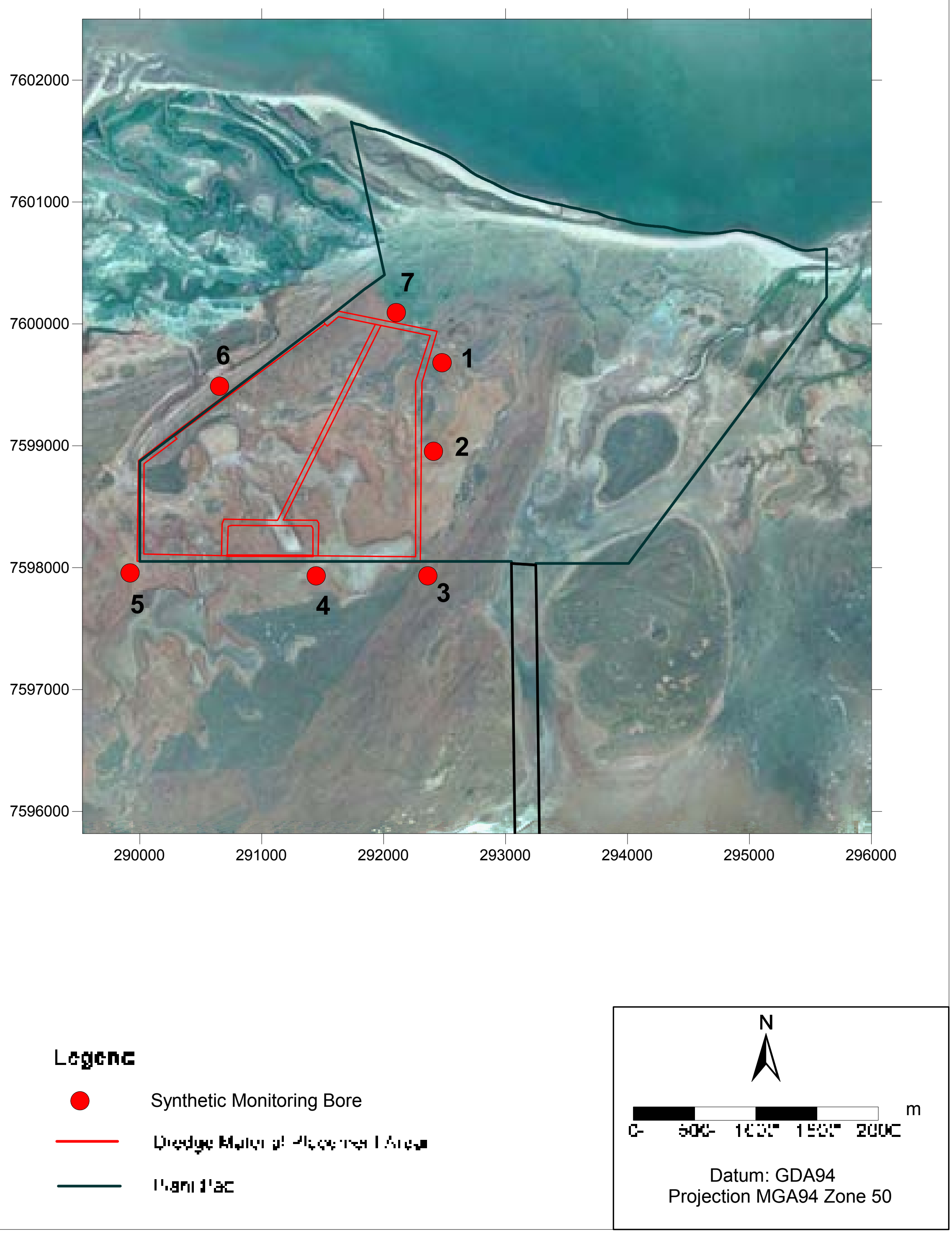

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Location Plan for Synthetic Monitoring Bores	
URS	Drawn: [illegible] Approved: [illegible] Date: [illegible]	Figure: [illegible]	Rev 0
	Job No: [illegible] File No: [illegible]		A4

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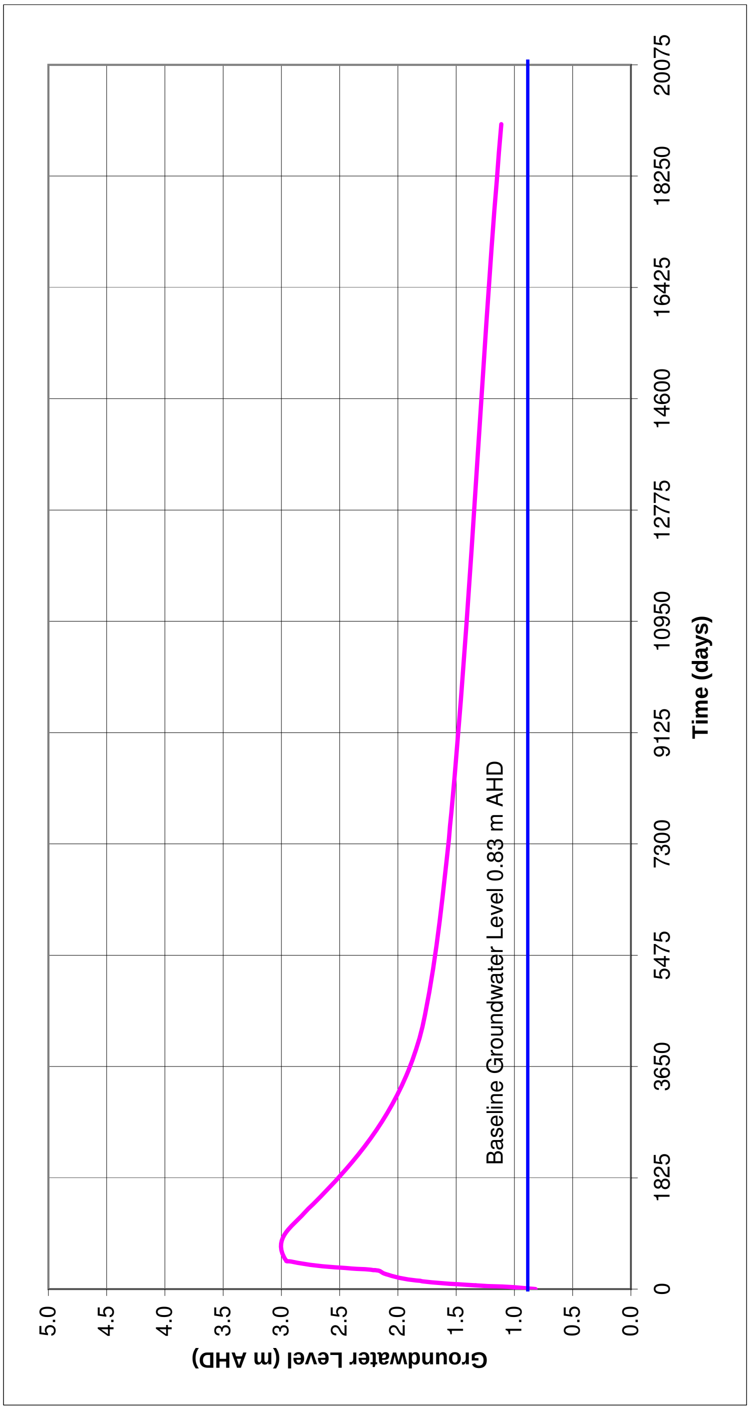

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Predicted Synthetic Monitoring Bore Hydrograph - Site 1	
URS	Drawn: WY / Job No. 42907466	Approved: IGB / File No. 42907466-GW-043.xls	Date: 13/05/2010 / Figure: 6-14a / Rev. A / A4

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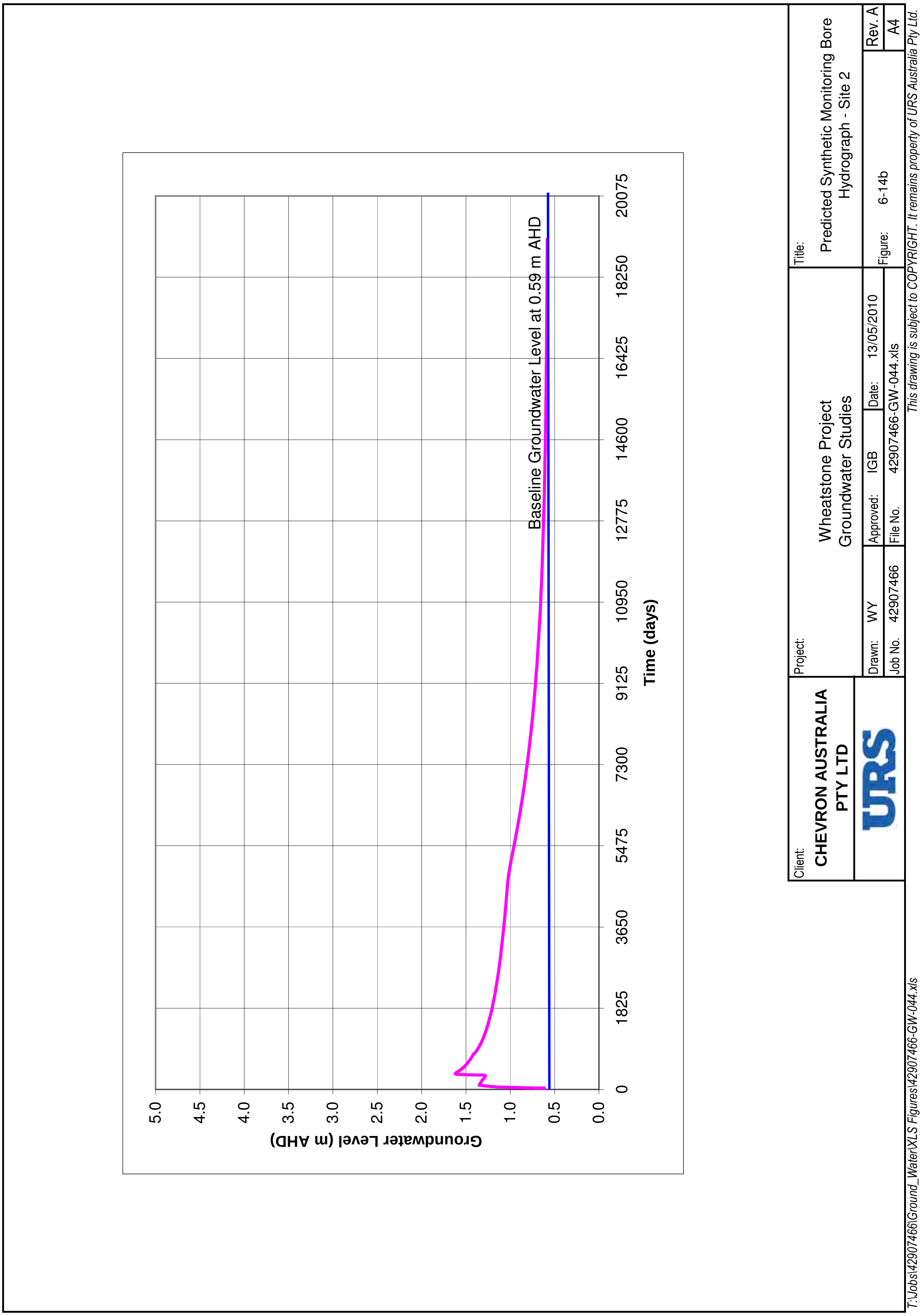
Groundwater Level (m AHD)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1825
3650
5475
7300
9125
10950
12775
14600
16425
18250
20075
Time (days)
Baseline Groundwater Level at 0.59 m AHD
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project Groundwater Studies
Title:
Predicted Synthetic Monitoring Bore Hydrograph - Site 2
Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-044.xls
Figure: 6-14b
Rev. A
A4
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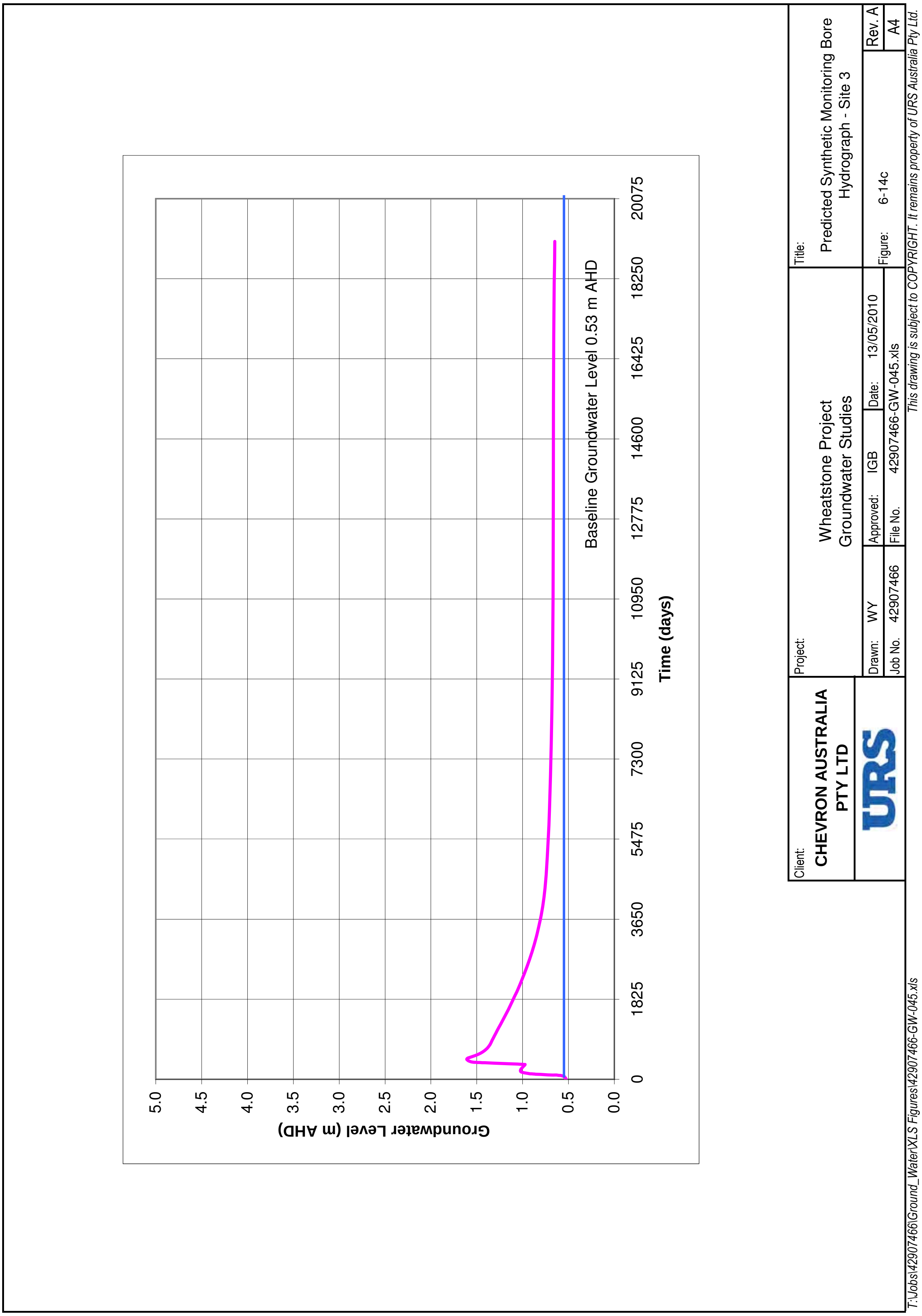
Groundwater Level (m AHD)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1825
3650
5475
7300
9125
10950
12775
14600
16425
18250
20075
Time (days)
Baseline Groundwater Level 0.53 m AHD
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Predicted Synthetic Monitoring Bore Hydrograph - Site 3
Drawn: WY
Approved: IGB
Date: 13/05/2010
Figure: 6-14c
Rev. A
Job No. 42907466
File No. 42907466-GW-045.xls
A4
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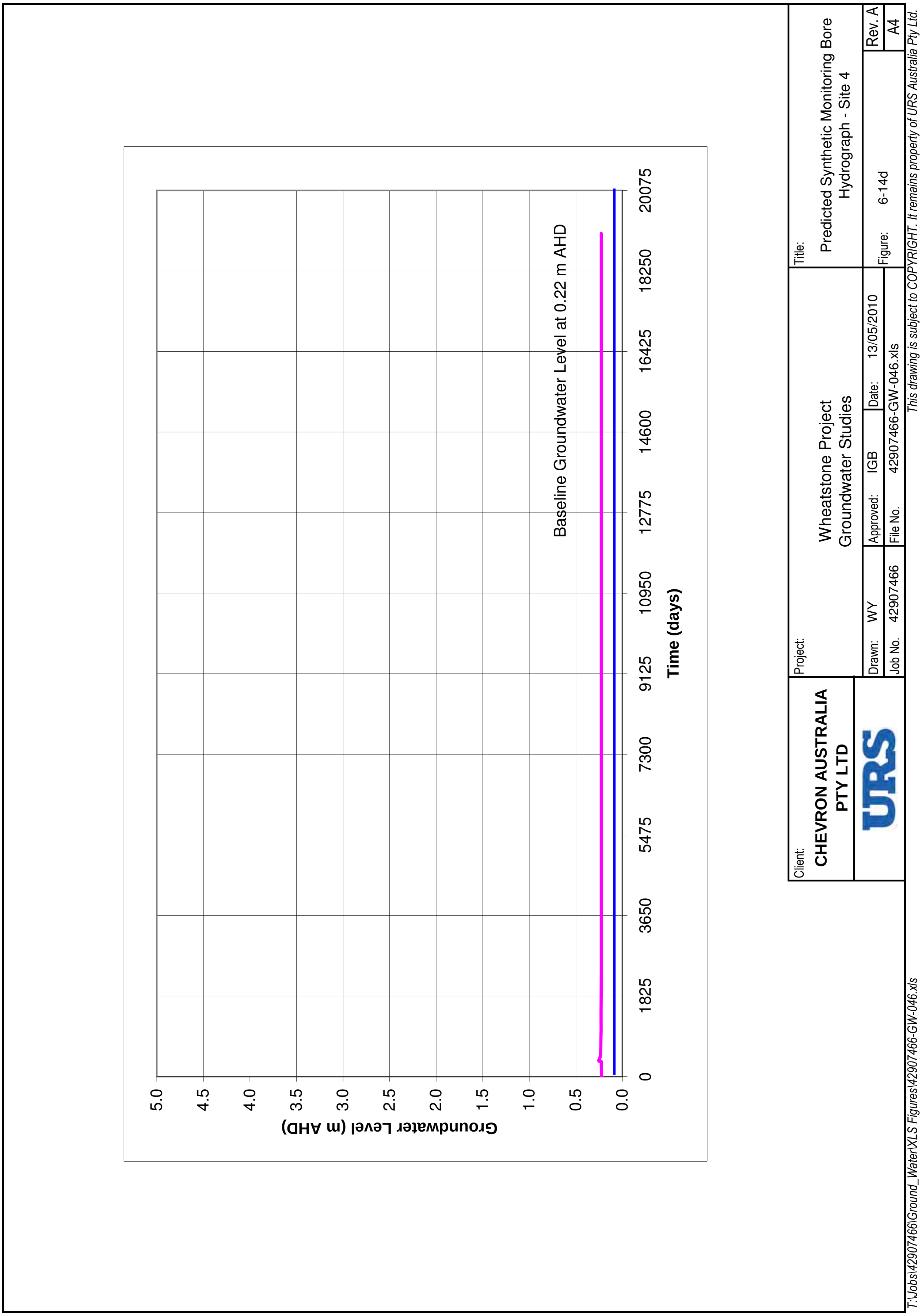
Baseline Groundwater Level at 0.22 m AHD
Groundwater Level (m AHD)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1825
3650
5475
7300
9125
10950
12775
14600
16425
18250
20075
Time (days)
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Predicted Synthetic Monitoring Bore Hydrograph - Site 4
Drawn: WY
Approved: IGB
Date: 13/05/2010
Figure: 6-14d
Rev. A
A4
Job No. 42907466
File No. 42907466-GW-046.xls
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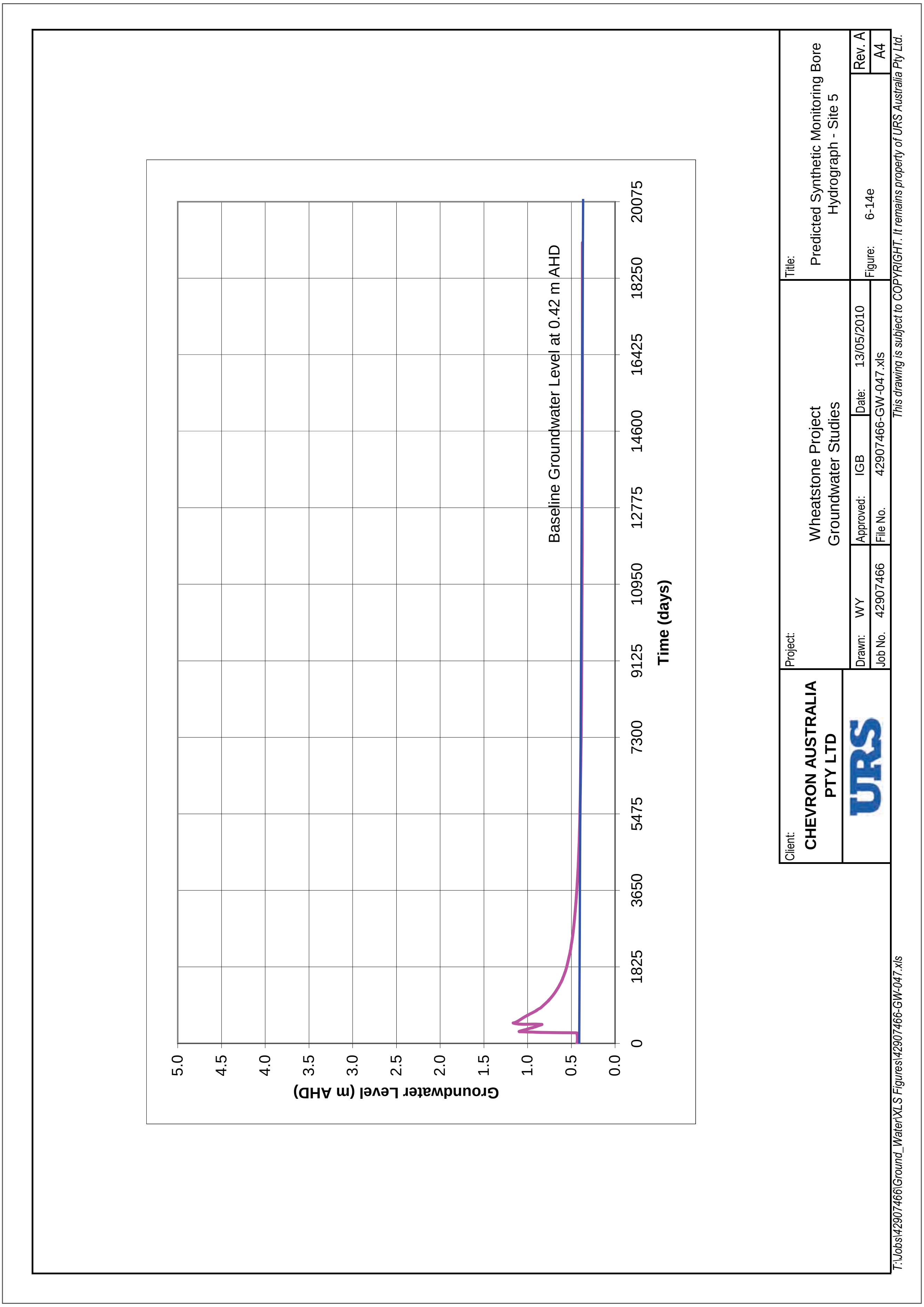
Baseline Groundwater Level at 0.42 m AHD
Groundwater Level (m AHD)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1825
3650
5475
7300
9125
10950
12775
14600
16425
18250
20075
Time (days)
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project Groundwater Studies
Title:
Predicted Synthetic Monitoring Bore Hydrograph - Site 5
Drawn: WY
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-047.xls
Figure: 6-14e
A4
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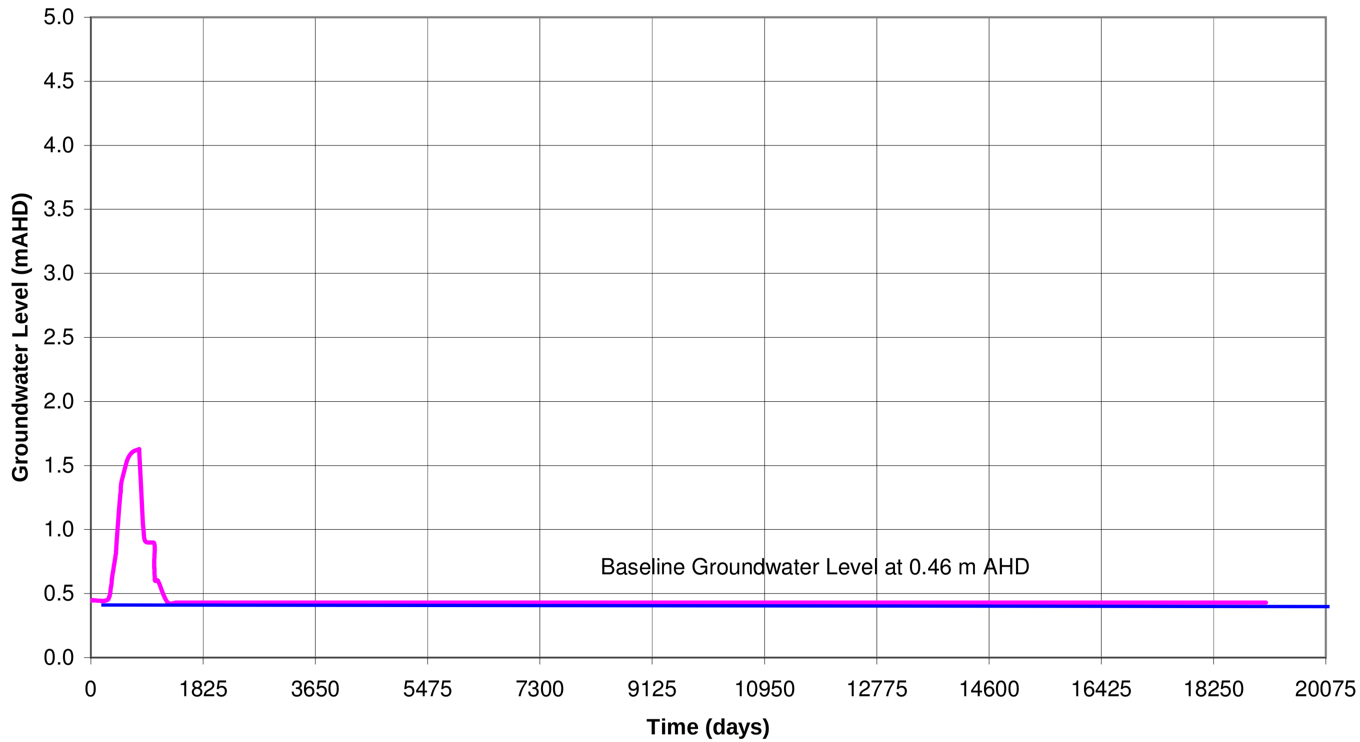

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Predicted Synthetic Monitoring Bore Hydrograph - Site 6
URS	Drawn: WY; Approved: IGB; Date: 13/05/2010; Job No. 42907466; File No. 42907466-GW-048.xls	Figure: 6-14f; Rev. A; A4

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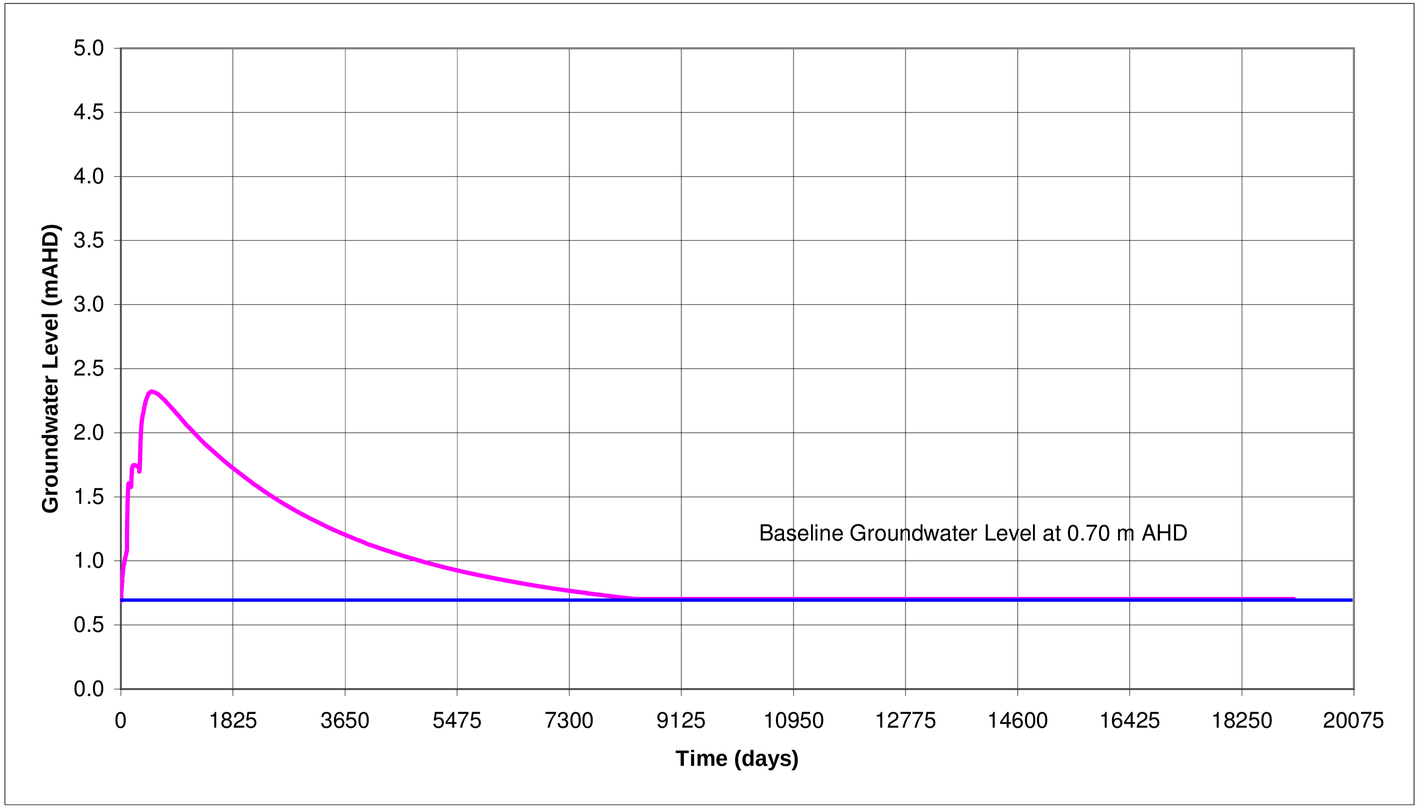

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Predicted Synthetic Monitoring Bore Hydrograph - Site 7
URS	Drawn: WY / Approved: IGB / Date: 13/05/2010	Figure: 6-14g / Rev. A
	Job No. 42907466 / File No. 42907466-GW-049.xls	A4

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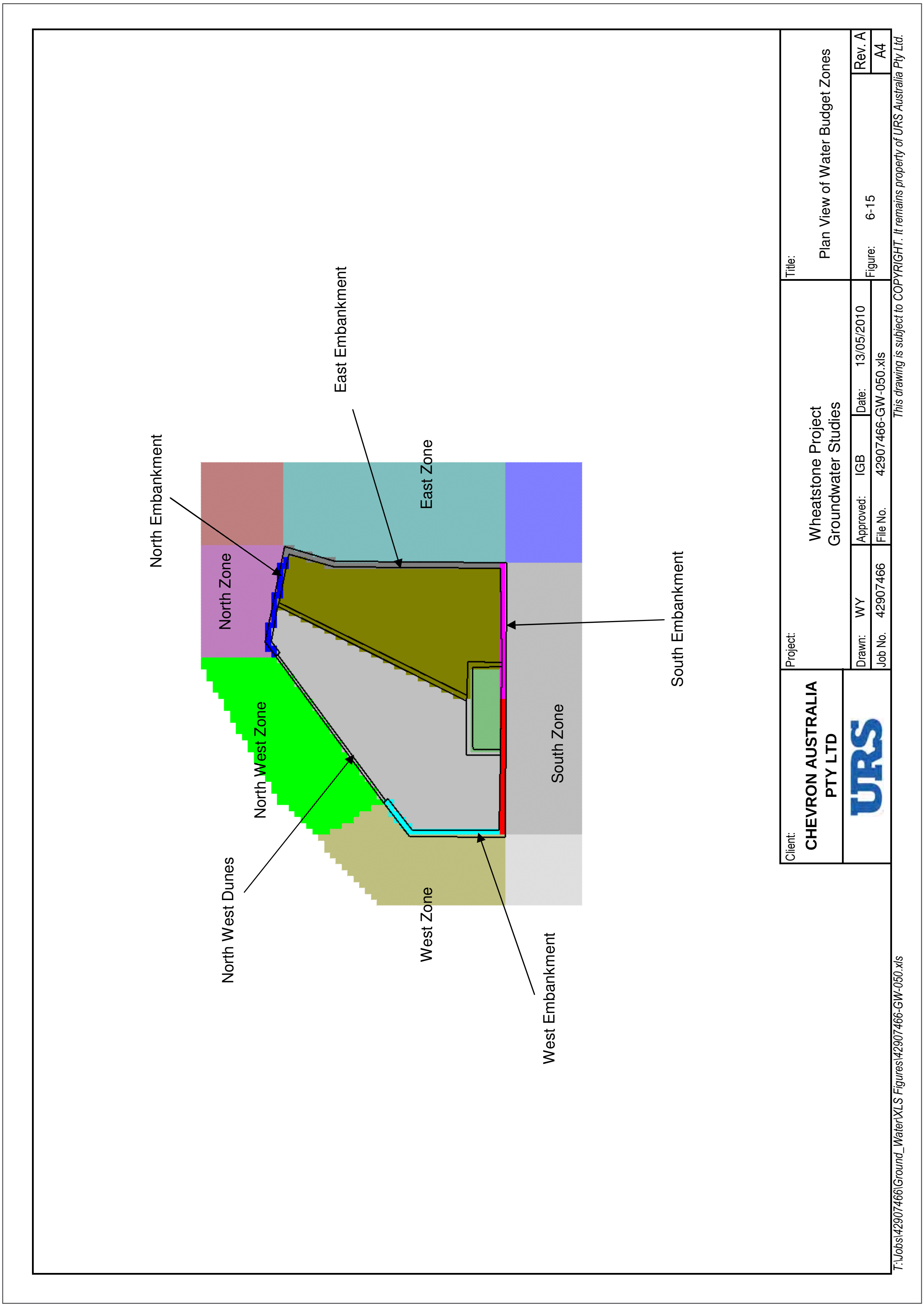
North Embankment
East Embankment
North Zone
East Zone
South Embankment
North West Zone
South Zone
North West Dunes
West Zone
West Embankment
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project
Groundwater Studies
Title:
Plan View of Water Budget Zones
Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-050.xls
Figure: 6-15
Rev. A
A4
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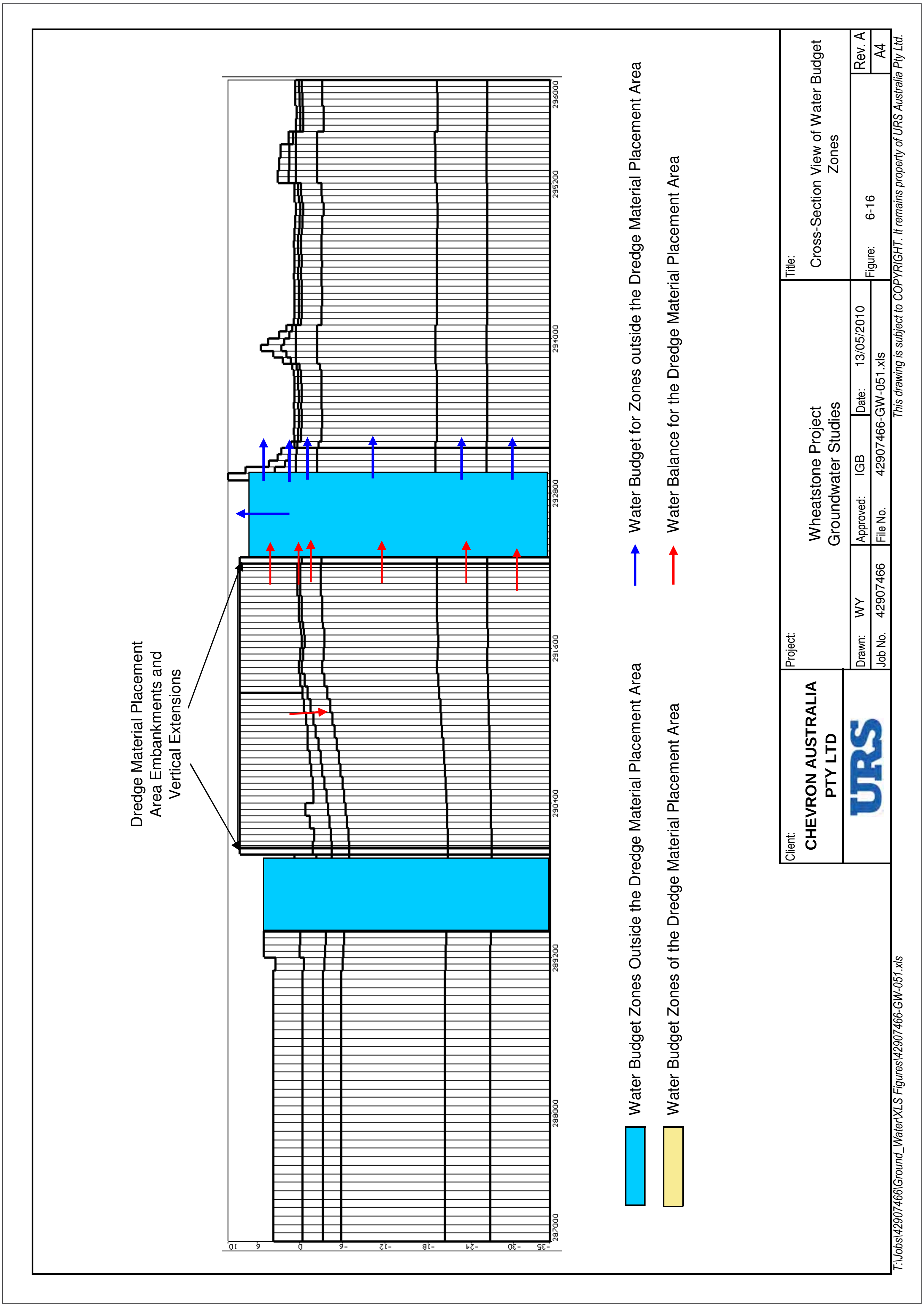
Dredge Material Placement Area Embankments and Vertical Extensions
Water Budget Zones Outside the Dredge Material Placement Area
Water Budget Zones of the Dredge Material Placement Area
Water Budget for Zones outside the Dredge Material Placement Area
Water Balance for the Dredge Material Placement Area
Client: CHEVRON AUSTRALIA PTY LTD
URS
Project: Wheatstone Project Groundwater Studies
Title: Cross-Section View of Water Budget Zones
Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-051.xls
Figure: 6-16
Rev. A
A4
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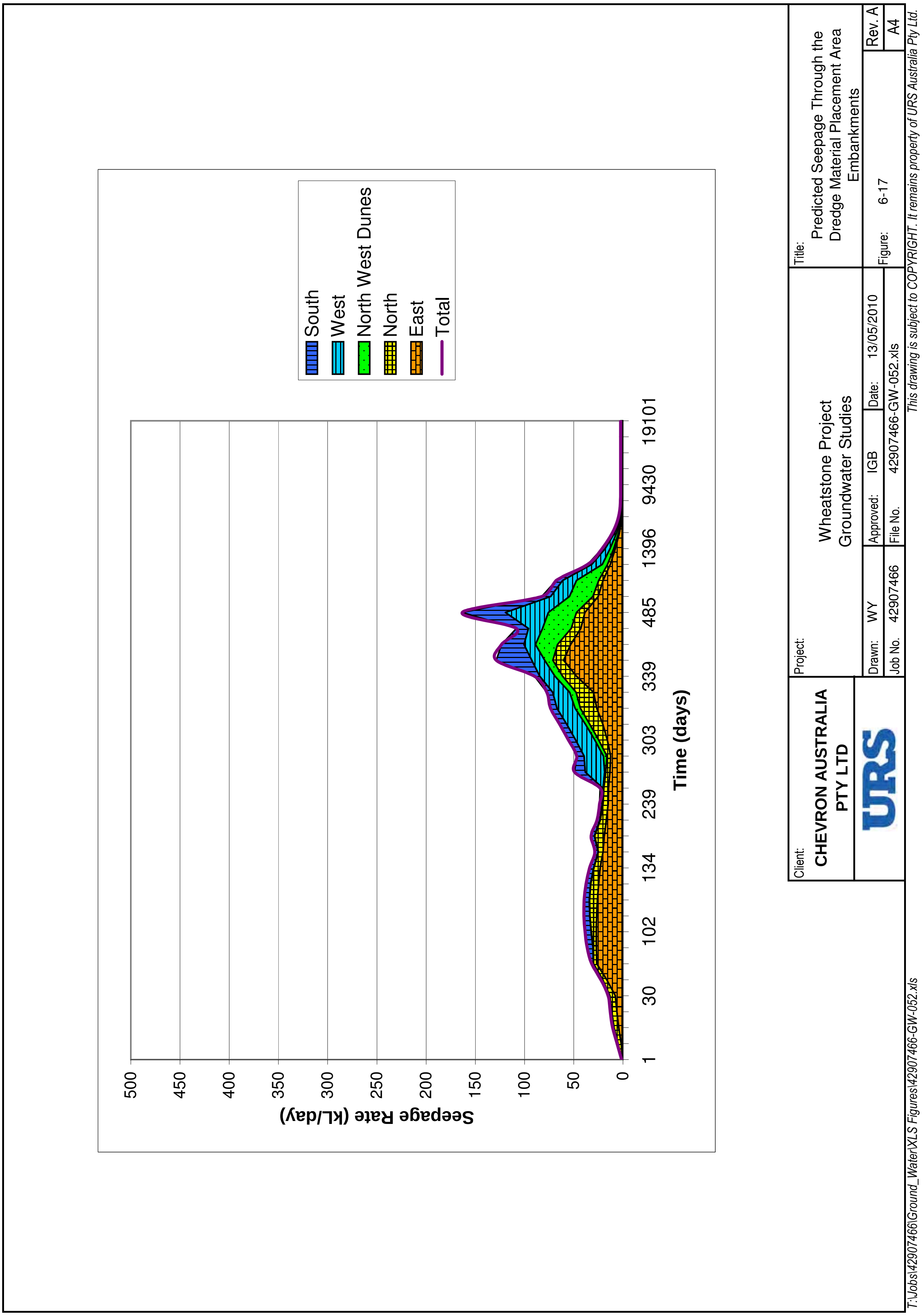
Seepage Rate (kL/day)
0
50
100
150
200
250
300
350
400
450
500
Time (days)
1
30
102
134
239
303
339
485
1396
9430
19101
South
West
North West Dunes
North
East
Total
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
Predicted Seepage Through the Dredge Material Placement Area Embankments
Drawn: WY
Approved: IGB
Date: 13/05/2010
Figure: 6-17
Rev. A
Job No. 42907466
File No. 42907466-GW-052.xls
A4
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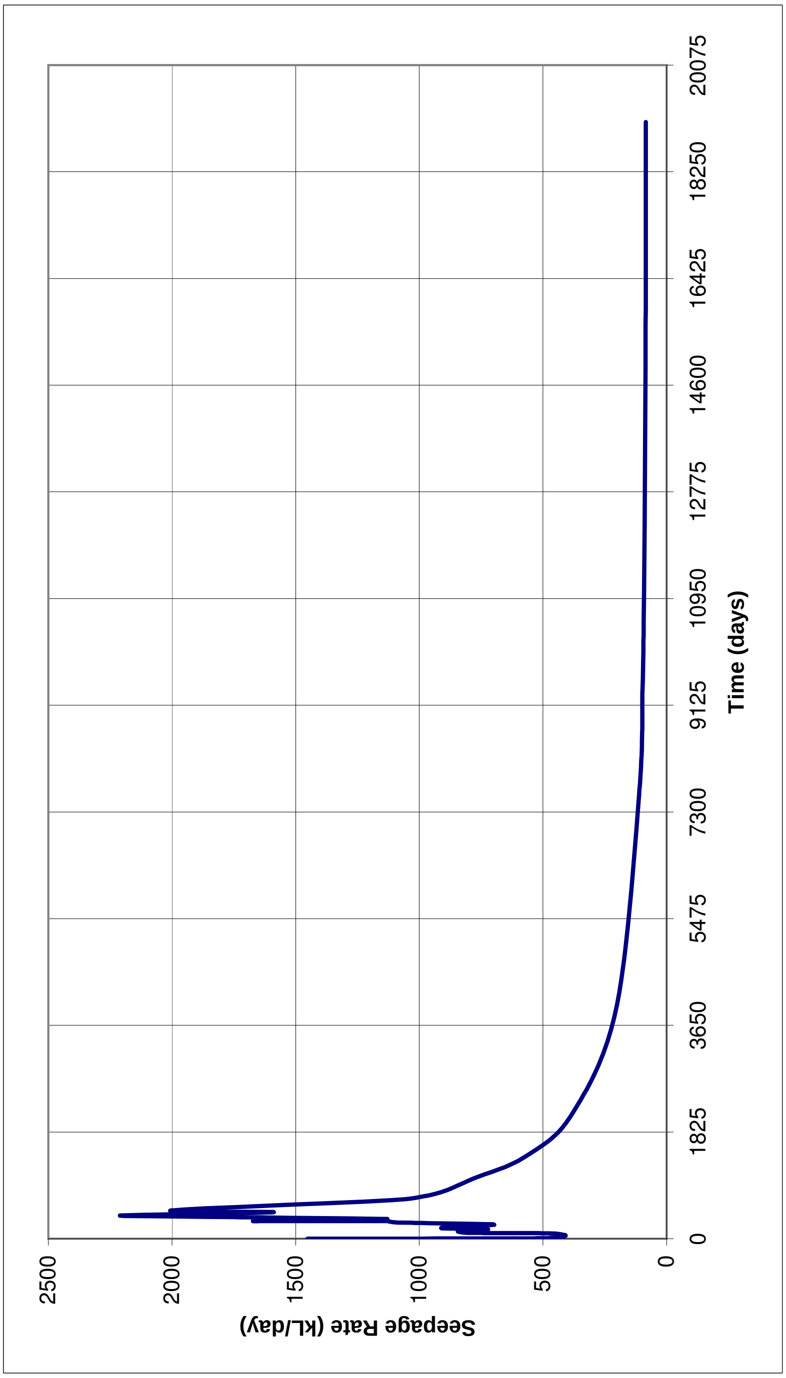
T:\Jobs\42907466\Ground_Water\XLS Figures\42907466-GW-052.xls



Client: **CHEVRON AUSTRALIA PTY LTD**

URS

Project: Wheatstone Project Groundwater Studies

Title: Predicted Seepage Through Base of the Dredge Material Placement Area

Drawn:	WY	Approved:	IGB	Date:	13/05/2010
Job No.	42907466	File No.	42907466-GW-053.xls	Figure:	6-18

Rev. A

A4

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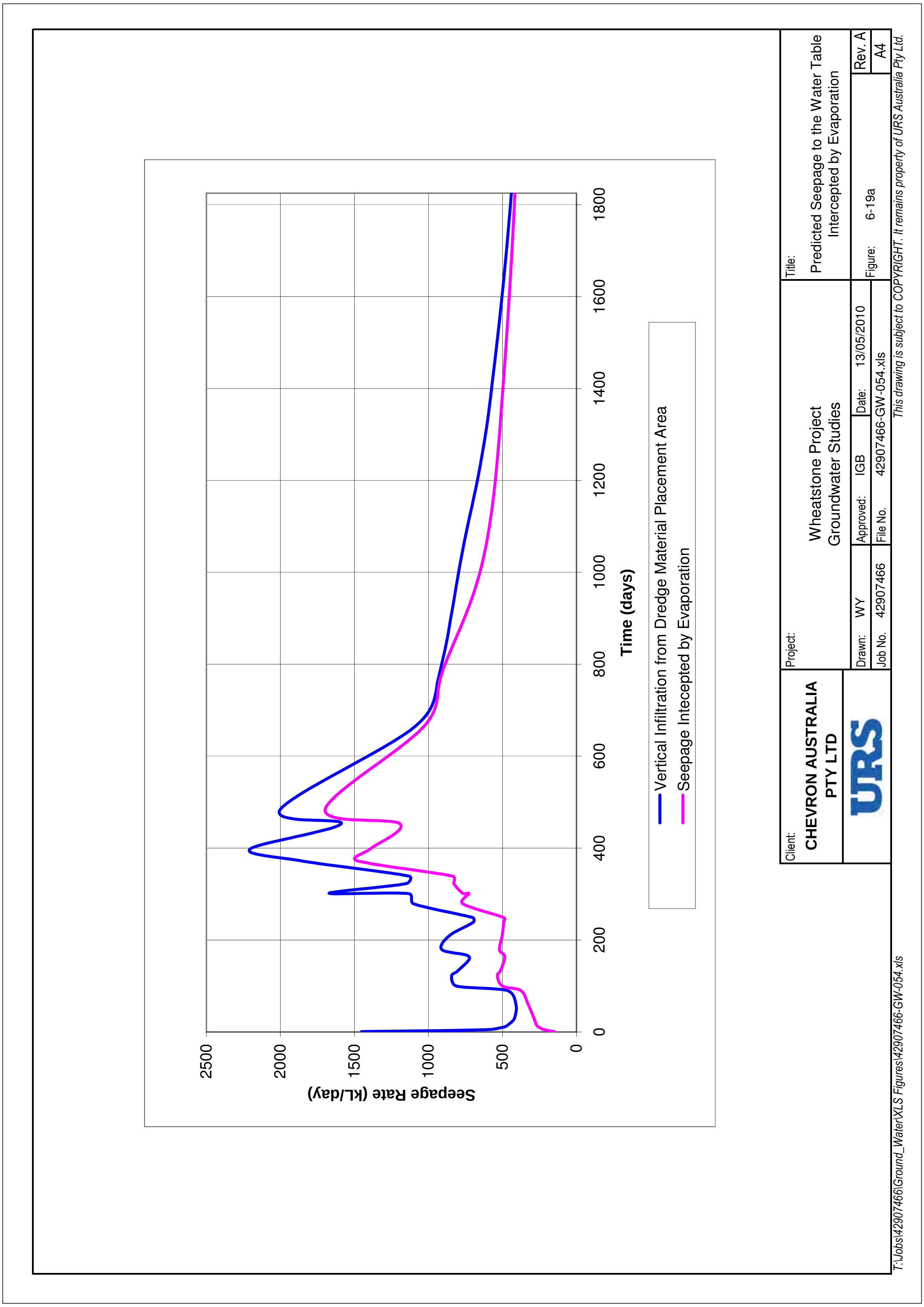

Seepage Rate (kL/day)
0
500
1000
1500
2000
2500
Time (days)
0
200
400
600
800
1000
1200
1400
1600
1800
Vertical Infiltration from Dredge Material Placement Area
Seepage Intecepted by Evaporation
Client:
CHEVRON AUSTRALIA PTY LTD
Project:
Wheatstone Project Groundwater Studies
Title:
Predicted Seepage to the Water Table Intercepted by Evaporation
Drawn: WY
Approved: IGB
Date: 13/05/2010
Job No. 42907466
File No. 42907466-GW-054.xls
Figure: 6-19a
Rev. A
A4
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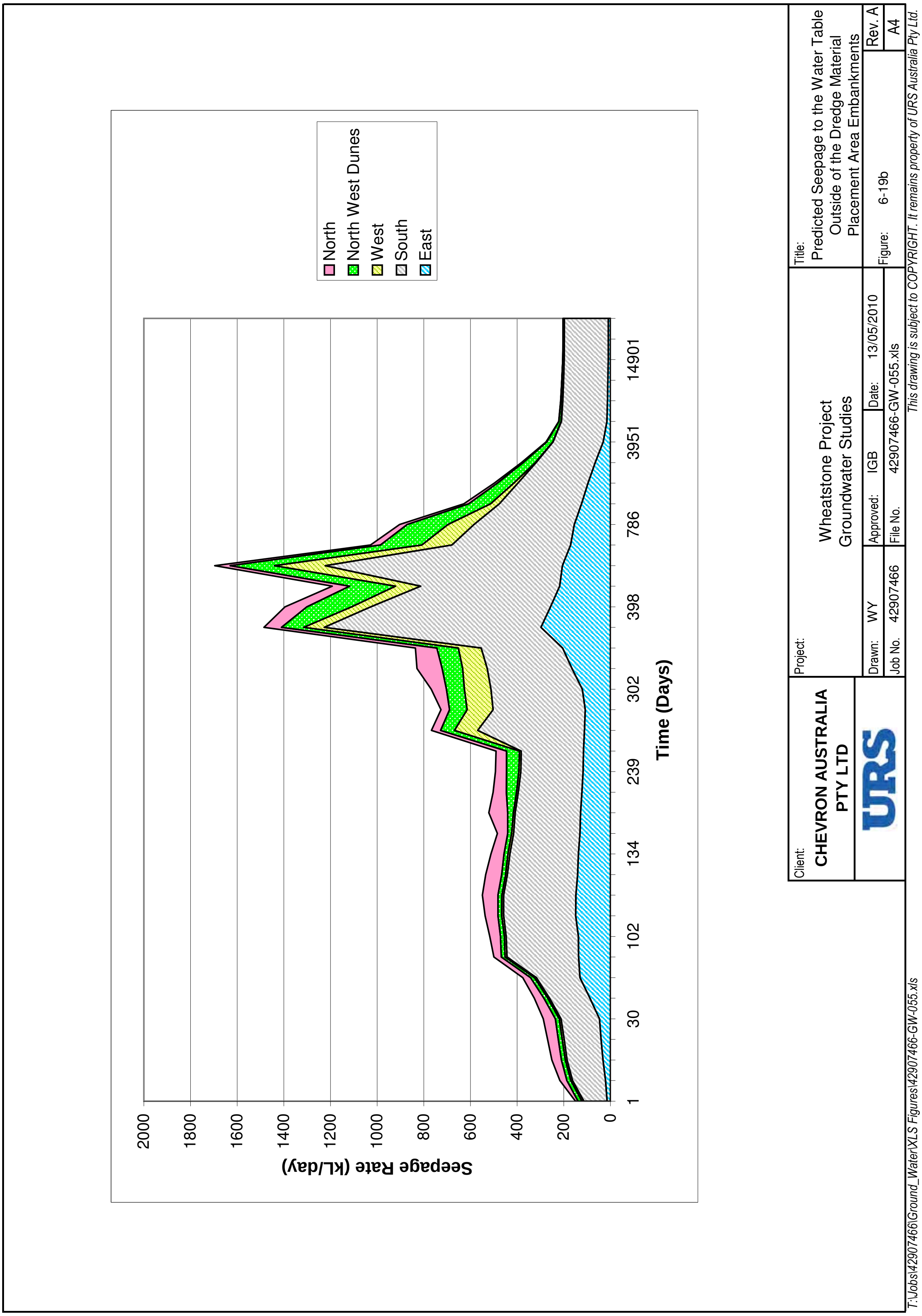
Seepage Rate (kL/day)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1
30
102
134
239
302
398
786
3951
14901
Time (Days)
North
North West Dunes
West
South
East
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
Predicted Seepage to the Water Table Outside of the Dredge Material Placement Area Embankments
Drawn: WY
Approved: IGB
Date: 13/05/2010
Rev. A
Job No. 42907466
File No. 42907466-GW-055.xls
Figure: 6-19b
A4
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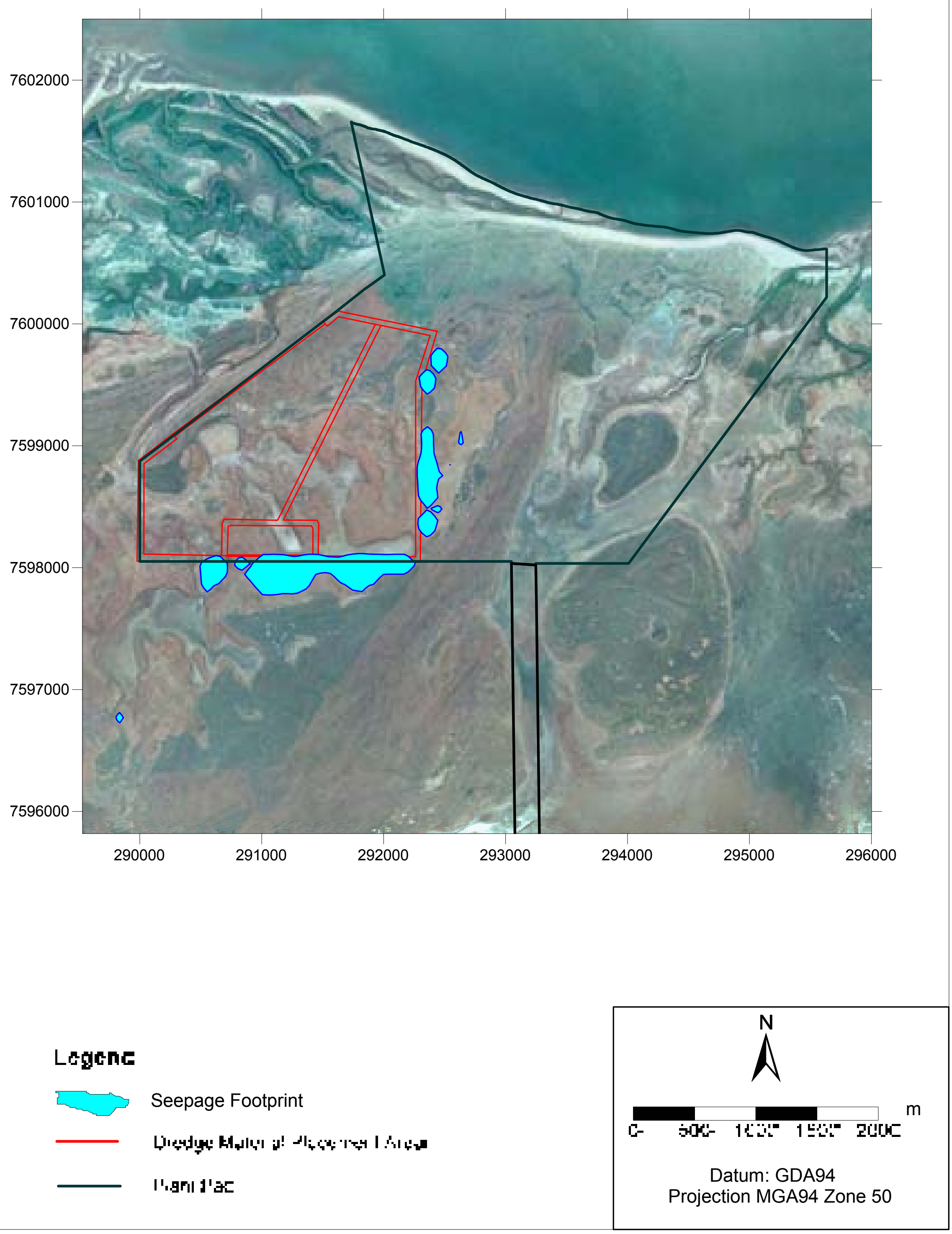

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies		Title: Seepage Footprint 100 Days after Commencement of Dredge Material Placement
URS	Drawn: [illegible]	Approved: [illegible]	Date: [illegible]
	Job No: [illegible]	File No: [illegible]	Figure: [illegible] — Rev 0 — A4

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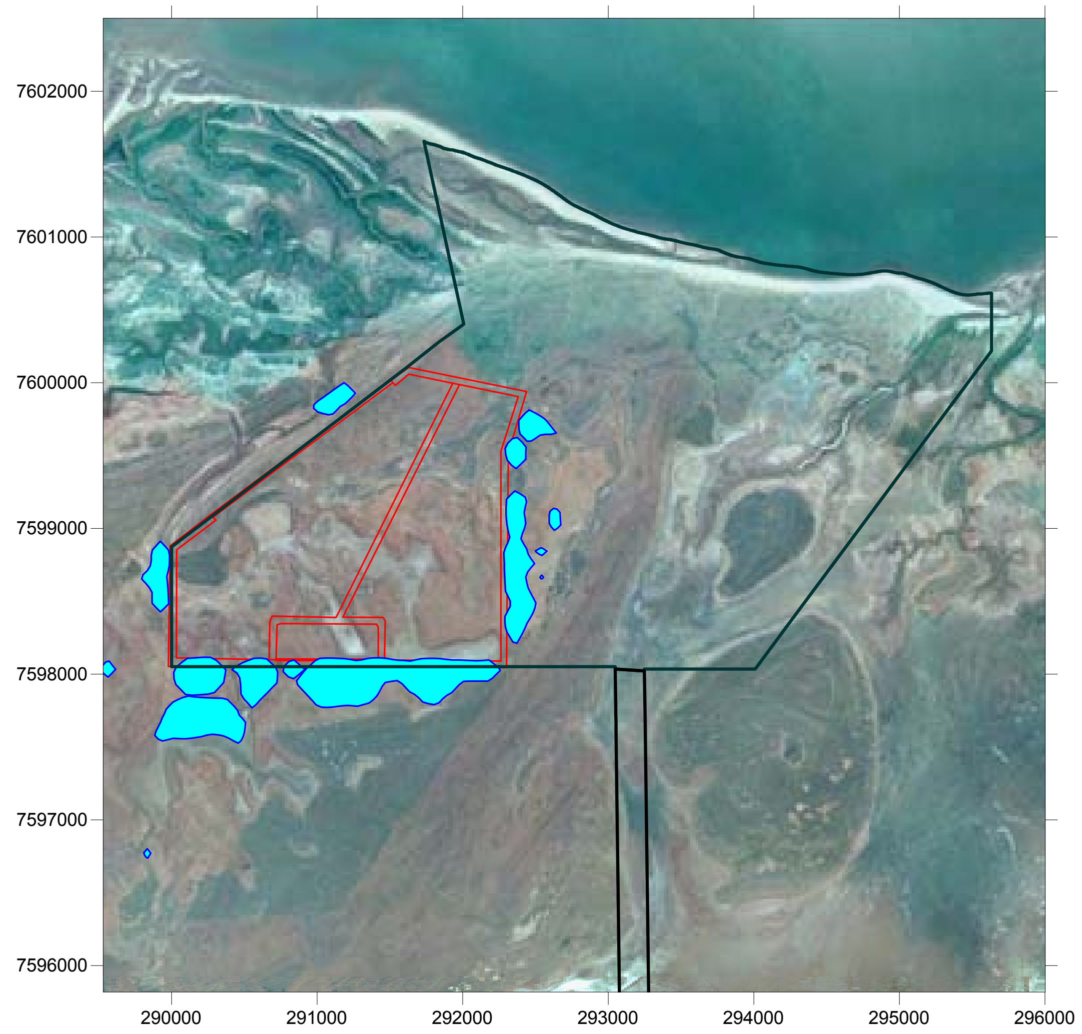

Legend

Seepage Footprint

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: Seepage Footprint 301 Days after Commencement of Dredge Material Placement
URS	Drawn: / Approved: / Date: / Job No: / File No:	Figure: Rev 0 A4

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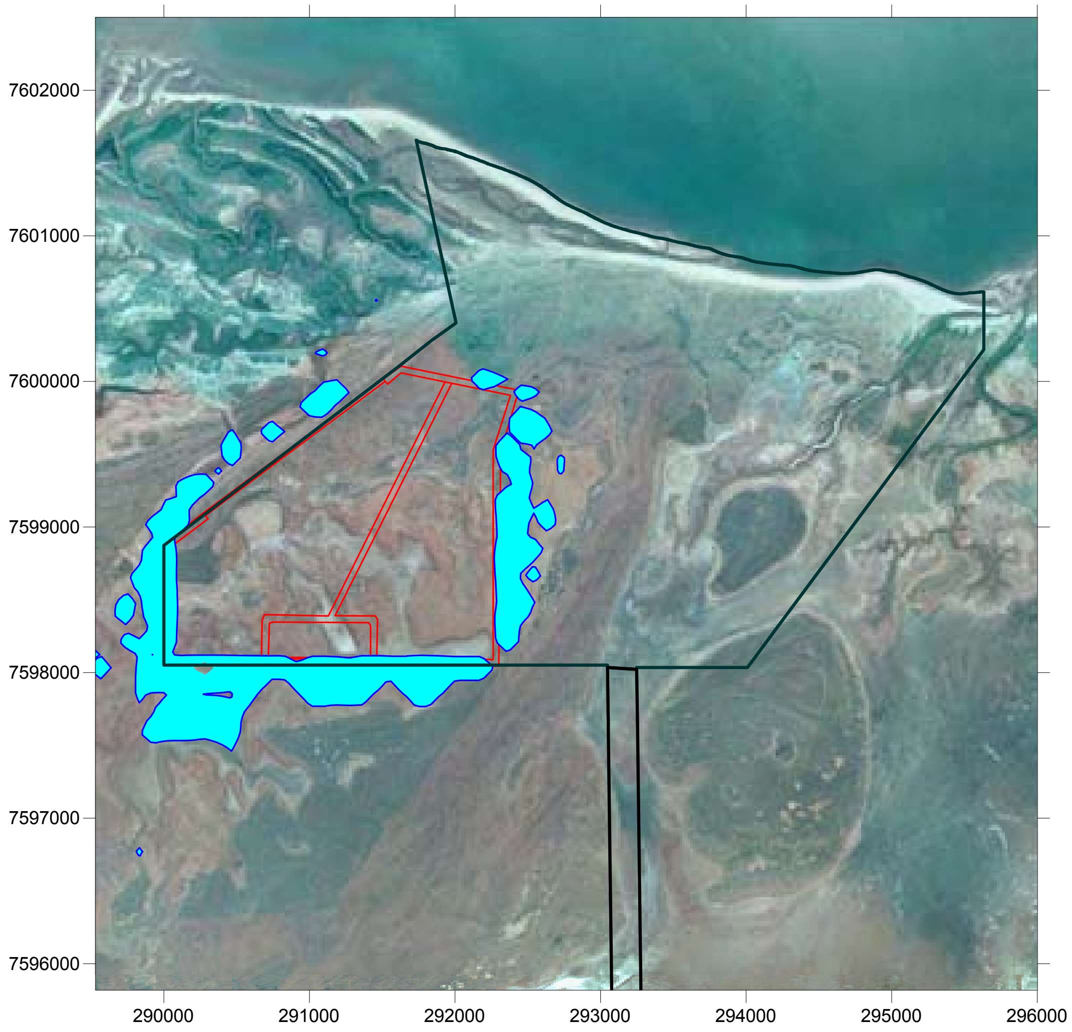

Legend

Seepage Footprint

[illegible]

[illegible]

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: Seepage Footprint 485 Days after Commencement of Dredge Material Placement
URS	Drawn: [illegible] / Approved: [illegible] / Date: [illegible] / Job No: [illegible] / File No: [illegible]	Figure: [illegible] / Rev 0 / A4

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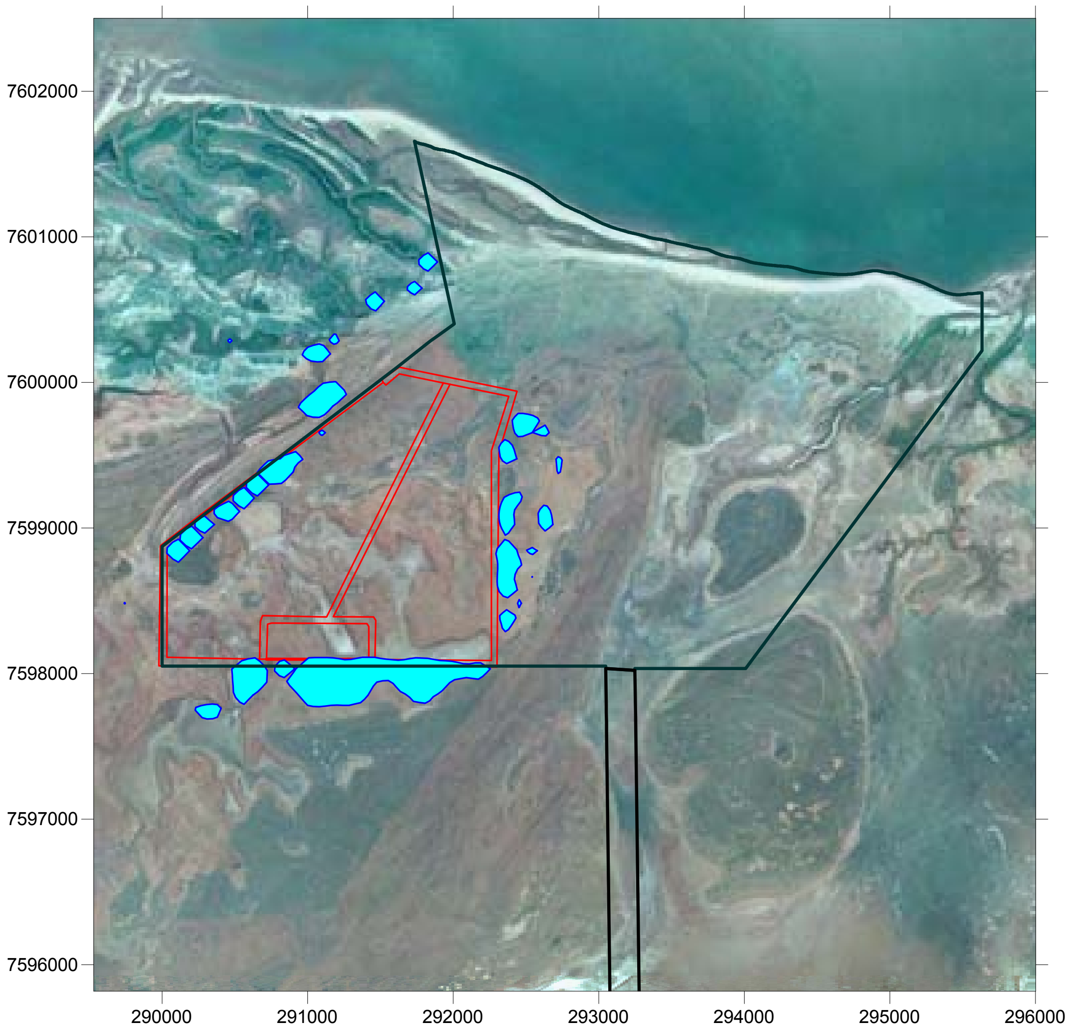

Legend

- Seepage Footprint
- Dredge Material Placement Area

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Seepage Footprint Five Years after Commencement of Dredge Material Placement
URS	Drawn: / Approved: / Date: / Job No: / File No:	Figure: / Rev 0 / A4

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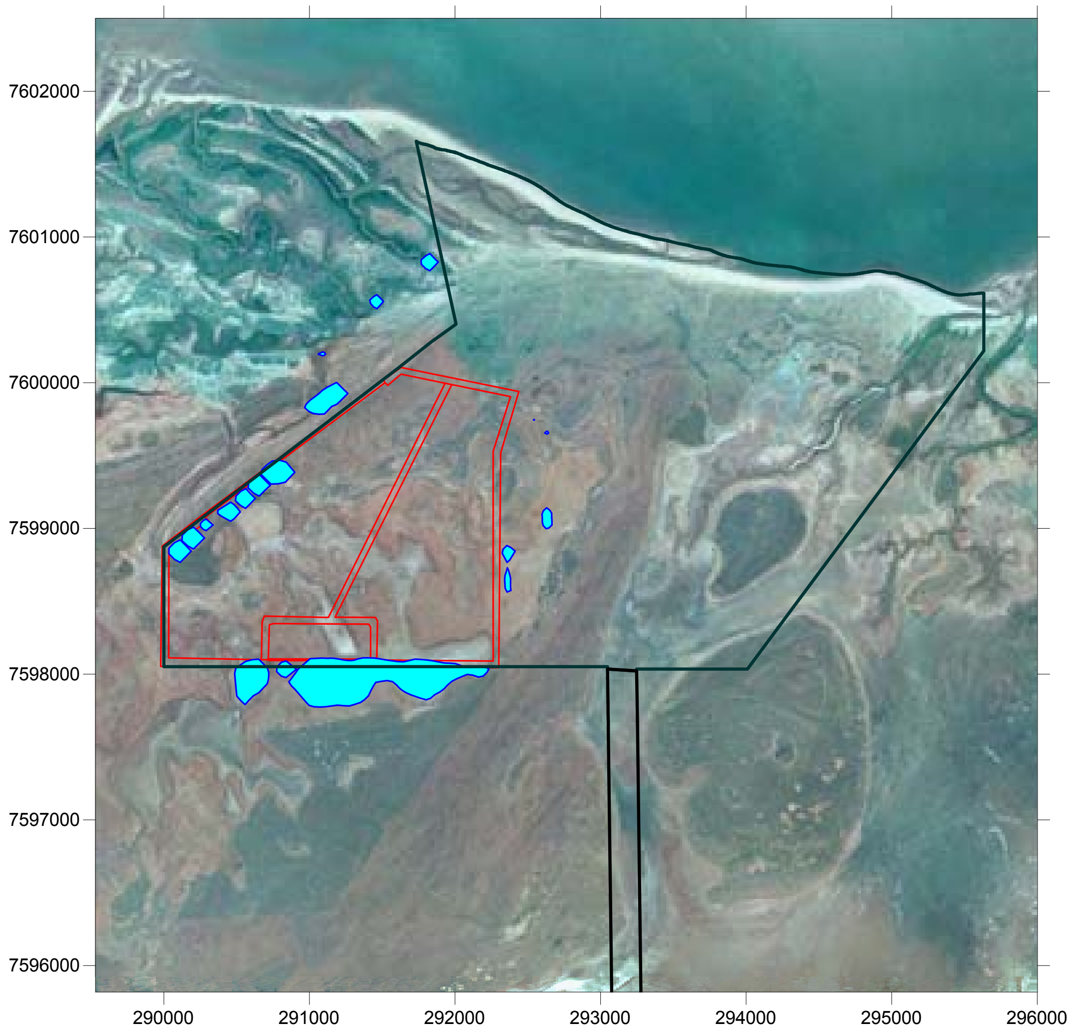

Legend

- Seepage Footprint
- Dredge Material Placement Area

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client:	Project:	Title:
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Groundwater Studies	Seepage Footprint Ten Years after Commencement of Dredge Material Placement
URS	Drawn: / Approved: / Date: / Job No: / File No:	Figure: / Rev 0 / A4

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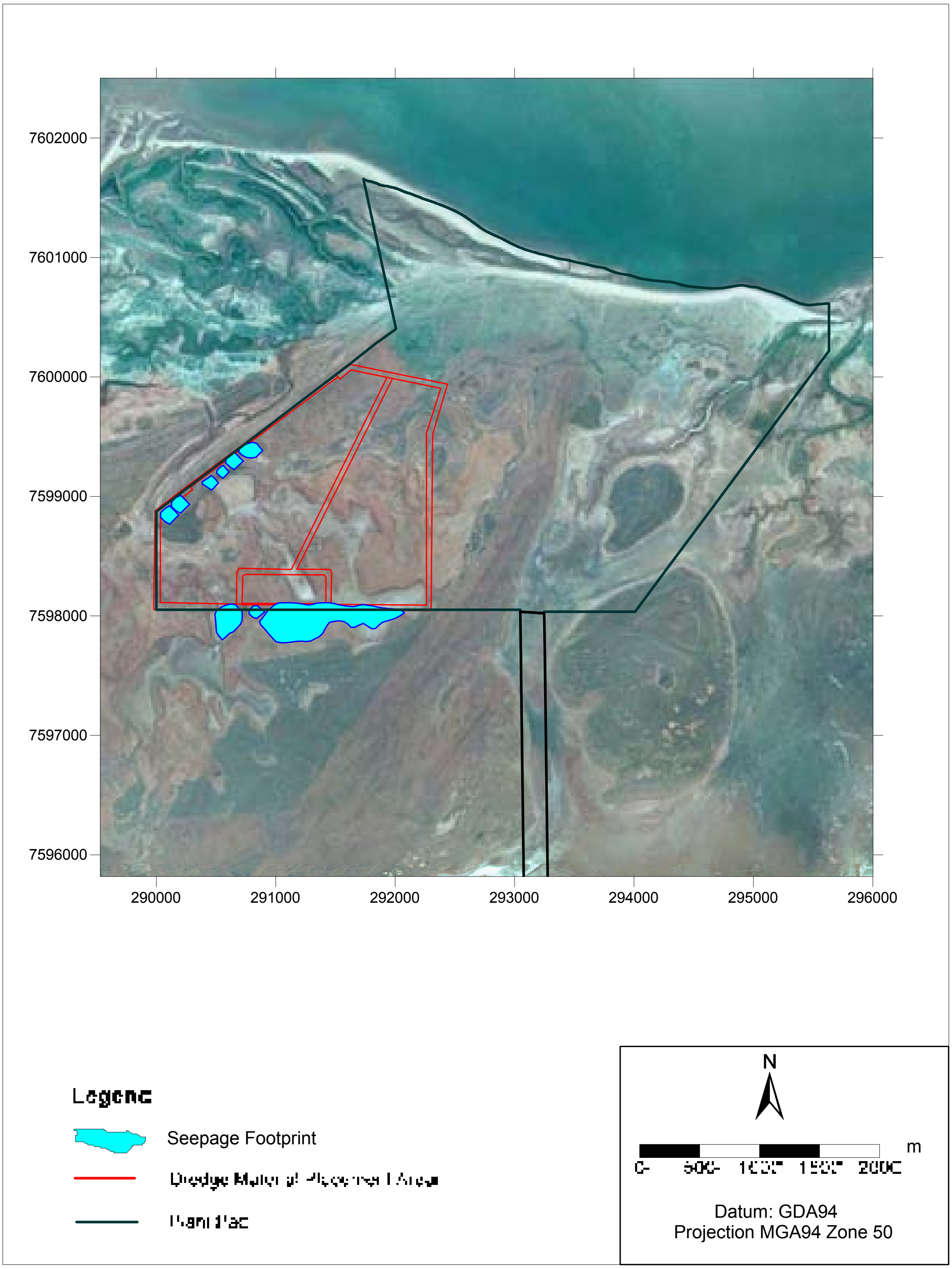

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: Seepage Footprint 50 Years after Commencement of Dredge Material Placement
URS	Drawn: / Approved: / Date: / Job No: / File No:	Figure: / Rev 0 / A4

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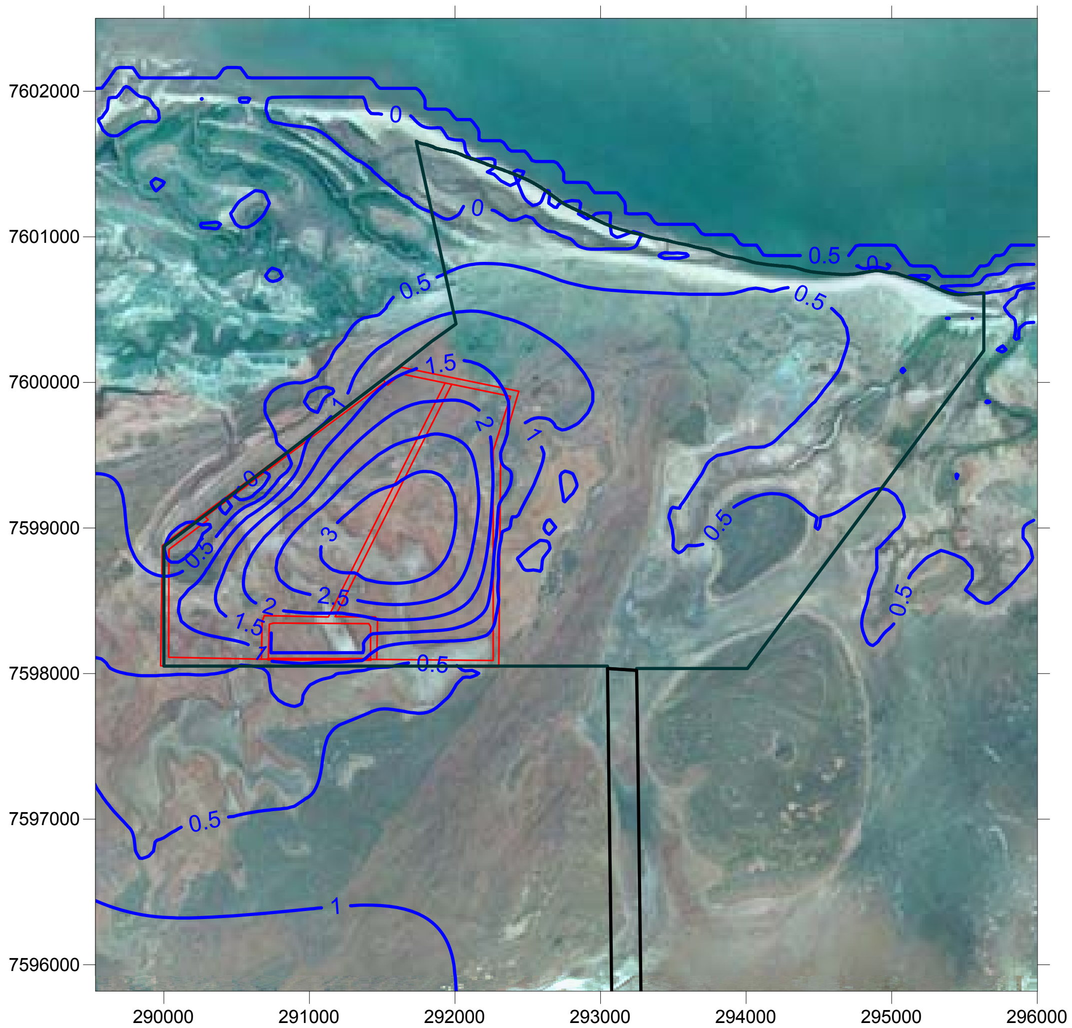

Legend

Groundwater Level (m AHD)

[illegible]

[illegible]

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: Predicted Water Table Contours (m AHD) Five Years after Commencement of Dredge Material Placement
URS	Drawn: [illegible] Approved: [illegible] Date: [illegible] / Job No: [illegible] File No: [illegible]	Figure: [illegible] Rev 0 A4

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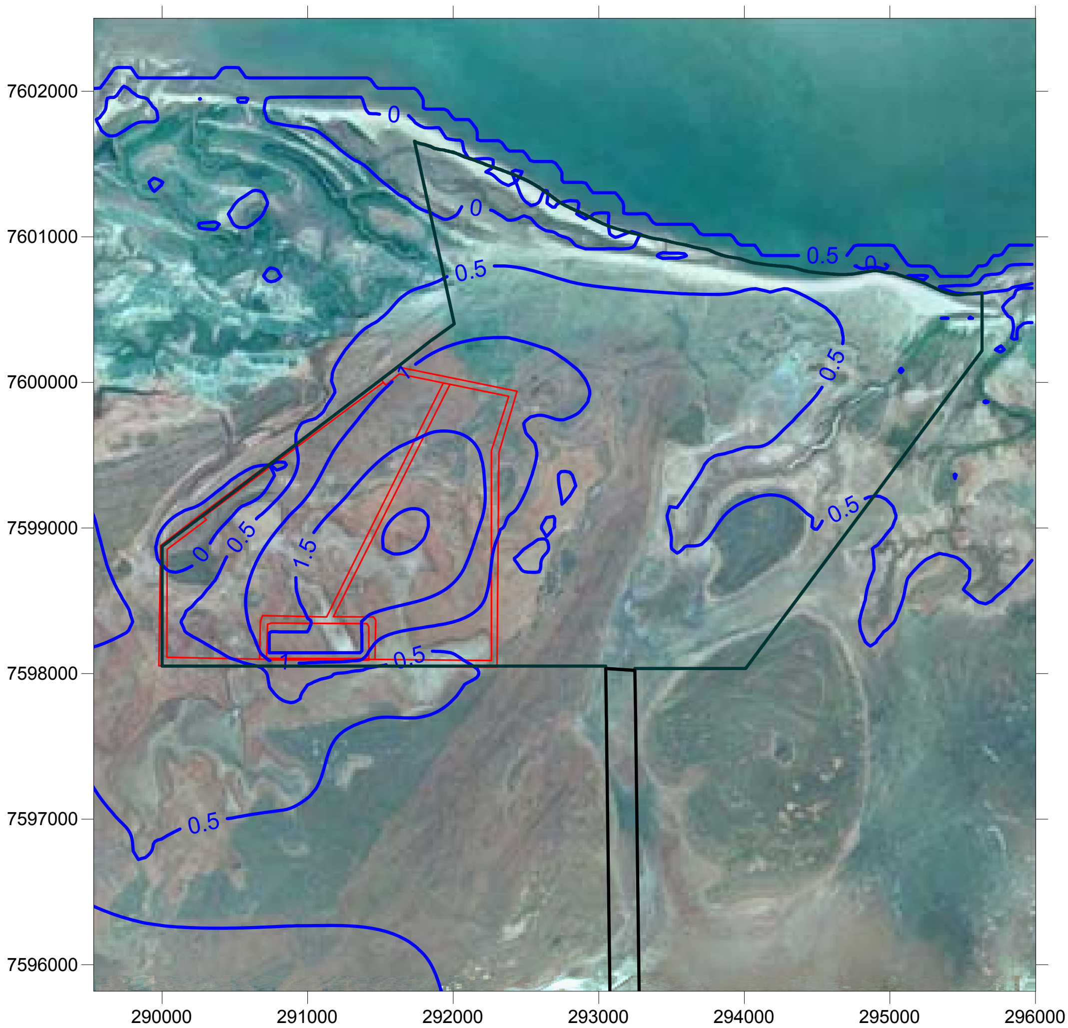

Legend

Blue line	Groundwater Level (m AHD)
Red line	[illegible]
Dark green line	[illegible]

N

0 500 1000 1500 2000 m

Datum: GDA94
Projection MGA94 Zone 50

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies		Title: Predicted Water Table Contours (m AHD) Ten Years after Commencement of Dredge Material Placement	
URS	Drawn: [illegible]	Approved: [illegible]	Date: [illegible]	Rev 0
	Job No: [illegible]	File No: [illegible]	Figure: [illegible]	A4

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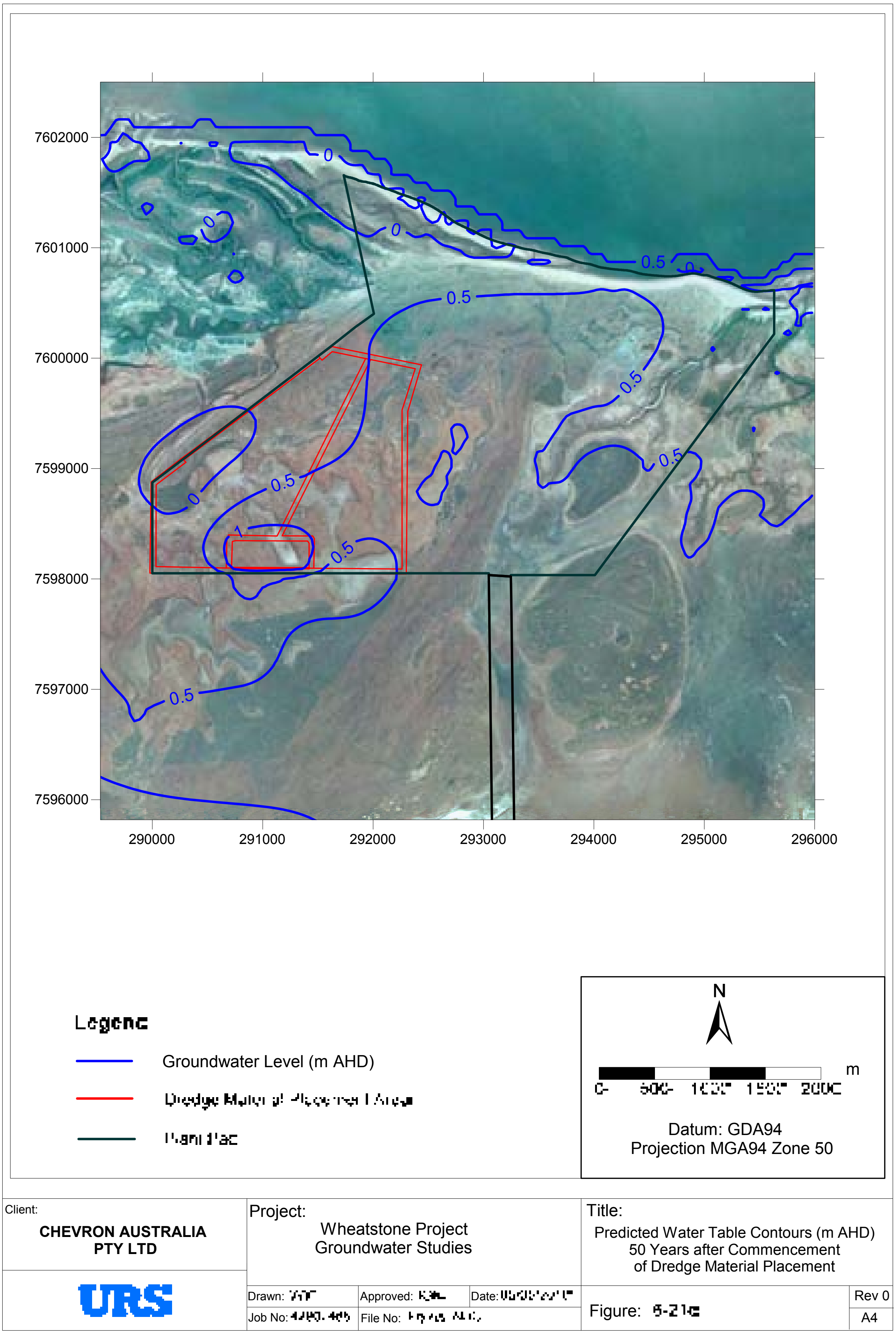

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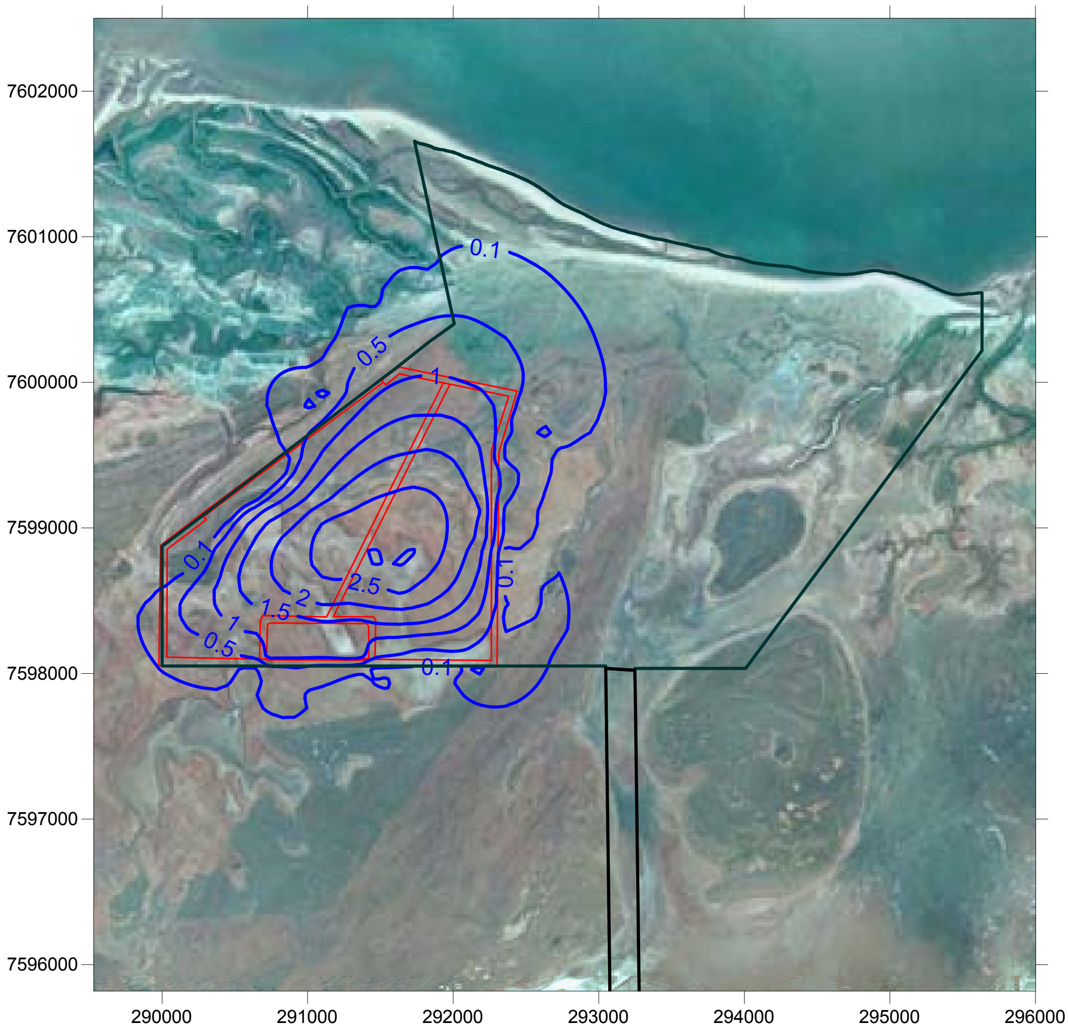

Legend

Groundwater Mounding

Dredge Material Placement Area

[illegible]

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: **CHEVRON AUSTRALIA PTY LTD**

URS

Project: Wheatstone Project Groundwater Studies

Title: Predicted Water Table Mounding Five Years after Commencement of Dredge Material Placement

Drawn: [illegible] | Approved: [illegible] | Date: [illegible] | Rev 0

Job No: [illegible] | File No: [illegible] | Figure: [illegible] | A4

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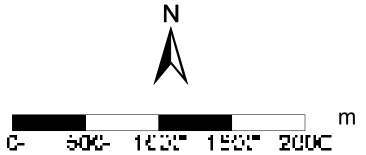
Legend

Groundwater Mounding



Datum: GDA94
Projection MGA94 Zone 50

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Predicted Water Table Mounding Ten Years after Commencement of Dredge Material Placement
URS	Drawn: · Approved: · Date: · Job No: · File No:	Figure: · Rev 0 · A4

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Groundwater Mounding

N

m

Datum: GDA94
Projection MGA94 Zone 50

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project Groundwater Studies	Title: Predicted Water Table Mounding 50 Years after Commencement of Dredge Material Placement
URS	Drawn: / Approved: / Date: / Job No: / File No:	Figure: / Rev 0 / A4

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Appendix A Monitoring Bore Master Sheet and Logs

URS

42907466/WHST-STU-WA-RPT-0090/0

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

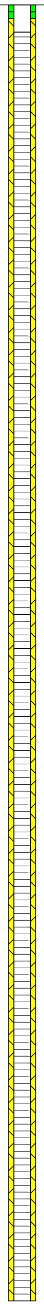
BOREHOLE **E002F**

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**

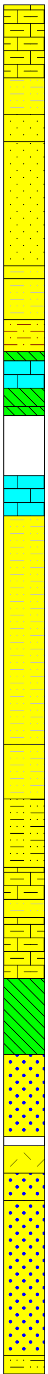
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E002**	EASTING	**0291153 mE**
START DATE	**31/3/09**	NORTHING	**7595088 mN**
COMPLETION DATE	**1/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**2.36 m bgl**		

BORE CONSTRUCTION



- Bentonite Seal (0 - 0.15 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.5 - 0.3 m)
- 9.5 - 13.0 mm Graded Gravel Pack (0.15 - 14.2 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.3 - 14.2 m)
- EOH (15 m)

LITHOLOGY



DEPTH (m): 0 – 15

DESCRIPTION

- 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.
- 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.

FIELD EC	AIRLIFT YIELD
117.9 mS/cm	0.5 L/sec

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

URS

BORE COMPLETION REPORT

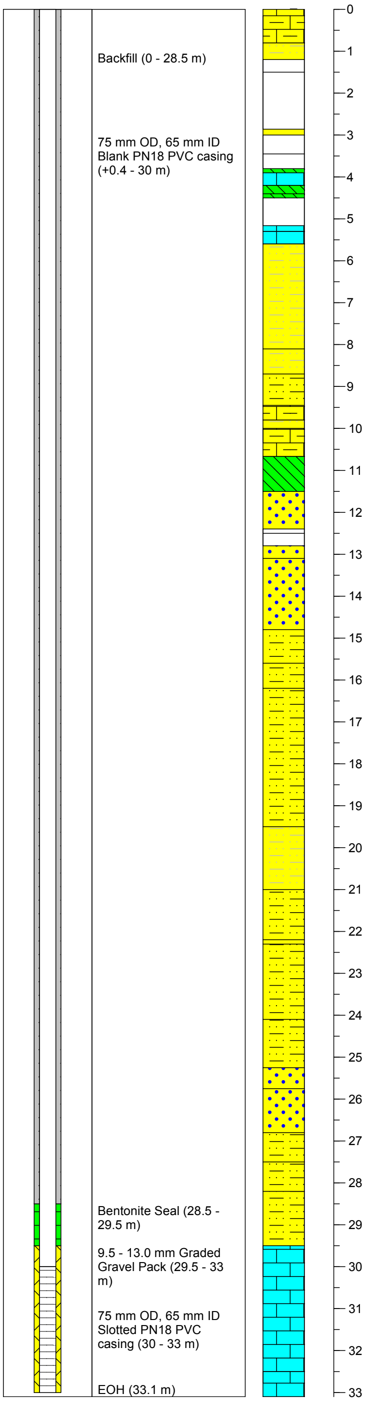
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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 | 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.		

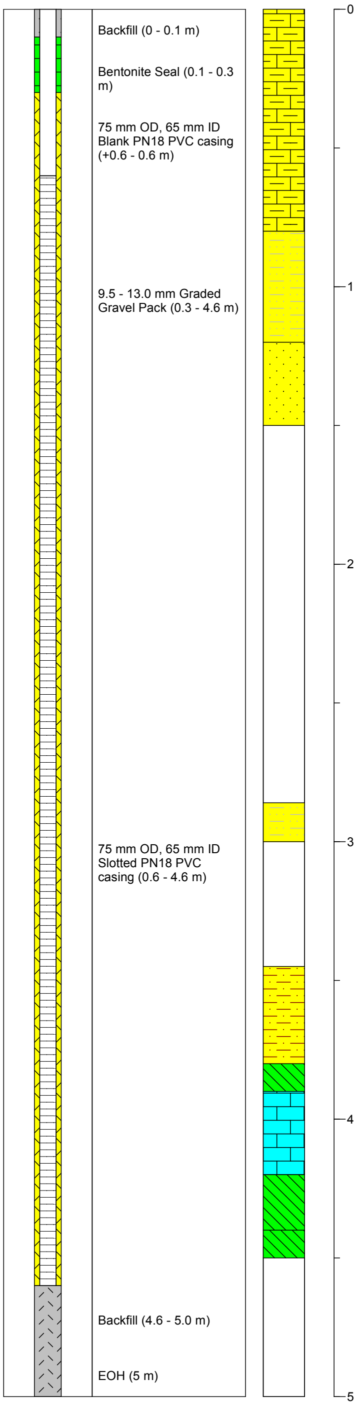
DRAWN BY **CO** DATE **24/06/09** CHECKED BY **DL** APPENDIX

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**
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER	**42907100**
CLIENT	**Chevron Australia Pty Ltd**
LOCATION	**E002**
START DATE	**30/3/09**
COMPLETION DATE	**31/3/09**
LOGGED BY	**GB**
SWL	**2.33 m bgl**
EASTING	**0291156 mE**
NORTHING	**7595091 mN**
R.L. OF COLLAR	**TBA**
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**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



Depth (m)	Description	Field EC	Airlift Yield
0 – 0.8	SANDY CLAY: Red brown, very fine to medium, quartz, sub angular, 2% coarse, 70% fine.		
0.8 – 1.2	SILTY CLAY: Red brown, fine clay, damp, minor silt, sand and coarse quartz grains.		
1.2 – 1.5	SILTY SAND : Red brown, medium to fine grained, becoming dry, moderately sorted, sub angular, minor clay.		
1.5 – 2.86	CORE LOSS: Core Loss/ SPT, red brown, silty sand.	65.0 mS/cm	0.3 L/sec
2.86 – 3.0	SILTY CLAY: Red brown, ferruginous fragments, very fine silty clay, minor bands of hard moderately cemented clay.		
3.0 – 3.45	SPT		
3.45 – 3.8	CEMENTED SAND: Light brown to pale grey, cemented quartz, shell sandstone nodules, clayey matrix, red brown clay, moderately well sorted, sub angular.		
3.8 – 3.9	CLAY: Light to mid brown to red brown, marine sediments, calcareous, coral, shell fragments, well cemented.		
3.9 – 4.2	LIMESTONE: Dark red brown clayey matrix, white cream calcareous coral, hard, nodules.		
4.2 – 4.4	CLAY: Dark red brown, minor fine to very fine quartz garins, well consolidated.		
4.4 – 4.5	CLAY: Red brown to dark grey, nodules, well cemented.		
4.5 – 5	CORE LOSS: Core Loss/ SPT, red brown, silty sand.		

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BORE COMPLETION REPORT

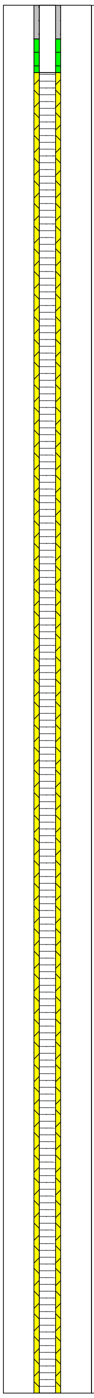
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E003F**
DESCRIPTION	**Subterranean Fauna Monitoring bore**

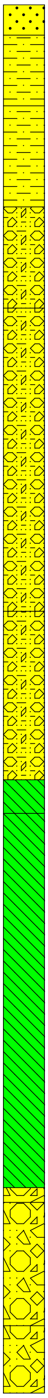
DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**20.6 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**20.6 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E003**	EASTING	**291105 mE**
START DATE	**30/3/09**	NORTHING	**7595517 mN**
COMPLETION DATE	**1/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**4.38 m bgl**		

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD



Bore construction:
- Backfill (0 - 0.5 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+1.1 - 1 m)
- Bentonite Seal (0.5 - 1 m)
- 9.5 - 13.0 mm Graded Gravel Pack (1 - 20.6 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (1 - 20.6 m)
- EOH (20.6 m)



Depth (m)	Description
0 - 0.45	SAND: Moderately sorted siliceous, unlithified, brown/grey.
0.45 - 1.5	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.
1.5 - 3	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.
3 - 4.5	GRAVEL AND SAND: Brown, siliceous, unlithified, moderately weathered, rounded. Moderately sorted with common shell fragments to 10 mm throughout.
4.5 - 9	GRAVEL AND SAND: As above becoming darker, red to brown Still unconsolidated. Minor organic material at 5 - 5.1 m.
9 - 11.5	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.
11.5 - 12	CLAY: Stiff, brown, minor banding.
12 - 17.5	CLAY: Stiff brown clay. Very fine grained, weathered (mottled between) 14.5 - 15 m. Blackish oxidation throughout. Aquitard (minor carbonaceous shinning).
17.5 - 18	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.
18 - 19.6	CONGLOMERATE: Mottled brown clay. Partially lithified, very fine grained, siliceous.
19.6 - 20.6	CONGLOMERATE: Same as above.

FIELD EC: 101.1 mS/cm

AIRLIFT YIELD: 0.9 L/sec

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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	**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**	EASTING	**0291246 mE**
START DATE	**26/3/09**	NORTHING	**7595552 mN**
COMPLETION DATE	**29/3/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**5.93 m bgl**		

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
Bentonite Seal (0 - 0.5 m)		0	SAND: Red, dry, minor silt and clay, small proportion of silcrete gravel (20%).		
75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.5 - 1.0 m)		1	SANDSTONE: Porous, fine to medium grained, siliceous with shell fragments, moderate to strongly weathered, some areas only partially lithified.		
		2	SAND: Brown - red, unlithified, moderately weathered, well sorted.		
		3	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%).		
		4	SANDSTONE: Slightly calcareous, fine to medium grained, well sorted, well rounded, moderately lithified, becomes hard at base, siliceous (minor shell fragments < 5%).		
		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.		
		6	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.		
		7	SAND: Brown, unlithified, slightly weathered, well to moderately sorted, fine to medium grained, siliceous, some black organic material (about 10%).		
		8			
		9	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 %).		
		10		102.9 mS/cm	0.8 L/sec
		11			
9.5 - 13.0 mm Graded Gravel Pack. (0 - 21.5 m)		12	CORE LOSS		
			CLAY: Brown, very fine grained, 80% clay 20% fine sand, minor organic material, well sorted, weathered.		
		13	CLAY: Brown, as above, moderately to well sorted, with some minor gravel (quartz grains) about 10 %.		
75 mm OD, 65 mm ID Slotted PN18 PVC casing (1.0 - 21.1 m)		14	CLAY: As above, getting harder/ finer, almost claystone.		
		15			
		16	CLAYSTONE: Brown - red, hard, moderately lithified, moderately mottled, minor (<10%) black organics.		
		17			
		18	CLAYSTONE: Brown - red, fine grained, mottled, weathered, (about 30%) silt, odd shaped gravel to <5 mm.		
		19	POLYMITIC CONGLOMERATE: Poorly sorted angular clasts of basalt, ironstone, quartz and undifferentiated sediment, matrix consists of brown, red silty clay, matrix 60% - clasts 40%.		
		20	CLAYSTONE: Red - brown, 20% silt, mottled, sharp transition from above paleochannel deposit.		
EOH (21.1 m)		21			

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

URS BORE COMPLETION REPORT

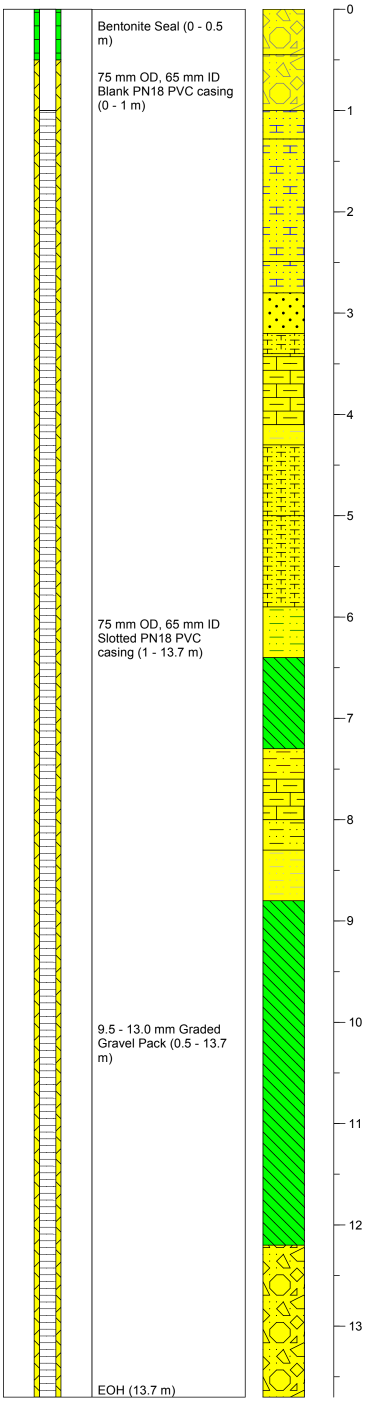
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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**	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	**2.11 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 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

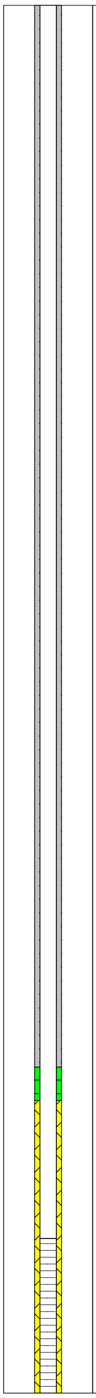
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

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



Backfill (0 - 25.4 m)

75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.1- 29.5)

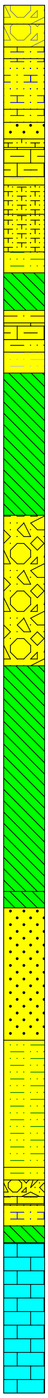
Bentonite Seal (25.4 - 29.5 m)

9.5 - 13.0 mm Graded Gravel Pack (29.5 - 33.2 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (29.5 - 33.2)

EOH (33.2 m)

LITHOLOGY



DEPTH (m): 0 – 33

DESCRIPTION
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	AIRLIFT YIELD
103.0 mS/cm	0.7 L/sec

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

URS BORE COMPLETION REPORT

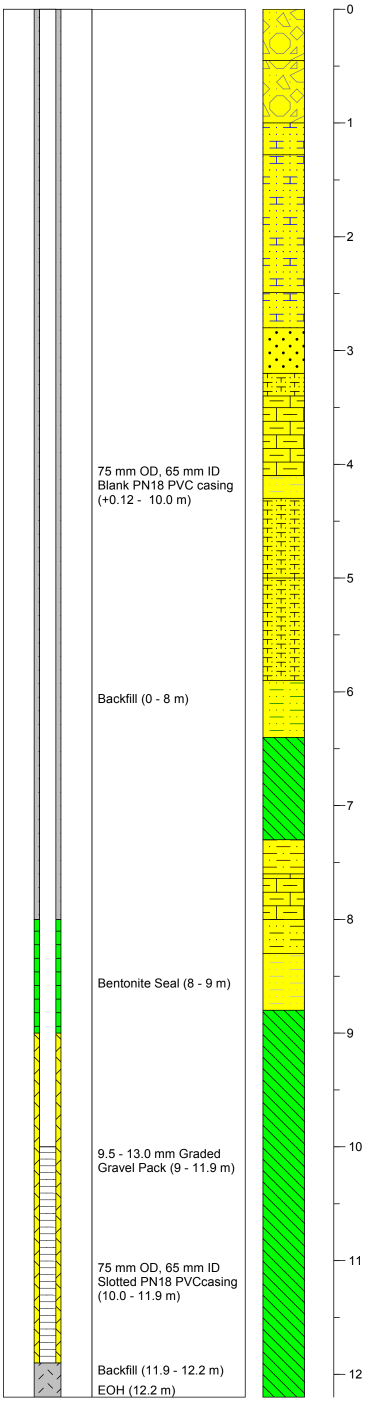
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

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



DESCRIPTION
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.

FIELD EC: 96.0 mS/cm (at approx. 11 m)

AIRLIFT YIELD: 0.2 L/sec

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BORE COMPLETION REPORT

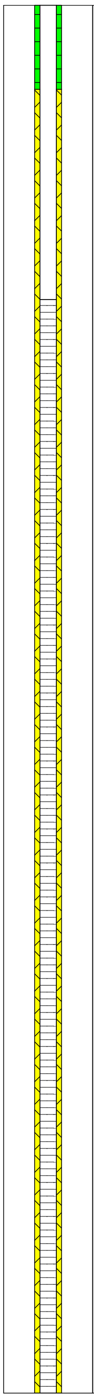
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

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**	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	**2.10 m bgl**		

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD



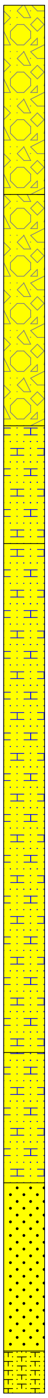
Bentonite Seal (0 - 0.2 m)

75 mm OD, 65 mm ID Blank PN18 PVC casing (0 - 0.7 m)

9.5 - 13.0 mm Graded Gravel Pack (0.2 - 3.3 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.7 - 3.3 m)

EOH (3.3 m)



Depth (m): 0, 1, 2, 3

DESCRIPTION
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.

FIELD EC: 12.7 mS/cm

AIRLIFT YIELD: 0.1 L/sec

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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

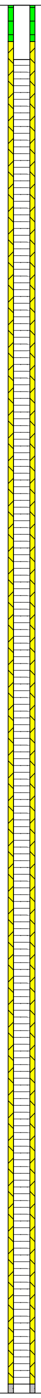
BOREHOLE **E006F**

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**

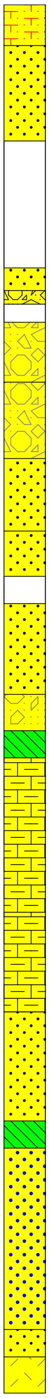
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E006**	EASTING	**292537 mE**
START DATE	**6/4/09**	NORTHING	**7598300 mN**
COMPLETION DATE	**7/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**BP/CO**		
SWL	**1.10 m bgl**		

BORE CONSTRUCTION



- Bentonite Seal (0 -0.4 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.1 - 0.5 m)
- 9.5 - 13.0 mm Graded Gravel Pack. (0.4 - 15.2 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.5 - 15.2 m)
- Backfill (15.2 -15.3 m)
- EOH (15.3 m)

LITHOLOGY



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0	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.		
3	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%).		
4	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.		
5	SAND: Calcareous, more sandy, coarse grained, good porosity and permability, minor beach material (10%), moderately lithified and weathered, moderately sorted.		
6	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%).		
8	CLAY: Red brown, 5% sand, sub rounded, high plasticity.	128.8 mS/cm	0.5 L/sec
	SANDY CLAY: Brown, very fine grained, 80% clay 20% fine sand, minor organic material, well sorted, weathered.		
10	SANDY CLAY: Brown, as above, moderately to well sorted, with some minor gravel (quartz grains etc.) about 10%.		
11	SAND: As above, getting harder/ finer, almost claystone.		
12	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.		
15	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

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	**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**		

BORE CONSTRUCTION

- Bentonite Seal (0.0 - 0.6 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.1 - 1 m)
- 9.5 - 13.0 mm Graded Gravel Pack. (0.6 - 18.5 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (1 - 18.5 m)
- EOH (18.5 m)

DEPTH (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18

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

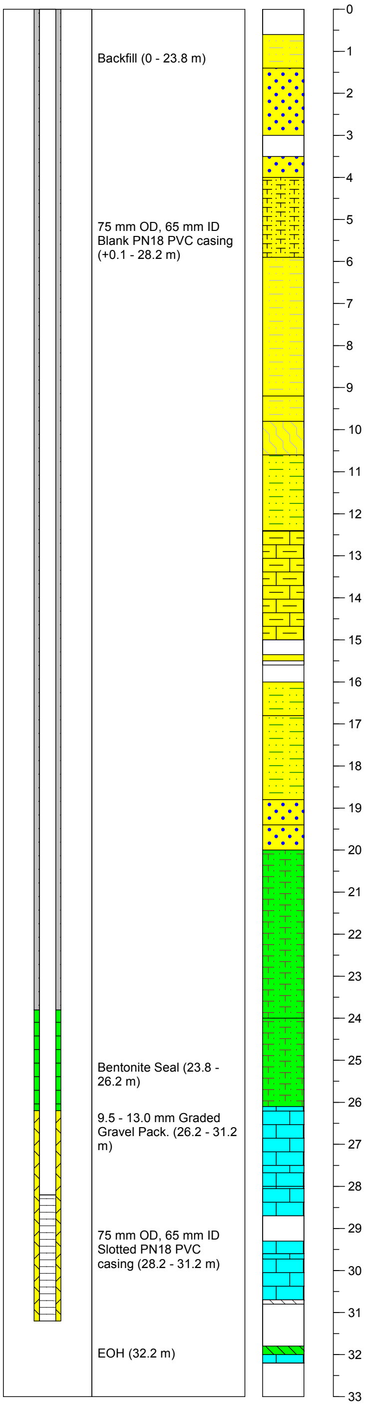
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

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.	176.2 mS/cm	2.0 L/sec
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.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

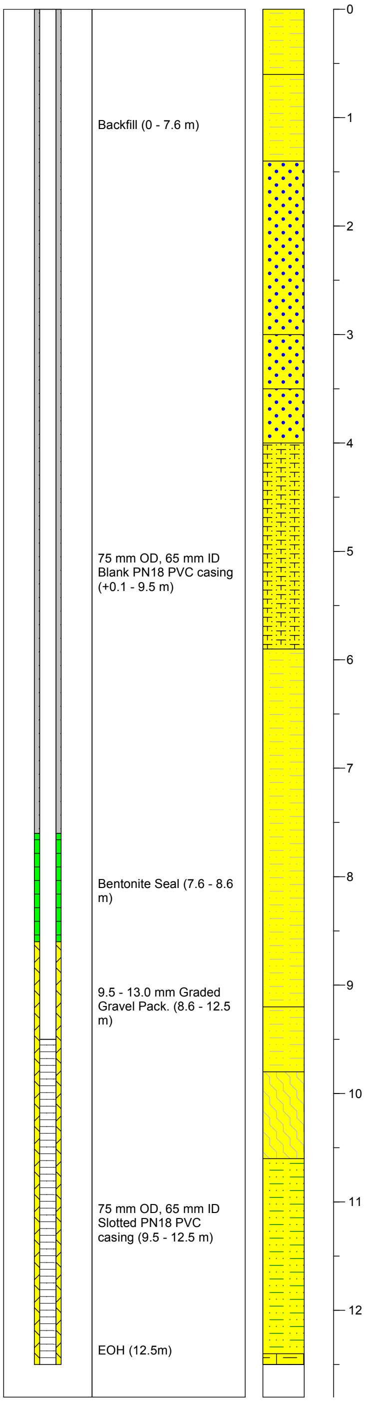
BORE COMPLETION REPORT

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**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**		
TOTAL DRILLED DEPTH	**12.5 m**	CLIENT	**Chevron Australia Pty Ltd**		
HOLE DIAMETER	**122 mm**	LOCATION	**E007**	EASTING	**0292711 mE**
TOTAL CASED DEPTH	**12.5 m**	START DATE	**8/4/09**	NORTHING	**7598613 mN**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**11/4/09**	R.L. OF COLLAR	**TBA**
		LOGGED BY	**GB**		
		SWL	**1.59 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



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).		
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.	135 mS/cm	0.7 L/sec
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.		

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

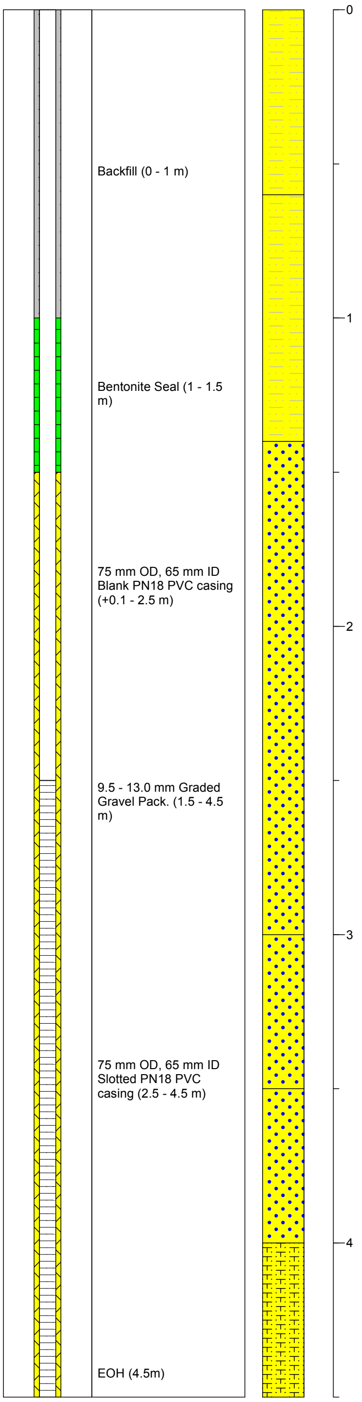
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

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.		

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BORE COMPLETION REPORT

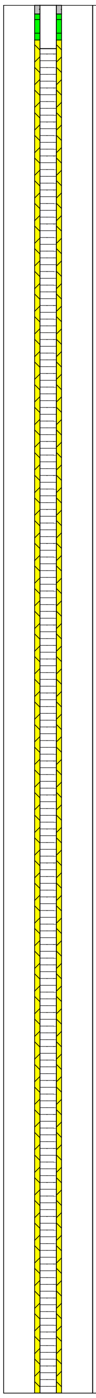
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E008F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**16 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**E008**
TOTAL CASED DEPTH	**16 m**	START DATE	**18/4/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**19/4/09**
		LOGGED BY	**CO**
		SWL	**5.02 m bgl**

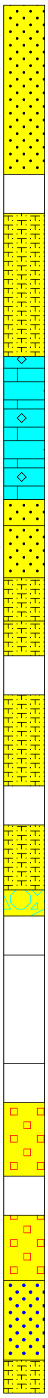
EASTING	**293243 mE**
NORTHING	**7599460 mN**
R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION



- Bentonite Seal (0.1 - 0.4 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.05 - 0.5 m)
- 9.5 - 13.0 mm Graded Gravel Pack (0.4 - 16 m)
- 75 mm OD, 65 mm ID Slotted PN 18 PVC casing (0.5 - 16 m)
- EOH (16 m)

LITHOLOGY



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0	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.		
16	SILTY SAND: Red brown, moderately consolidated, medium to fine sand. Sub rounded, moderately sorted with 5% silt. Major iron staining. Quartz major.		

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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	**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	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
Backfill (0.0 - 0.1 m) Bentonite Seal (0.1 - 0.4 m) 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.1 - 0.5 m)	0	SILTY SAND: Red brown sub rounded to sub angular (mostly sub angular) moderately sorted, poorly consolidated, quartz major sand with 2% silt.		
	1	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.		
	2	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.		
	3	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.		
	4			
	5	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.		
	6	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.		
	7	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.		
	8	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.	128.8 mS/cm	1.5 L/sec
	9	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.		
	10	SILTY SAND: Silty sand, red brown, fine to medium grained sand, sub rounded, moderately consolidated. Quartz major, with feldspar. No fossil content, 15% silt.		
	11	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.		
9.5 - 13.0 mm Graded Gravel Pack. (0.4 - 16 m)	12	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		
	13			
75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.5 - 16 m)	14	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.		
	15	CLAYEY SAND: Red brown, fine to medium grained, sub rounded to sub angular, poorly sorted well consolidated sand.		
EOH (16 m)	16			

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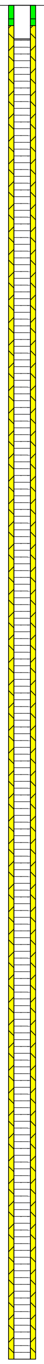
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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**
START DATE	**14/4/09**
COMPLETION DATE	**16/4/09**
LOGGED BY	**CO**
SWL	**1.99 m bgl**
EASTING	**293462 mE**
NORTHING	**7599684 mN**
R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



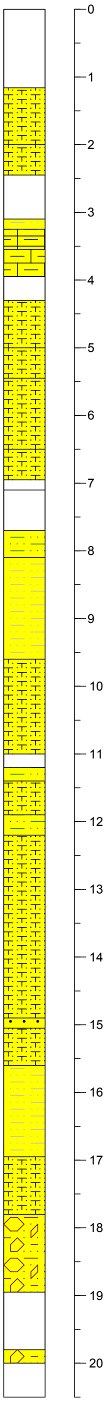
Betonite Seal (0 - 0.3 m)

75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.1 - 0.5 m)

9.5 - 13.0 mm Graded Gravel Pack. (0.3 - 20 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.5 - 20 m)

EOH (20 m)



Depth (m)	Description
0	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 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 plasticity 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.
	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
20	PALEOCHANNEL DEPOSIT: Tan brown with minor sand. Gravel is medium to very coarse (15 - 70 mm). Made up of bif, dolerite, sandstone, and quartz.

FIELD EC: 124 mS/cm

AIRLIFT YIELD: 1.5 L/sec

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BORE COMPLETION REPORT

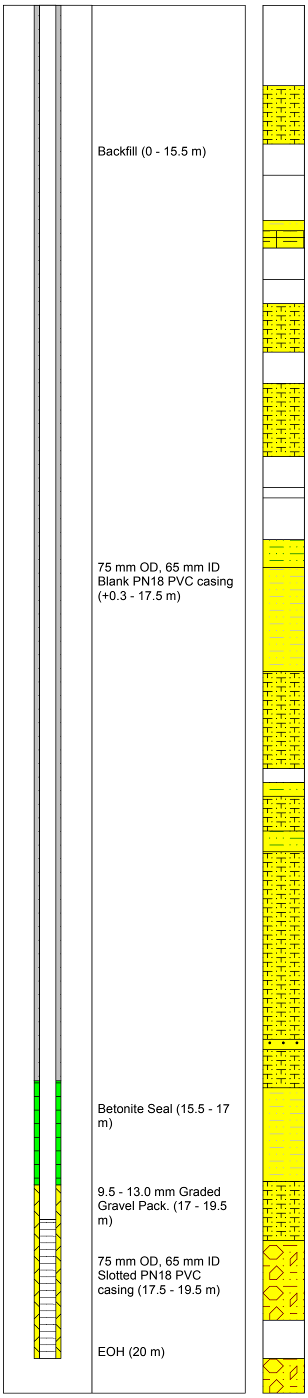
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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
0	CORE LOSS		
1	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.		
2	SPT		
	CORE LOSS		
3	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.		
4	SANDY CLAY: Same as above but slightly less consolidated.		
	SPT		
	CORE LOSS		
5	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		
6	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		
7	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.		
8	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.		
9.5	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.		
11	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.		
12	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.		
13	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.		
15	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.		
16	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.		
17	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.		
18	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.		
19	CORE LOSS		3 L/sec
	PALEOCHANNEL DEPOSIT: Tan brown with minor sand. Gravel is medium to very coarse (15-70 mm). Made up of bif, dolerite, sandstone, and quartz.		
20			

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BORE COMPLETION REPORT

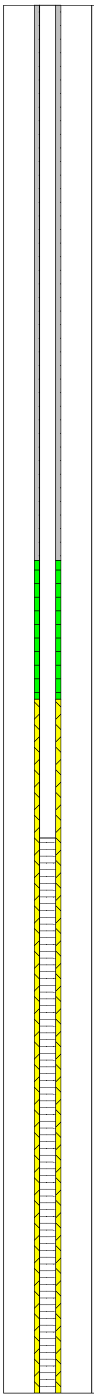
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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



Backfill (0 - 2.5 m)

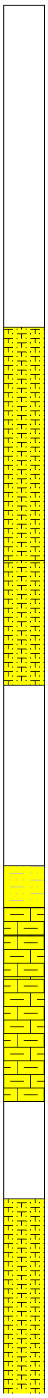
75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.11 - 3 m)

Betonite Seal (2.5 - 2.7 m)

9.5 - 13.0 mm Graded Gravel Pack. (2.7 - 5 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (3 - 5 m)

EOH (5 m)



Depth (m)	Description	Field EC	Airlift Yield
0	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.		
2	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		
3	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 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.		
4	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.		
5			

DRAWN BY **CE** DATE **24/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

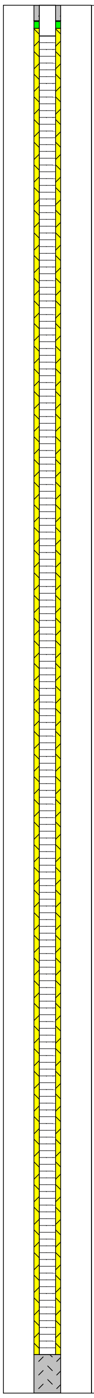
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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**

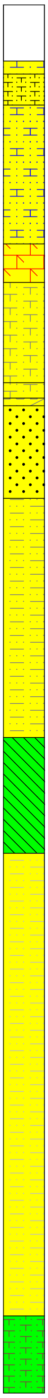
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E011**	EASTING	**294123 mE**
START DATE	**12/4/09**	NORTHING	**7600692 mN**
COMPLETION DATE	**14/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**TBC**		
SWL	**0.86 m bgl**		

BORE CONSTRUCTION



- Backfill (0 - 0.2 m)
- Bentonite Seal (0.2 - 0.3 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.5 - 0.4 m)
- 9.5 - 13.0 mm Graded Gravel Pack (0.3 - 17.5 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.4 - 17.5 m).
- Backfill (17.5 - 18 m)
- EOH (18 m)

LITHOLOGY



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0	CORE LOSS		
	CALCAREOUS SANDSTONE: Creamy brown, vuggy, fine to medium grained sand (quartz), hard, well cemented and lithified.		
1	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.		
3	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.		
5	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.		
6	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
9	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.		
11	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.		
17	CLAYSTONE: Creamy orange - brown, claystone/sandstone, fine to medium grained, abundant calcrete nodules, gritty, calcareous.		
18			

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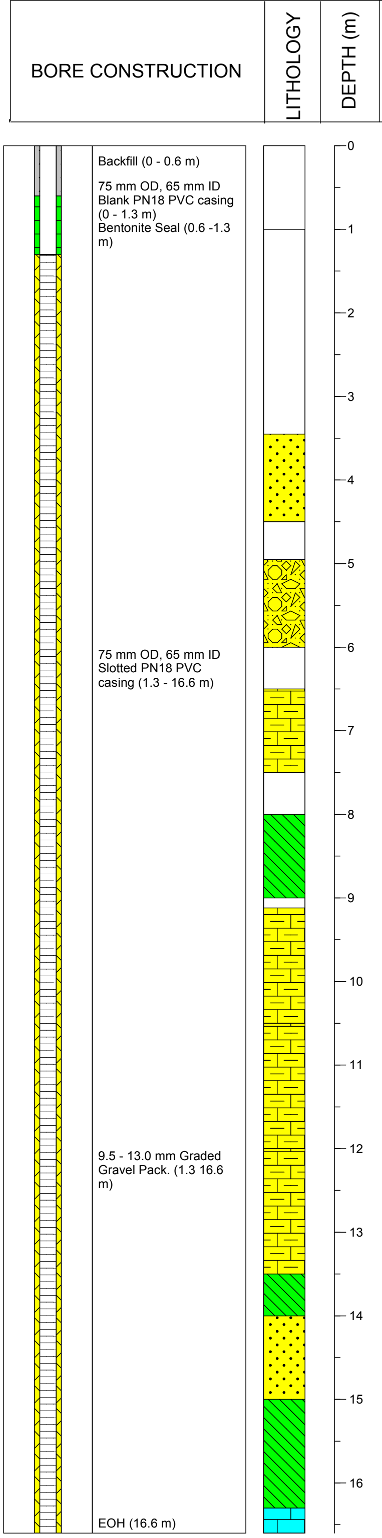
URS BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E012F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**		
TOTAL DRILLED DEPTH	**16.6 m**	CLIENT	**Chevron Australia Pty Ltd**		
HOLE DIAMETER	**122 mm**	LOCATION	**E013**	EASTING	
TOTAL CASED DEPTH	**16.6 m**	START DATE	**10/4/09**	NORTHING	
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**11/4/09**	R.L. OF COLLAR	**TBA**
		LOGGED BY	**DL**		
		SWL	**1.00 m bgl**		



DESCRIPTION	FIELD EC	AIRLIFT YIELD
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.	91.6 mS/cm	1.2 L/sec
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.		

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URS

BORE COMPLETION REPORT

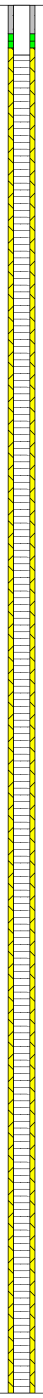
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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



Backfill (0 - 0.4 m)

Bentonite Seal (0.4 - 0.6 m)

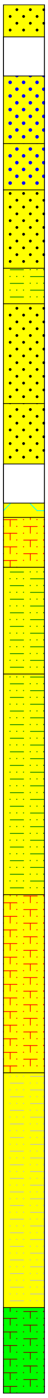
75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.1 - 0.7 m)

9.5 - 13.0 mm Graded Gravel Pack. (0.6 - 19.5 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.7 - 19.5 m)

EOH (19.5 m)

LITHOLOGY



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0	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.		
1	SANDSTONE: Moderately well cemented, hard, calcareous, fine to coarse grained, poorly sorted quartz in a silty matrix, creamy orange, some shells.		
2	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.		
3	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).		
4	CLAYEY SAND: Fine grained, moderately sorted qtz / feld, soft, moderate plasticity clay, no shells, but foramnifera present, well compacted.		
5	SAND: Fine to medium grained, loose, sub angular - sub rounded, poor - moderately sorted, moderately hard, some cementing, no shells, qtz/feld, calcareous, becomes softer.		
6	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		
7	CLAYEY SILT: Dark brown, firm - brittle.		
	SANDY SILTY CLAY: With gravel, angular to sub rounded gravels.		
8	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.		
9 - 12	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
13 - 14	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.		
15 - 18	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.		
19	CLAYSTONE SILTSTONE: Contains patches of Sandstone. Gritty, orange brown, less calcrete but there is one band at 19.3 m.		

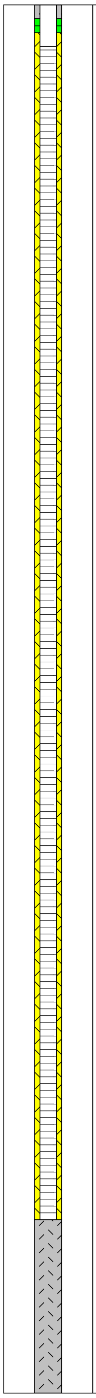
DRAWN BY **CE** DATE **25/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

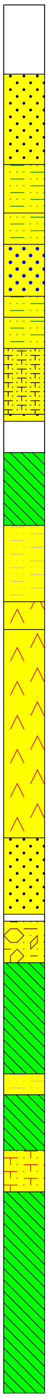
BOREHOLE	**E015F**
DESCRIPTION	**Subterranean Fauna Monitoring Bore**
DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**20 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**17.5 m**
CASING DIAMETER	**65 mm ID**
PROJECT NAME	**Wheatstone Environmental Monitoring 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



- Backfill (0 - 0.2 m)
- Bentonite Seal (0.2 - 0.4 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.52 - 0.6 m)
- 9.5 - 13.0 mm Graded Gravel Pack. (0.4 - 17.5 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.6 - 17.5 m)
- Backfill (17.5 - 20 m)
- EOH (20 m)

LITHOLOGY



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0	CORE LOSS: Most likely sand.		
1	SAND: Red brown, fine grained, well sorted, sub angular to sun rounded (mostly sub rounded), slightly clayey (5%).		
2	CLAYEY SAND: Grades into clayey sand with well cemented sandstone nodules, fine grained.		
3	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.		
4	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.		
5	SILTY SAND: Minor clay, chocolate brown, very fine to fine grained, moderately sorted, sub angular to sub rounded (generally sub angular), quartz.		
6	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.		
7	SILTY CLAY: Brown/red, firm to hard,moderate plasticity, brittle in sections, occassional weakly cemented siltstone nodules.		
8	CLAYEY SILTY SAND: Red/brown, fine grained, well sorted, sub rounded quartz.		
9	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
10			
11			
12	SAND: Red/ brown, fine to medium gained, moderately sorted, sub-angular to sub rounded quartz		
13	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.		
14	CLAY: Red/brown, clay/ claystone, hard, very fined grained, mottled, patches of fine grained sand (quartz), sub angular to sub rounded, moderately sorted.		
15	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.		
16	SANDY SILTY CLAY: Red/ brown, fine grained.		
17	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.		
18			
19			
20			

DRAWN BY **CE** DATE **2/6/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

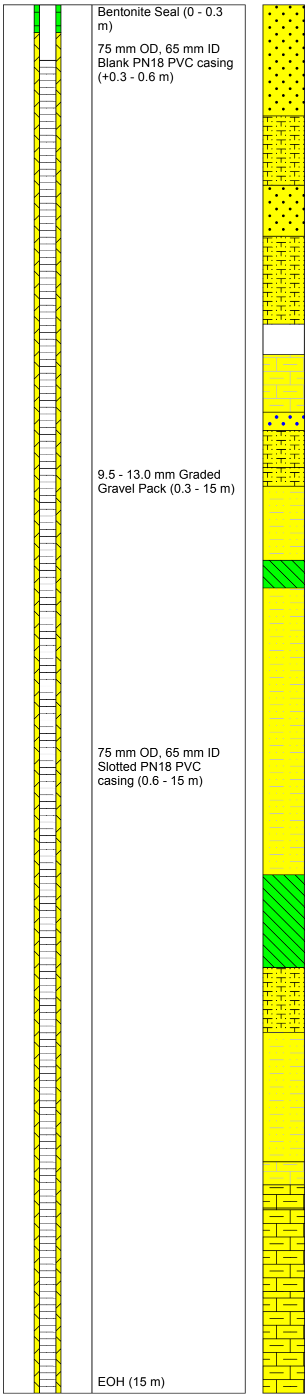
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E016F**

DESCRIPTION **Subterranean Fauna Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**15 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**E016**
TOTAL CASED DEPTH	**15 m**	START DATE	**6/4/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**6/4/09**
		LOGGED BY	**GB**
		SWL	**3.11 m bgl**

EASTING	**0290313 mE**
NORTHING	**7596335 mN**
R.L. OF COLLAR	**TBA**



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0 – 1.2	SAND: Red brown, silty, fine to medium grained, sub angular, moderately sorted, soft, loose.	96.3 mS/cm	0.1 L/sec
1.2 – 1.95	SILTY SAND: Red brown, very fine to fine grained, sub angular, moderately well sorted, silty.		
1.95 – 2.5	SAND: Red brown, fine to medium grained, silty, poorly sorted, soft, minor cemented sandstone nodules.		
2.5 – 3.45	SILTY SAND: Red brown, very fine to fine grained, silty, soft, minor gravelly sandstone nodules, minor grey medium grained sandstone nodules.		
3.45 – 3.8	CORE LOSS: Red brown, ferruginous fragments, very fine silty clay, minor bands of hard moderately cemented clay.		
3.8 – 4.4	GRAVELLY CLAY: Red brown, fine to medium sand, minor cemented sand, sugary texture, minor shell fragments, moderately hard.		
4.4 – 4.6	SANDSTONE: Brown, well cemented, hard, oxidized in part, limestone, calcareous		
4.6 – 5.0	SILTY SAND: Red brown, very fine to fine grained, minor coarse quartz grains, sub angular.		
5.0 – 5.2	SILTY SAND: Red brown, shell fragments, very fine silty, minor white shells and gravels, well rounded.		
5.2 – 6.0	SILTY CLAY: Red brown to brown, fine silty sand in clay matrix, minor cemented carbonaceous fragments.		
6.0 – 6.3	CLAY: Red brown, silty, minor holes/ veinlets, lake clay, saline, brittle.		
6.3 – 9.4	SILTY CLAY: Red brown, very fine silty grains, mod sorted, soft.		
9.4 – 10.4	CLAY: Red brown, silty, soft, brittle, becoming well consolidated.		
10.4 – 11.1	SILTY SAND: Red brown, very fine to fine grained, sub angular, soft.		
11.1 – 12.5	SILTY CLAY: Red brown, very fine silty sand, clay matrix.		
12.5 – 12.85	GRAVELLY CLAY: Red brown, very fine to fine grained quartz sand, sub angular, brittle clay, slightly plastic, minor nodules of well cemented sandstone.		
12.85 – 13.1	SANDY CLAY: Red brown, as above with little nodules.		
13.1 – 13.9	SANDY CLAY: Red brown, fine to medium quartz sand in clay martix, minor well cemented sandstone nodules/ gravel.		
13.9 – 15	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

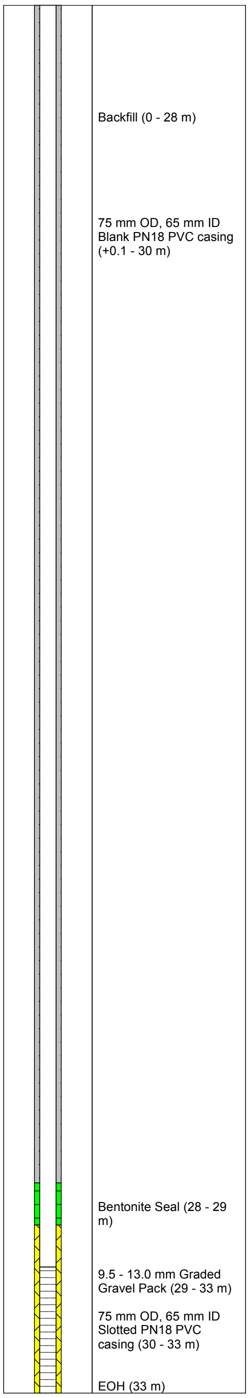
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

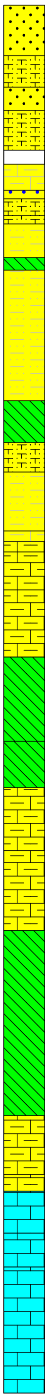
BOREHOLE	**E016G-D**
DESCRIPTION	**Deep Groundwater Monitoring Bore**

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





DEPTH (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33

DESCRIPTION
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.

FIELD EC: 155.9 mS/cm

AIRLIFT YIELD: 2.5 L/sec

DRAWN BY **CO**	DATE **26/6/09**	CHECKED BY **DL**	APPENDIX

BORE COMPLETION REPORT

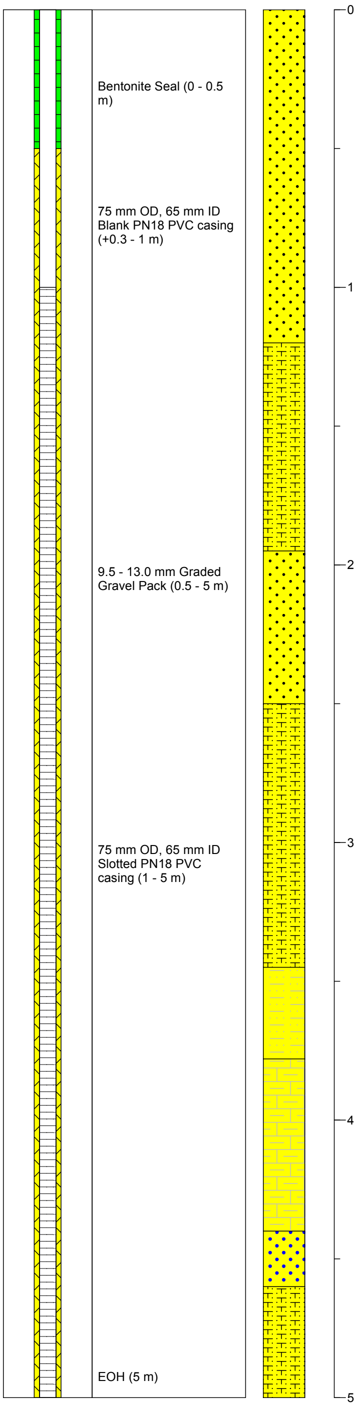
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E016G-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**	EASTING	**0290313 mE**
START DATE	**31/3/09**	NORTHING	**7596335 mN**
COMPLETION DATE	**1/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**3.10 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.	44.0 mS/cm	
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.		

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URS BORE COMPLETION REPORT

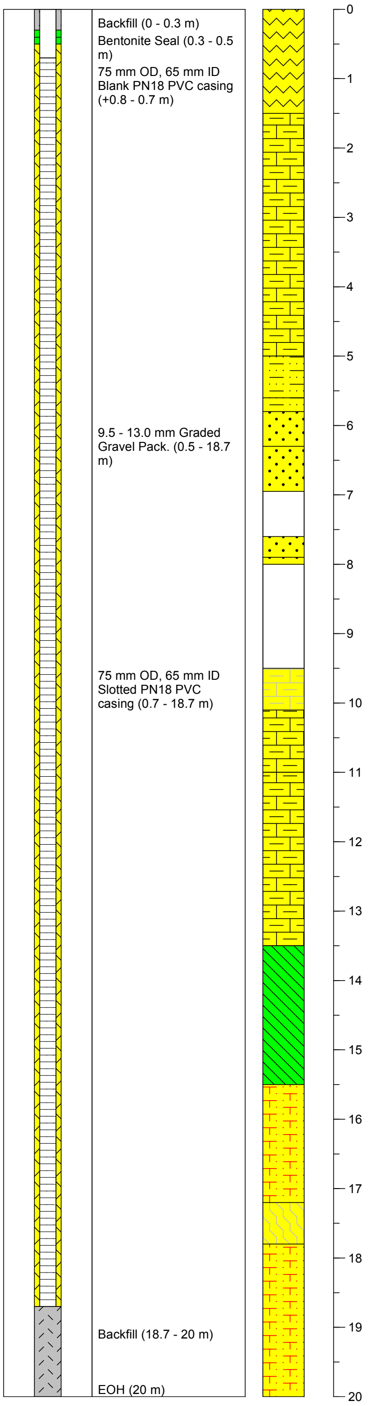
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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.	107.8 mS/cm	2 L/sec
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.		

DRAWN BY **BP**	DATE **26/6/09**	CHECKED BY **DL**	APPENDIX

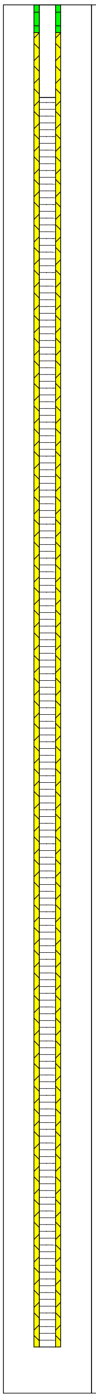
BORE COMPLETION REPORT

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



Bentonite Seal (0 - 0.3 m)

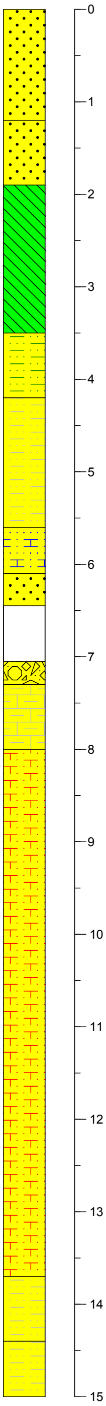
75 mm OD, 65 mm ID Blank PN18 PVC casing (0 - 1 m)

9.5 - 13.0 mm Graded Gravel Pack (0.3 - 14.5m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (1 - 14.5 m)

Collapse / Gravel Bridged zone (14.5 - 15 m)

EOH (15 m)



Depth (m)	Description	Airlift yield
0	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.	
2	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.	
8	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).	
15		

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BORE COMPLETION REPORT

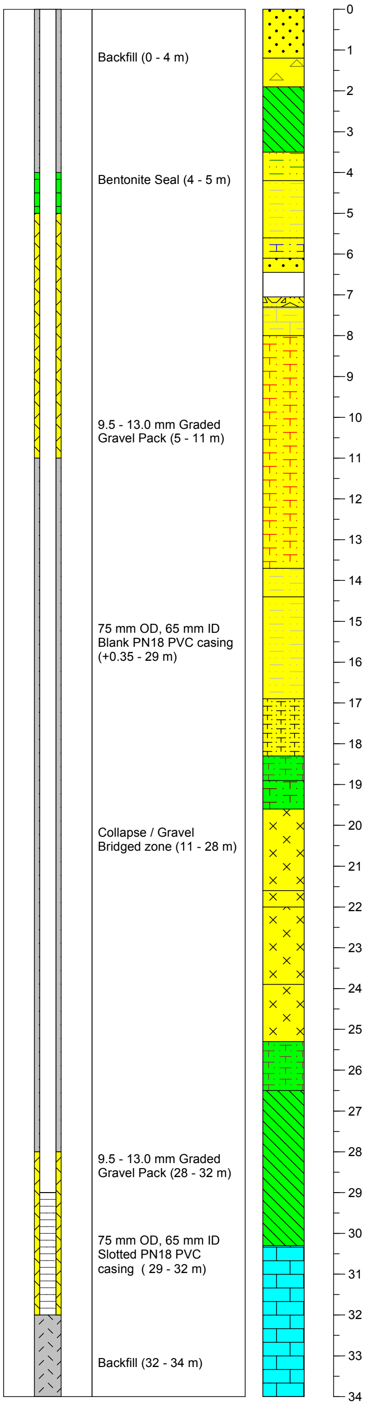
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E018G-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

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BORE COMPLETION REPORT

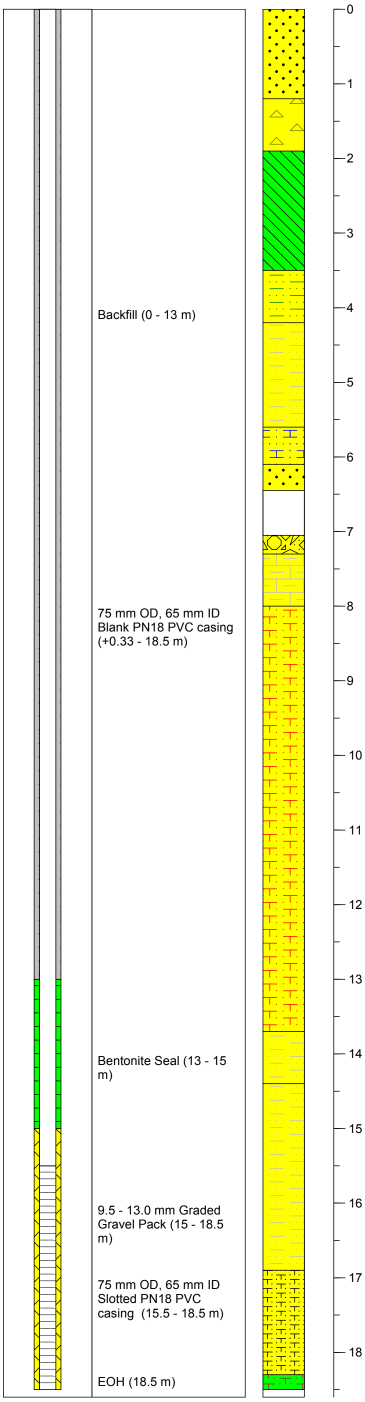
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E018G-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



DESCRIPTION
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.
CLAYSTONE: Grades to red brown claystone, hard, brittle (finger pressure) with increasing calcrete/sandstone clasts.

AIRLIFT YIELD: 1 L/sec (at approx. 17 m)

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URS BORE COMPLETION REPORT

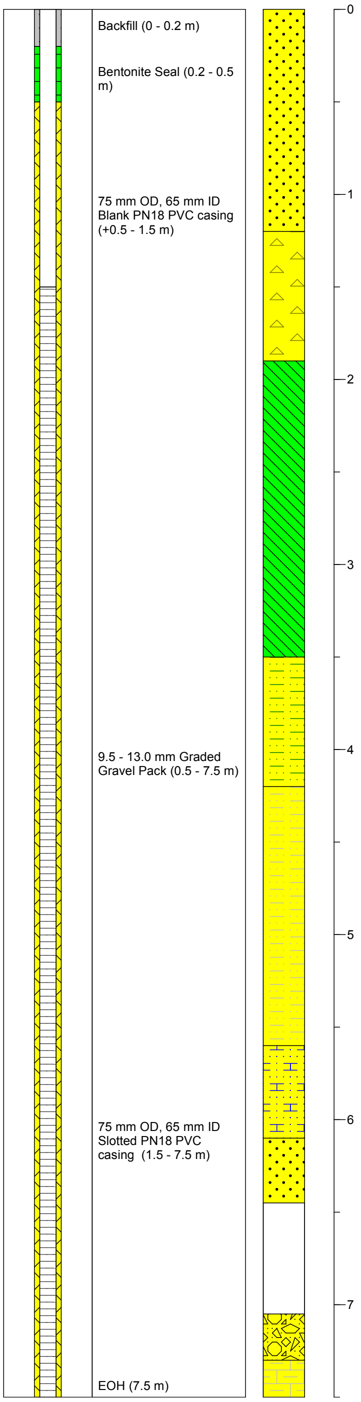
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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



DESCRIPTION

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.

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.

AIRLIFT YIELD: 0.5 L/sec

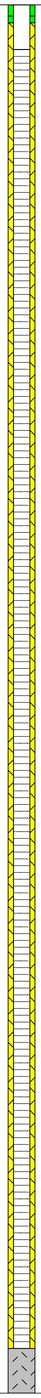
DRAWN BY **CE**	DATE **26/6/09**	CHECKED BY **DL**	APPENDIX

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**
START DATE	**25/3/09**
COMPLETION DATE	**30/3/09**
LOGGED BY	**GB**
SWL	
EASTING	**293691 mE**
NORTHING	**7600753 mN**
R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



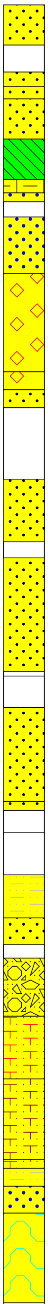
Bentonite Seal (0 - 0.2 m)

75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.24 - 0.5 m)

9.5 - 13.0 mm Graded Gravel Pack. (0.2 -15 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.5 - 15 m)

EOH (15.5 m)



DESCRIPTION

- 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.
- 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.

AIRLIFT YIELD: 0.5 L/sec (at approx. 7 m)

DRAWN BY **CO** DATE **12/5/09** CHECKED BY **DL** APPENDIX

URS BORE COMPLETION REPORT

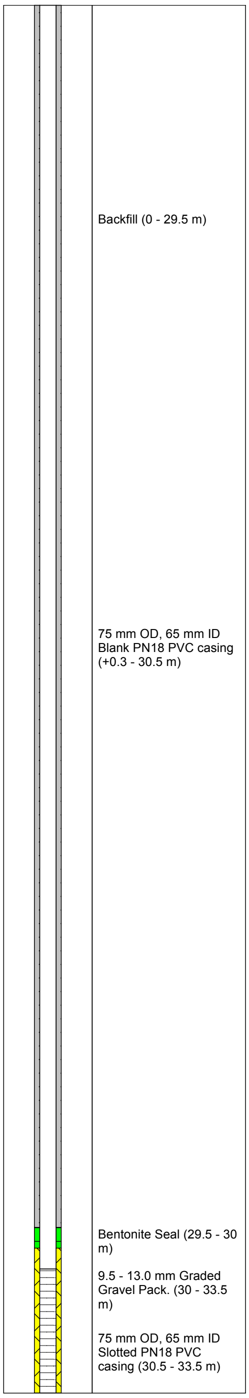
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

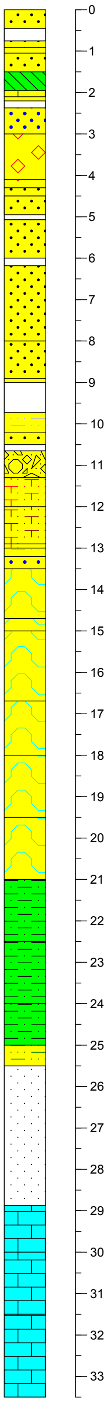
BOREHOLE	**E019G-D**
DESCRIPTION	**Deep Groundwater Monitoring Bore**

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**	EASTING	**293688 mE**
START DATE	**29/4/09**	NORTHING	**7600753 mN**
COMPLETION DATE	**3/5/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL			

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD





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: 161.9 mS/cm

AIRLIFT YIELD: 2 L/sec

DRAWN BY **CE**	DATE **27/5/09**	CHECKED BY **DL**	APPENDIX

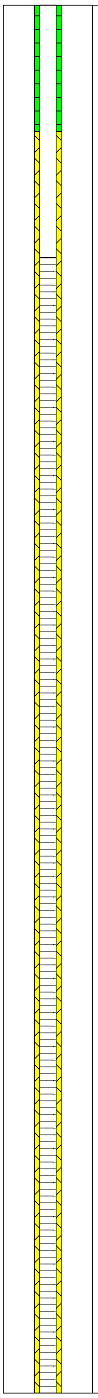
BORE COMPLETION REPORT

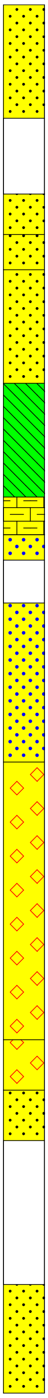
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**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	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
Bentonite Seal (0 - 0.5 m)	0	SAND: Well sorted sand with shell fragments - dark brown red loose - silica 80% - k-feldspar 10%, 10% other, mica, dark minerals.		
75 mm OD, 65 mm ID Blank PN18 PVC casing (0 - 1 m)		CORE LOSS		
		SAND: Dense sand, slightly clayey well sorted, brown and firm.		
	1	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.		
	2	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.	34.5 mS/cm	0.5 L/sec
9.5 - 13.0 mm Graded Gravel Pack. (0.5 - 5.5 m)	3	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.		
	4	CALCARENITE: Solid but not cemented with fragments of calcarenite approx. 2 cm diameter.		
		SAND: Loose sand with calcarenite fragments.		
		CORE LOSS		
75 mm OD, 65 mm ID Slotted PN18 PVC casing (1 - 5.5 m)	5	SAND: Firm sand - slightly plastic (50%) shell fragments - grain size 0.5 mm, red brown.		
EOH (5.5 m)				

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

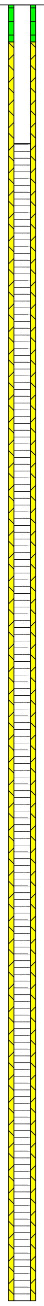
BOREHOLE **E021F**

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**

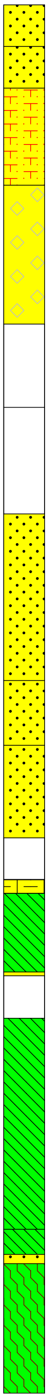
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E021**	EASTING	**293984 mE**
START DATE	**20/4/09**	NORTHING	**7600707 mN**
COMPLETION DATE	**21/4/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**GB**		
SWL	**1.00 m bgl**		

BORE CONSTRUCTION



- Bentonite Seal (0 - 0.4 m)
- 75 mm OD, 65 mm ID Blank PN18 Pvc casing (+0 .74 - 1.5 m)
- 75 mm OD, 65 mm ID Slotted PN18 Pvc casing (1.5 - 14 m)
- 9.5 - 13.0 mm Graded Gravel Pack. (0.4 -14 m)
- Collapse (14 - 15 m)
- EOH (15 m)

LITHOLOGY



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0 – 0.45	SAND: Fine to medium grained, poor to moderately sorted, sub angular to sub rounded quartz, brown.		
0.45 – 0.9	SAND: Fine to medium grained, poor to moderately sorted, sub angular to sub rounded quartz, brown.		
0.9 – 1.95	SANDY SILTY CLAY: Orangey brown, fine to coarse, poorly sorted, angular, with some shells (bivalves).		
1.95 – 3.45	CALCAREOUS/SAND/ SANDSTONE: Fine to medium grained light brown moderately cemented, sub angular, minor shell fragments.		
3.45 – 4.35	CORE LOSS		
4.35 – 5.5	CORE LOSS		
5.5 – 7.3	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
7.3 – 8.0	SAND: Silty dark brown.		
8.0 – 9.0	SAND: Becomes silty and clayey and well rounded, more compacted at 9 m.		
9.0 – 9.45	CORE LOSS		
9.45 – 9.65	SANDY CLAY: Shell fragments and rock fragments - sub rounded.		
9.65 – 10.45	CLAY: Dark brown fine grained, some shell fragments		
10.45 – 10.65	SAND: Unconsolidated.		
10.65 – 10.9	CORE LOSS		
10.9 – 13.2	CLAY: Clay fine grained dark brown 0.1 mm grain size.		
13.2 – 13.45	CLAY: Less clay content more friable grainsize 0.5 mm some pebbles.		
13.45 – 13.65	SAND: Some core loss. Sandy, clayey grain size 0.5 mm quartz sub rounded.		
13.65 – 15	CLAY/CALCRETE: More cemented hard clays and calcrete - dark grey cream.		

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BORE COMPLETION REPORT

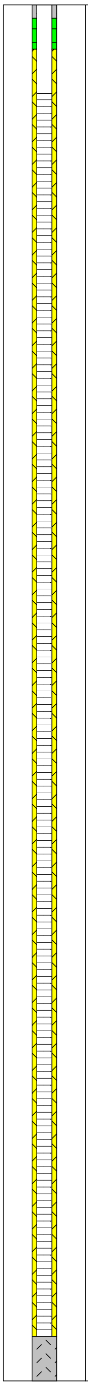
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E014F**
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**

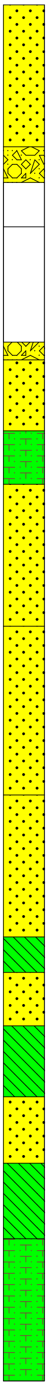
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E014**	EASTING	**0291024 mE**
START DATE	**23/5/09**	NORTHING	**7599362 mN**
COMPLETION DATE	**24/5/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CW**		
SWL	**2.73 m bgl**		

BORE CONSTRUCTION



- Backfill (0 - 0.15 m)
- Bentonite Seal (0.15 - 0.5 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.56 - 1 m)
- 9.5 - 13.0 mm Graded Gravel Pack (0.5 - 15 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (1 - 15 m)
- Collapse (15 - 15.5 m)
- EOH (15.5 m)

LITHOLOGY



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0 - 1.6	SAND: Red brown, fine grained, well sorted, sub angular - sub rounded, soft core. Components: Quartz, silty matrix (> 5 %).		
1.6 - 2	GRAVEL: Partly cemented to completely subrounded. Sandstone components in a sandy/silty matrix. Layered: cm sandstone, cm conglomerate (in red matrix 5 - 10%). Change of conglomerated soft rock.		
2 - 2.5	SPT: Partly cemented to completely subrounded. Sandstone components in a sandy/silty matrix. Layered: cm sandstone, cm conglomerate (in red matrix 5 - 10%). Change of conglomerated soft rock.		
2.5 - 3.8	SPT/ CORE LOSS: Sand. As above.		
3.8 - 4	GRAVEL: Grey-red components. Sandstone, ironstone. In a silty, clayey matrix (5 %). Soft, unconsolidated.		
4 - 4.8	SAND: Silty, red-brown, well sorted, subrounded, mainly quartz.		
4.8 - 5.4	CLAYSTONE: Red brown, sandstone to claystone, some traces of heavy minerals.		
5.4 - 7	SAND: Fine grained, red brown, well rounded, well sorted with some larger fragments of shells, mostly quartzile, calcitic oxides (minor black heavy minerals).		
7 - 8.9	SAND: Gravel components (2 - 3 cm), subangular, consists of sandstone (will heavily weather or surface up to 7 cm long)	105.6 mS/cm	0.5 L/sec
8.9 - 10.5	SAND: Clayey, dark red brown sand, gravel components (1 - 2 cm), increasing clay content to the bottom.		
10.5 - 10.9	CLAY: Sandy, dark red brown, high plasticity, less sand with gravel angular components (sandstone, quartz).		
10.9 - 11.5	SAND: Fine grained, dark brown, loose sand, well sorted, silty at bottom, mainly quartzite.		
11.5 - 12.3	CLAY: Red brown, some gravel of sandstone.		
12.3 - 13.05	SAND: Silty with increasing compounds of gravel (sandstone).		
13.05 - 13.9	CLAY: Red brown, gravel (sandstone), high plasticity, stiff and compacted, minor sandy parts, compaction increasing to bottom.		
13.9 - 15.5	CLAYSTONE: Red brown, gravel, high plasticity, stiff and compacted, minor sandy parts, highly compacted to a claystone.		

DRAWN BY **RM** DATE **21/07/09** 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 **E014G-I**
DESCRIPTION **Intermediate Groundwater 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	**E014**	EASTING	**0291024 mE**
START DATE	**24/5/09**	NORTHING	**7599362 mN**
COMPLETION DATE	**25/5/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CW**		
SWL	**2.66 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD

Bore construction:
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.58 - 12 m)
- Backfill (0 - 10.5 m)
- Bentonite Seal (10.5 - 11 m)
- 9.5 - 13.0 mm Graded Gravel Pack (11 - 15 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (12 - 15 m)
- Collapse (15 - 15.5 m)
- EOH (15.5 m)

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

Description:
- SAND: Fine grained, red brown, well sorted, quartzite.
- GRAVEL: Clayey matrix, some parts well cemented components of sandstone, subrounded to subangular.
- CORE LOSS
- GRAVEL: Clayey matrix, some parts well cemented components of sandstone, subrounded to subangular.
- CORE LOSS
- GRAVEL: Clayey matrix, some parts well cemented components of sandstone, subrounded to subangular.
- SAND: Silty, clayey, red brown, well sorted with gravel components.
- CLAYSTONE: Red brown, increasing into 3 - 4 cm parts, compact.
- CALCRITE: Red brown, silty, sandy with fragments of shells.
- SAND: Clayey, compacted, red borwn, quartzite, well rounded, fragments of shells, black heavy minerals.
- CORE LOSS: Sandy, red brown, darker than above with some gravel and calcrite layers, compacted.
- SAND: Clayey, sandy, partly cemented, gradually changes to clay, some embedded gravel (angular, 5 - 7 cm, sandstone), highly weathered surface, some calcified parts (calcrite).
- CLAY: Sandy, red brown, darker than above with some gravel and calcrite layers, compacted.
- SAND: Clayey, red brown, some gravel (sandstone).
- CLAY: Sandy, red brown with gravel (1 - 2 cm).
- SANDSTONE: With gravel and fragments of shells, weathered cavities.
- CLAY: Sandy with gravel, high plasticity, compacted, partly cemented.
- CLAYSTONE: Red brown, highly compacted with veins of grey sand.

Field EC: 107.5 mS/cm

DRAWN BY **RM** DATE **21/07/09** CHECKED BY **DL** APPENDIX

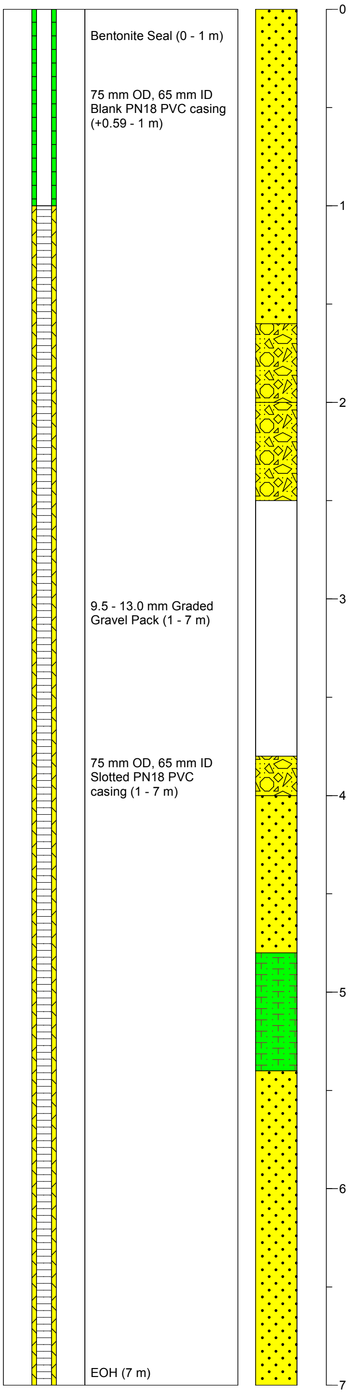
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E014G-S**
DESCRIPTION	**Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**7 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**7 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E014**	EASTING	**0291024 mE**
START DATE	**26/5/09**	NORTHING	**7599357 mN**
COMPLETION DATE	**26/5/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CW**		
SWL	**2.64 m bgl**		



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0 - 1.6	SAND: Red brown, fine grained, well sorted, sub angular - sub rounded, soft core. Components: Quartz, silty matrix (> 5 %).		
1.6 - 2.0	GRAVEL: Partly cemented to completely subrounded. Sandstone components in a sandy/silty matrix. Layered: cm sandstone, cm conglomerate (in red matrix 5 - 10%). Change of conglomerated soft rock.		
2.0 - 2.5	GRAVEL: Partly cemented to completely subrounded. Sandstone components in a sandy/silty matrix. Layered: cm sandstone, cm conglomerate (in red matrix 5 - 10%). Change of conglomerated soft rock.		
2.5 - 3.8	SPT/ CORE LOSS: Sand. Partly cemented to completely subrounded. Sandstone components in a sandy/silty matrix. Layered: cm sandstone, cm conglomerate (in red matrix 5 - 10%). Change of conglomerated soft rock.		
3.8 - 4.0	GRAVEL: Grey-red components. Sandstone, ironstone. In a silty, clayey matrix (5 %). Soft, unconsolidated.		
4.0 - 4.8	SAND: Silty, red-brown, well sorted, subrounded, mainly quartz.	67.6 mS/cm	
4.8 - 5.4	CLAYSTONE: Red brown, sandstone to claystone, some traces of heavy minerals.		
5.4 - 7.0	SAND: Fine grained, red brown, well rounded, well sorted with some larger fragments of shells, mostly quartzile, calcitic oxides (minor black heavy minerals).		

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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: EO22 Production Bore

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**Mud Rotary Blade**
TOTAL DRILLED DEPTH	**10 m**
HOLE DIAMETER	**255 mm**
TOTAL CASED DEPTH	**10 m**
CASING DIAMETER	**125 mm**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**EO22**	EASTING	**293464 mE**
START DATE	**16/09/09**	NORTHING	**7599690 mN**
COMPLETION DATE	**16/09/09**	R.L. OF COLLAR	**3.48 m AHD**
SWL	**2.93 m btc**	LOGGED BY	**B.S**
MEASUREMENT DATE	**30/10/2009**		

BORE CONSTRUCTION	DEPTH (m)	DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD
Bentonite Seal (0 - 1.2 m)	0	SILTY SAND: Silty sand, red		
	1	SANDY CLAY: Sandy - silty clay with minor quartz 1-2mm, grey-red (pink)		
	2	CLAYEY SAND: Silty - clayey sand with minor quartz 1-2mm, grey		
125 mm OD Blank PN18 PVC casing (+0.56 - 3 m)	3	CLAYEY SAND: Silty clayey sand, fine, brown		
	4	CLAYEY SAND: Silty clayey sand, fine		
125 mm OD Slotted PN18 PVC casing (3 - 7 m)	5	CLAYEY SAND: Clayey sand, brown - grey, shell fragments		
	6	SAND: Fine sand, minor silt and clay, brown-grey with shell fragments	111 mS/cm	
1.6 - 3.2 mm Graded Gravel Pack (1.2 - 10 m)	8	CLAYEY SAND: Silty-clayey fine sand with minor shell fragments, brown-grey		2.0 L/sec
125 mm OD Blank PN18 PVC casing (7 - 10 m)	9	SILTY CLAY: Silty clay with fine sand, brown		
	10			

DRAWN BY **A.P** DATE **01/12/09** 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 **E023FG-D**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**34 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**34 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E023**	EASTING	**292463 mE**
START DATE	**28/5/09**	NORTHING	**7600535 mN**
COMPLETION DATE	**30/5/09**	R.L. OF COLLAR	**TBA**
SWL	**SWL**	LOGGED BY	**CW**
MEASUREMENT DATE	**Date**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD

Bore construction:

- Backfill (0 - 27 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.64 - 27 m)
- Bentonite Seal (27 - 29 m)
- 9.5 - 13.0 mm Graded Gravel Pack (29 - 34 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (31 - 34 m)
- EOH (34m)

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36

Description:

- SAND: Red, brown, soft, well sorted, well rounded, mostly quartz, mica.
- CORE LOSS
- SAND: Red, brown, soft, well sorted, well rounded, mostly quartz, mica.
- CORE LOSS
- SAND: Red, brown, soft, well sorted, well rounded, mostly quartz, mica.
- 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.
- CLAYEY SAND: Red, brown moderately plastic.
- SAND: Dark brown subangular to sub rounded, mostly quartz, Orthoclase ?
- CORE LOSS
- CLAYEY SAND: Sandy, some gravel, red/brown, becoming stiff from 11.75.
- SAND: Clayey, red/brown to coffee-cream from 12.5. Well rounded to subrounded finr grained with some well cemented layers. Gravel from 13.00 - 13.35
- CLAYSTONE: Red/brown, developing sand to clay into hard compacted claystone. Calcareous orthogenic, some gravel calcritic from 17.20m with nodules of green clay
- CLAYSTONE: Red/brown, developing sand to clay into hard compacted claystone. Calcareous orthogenic, some gravel calcritic from 17.20m with nodules of green clay. Some sandstone 3-5cm, angular and weathered.
- CONGLOMERATE: Matrix of silty clay, 15% very hard and cemented, subrounded to well rounded
- CLAYSTONE: red/brown, dark with some clasts of sandstone veins of calcite, very solid with some sand content
- SANDSTONE: Coffee red brown, gray-green clay nodules and grey sand patches, high consolidated calcareous, mainly corse, 27.5solid, compact sandstone 28.05 permiable erosion surface
- CAVITY
- CAVITY: Infilled with broken limestone, clay
- LIMESTONE: White, compact
- LIMESTONE BRECCIA: Red, brown to grey, cemented and fractured
- LIMESTONE BRECCIA: Solid, coffee brown to grey with clasts of limestone up to 3cm, few joints (most cemented with calcite)
- CAVITY
- CAVITY
- LIMESTONE: White, grey, red.

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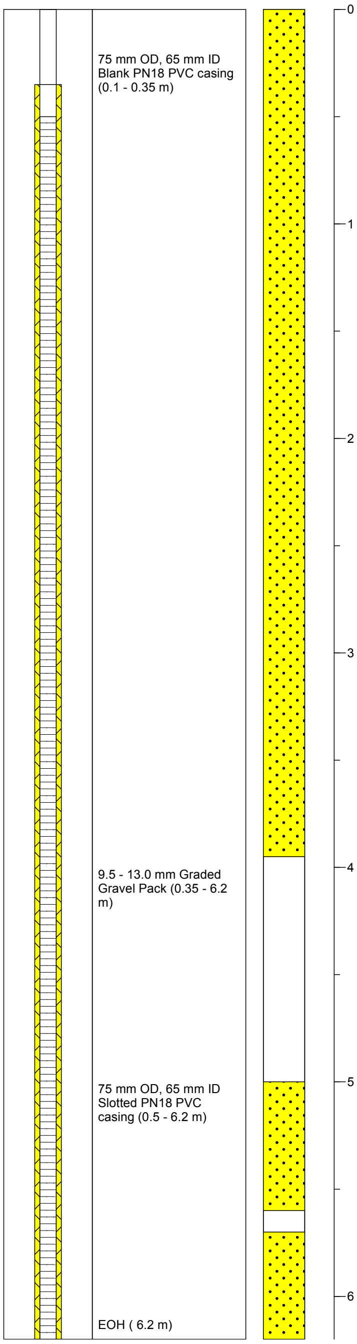
URS BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E023FG-S**
DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**6.2 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**6.2 m**
CASING DIAMETER	**65 mm ID**
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER	**42907100**
CLIENT	**Chevron Australia Pty Ltd**
LOCATION	**E023**
START DATE	**28/5/09**
COMPLETION DATE	**30/5/09**
LOGGED BY	**CW**
EASTING	**292465 mE**
NORTHING	**7600538 mN**
R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD



Depth (m)	Description
0 – 3.95	SAND: Red, brown, soft, well sorted, well rounded, mostly quartz, mica.
3.95 – 5.0	CORE LOSS
5.0 – 5.6	SAND: Red, brown, soft, well sorted, well rounded, mostly quartz, mica.
5.6 – 5.7	CORE LOSS
5.7 – 6.2	SAND: Red, brown, soft, well sorted, well rounded, mostly quartz, mica.

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BORE COMPLETION REPORT

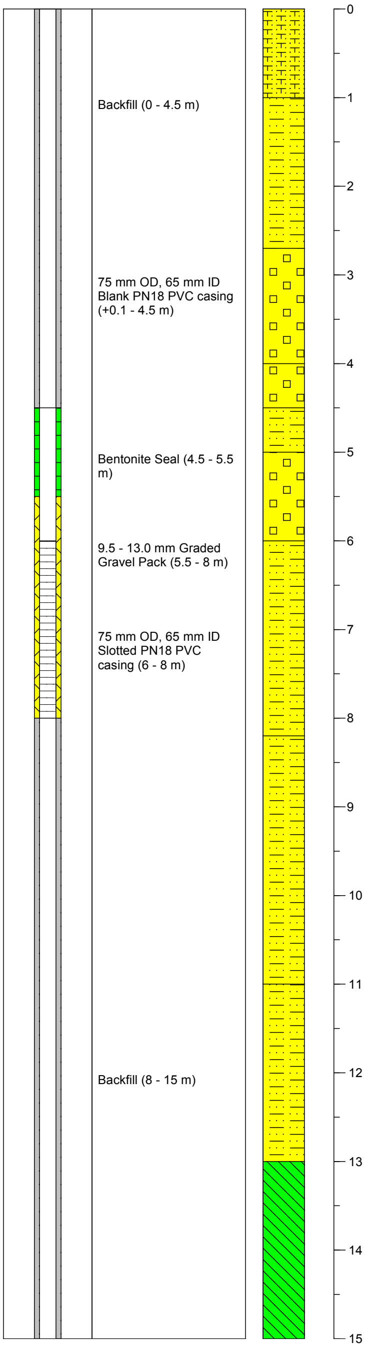
BOREHOLE E024FG-I

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**15 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**8 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E024**	EASTING	**291590 mE**
START DATE	**26/6/09**	NORTHING	**7599721 mN**
COMPLETION DATE	**27/6/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CW**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD



Depth (m)	Description
0 - 1	SILTY SAND: Fine to medium grained, loose, red, brown
1 - 2.7	SANDY CLAY: Fine to medium grained, loose, red, brown, low plasticity, loose to moderately tight.
2.7 - 4	GRAVELLY CLAY: Same fine grained sand, 30% gravel ± 20mm. Sun angular to angular, low to moderate plasticity, loose to medium to tight, red, brown.
4 - 4.5	GRAVELLY CLAY: As above, larger gravels to ± 35mm, sub rounded to sub angular, shell fragments (15-20%)
4.5 - 5	SANDY CLAY: Very fine grained sand, low to moderate plasticity, moderately tight, red to dark brown.
5 - 6	GRAVELLY CLAY: Gravel ± 25mm, sub rounded to sub angula, low to moderate plasticity, looset o moderately tight, red to brown.
6 - 8.2	SANDY CLAY: Low to moderate plasticity, fine grained sand, moderately tight, red, brown.
8.2 - 11	SANDY CLAY: Fine to medium grained, moderately tight red, brown. Some clay, medium density.
11 - 13	SANDY CLAY: Low plasticity, moderately tight, some occassional gravel, rounded, very fine grained sands, red, brown.
13 - 15	CLAY: Low plasticity, moderately tight to tight < 5%, some fine grained sands, red/brown.

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BORE COMPLETION REPORT

URS Australia Pty Ltd
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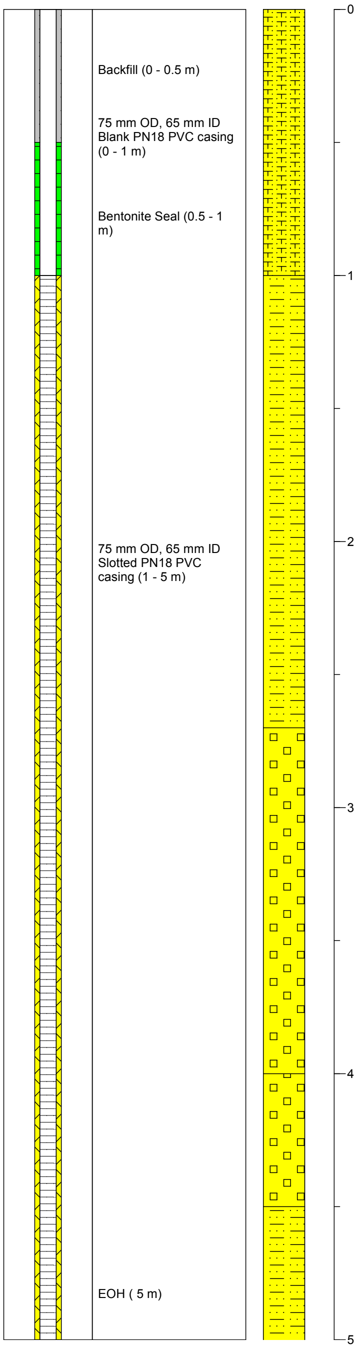
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE E024FG-S

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**5 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**E024**
TOTAL CASED DEPTH	**5 m**	START DATE	**26/6/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**27/6/09**
		LOGGED BY	**CW**
		EASTING	**291591 mE**
		NORTHING	**7599723 mN**
		R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD



Depth (m)	Description
0 - 1	SILTY SAND: Fine to medium grained, loose, red, brown
1 - 2.7	SANDY CLAY: Fine to medium grained, loose, red, brown, low plasticity, loose to moderately tight.
2.7 - 4	GRAVELLY CLAY: Same fine grained sand, 30% gravel ± 20mm. Sun angular to angular, low to moderate plasticity, loose to medium to tight, red, brown.
4 - 4.5	GRAVELLY CLAY: As above, larger gravels to ± 35mm, sub rounded to sub angular, shell fragments (15-20%)
4.5 - 5	SANDY CLAY: Very fine grained sand, low to moderate plasticity, moderately tight, red to dark brown.

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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

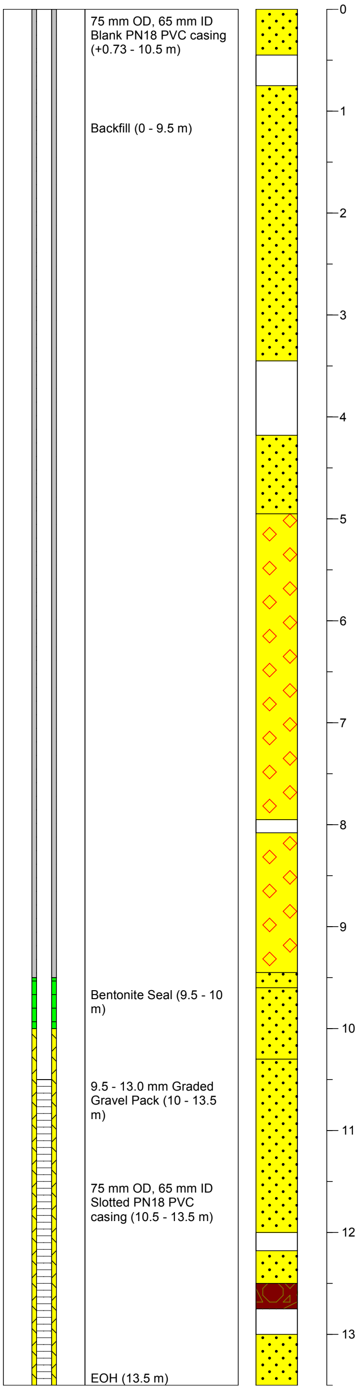
BOREHOLE **E025FG-D**

DESCRIPTION **Intermediate/Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**13.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**13.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E025**	EASTING	**0291799 mE**
START DATE	**5/6/09**	NORTHING	**7600224 mN**
COMPLETION DATE	**6/6/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**BP**		
SWL	**6.72 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



Description:

- SAND: Red sand, fine grained, siliceous, well sorted, mature.
- CORE LOSS
- SAND: Red sand, fine grained, siliceous, well sorted, mature.
- CORE LOSS
- SAND: Red sand with minor cemented gravel at 4.95 m, fine grained, siliceous, well sorted, mature.
- CALCARENITE: White brown, lithified, fine grained, siliceous sand in a fine - medium grained calcareous matrix. Moderately sorted, highly porous and permeable.
- CORE LOSS
- CALCARENITE: White brown, lithified, fine grained, siliceous sand in a course grained calcareous matrix. Highly porous and permeable, poorly sorted, 80% shell material in a matrix of fine grained calcareous and siliceous material.
- SAND: Brown sand/beach shingle, 80% fine grained siliceous quartz sand wth 20% shell fragments.
- SAND: Brown sand, fine grained, well sorted, siliceous sand with <5% fine calcareous material.
- SAND: Beach sand/shingle, 70% silt, fine grained, siliceous material as a cement to approximately 20% shell fragments. Becoming siltier downhole.
- CORE LOSS
- SAND: Beach sand/shingle, 70% silt, fine grained, siliceous material as a cement to approximately 20% shell fragments. Becoming siltier downhole.
- PALEOCHANNEL DEPOSIT: Unlithified pebble conglomerate, polymictic, angular-round clasts of quartz, layered chert BIF and siltstone. Clasts are approximately 70% siliceous red brown matrix of the sand.
- CORE LOSS
- SAND: Brown, moderately sorted, fine - medium grained siliceous sand (90%). Polymicic coarse grained -sm pebble clasts that decrease downhole.

Field EC: 72.7 mS/cm

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BORE COMPLETION REPORT

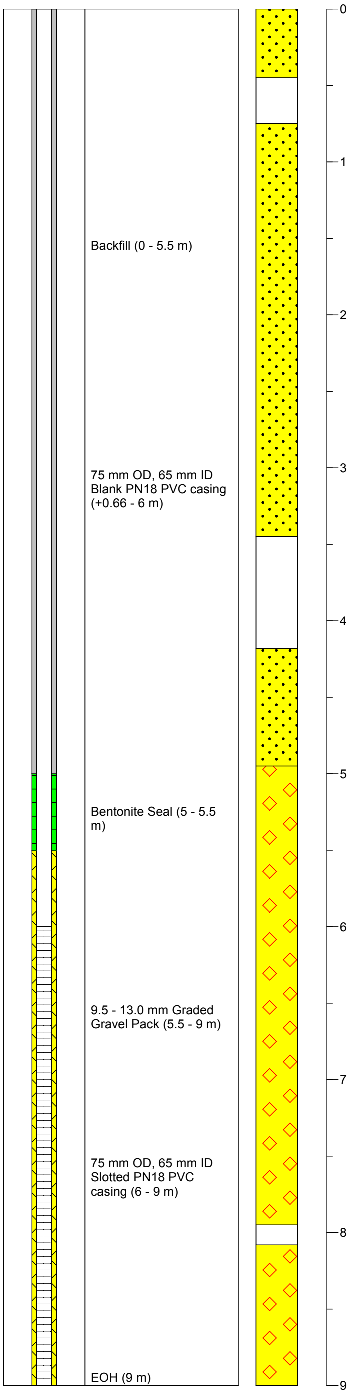
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E025FG-I**
DESCRIPTION	**Intermediate Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**9 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**9 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E025**	EASTING	**0291799 mE**
START DATE	**7/6/09**	NORTHING	**7600223 mN**
COMPLETION DATE	**7/6/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**BP**		
SWL	**6.62 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
0 - 0.45	SAND: Red sand, fine grained, siliceous, well sorted, mature.		
0.45 - 0.75	CORE LOSS		
0.75 - 3.45	SAND: Red sand, fine grained, siliceous, well sorted, mature.		
3.45 - 4.18	CORE LOSS		
4.18 - 4.95	SAND: Red sand with minor cemented gravel at 4.95 m, fine grained, siliceous, well sorted, mature.		
4.95 - 7.95	CALCARENITE: White brown, lithified, fine grained, siliceous sand in a fine - medium grained calcareous matrix. Moderately sorted, highly porous and permeable.	6.41 mS/cm	
7.95 - 8.08	CORE LOSS		
8.08 - 9	CALCARENITE: White brown, lithified, fine grained, siliceous sand in a course grained calcareous matrix. Highly porous and permeable, poorly sorted, 80% shell material in a matrix of fine grained calcareous and siliceous material.		

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BORE COMPLETION REPORT

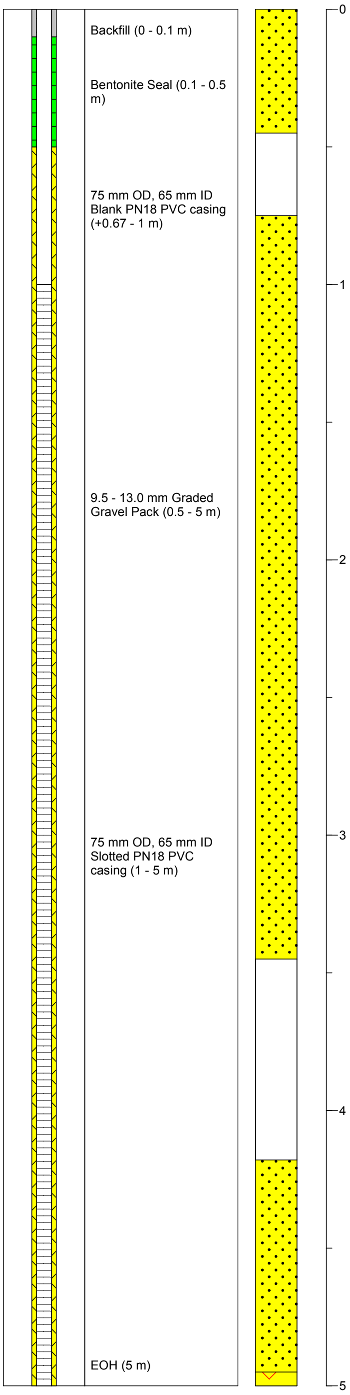
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E025FG-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	**E025**	EASTING	**0291800 mE**
START DATE	**7/6/09**	NORTHING	**7600221 mN**
COMPLETION DATE	**7/6/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**BP**		
SWL	**Dry**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



DEPTH (m)	DESCRIPTION
0 – 0.45	SAND: Red sand, fine grained, siliceous, well sorted, mature.
0.45 – 0.75	CORE LOSS
0.75 – 3.45	SAND: Red sand, fine grained, siliceous, well sorted, mature.
3.45 – 4.18	CORE LOSS
4.18 – 4.95	SAND: Red sand with minor cemented gravel at 4.95 m, fine grained, siliceous, well sorted, mature.
4.95 – 5	CALCARENITE: White brown, lithified, fine grained, siliceous sand in a fine - medium grained calcareous matrix. Moderately sorted, highly porous and permeable.

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URS URS Australia Pty Ltd
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Fax: (08) 9326 0296

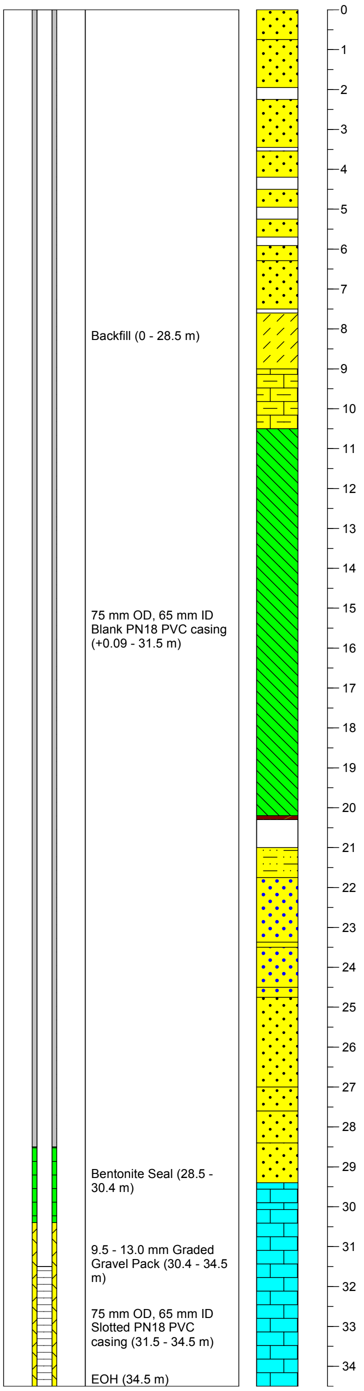
BORE COMPLETION REPORT

BOREHOLE	**E026FG-D**
DESCRIPTION	**Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**34.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**34.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E026**	EASTING	**0292030 mE**
START DATE	**8/6/09**	NORTHING	**7599733 mN**
COMPLETION DATE	**17/6/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**BP**		
SWL	**4.68 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
SAND: Red, siliceous, fine grained and well sorted.		
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.		
CORE LOSS		
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.		
CORE LOSS		
SAND: Siliceous, calcareous gravel, approximately 70% siliceous red brown sand.		
CORE LOSS		
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.		
CORE LOSS		
SAND: Siliceous, red brown, fine-medium grained, very well sorted, less than 10% calcarenite gravel pieces.		
CORE LOSS		
SAND: Siliceous, red brown, fine-medium grained, very well sorted.		
SAND: Siliceous, brown white, with a higher percentage of white pisolites (up to 80%) in comparison to quartz. Very well sorted, mature rounded grains, lightly cemented. Calcareous shell material increases downhole.		
Approximately 60% shell materials.		
SAND/SILT: Brown, siliceous, approximately 70% silt, 30% sand, silt content increases downhole, becoming approximately 20% clayey from 8.25 m onwards.		
SILTY CLAY: Brown red, cemented but not lithified, approximately 50% clay.		
CLAY: Brown, siliceous with black mottling. Strongly cemented/coherent, hard, sandy.	169.6 mS/cm	
PALEOCHANNEL DEPOSIT: Unlithified pebble conglomerate (paleochannel river gravel), poorly sorted, sub-angular clasts, polymictic with quartz, BIF, dolerite present. Approximately 80% pebbles, matrix is red brown, siliceous, sandy.		
CORE LOSS		
SANDY CLAY: Brown, siliceous with a 5 mm bound of pebble conglomerate as above at 21.5 m.		
SANDSTONE: Brown, stiff/coherent, well sorted, fine-medium grained, sub-rounded quartz in a slightly clayey matrix.		
SANDSTONE: Brown, stiff/coherent, well sorted, fine-medium grained, sub-rounded quartz in a slightly clayey matrix, patches of white mottling.		
SANDSTONE: Reactive clay mottling, increasing to approximately 30% of core. Irregular carbonaceous banding starting to appear. These bands are between 5 - 10 mm wide and are white grey.		
SANDSTONE: Brown, fine to medium grained, quartz (80%) in a clayey matrix (20%). Minor mottling.		
SAND: Red brown, consolidated sand, fine and well sorted. A few white grey, carbonaceous bands above 25 (up to 2 cm wide).		
SAND: Red brown, consolidated sand.		
SAND: Fine to coarse grained, red brown, consolidated sand. Clasts (5 mm to 20 mm). Poorly sorted, subangular, grey with brown cement, siliceous.		
SAND: Red brown, consolidated, fine, well sorted.		
LIMESTONE: Clasts of siliceous brown, subangular, poorly sorted, well cemented.		
LIMESTONE: White to yellow, fine grained, well cemented with clasts (up to 2 cm), a few joins at 29.9 m to 30.5 m (Breccia style becoming more competent), with a soft white patch and yellow, hard, fine blocks becoming frequent.		

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URS BORE COMPLETION REPORT

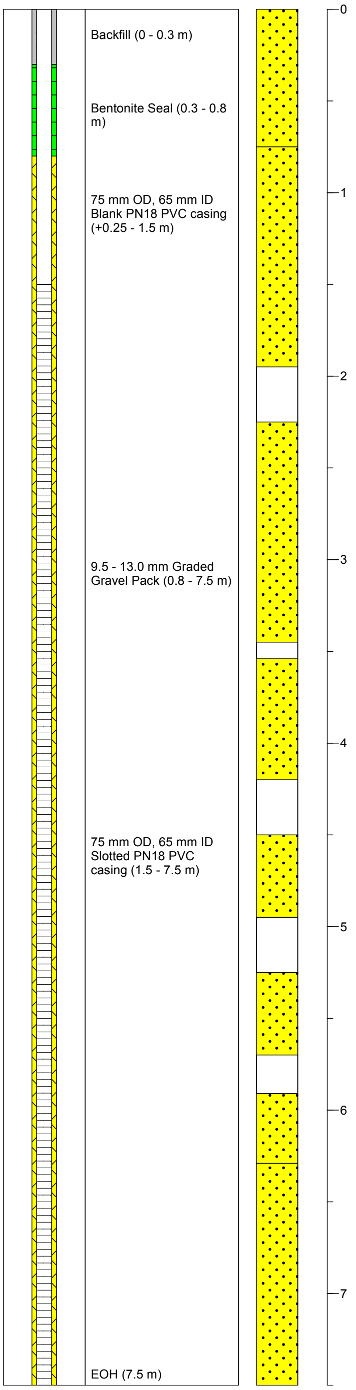
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E026FG-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	**E026**	EASTING	**0292032 mE**
START DATE	**17/6/09**	NORTHING	**7599733 mN**
COMPLETION DATE	**17/6/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**AB**		
SWL	**3.44 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



DESCRIPTION
SAND: Red, siliceous, fine grained and well sorted.
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.
CORE LOSS
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.
CORE LOSS
SAND: Siliceous, calcareous gravel, approximately 70% siliceous red brown sand.
CORE LOSS
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.
CORE LOSS
SAND: Siliceous, red brown, fine-medium grained, very well sorted, less than 10% calcarenite gravel pieces.
CORE LOSS
SAND: Siliceous, red brown, fine-medium grained, very well sorted.
SAND: Siliceous, brown white, with a higher percentage of white pisolites (up to 80%) in comparison to quartz. Very well sorted, mature rounded grains, lightly cemented. Calcareous shell material increases downhole.

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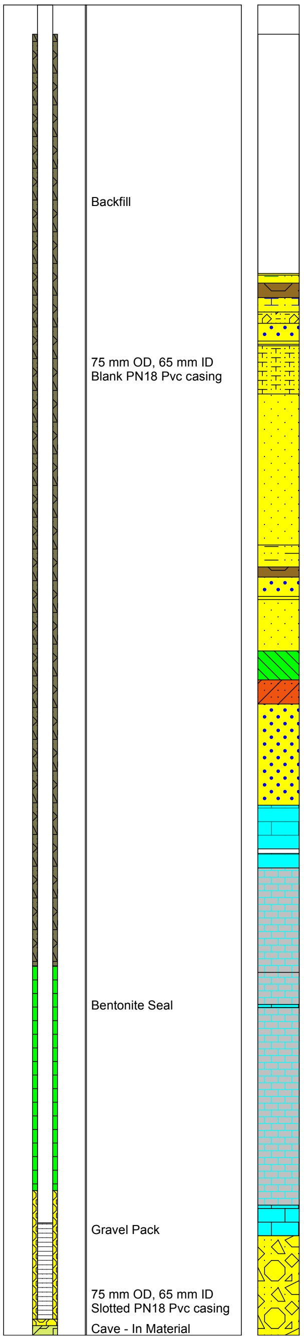
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **EO27FG-D**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**40.5 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**EO27**
TOTAL CASED DEPTH	**40 m**	START DATE	**14/5/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**17/5/09**
		LOGGED BY	**CO**
		EASTING	**293135**
		NORTHING	**7598677**
		R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FORMATION | EC PROFILE | HYDRO DATA



Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

DESCRIPTION

- CORE LOSS: See EO27a for nearby stratigrapy.
- Sandstone: Carbonaceous; Yellow brown, fragments of carbonaceous (coral), very broken, clay matrix. (possible aquifer).
- Clayey Sand: Red - brown, fine grained, sub - rounded to sub angular, mod sorted, quartz sand, with 15 % clay matrix, mod - well consolidated.
- GRAVELLY CLAY: Grey tan sandstone gravel (5 - 25 mm), that is made up of a fine - coarse grained, sub - rounded, quartz sand that is well cemented, clay is red - brown, mod plasticity, 25 % of core.
- Calcareous Sandstone: Yellow - brown, very variable, in patches is well cemented, but has bands of uncemented sand. Sandstone is fine to medium sand, sub - rounded, poorly sorted, with a large number of 10 - 20 mm clasts, which include, BIF, feldspar, quartz, and dolerite. Also has high shell content, very vuggy, up to 5 cm in diameter.
- Gravel and Sand: Paleochannel Deposit; yellow brown, fine to coarse, sub rounded to sub angular, poorly sorted quartz sand. Gravel is a mixture of Dolerite, BIF, Feldspar, the gravel is smooth and oval shaped and is horizontally layered, it is a paleochannel, so parts show minor cementing. Gravel ranges from 5 - 25 mm, with 1 piece of dolerite up to 50 mm.
- Sandstone: Yellow brown, Same as 9.0 - 9.55
- Sand: Grey yellow brown, fine grained, sub - rounded, well sorted, well cemented, bedding present, quartz and Ironstone.
- Sandstone: Yellow brown, same as 9.0 - 9.55.
- Silty Sand: Red - brown, well consolidated, with cemented patches, fine grained, sub rounded to sub angular quzrtz sand with 5 % silt.
- SANDY CLAY: Yellow - red - brown, very fine, sub - rounded, mod sorted quartz sand, in a poor - mod plasticity, stiff clay. (Sand 25 %). Cemented in parts, these are lighter in colour, and very random in shape. From 14.5 these cemented areas are very well cemented.
- Sandy Silt: Red - brown, very fine, sub - rounded, mod sorted quartz sand, in a silt matrix. (Sand only 15 %, well consolidated). Large amount of sandstone clasts, (5 - 10 mm) these are made up of fine, sub rounded - sub angular, mod sorted, quartz and Ironstone sand. Mod cemented.
- GRAVELLY CLAY: Red brown, mod - plasticity, stiff clay matrix holding angular sandstone gravel. Sandstone is a fine to coarse, poorly sorted, sub - rounded to sub angular to sub angular quartz and ironstone sand that is well cemented. Moderate presence of shells.
- Sandstone: Light grey, calcareous sandstone with high fossil content. Sandstone is made up of fine to coarse sand, sub round - sub angular, poorly sorted, made up of quartz, BIF, Ironstone, and Feldspar, Vuggy (3 - 8 mm). Has a large fracture at 17.15 cm (2 - 4 cm in diameter). Large clasts of dolerite.
- SANDY CLAY: Paleochannel Deposit; red - brown, gravelly. A fine to coarse gravel, smooth, oval shaped, poorly sorted, made up of quartz, dolerite, ironstone and BIF. In a sandy clay matrix (10 % sand).
- SANDY CLAY: Red - brown, a mod plasticity, stiff clay, with (15 %) fine, su rounded, well sorted quartz sand. Has a large (80 - 100 mm) clast of Sandstone in it. Heavily mottled from 18 - 19 m). Cemented in parts, orthogenic, very random in shape.
- Clay: Red - brown, mod plasticity, very stiff clay with mottles. Sandstone nodules.
- SILTY CLAY: Red - brown, poor plasticity, stiff clay with 20 % silt, mottled, sandstone nodules.
- Sandstone: Red tan, fine to coarse , poorly sorted, well cemented, quartz and iron stone sand. Vuggy, vuggs filled with clay from above. High shell content, soft rock (weak). 23.05 - 23.35 Cavity - filled with fine to medium sand with 10 % clay. Sub - rounded, poorly sorted. 23.50 - 23.73, brecciated with quartz, BIF Ironstone, Feldspar.
- Limestone Mudstone: Conglomeratoc; grey - white / red - brown calcarenite with large (up to 100 mm) clasts of mudstone. Highly carbonaceous limestone, highly weathered, vuggy, large amount of cavities (30 - 200 mm), burrows, weak rock.
- CORE LOSS
- Limestone Mudstone: Same as 24.0 - 25.36, very large gypsum crystal present.
- Calculutite: Pale grey, moderately weathered, weak rock, with patches of very broken, very soft material. Cavity rich, with burrows. 2 fractures (1 about 5mm, the other about 30 mm).
- Calculutite: As above but very weak, core is almost a carbonate silt (unlithified). Very vuggy. Fragments of stronger material are calculite, it is almost like a gravel throughout the core.
- Limestone: Brecciated; pale yellow - white. Moderately weathered, weak, oval shaped carbonate gravel (5 - 10 mm), in limestone.
- Calculutite: Pale yellow - white, weak, slightly weathered limestone, large (up to 200 mm) cavities. These are filled with limestone gravel and carbonate silt. Vuggy (up to 20 mm).
- Limestone: Yellow - white. Hard, vuggy (3 - 10 mm), well formed limestone, areas where core is almost a conglomerate with a very hard siltstone, poorly sorted.
- Conglomerate: Yellow - tan limestone and siltstone conglemerate. 5 - 55 cm clasts in a fine matrix. Sub - angular, vuggy (5 - 13 mm), large fracture at 37.6 m (5cm thick), cavities up to 150 mm, cavities and vuggs filled with high plasticity clay.

DRAWN BY **BP** | DATE **14/06/09** | CHECKED BY **DL** | FIGURE **TBA**

URS

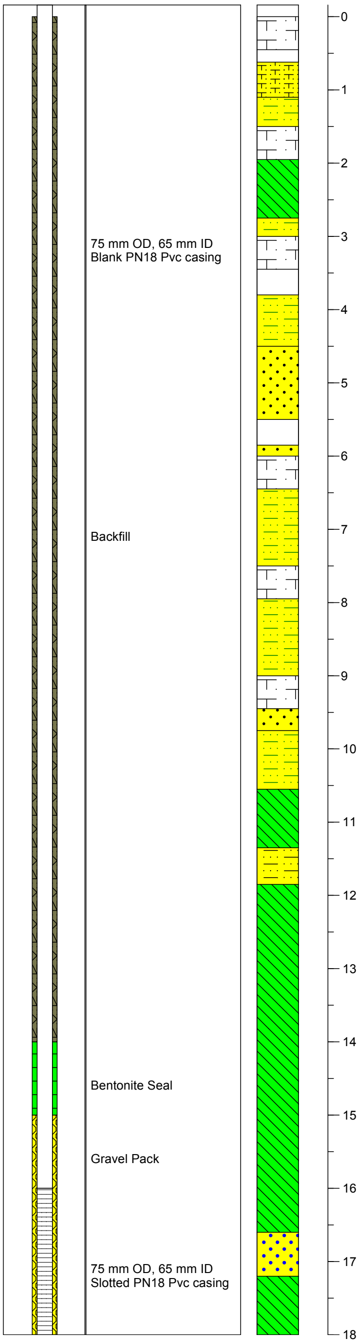
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **EO27FG-I**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**18**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**EO27**
TOTAL CASED DEPTH	**18 m**	START DATE	**12/5/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**13/5/09**
		LOGGED BY	**CO**
		EASTING	**293131**
		NORTHING	**7598679**
		R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FORMATION | EC PROFILE | HYDRO DATA



DESCRIPTION

- SPT
- CORE LOSS
- Silty Sand: Red - brown, fine, sub - rounded, well sorted quartz sand, minor iron staining. 5 % silt, minor organics, very soft core.
- Clayey Sand: Red - brown; fine, sub rounded, well sorted quartz sand, minor clay, more organics than above, still soft.
- SPT
- Clay: Yellow - grey. very sticky, soft, mod - high plasticity, minor sand, very minor sandstone gravel.
- Clayey Sand: Dark grey, fine grained, well sorted, quartz sand, 5 % clay, organics present.
- SPT
- CORE LOSS
- Clayey Sand: Red - brown, fine grained, well sorted, quartz sand, sub rounded, to sub angular, no organics, minor mottling (grey).
- Sand: Gravelly, red - brown, well cemented, fine to medium grained, subrounded, to sub angular, quartz sandstone gravel (up to 15 mm) in a medium grained, sub rounded moderately sorted, quartz sand. Core is soft.
- CORE LOSS
- Sand: Gravelly, red - brown. As above but gravel gets much larger (up 50 mm).
- SPT
- Clayey Sand: Red - brown, fine, sub rounded, well sorted, quartz sand, with 5 % clay, minor sandstone gravel (up to 20 mm) much less frequent than before. Mod consolidated.
- SPT
- Clayey Sand: Brown, same as 6.47 - 7.5, but very well consolidated sand, fine grained, with pebbles of quartz occasionaly,moderately sorted, in parts is poorly cemented sandstone, sub - rounded to sub - angular, quartz major, 5 m fracture of 9.6.
- SPT
- Sand: Yellow greenish brown. Very well consolidated sand, fine grained, with pebbles of quartz occasionaly, moderately sorted, in parts is poorly cemented sandstone, sub - rounded to sub angular, quartz major, 5 mm fracture at 9.6.
- Clayey Sand: Brown, fine, sub - rounded, mod sorted, quartz sand, with 10 % clay. Well consolidated sandstone clasts becoming more frequent from 10.0 - 10.2 m. Several dolerite pebbles in core.
- Clay: Red brown. Stiff, mod plasticity clay with minor sand and occasional sandstone clasts (5 - 10 mm).
- Siltstone: Yellow brown, very well consolidated, very well cemented silt, hard, very vuggy (5 - 15 mm). Cavities are from 11.45 - 11.56 and another at 11.70 - 11.73. Vuggs and cavities filled by clay from above. Suggary texture, calcareous.
- Clay: Red brown, same as 10.55 - 11.35 m. Grey mottling, very stiff.
- Sandstone: Pale grey, well cemented, med - hard, shell rich sandstone, vuggy, calcareous, vuggs filled with red - brown clay from above. Clasts of siltstone. Large fracture at 17.1 m (4 cm wide) filled with clay from above.
- Clay: Same as 11.85 - 16.6, but with frequent sandstone clasts.

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URS BORE COMPLETION REPORT

URS Australia Pty Ltd
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Phone: (08) 9326 0100
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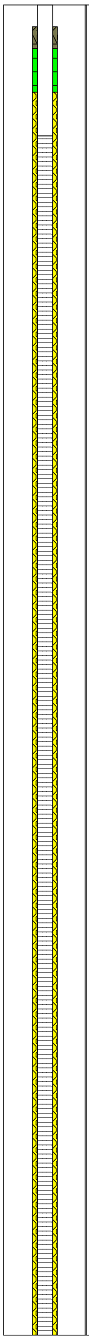
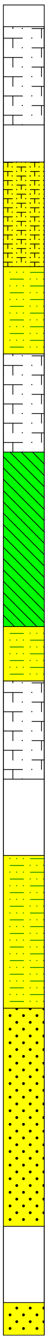
BOREHOLE **EO27FG-S**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**6 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**E027FG-S**
TOTAL CASED DEPTH	**6 m**	START DATE	**13/5/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**13/5/09**
		LOGGED BY	**CO**
		EASTING	**293135**
		NORTHING	**7598681**
		R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FORMATION	EC PROFILE	HYDRO DATA



Backfill
Bentonite Seal
75 mm OD, 65 mm ID Blank PN18 Pvc casing
75 mm OD, 65 mm ID Slotted PN18 Pvc casing
Gravel Pack



Depth (m)	Description
0	SPT
	CORE LOSS
	Silty Sand: Red - brown, fine, sub - rounded, well sorted quartz sand, minor iron staining. 5 % silt, minor organics, very soft core.
1	Clayey Sand: Red - brown; fine, sub rounded, well sorted quartz sand, minor clay, more organics than above, still soft.
	SPT
2	Clay: Yellow - grey. very sticky, soft, mod - high plasticity, minor sand, very minor sandstone gravel.
	Clayey Sand: Dark grey, fine grained, well sorted, quartz sand, 5 % clay, organics present.
3	SPT
	CORE LOSS
4	Clayey Sand: Red - brown, fine grained, well sorted, quartz sand, sub rounded, to sub angular, no organics, minor mottling (grey).
5	Sand: Gravelly, red - brown, well cemented, fine to medium grained, subrounded, to sub angular, quartz sandstone gravel (up to 15 mm) in a medium grained, sub rounded moderately sorted, quartz sand. Core is soft.
	CORE LOSS
6	Sand: Gravelly, red - brown. As above but gravel gets much larger (up 50 mm).

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BORE COMPLETION REPORT

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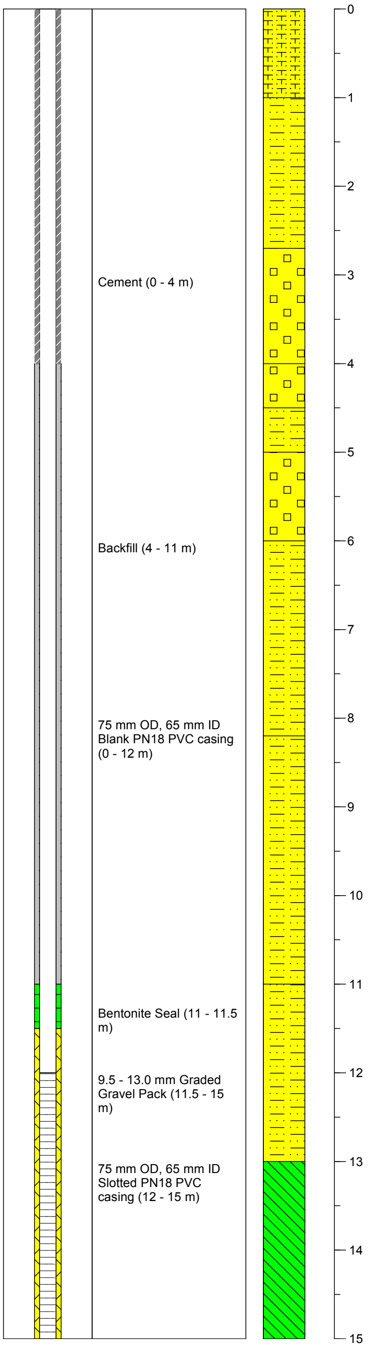
BOREHOLE **E028FG-I**

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	**E028**	EASTING	**290045 mE**
START DATE	**4/8/09**	NORTHING	**7595657 mN**
COMPLETION DATE	**5/8/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CW**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD



DEPTH (m)	DESCRIPTION
0 - 1	SILTY SAND: Fine to medium grained, loose, red, brown
1 - 2.7	SANDY CLAY: Fine to medium grained, loose, red, brown, low plasticity, loose to moderately tight.
2.7 - 4	GRAVELLY CLAY: Same fine grained sand, 30% gravel ± 20mm. Sun angular to angular, low to moderate plasticity, loose to medium to tight, red, brown.
4 - 4.5	GRAVELLY CLAY: As above, larger gravels to ± 35mm, sub rounded to sub angular, shell fragments (15-20%)
4.5 - 5	SANDY CLAY: Very fine grained sand, low to moderate plasticity, moderately tight, red to dark brown.
5 - 6	GRAVELLY CLAY: Gravel ± 25mm, sub rounded to sub angula, low to moderate plasticity, looset o moderately tight, red to brown.
6 - 8.2	SANDY CLAY: Low to moderate plasticity, fine grained sand, moderately tight, red, brown.
8.2 - 11	SANDY CLAY: Fine to medium grained, moderately tight red, brown. Some clay, medium density.
11 - 13	SANDY CLAY: Low plasticity, moderately tight, some occassional gravel, rounded, very fine grained sands, red, brown.
13 - 15	CLAY: Low plasticity, moderately tight to tight < 5%, some fine grained sands, red/brown.

DRAWN BY **CE** DATE **18/8/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

URS Australia Pty Ltd
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Phone: (08) 9326 0100
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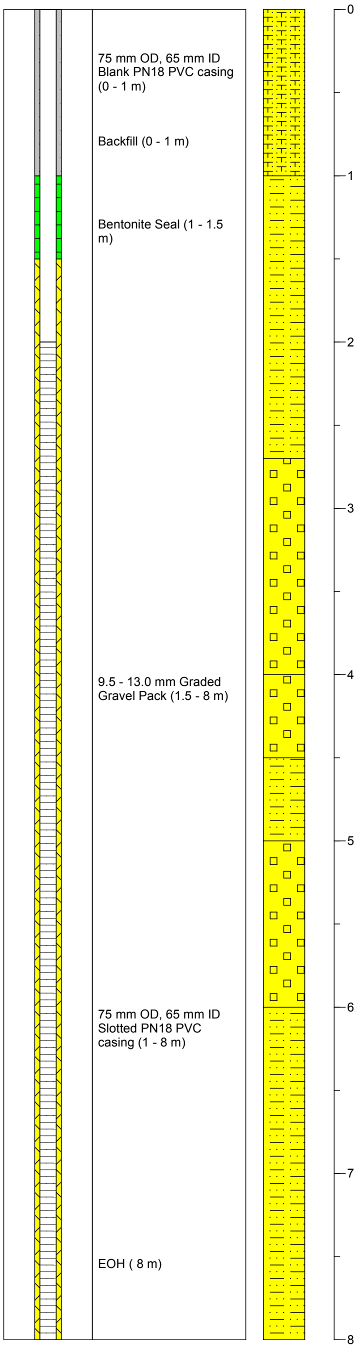
BOREHOLE	**E028FG-S**
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER	**42907100**
CLIENT	**Chevron Australia Pty Ltd**
LOCATION	**E028**
START DATE	**4/8/09**
COMPLETION DATE	**5/8/09**
LOGGED BY	**CW**
EASTING	**290045 mE**
NORTHING	**7595657 mN**
R.L. OF COLLAR	**TBA**
DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**8 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**8 m**
CASING DIAMETER	**65 mm ID**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD



Depth (m)	Description
0	SILTY SAND: Fine to medium grained, loose, red, brown
1	SANDY CLAY: Fine to medium grained, loose, red, brown, low plasticity, loose to moderately tight.
2.7	GRAVELLY CLAY: Same fine grained sand, 30% gravel ± 20mm. Sun angular to angular, low to moderate plasticity, loose to medium to tight, red, brown.
4	GRAVELLY CLAY: As above, larger gravels to ± 35mm, sub rounded to sub angular, shell fragments (15-20%)
4.5	SANDY CLAY: Very fine grained sand, low to moderate plasticity, moderately tight, red to dark brown.
5	GRAVELLY CLAY: Gravel ± 25mm, sub rounded to sub angula, low to moderate plasticity, looset o moderately tight, red to brown.
6	SANDY CLAY: Low to moderate plasticity, fine grained sand, moderately tight, red, brown.

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BORE COMPLETION REPORT

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Phone: (08) 9326 0100
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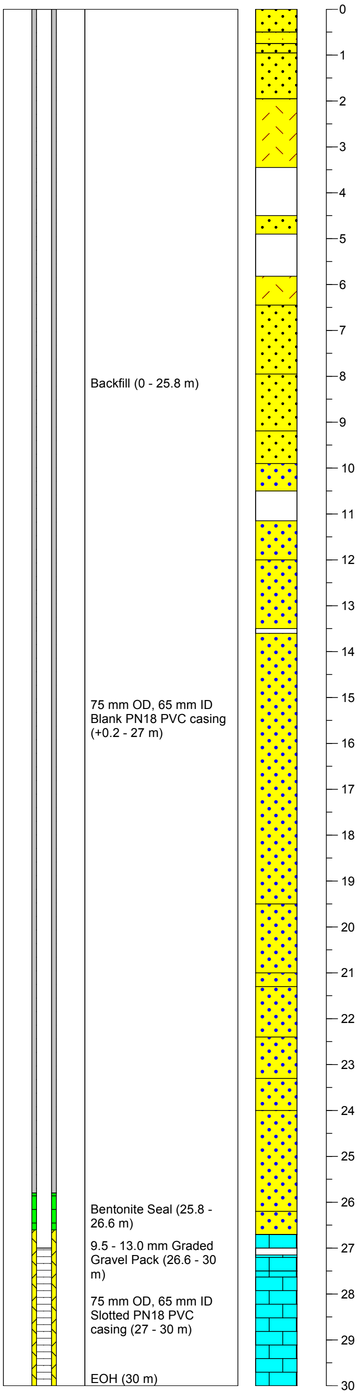
BOREHOLE	**E029G-D**
DESCRIPTION	**Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**30 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**30 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E029**	EASTING	**0290734 mE**
START DATE	**26/6/09**	NORTHING	**7597191 mN**
COMPLETION DATE	**28/6/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**AB**		
SWL	**TBA**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



Description
CORE LOSS
SAND: Red, siliceous, fine grained and well sorted.
SILTY SAND : Red brown, fine and well worted, soft core, minor organics.
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.
SAND: Red brown, fine, rounded, well sorted, very soft core, minor clay and minor organics.
CLAYEY SAND : Red brown, fine grained, rounded and well sorted, soft core, poorly consolidated.
CORE LOSS
SAND: Red brown, rounded to sub-rounded, fine, well sorted, becoming more consolidated, minor clay with gravel of fine quartz sand.
CORE LOSS
CLAYEY SAND : Sandstone clasts, red brown to light brown, fine grained, well sorted, subangular, within a sandy and clayey sand matrix, indurated shells in clast.
SAND: Red brown, consolidated, fine to coarse grained, moderately sorted with clasts of light brown sandstone well cemented, fine grained, minor clay.
SAND: Red brown, fine grained, well sorted, moderately consolidated with clasts of brown sandstone, fine and well sorted, well cemented and sub-rounded.
SAND: Red brown, consolidated, fine grained with light brown sandstone (up to 3 cm), fine to coarse grained with vein of white mineral, minor clay.
SANDSTONE: Red brown band of sandstone, fine grained, well sorted and cemented, interbedded with clayey sand (up to 5 cm), fine and well sorted.
CORE LOSS
SANDSTONE: Sandstone becoming more competent, red brown, fine grained, well sorted, well cemented, minor clay.
SANDSTONE: Massive sandstone, fine to coarse grained, red brown, few quartz (up to 1 cm), well cemented, sub-rounded, poorly sorted.
CORE LOSS
SANDSTONE: Red brown, fine to coarse grained, quartz and grey to light brown clasts of indurated sandstone, very well cemented sub-rounded and poorly sorted. Some veins of calcite and some voids.
SANDSTONE: Red brown, coarse grained, well cemented with grey clasts (up to 3 cm), calcareous with calcite veins, poorly sorted, calcareous bands more frequent.
SANDSTONE: Red brown, coarse with numerous calcareous clasts, well cemented, poorly sorted.
SANDSTONE: Red brown, fine grained, well sorted and cemented, calcareous grey band at 21.5 m (3 cm thick) and several grey clasts after 21.8 m.
SANDSTONE: Fine grained, red brown, well cemented and sorted with grey carbonaceous clast becoming frequent.
SANDSTONE: Red brown/grey, fine grained, well sorted, poorly cemented in carbonaceous zone at 23.30 to 23.50, becoming mainly carbonaceous and grey at 24 m.
SANDSTONE: Red brown, fine grained, well sorted and cemented.
SANDSTONE: Red brown, coarse (up to 1 m), poorly sorted, well cemented, calcareous yellow brown clasts.
LIMESTONE: Breccia limestone, white to light brown, fine grained and well cemented, poorly sorted, subangular with clasts up to 5 cm. Competent rock.
CORE LOSS
LIMESTONE: Breccia limestone, yellow, fine grained, poorly cemented, detritic clasts, subangular with voids, large gypsum crystal (6 cm x 3 cm).
LIMESTONE: Breccia limestone, white grey, yellow, fine grained, well cemented, poorly sorted, voids at 28.1 m, competent rock, brown, calcareous clasts (up to 10 cm), sub-rounded to subangular.

DRAWN BY **RM**	DATE **23/07/09**	CHECKED BY **DL**	APPENDIX

BORE COMPLETION REPORT

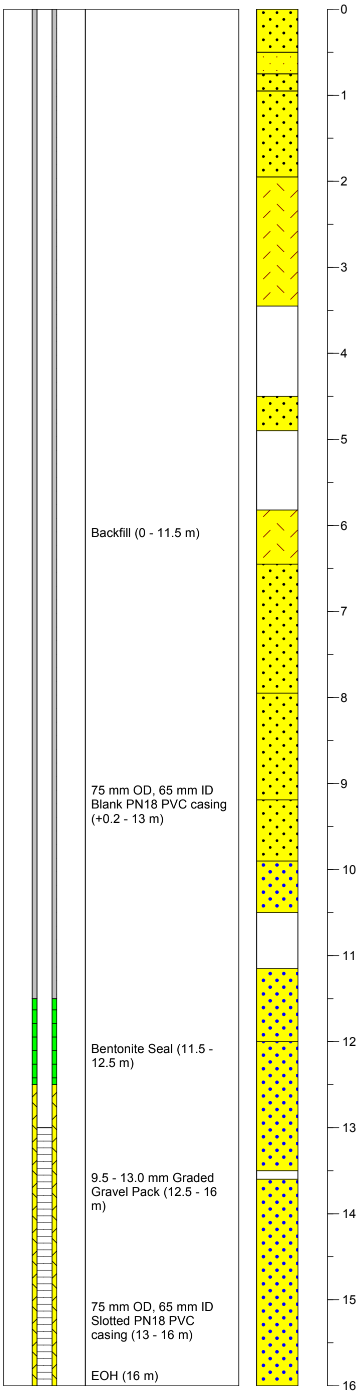
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E029G-I**
DESCRIPTION	**Intermediate Groundwater 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	**E029**	EASTING	**0290736 mE**
START DATE	**26/6/09**	NORTHING	**7597188 mN**
COMPLETION DATE	**28/6/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**AB**		
SWL	**TBA**		

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD



DESCRIPTION:

CORE LOSS

SAND: Red, siliceous, fine grained and well sorted.

SILTY SAND : Red brown, fine and well worted, soft core, minor organics.

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.

SAND: Red brown, fine, rounded, well sorted, very soft core, minor clay and minor organics.

CLAYEY SAND : Red brown, fine grained, rounded and well sorted, soft core, poorly consolidated.

CORE LOSS

SAND: Red brown, rounded to sub-rounded, fine, well sorted, becoming more consolidated, minor clay with gravel of fine quartz sand.

CORE LOSS

CLAYEY SAND : Sandstone clasts, red brown to light brown, fine grained, well sorted, subangular, within a sandy and clayey sand matrix, indurated shells in clast.

SAND: Red brown, consolidated, fine to coarse grained, moderately sorted with clasts of light brown sandstone well cemented, fine grained, minor clay.

SAND: Red brown, fine grained, well sorted, moderately consolidated with clasts of brown sandstone, fine and well sorted, well cemented and sub-rounded.

SAND: Red brown, consolidated, fine grained with light brown sandstone (up to 3 cm), fine to coarse grained with vein of white mineral, minor clay.

SANDSTONE: Red brown band of sandstone, fine grained, well sorted and cemented, interbedded with clayey sand (up to 5 cm), fine and well sorted.

CORE LOSS

SANDSTONE: Sandstone becoming more competent, red brown, fine grained, well sorted, well cemented, minor clay.

SANDSTONE: Massive sandstone, fine to coarse grained, red brown, few quartz (up to 1 cm), well cemented, sub-rounded, poorly sorted.

CORE LOSS

SANDSTONE: Red brown, fine to coarse grained, quartz and grey to light brown clasts of indurated sandstone, very well cemented sub-rounded and poorly sorted. Some veins of calcite and some voids.

DRAWN BY **RM**	DATE **23/07/09**	CHECKED BY **DL**	APPENDIX

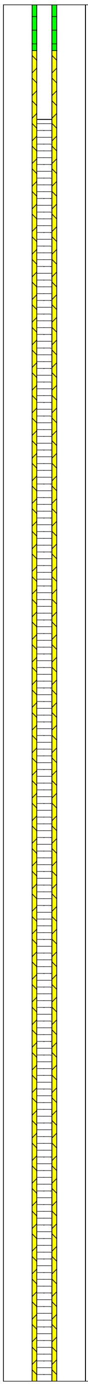
BORE COMPLETION REPORT

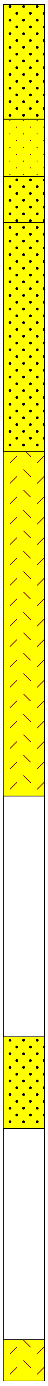
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E029G-S**
DESCRIPTION	**Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**6 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**6 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E029**	EASTING	**0290736 mE**
START DATE	**28/6/09**	NORTHING	**7597189 mN**
COMPLETION DATE	**4/7/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**AB**		
SWL	**TBA**		





BORE CONSTRUCTION	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD
Bentonite Seal (0 - 0.2 m) 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.2 - 0.5 m)	0	CORE LOSS		
		SAND: Red, siliceous, fine grained and well sorted.		
		SILTY SAND : Red brown, fine and well worted, soft core, minor organics.		
	1	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.		
9.5 - 13.0 mm Graded Gravel Pack (0.2 - 6 m)	2	SAND: Red brown, fine, rounded, well sorted, very soft core, minor clay and minor organics.		
		CLAYEY SAND : Red brown, fine grained, rounded and well sorted, soft core, poorly consolidated.		
	3			
		CORE LOSS		
75 mm OD, 65 mm ID Slotted PN18 PVC casing (0.5 - 6 m)	4			
		SAND: Red brown, rounded to sub-rounded, fine, well sorted, becoming more consolidated, minor clay with gravel of fine quartz sand.		
	5	CORE LOSS		
EOH (6 m)		CLAYEY SAND : Sandstone clasts, red brown to light brown, fine grained, well sorted, subangular, within a sandy and clayey sand matrix, indurated shells in clast.		
	6			

DRAWN BY **RM** DATE **23/07/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

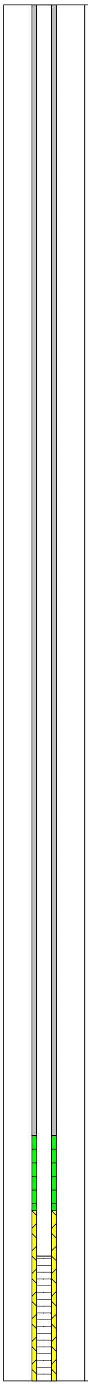
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E030G-D**
DESCRIPTION	**Deep Groundwater Monitoring Bore**

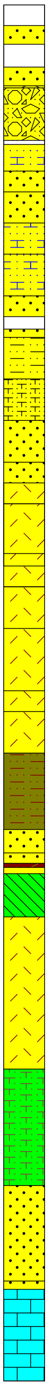
DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**33.1 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**33.1 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E030**	EASTING	**0292209 mE**
START DATE	**12/7/09**	NORTHING	**7596336 mN**
COMPLETION DATE	**14/7/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**ER/BP**		
SWL	**TBA**		

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD



Bore construction:
- Backfill (0 - 27.2 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.2 - 30.1 m)
- Bentonite Seal (27.2 - 29 m)
- 9.5 - 13.0 mm Graded Gravel Pack (29 - 33.1 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (30.1 - 33.1 m)
- EOH (33.1 m)



Depth (m): 0 to 33

Description:
- CORE LOSS
- SAND: Red brown, well sorted, fine grained with cemented pebbles.
- CORE LOSS: Red brown, gravelly sand.
- SAND: Red brown with some gravel (approximately 20%).
- GRAVEL: Gravel lense of approximately 5 cm.
- GRAVEL: Gravel (approximately 10 cm) and clayey sand, red brown, well sorted, rounded, not consolidated sand, band of cemented sand between 2.80 - 2.87 m.
- CORE LOSS
- CALCAREOUS SANDSTONE: Red brown, consolidated, fine grained, well sorted.
- SAND: Very consolidated, cemented sand, hard, pale brown, well rounded.
- SAND: Very well cemented, numerous voids.
- CALCAREOUS SANDSTONE: Well consolidated, pale brown, well sorted, fine grained.
- CALCAREOUS SANDSTONE: Well consolidated, calcareous sandstone, well sorted, pale brown.
- SAND: Unconsolidated, numerous shell fragments.
- CORE LOSS
- SAND: Unconsolidated, numerous shell fragments, clayey.
- SANDY CLAY: Unconsolidated sand, increasing in abundance of clay downhole, shell fragments, red brown with mineralised vein of carbonate (10 cm).
- SILTY SAND: Consolidated, cemented, red brown, calcareous sandstone, with numerous shell fragments in different layers.
- SAND: Red brown, some sandstone clasts and clay, well sorted, fine grained, not consolidated.
- SAND: Red brown, unconsolidated, well sorted, fine grained.
- CLAYEY SAND : Pale brown, fine grained, well sorted.
- CLAYEY SAND : Red brown, well sorted, homogenous.
- CLAYEY SAND : Well sorted, pale red brown, fine grained, well sorted, not lithified.
- CLAYEY SAND : Pale brown, fine grained, well sorted, unconsolidated.
- CLAYEY SAND : Brown, well sorted.
- CLAYEY SAND : Homogenous, fine grained.
- CLAYEY SAND : Pale brown, unconsolidated, homogenous, not lithified.
- CLAY/CLAYSTONE: Red brown, stiff, approximately 80/50 clay/sand. Black mottling present.
- SAND: Brown red sand, unlithified but cemented, fine to medium grained, siliceous, round to sub-rounded grains. Moderately sorted.
- SAND: Brown red sand, unlithified but cemented, fine to medium grained, siliceous, round to sub-rounded grains. Approximately 90% sand, 10% gravel, minor polymictic gravel (quartz, doelrite, BIF). Gravel is angular. Moderately to poorly sorted.
- PALEOCHANNEL DEPOSIT: Brown red sand, unlithified but cemented, fine to medium grained, siliceous, round to sub-rounded grains. Approximately 50% sand, 50% gravel, poorly sorted, minor polymictic gravel (quartz, dolerite, BIF).
- SANDY CLAY: Red brown, fine grained, moderate to well sorted, siliceous.
- CLAY: Red brown, well cemented, white staining, stiff with black mottling.
- CLAYEY SAND : Red brown, siliceous, fine grained sand with stiff clay, approximately 50% sand, 50% clay, well sorted.
- CLAYSTONE: Massive red brown grey clay. Grey mottling increases downhole. Very well cemented.
- SAND: Brown-red-yellow-grey, fine to medium grained, siliceous, well sorted, moderately cemented sand with minor grey-white mottling.
- SAND: Brown-red-yellow-grey, fine to medium grained, siliceous, well sorted, moderately cemented sand with minor grey-white mottling, large fractures (, 10 mm wide) filled with clear, coarse gypsum crystals.
- LIMESTONE: White-yellow-cream-brown trealla limestone, fine to medium grained, carbonaceous/siliceous sandstone, moderate to poorly sorted, rounded grains, moderately to well lithified.

DRAWN BY	DATE	CHECKED BY	APPENDIX
RM	**23/07/09**	**DL**	

URS

BORE COMPLETION REPORT

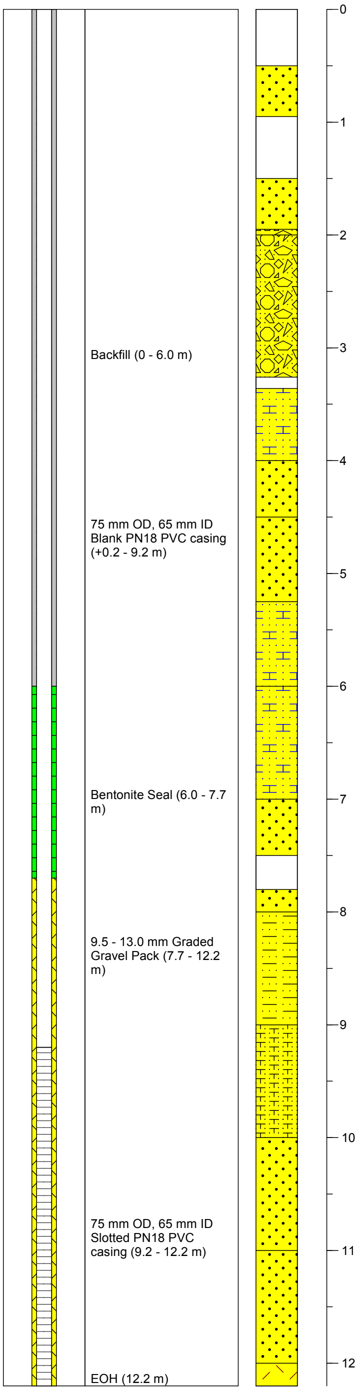
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E030G-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	**12.2 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E030**	EASTING	**0292210 mE**
START DATE	**14/7/09**	NORTHING	**7596337 mN**
COMPLETION DATE	**14/7/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**ER**		
SWL	**TBA**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	FIELD EC	AIRLIFT YIELD
CORE LOSS		
SAND: Red brown, well sorted, fine grained with cemented pebbles.		
CORE LOSS		
SAND: Red brown with some gravel (approximately 20%).		
GRAVEL: Gravel lense of approximately 5 cm.		
GRAVEL: Gravel (approximately 10 cm) and clayey sand, red brown, well sorted, rounded, not consolidated sand, band of cemented sand between 2.80 - 2.87 m.		
CORE LOSS		
CALCAREOUS SANDSTONE: Red brown, consolidated, fine grained, well sorted.		
SAND: Very consolidated, cemented sand, hard, pale brown, well rounded.		
SAND: Very well cemented, numerous voids.		
CALCAREOUS SANDSTONE: Well consolidated, pale brown, well sorted, fine grained.		
CALCAREOUS SANDSTONE: Well consolidated, calcareous sandstone, well sorted, pale brown.		
SAND: Unconsolidated, numerous shell fragments.		
CORE LOSS		
SAND: Unconsolidated, numerous shell fragments, clayey.		
SANDY CLAY: Unconsolidated sand, increasing in abundance of clay downhole, shell fragments, red brown with mineralised vein of carbonate (10 cm).		
SILTY SAND: Consolidated, cemented, red brown, calcareous sandstone, with numerous shell fragments in different layers.		
SAND: Red brown, some sandstone clasts and clay, well sorted, fine grained, not consolidated.		
SAND: Red brown, unconsolidated, well sorted, fine grained.		
CLAYEY SAND : Red brown, well sorted, homogenous.		

DRAWN BY **RM** DATE **23/07/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

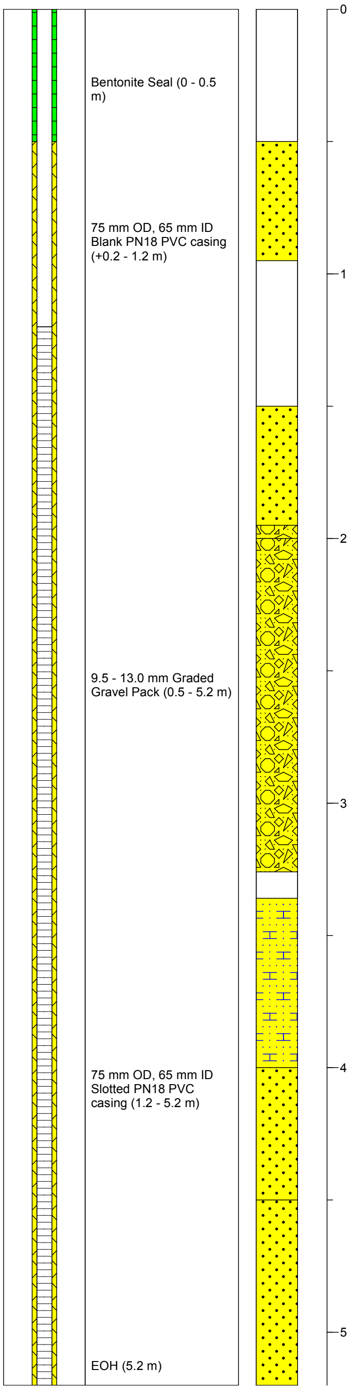
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E030G-S**
DESCRIPTION	**Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**5.2 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**E030**
TOTAL CASED DEPTH	**5.2 m**	START DATE	**14/7/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**14/7/09**
		LOGGED BY	**ER**
		SWL	**TBA**

EASTING	**0292211 mE**
NORTHING	**7596338 mN**
R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD



DESCRIPTION
CORE LOSS
SAND: Red brown, well sorted, fine grained with cemented pebbles.
CORE LOSS: Red brown, gravelly sand.
SAND: Red brown with some gravel (approximately 20%).
GRAVEL: Gravel lense of approximately 5 cm.
GRAVEL: Gravel (approximately 10 cm) and clayey sand, red brown, well sorted, rounded, not consolidated sand, band of cemented sand between 2.80 - 2.87 m.
CORE LOSS
CALCAREOUS SANDSTONE: Red brown, consolidated, fine grained, well sorted.
SAND: Very consolidated, cemented sand, hard, pale brown, well rounded.
SAND: Very well cemented, numerous voids.

DRAWN BY **RM** DATE **24/07/09** CHECKED BY **DL** APPENDIX

URS BORE COMPLETION REPORT

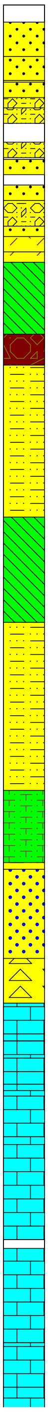
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE E031G-D

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**67.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**67.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E031**	EASTING	**TBC mE**
START DATE	**15/7/09**	NORTHING	**TBC mN**
COMPLETION DATE	**21/7/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**BP**		

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD



Bore construction:
- Backfill (0 - 49.5 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.2 - 55.5 m)

Depth (m): 0 – 41

Description:

- CORE LOSS
- SAND: Loose; red - brown, siliceous, fine - medium grained, predominantly quartz, moderately sorted with some organic material.
- 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.
- SAND: (Push tube); material inferred to be the same as 2.2 m - 2.25 m.
- GRAVEL AND SAND: Gravelly sand
- GRAVEL AND SAND: Gravelly sand; sand is same as 2.2 m - 2.25 m, but with around 30 % white, carbonaceous / calcarenite gravel.
- CORE LOSS
- GRAVEL AND SAND: Material the same as 3 - 3.45 m.
- CORE LOSS
- SAND: Brown, siliceous; fine - medium grained, poorly sorted with shell fragments.
- CORE LOSS
- SAND: Brown; same as 4.5 m - 4.95 m.
- GRAVEL AND SAND: Sandy gravel; brown - white, with around 50 % shell content (< 2 mm). Gravel is calcarenite. Sand is siliceous. Poorly sorted.
- Sand: Brown sand; siliceous, medium grained, moderately sorted. Becoming clayey down - hole.
- CLAYEY SAND : Brown, fir, semi - consolidated.
- CLAYEY SAND : Brown, plastic, semi - consolidated.
- CLAY: Clay; brown, coherent, firm - hard.
- PALEOCHANNEL DEPOSIT: Clayey sand with paleochannel gravel; 90 % red - brown siliceous sand, fine - medium grained. Wells sorted, with around 10 % polymictic gravel (qtz, dolerite) scattered throughout. Moderately sorted.
- SANDY CLAY: Red - brown, coherent, white mottling, hard.
- CLAY: Brown, hard, massive.
- SANDY CLAY: Brown - red, firm - hard, coherent, partially mottled (off - white). < 30 % fine grained siliceous sand.
- CLAYSTONE: Coherent, hard, red - brown, massive clay. Off white mottling throughout.
- SANDY CLAY: Brown, hard, coherent.
- SANDSTONE: Moderately lithified, coherent, light brown - cream. Very well sorted, fine grained, sub - rounded to rounded massive quartz.
- BRECCIA: Sand / limestone breccia. Pebble sized yellow - white clasts of Trealla Limestone (calcareous, friable) (70 %), in a red - brown matrix of siliceous / calcareous sand and silt. Poorly sorted. Deeply weathered, Vuggy.
- LIMESTONE: Trealla limestone; calcirudite - calcilulite, fossiliferous, brecciated, predominantly hard and coherent (around 75 %), but there are some friable areas / sheared zones between 29.3 m - 29.6 m. Breccia fragments are > 10 cm in extent. Matrix is brown sandy silt whereas the limestone is white. Vuggy. Minor fractures are infilled by gypsum crystals.
- LIMESTONE: Trealla limestone; massive, white - cream -brown, weakly weathered with minor calcite veins. Lithified but friable. Fossiliferous. Very fine - grained calcareous (calcirudite - calcilutite), marbled texture. Vuggy.
- LIMESTONE: As above but brecciated.
- LIMESTONE: Trealla limestone; massive, with minor shearing / fracturing. Vuggy.
- LIMESTONE: Trealla limestone; brecciated.
- LIMESTONE: Trealla limestone; massive, coherent.
- LIMESTONE: Trealla limestone; very fractured with soapy shear zones. Small caverns likely. Fractures are infilled with puggy material derived from the surrounding limestone. Vuggy.
- LIMESTONE: Brecciated trealla limestone; As above but with significant amounts of clay infilling the fractures. Gypsum crystals also present around 10 cm wide scattered throughout (10 %). Fossiliferous.
- CORE LOSS
- LIMESTONE: Brecciated Trealla limestone; as above with numerous voids and fractures throughout. Vuggy.
- LIMESTONE: Trealla limestone; partially brecciated (clasts < 20 cm long and wide) but more coherent than above. Still friable in clayey fracture zones. More brown / light brown than above (staining / weathering). Some green grey splotchy clay at 39.5, 40, 40.2. These areas also contain fractures along brecciated borders (40.24). Vuggy.
- LIMESTONE: Trealla limestone; as above but coeherent / massive (non brecciated). Cream - brown. Fossiliferous. Vuggy. Fractured.

Electrical conductivity: 117.3 mS/cm

Airlift yield: 2.0 L/sec

DRAWN BY **BP**	DATE **29/07/09**	CHECKED BY **DL**	APPENDIX

BORE COMPLETION REPORT

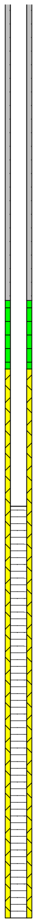
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **E031G-D**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**67.5 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**67.5 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E031**	EASTING	**TBC mE**
START DATE	**15/7/09**	NORTHING	**TBC mN**
COMPLETION DATE	**21/7/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**BP**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD

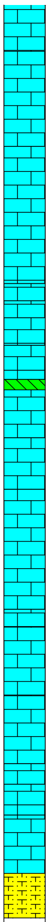


Bentonite Seal (49.5 - 51.5 m)

9.5 - 13.0 mm Graded Gravel Pack (51.5 - 67.5 m)

75 mm OD, 65 mm ID Slotted PN18 PVC casing (55.5 - 67.5 m)

EOH (67.5 m)



Depth (m): 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80

LIMESTONE: Trealla limestone; as above but coherent. this interval is softer / more friable. Grain size is also coarser (25 % medium grained sand). Massive. 20 cm wide cavity at 44.74 - 44.84.

LIMESTONE: Trealla limestone; as above but very hard and vuggy. Weak green chloritic alteration beginning to appear. Alteration is fine grained and pervasive. Planar fractures occur at regular intervals < 20 cm apart. Alteration occurs at fractured or vuggy areas.

LIMESTONE: Trealla limestone; as above but less hard and vuggy. Friable. Pervasive areas (around 15 %) of green - grey chlorite - silica alteration starting to appear.

LIMESTONE: Trealla limestone; grey - green, weakly fractured. Moderate, pervasive clhloritic alteration throughout. Alteration is dark grey (qtz) - green (chlorite) and very fine grained / microgranular. The original rock fabric is still preserved.

LIMESTONE: Trealla limestone; massive, dark - green, coherent but plastic clay. Silty. Some small lenses of limestone remain (around 10 %).

LIMESTONE: Trealla limestone; green - grey - yellow, moderate to strongly pervasive silica - sericite - kaolinite alteration. The rockmass is still hard but weakly fractured and brecciated. Marble like texture.

LIMESTONE: Trealla limestone; as above, but brecciated and with less chlorite. Rockmass is moderately altered by sericite - quartz.

LIMESTONE: Trealla limestone; cream - yellow - white, brecciated with weak - moderate qtz - sericite - chlorite alteration.

LIMESTONE: Trealla limestone; massive, hard, very fine grained, grey - green. Moderate pervasive chlorite alteration.

CLAY: Trealla limstone; lens of massive chlorritic clay. Dark green, coherent but friable.

LIMESTONE: Trealla limstone / Clay; massive, reasonably hard limestone. Strong and pervasive chorite - quartz alteration. Around 20 % clay (chloritic). Dark green - grey - cream. Disseminated fine - medium grained pyrite (10 % of rockmass) occurs along fractures.

LIMESTONE: Trealla limestone; yellow - cream - green. Coherent. Patchy but pervasive chlorite - sericite alteration. Silica flooding.

LIMESTONE: Trealla limestone; as above but cream - yellow. Slightly oxidised. Less chloritic alteration than above. Strongly pervasive kaolinite alteration is dominant. Minor clay occurs at weathered sites. Patchy texture in a coherent but friable rockmass.

LIMESTONE: Trealla Limstone / Clay; Strongly altered. The rock fabric is 100 % destroyed / replaced by chlorite alteration. Brown - green, stiff but fraiable lenses of clay occur at patchy sites of weakness.

LIMESTONE: Trealla limestone; altered, patchy but very strong and completely pervasive chlorite - quartz alteration. Rockmass still contains evidence of the original Trealla fabric. Rockmass is coherent but there are numerous zones of patchy chloritic clay throughout. Grain size is is still very fine.

LIMESTONE: Trealla limestone; altered, as above but with a higher percentage of quartz alteration. Very hard. Grey - dull green. Fractures occur at 61.9 and 62.5. Minor vuggs throughout.

LIMESTONE: Trealla limestone; altered, massive, very fine grained. Strong - pervasive silica - sericite - chlorite alteration throughout. Cream - yellow. Very hard.

LIMESTONE: Trealla limestone; altered, as above but green - cream. Dominantly chlorite alteration.

LIMESTONE: Trealla limestone; altered and brecciated. Clasts of strongly chlorite - sericite - quartz altered limestone are surrounded by infilling chlorite - calcite veins. Vuggy. Cream - yellow. Coherent and hard.

LIMESTONE: Trealla limestone; altered, as above but not as brecciated. Farctures at 65.3 m, 65.5 m and 65.73 m.

SILTY SAND: Sharp contact / unconformity into very well sorted, mature quartz grains. Green - grey. Massive and unlithified, loose silt and sand. Weak chlorite alteration observed.

DRAWN BY **BP** DATE **29/07/09** CHECKED BY **DL** APPENDIX

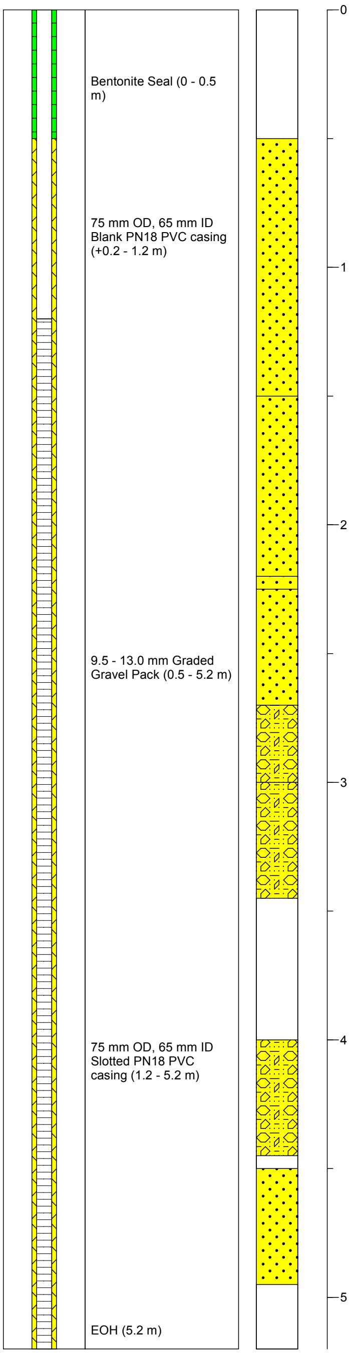
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E031G-S**
DESCRIPTION	**Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**		
TOTAL DRILLED DEPTH	**5.2 m**	CLIENT	**Chevron Australia Pty Ltd**		
HOLE DIAMETER	**122 mm**	LOCATION	**E031**	EASTING	**TBC mE**
TOTAL CASED DEPTH	**5.2 m**	START DATE	**21/7/09**	NORTHING	**TBC mN**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**21/7/09**	R.L. OF COLLAR	**TBA**
		LOGGED BY	**BP**		
		SWL	**2.06 m bgl**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FIELD EC | AIRLIFT YIELD



DESCRIPTION	FIELD EC	AIRLIFT YIELD
CORE LOSS		
SAND: Loose; red - brown, siliceous, fine - medium grained, predominantly quartz, moderately sorted with some organic material.		
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.		
SAND: (Push tube); material inferred to be the same as 2.2 m - 2.25 m.	44.8 mS/cm	0.1 L/sec
GRAVEL AND SAND: Gravelly sand		
GRAVEL AND SAND: Gravelly sand; sand is same as 2.2 m - 2.25 m, but with around 30 % white, carbonaceous / calcarenite gravel.		
CORE LOSS		
GRAVEL AND SAND: Gravelly sand; sand is same as 2.2 m - 2.25 m, but with around 30 % white, carbonaceous / calcarenite gravel.		
CORE LOSS		
SAND: Brown, siliceous ; fine - medium grained, poorly sorted with shell fragments.		
CORE LOSS		

DRAWN BY **RM** DATE **29/07/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

URS Australia Pty Ltd
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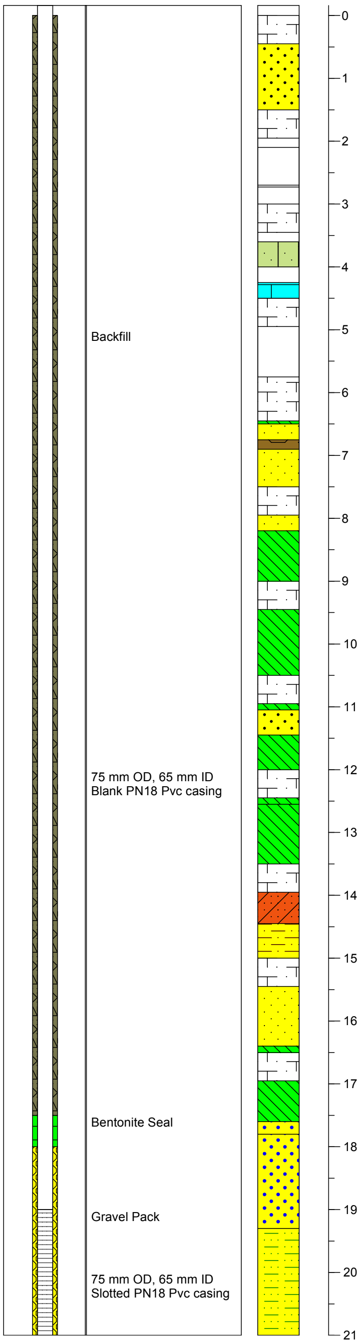
Fax: (08) 9326 0296

BOREHOLE E032FG-D

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**21 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**EO32**
TOTAL CASED DEPTH	**21 m**	START DATE	**7/5/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**9/5/09**
		LOGGED BY	**CO**
		EASTING	**294583**
		NORTHING	**7600425**
		R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FORMATION | EC PROFILE | HYDRO DATA



DESCRIPTION
SPT
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.
SPT: Sand as above
CORE LOSS
Sand - dark brown. Same as 1.05 - 1.45 m.
CORE LOSS
Sand - dark brown, same as 1.05 - 1.5, just more silt (4 %)
SPT: Same as 2.73 - 3.0
CORE LOSS
SILTY SAND : Silty Sand - dark brown. Fine sand with around 10 % silt. Minor organic content. sand is subrounded, well sorted, quartz major with Ironstone, poorly consolidated. Includes a few sandstone clasts that are well cemented quartz sand, fine grained, sub - rounded, clasts are sub angular
CORE LOSS
Oolitic Limestone: Pale yellow tan. Calcareous. 80 % ooids cemented with calcrete. Vuggy, weathered, very broken shells present (5 - 15 mm). Sand from above fills vugs and broken areas.
SPT
CORE LOSS
SPT
Clay: Brown, around 40 % fine, sub rounded, well sorted, quartz sand in a mid plasticity clay, firm.
SANDY CLAY: Red - brown, around 40 % fine, sub - rounded, well sorted quartz sand, in a mid plasticity clay, firm. Large amount of sandstone clasts. These are fine to coarse, quartz sands, poorly sorted, well cemented with calcite. Clasts are sub angular, have vuggy texture.
GRAVELLY CLAY: sandy, red - brown, fine, sub - rounded, well sorted, quartz sand, in a mid plasticity clay, with sandstone gravel, upper 5cmis 15 - 20 mm diameter sub rounded to sub angular (small paleochannel)
SANDY CLAY: Red - brown, same as 6.5 - 6.75 m
SPT
SANDY CLAY: Red - brown, same as 6.5 - 6.75
Clay: Red - brown, mod plasticity, firm, minor fine sub rounded quartz sand. very minor sandstone clasts, which are orthogenic sandstone, angular, well cemented, quartz sand. Vuggy texture.
SPT
Clay: Same as 8.2- 9.0, clay - red - brown - no clasts - firm. Clayey sandy - red brown layers, fine to medium sand, sub angular, mod sorted, mod consolidated. layers at 9.55 (1 cm thick), 9.73 (4 cm) & 9.85 (1 cm).
SPT
Clay: Clay - red brown, high plasticity, firm, minor fine sub rounded quartz sand. Vuggy texture.
Sand: Sand; red - brown, very fine to med grained sand, sub rounded to rounded, poorly sorted, quartz major, moedrately consolidated.
Clay: Red - brown, same as 10.95 - 11.05
SPT
Clay: Red - brown, same as 10.95 to 11.05
Clay: Red - brown, high plasticity, firm, minor fine sub - rounded quartz sand, vuggy texture, contains 10 % sandstone clasts, 5 - 15 mm diameter made up of fine to medium sub angular quartz and Ironstone. calcite cement. Sandstone clasts becoming less frequent from 13.1 m. Grey mottling present from 13.2 m.
SPT
SILTY CLAY: Red - brown, mod plasticity, firm clay, minor silt, with minor very very fine quartz sand. Lighter patches appear to be calcareous. Sandstone clasts becoming less frequent than above SPT and much smaller (3 - 8 mm)
Silt: Red - brown; firm, with very minor, very fine quartz sand, this is sub rounded. Sandstone clasts becoming rare, still 3 - 8 mm, sub angular.
SPT
SANDY CLAY: Low permeability, very stiff clay with fine grained, sub rounded quartz sand. Several siltstone bands, well cemented, vuggy, contain minor fine sub - rounded quartz grains.
Clay: Red - brown. same as 16.4 - 16.6
SPT
Clay: Red - brown. same as 16.4 - 16.5
Sandstone: Brown - yellow; calcareous, fine grained, sub rounded, quartz sand, well cemented, very vuggy (up to 30 mm). Vugs filled with clay from above, well connected.
Sandstone: Yellow - brown; Same as above, but much more solid, vugs only small (up to 10 mm) and poorly connected. Shell rich @ 18.1, clasts of siltstone (5 - 35 mm), large vugs from 18.6, these are filled witha light grey calcareous silt.
Clayey Sand: Red brown; 80 % fine grained, sub rounded, mod sorted, quartz sand major, minor ironstone, 20 % mod plasticity clay. mod consolidated core. Clasts of sandstone (20 - 50 m)

DRAWN BY **BP** DATE **12/06/09** CHECKED BY **DL** FIGURE **TBA**

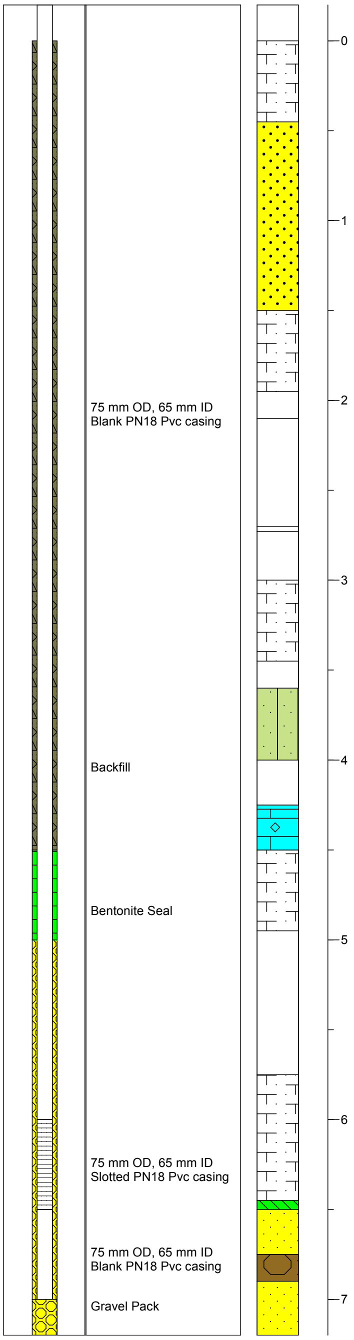
URS BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE E032FG-I

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**7.2**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**EO32**
TOTAL CASED DEPTH	**7 m**	START DATE	**9/5/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**10/5/09**
		LOGGED BY	**CO**
		EASTING	**294583**
		NORTHING	**7600422**
		R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FORMATION | EC PROFILE | HYDRO DATA



DESCRIPTION

- SPT
- 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.
- SPT: Sand as above
- CORE LOSS
- Sand - dark brown. Same as 1.05 - 1.45 m.
- CORE LOSS
- Sand - dark brown, same as 1.05 - 1.5, just more silt (4 %)
- SPT: Same as 2.73 - 3.0
- CORE LOSS
- SILTY SAND : Silty Sand - dark brown. Fine sand with around 10 % silt. Minor organic content. sand is subrounded, well sorted, quartz major with Ironstone, poorly consolidated. Includes a few sandstone clasts that are well cemented quartz sand, fine grained, sub - rounded, clasts are sub angular
- CORE LOSS
- Oolitic Limestone: Pale yellow tan. Calcareous. 80 % ooids cemented with calcrete. Vuggy, weathered, very broken shells present (5 - 15 mm). Sand from above fills vugs and broken areas.
- SPT
- CORE LOSS
- SPT
- Clay: Brown, around 40 % fine, sub rounded, well sorted, quartz sand in a mid plasticity clay, firm.
- SANDY CLAY: Red - brown, around 40 % fine, sub - rounded, well sorted quartz sand, in a mid plasticity clay, firm. Large amount of sandstone clasts. These are fine to coarse, quartz sands, poorly sorted, well cemented with calcite. Clasts are sub angular, have vuggy texture.
- GRAVELLY CLAY: sandy, red - brown, fine, sub - rounded, well sorted, quartz sand, in a mid plasticity clay, with sandstone gravel, upper 5cmis 15 - 20 mm diameter sub rounded to sub angular (small paleochannel)
- SANDY CLAY: Red - brown, same as 6.5 - 6.75 m

DRAWN BY **BP** DATE **13/06/09** CHECKED BY **DL** FIGURE **TBA**

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 **E032FG-S**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**4**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**EO32**
TOTAL CASED DEPTH	**4 m**	START DATE	**11/5/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**11/5/09**
		LOGGED BY	**CO**
		EASTING	**294583**
		NORTHING	**7600420**
		R.L. OF COLLAR	**TBA**

BORE CONSTRUCTION	DEPTH (m)	DESCRIPTION
75 mm OD, 65 mm ID Blank PN18 Pvc casing	0	SPT
Backfill		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.
Bentonite Seal	1	
Gravel Pack		SPT: Sand as above
	2	CORE LOSS
		Sand - dark brown. Same as 1.05 - 1.45 m.
		CORE LOSS
		Sand - dark brown, same as 1.05 - 1.5, just more silt (4 %)
75 mm OD, 65 mm ID Slotted PN18 Pvc casing	3	SPT: Same as 2.73 - 3.0
		CORE LOSS
		SILTY SAND : Silty Sand - dark brown. Fine sand with around 10 % silt. Minor organic content. sand is subrounded, well sorted, quartz major with Ironstone, poorly consolidated. Includes a few sandstone clasts that are well cemented quartz sand, fine grained, sub - rounded, clasts are sub angular
	4	

LITHOLOGY | FORMATION | EC PROFILE | HYDRO DATA

DRAWN BY **BP** DATE **13/06/09** CHECKED BY **DL** FIGURE **TBA**

URS

BORE COMPLETION REPORT

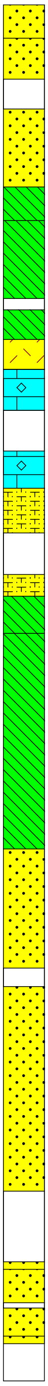
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E033FG-I**
DESCRIPTION	**Intermediate Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**18 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	**E033**	EASTING	**0293170 mE**
START DATE	**21/5/09**	NORTHING	**7600361 mN**
COMPLETION DATE	**22/5/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CO/CW**		
SWL	**1.81 m bgl**		

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FIELD EC	AIRLIFT YIELD



BORE CONSTRUCTION:

- Backfill (0 - 8.6 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.72 - 14 m)
- Bentonite Seal (8.6 - 10.5 m)
- 9.5 - 13.0 mm Graded Gravel Pack (10.5 - 18 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (11 - 14 m)
- EOH (18 m)

DEPTH (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18

DESCRIPTION:

- SAND: Red brown, fine grained, subrounded-subangular, well sorted, loose, quartz major with ironstone.
- SAND: Red brown, , fine grained, subrounded-subangular, well sorted, loose, quartz sand, quartz major with moderate organic content.
- CORE LOSS
- SAND: Red brown, fine grained, sub rounded-subangular, well sorted, loose (slightly more consolidated than above), quartz sand, minor organic content, minor shell content.
- CLAY: Dark grey, soft, sticky clay, high plasticity, very high organic content.
- CLAY: Dark grey, moderately stiff, high plasticity, very high organic content.
- CORE LOSS
- CLAY: Dark grey, As 2.9- 3.5 m, becoming slightly sandy towards base.
- CLAYEY SAND : Dark grey, fine grained, subrounded, well sorted, quartz sand with minor clay, minor organics, poorly consolidated.
- OOLITIC LIMESTONE: Yellow tan, moderately hard, well cemented ooids, vuggy texture infilled with brown clay, moderate shell content.
- CORE LOSS
- OOLITIC LIMESTONE: Yellow tan, moderately hard, well cemented ooids, vuggy texture infilled with brown clay, moderate shell content.
- SILTY SAND: Brown, fine grained, subrounded, well sorted, quartz sand with minor silt, minor shell fragments, poor to moderately consolidated, sandstone, nodule (3- 6 mm), well cemented.
- CORE LOSS
- SILTY SAND: Brown, fine grained, subrounded, well sorted, quartz sand with minor silt, minor shell fragments, poor to moderately consolidated, sandstone, nodule (3- 6 mm), well cemented.
- CLAY: Brown, stiff, low to moderate plasticity, clay with minor sand (may be contamination from uphole).
- CLAY: Red brown, stiff, high plasticity, minor cemented nodules, mudstone, weakly cemented.
- SAND: Red brown, fine to medium grained, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated.
- CORE LOSS
- SAND: Red brown, fine to medium grained, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated.
- CORE LOSS
- SAND: Red brown, fine to medium grained, slight clay content, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated.
- SAND: Red brown, fine to medium grained, slight clay content, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated, poorly consolidated.
- CORE LOSS
- SAND: Red brown, fine to medium grained, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated.
- SAND: Red brown, clayey, consolidated with fine layers of quartzite (fine grey sand), some with rounded components of quartz (up to 3 cm).

FIELD EC: 92 mS/cm

AIRLIFT YIELD: 2 L/sec

DRAWN BY **RM**	DATE **24/07/09**	CHECKED BY **DL**	APPENDIX

URS BORE COMPLETION REPORT

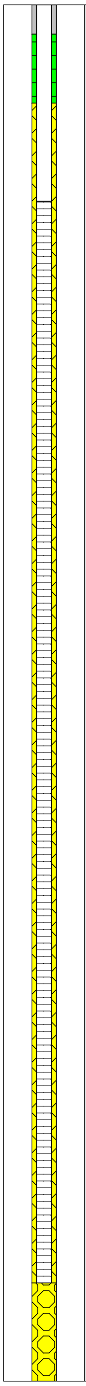
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E033FG-S**
DESCRIPTION	**Shallow Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**7 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**6.5 m**
CASING DIAMETER	**65 mm ID**

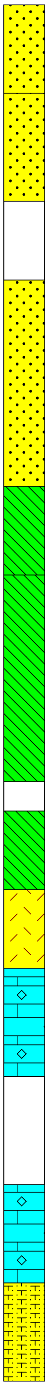
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E033**	EASTING	**0293169 mE**
START DATE	**17/5/09**	NORTHING	**7600359 mN**
COMPLETION DATE	**21/5/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CW**		
SWL	**1.96 m bgl**		

BORE CONSTRUCTION



- Backfill (0 - 0.15 m)
- Bentonite Seal (0.15 - 0.5 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.79 - 1 m)
- 9.5 - 13.0 mm Graded Gravel Pack (0.5 - 7 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (1 - 6.5 m)
- EOH (7 m)

LITHOLOGY



DEPTH (m): 0 – 7

DESCRIPTION
SAND: Red brown, fine grained, subrounded-subangular, well sorted, loose, quartz major with ironstone.
SAND: Red brown, , fine grained, subrounded-subangular, well sorted, loose, quartz sand, quartz major with moderate organic content.
CORE LOSS
SAND: Red brown, fine grained, sub rounded-subangular, well sorted, loose (slightly more consolidated than above), quartz sand, minor organic content, minor shell content.
CLAY: Dark grey, soft, sticky clay, high plasticity, very high organic content.
CLAY: Dark grey, moderately stiff, high plasticity, very high organic content.
CORE LOSS
CLAY: Dark grey, As 2.9- 3.5 m, becoming slightly sandy towards base.
CLAYEY SAND : Dark grey, fine grained, subrounded, well sorted, quartz sand with minor clay, minor organics, poorly consolidated.
OOLITIC LIMESTONE: Yellow tan, moderately hard, well cemented ooids, vuggy texture infilled with brown clay, moderate shell content.
CORE LOSS
OOLITIC LIMESTONE: Yellow tan, moderately hard, well cemented ooids, vuggy texture infilled with brown clay, moderate shell content.
SILTY SAND: Brown, fine grained, subrounded, well sorted, quartz sand with minor silt, minor shell fragments, poor to moderately consolidated, sandstone, nodule (3- 6 mm), well cemented.

FIELD EC	AIRLIFT YIELD
13.6 mS/cm	0.2 L/sec

DRAWN BY **RM** DATE **24/07/09** CHECKED BY **DL** APPENDIX

URS BORE COMPLETION REPORT

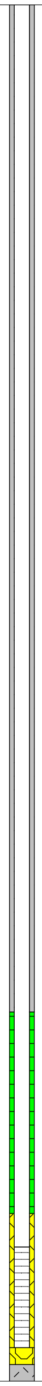
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE	**E033FG-D**
DESCRIPTION	**Deep Groundwater Monitoring Bore**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ diamond**
TOTAL DRILLED DEPTH	**41 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**40 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**E033**	EASTING	**0293172 mE**
START DATE	**17/5/09**	NORTHING	**7600363 mN**
COMPLETION DATE	**21/5/09**	R.L. OF COLLAR	**TBA**
LOGGED BY	**CO/CW**		
SWL	**1.95 m bgl**		

BORE CONSTRUCTION | **LITHOLOGY** | **DEPTH (m)** | **DESCRIPTION** | **FIELD EC** | **AIRLIFT YIELD**



Backfill (0 - 30 m)

75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.78 - 37 m)

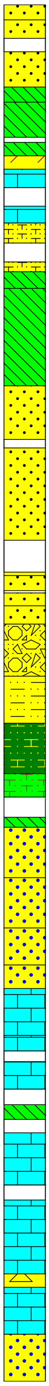
75 mm OD, 65 mm ID Slotted PN18 PVC casing (37 - 40 m)

Bentonite Seal (30 - 36 m)

9.5 - 13.0 mm Graded Gravel Pack (36 - 40.5 m)

Collapse (40.5 - 41 m)

EOH (41 m)



Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41

DESCRIPTION:

- SAND: Red brown, fine grained, subrounded-subangular, well sorted, loose, quartz major with ironstone.
- SAND: Red brown, , fine grained, subrounded-subangular, well sorted, loose, quartz sand, quartz major with moderate organic content.
- CORE LOSS
- SAND: Red brown, fine grained, sub rounded-subangular, well sorted, loose (slightly more consolidated than above), quartz sand, minor organic content, minor shell content.
- CLAY: Dark grey, soft, sticky clay, high plasticity, very high organic content.
- CLAY: Dark grey, moderately stiff, high plasticity, very high organic content.
- CORE LOSS
- CLAY: Dark grey, As 2.9- 3.5 m, becoming slightly sandy towards base.
- CLAYEY SAND : Dark grey, fine grained, subrounded, well sorted, quartz sand with minor clay, minor organics, poorly consolidated.
- OOLITIC LIMESTONE: Yellow tan, moderately hard, well cemented ooids, vuggy texture infilled with brown clay, moderate shell content.
- CORE LOSS
- OOLITIC LIMESTONE: Yellow tan, moderately hard, well cemented ooids, vuggy texture infilled with brown clay, moderate shell content.
- SILTY SAND: Brown, fine grained, subrounded, well sorted, quartz sand with minor silt, minor shell fragments, poor to moderately consolidated, sandstone, nodule (3- 6 mm), well cemented.
- CORE LOSS
- SILTY SAND: Brown, fine grained, subrounded, well sorted, quartz sand with minor silt, minor shell fragments, poor to moderately consolidated, sandstone, nodule (3- 6 mm), well cemented.
- CLAY: Brown, stiff, low to moderate plasticity, clay with minor sand (may be contamination from uphole).
- CLAY: Red brown, stiff, high plasticity, minor cemented nodules, mudstone, weakly cemented.
- SAND: Red brown, fine to medium grained, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated.
- CORE LOSS
- SAND: Red brown, fine to medium grained, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated.
- CORE LOSS
- SAND: Red brown, fine to medium grained, slight clay content, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated.
- SAND: Red brown, fine to medium grained, slight clay content, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated, poorly consolidated.
- CORE LOSS
- SAND: Red brown, fine to medium grained, subrounded, to subangular, moderately sorted, quartz major with BIF, Feldsper and Ironstone mica, poorly consolidated.
- SAND: Red brown, clayey, consolidated with fine layers of quartzite (fine grey sand), some with rounded components of quartz (up to 3 cm).
- GRAVEL: Gravel in a sandy silty matrix, matrix reducing downhole (from 15% to 5%), components well rounded, quartz up to 3 - 5 cm, angular to subangular BIF and claystone (2 - 3 cm), very compacted.
- SILTSTONE: Red brown, very consolidated, silty sandy with nodules of sandstone (2 - 3 cm) in a clay matrix, hard, compact, fine layers of grey clay (high plasticity).
- CLAY/SILTSTONE: Red brown with grey silt lenses, with calcareous material from 22.4 - 22.6, high consolidated calcarenitic nodules and disappearing downhole.
- CLAYSTONE: Red brown with layers of less consolidated clay.
- CLAY: Red brown with layers of less consolidated clay.
- SANDSTONE: Red brown, highly consolidated sandstone, with grey layers of fine sand, components of quartz (up to 30 mm).
- SANDSTONE: Red brown, highly consolidated sandstone, with increasing grey layers of fine sand, components of quartz (up to 30 mm), fragments of shells and ooids, 3 - 5% porosity in small pores.
- SANDSTONE: Dark red brown with consolidated caverns (2 - 5 cm), filled with calcitic sand, less fragements.
- SANDSTONE: Dark red, calcitic, leyered with some breccia, refilled caverties (approximately 5 cm), increases carbon content at 28.8 - 29 m.
- LIMESTONE: Changes from sandstone to carbonitic breccia in a white to grey silty matrix, cavities filled with calcite and red clay, components of breccia, shell fragments.
- LIMESTONE: White with breccia fragments (less than at 29.3 - 30.7 m), silty clayey matrix.
- CORE LOSS
- LIMESTONE: Hard, massive, white, some voids and caverties, calcified fractures, components of red limestone (less than at 29.3 - 30.7).
- CORE LOSS
- CLAY: Filling of cavity, calcite, silty crushed fragments of white limestone.
- CORE LOSS
- LIMESTONE: White, vuggy, high porosity, cavities at 33.6 m, 33.9 m, 34.4 m, 34.6 m, 34.8 m, infilled with white cream clay.
- CORE LOSS
- LIMESTONE: White with breccia, vuggy, high porosity, cavities at 36.4 m, 36.8 - 37.08 m, 37.32 - 37.58 m, 37.8 - 37.9 m. Fillings of cavities: white clay, broken rock of white clay/limestone.
- BRECCIA: Siltstone matrix with limestone componetns, angular, changing from white to red brown downhole.
- LIMESTONE: Red brown, very compact, 3 - 5% permeability, fracture at 38.3 - 38.4 m and 34.1 - 34.2 m.
- SANDSTONE: Cream brown with shell fragments, very compact, hard dilution, small cavities (2 - 3 cm), clay filled, massive, 3 - 5% permeability.

FIELD EC: 175.5 mS/cm

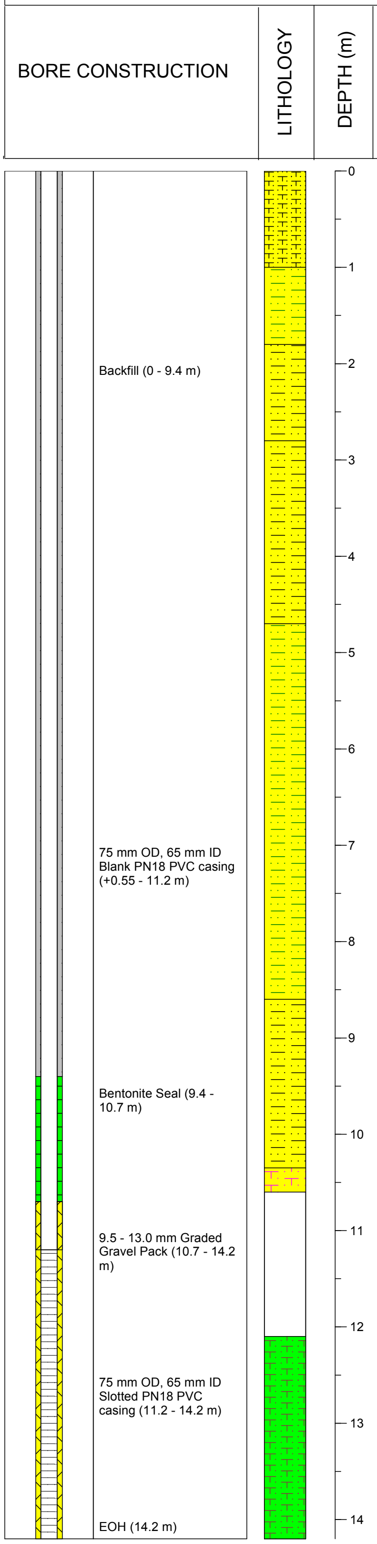
AIRLIFT YIELD: 2 L/sec

DRAWN BY **RM**	DATE **24/07/09**	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	**EO46FG-I**		
DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**PQ Diamond**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**14.2 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**E048**
TOTAL CASED DEPTH	**14.2 m**	START DATE	**14/10/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**17/10/09**
		SWL	**2.98 m btc**
		MEASUREMENT DATE	**29/10/2009**
		EASTING	**293199 mE**
		NORTHING	**7593723 mN**
		R.L. OF COLLAR	**TBA**
		LOGGED BY	**DL**



DEPTH (m)	DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD
0 - 1	SILTY SAND: Fine grained, brown sub angular to sub rounded, medium to well sorted quarts, 5% Feldspar becomes medium grained, poor - moderately sorted, sub angulat to soub rounded quartz, 10%, feldspar at base (coarsening toward base.		
1 - 1.8	CLAYEY SAND: Fine to medium grained quartz, slightly firm, moderately plastic, brown (60% sand/ 60% clay).		
1.8 - 2.8	SANDY CLAY: Fine to medium grained quartz, slightly firm, moderately plastic, brown (40% sand/ 60%clay).		
2.8 - 4.7	SANDY CLAY: Fine to medium grained quartz, slightly firm, moderately plastic, brown (40% sand/ 60%clay) with sandstone gravels, fine to medium grained, coarser and rough/angular, soft, contains fossiled shellfish - bivalves at 3 m.		
4.7 - 8.6	CLAYEY SAND: Red, brown, hard, brittle, low to moderately plastic, orthogenic, calcrete from 5 - 7.3 m, fine grained sand layers.	77.1 mS/com	0.5 L/sec
8.6 - 10.35	SANDY CLAY: Bands of sand throughout (% of sand varies) alternates clay. Sandy silty clays.		
10.35 - 10.6	SANDY SILTY CLAY: Well rounded river style pebbles to cobble size.		
10.6 - 12.1	CORE LOSS		
12.1 - 14.2	CLAYSTONE: Grades to claystone, hardens, less calcrete, silty and slightly sandy in patches, grey patches of weathered calcrete.		

DRAWN BY **CE** DATE **6/11/09** CHECKED BY **DL** APPENDIX

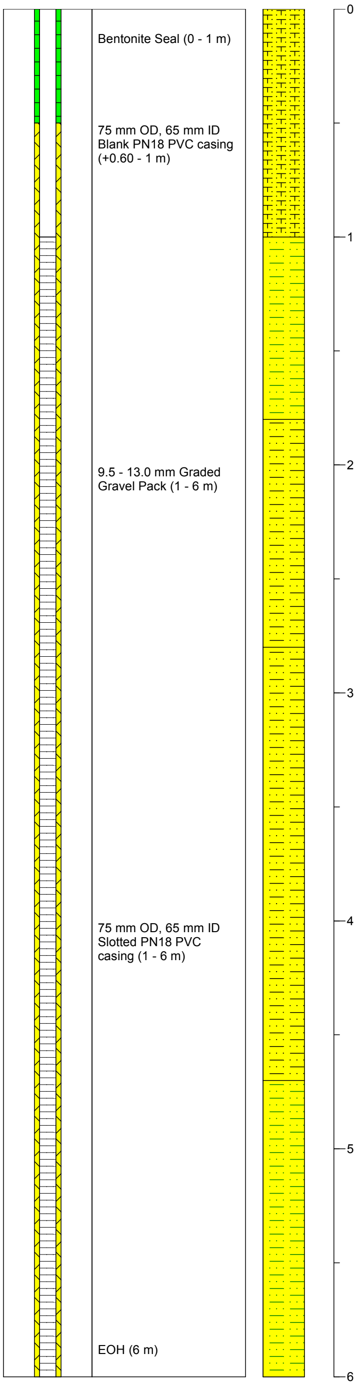
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **EO46FG-S**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
DRILLING METHOD	**PQ Diamond Core**	PROJECT NUMBER	**42907100**		
TOTAL DRILLED DEPTH	**6 m**	CLIENT	**Chevron Australia Pty Ltd**		
HOLE DIAMETER	**122 mm**	LOCATION	**EO46**	EASTING	**293201 mE**
TOTAL CASED DEPTH	**6 m**	START DATE	**17/10/09**	NORTHING	**7593721 mN**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**17/10/09**	R.L. OF COLLAR	**TBA**
		SWL	**2.73 m btc**	LOGGED BY	**D.L**
		MEASUREMENT DATE	**29/10/2009**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD
SILTY SAND: Fine grained, brown sub angular to sub rounded, medium to well sorted quarts, 5% Feldspar becomes medium grained, poor - moderately sorted, sub angulat to soub rounded quartz, 10%, feldspar at base (coarsening toward base		
CLAYEY SAND: Fine to medium grained quartz, slightly firm, moderately plastic, brown (60% sand/ 60%clay)		
SANDY CLAY: Fine to medium grained quartz, slightly firm, moderately plastic, brown (40% sand/ 60%clay)		
SANDY CLAY: Fine to medium grained quartz, slightly firm, moderately plastic, brown (40% sand/ 60%clay) with sandstone gravels, fine to medium grained, coarser and rough/angular, soft, contains fossiled shellfish - bivalves at 3 m	83.5 mS/cm	0.25 L/sec
CLAYEY SAND: Red, brown, hard, brittle, low to moderately plastic, calcrete from 5 - 7.3 m, fine grained sand layers		

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BORE COMPLETION REPORT

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Level 3, 20 Terrace Rd, East Perth WA, 6004
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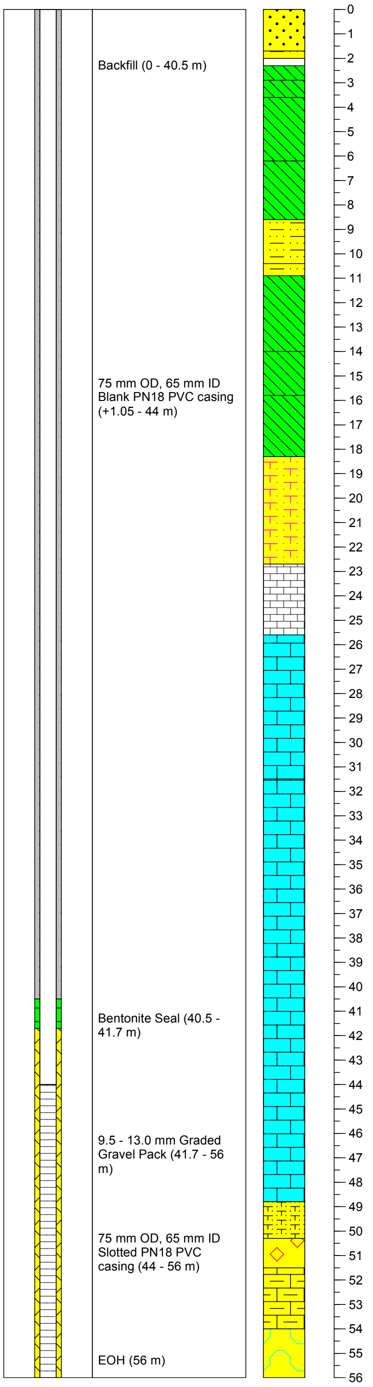
BOREHOLE	**EO47FG-D**
DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ Diamond**
TOTAL DRILLED DEPTH	**56 m**
HOLE DIAMETER	**122 m**
TOTAL CASED DEPTH	**56 m**
CASING DIAMETER	**65 mm ID**
PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
PROJECT NUMBER	**42907100**
CLIENT	**Chevron Australia Pty Ltd**
LOCATION	**EO47**
START DATE	**18/10/09**
COMPLETION DATE	**22/10/09**
SWL	**2.72 m btc**
MEASUREMENT DATE	**29/10/2009**
EASTING	**294211 mE**
NORTHING	**7592307 mN**
R.L. OF COLLAR	**TBA**
LOGGED BY	**B.S**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m)



DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD
SAND: Reddish brown fine to medium grained, moderately sorted, sub angular to sub rounded quartz, 5 % feldspar, very minor dark minerals.		
SANDY CLAY: Red brown, fine grained, firm, brittle.		
CORE LOSS		
CLAY: Slightly silty clay, less sand.		
CLAY: Sub rounded sandstone gravels (3 mm - 10 mm diameter) fine grained.		
CLAY: Brown, mottled, low plasticity, brittle.		
CLAY: Brown, mottled, low plasticity, brittle. Infrequent calcrete clasts.		
SANDY CLAY: Brown, mottled, low plasticity, brittle. Infrequent calcrete clasts. 30 % sand, fine to medium grained, moderate to poorly sorted quartz, less sand but more silt from 9.7 m to 10.4 m.		
SANDY CLAY: Brown, mottled, low plasticity, brittle. Infrequent calcrete clasts. 30 % sand, fine to medium grained, moderate to poorly sorted quartz, with sandstone gravel fragments.		
CLAY: Hard, brittle with weathered grey patches, orange/brown, large calcrete clasts, some sandstone gravel, silty. Highly weathered from 12.2 - 12.6 m.		
CLAY: Smoother, brown, moderately plastic, firm, grey, weathered calcrete large orthoclase (14.4 m - 14.7 m)m		
CLAY: Hard, brittle with weathered grey patches, orange/brown, large calcrete clasts, some sandstone gravel, silty. Highly weathered from 12.2 - 12.6. Broken large. Smoother, brown, moderately plastic, firm, grey, weathered calcrete large orthoclase altenating to smooth brown clay - silty clay with calcrete (weathered) sandstone gravels (weathered).		
SANDY SILTY CLAY: Hard, brittle, proportion of weathered grey clayey calcrete increases at 20.4 m.		
SAPROCK: Clay and yellowish white bands of calcrete, weathered and reddish, hard, silty claystone layers, fractured throughout and conglomerate with clay matrix (contact to weathered transition zone - trealla limestone) becoming fresher at 24 m.	78 mS/cm	0.5 L/sec
LIMESTONE: Fresh, whitish clay yellow calcite, highly fractured throughout, vuggy particulary from 26.5 m and 26.8 - 27 m, large gypsum crystals infrequently large fractures - 27.7 to 27.9, very broken vugs frequently with secondary infill of silty clay, 100 mm spacing on fractures, fractures increasing from 27.9 m greater clay infill, creamy yellow, strong fracturing again from 30.9 - 31.5, broken.		
LIMESTONE: Calcilutite creamy white, clay infill decreased (10 %) fresh, few fractures, hard, few vugs, grades into more days and conglomeritic, 32.8 - 34.4 m secondary infill and silty sandy clay, softer. Minor gypsum crystles at 39.1 - 39.3 m occurs in elongate bands, clay infill at 40.3 40.5 m creamy brown (clay bands occur throughout). Fractures, vugs, decreasing at 43.5 m grades from a moderate sandy calcarenite to a smooth calsilite. Sandy patches occur regularly to 43.5 m and are slightly vuggy with small vugs to 2 mm diameter, calsilite smooth, less vuggy, dark grey shale infill at 45.7 - 46 m, broken fractured at 46 m, grades back to slightly sandy calcarenite with five vugs, yellowish at 46.7 m to 48.8 m.		
SILTY SAND: Yellow gray, hard, brittle, easily broken with finger pressure (sharp contact) well cemented.		
CALCARENITE: Grades back to yellow-white to moderately fractured calcarenite with some secondary clay/silt infill.		
SILTY CLAY: Creamy grey, with conglomerate carbonate transitional same at bottom of trealla limestone, well cemented.		
CLAYEY SILT: Greenish, brittle, hard, easily broken with finger pressure, well cemented bands of sandy clay, fine, yellow, not cemented 56.6 - 56.6 m.		

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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 **EO47FG-I**

DRILLING COMPANY	**Hagstrom Drilling**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**
DRILLING METHOD	**122 mm Blade**	PROJECT NUMBER	**42907100**
TOTAL DRILLED DEPTH	**12 m**	CLIENT	**Chevron Australia Pty Ltd**
HOLE DIAMETER	**122 mm**	LOCATION	**EO47**
TOTAL CASED DEPTH	**13 m**	START DATE	**22/10/09**
CASING DIAMETER	**65 mm ID**	COMPLETION DATE	**22/10/09**
		SWL	**2.1 m btc**
		MEASUREMENT DATE	**29/10/2009**
		EASTING	**294211 mE**
		NORTHING	**7592310 mN**
		R.L. OF COLLAR	**TBA**
		LOGGED BY	**B.S**

BORE CONSTRUCTION	DEPTH (m)	DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD
Backfill (0 - 7.2 m)	0 – 1.7	SAND: Reddish brown fine to medium grained, moderately sorted, sub angular to sub rounded quartz, 5 % feldspar, very minor dark minerals.		
	1.7 – 2.0	SANDY CLAY: Red brown, fine grained, firm, brittle.		
	2.0 – 2.3	CORE LOSS		
	2.3 – 2.9	SANDY CLAY: Slightly silty clay, less sand.		
	2.9 – 3.6	CLAY: Sub rounded sandstone gravels (3 mm - 10 mm diameter) fine grained.		
75 mm OD, 65 mm ID Blank PN18 PVC casing (+0.72 - 9 m)	3.6 – 6.2	CLAY: Brown, mottled, low plasticity, brittle.	126.5 mS/cm	0.25 L/sec
Bentonite Seal (7.2 - 8.4 m)	6.2 – 8.6	CLAY: Brown, mottled, low plasticity, brittle. Infrequent calcrete clasts.		
9.5 - 13.0 mm Graded Gravel Pack (8.1 - 12 m)	8.6 – 10.4	SANDY CLAY: Brown, mottled, low plasticity, brittle. Infrequent calcrete clasts. 30 % sand, fine to medium grained, moderate to poorly sorted quartz, less sand but more silt from 9.7 m to 10.4 m.		
	10.4 – 11.0	SANDY CLAY: Brown, mottled, low plasticity, brittle. Infrequent calcrete clasts. 30 % sand, fine to medium grained, moderate to poorly sorted quartz, with sandstone gravel fragments.		
75 mm OD, 65 mm ID Slotted PN18 PVC casing (9 - 12 m)	11.0 – 13.0	CLAY: Hard, brittle with weathered grey patches, orange/brown, large calcrete clasts, some sandstone gravel, silty. Highly weathered from 12.2 - 12.6 m.		
EOH (13 m)	13			

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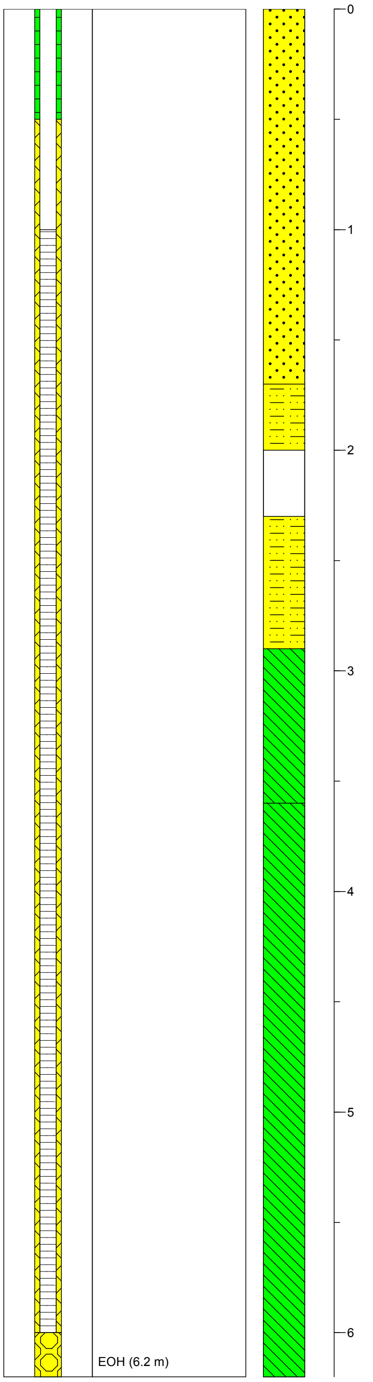
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **EO47FG-S**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**122 mm Blade**
TOTAL DRILLED DEPTH	**6 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**6.2 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**EO47**	EASTING	**294211 mE**
START DATE	**18/10/09**	NORTHING	**7592312 mN**
COMPLETION DATE	**22/10/09**	R.L. OF COLLAR	**TBA**
SWL	**2.29 m btc**	LOGGED BY	**B.S**
MEASUREMENT DATE	**29/10/2009**		



DEPTH (m)	DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD
0–1.7	SAND: Reddish brown fine to medium grained, moderately sorted, sub angular to sub rounded quartz, 5 % feldspar, very minor dark minerals.		
1.7–2.0	SANDY CLAY: Red brown, fine grained, firm, brittle.		
2.0–2.3	CORE LOSS		
2.3–2.9	SANDY CLAY: Slightly silty clay, less sand.		
2.9–3.6	CLAY: Sub rounded sandstone gravels (3 mm - 10 mm diameter) fine grained.		
3.6–6.2	CLAY: Brown, mottled, low plasticity, brittle.	57.9 mS/cm	0.2 L/sec

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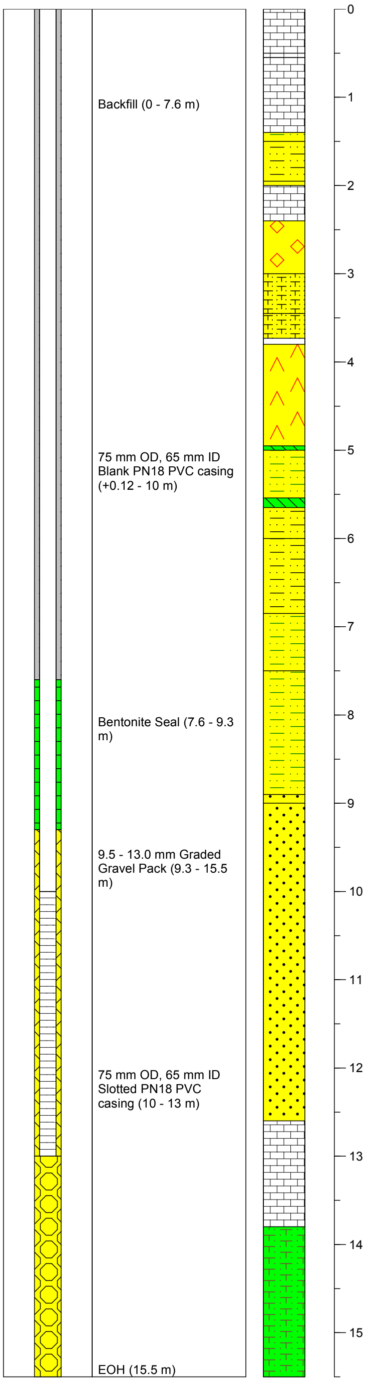
BORE COMPLETION REPORT

URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

DRILLING COMPANY	**Hagstrom Drilling**	BOREHOLE	**EO48FG-I**		
DRILLING METHOD	**122 mm Blade**	PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
TOTAL DRILLED DEPTH	**15.5 m**	PROJECT NUMBER	**42907100**		
HOLE DIAMETER	**12 mm**	CLIENT	**Chevron Australia Pty Ltd**		
TOTAL CASED DEPTH	**13 m**	LOCATION	**EO48**	EASTING	**296274 mE**
CASING DIAMETER	**65 mm ID**	START DATE	**14/10/09**	NORTHING	**7591598 mN**
		COMPLETION DATE	**17/10/09**	R.L. OF COLLAR	**TBA**
		SWL	**2.84 m btc**	LOGGED BY	**B.S**
		MEASUREMENT DATE	**29/10/2009**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD



- SILTY CLAYEY SAND: Gravel, red brown.
- SILTY CLAYEY SAND: Red brown, fine grained, firm, brittle.
- SILTY CLAYEY SAND: Fine to medium, red, brown.
- CLAYEY SAND: Fine to medium, red, brown.
- SANDY CLAY: Calcrete clasts, red brown, high plasticity.
- SANDY CLAY: Brown, mottled, low plasticity, brittle.
- SILTY CLAY GRAVEL: Some sand, gravel is angular to sub rounded, consisting of fine grained calcarenite (shell fragments in fine grained grey matrix) poorly sorted, red to brown.
- CALCARENITE: Secondary clay infill in vugs (shell fragments).
- SILTY SAND: Gravel, fine subrounded, moderately sorted.
- SILTY SAND: Gravel, fine subrounded, moderately sorted.
- CORE LOSS
- CLAYEY SILTY SAND: Gravel, fine, subrounded, moderately sorted.
- CLAY: High plasticity with weathered calcrete, red - brown.
- CLAYEY SAND: Calcrete clasts, weathered, minor sand, red - brown, high plasticity.
- CLAY: Calcrete clasts, weathered, minor sand, red - brown, high plasticty.
- SANDY CLAY: Calcrete clasts, red brown,some minor sand.
- SANDY CLAY: Weathered calcrete clasts, some minor sands, red - brown.
- CLAYEY SAND: Fine grained sand, <5 %, fine, red - brown, wet.
- CLAYEY SAND: Fine to medium grained, <5% fine calcareous sandstone.
- SAND: Medium grained, loose, dark brown/ grey.
- SAND: Medium grained <1% river gravel, loose, brown, wet.
- SANDY GRAVEL: Well rounded, gravels to 40 mm, fine to medium grained sand, well sorted, loose.
- CLAYSTONE: Fine to loose gravel clasts of carbonate red - brown.

ELECTRICAL CONDUCTIVITY: 91.2 mS/cm

AIRLIFT YIELD: 2 L/sec

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URS BORE COMPLETION REPORT

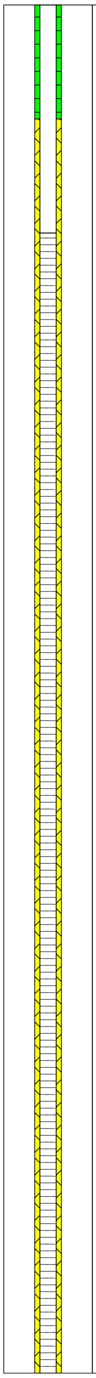
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE: **EO48FG-S**

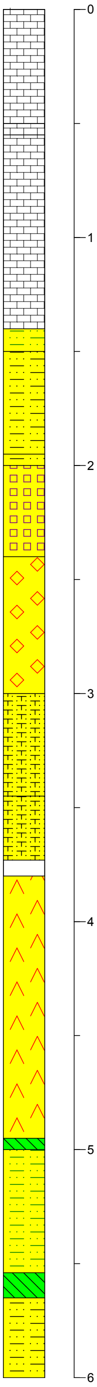
DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**PQ Diamond**
TOTAL DRILLED DEPTH	**6 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**6 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**EO48**	EASTING	**293201 mE**
START DATE	**28/10/09**	NORTHING	**7593721 mN**
COMPLETION DATE	**28/10/09**	R.L. OF COLLAR	**TBA**
SWL	**3.5 m btc**	LOGGED BY	**B.S**
MEASUREMENT DATE	**29/10/2009**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD



Bore construction:
- Bentonite Seal (0 - 0.5 m)
- 75 mm OD, 65 mm ID Blank PN18 PVC casing (+1.05 - 1 m)
- 9.5 - 13.0 mm Graded Gravel Pack (0.5 - 6 m)
- 75 mm OD, 65 mm ID Slotted PN18 PVC casing (1 - 6 m)
- EOH (6 m)



Description (depth 0 – 6 m):
- SILTY CLAYEY SAND: Gravel, red brown.
- SILTY CLAYEY SAND: Red brown, fine grained, firm, brittle.
- SILTY CLAYEY SAND: Fine to medium, red, brown.
- CLAYEY SAND: Fine to medium, red, brown.
- SANDY CLAY: Calcrete clasts, red brown, high plasticity.
- SANDY CLAY: Brown, mottled, low plasticity, brittle.
- SILTY SANDY GRAVEL: Some sand, gravel is angular to sub rounded, consisting of fine grained calcarenite (shell fragments in fine grained grey matrix) poorly sorted, red to brown.
- CALCARENITE: Secondary clay infill in vugs (shell fragments).
- SILTY SAND: Gravel, fine subrounded, moderately sorted.
- SILTY SAND: Gravel, fine subrounded, moderately sorted.
- CORE LOSS
- CLAYEY SILTY SAND: Gravel, fine, subrounded, moderately sorted.
- CLAY: High plasticity with weathered calcrete, red - brown.
- CLAYEY SAND: Calcrete clasts, weathered, minor sand, red - brown, high plasticty.
- CLAY: Calcrete clasts, weathered, minor sand, red - brown, high plasticty.
- SANDY CLAY: Calcrete clasts, red brown,some minor sand.

Electrical conductivity (at ~3 m): 50.7 mS/cm

Airlift yield (at ~3 m): 0.1 L/sec

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URS BORE COMPLETION REPORT

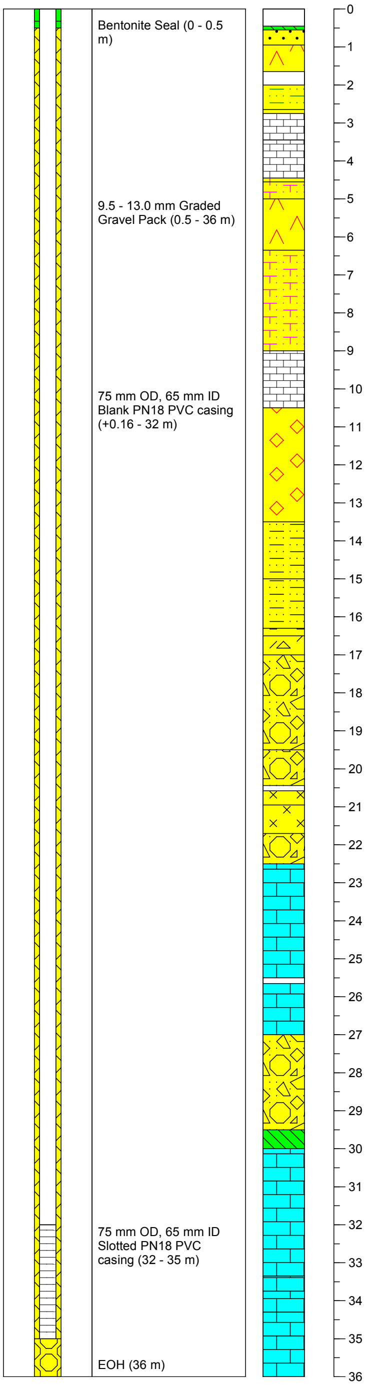
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE EO52FG-D

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**Mud Rotary**
TOTAL DRILLED DEPTH	**35 m**
HOLE DIAMETER	**122 mm**
TOTAL CASED DEPTH	**36 m**
CASING DIAMETER	**65 mm ID**

PROJECT NAME	**Wheatstone Environmental Monitoring Bores**		
PROJECT NUMBER	**42907100**		
CLIENT	**Chevron Australia Pty Ltd**		
LOCATION	**EO52**	EASTING	**300274 mE**
START DATE	**23/10/09**	NORTHING	**7590245 mN**
COMPLETION DATE	**27/10/09**	R.L. OF COLLAR	**TBA**
SWL	**2.12 m btc**	LOGGED BY	**B.S**
MEASUREMENT DATE	**30/10/2009**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD



DESCRIPTION
Silt Sandy Clay: Low plasticity, red - brown.
Clay: High plasticity, light grey, plant roots.
SAND: Silty clay. Compacted, red brown.
CLAYEY SILTY SAND: Fine, red - brown, more compacted and higher clay content, between 1.1 - 1.55. 1.55 - 1.65 is less compacted.
SAMPLE LOSS
CLAYEY SAND: Fine, very soft, red - brown.
CLAYEY SAND: Fine, red - brown with gravel of sandstone (calcareous), subangular, poorly sorted, red - grey.
SILTY CLAYEY SAND: SAMPLE LOSS
SILTY CLAYEY SAND: Fine, compacted, red- brown.
SANDY SILTY CLAY: Fine, red - brown.
SANDY SILTY CLAY: Moderately plastic, red-brown.
CLAYEY SILTY SAND: Fine, compacted, lithified at 5.20 - 5.35, soft to medium sand with fine gravel (subrounded and well sorted), becoming coarse to medium grained sand at 5.85 - 6.35 m.
SANDY SILTY CLAY: calcareous sandstone clasts, compact, fine gravel sub rounded, poorly sorted, parts lithified (6.55- 6.65 and 8.00 - 8.65) some organic material(black patches) slicken sided parts in the clay. The lithified parts are vuggy calcarenite with clay infill.
SILTY CLAYEY SAND: Red brown, mottled light grey with weathered calcarenite medium plasticity with clay infill (9.00 - 9.35, 9.40 - 5.80 and 10.05 - 10.50).
CALCARENITE: Extremely weathered, grey, vuggy with clay infill, homogenous red - brown clay.
SANDY CLAY: Compacted with clasts of weathered calcareinte, partly lithified minor gravel fine, sub rounded, less compact then above, red - brown.
SANDY CLAY: Compacted with clasts of calcarenite, weathered, partly lithified, organic (black patches) red - brown.
GRAVELLY CLAY: Minor sand (fine) gravel: fine to subrounded, well sorted, more compacted towards 16.50, red brown.
GRAVELLY SANDY CLAY: Fine, subrounded, well sorted, organic patches (black) red - brown.
CONGLOMERATE: Weathered with clay infill. Conglomerate made up of fine gravel, subrounded and minor calcarenite (weathered) red brown with grey - green grey weathered calcarenite.
CONGLOMERATE: Weathered, friable and vuggy with clay infill, red- brown, extremely weathered.
SAMPLE LOSS
SILTY CLAYSTONE: Friable, weathered, brown yellow.
SILTY CLAYSTONE: Weathered, dark grey, friable vuggy with red brown clay infill, partly yellow, minor sand in fine fissures, minor gypsum.
CONGLOMERATE: Clasts of limestone (Ø150 mm) white grey in clayey sandy matrix, red - brown fractures (<3 mm wide) filled with gypsum (transition to Trealla).
LIMESTONE: Weathered with clay infill in fractures (several cm to 50 mm) fractures, white, tight grey, open fissures, >1 mm wide, light grey, yellow.
SAMPLE LOSS
LIMESTONE: Weathered, fractures with clay infill, light grey, yellow brown blotches in clay, fractures up to 100 mm, open fissures <1 mm, friable.
CONGLOMERATE: Weathered , clay cream, light grey, fractures of 27.15, 27.25, 27.36, 27.55, 27.71, 28.15, 28.41, friable (calacarenite) 28.63, 28.7, 29.10, 29.20, 29.30 m.
CLAY: Completely weathered, only clay, light grey, yellow, some fresher clasts of calcerous mudstone, light red with very fine fissures.
LIMESTONE: Moderately weathered with fractures at 30.05, 30.12, 30.20, 31.5, 31.6, 31.65, 32.15, 32.3 extensive from 31.00 m cavities up to 150 mmfilled with clay (yellow) 31.00 - 31.50 very brittle, cream to light red.
LIMESTONE: Completely weathered, mostly weathered limestone, mostly clay with few brittle clasts, yellow, cream, light red.
LIMESTONE: Weathered and fractured with cavities (~ 10 mm, open / larger cavites 50 mm) infill with clay, cream, clay is yellow fractures at 33.87, 34.09, 34.28.
LIMESTONE: Moderately weathered, crea, ligh red, 34.45 - 35.10, fractures at 34.77, 34.93, 35.5, 35.93. Cavities up to 30 mm. infilled with soft clay, yellow, plenty of fossiles (imprints of molluscs).

ELECTRICAL CONDUCTIVITY: 175.7 mS/cm

AIRLIFT YIELD: 0.4 mS/cm

DRAWN BY **C.E** DATE **6/11/09** CHECKED BY **DL** APPENDIX

BORE COMPLETION REPORT

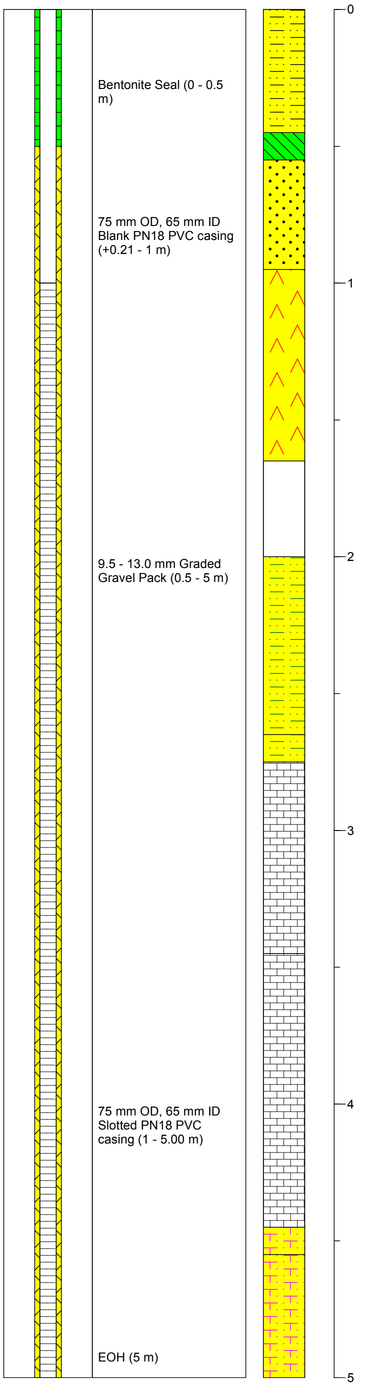
URS Australia Pty Ltd
Level 3, 20 Terrace Rd, East Perth WA, 6004
Phone: (08) 9326 0100
Fax: (08) 9326 0296

BOREHOLE **EO52FG-S**

DRILLING COMPANY	**Hagstrom Drilling**
DRILLING METHOD	**Mud Rotary**
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	**EO52**	EASTING	**300274 mE**
START DATE	**27/10/09**	NORTHING	**7590245 mN**
COMPLETION DATE	**27/10/09**	R.L. OF COLLAR	**TBA**
SWL	**1.38 m btc**	LOGGED BY	**B.S**
MEASUREMENT DATE	**30/10/2009**		

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | ELECTRICAL CONDUCTIVITY | AIRLIFT YIELD



DESCRIPTION	ELECTRICAL CONDUCTIVITY	AIRLIFT YIELD
SILTY SANDY CLAY: Low plasticity, red - brown.		
CLAY: High plasticity, light grey, plant roots.		
SAND: Silty clay. Compacted, red brown.		
CLAYEY SILTY SAND: Fine, red - brown, more compacted and higher clay content, between 1.1 - 1.55. 1.55 - 1.65 is less compacted.		
SAMPLE LOSS		
CLAYEY SAND: Fine, very soft, red - brown.	92.8 mS/cm	0.25 L/sec
CLAYEY SAND: Fine, red - brown with gravel of sandstone (calcareous), subangular, poorly sorted, red - grey.		
SILTY CLAYEY SAND: Red - brown with gravel of calcrete, sub- angular, poorly sorted, compacted.		
SILTY CLAYEY SAND: Fine, compacted, red- brown.		
SANDY SILTY CLAY: Fine, red - brown.		
SANDY SILTY CLAY: Moderately plastic, red-brown.		

DRAWN BY **C.E** DATE **6/11/09** CHECKED BY **DL** APPENDIX

CHEVRON WHEATSTONE PROJECT
SUMMARY OF GROUNDWATER AND ENVIRONMENTAL MONITORING BORE INSTALLATION

MARCH 2009

Note: Sub = Subterranean
* Current pvc collar height, will be updated following placement of steel collars

X EC Meter not working

same as PVC
need to check if survey data is PVC or steel

Site No.	Bore No.	Status	Final Site ID	Location Easting (mE)	Northing (mN)	Ground R.L. (m AHD)	Date Started	Date Completed	Depth Drilled (m)	Cased Depth (m)	Casing Blank (m)	Casing Slotted (m)	*Collar Height (m)	Collar R.L. (m AHD)	Airlift Yield (L/sec)	Airlift Duration (mins)	Field Water Quality EC (mS/cm)	Field Water Quality pH	Static Water Level (m btc)	Static Water Level (m bgl)	Static Water Level (m AHD)	Sump Water Quality Date	Sump Water Quality EC (mS/cm)	Sump Water Quality pH
2	MB2a	Deep	E002G-D	291156.67	7595090.79	3.76	25/03/2009	30/03/2009	33.1	33.1	30.4	3	0.37		2.0	35.0	187.6	7.7	3.86	3.49		9/04/2009	24.0	7.17
	MB2b	Shallow	E002G-S	291157.02	7595090.01	3.73	30/03/2009	31/03/2009	5	4.6	1.2	4	0.64		0.3	21.0	65.0	8.0	2.97	2.33		9/04/2009	24.0	7.17
	MB2c	Sub	E002F	291153.83	7595087.03	3.72	31/03/2009	1/04/2009	15	14.2	0.8	13.9	0.50		0.5	30.0	117.9	7.8	2.86	2.36		9/04/2009	24.0	7.17
3	MB3a	Sub	E003F	291103.72	7595517.31	5.68	29/03/2009	1/04/2009	20.6	20.6	0.85	19.6	1.06		0.9	40.0	101.1	7.72	5.44	4.38		23/04/2009	N/A (silt)	N/A (silt)
4	MB4a	Sub	E004F	291243.60	7595539.01	7.2	25/03/2009	29/03/2009	21.1	21.1	2	20.1	0.97		0.8	40	102.9	7.65	6.90	5.93		23/04/2009	N/A (silt)	N/A (silt)
5	MB5a	Deep	E005G-D	291481.42	7596954.43	3.43	1/04/2009	3/04/2009	33.2	33.2	29.5	3.7	0.1		0.7	20	103.0	7.6	2.83	2.73		16/04/2009	22.1	7.4
	MB5b	Intermediate / Aquitard	E005G-I	291482.98	7596954.70	3.47	4/04/2009	4/04/2009	12.2	11.9	10	1.9	0.12		0.2	15	96.0	7.9	2.3	2.18		16/04/2009	22.1	7.4
	MB5c	Shallow	E005G-S	291484.50	7596954.99	3.51	5/04/2009	5/04/2009	3.3	3.3	0.7	2.6	0.2		0.1	30	12.7	8.9	2.3	2.10		16/04/2009	22.1	7.4
	MB5d	Sub	E005F	291486.94	7596955.43	3.59	5/04/2009	6/04/2009	13.7	13.7	2	12.7	0.14		0.3	40	83.0	7.9	2.25	2.11		16/04/2009	22.1	7.4
6	MB6a	Sub	E006F	292536.49	7598298.46	1.91	6/04/2009	7/04/2009	15.3	15.3	1	14.7	0.07		0.5	40	128.8	7.5	1.17	1.10		23/04/2009	11.9	6.95
17	MB17a	Sub	E017F	290021.25	7596324.95	1.64	1/04/2009	3/04/2009	20	18.6	19.4	3.9	0.8		2	45	107.8	7.5	1.87	1.07		19/04/2009	24.7	8.1
18	MB18a	Deep	E018G-D	293927.20	7600285.69	2.46	14/04/2009	17/04/2009	34	32	29.5	3	0.35		2.5	10	X	7.03	2.66	2.31		24/04/2009	7.3	6.5
	MB18b	Intermediate	E018G-I	293925.71	7600287.69	2.39	17/04/2009	18/04/2009	18.5	18.5	16	3	0.33		1	20	X (101.8)	7.31	2.18	1.85		24/04/2009	7.3	6.5
	MB18c	Shallow	E018G-S	293924.00	7600289.85	2.39	19/04/2009	19/04/2009	7.5	7.5	2	6	0.45		0.5	20	X (61.3)	7.2	1.95	1.50		27/04/2009	7.3	6.5
	MB18d	Sub	E018F	293922.52	7600291.59	2.48	19/04/2009	20/04/2009	15	14.5	1	13.5	0.23		0.5	1	X (25.1)	7.58	1.8	1.57		27/04/2009	7.3	6.5
19	MB19a	Deep	E019G-D	293684.44	7600753.02	1.34	29/04/2009	3/05/2009	34	33.5	30.5	3	0.28		2	35	161.9	6.36	2.73	2.07	-0.338	7/05/2009	N/A	N/A
	MB19b	Shallow	E019G-S	293686.85	7600752.59	1.44	4/05/2009	4/05/2009	5.5	5.5	1	4.5	-0.05		0.5	40	34.5	7.42	1.64	1.04	0.626	7/05/2009	N/A	N/A
	MB19c	Sub	E019F	293689.50	7600752.03	1.5	4/05/2009	5/05/2009	15.5	15	0.5	14.5	0.24		0.5	15	97.5	6.97	1.71	1.12	0.522	7/05/2009	N/A	N/A
21	MB21a	Sub	E021F	293982.98	7600708.00	1.64	20/04/2009	21/04/2009	15	14	1.5	14	0.74		1	43	85.5	7.85	1.74	1.00		21/04/2009	N/A	N/A
Phase 2		**May 09 to July 09**																						
Site No.	Bore No.	Status				Ground R.L. (m AHD)	Date Started	Date Completed	Depth Drilled (m)	Cased Depth (m)	Casing Blank (m)	Casing Slotted (m)	*Collar Height (m)	Collar R.L. (m AHD)	Airlift Yield (L/sec)	Airlift Duration (mins)	Field Water Quality EC (mS/cm)	Field Water Quality pH	Static Water Level (m btc)	Static Water Level (m bgl)	Static Water Level (m AHD)	Sump Water Quality Date	Sump Water Quality EC (mS/cm)	Sump Water Quality pH
32	EO32a	deep	E032FG-D	294582.72	7600425.02	2.49	7/05/2009	9/05/2009	21	21	19	2	0.16		0.3	45	139.9	7.54	2.18	2.02		15/06/2009	18.3	8.11
	EO32b	intermed	E032FG-I	294583.17	7600422.32	2.43	9/05/2009	10/05/2009	7.2	7	6.5	0.5	0.2		0.3	40	77.4	7.58	1.93	1.73		15/06/2009	18.3	8.11
	EO32c	shallow	E032FG-S	294583.64	7600420.11	2.3	11/05/2009	11/05/2009	4	4	0.5	3.5	0.19		0.2	40	52.5	8.25	1.75	1.56		15/06/2009	18.3	8.11
27	EO27a	intermed	E027FG-I	293131.63	7598678.91	2.61	12/05/2009	13/05/2009	18	18	16	2	0.16		0.5	45	172.4	7.39	2.06	1.90		5/06/2000	21.32	8.01
	EO27b	shallow	E027FG-S	293133.91	7598677.49	2.55	13/05/2009	13/05/2009	6	6	5.5	0.5	0.1		0.3	45	250	7.21	1.79	1.69		5/06/2000	21.32	8.01
	EO27c	deep	E027FG-D	293135.82	7598676.44	2.6	14/05/2009	17/05/2009	40.5	40	37	3	0.91		2	30	198.5	6.65	3.13	2.22		5/06/2000	21.32	8.01
33	EO33a	deep	E033FG-D	293169.25	7600363.76	2.59	17/05/2009	21/05/2009	41	40	37	3	0.15		2	10	175.5	7.21	3.04	2.89		8/06/2009	7.75	9.10
	EO33b	intermed	E033FG-I	293169.00	7600361.71	2.63	21/05/2009	21/05/2009	18	14	11	3	0.14		2	25	92	7.26	2.13	1.99		8/06/2009	7.75	9.10
	EO33c	shallow	E033FG-S	293168.66	7600359.65	2.58	22/05/2009	23/05/2009	7	6.5	1	5.5	0.08		0.2	45	13.63	7.66	2.73	1.94		8/06/2009	7.75	9.10
14	EO14a	sub	E014F	291024.13	7599362.53	3.31	23/05/2009	24/05/2009	15.5	15	1	14	0.09		0.5	40	105.6	7.47	3.19	2.64		1/06/2009	11.09	9.23
	EO14b	intermed	E014G-I	291023.87	7599360.48	3.28	24/05/2009	25/05/2009	15.5	15	12	3	0.11		1	20	107.5	7.28	3.2	2.62		1/06/2009	11.09	9.23
	EO14c	shallow	E014G-S	291023.67	7599358.53	3.25	26/05/2009	26/05/2009	7	7	1	6	0.95		0.2	80	67.6	7.89	3.2	2.61		1/06/2009	11.09	9.23
24	EO24a	intermed	E024FG-I	291590.03	7599721.78	2.65	26/05/2009	27/05/2009	15	8	6	2	0.18		1.5	20	73.8	7.7	2.13	1.95		6/06/2009	7.13	9.03
	EO24b	shallow	E024FG-S	291591.54	7599723.82	2.59	27/05/2009	27/05/2009	5	5	4	1	0.26		0.1	30	101.2	8.18	2.19	1.93		6/06/2009	7.13	9.03
23	EO23a	deep	E023FG-D	292463.25	7600535.22	4.66	27/05/2009	29/05/2009	34	34	31	3	0.14		2.5	20	162.7	7.01	5	4.86		7/06/2009	4.27	10.06
Removed	EO23b	shallow	[redacted]				29/05/2009	30/05/2009	5	5	0.5	4.5	0.15		sanded up				Dry			7/06/2009	4.27	10.06
Re-drilled	EO23bn	shallow	E023FG-S	292465.73	7600538.44	4.54	18/06/2009	18/06/2009	6.2	6.2	0.7	5.5			0.06	70	33.4	8.2	4.54	3.88			-	-
25	EO25a	intermed/Deep	E025FG-D	291797.16	7600222.21	7.47	5/04/2009	6/04/2009	13.5	13.5	10.5	3	0.21		2	20	72.7	7.16	7.43	6.7		26/06/2009	0.88	8.72
	EO25b	intermed (calcarenite)	E025FG-I	291797.82	7600221.84	7.46	7/06/2009	7/06/2009	9	9	6	3	0.18		0.06 (poorly developed)	30	6.41	8.58	7.31	6.65		26/06/2009	0.88	8.72
	EO25c	shallow	E025FG-S	291799.17	7600221.06	4.54	7/06/2009	7/06/2009	5	5	4	1	0.1		0	20	-	-	Dry	Dry		26/06/2009	0.88	8.72
26	E026a	deep	E026FG-D	292032.47	7599731.04	4.25	8/06/2009	17/06/2009	34.5	34.5	31.5	3	0.09		0.9	15	169.6	6.89	5.09	5		27/06/2009	1.74	9.30
	E026b	shallow	E026FG-S	292030.31	7599731.38	4.18	17/06/2009	17/06/2009	7.5	7.5	1.5	6	0.25		0.1	45	42.8	7.72	4.3	4.05		27/06/2009	1.74	9.30
29	EO29a	deep	EO29G-D	290734.06	7597189.81	1.88	26/06/2009	28/06/2009	30	30	27	3	0.54		0.3	65	112.5	6.73	2.18	1.64		19/07/2009		
	EO29b	shallow	EO29G-S	290734.33	7597188.15	1.91	28/06/2009	4/07/2009	6	6	0.5	5.5	0.65		0.2	90	93.8	6.88	2.04	1.39		19/07/2009		
	EO29c	Intermediate	EO29G-I	290734.67	7597186.55	1.97	4/07/2009	5/07/2009	16.3	16	13	3	0.63		0.3	64	79.8	6.77	2.29	1.66		19/07/2009		
30	EO30a	deep	EO30G-D	292207.44	7596336.16	8.880	12/07/2009	14/07/2009	33.1	33.1	30.62	3	0.72		0.3	23	171.1	6.78	9.2	8.38		19/07/2009		
	EO30b	intermediate	EO30G-I	292208.33	7596337.22	8.900	14/07/2009	14/07/2009	12.2	12.2	9.815	3	0.815		0.2	43	90.1	7.17	8.54	7.77		19/07/2009		
	EO30c	shallow	EO30G-S	292209.12	7596338.26	8.930	14/07/2009	14/07/2009	5.2	5.2	1.955	4	0.955		Dry	N/A	N/A	N/A	Dry	N/A		19/07/2009		
31	E031a	deep	E031FG-D	292856.29	7597524.01	2.910	15/07/2009	20/07/2009	67.5	67.5	55.5	12	0.92		2	15	117.3	7.04	2.5	1.58		23/07/2009	2.57	7.37
	E031b	shallow	E031FG-S	292854.38	7597524.24	2.910	20/07/2009	20/07/2009	7.5	7.5	1.5	6	0.89		0.1	45	44.8	7.72	4.25	2.06		23/07/2009	2.57	7.37
28	E028	intermediate	E028G-I	290041.54	7595645.35	3.590	4/08/2009	5/08/2009	15	15	12	3	0.500		1	33	72	6.8	3.13	2.99		6/08/2009	3.48	7.29
		shallow	E028G-S	290041.90	7595647.15	3.520	5/08/2009	5/08/2009	8	8	1	7	0.160		0.2	25	60.1	7.33	3.35	2.80		6/08/2009	3.48	7.29
22	E022	Test Bore	E022	293460.00	7599690.00		16/09/2009	16/09/2009	10	10	6	4	0.56		2	30	111	7.45	3.015	2.46		21/09/2009	1.53	8.36
Phase 2 - Camp and Corridor																								
46	E046a	intermediate/aquitard	E046FG-I	293199.23	7593722.94	3.65	14/10/2009	17/10/2009	14.2	14.2	11.2	3	0.66		0.5	15	77.1	7.26	2.98	2.980		29/10/2009	3.83	6.35
	E046b	shallow	E046FG-S	293200.70	7593720.36	3.57	17/10/2009	17/10/2009	6	6	1	5	0.65		0.25	37	83.5	7.54	2.73	2.730		29/10/2009	3.83	6.35
47	E047a	Deep	E047FG-D	294209.24	7592313.09	2.78	18/10/2009	22/10/2009	57	56	44	12	0.17		0.5	15	78	7.5	2.18	2.01		29/10/2009	43.2	6.98
	E047b	Intermediate	E047FG-I	294209.13	7592310.89	2.78	22/10/2009	22/10/2009	13	12	9	3	0.72		0.25	15	126.5	7.19	2.1	1.38		29/10/2009	6.65	10.38
	E047c	Shallow	E047FG-S	294208.91	7592308.77	2.78	23/10/2009	23/10/2009	6.2	6	1	5	1.05		0.2	20	57.9	7.96	2.29	1.24		29/10/2009	6.65	10.38
52	E052a	Deep	E052FG-D	300284.63	7590245.15	3.09	23/10/2009	27/10/2009	36	35	32	3	0.16		0.4	15	175.7	7.13	2.12	2.12		30/10/2009	7.08	7.19
	E052b	Shallow	E052FG-S	300290.10	7590243.73	3.09	27/10/2009	27/10/2009	5	5	1	4	0.21		0.25	25	92.8	7.27	1.38	1.22		30/10/2009	7.53	7.2
48	E048a	intermediate	E048FG-I	296274.49	7591599.49	4.71	23/10/2009	26/10/2009	15	13	10	3	0.12		2	15	91.2	7.37	2.84	2.84		29/10/2009	7.92	7.18
	E048b	shallow	E048FG-S	296274.27	7591597.53	4.71	27/10/2009	27/10/2009	6	6	1	5	1.05		0.1	25	50.7	7.67	3.5	3.38		29/10/2009	7.92	7.18

Bore No.	Height PVC Collar (m above gl) [Phase 2: Stick up (m above gl)]	Height Steel Collar CD measured 26/6/09 (m above gl) [Phase 2: Stick up (m above gl)]	Height Steel Collar survey data (m above gl)	Ground Level survey data (m AHD)	PVC Collar R.L. survey data (m AHD)	Steel Collar R.L. measured (m AHD)	Steel Collar R.L. survey data (m AHD)	Static Water Level (using surveyed ground level) Date	(m btc)	(m bgl)	(m AHD)
MB17a		0.795	0.688	1.637	2.325	2.432	2.325	26/06/2009	1.885	1.197	0.440
MB18a	0.347	0.510	0.347	2.464	2.811	2.974	2.811	26/06/2009	2.994	2.647	-0.183
MB18b	0.369	0.470	0.369	2.391	2.760	2.861	2.760	26/06/2009	2.330	1.961	0.430
MB18c	0.500	0.585	0.500	2.394	2.894	2.979	2.894	26/06/2009	2.145	1.645	0.749
MB18d	0.319	0.540	0.319	2.481	2.800	3.021	2.800	26/06/2009	2.196	1.877	0.604
MB19a	0.611	0.669	0.611	1.343	1.954	2.012	1.954	26/06/2009	2.101	1.490	-0.147
MB19b	0.556	0.697	0.556	1.439	1.995	2.136	1.995	26/06/2009	1.210	0.654	0.785
MB19c	0.568	0.590	0.568	1.502	2.069	2.092	2.069	26/06/2009	1.312	0.744	0.757
MB21a	0.780	0.875	0.780	1.638	2.418	2.513	2.418				
EO32a	0.345	0.476	0.345	2.494	2.839	2.970	2.839	26/06/2009	2.192	1.847	0.647
EO32b	0.381	0.491	0.381	2.426	2.807	2.917	2.807	26/06/2009	2.022	1.641	0.785
EO32c	0.367	0.480	0.367	2.299	2.667	2.779	2.667	26/06/2009	2.087	1.720	0.580
EO27a	0.768	0.800	0.768	2.609	3.377	3.409	3.377	26/06/2009	2.446	1.678	0.931
EO27b	0.721	0.744	0.721	2.553	3.274	3.297	3.274	26/06/2009	2.439	1.718	0.835
EO27c	0.662	0.750	0.662	2.603	3.266	3.353	3.266	26/06/2009	2.910	2.248	0.356
EO33a	0.709	0.748	0.709	2.594	3.303	3.342	3.303	26/06/2009	2.694	1.985	0.609
EO33b	0.682	0.722	0.682	2.627	3.309	3.349	3.309	26/06/2009	2.529	1.847	0.780
EO33c	0.682	0.790	0.682	2.578	3.260	3.368	3.260	26/06/2009	2.750	2.068	0.510
EO14a	0.468	0.554	0.468	3.307	3.775	3.861	3.775	26/06/2009	3.195	2.727	0.580
EO14b	0.537	0.576	0.537	3.279	3.815	3.855	3.815	26/06/2009	3.198	2.661	0.617
EO14c	0.560	0.590	0.560	3.253	3.813	3.843	3.813	26/06/2009	3.198	2.638	0.615
EO24a	0.484	0.609	0.484	2.648	3.132	3.257	3.132	26/06/2009	2.541	2.057	0.591
EO24b	0.795	0.845	0.795	2.588	3.384	3.433	3.384	26/06/2009	2.778	1.983	0.606
EO23a	0.643	0.759	0.643	4.661	5.304	5.420	5.304	26/06/2009	5.765	5.122	-0.461
EO23b											
EO23bn	0.676	0.659	0.676	4.544	5.220	5.203	5.220	26/06/2009	4.370	3.694	0.850
EO25a	0.617	0.732	0.617	7.473	8.090	8.205	8.090	26/06/2009	7.336	6.719	0.754
EO25b	0.598	0.663	0.598	7.455	8.053	8.118	8.053	26/06/2009	7.221	6.623	0.832
EO25c	0.592	0.668	0.592	7.392	7.984	8.060	7.984	26/06/2009	Dry		
E026a	0.207	0.090	0.207	4.251	4.458	4.341	4.458	26/06/2009	4.765	4.558	-0.307
E026b	0.290	0.250	0.290	4.184	4.474	4.434	4.474	26/06/2009	3.687	3.397	0.787
EO29a	-	0.550	0.550	1.88	N/A	2.430	2.430	N/A	N/A	N/A	N/A
EO29b	-	0.670	0.670	1.91	N/A	2.580	2.580	N/A	N/A	N/A	N/A
EO29c	-	0.650	0.650	1.97	N/A	2.620	2.620	N/A	N/A	N/A	N/A
EO30a	-	0.860	0.860	8.880	N/A	9.740	9.740	N/A	N/A	N/A	N/A
EO30b	-	0.780	0.780	8.900	N/A	9.680	9.680	N/A	N/A	N/A	N/A
EO30c	-	0.870	0.870	8.930	N/A	9.800	9.800	N/A	N/A	N/A	N/A
E031a	-		0.920	2.910	N/A		3.830	N/A	N/A	N/A	N/A
E031b	-		0.890	2.910	N/A		3.800	N/A	N/A	N/A	N/A
E028	0.500		0.170	3.590	N/A		3.760	N/A	N/A	N/A	N/A
(shallow)	0.160		0.550	3.520	N/A		4.070	N/A	N/A	N/A	N/A
E022	0.560		0.470	3.010	N/A		3.480	N/A	N/A	N/A	N/A
E046a	0.550		0.660	3.650	N/A		4.310	N/A	N/A	N/A	N/A
E046b	0.600		0.650	3.570	N/A		4.220	N/A	N/A	N/A	N/A
E047a	0.17		0.710	2.780	N/A		3.490	N/A	N/A	N/A	N/A
E047b	0.72		0.730	2.780	N/A		3.510	N/A	N/A	N/A	N/A
E047c	1.05		0.790	2.780	N/A		3.570	N/A	N/A	N/A	N/A
E052a	0.16		0.690	3.090	N/A		3.780	N/A	N/A	N/A	N/A
E052b	0.21		0.750	3.090	N/A		3.840	N/A	N/A	N/A	N/A
E048a	0.12		0.800	4.710	N/A		5.510	N/A	N/A	N/A	N/A
E048b	1.05		0.790	4.710	N/A		5.500	N/A	N/A	N/A	N/A

Bore No.	Date	(m btc) steel	(m bgl)	(m AHD)	Date	(m btc) steel	(m bgl)	(m AHD)	Date	(m btc) steel	(m bgl)	(m AHD)	Date	(m btc) steel	(m bgl)	(m AHD)	Date	(m btc) steel	(m bgl)	(m AHD)
MB2a	30/07/2009	4.300	3.890	-0.130	9/08/2009	4.290	3.880	-0.120	16/09/2009	4.32	3.910	-0.150	16/10/2009	4.37	3.96	-0.200				
MB2b	30/07/2009	3.340	2.828	0.900	9/08/2009	3.36	2.848	0.880	16/09/2009	4.44	3.928	-0.200	16/10/2009	3.5	2.99	0.740				
MB2c	30/07/2009	3.300	2.816	0.900	9/08/2009	3.31	2.826	0.890	16/09/2009	3.38	2.896	0.820	16/10/2009	3.44	2.96	0.760				
MB3a	30/07/2009	5.230	4.659	1.020	9/08/2009	5.24	4.669	1.010	16/09/2009	5.31	4.739	0.940	16/10/2009	5.36	4.79	0.890				
MB4a	30/07/2009	6.780	6.129	1.070	9/08/2009	6.79	6.139	1.060	16/09/2009	6.86	6.209	0.990	16/10/2009	6.9	6.25	0.950				
MB5a	30/07/2009	3.820	3.211	0.214	9/08/2009	3.85	3.241	0.184	16/09/2009	3.95	3.341	0.084	16/10/2009	4.03	3.42	0.004				
MB5b	30/07/2009	3.280	2.672	0.796	9/08/2009	3.3	2.692	0.776	16/09/2009	3.4	2.792	0.676	16/10/2009	3.47	2.86	0.606				
MB5c	30/07/2009	3.170	2.531	0.976	9/08/2009	3.19	2.551	0.956	16/09/2009	3.31	2.671	0.836	16/10/2009	3.4	2.76	0.746				
MB5d	30/07/2009	3.240	2.606	0.980	9/08/2009	3.26	2.626	0.960	16/09/2009	3.37	2.736	0.850	16/10/2009	3.46	2.83	0.760				
MB6a	30/07/2009	1.840	1.228	0.685	9/08/2009	1.87	1.258	0.655	17/09/2009	1.96	1.348	0.565	17/10/2009	2.02	1.41	0.505				
MB7a	30/07/2009	3.220	2.446	0.172	9/08/2009	3.27	2.496	0.122	17/09/2009	3.34	2.566	0.052	17/10/2009	3.37	2.60	0.022				
MB7b	30/07/2009	2.680	1.897	0.665	9/08/2009	2.71	1.927	0.635	17/09/2009	2.81	2.027	0.535	17/10/2009	2.86	2.08	0.485				
MB7c	30/07/2009	2.590	1.876	0.671	9/08/2009	2.62	1.906	0.641	17/09/2009	2.73	2.016	0.531	17/10/2009	2.8	2.09	0.461				
MB7d	30/07/2009	2.640	1.882	0.702	9/08/2009	2.67	1.912	0.672	17/09/2009	2.78	2.022	0.562	17/10/2009	2.85	2.09	0.492				
MB8a	30/07/2009	5.670	5.315	0.552	9/08/2009	5.72	5.365	0.502	17/09/2009	5.81	5.455	0.412	19/10/2009	5.82	5.46	0.402				
MB9a	30/07/2009	5.690	4.933	0.658	9/08/2009	5.75	4.993	0.598	17/09/2009	5.845	5.088	0.503	19/10/2009	5.84	5.08	0.508				
MB10a	30/07/2009	2.890	2.534	0.216	9/08/2009	2.93	2.574	0.176	17/09/2009	2.985	2.629	0.121	19/10/2009	2.92	2.56	0.186				
MB10b	30/07/2009	2.710	2.207	0.626	9/08/2009	2.78	2.277	0.556	17/09/2009	2.86	2.357	0.476	19/10/2009	2.83	2.33	0.506				
MB10c	30/07/2009	2.650	2.231	0.566	9/08/2009	2.71	2.291	0.506	17/09/2009	2.78	2.361	0.436	19/10/2009	2.76	2.34	0.456				
MB11a	30/07/2009	1.780	1.153	0.345	9/08/2009	1.75	1.123	0.375	17/09/2009	1.885	1.258	0.240	27/10/2009	1.92	1.29	0.205				
MB12a	30/07/2009	1.450	1.077	0.381	9/08/2009	1.44	1.067	0.391	17/09/2009	1.54	1.167	0.291	27/10/2009	1.99	1.62	-0.159				
MB13a	30/07/2009	1.770	1.179	0.612	9/08/2009	1.78	1.189	0.602	17/09/2009	1.92	1.329	0.462	27/10/2009							
MB15a	30/07/2009	4.750	4.118	0.870	9/08/2009	4.78	4.148	0.840	16/09/2009	4.88	4.248	0.740	17/10/2009	4.95	4.32	0.670				
MB16a	30/07/2009	4.560	4.091	-0.040	9/08/2009	4.58	4.111	-0.060	17/09/2009	4.66	4.191	-0.140	17/10/2009	4.73	4.26	-0.210				
MB16b	30/07/2009	4.030	3.422	0.658	9/08/2009	4.05	3.442	0.638	16/09/2009	4.14	3.532	0.548	17/10/2009	4.21	3.60	0.478				
MB16c	30/07/2009	4.170	3.486	0.641	9/08/2009	4.19	3.506	0.621	16/09/2009	4.28	3.596	0.531	17/10/2009	4.35	3.67	0.461				
MB17a	30/07/2009	1.920	1.232	0.405	9/08/2009	1.93	1.242	0.395	16/09/2009	2.01	1.322	0.315	17/10/2009	2.06	1.37	0.265				
MB18a	30/07/2009	3.270	2.923	-0.459	9/08/2009	3.2	2.853	-0.389	17/09/2009	3.27	2.923	-0.459	19/10/2009	3.24	2.89	-0.429				
MB18b	30/07/2009	2.610	2.241	0.150	9/08/2009	2.57	2.201	0.190	17/09/2009	2.625	2.256	0.135	19/10/2009	2.61	2.24	0.150				
MB18c	30/07/2009	2.400	1.900	0.494	9/08/2009	2.37	1.870	0.524	17/09/2009	2.45	1.950	0.444	19/10/2009	2.41	1.91	0.484				
MB18d	30/07/2009	2.450	2.131	0.350	9/08/2009	2.42	2.101	0.380	17/09/2009	2.49	2.171	0.310	19/10/2009	2.47	2.15	0.330				
MB19a	30/07/2009	2.740	2.129	-0.786	9/08/2009	2.35	1.739	-0.396	17/09/2009	2.65	2.039	-0.696	27/10/2009	2.81	2.20	-0.856				
MB19b	30/07/2009	1.660	1.104	0.335	9/08/2009	1.51	0.954	0.485	17/09/2009	1.69	1.134	0.305	27/10/2009	1.81	1.25	0.185				
MB19c	30/07/2009	1.730	1.162	0.339	9/08/2009	1.57	1.002	0.499	17/09/2009	1.77	1.202	0.299	27/10/2009	1.9	1.33	0.169				
MB21a	30/07/2009	2.140	1.360	0.278	9/08/2009	2.05	1.270	0.368	17/09/2009	2.17	1.390	0.248	27/10/2009	2.28	1.50	0.138				
EO32a	30/07/2009	2.700	2.355	0.139	9/08/2009	2.51	2.165	0.329	17/09/2009	2.64	2.295	0.199	20/10/2009	2.69	2.34	0.149				
EO32b	30/07/2009	2.360	1.979	0.447	9/08/2009	2.32	1.939	0.487	17/09/2009	2.435	2.054	0.372	20/10/2009	2.43	2.05	0.377				
EO32c	30/07/2009	2.190	1.823	0.477	9/08/2009	2.15	1.783	0.517	17/09/2009	3.09	2.723	-0.423	20/10/2009	2.27	1.90	0.397				
EO27a	30/07/2009	2.730	1.962	0.647	9/08/2009	2.8	2.032	0.577	16/09/2009	2.87	2.102	0.507	18/10/2009	2.88	2.11	0.497				
EO27b	30/07/2009	2.630	1.909	0.644	9/08/2009	2.64	1.919	0.634	16/09/2009	2.7	1.979	0.574	18/10/2009	2.76	2.04	0.514				
EO27c	30/07/2009	3.340	2.678	-0.074	9/08/2009	3.38	2.718	-0.114	16/09/2009	3.44	2.778	-0.174	18/10/2009	3.43	2.77	-0.164				
EO33a	30/07/2009	3.910	3.201	-0.607	9/08/2009	3.76	3.051	-0.457	17/09/2009	3.98	3.271	-0.677	27/10/2009	4.02	3.31	-0.717				
EO33b	30/07/2009	2.960	2.278	0.349	9/08/2009	2.86	2.178	0.449	17/09/2009	3.03	2.348	0.279	27/10/2009	3.08	2.40	0.229				
EO33c	30/07/2009	2.730	2.048	0.530	9/08/2009	2.65	1.968	0.610	17/09/2009	2.27	1.588	0.990	27/10/2009	2.93	2.25	0.330				
EO14a	30/07/2009	3.270	2.802	0.505	9/08/2009	3.29	2.822	0.485	17/09/2009	3.395	2.927	0.380	27/10/2009	3.47	3.00	0.305				
EO14b	30/07/2009	3.270	2.733	0.545	9/08/2009	3.16	2.623	0.655	17/09/2009	3.265	2.728	0.550	27/10/2009	3.34	2.80	0.475				
EO14c	30/07/2009	3.260	2.700	0.553	9/08/2009	3.16	2.600	0.653	17/09/2009	3.395	2.835	0.418	27/10/2009	3.47	2.91	0.343				
EO24a	30/07/2009	2.630	2.146	0.502	9/08/2009	2.65	2.166	0.482	17/09/2009	2.76	2.276	0.372	27/10/2009	2.83	2.35	0.302				
EO24b	30/07/2009	2.840	2.045	0.544	9/08/2009	2.88	2.085	0.504	17/09/2009	2.965	2.170	0.419	27/10/2009	3.04	2.24	0.344				
EO23a	30/07/2009	5.710	5.067	-0.406	9/08/2009	5.88	5.237	-0.576	17/09/2009	6.055	5.412	-0.751	27/10/2009	6.09	5.45	-0.786				
EO23b																				
EO23bn	30/07/2009	4.540	3.864	0.680	9/08/2009	4.57	3.894	0.650	17/09/2009	4.66	3.984	0.560	27/10/2009	4.72	4.04	0.500				
EO25a	30/07/2009	7.430	6.813	0.660	9/08/2009	7.46	6.843	0.630	17/09/2009	7.565	6.948	0.525	27/10/2009	7.64	7.02	0.450				
EO25b	30/07/2009	7.310	6.712	0.743	9/08/2009	7.33	6.732	0.723	17/09/2009	7.44	6.842	0.613	27/10/2009	7.51	6.91	0.543				
EO25c		Dry			9/08/2009	Dry			17/09/2009	Dry				Dry						
E026a	30/07/2009	5.090	4.883	-0.632	9/08/2009	5.09	4.883	-0.632	17/09/2009	5.16	4.953	-0.702	27/10/2009	5.2	4.99	-0.742				
E026b	30/07/2009	4.300	4.010	0.174	9/08/2009	4.32	4.030	0.154	17/09/2009	4.425	4.135	0.049	27/10/2009	4.5	4.21	-0.026				
EO29a	30/07/2009	2.180	1.630	0.250	9/08/2009	2.01	1.460	0.420	16/09/2009	2.11	1.560	0.320	23/10/2009	2.19	1.64	0.240				
EO29b	30/07/2009	2.040	1.370	0.540	9/08/2009	2.06	1.390	0.520	16/09/2009	2.15	1.480	0.430	23/10/2009	2.23	1.56	0.350				
EO29c	30/07/2009	2.290	1.640	0.330	9/08/2009	1.93	1.280	0.690	17/09/2009	3.065	2.415	-0.445	23/10/2009	2.1	1.45	0.520				
EO30a	30/07/2009	9.200	8.340	0.540	9/08/2009	8.93	8.070	0.810	17/09/2009	2.33	1.470	7.410	23/10/2009	12.4	11.54	-2.660				
EO30b	30/07/2009	8.540	7.760	1.140	9/08/2009	8.52	7.740	1.160	17/09/2009	8.57	7.790	1.110	23/10/2009	10.16	9.38	-0.480				
EO30c	30/07/2009	Dry			9/08/2009	Dry			17/09/2009	Dry			23/10/2009	dry						
E031a	30/07/2009	2.500	1.580	1.330	9/08/2009	2.27	1.350	1.560	17/09/2009	2.33	1.410	1.500	23/10/2009	2.35	1.43	1.480				
E031b	30/07/2009	2.950	2.060	0.850	9/08/2009	2.98	2.090	0.820	17/09/2009	3.09	2.200	0.710	23/10/2009	3.15	2.26	0.650				
E028	N/A	N/A	N/A	N/A	9/08/2009	2.98	2.810	0.780	17/09/2009	3.065	2.895	0.695	23/10/2009	3.15	2.98	0.610				
(shallow)	N/A	N/A	N/A	N/A	9/08/2009	3.32	2.770	0.750	17/09/2009	3.4	2.850	0.670	23/10/2009	3.5	2.95	0.570				
E022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19/10/2009	3.14	2.67	0.340				
E046a	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29/10/2009	2.98	2.32	1.33	40135.00	2.99	2.33	1.32
E046b	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29/10/2009	2.73	2.73	1.49	40135.00	2.77	2.12	1.45
E047a	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29/10/2009	2.72	2.01	0.77	40136.00	2.61	1.90	0.88
E047b	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29/10/2009	2.11	1.38	1.40	40136.00	2.03	1.30	1.48
E047c	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29/10/2009	2.03	1.24	1.54	40136.00	2.04	1.25	1.53
E052a	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30/10/2009	2.81	2.12	0.97	40136.00	2.85	2.16	0.93
E052b	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30/10/2009	1.97	1.22	1.87	40136.00	1.93	1.18	1.91
E048a	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29/10/2009	3.52	2.72	1.99	40136.00	3.39	2.59	2.12
E048b	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29/10/2009	3.24	2.45	2.26	40136.00	3.44	2.65	2.06

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B

Appendix B Drive Point Piezometer Master Sheet

URS

CHEVRON WHEATSTONE PROJECT
SUMMARY OF DRIVE POINT PIEZOMETER INSTALLATION
* (refer to comments)
31/08//2009

Site No.	Bore No.	Status	Final Site ID	Updated from Coffey Survey – Location Easting (mE)	Location Northing (mN)	Ground R.L. Coffey Survey Aug 09 (m AHD)	Date Started	Date Completed	Casing Blank (m)	Casing Slotted (m)	*Collar Height (m)	Collar 30/07/2009	Collar R.L. Coffey Survey	Static Water Level (m btc)	Static Water Level (m bgl)	Static Water Level (m AHD)	Date
EO34	Shallow	Completed	EO34G-S	294515.08	7600206.52	1.07	9/07/2009	9/07/2009	0.53	0.29	0.42	0.39	1.46	0.97	0.55		9/07/2009
	Deep	Completed	EO34G-D	294514.97	7600207.01	1.06	9/07/2009	9/07/2009	2.73	0.29	0.27	0.26	1.32	1.05	0.78		17/09/2009
EO35	Shallow	Completed	E035G-S	294132.74	7600044.5	1.23	23/07/2009	23/07/2009	0.00-0.8	0.80-1.10	0.42	0.41	1.64				
	Deep	Completed	E035G-D	294133.75	7600044.83	1.17	23/07/2009	23/07/2009	0.00-2.84	2.84-3.10	0.16	0.17	1.34	0.95	0.79		23/07/2009
EO36	Shallow	Completed	E036G-S	293397.9	7599406.23	1.15	23/07/2009	23/07/2009	0.00-0.84	0.84-1.15	0.16	0.16	1.31				
	Deep	Completed	E036G-D	293398.08	7599405.17	1.15	23/07/2009	23/07/2009	0.00-2.70	2.70-3.00	0.3	0.26	1.41	0.91	0.61		23/07/2009
EO37	Shallow																
	Deep	Completed	E037G-D	292880.46	7597560.11	1.18	24/07/2009	24/07/2009	0.00-0.78	0.78-1.10	0.22	0.21	1.4				
EO38	Shallow	Completed	E038G-S	292622.59	7597597.38	1.49	24/07/2009	24/07/2009	0.00-0.90	0.90-1.10	0.1	0.09	1.58				
	Deep	Completed	E038G-D	292621.93	7597597.83	1.5	23/07/2009	23/07/2009	0.00-3.00	3.00-3.39	0.18	0.13	1.63				
EO39	Shallow	Partially Completed	E039G-S				9/07/2009					0.58					
	Deep	Partially Completed	E039G-D									0.43					
EO40	Shallow	Completed	E040G-S	292981	7599709		14/07/2009	14/07/2009	0.74	0.2	0.195	0.19		1.1	0.905		17/09/2009
	Deep	Completed	E040G-D	292981	7599708		14/07/2009	14/07/2009	2.33	0.6	0.67	0.67		1.55	0.88		17/09/2009
EO41	Shallow	Completed	E041G-S	292508	7598328		22/07/2009	22/07/2009	0.00-0.54	0.54-0.84	0.41	0.4					
	Deep	Completed	E041G-D	292507	7598328		22/07/2009	22/07/2009	0.00-1.67	1.67-2.27	0.6	0.59		1.16	0.56		22/07/2009
EO42	Shallow	Completed	EO42G-S	290845.06	7599136.68	1.27	10/07/2009	10/07/2009	??	??	0.41	0.41	1.68	Dry			
	Deep	Completed	E042G-D	290853.65	7599136.87	1.27	14/07/2009	14/07/2009	2.21	0.29	0.46	0.46	1.73	2.02	1.56		
EO43	Shallow	Completed	E043G-S	290544.36	7599160.63	0.99	24/07/2009	24/07/2009	0.00-0.71	0.71-1.05	0.29	0.28	1.27				
	Deep	Completed	E043G-D	290543.28	7599159.8	1	23/07/2009	24/07/2009	0.00-2.27	2.27-2.57	0.73	0.71	1.71				
EO44	Shallow	Completed	E044G-S	293188.26	7598658.59	1.06	22/07/2009	22/07/2009	0.00-0.70	0.70-1.00	0.49	0.48	1.54	0.95	0.46		22/07/2009
	Deep	Completed	E044G-D	293188.51	7598659.29	1.1	22/07/2009	22/07/2009	0.00-2.40	2.40-2.53	0.13	0.1	1.2	2.03	1.9		22/07/2009
EO45	Shallow	Completed	EO45G-S	290653	7597644		15/07/2009	15/07/2009	1.23	0.65	0.14	0.14		Dry			17/09/2009
	Deep	Completed	E045G-D	290753.62	7597212.21	1	25/07/2009	25/07/2009	0.00-1.86	1.86-2.05	0.14	0.1	1.15				
EO53	Shallow	Completed	EO53G-S	290049	7596453.13	1.32	28/07/2009	29/07/2009	0.00-1.73	1.73-2.20	0.27	0.27	1.59				
E054	Shallow																
	Deep	Completed	EO54G-D	294618	7598350		28/07/2009	29/07/2009	0.00-1.83	1.83-2.05	0.17	0.17					
E055	Shallow	Completed	E055G-S	292624.68	7598245.78	7.8	29/07/2009	29/07/2009	0.00-0.90	0.90-1.10	0.1	0.1	7.9				
EO56	Shallow	Completed	E056G-S	292154.14	7599630.82	1.43	24/07/2009	24/07/2009	0.00-1.46	1.46-1.85	0.14	0.1	1.53				
	Deep	Completed	E056G-D	292155.78	7599631.2	1.44	23/07/2009	23/07/2009	0.00-2.88	2.88-3.05	0.12	0.12	1.56				

Site No.	Bore No.	Ground R.L. Coffey Survey Aug 09 (m AHD)	Static Water Level (m btc)	Static Water Level (m bgl)	After Coffey Survey Aug 09 (m AHD)	Date	Static Water Level (m btc)	Static Water Level (m bgl)	After Coffey Survey Aug 09 (m AHD)	Date	Static Water Level (m btc)	Static Water Level (m bgl)	After Coffey Survey Aug 09 (m AHD)	Date	Comments
EO34	Shallow	1.07	1.02	0.63	0.44	30/07/2009	dry			17/09/2009	dry			27/10/2009	Intertidal environment; Saturated sands and clays. Patchy Saltbush.
	Deep	1.06	0.9	0.64	0.42	30/07/2009	2.23	1.97	-0.91	17/09/2009	0.96	0.7	0.36	27/10/2009	
EO35	Shallow	1.23	1.18	0.77	0.46	30/07/2009	1.38	0.97	0.26	17/09/2009	1.22	0.81	0.42	27/10/2009	Location moved. Patchy salt-scrub vegetation on sandy ground.
	Deep	1.17	0.95	0.78	0.39	30/07/2009	1.08	0.91	0.26	17/09/2009	0.89	0.72	0.45	27/10/2009	
EO36	Shallow	1.15	0.72	0.56	0.59	30/07/2009	dry			17/09/2009	0.64	0.48	0.67	21/10/2009	Location moved. Patchy salt-scrub vegetation on sandy ground.
	Deep	1.15	0.82	0.56	0.59	30/07/2009	0.9	0.64	0.51	17/09/2009	0.79	0.53	0.62	21/10/2009	
EO37	Shallow					30/07/2009									Location moved downstream of E031. Patchy salt-scrub vegetation on sandy ground. Could not get past hard formation at 1.40m.
	Deep	1.18	0.7	0.49	0.69	30/07/2009				17/09/2009					
EO38	Shallow	1.49	0.9	0.81	0.68	30/07/2009				17/09/2009					Patchy salt scrub with dense grass undergrowth.
	Deep	1.50	0.92	0.79	0.71	30/07/2009				17/09/2009					
EO39	Shallow		dry at 1.36			30/07/2009				17/09/2009					Original Location on Island: Post - Driver broke during first attempt on 9/07/09. Also had issues with the slotted casing falling back down into the drive point housing. Piezometers are in the ground awaiting completion. THESE ARE DRY.
	Deep		dry at 2.39			30/07/2009				17/09/2009					
EO40	Shallow		1.13	0.94	-0.94	30/07/2009	1.2	1.01	-1.01	17/09/2009	1.23	1.04	-1.04	27/10/2009	Sandy claypan environment. Patchy saltbush.
	Deep		1.6	0.93	-0.93	30/07/2009	1.69	1.02	-1.02	17/09/2009	1.66	1.03	-1.03	27/10/2009	
EO41	Shallow		0.99	0.59	-0.59	30/07/2009	dry			17/09/2009	dry			17/10/2009	Patchy salt scrub vegetation on sandy-calyey ground. (Handles of second post driver broke here, had to get welded custom made heavy duty one).
	Deep		1.12	0.53	-0.53	30/07/2009	1.22	0.63	-0.63	17/09/2009	1.28	0.69	-0.69	17/10/2009	
EO42	Shallow	1.27	dry			30/07/2009	1.75	1.34	-0.07	17/09/2009	dry			27/10/2009	Sandy claypan environment. Patchy saltbush.
	Deep	1.27	1.41	0.95	0.32	30/07/2009	dry			17/09/2009	0.64	0.18	1.09	27/10/2009	
EO43	Shallow	0.99	0.83	0.55	0.44	30/07/2009	1	0.72	0.27	17/09/2009	1.08	0.8	0.19	21/10/2009	Location moved. Patchy salt scrub vegetation on sandy-clayey ground, water in claypan about 100m SE from site. Hit hard ground , could not drive further down. End of piezometer only moist.
	Deep	1.00	1.27	0.56	0.44	30/07/2009	1.45	0.74	0.26	17/09/2009	1.52	0.81	0.19	21/10/2009	
EO44	Shallow	1.06	0.96	0.48	0.58	30/07/2009	dry			17/09/2009	dry			18/10/2009	Location moved. Patchy salt scrub vegetation on sandy-clayey ground.
	Deep	1.10	1.41	1.31	-0.21	30/07/2009	0.69	0.59	0.51	17/09/2009	0.7	0.6	0.50	18/10/2009	
EO45	Shallow		dry			30/07/2009				17/09/2009					Deep hole relocated close to E029 because at original site unable to go deeper than 1.30m. Both patchy claypan environments with water.
	Deep	1.00	0.66	0.56	0.44	30/07/2009	0.8	0.7	0.30	17/09/2009	0.86	0.76	0.24	23/10/2009	
EO53	Shallow	1.32	dry			30/07/2009				17/09/2009					Phase 1 Bore. Deep Piezometer could not be installed because ground too hard (thread broke).
E054	Shallow						0.53	0.53	-0.53						
	Deep		0.37	0.2		30/07/2009				18/09/2009	0.48	0.31	-0.31	27/10/2009	Phase 1 Bore at norhtern tip of big island. Could not get past 2m.
E055	Shallow	7.80	dry			30/07/2009	dry			17/09/2009	dry			27/10/2009	Location halfway up the dune west of site E006, dry.
EO56	Shallow	1.43	1.07	0.97	0.46	40024	1.16	1.06	0.37	18/09/2009	1.22	1.12	0.31	27/10/2009	Relocated unsuccessful E039 to SE of E026: patchy salt bush, some grass under growth on sandy-clayey ground.
	Deep	1.44	1.05	0.93	0.51	40024	1.14	1.02	0.42	18/09/2009	1.2	1.08	0.36	27/10/2009	

C

Appendix C Pump Test Analysis

URS

42907466/WHST-STU-WA-RPT-0090/0

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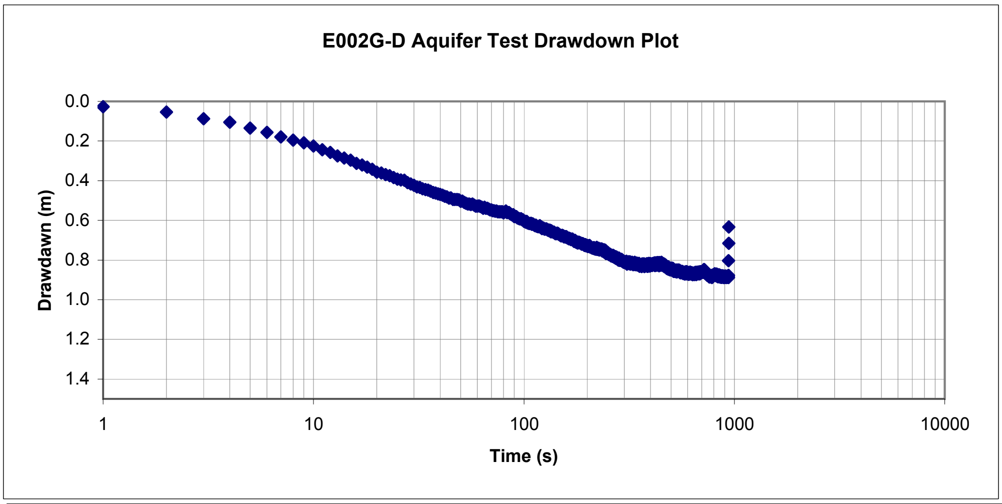
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Drawdown (m)
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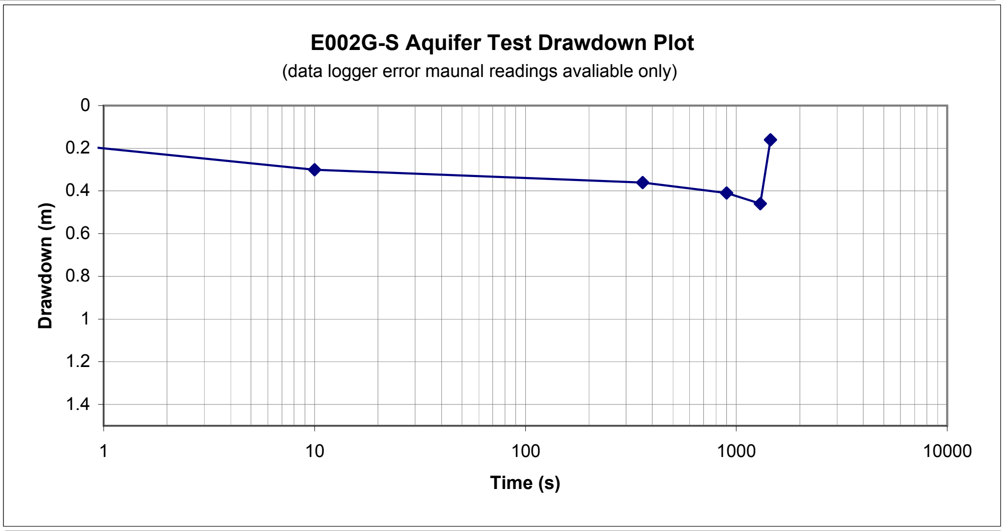
0.8
1.0
1.2
1.4
1
10
100
1000
10000
Time (s)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(data logger error maunal readings avaliable only)
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0.8
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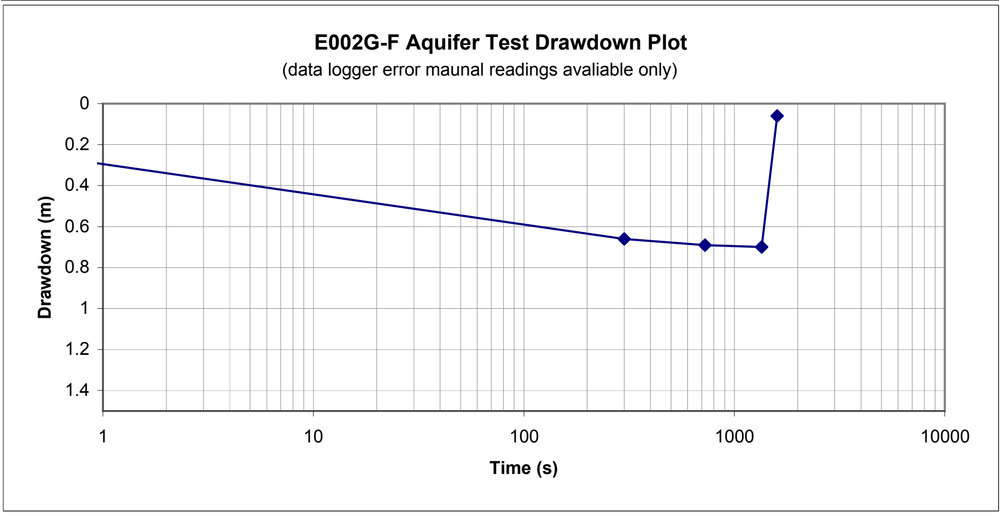
1.2
1.4
1
10
100
1000
10000
Time (s)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(data logger error maunal readings avaliable only)
Drawdown (m)
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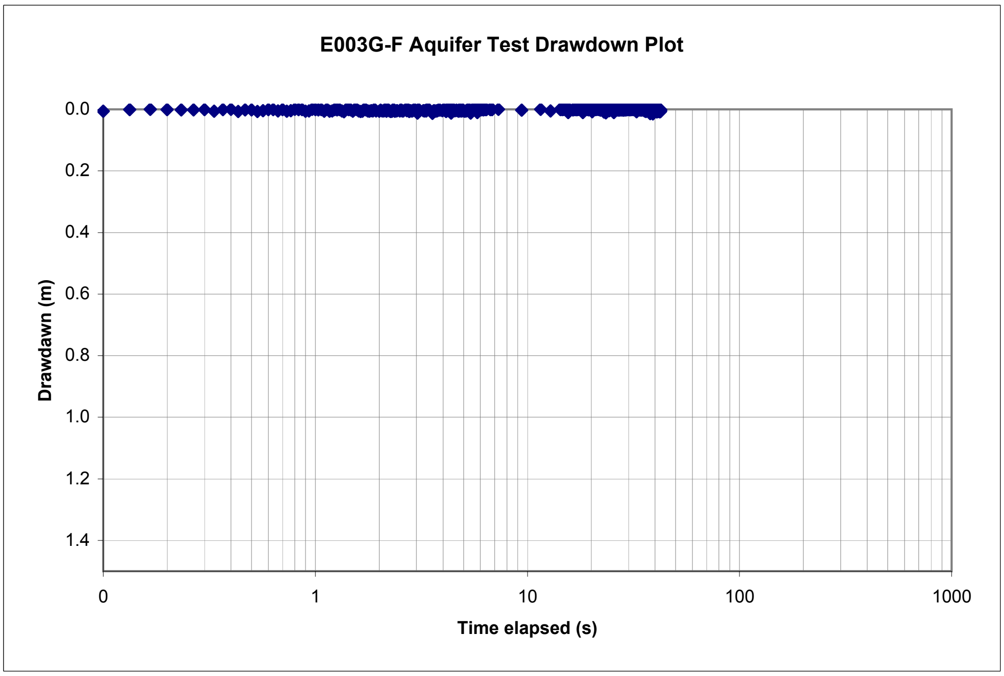
0.2
0.4
0.6
0.8
1
1.2
1.4
1
10
100
1000
10000
Time (s)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Drawdown (m)
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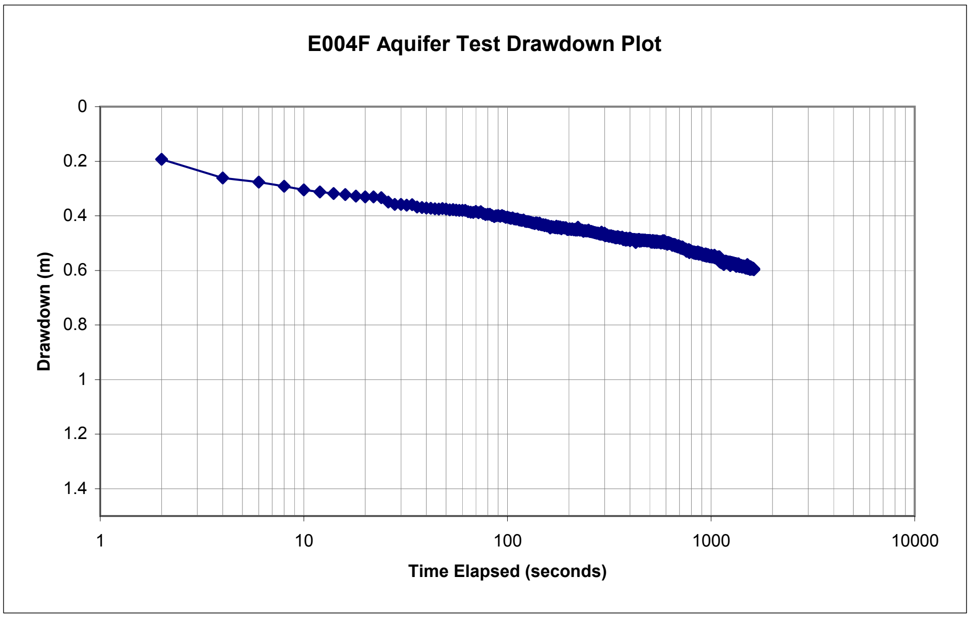
0.6
0.8
1.0
1.2
1.4
0
1
10
100
1000
Time elapsed (s)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Drawdown (m)
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0.4
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0.8
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1.2
1.4
1
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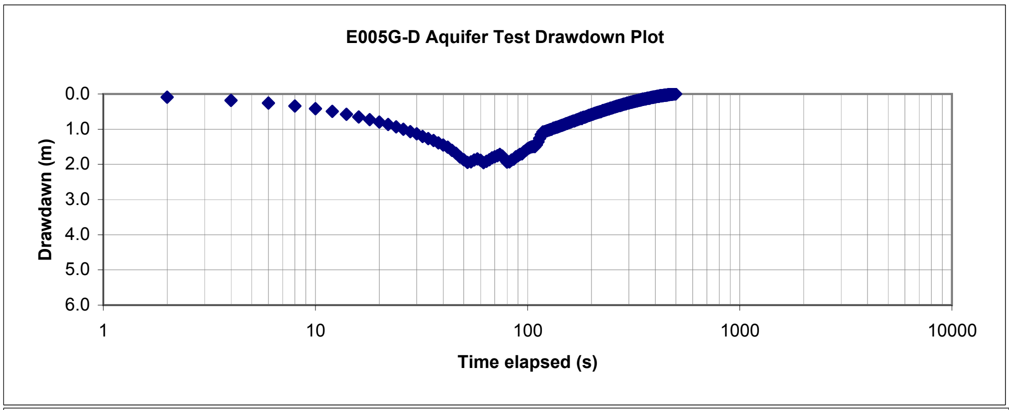
100
1000
10000
Time Elapsed (seconds)


E005G-D Aquifer Test Drawdown Plot
Drawdown (m)
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2.0
3.0
4.0
5.0
6.0
1
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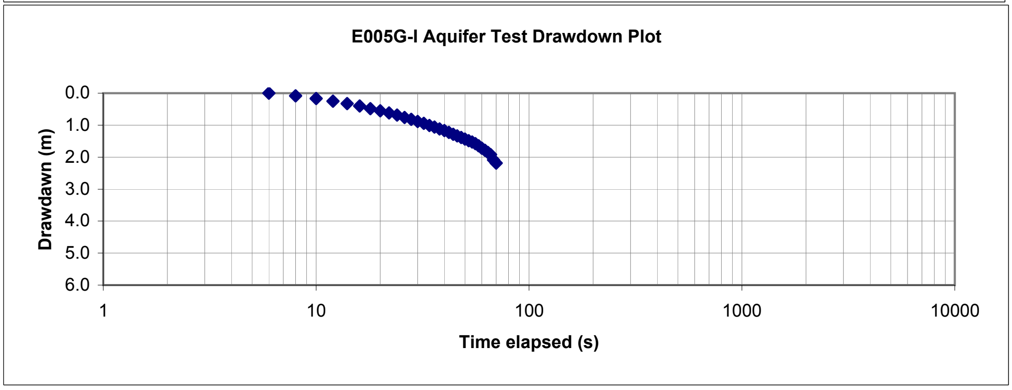
100
1000
10000
Time elapsed (s)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Drawdown (m)
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5.0
6.0
1
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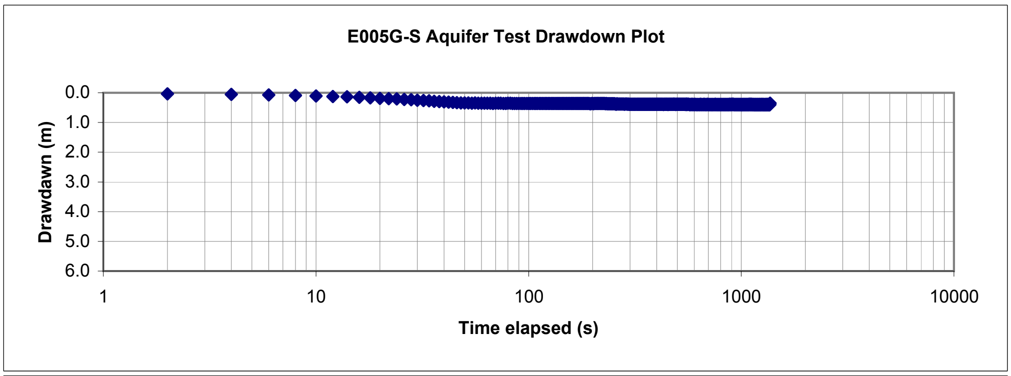
100
1000
10000
Time elapsed (s)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Drawdown (m)
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4.0
5.0
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1
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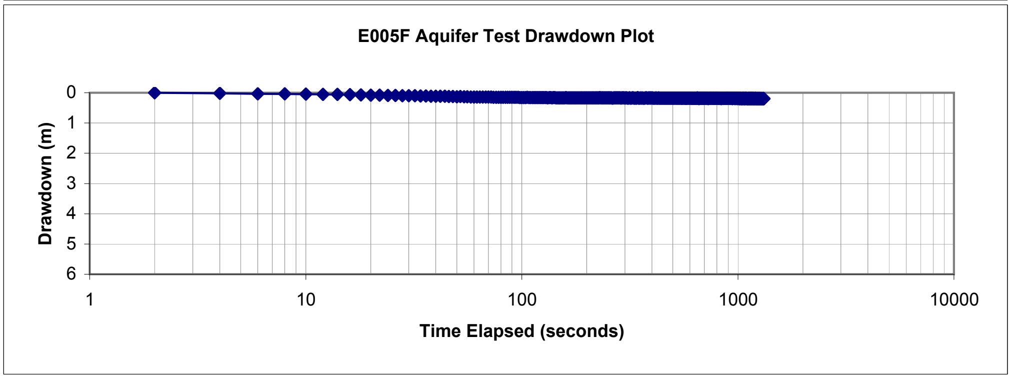
100
1000
10000
Time elapsed (s)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2
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4
5
6
1
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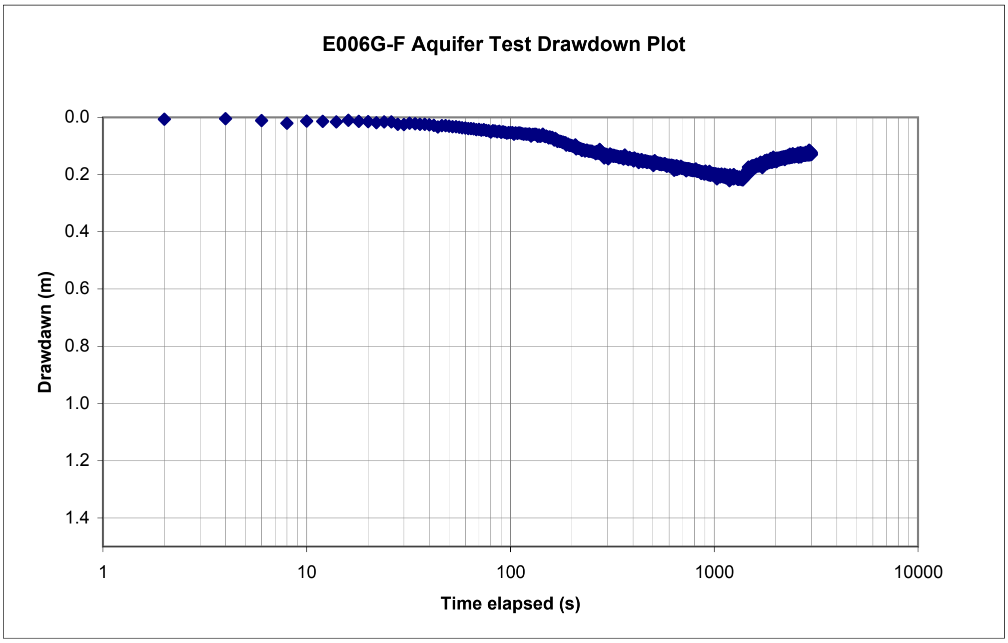
100
1000
10000
Time Elapsed (seconds)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Drawdown (m)
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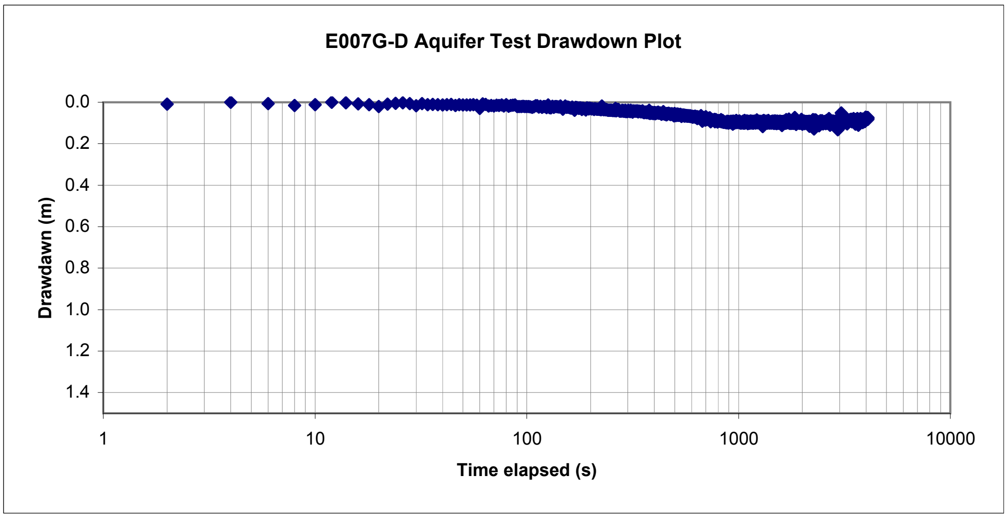
1.2
1.4
1
10
100
1000
10000
Time elapsed (s)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1.2
1.4
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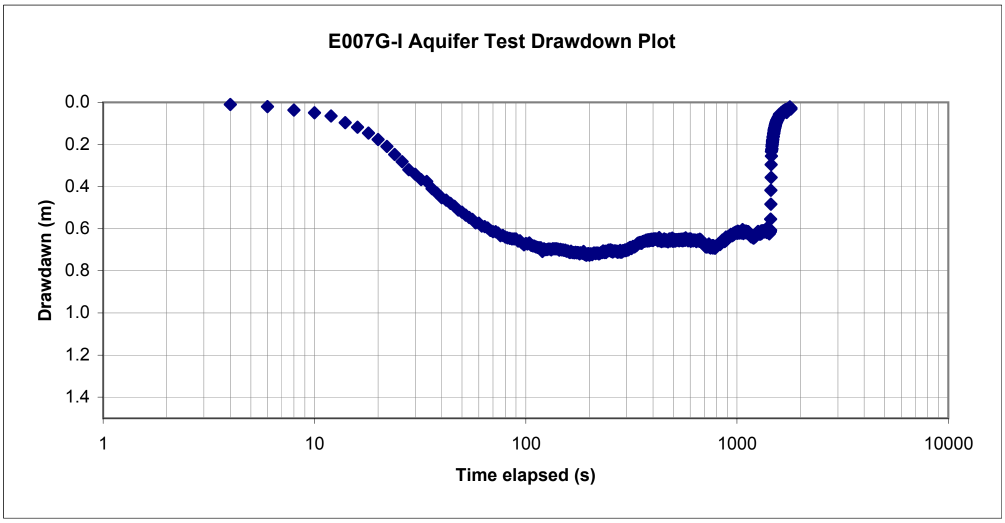
100
1000
10000
Time elapsed (s)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Drawdown (m)
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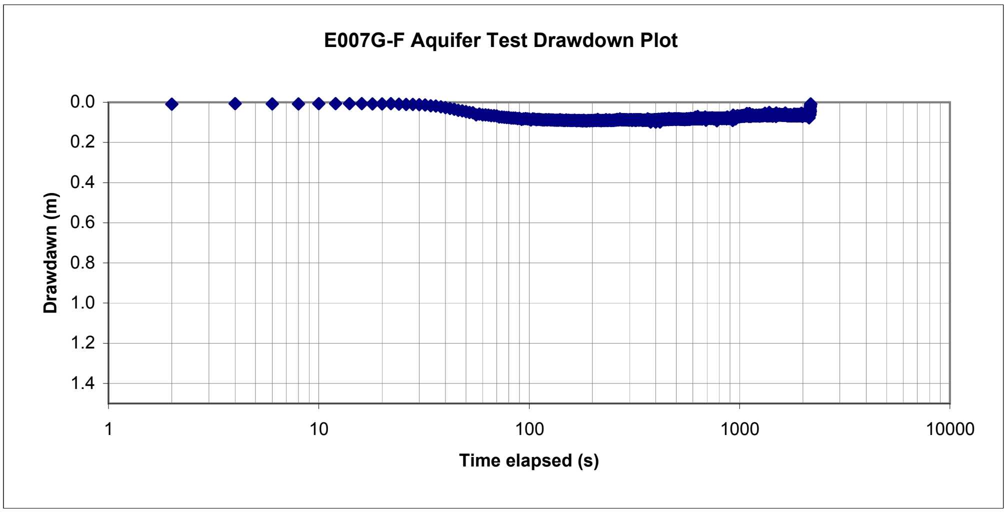
1.0
1.2
1.4
1
10
100
1000
10000
Time elapsed (s)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Drawdown (m)
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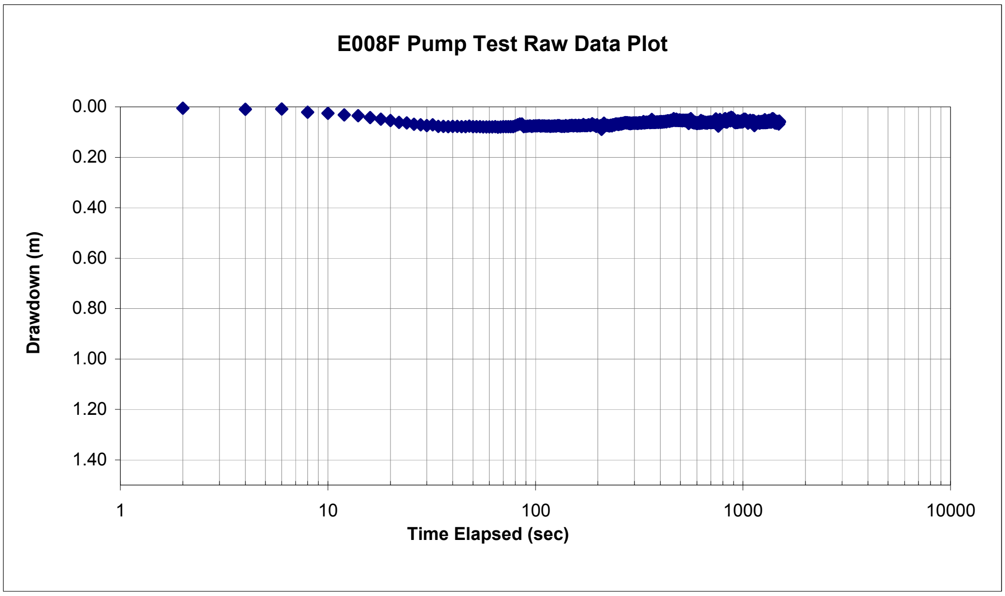
0.4
0.6
0.8
1.0
1.2
1.4
1
10
100
1000
10000
Time elapsed (s)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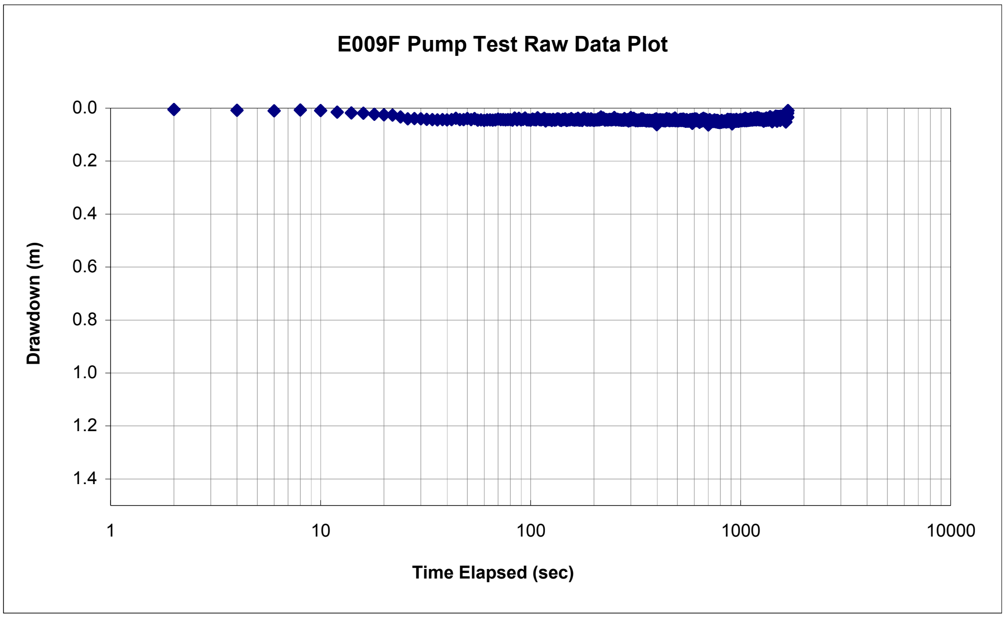
1.20
1.40
1
10
100
1000
10000
Time Elapsed (sec)


E009F Pump Test Raw Data Plot
Drawdown (m)
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0.6
0.8
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1.4
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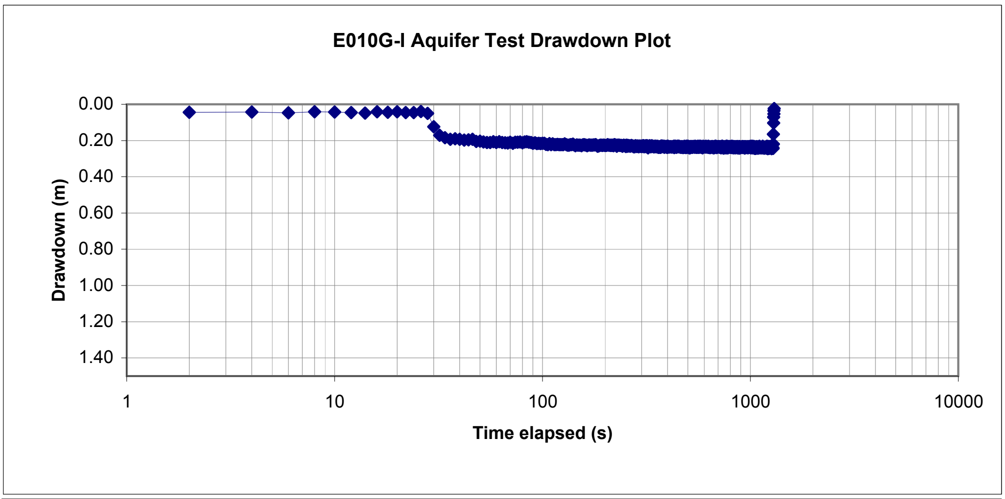
10
100
1000
10000
Time Elapsed (sec)



E010G-I Aquifer Test Drawdown Plot
Drawdown (m)
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1.00
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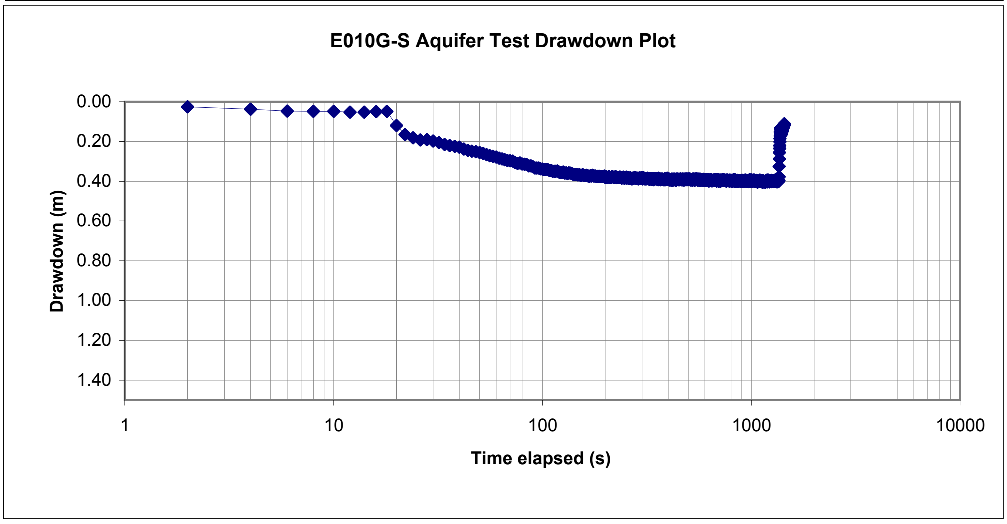
100
1000
10000
Time elapsed (s)



E010G-S Aquifer Test Drawdown Plot
Drawdown (m)
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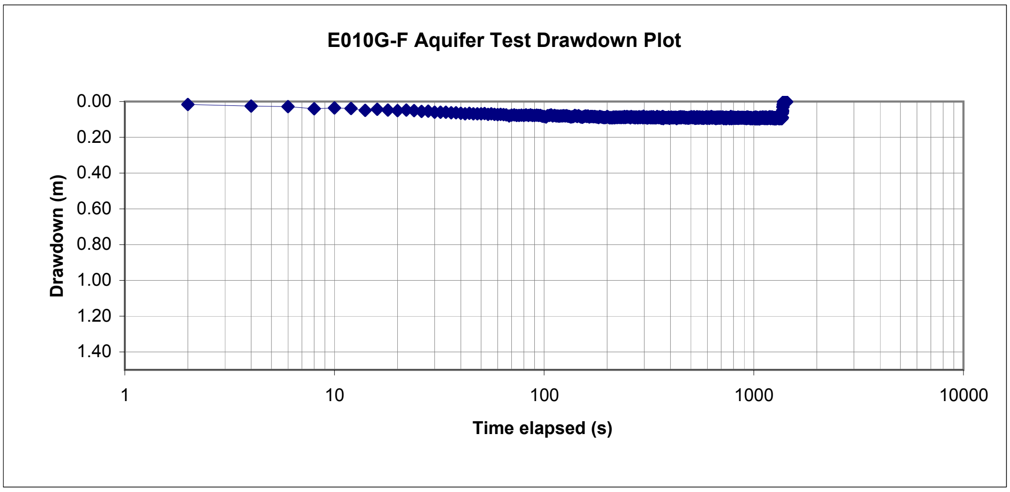
1
10
100
1000
10000
Time elapsed (s)



E010G-F Aquifer Test Drawdown Plot
Drawdown (m)
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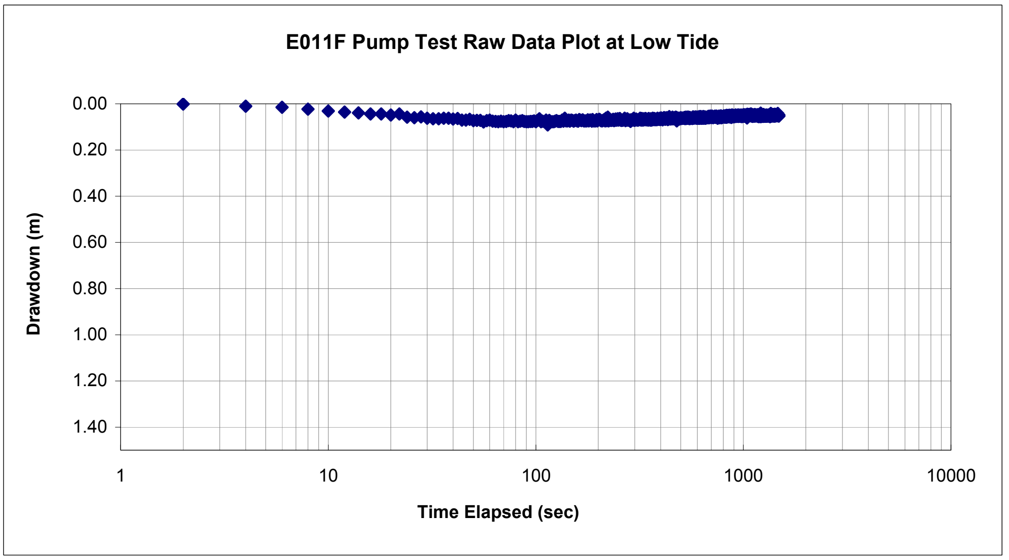
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)


E011F Pump Test Raw Data Plot at Low Tide
Drawdown (m)
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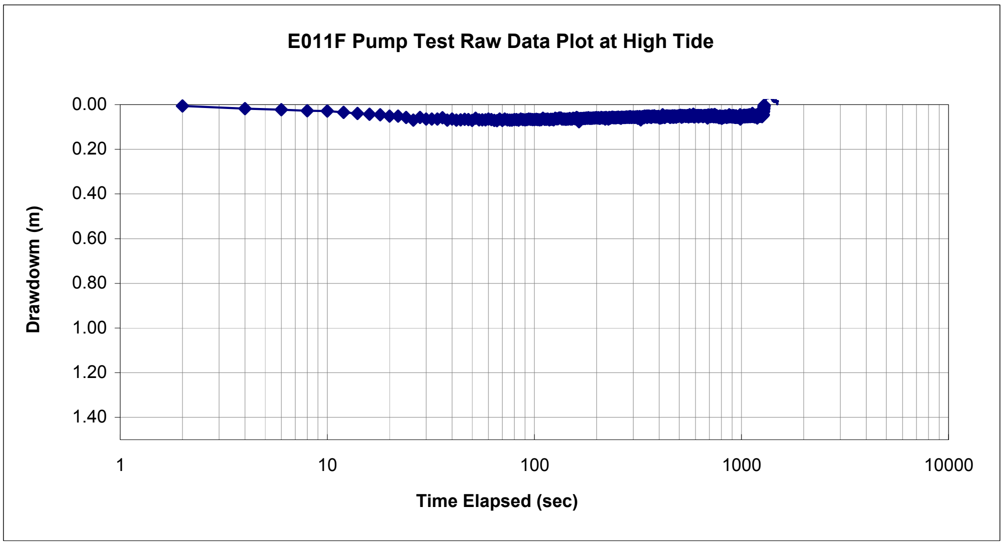
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time Elapsed (sec)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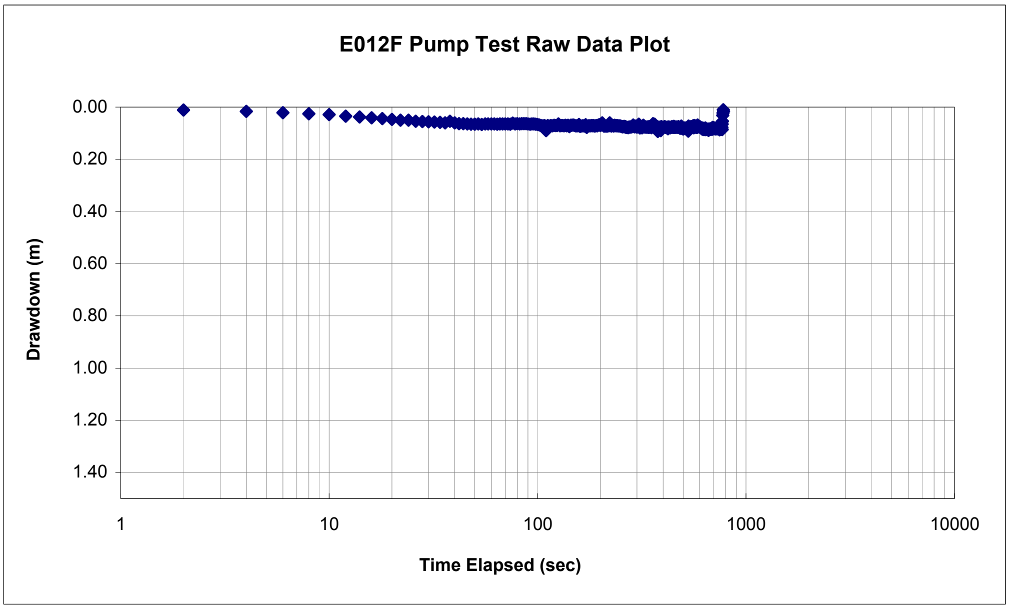
100
1000
10000
Time Elapsed (sec)


E012F Pump Test Raw Data Plot
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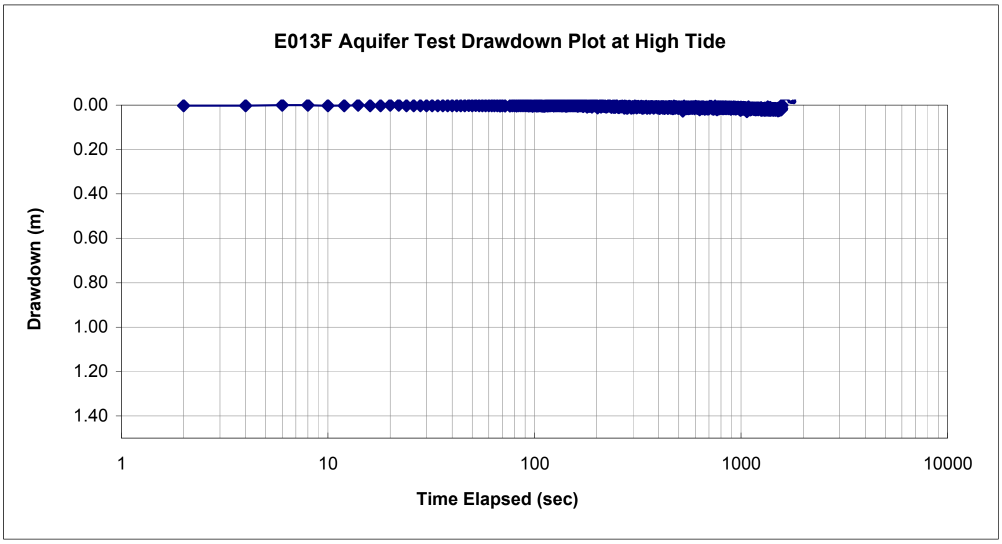
1.40
1
10
100
1000
10000
Time Elapsed (sec)


E013F Aquifer Test Drawdown Plot at High Tide
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0.60
0.80
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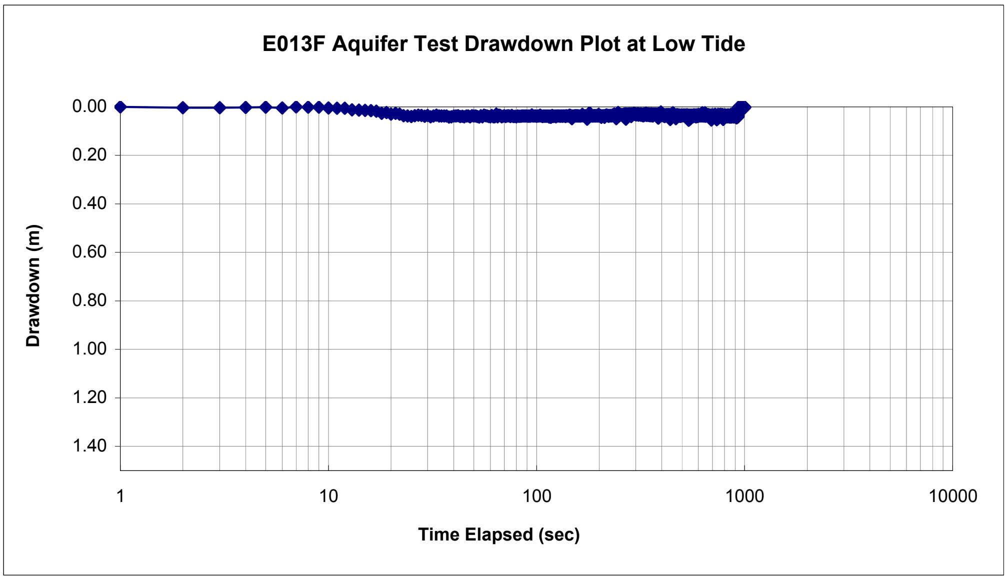
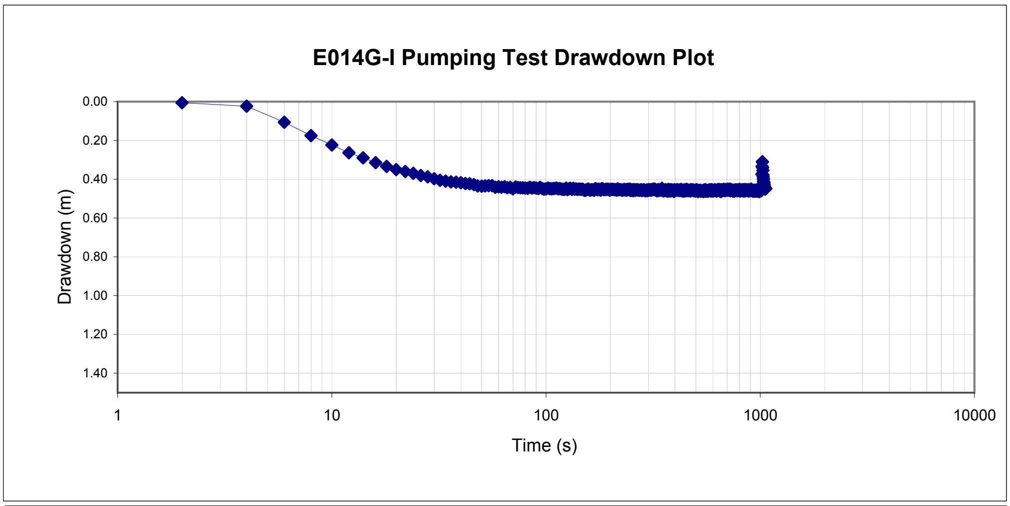
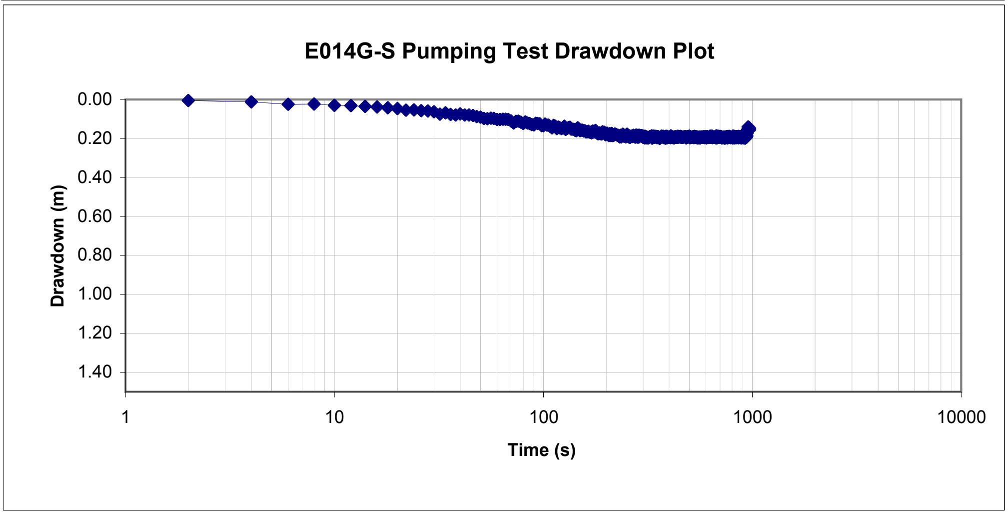
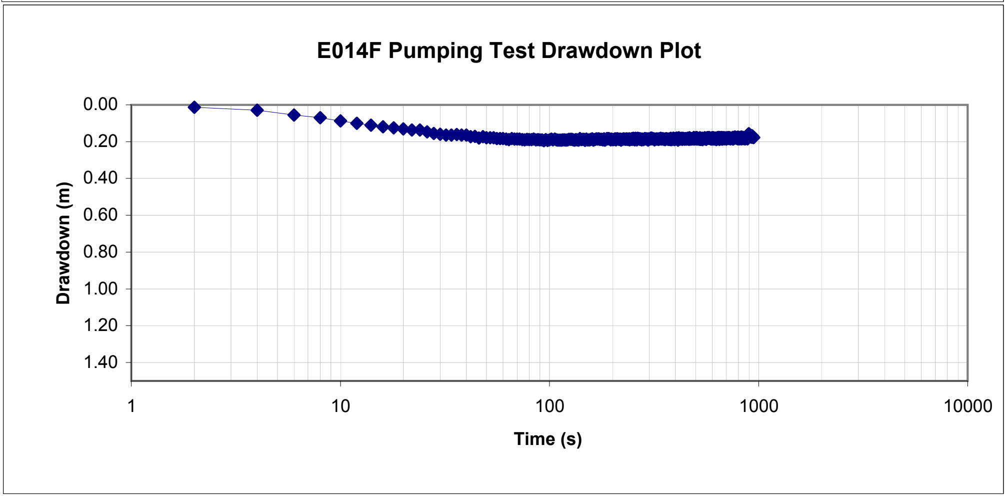
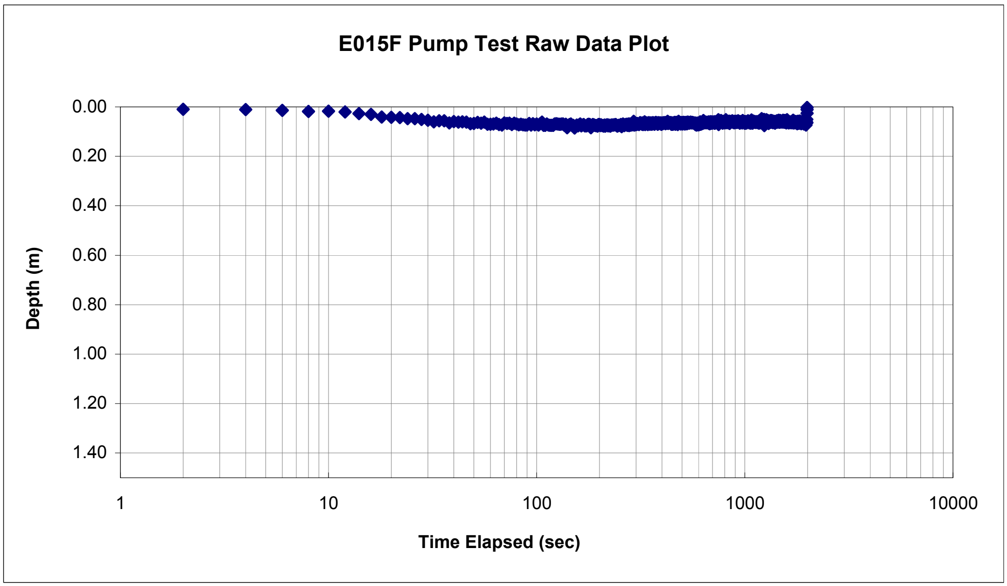
1.20
1.40
1
10
100
1000
10000
Time Elapsed (sec)

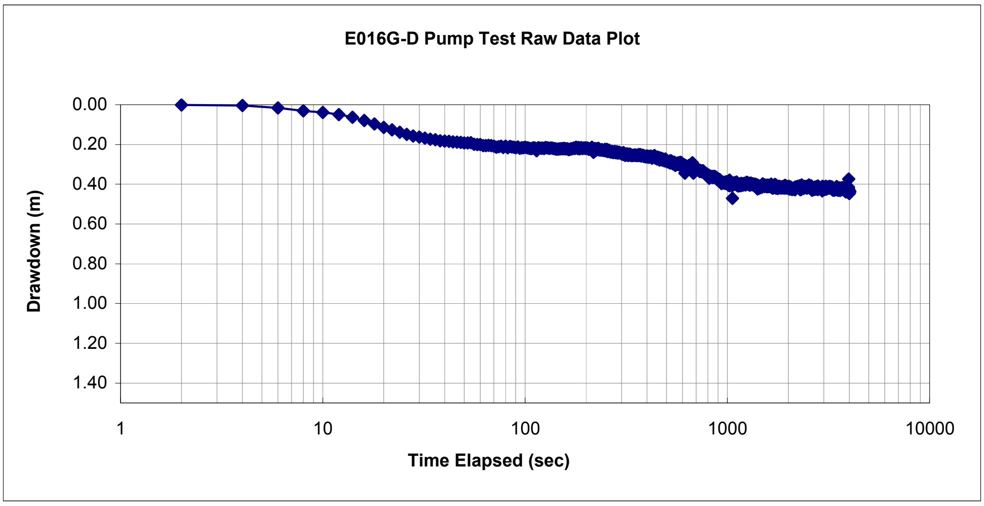

E013F Aquifer Test Drawdown Plot at Low Tide
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time Elapsed (sec)

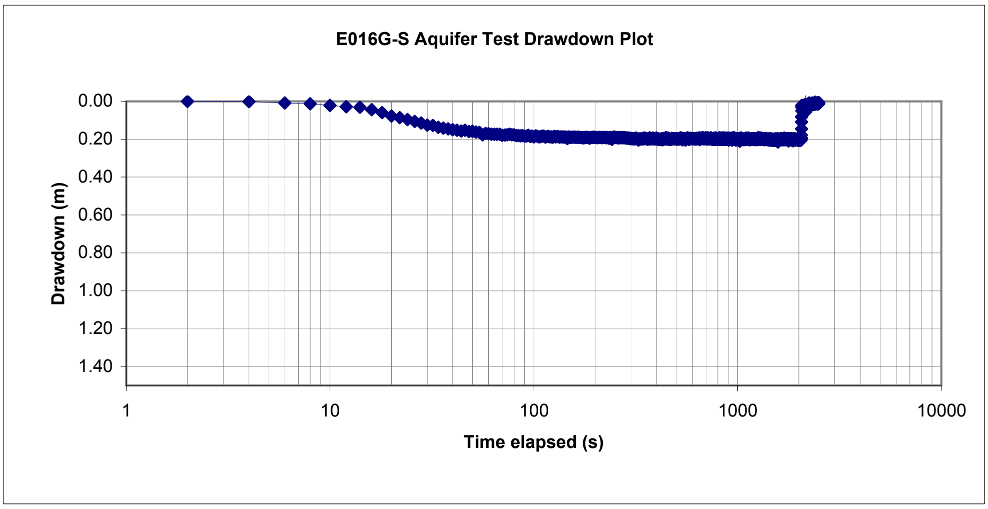

E014G-I Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

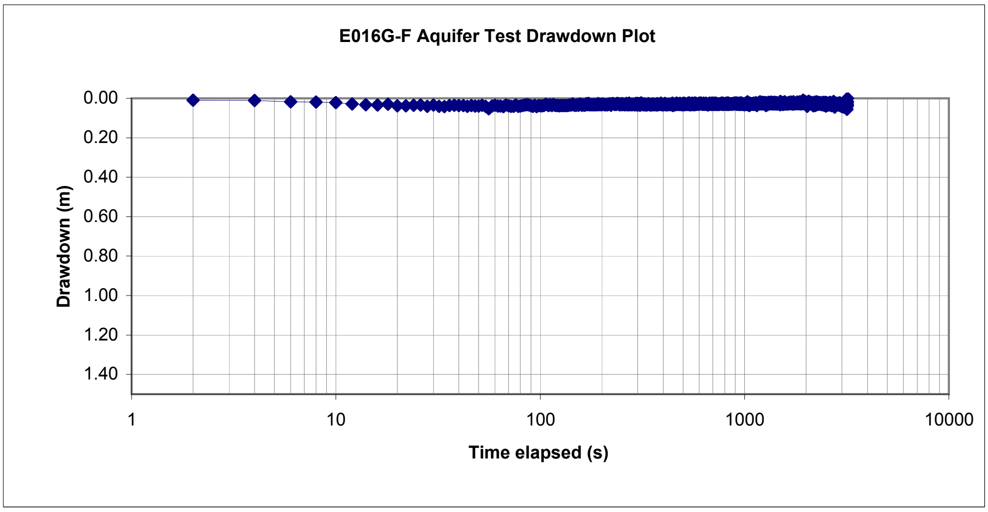

E014G-S Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

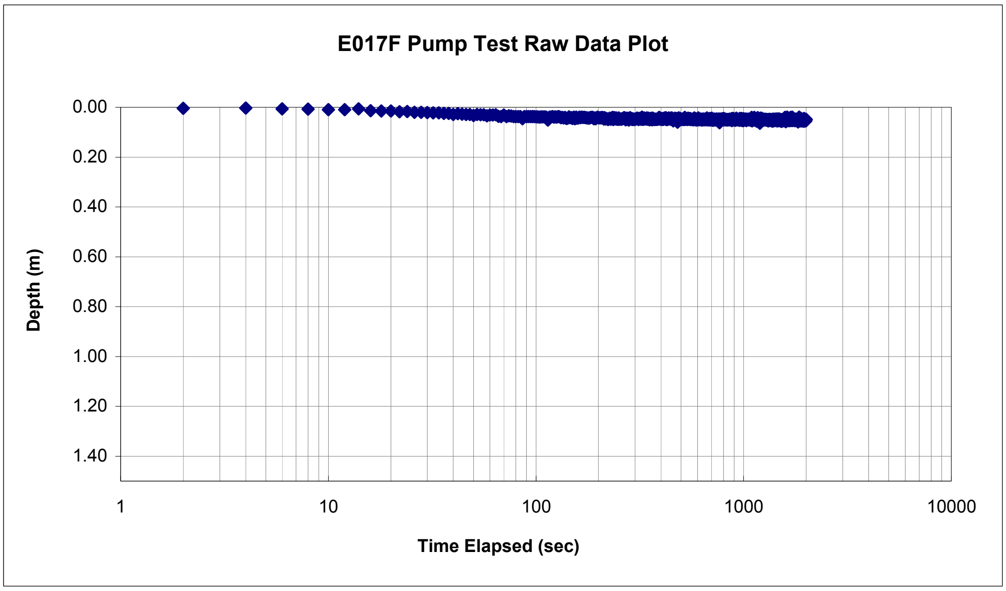

E014F Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)


E015F Pump Test Raw Data Plot
Depth (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time Elapsed (sec)

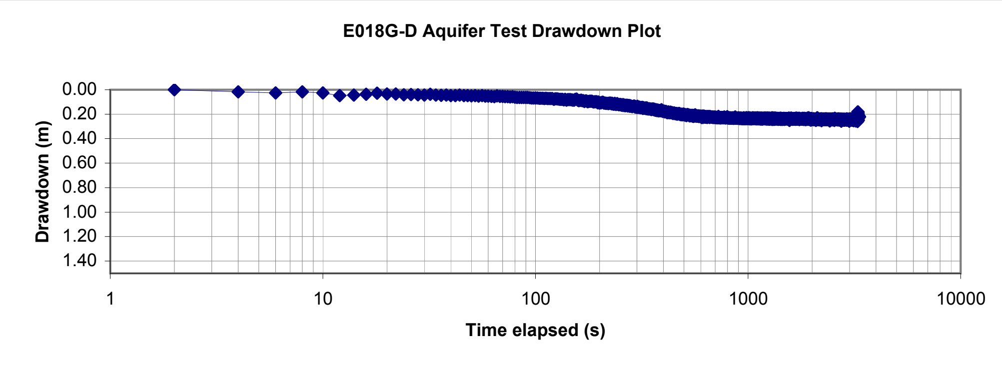

E016G-D Pump Test Raw Data Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time Elapsed (sec)

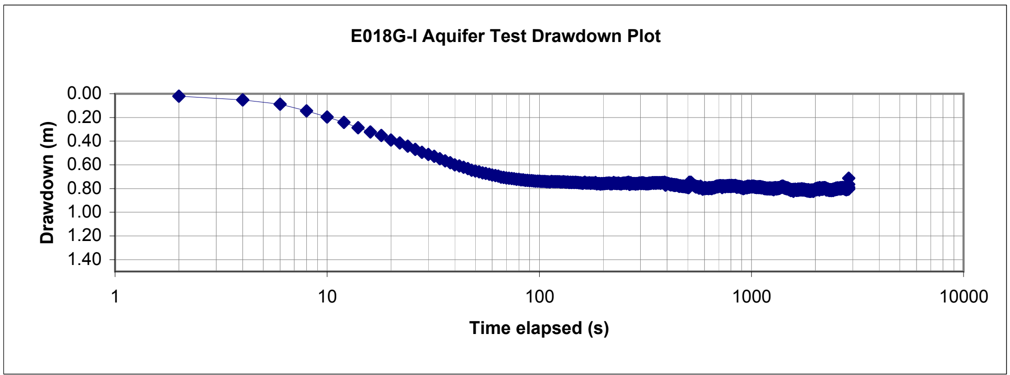

E016G-S Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)

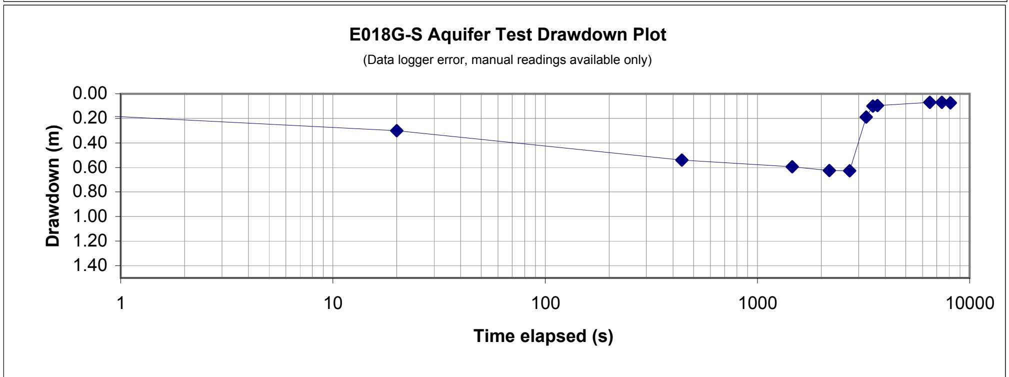

E016G-F Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)

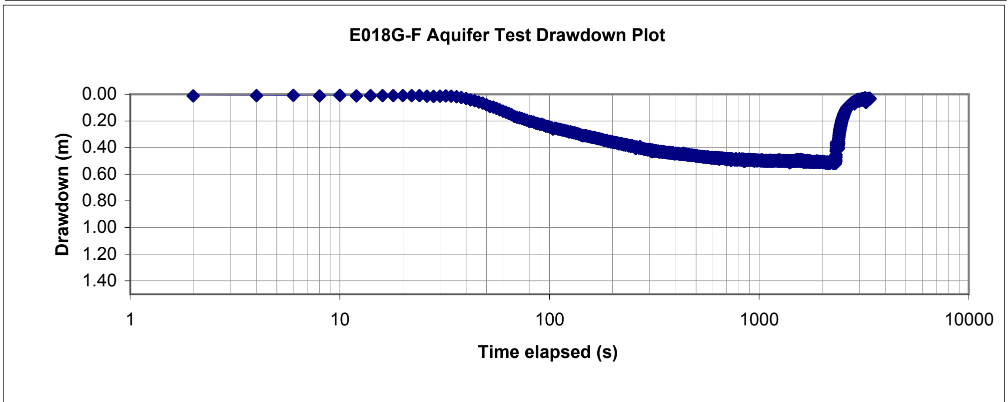


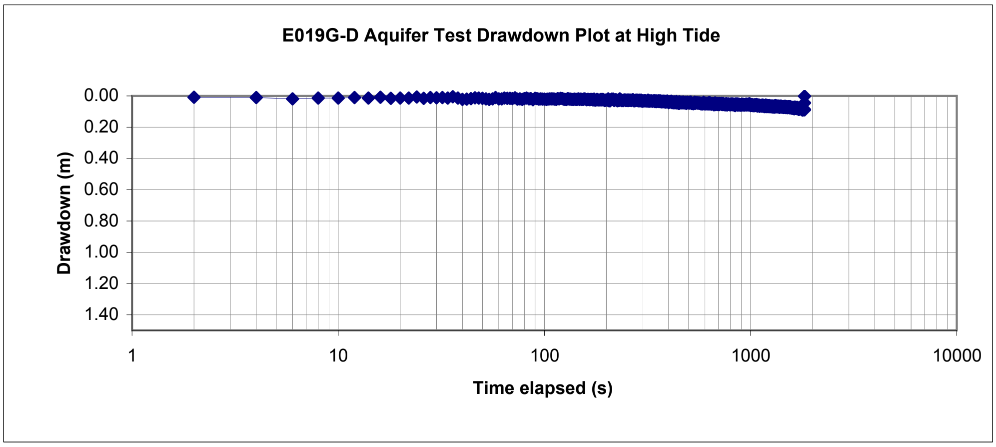
E017F Pump Test Raw Data Plot
Depth (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time Elapsed (sec)

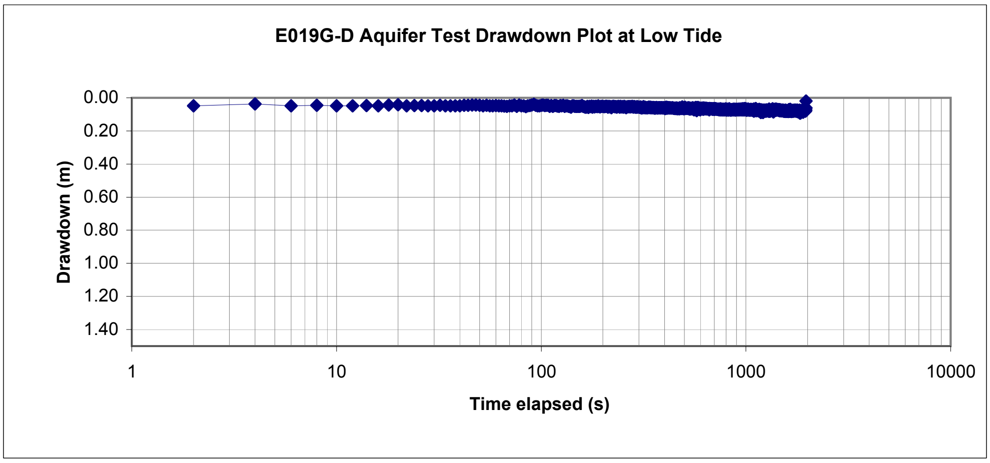

E018G-D Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)

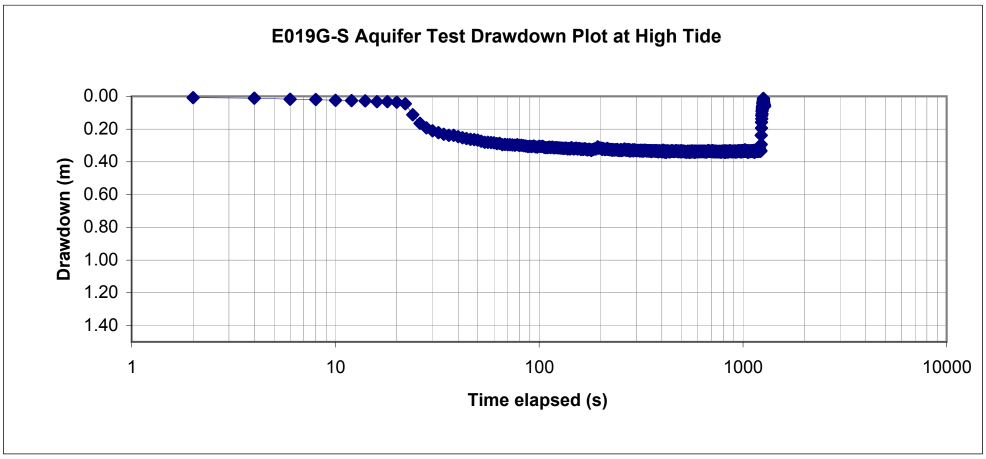

E018G-I Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)


E018G-S Aquifer Test Drawdown Plot
(Data logger error, manual readings available only)
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)

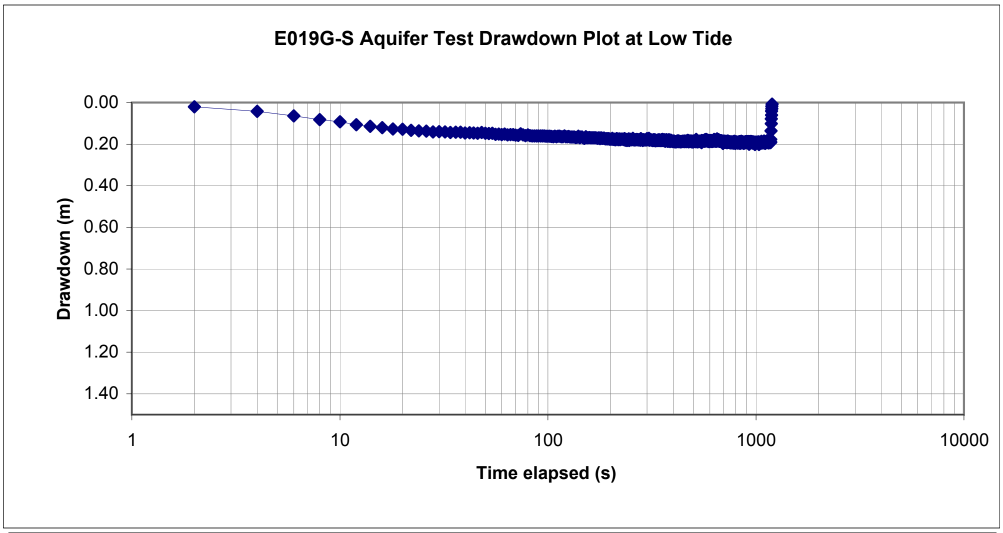

E018G-F Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)

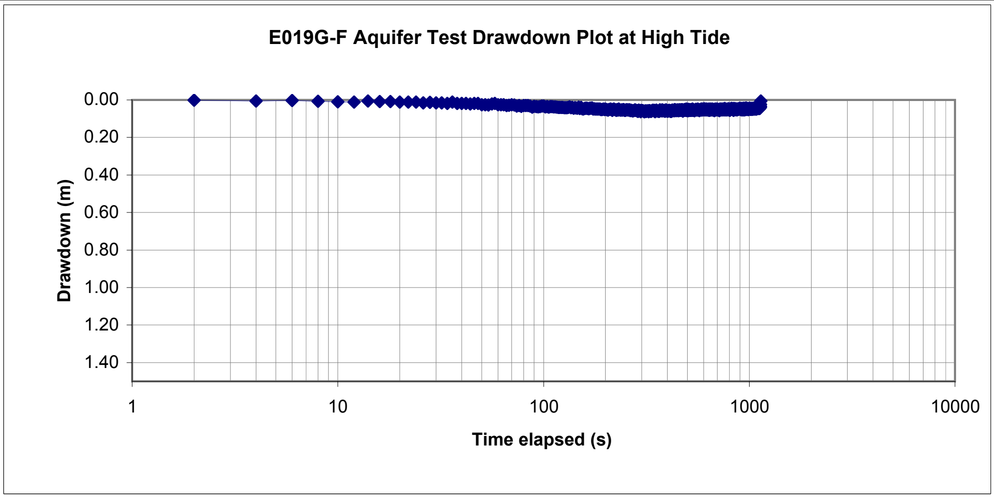


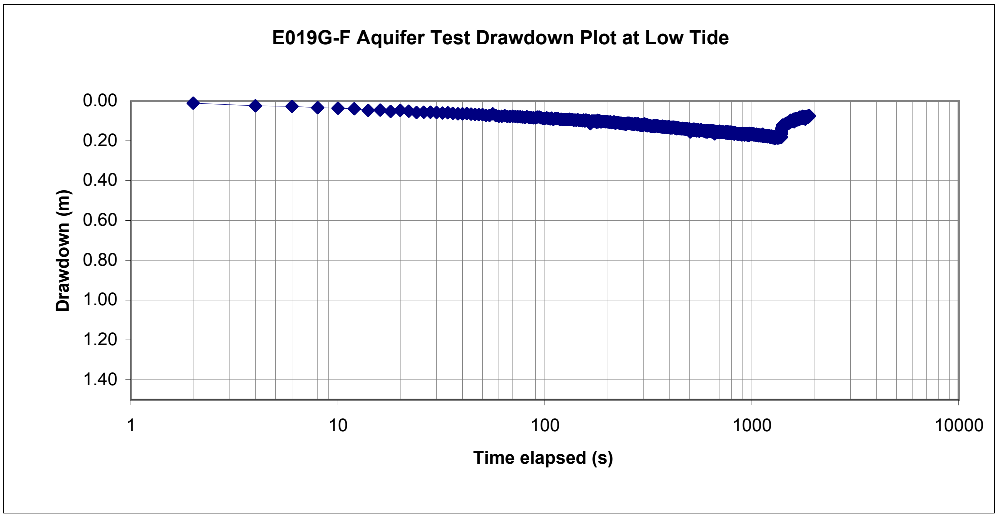


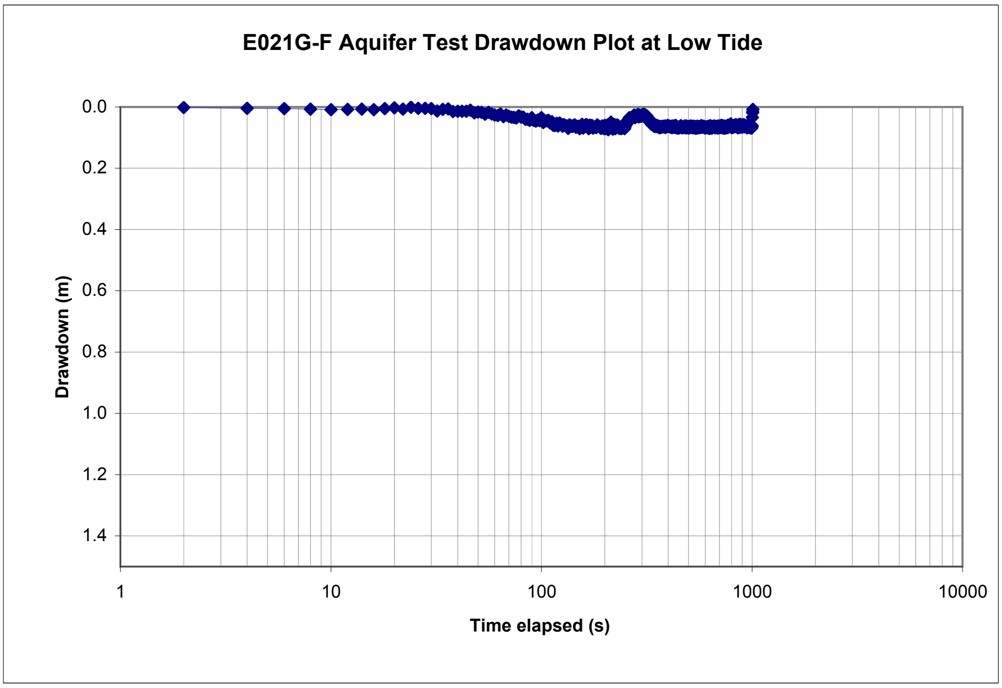


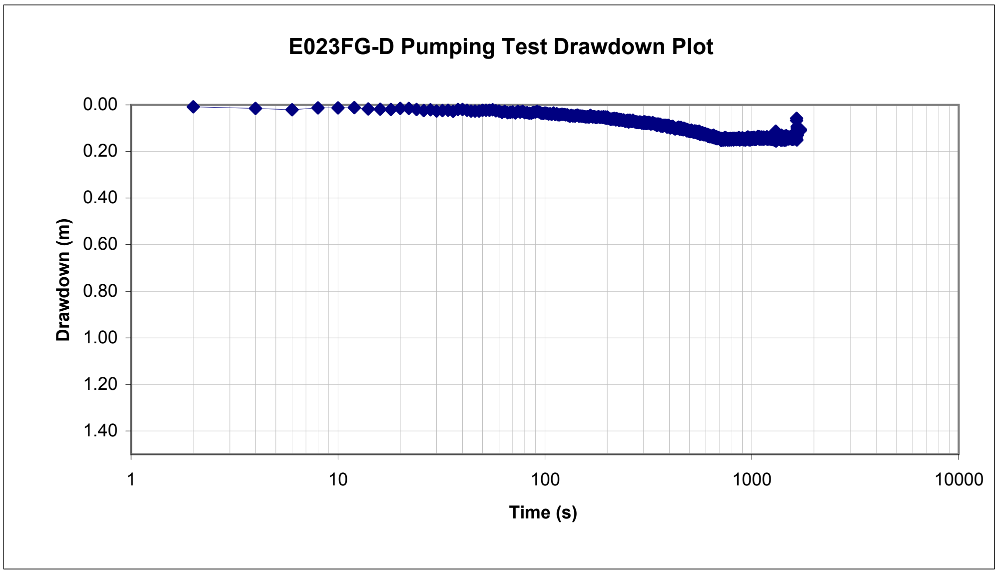
Drawdown plots for site E019 continued on next page

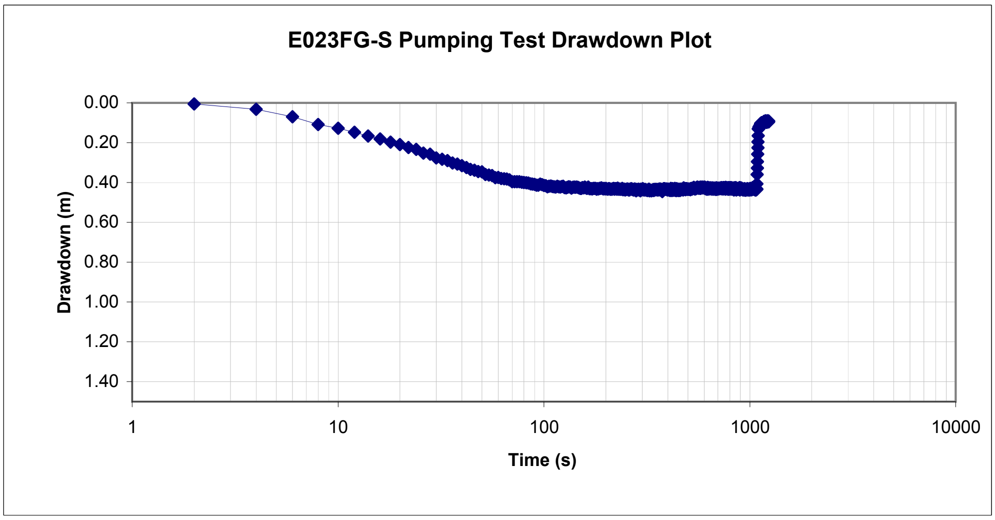

E019G-S Aquifer Test Drawdown Plot at Low Tide
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)

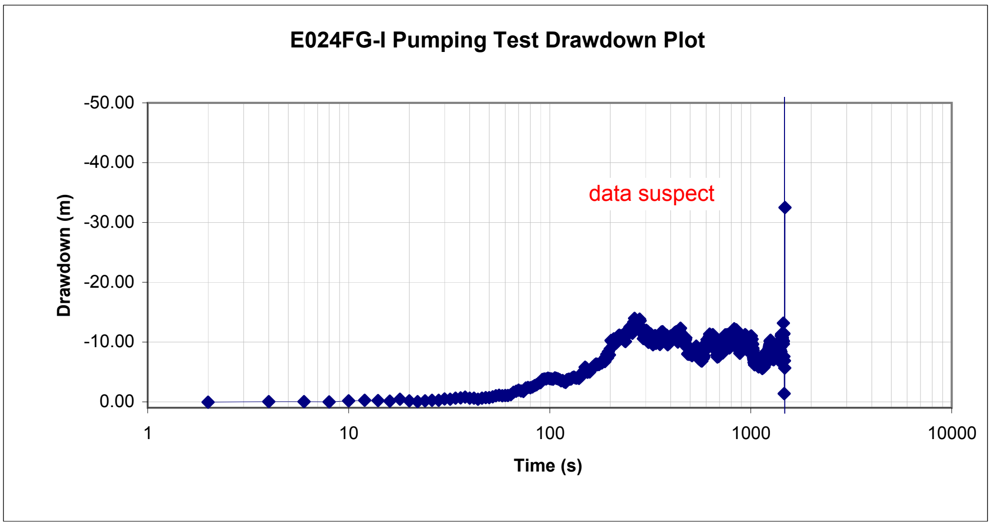

E019G-F Aquifer Test Drawdown Plot at High Tide
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)

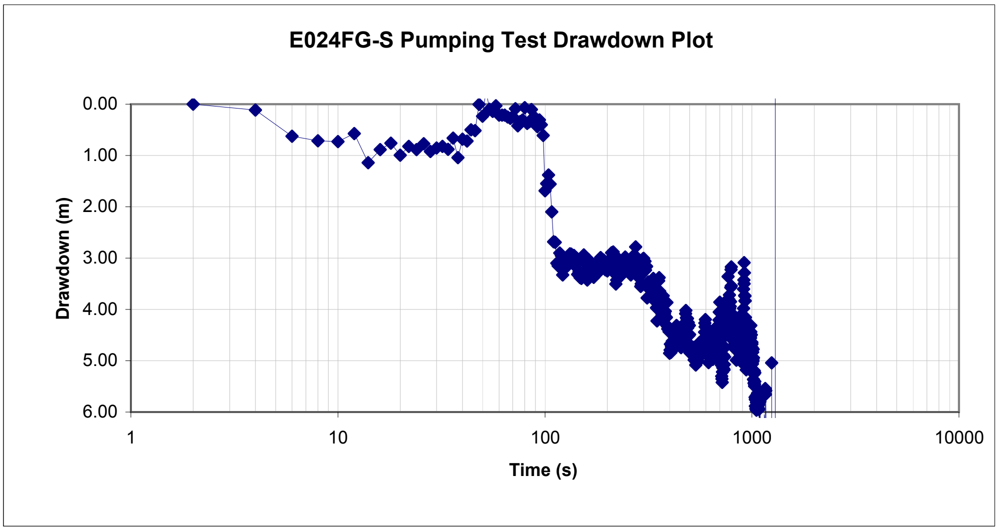

E019G-F Aquifer Test Drawdown Plot at Low Tide
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time elapsed (s)

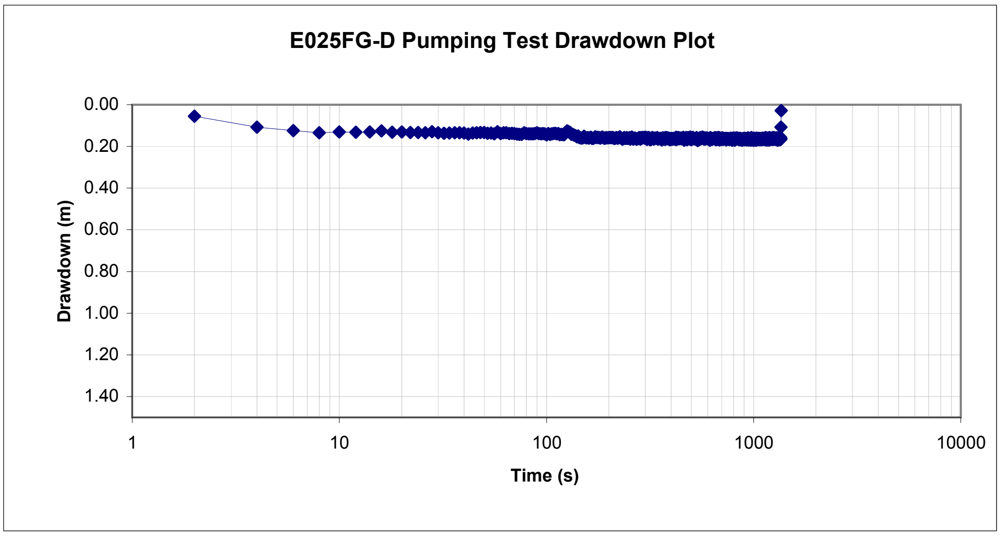

E021G-F Aquifer Test Drawdown Plot at Low Tide
Drawdown (m)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1
10
100
1000
10000
Time elapsed (s)

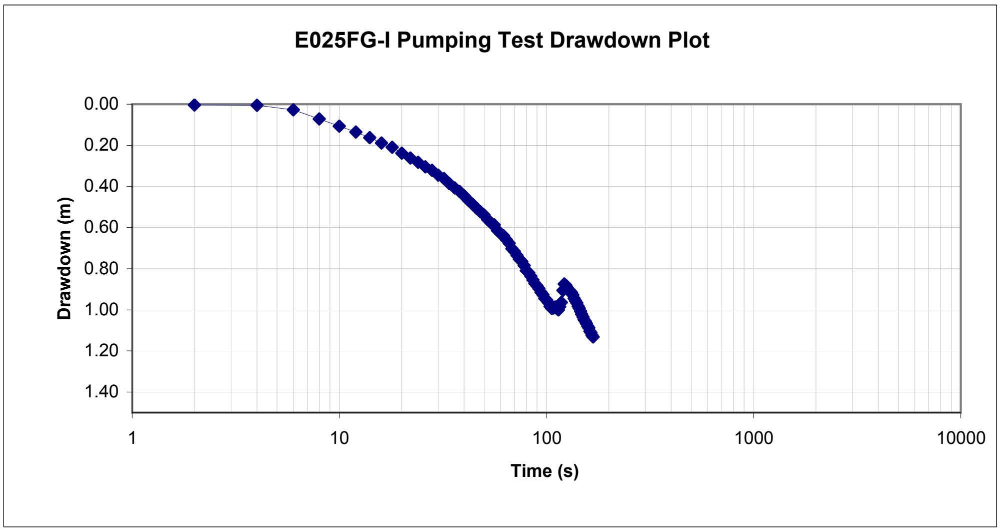

E023FG-D Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

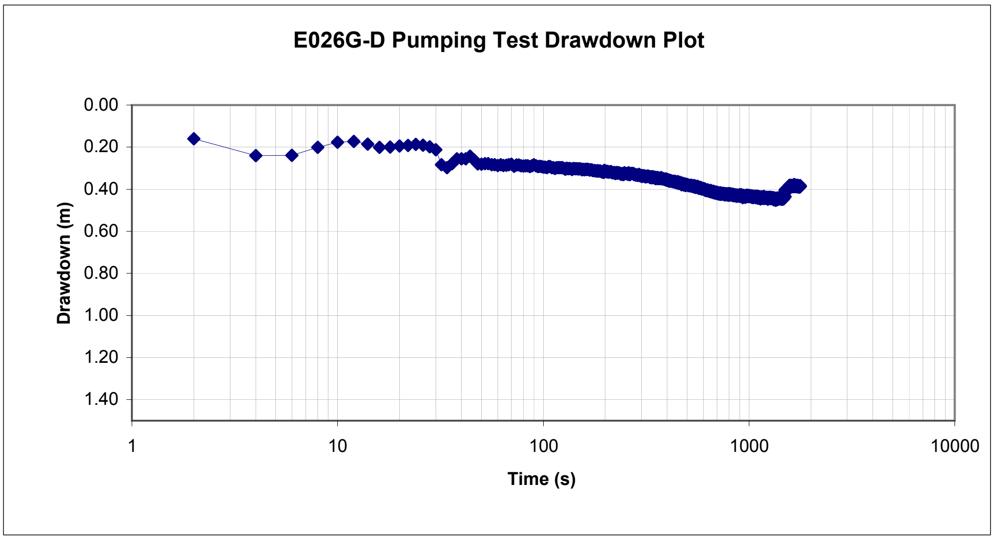

E023FG-S Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

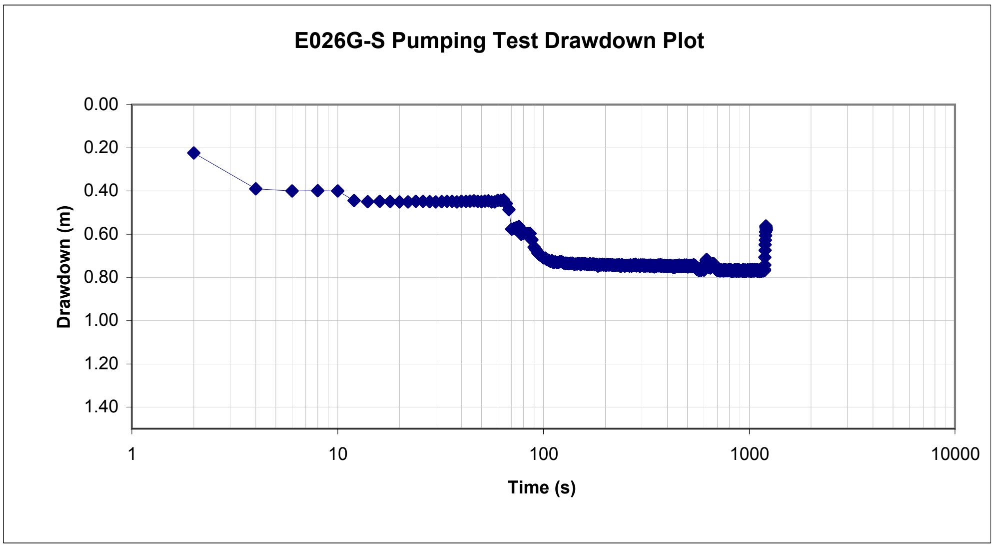

E024FG-I Pumping Test Drawdown Plot
Drawdown (m)
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
data suspect
1
10
100
1000
10000
Time (s)

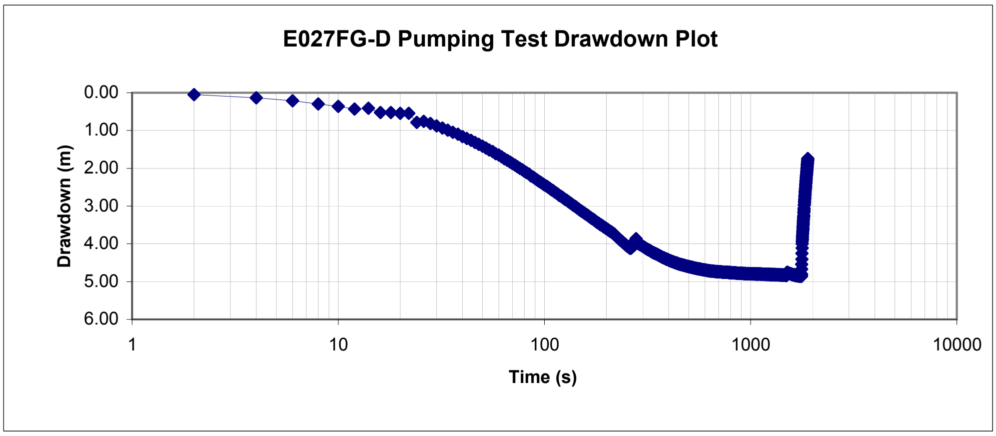

E024FG-S Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

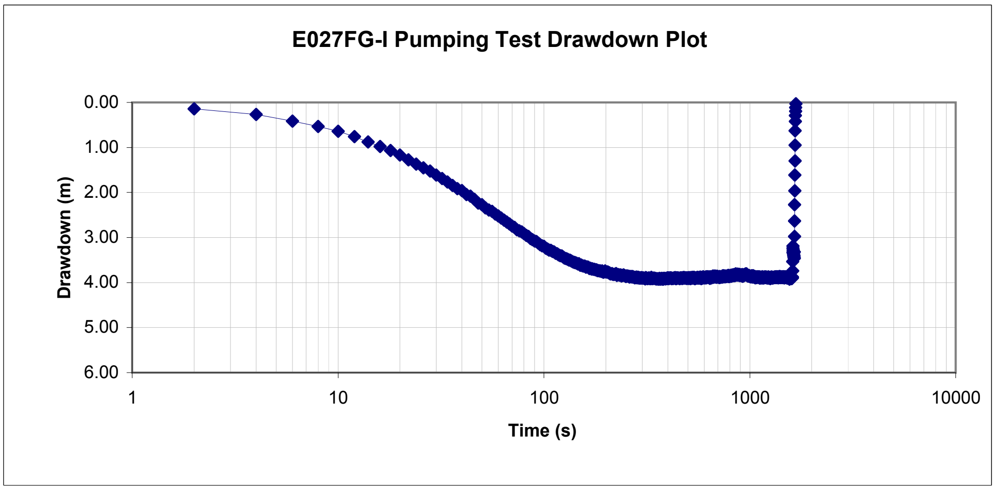

E025FG-D Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

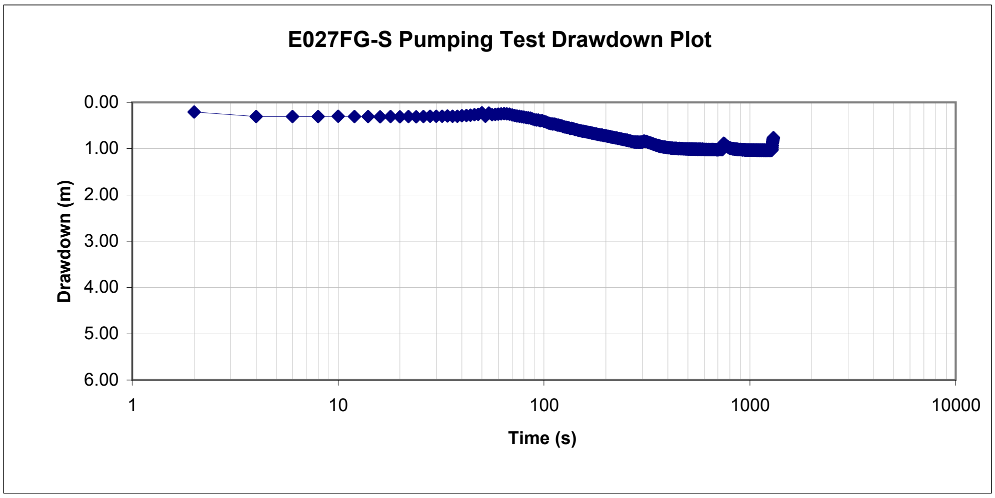

E025FG-I Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

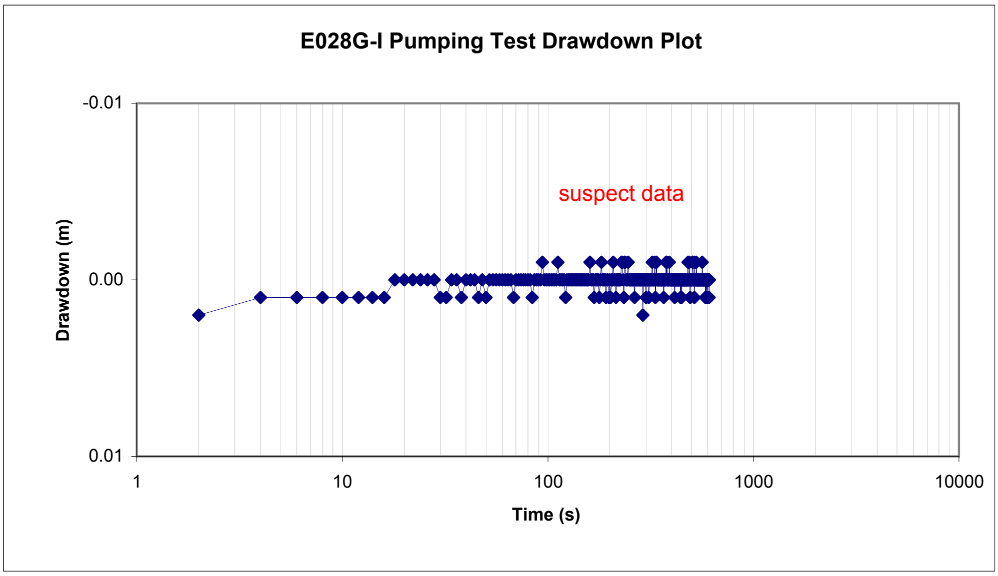

E026G-D Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

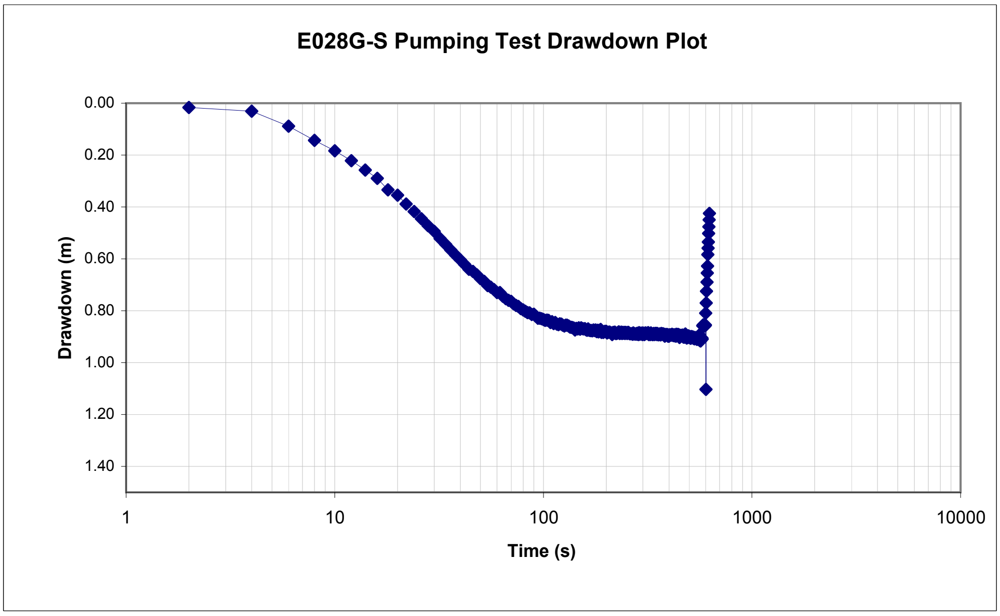

E026G-S Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

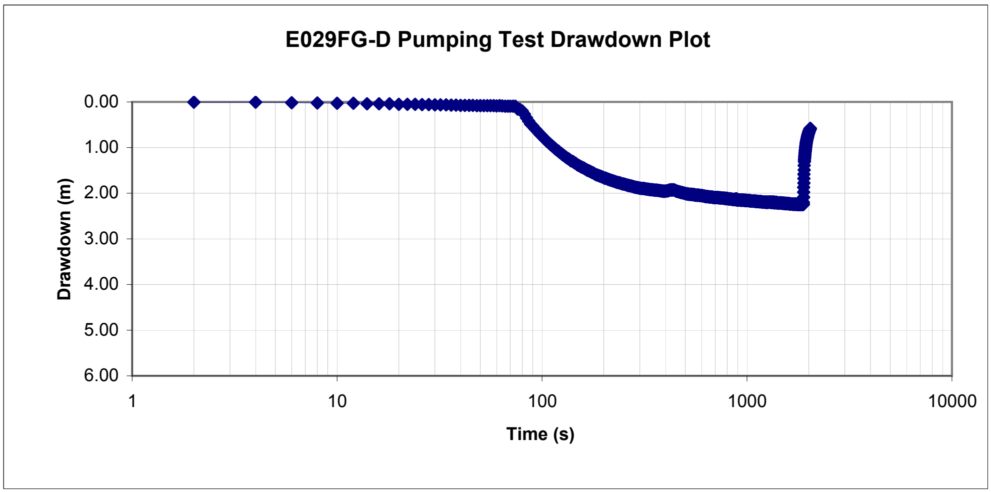

E027FG-D Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

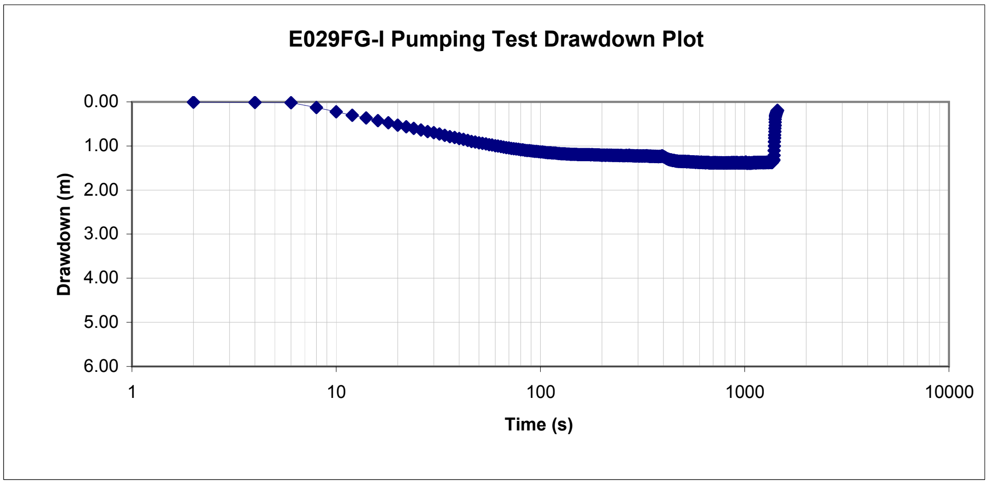

E027FG-I Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

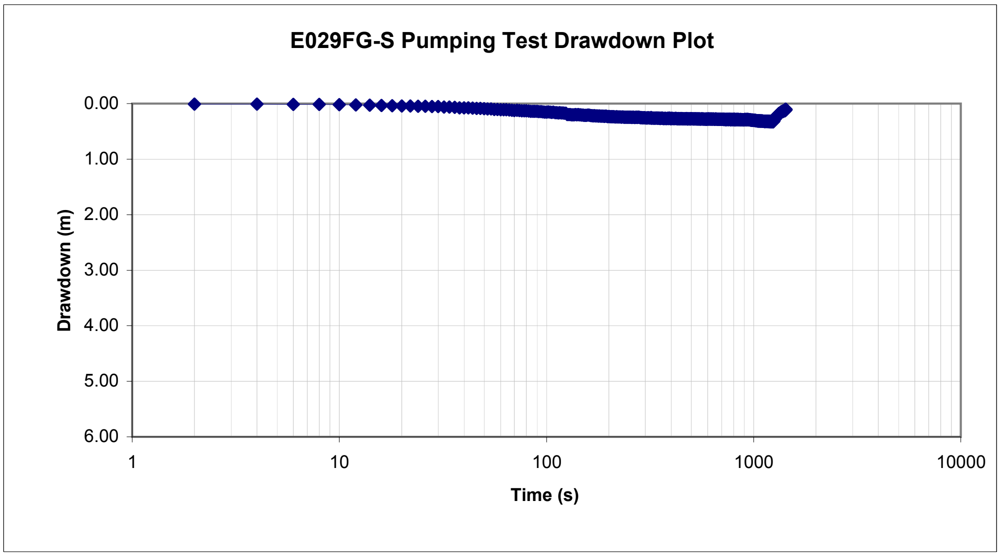

E027FG-S Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

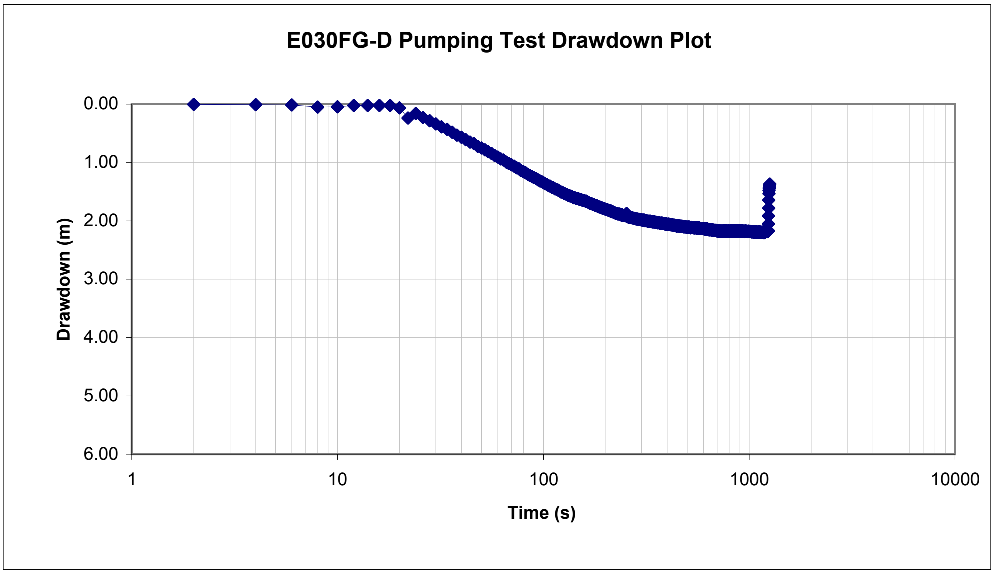

E028G-I Pumping Test Drawdown Plot
-0.01
0.00
0.01
Drawdown (m)
suspect data
1
10
100
1000
10000
Time (s)

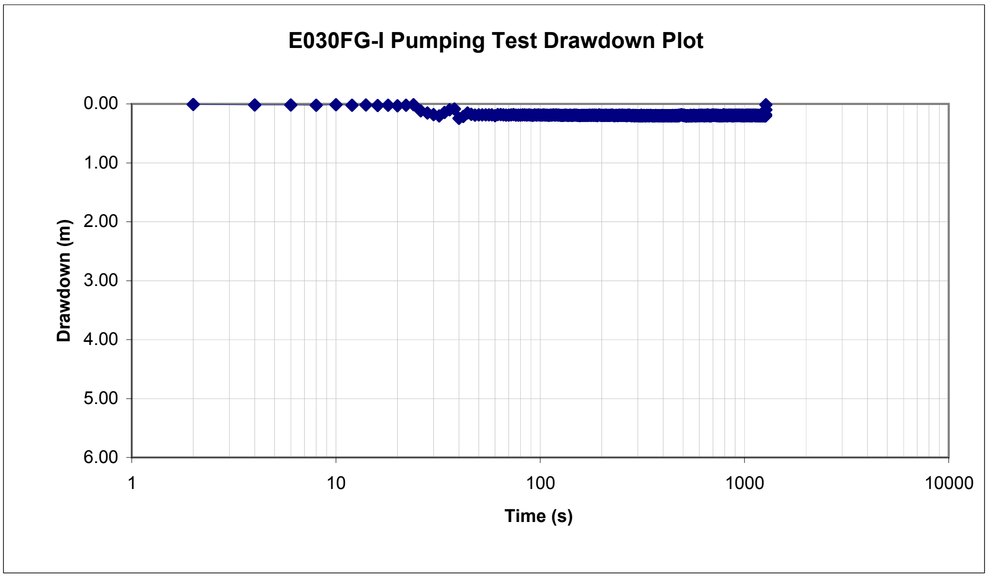

E028G-S Pumping Test Drawdown Plot
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
Drawdown (m)
1
10
100
1000
10000
Time (s)


E029FG-D Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

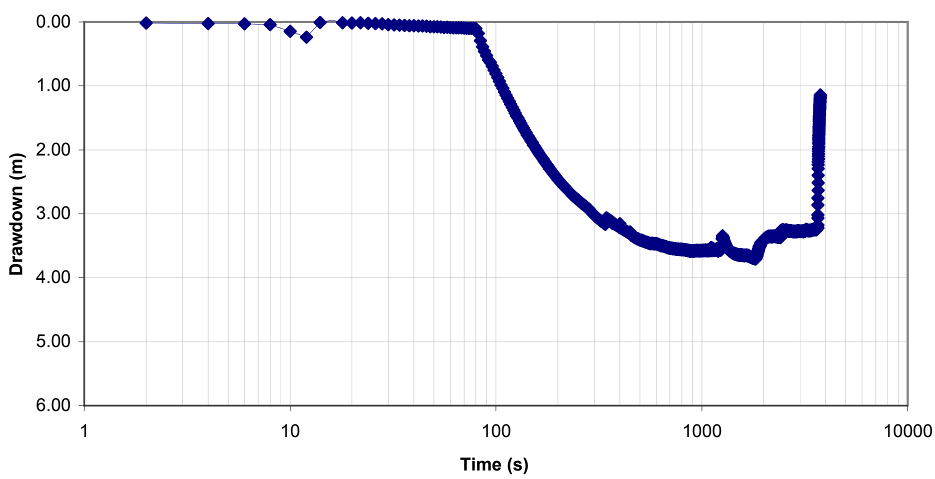

E029FG-I Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)


E029FG-S Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

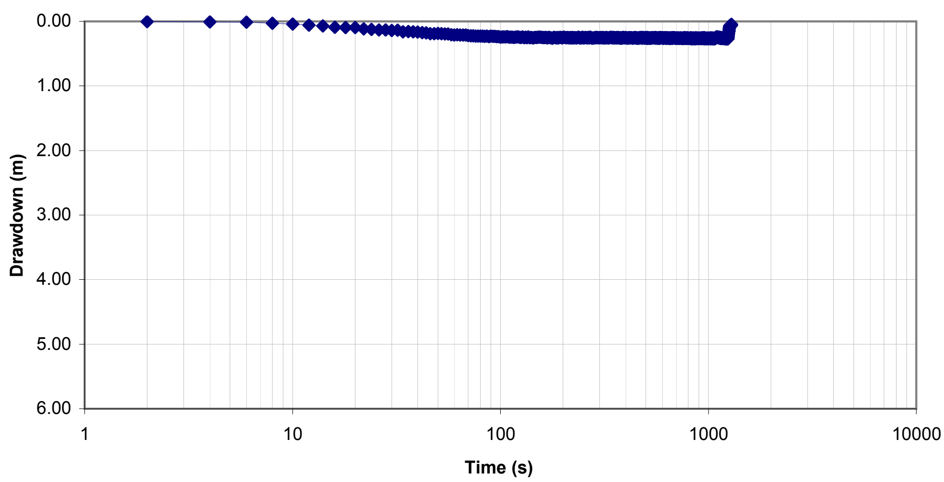

E030FG-D Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

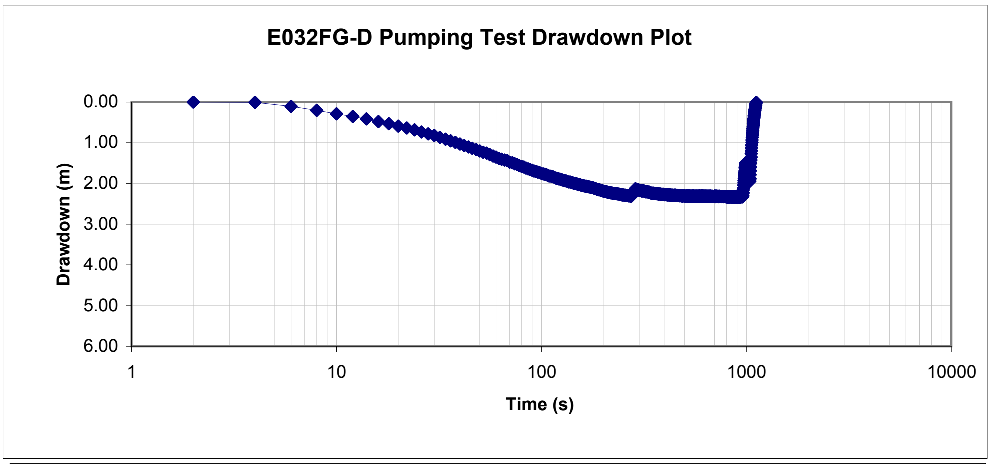

E030FG-I Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

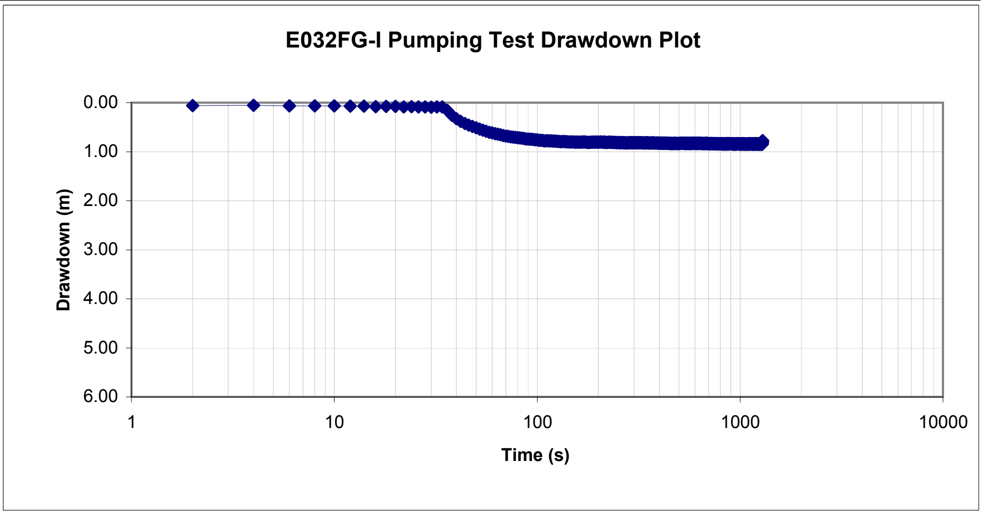
E031FG-D Pumping Test Drawdown Plot

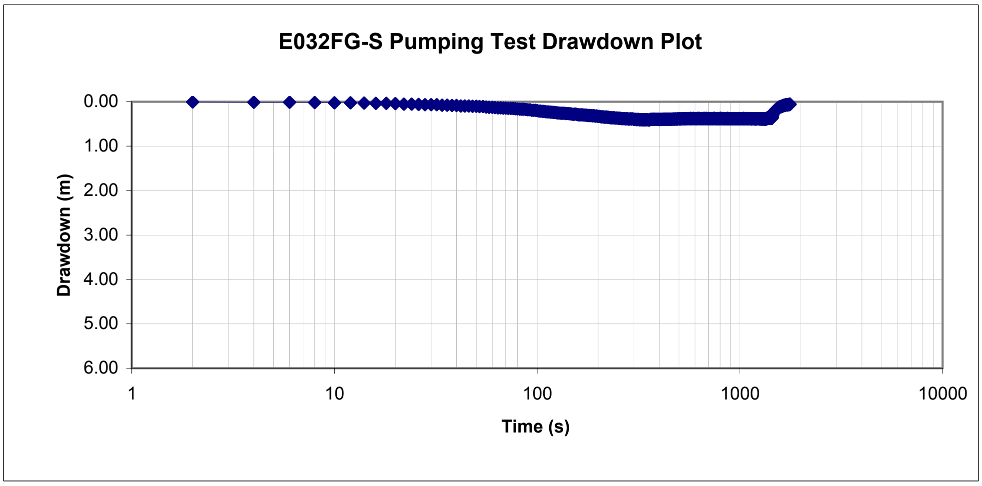


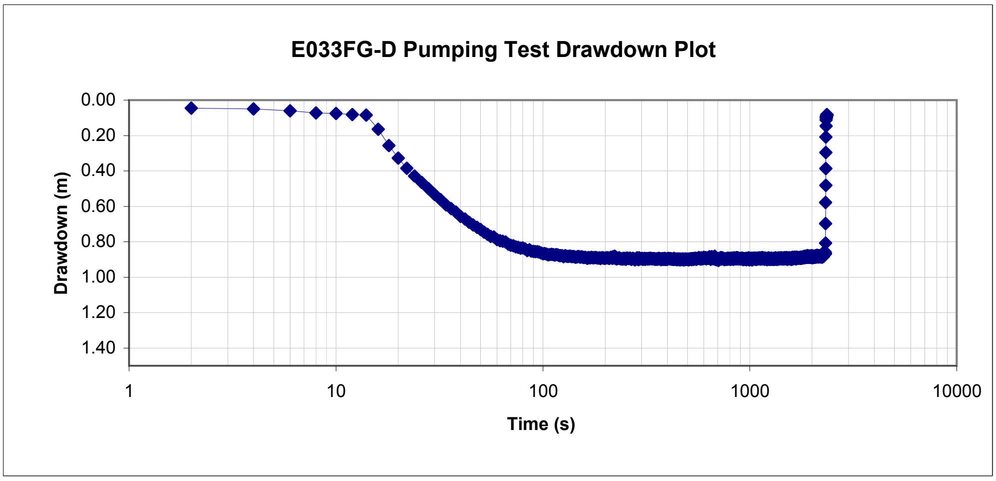
E031FG-S Pumping Test Drawdown Plot

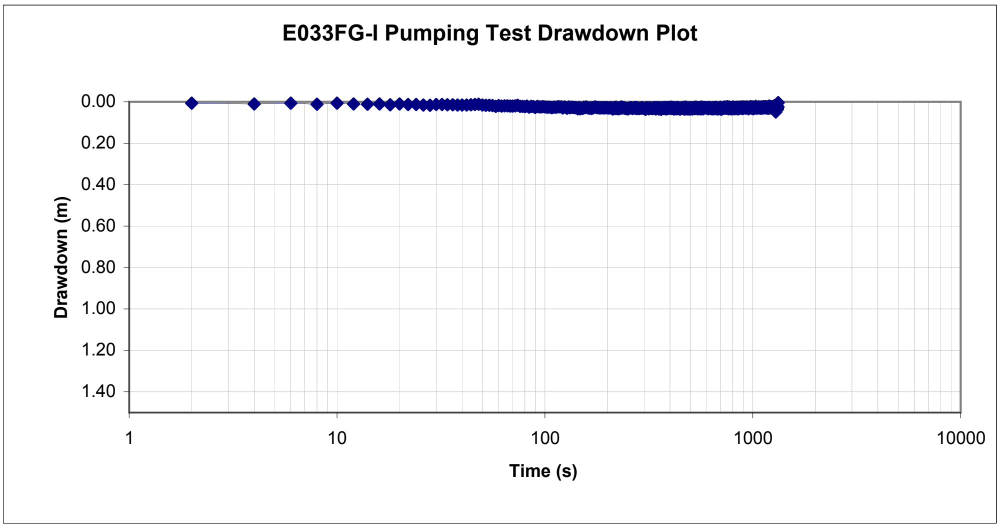


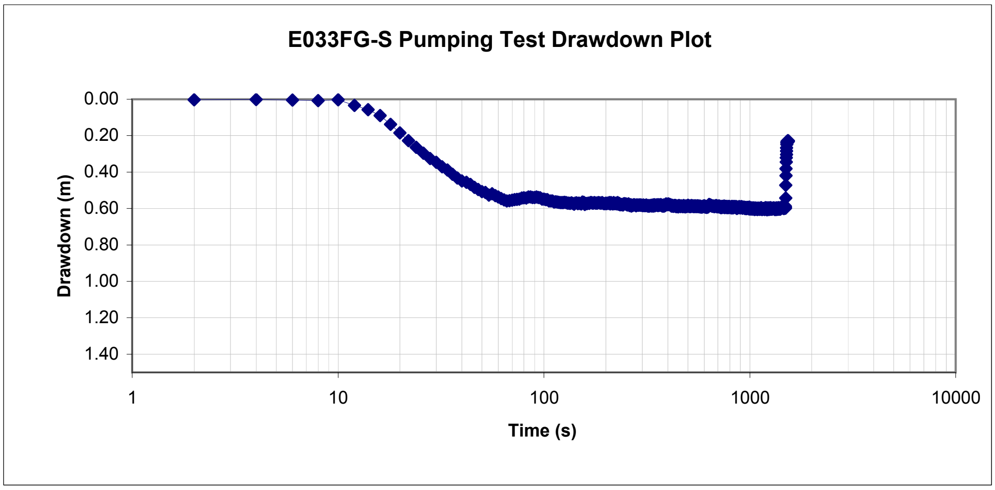

E032FG-D Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

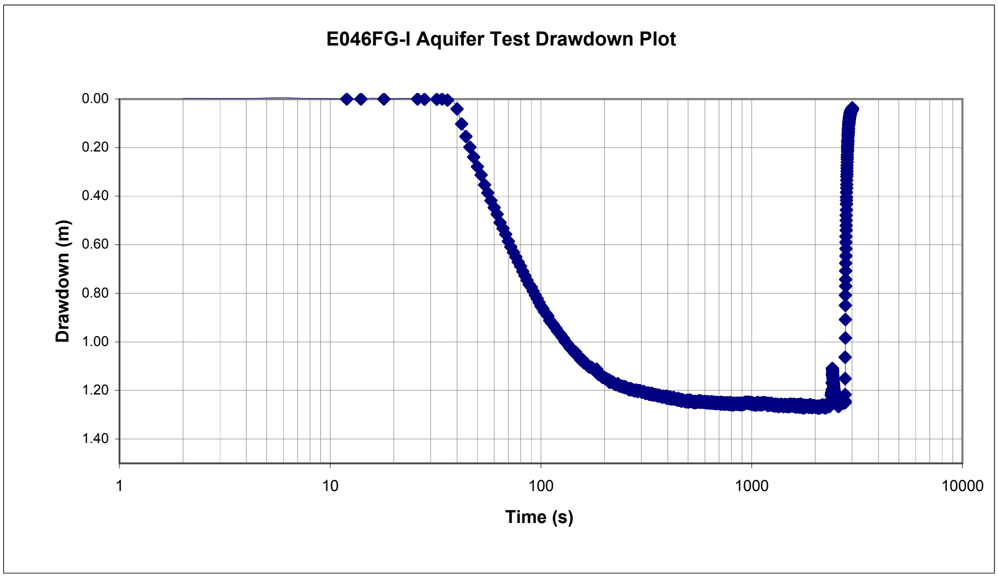

E032FG-I Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

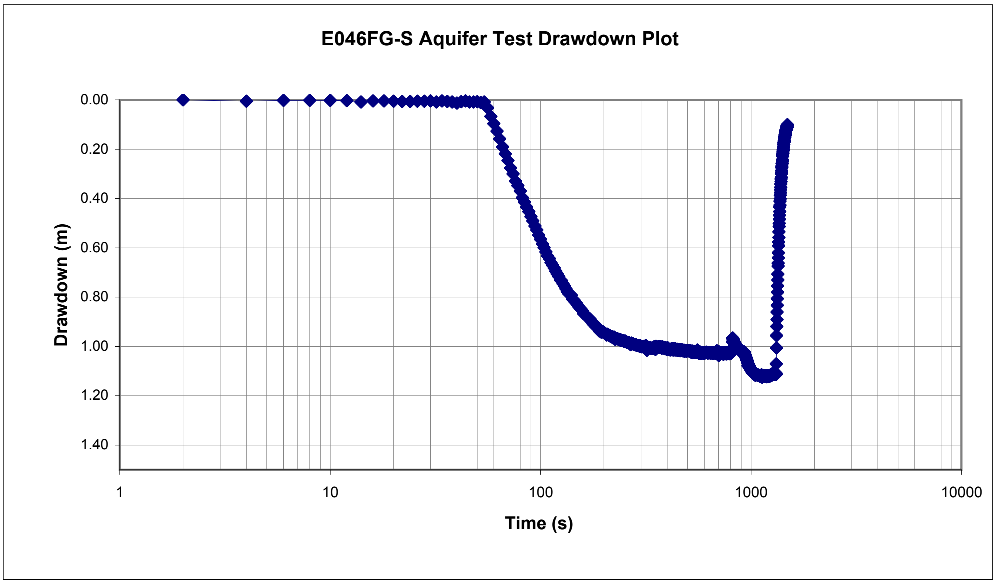

E032FG-S Pumping Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
10
100
1000
10000
Time (s)

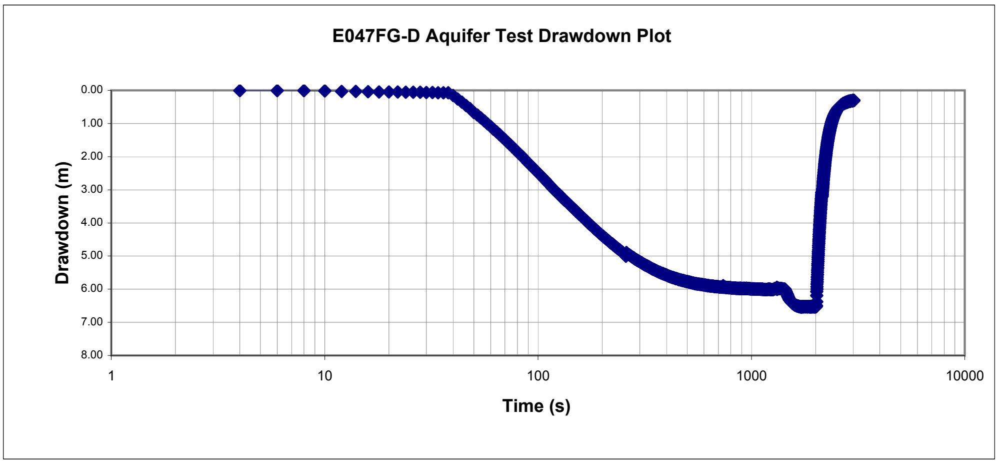

E033FG-D Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

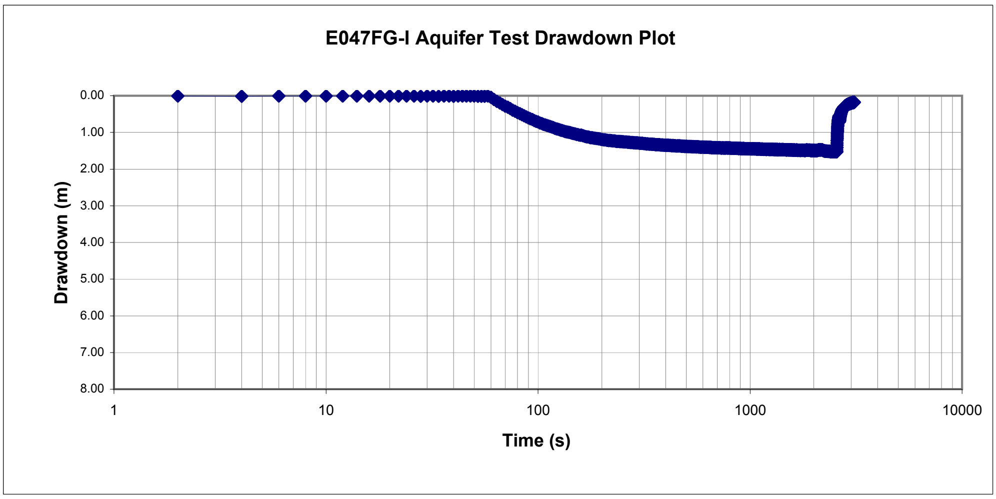

E033FG-I Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

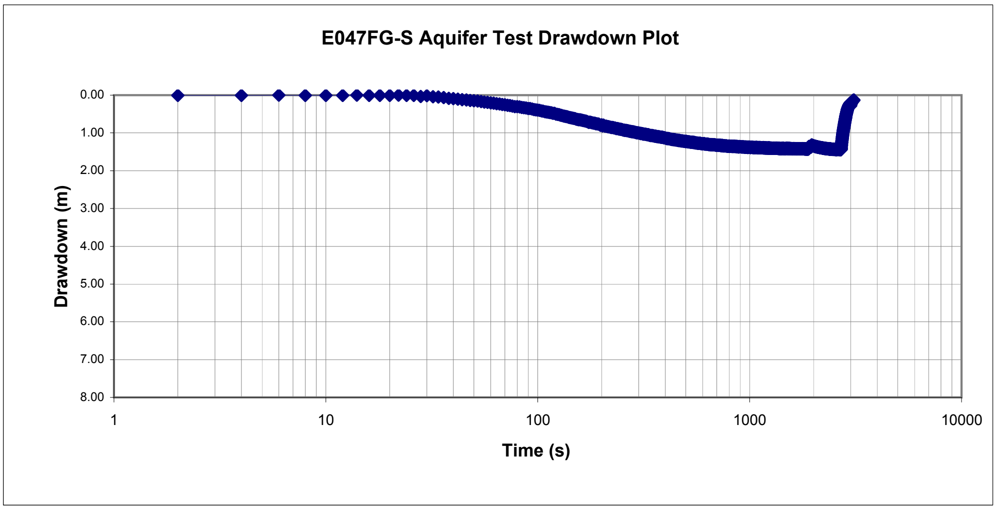

E033FG-S Pumping Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

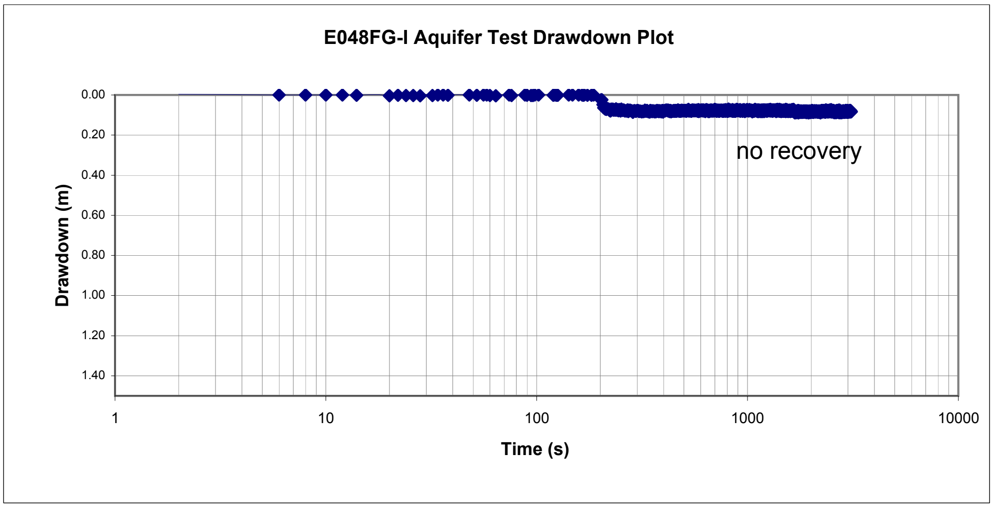

E046FG-I Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

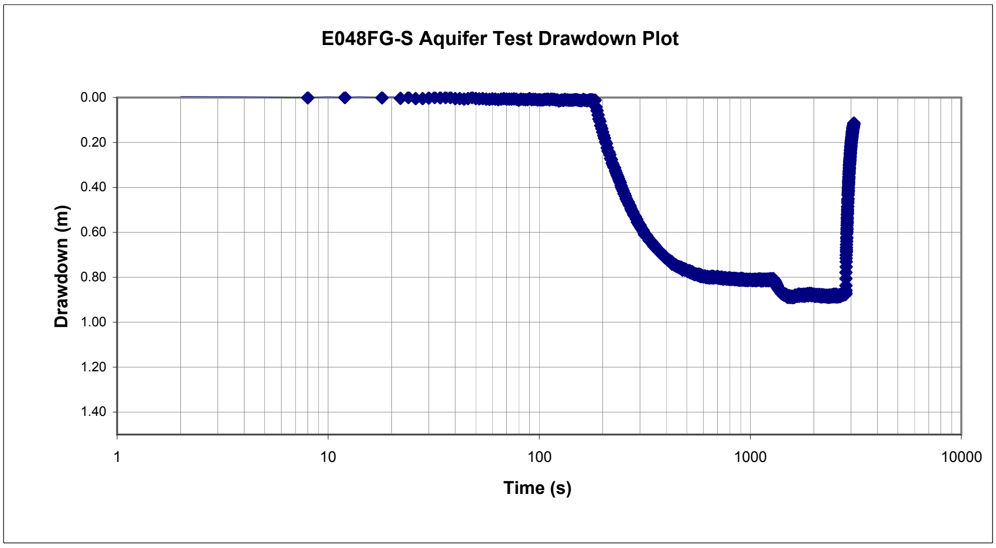

E046FG-S Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

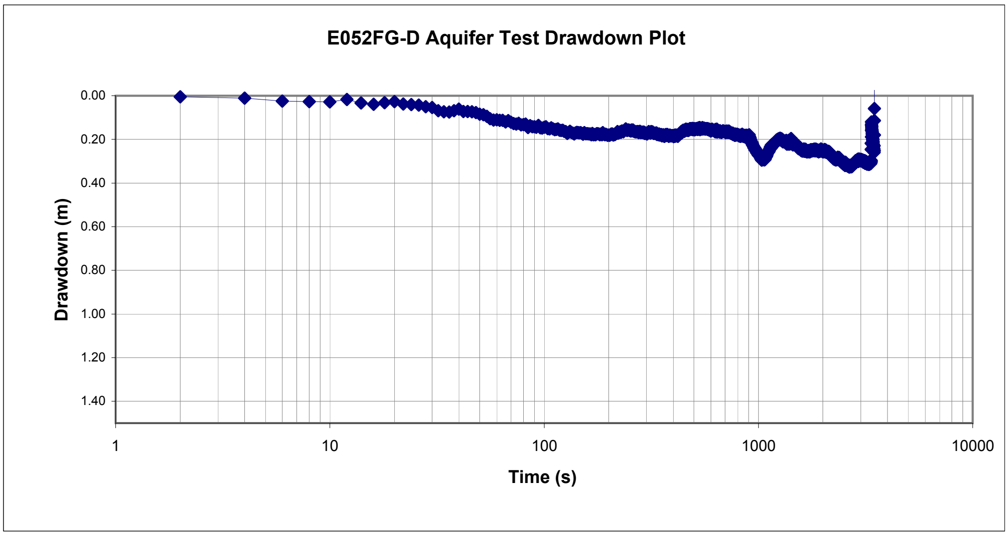

E047FG-D Aquifer Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
1
10
100
1000
10000
Time (s)

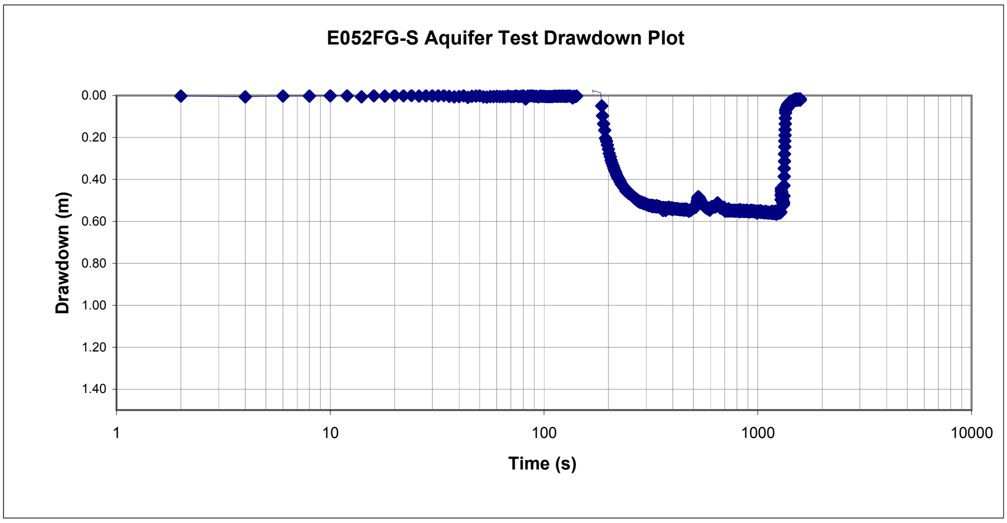

E047FG-I Aquifer Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
1
10
100
1000
10000
Time (s)

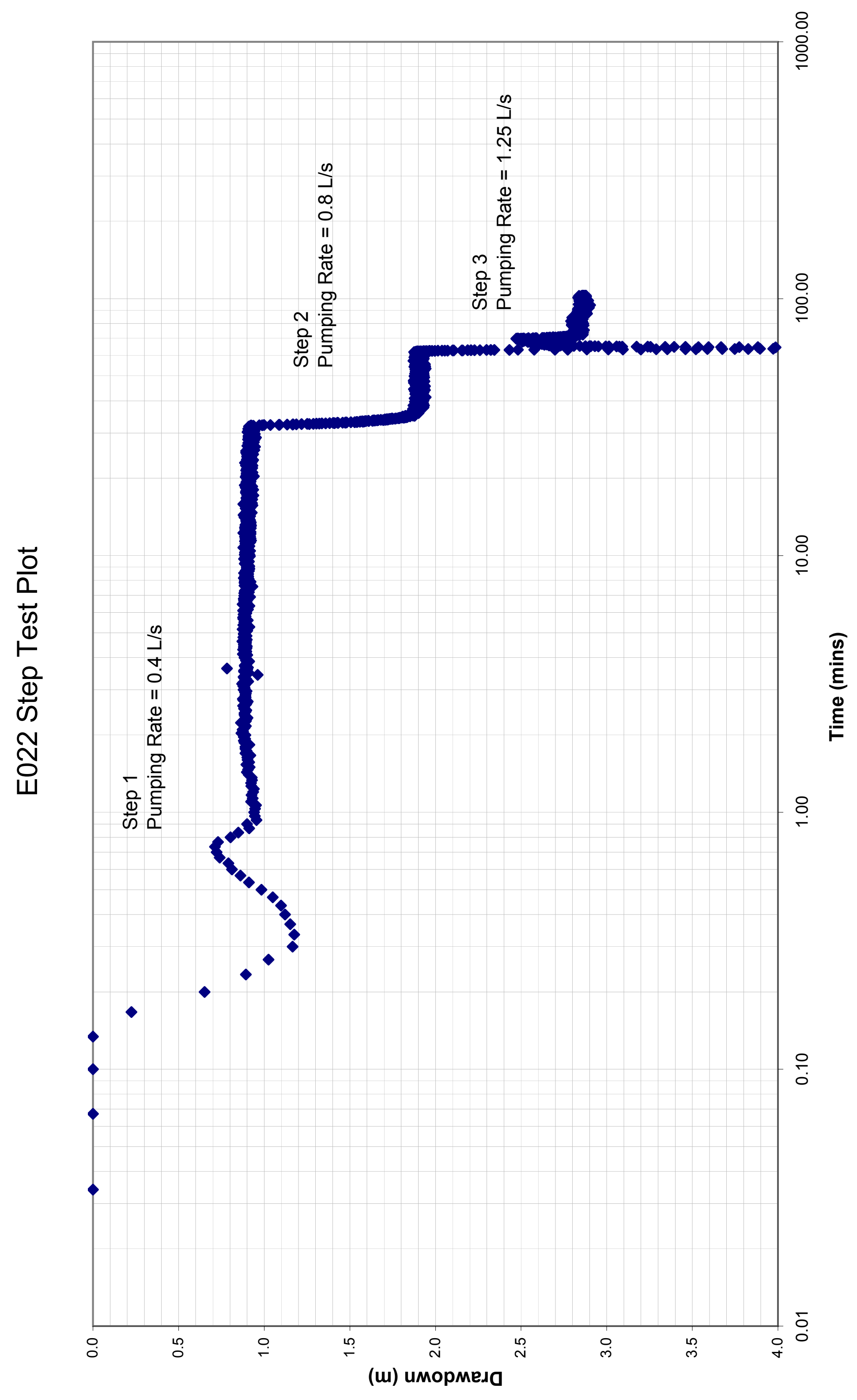

E047FG-S Aquifer Test Drawdown Plot
Drawdown (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
1
10
100
1000
10000
Time (s)

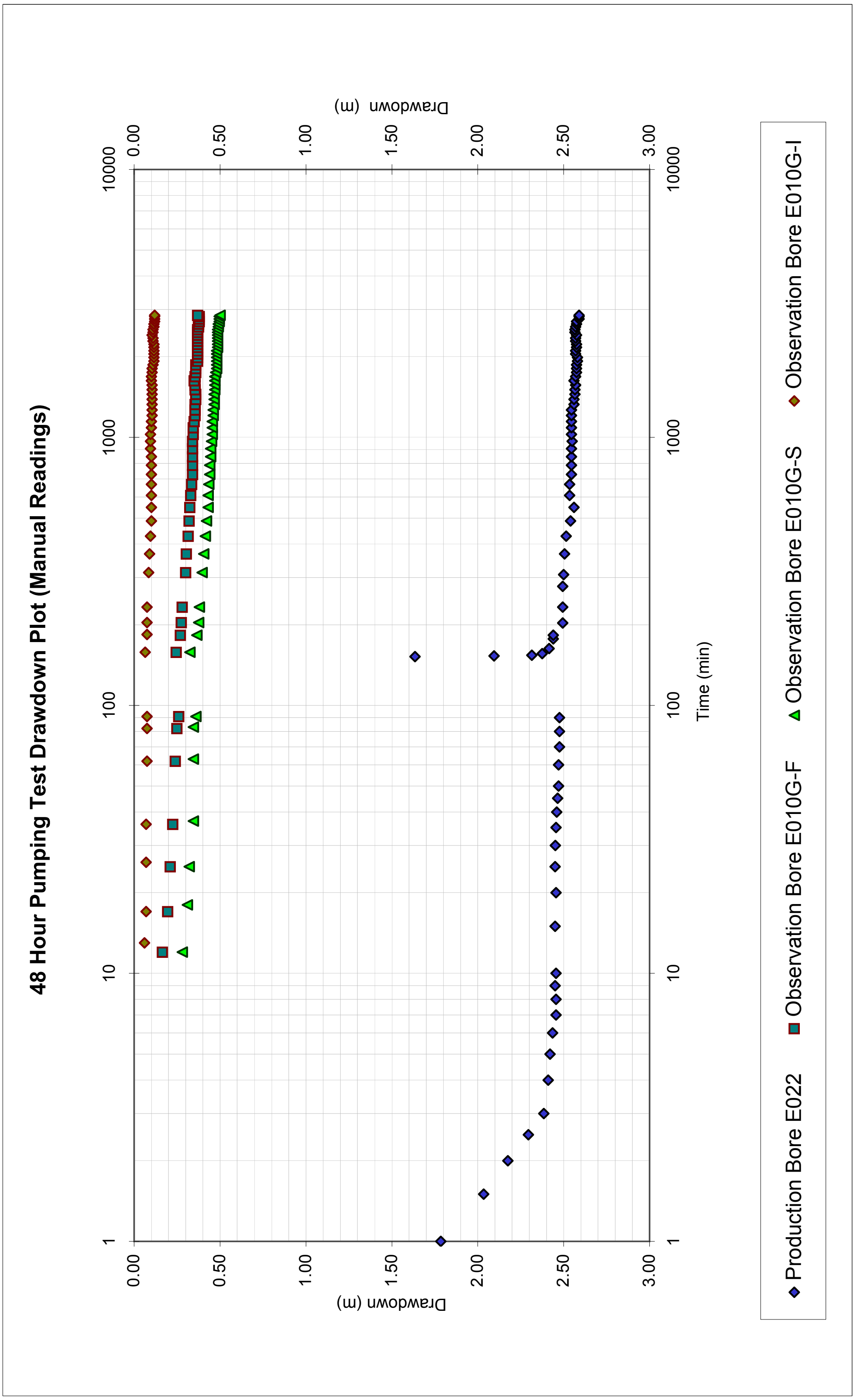

E048FG-I Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
no recovery
1
10
100
1000
10000
Time (s)

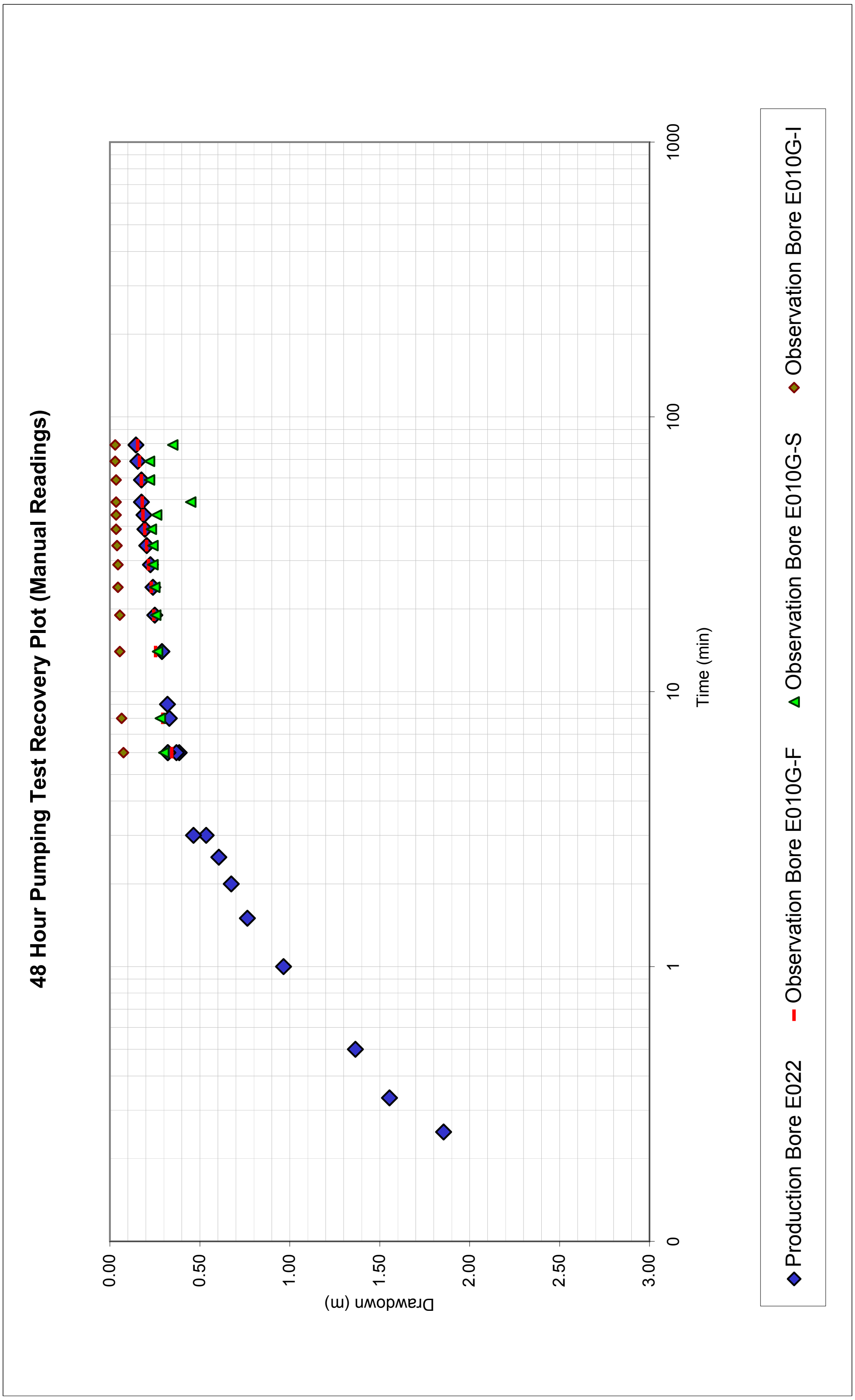

E048FG-S Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

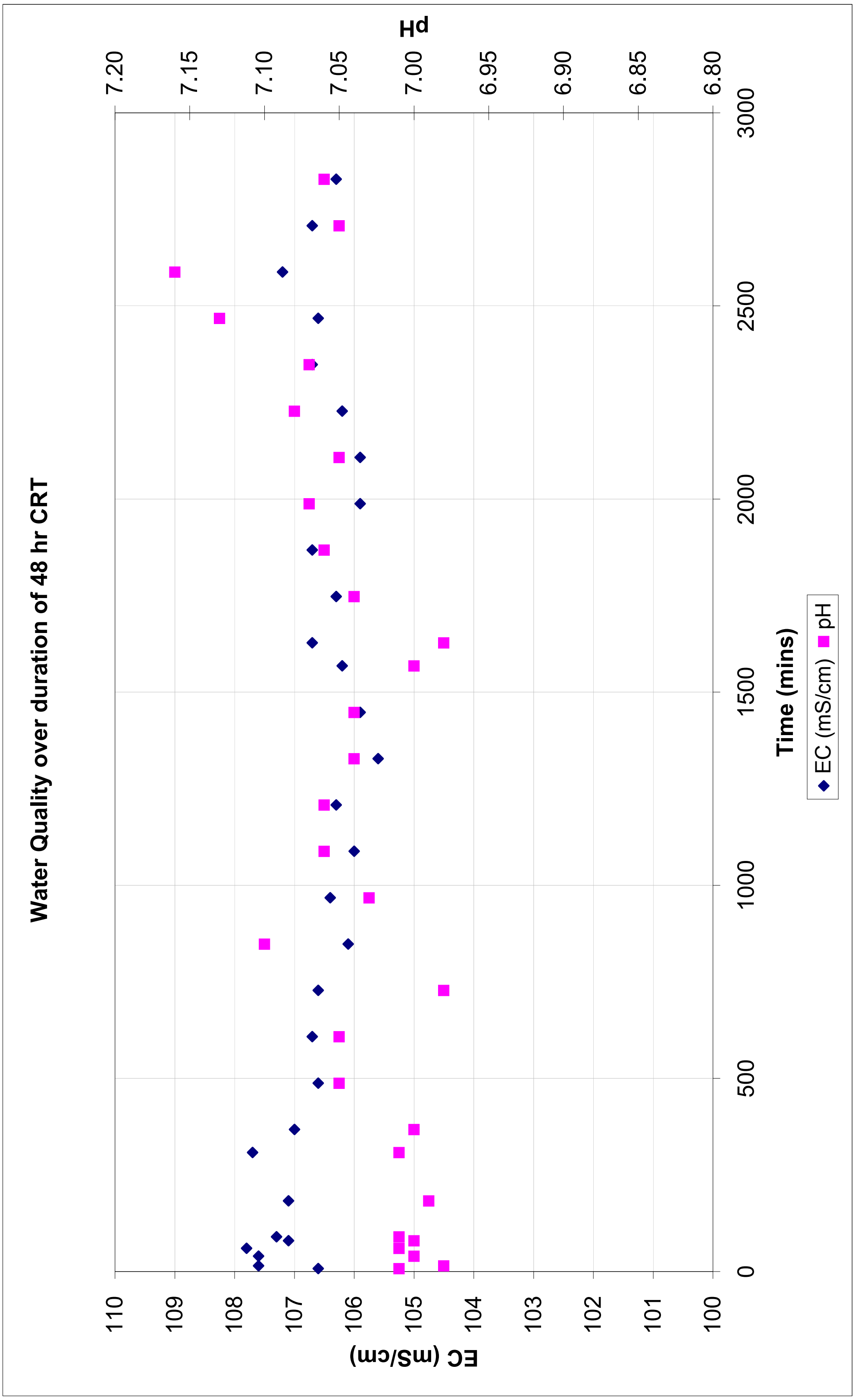

E052FG-D Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)

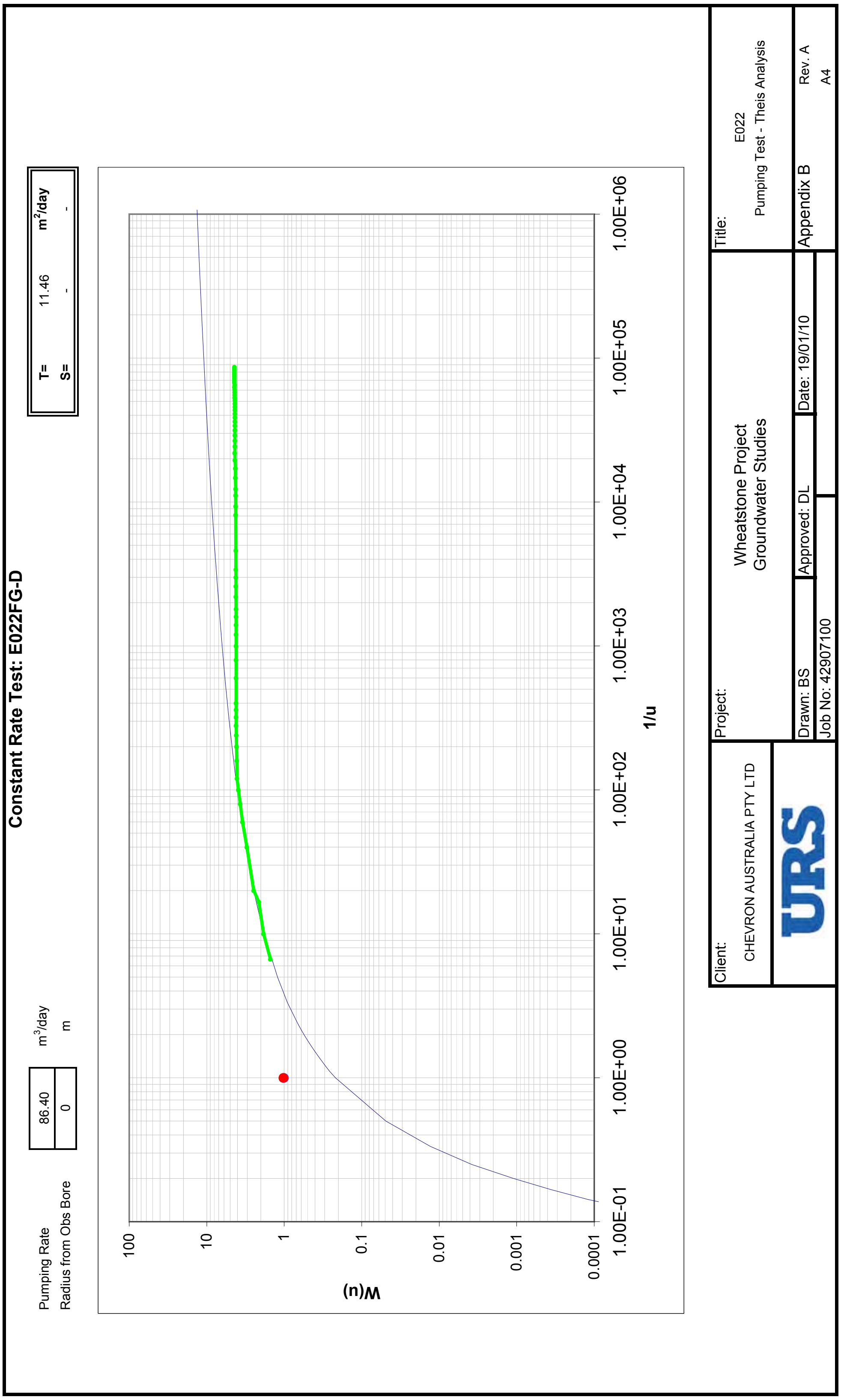

E052FG-S Aquifer Test Drawdown Plot
Drawdown (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
10
100
1000
10000
Time (s)


E022 Step Test Plot
Step 1
Pumping Rate = 0.4 L/s
Step 2
Pumping Rate = 0.8 L/s
Step 3
Pumping Rate = 1.25 L/s
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (mins)
0.01
0.10
1.00
10.00
100.00
1000.00


48 Hour Pumping Test Drawdown Plot (Manual Readings)
Drawdown (m)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Time (min)
1
10
100
1000
10000
Production Bore E022
Observation Bore E010G-F
Observation Bore E010G-S
Observation Bore E010G-I


48 Hour Pumping Test Recovery Plot (Manual Readings)
Drawdown (m)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Time (min)
0
1
10
100
1000
Production Bore E022
Observation Bore E010G-F
Observation Bore E010G-S
Observation Bore E010G-I


Water Quality over duration of 48 hr CRT
EC (mS/cm)
110
109
108
107
106
105
104
103
102
101
100
pH
7.20
7.15
7.10
7.05
7.00
6.95
6.90
6.85
6.80
0
500
1000
1500
2000
2500
3000
Time (mins)
EC (mS/cm)
pH


Constant Rate Test: E022FG-D
Pumping Rate 86.40 m³/day
Radius from Obs Bore 0 m
T= 11.46 m²/day
S= - -
W(u)
100
10
1
0.1
0.01
0.001
0.0001
1/u
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
E022
Pumping Test - Theis Analysis
Drawn: BS
Approved: DL
Date: 19/01/10
Appendix B
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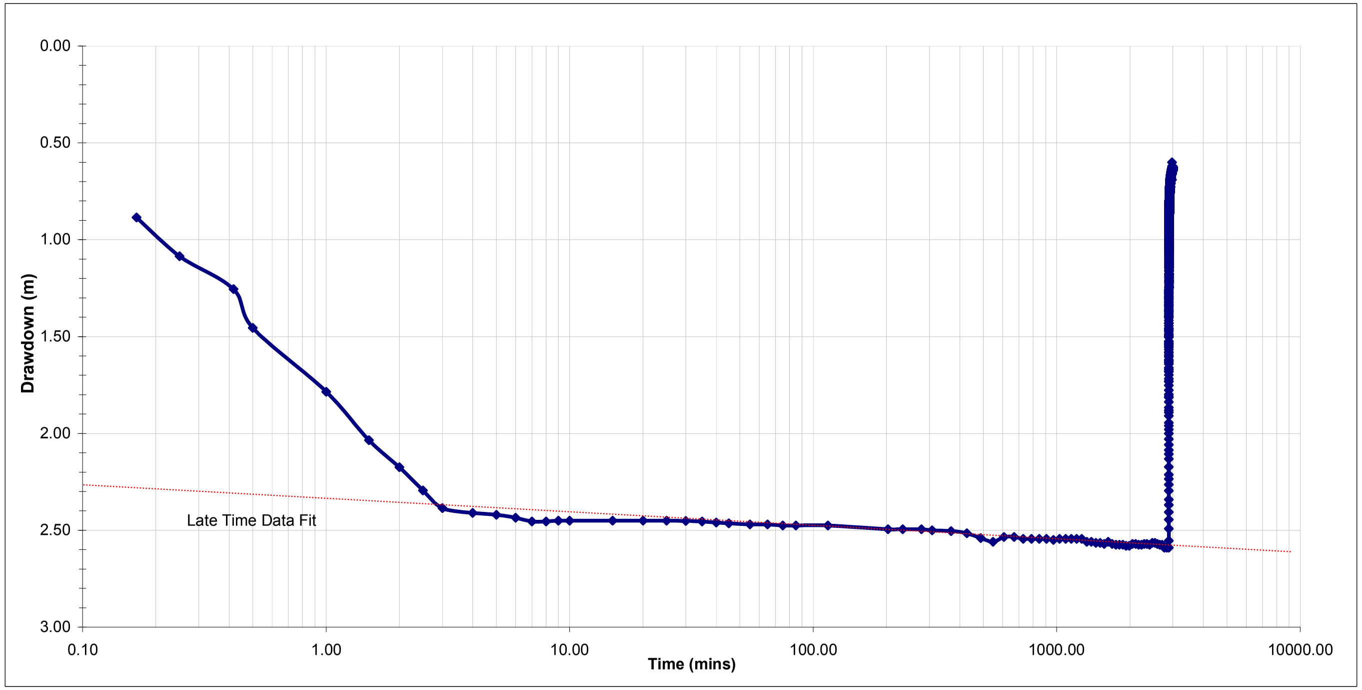
Job No: 42907100
A4

Constant Rate Test: Production Bore E022

Pumping Rate	8.64	m^3/day
Radius from Obs Bore	8.6	m
ΔS	0.06	m

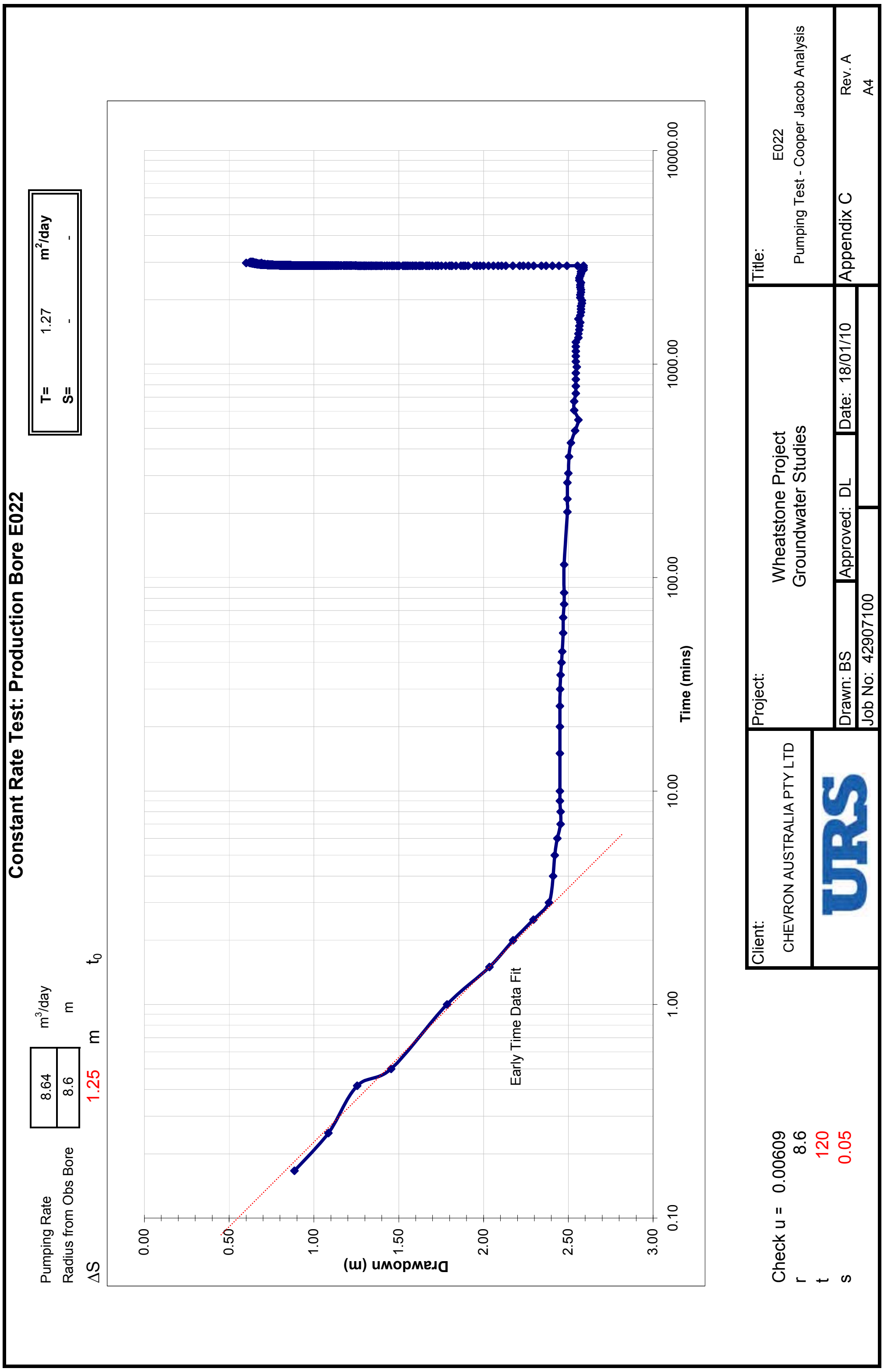
t_0

T=	26.37	m^2/day
S=	-	-



Check u =	0.00029
r	8.6
t	120
s	0.05

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies		Title: E022 Pumping Test - Cooper Jacob Analysis
URS	Drawn: BS	Approved: DL	Date: 18/01/10
	Job No: 42907100		Appendix C Rev. A A4

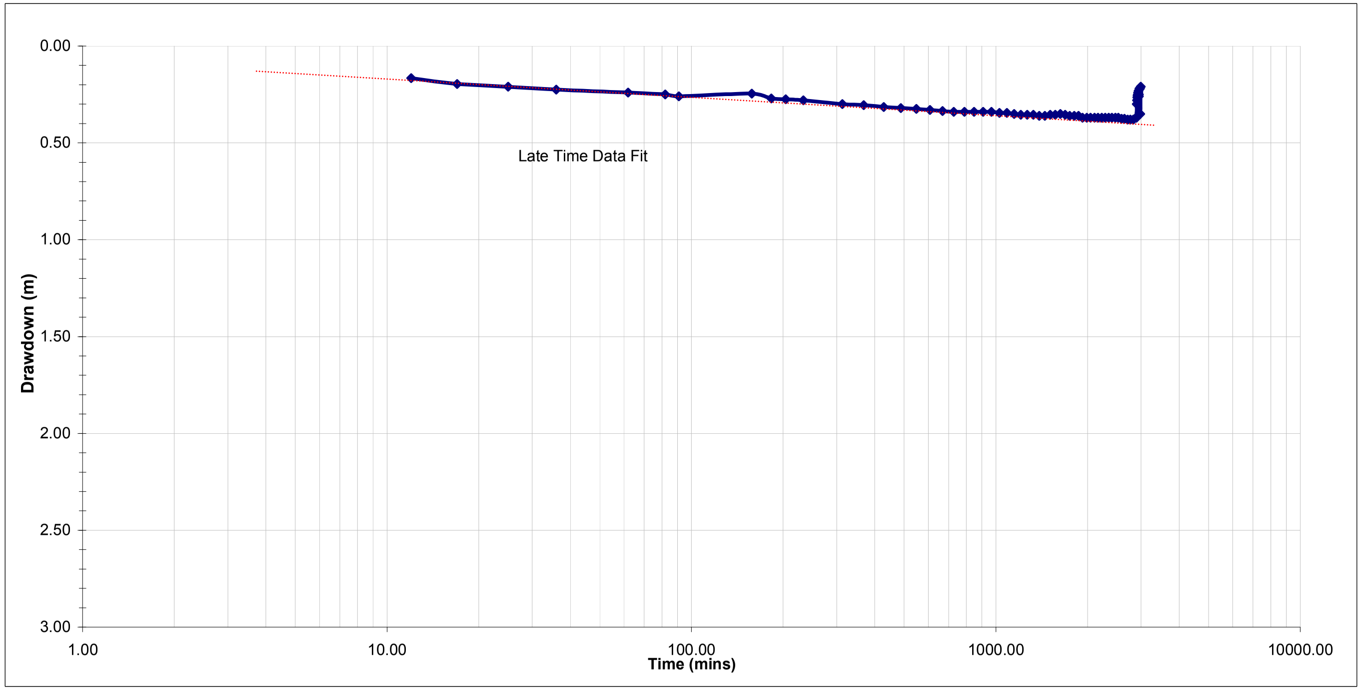

Constant Rate Test: Production Bore E022
Pumping Rate 8.64 m3/day
Radius from Obs Bore 8.6 m
ΔS 1.25 m
t0
T= 1.27 m2/day
S= - -
Early Time Data Fit
Drawdown (m)
Time (mins)
0.10
1.00
10.00
100.00
1000.00
10000.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Check u = 0.00609
r 8.6
t 120
s 0.05
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Title:
E022
Pumping Test - Cooper Jacob Analysis
Drawn: BS
Approved: DL
Date: 18/01/10
Job No: 42907100
Appendix C
Rev. A
A4

Constant Rate Test: Monitoring Bore E010G-S

Pumping Rate	8.64	m^3/day
Radius from Obs Bore	7.5	m
ΔS	0.1	m

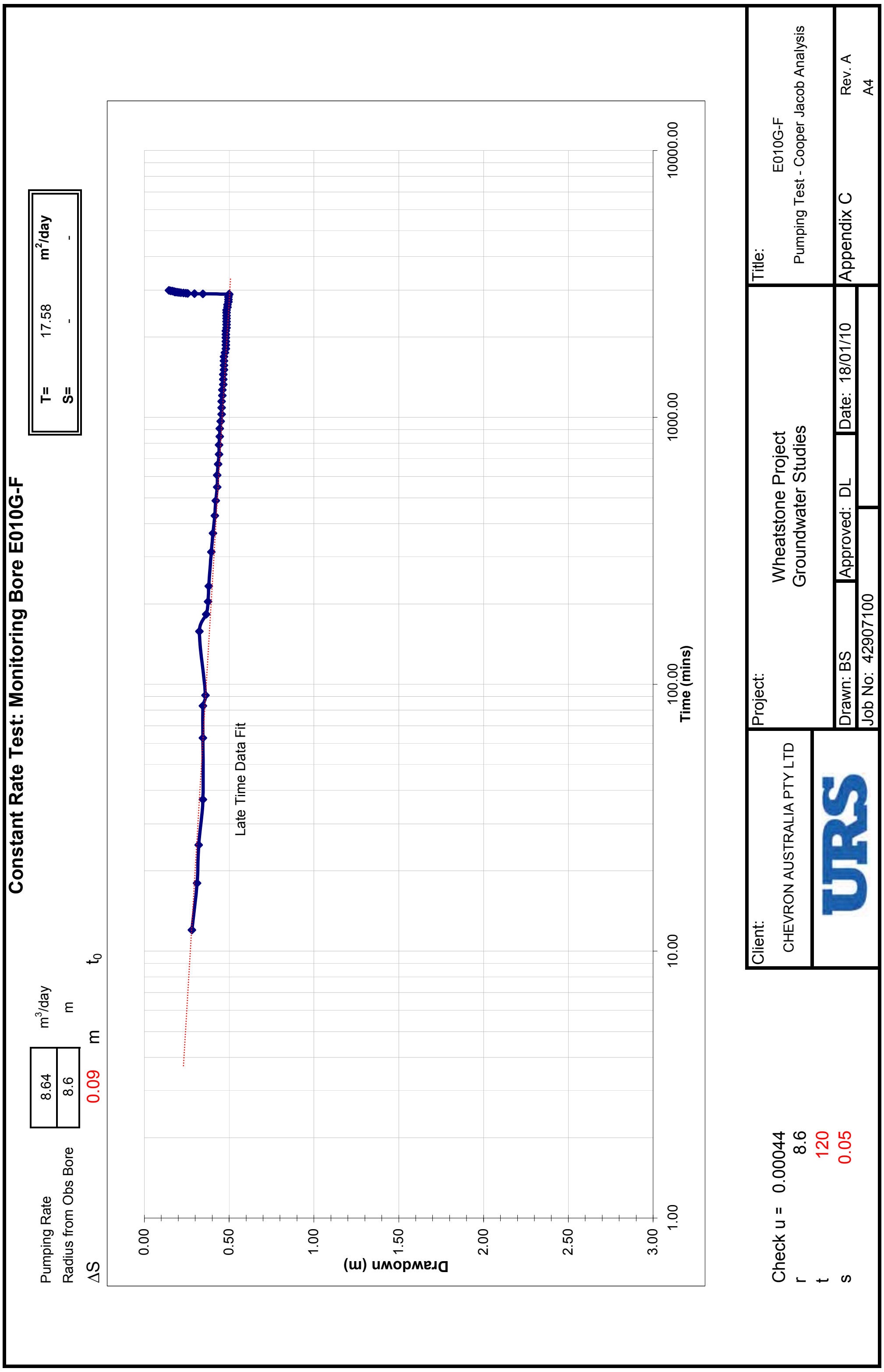
t_0

T=	15.82	m^2/day
S=	-	-



Check u = 0.00037
r 7.5
t 120
s 0.05

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Groundwater Studies	Title: E010G-S Pumping Test - Cooper Jacob Analysis
URS	Drawn: BS · Approved: DL · Date: 18/01/10 · Job No: 42907100	Appendix C · Rev. A · A4


Constant Rate Test: Monitoring Bore E010G-F
Pumping Rate 8.64 m³/day
Radius from Obs Bore 8.6 m
ΔS 0.09 m
t0
T= 17.58 m²/day
S= - -
Drawdown (m)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
1.00
10.00
100.00
1000.00
10000.00
Time (mins)
Late Time Data Fit
Check u = 0.00044
r 8.6
t 120
s 0.05
Client:
CHEVRON AUSTRALIA PTY LTD
URS
Project:
Wheatstone Project
Groundwater Studies
Drawn: BS
Approved: DL
Date: 18/01/10
Job No: 42907100
Title:
E010G-F
Pumping Test - Cooper Jacob Analysis
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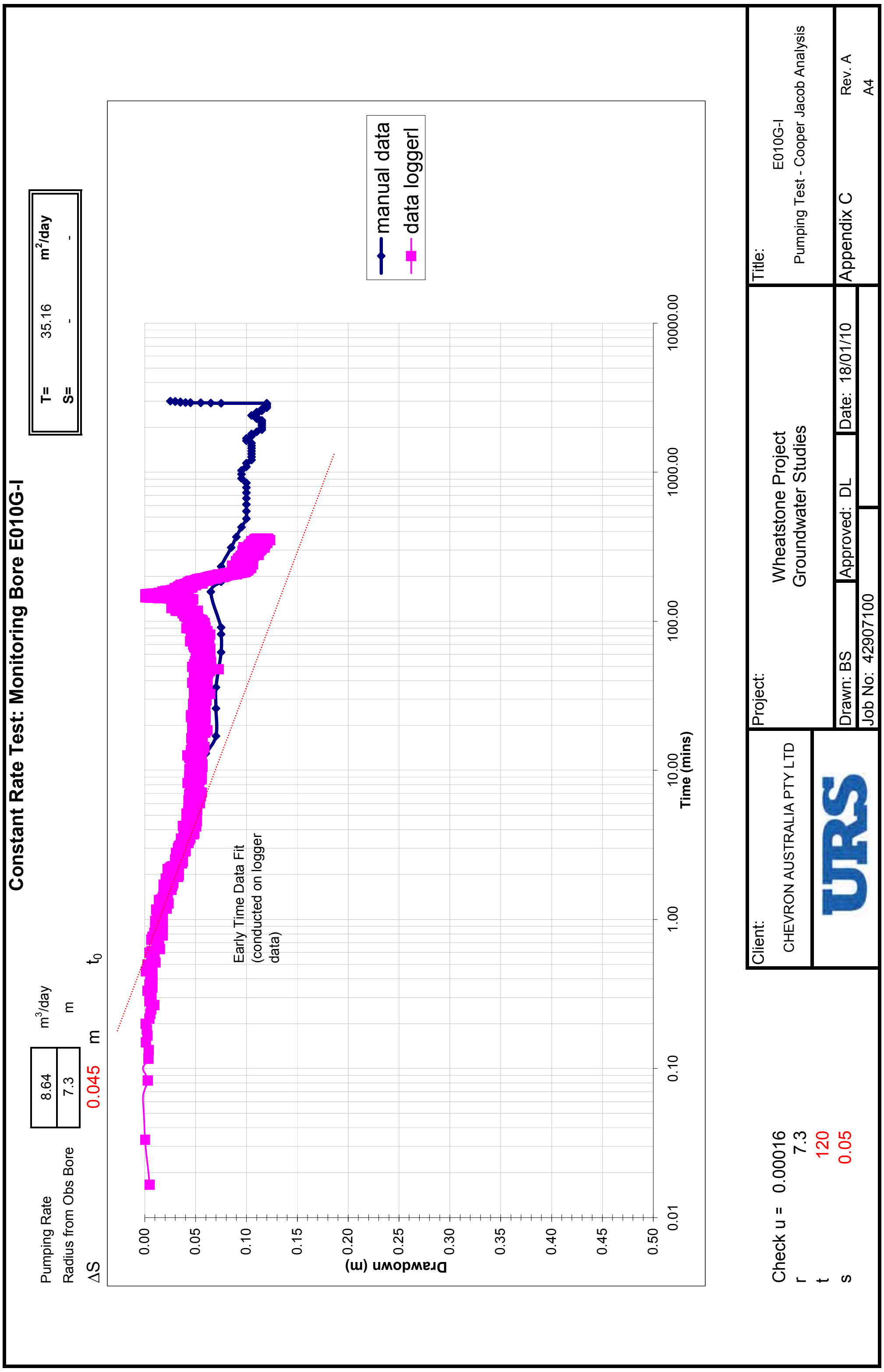
Constant Rate Test: Monitoring Bore E010G-I
Pumping Rate 8.64 m³/day
Radius from Obs Bore 7.3 m
ΔS 0.045 m
t0
T= 35.16 m²/day
S= - -
Drawdown (m)
Time (mins)
Early Time Data Fit (conducted on logger data)
manual data
data loggerl
Check u = 0.00016
r 7.3
t 120
s 0.05
Client: CHEVRON AUSTRALIA PTY LTD
Project: Wheatstone Project Groundwater Studies
Title: E010G-I Pumping Test - Cooper Jacob Analysis
Drawn: BS
Approved: DL
Date: 18/01/10
Job No: 42907100
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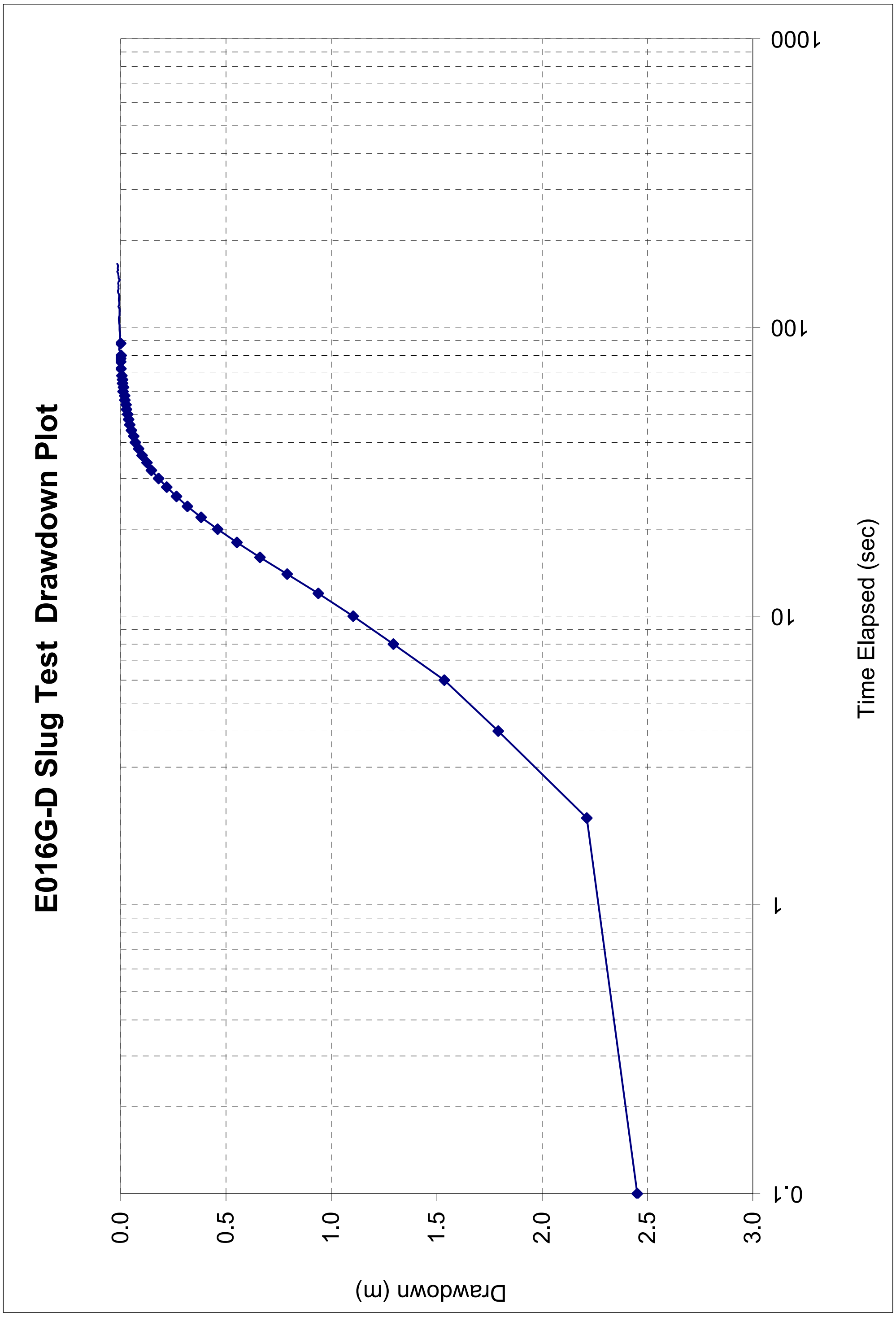
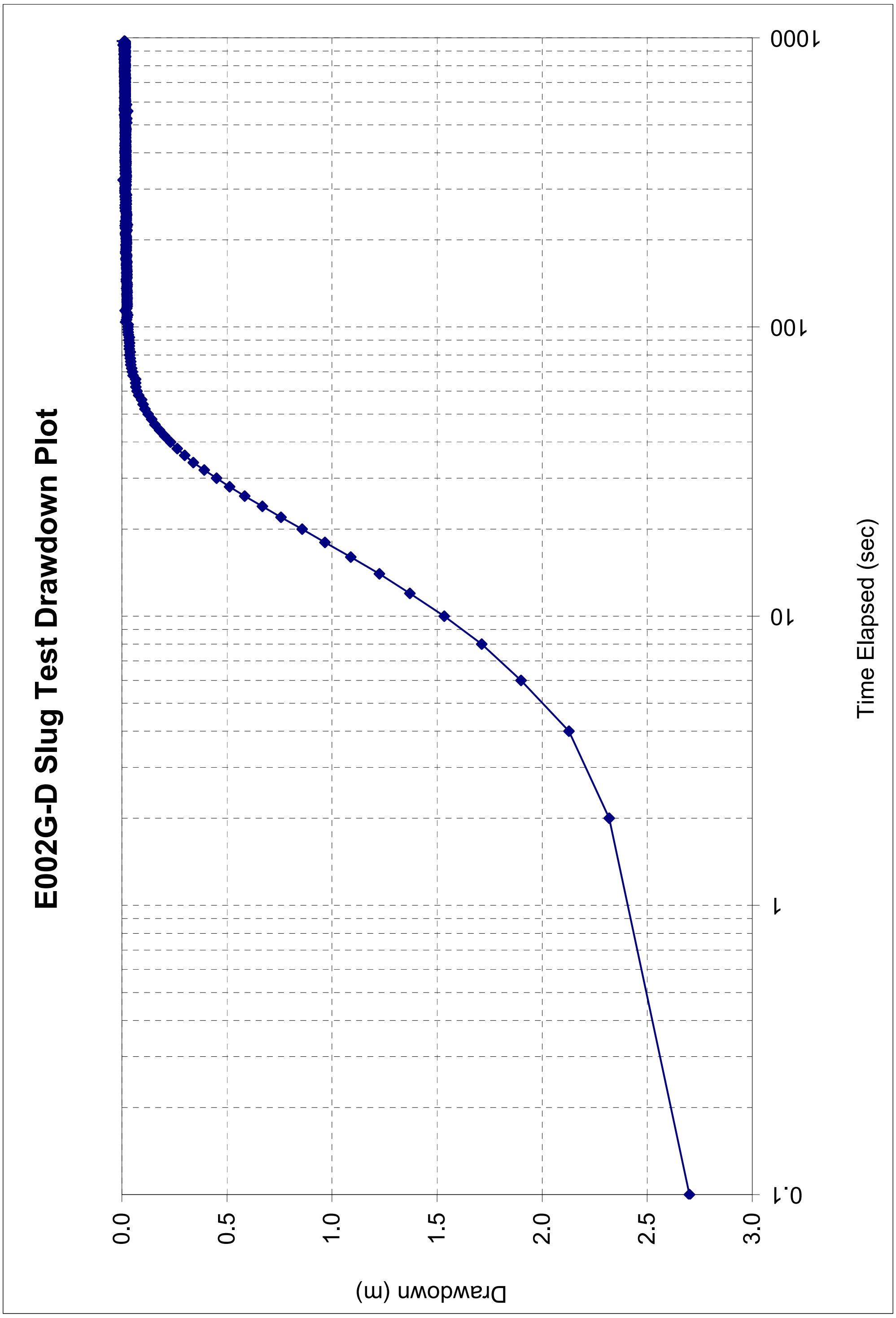
D

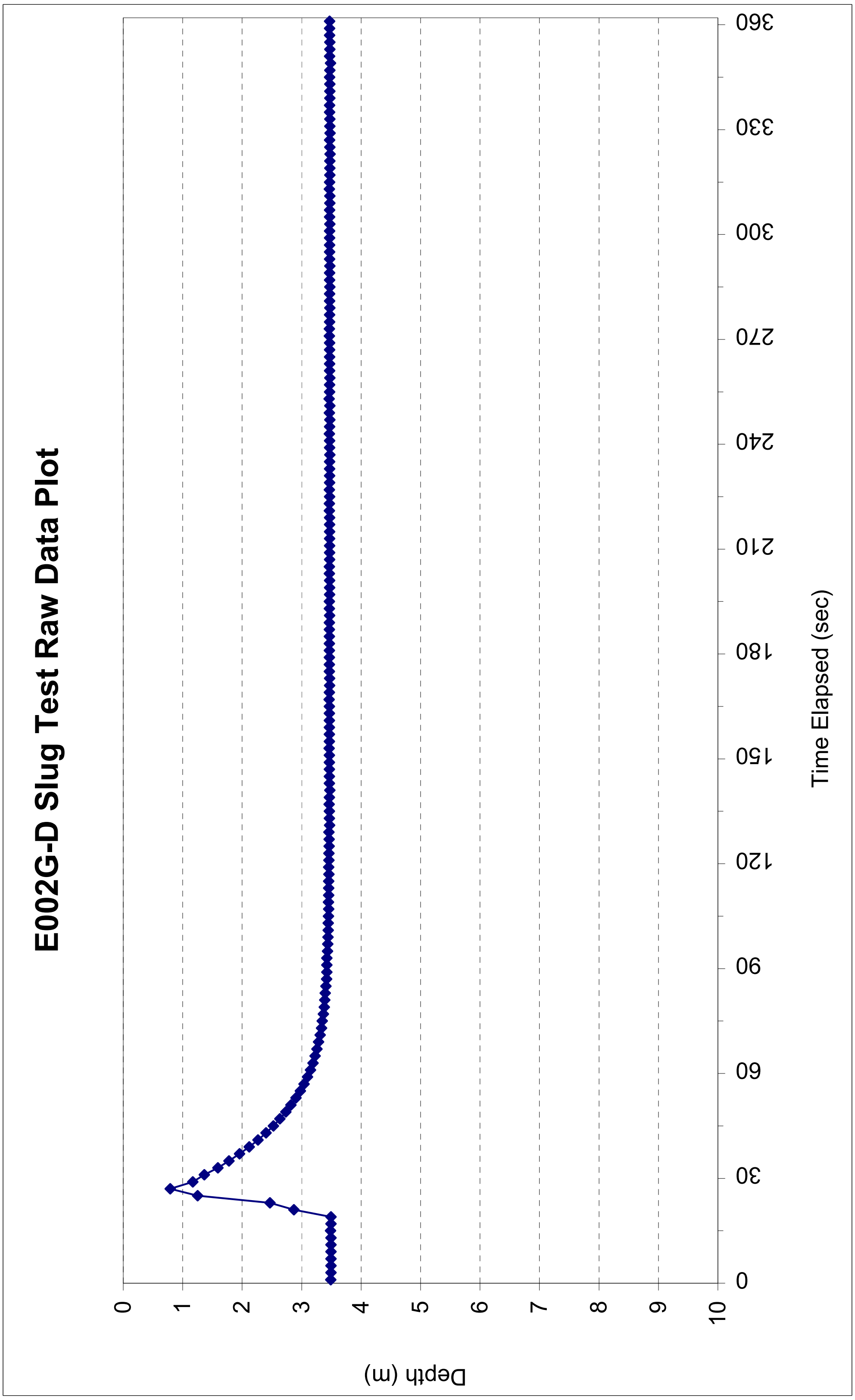
Appendix D Slug Test Analysis – Phase 1 and Phase 2

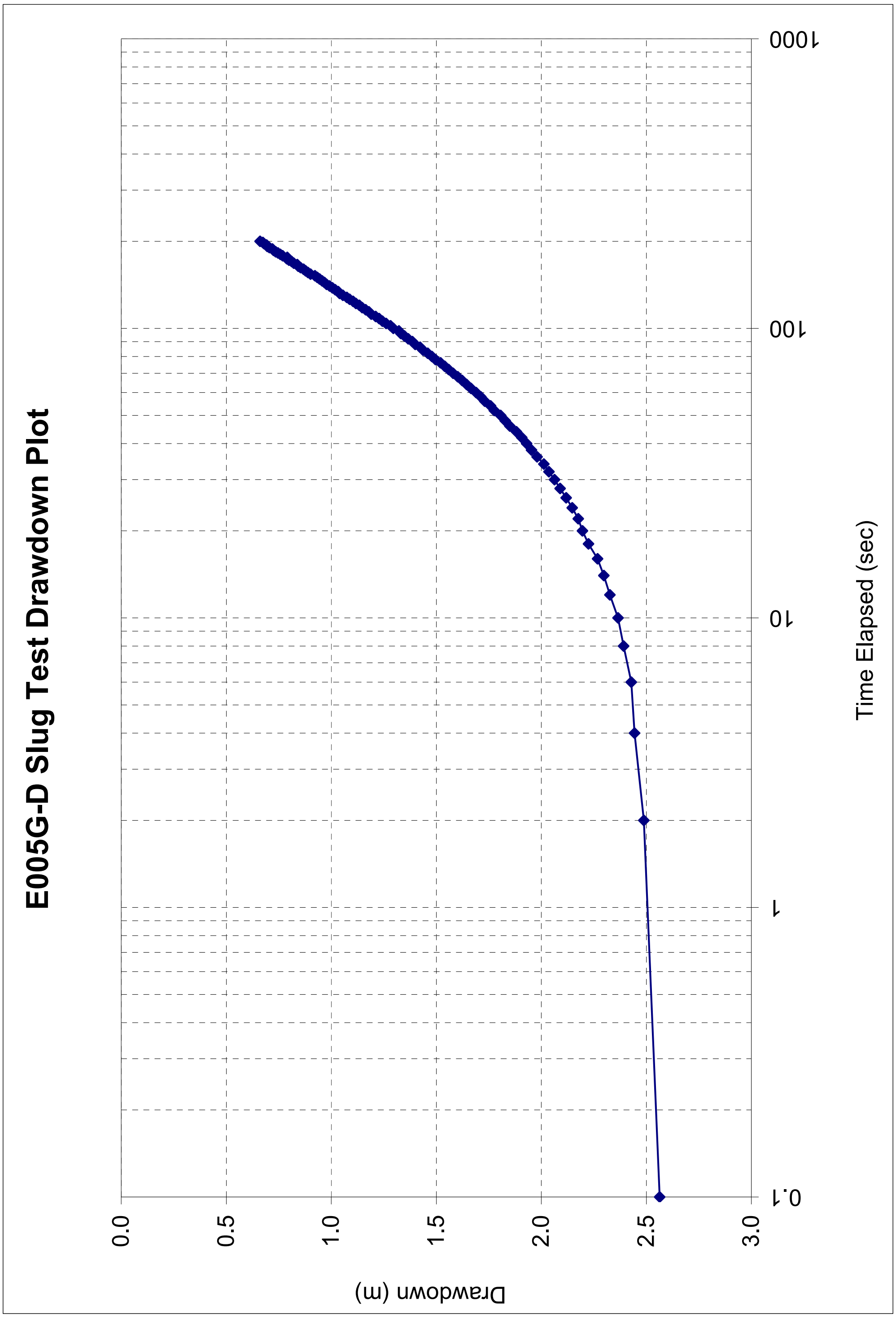
URS

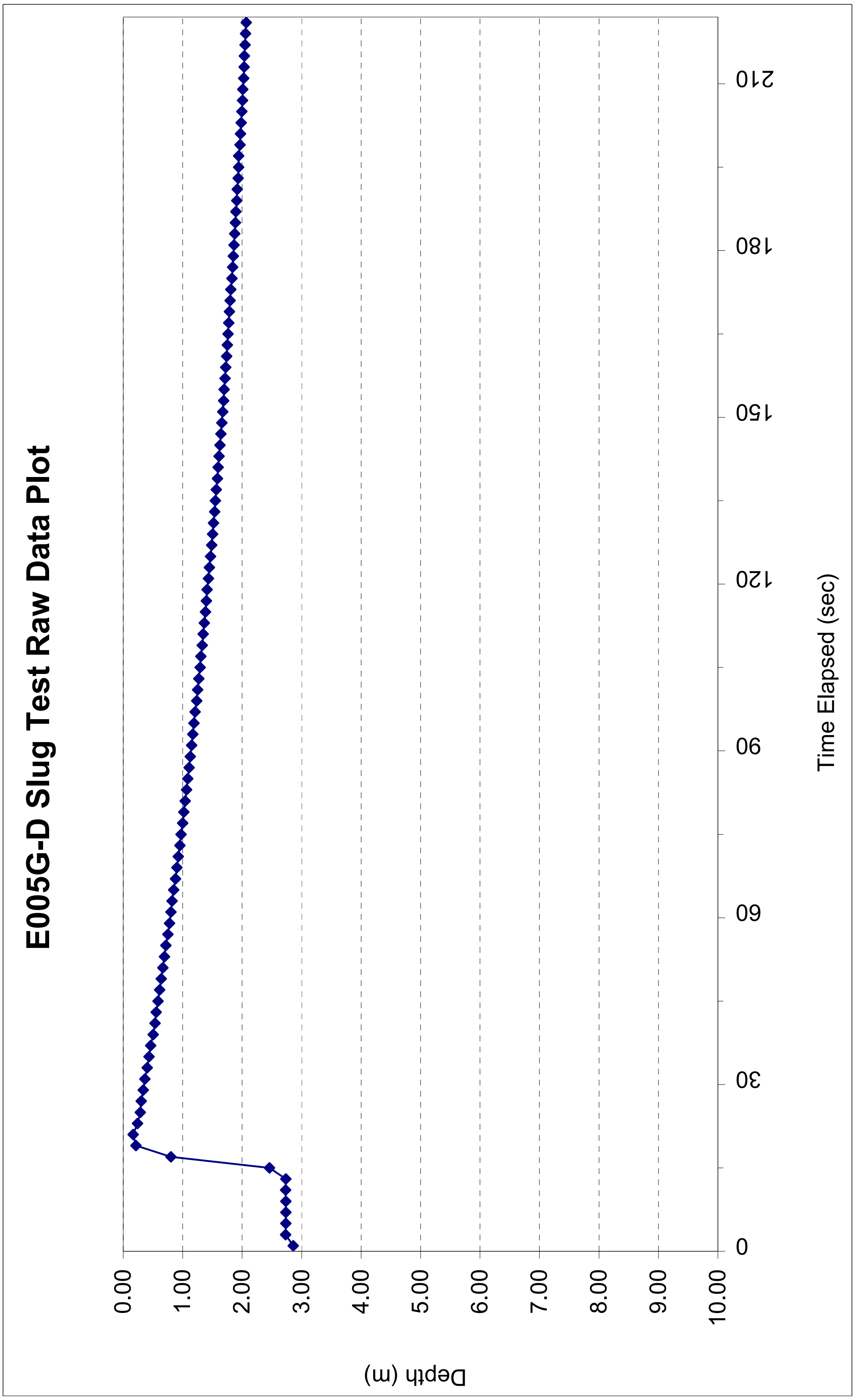
42907466/WHST-STU-WA-RPT-0090/0

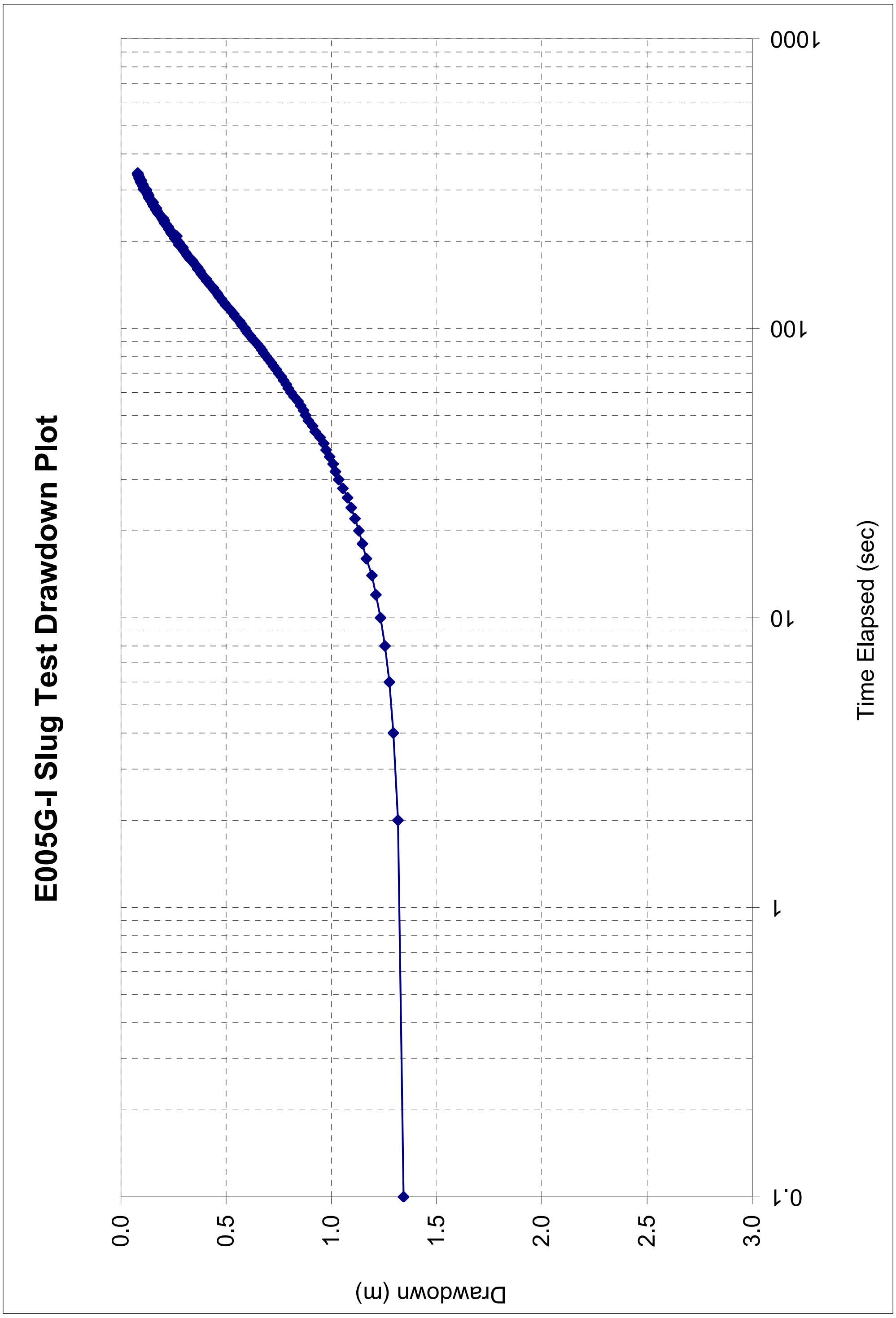

E016G-D Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100
1000

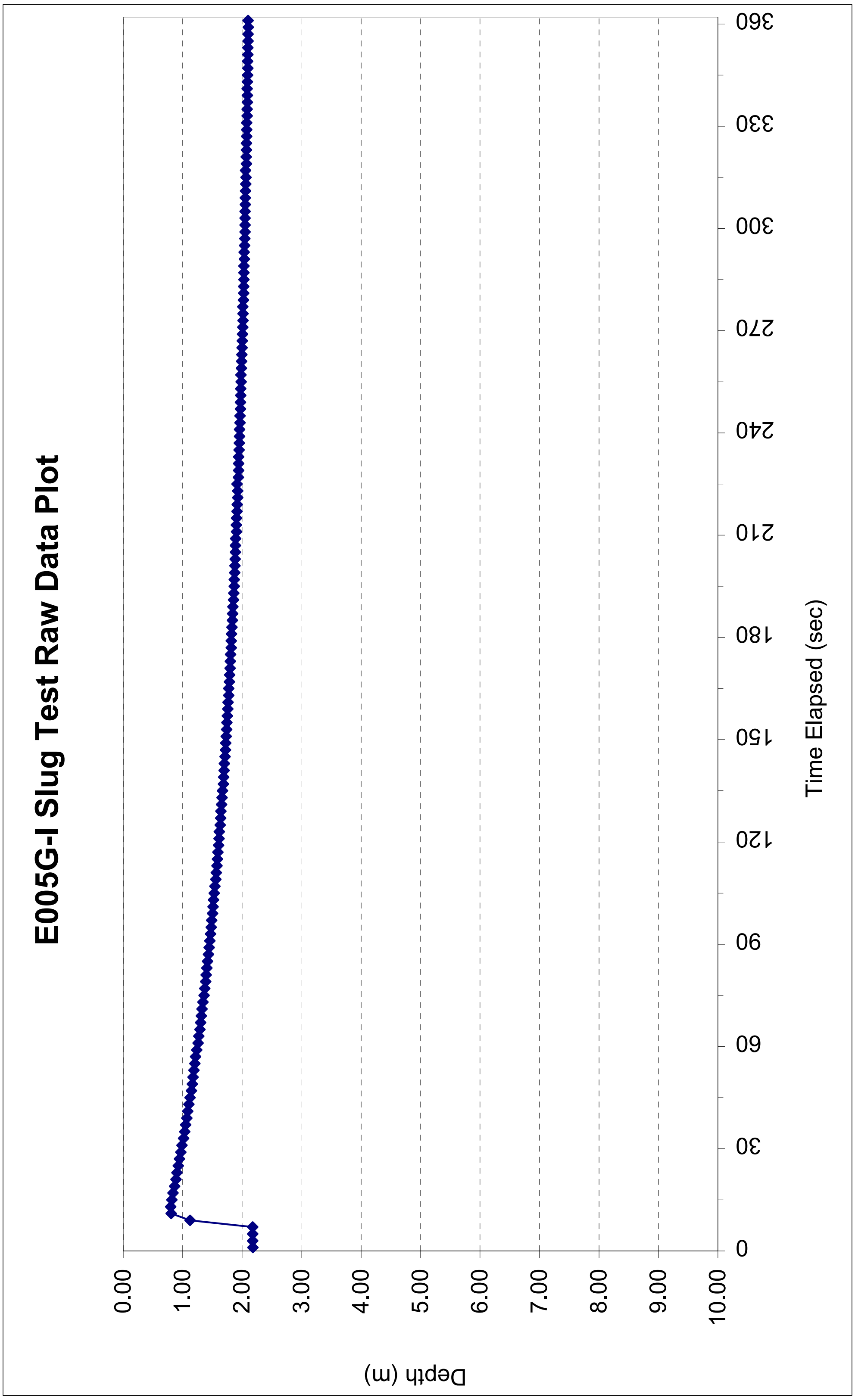

E002G-D Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100
1000

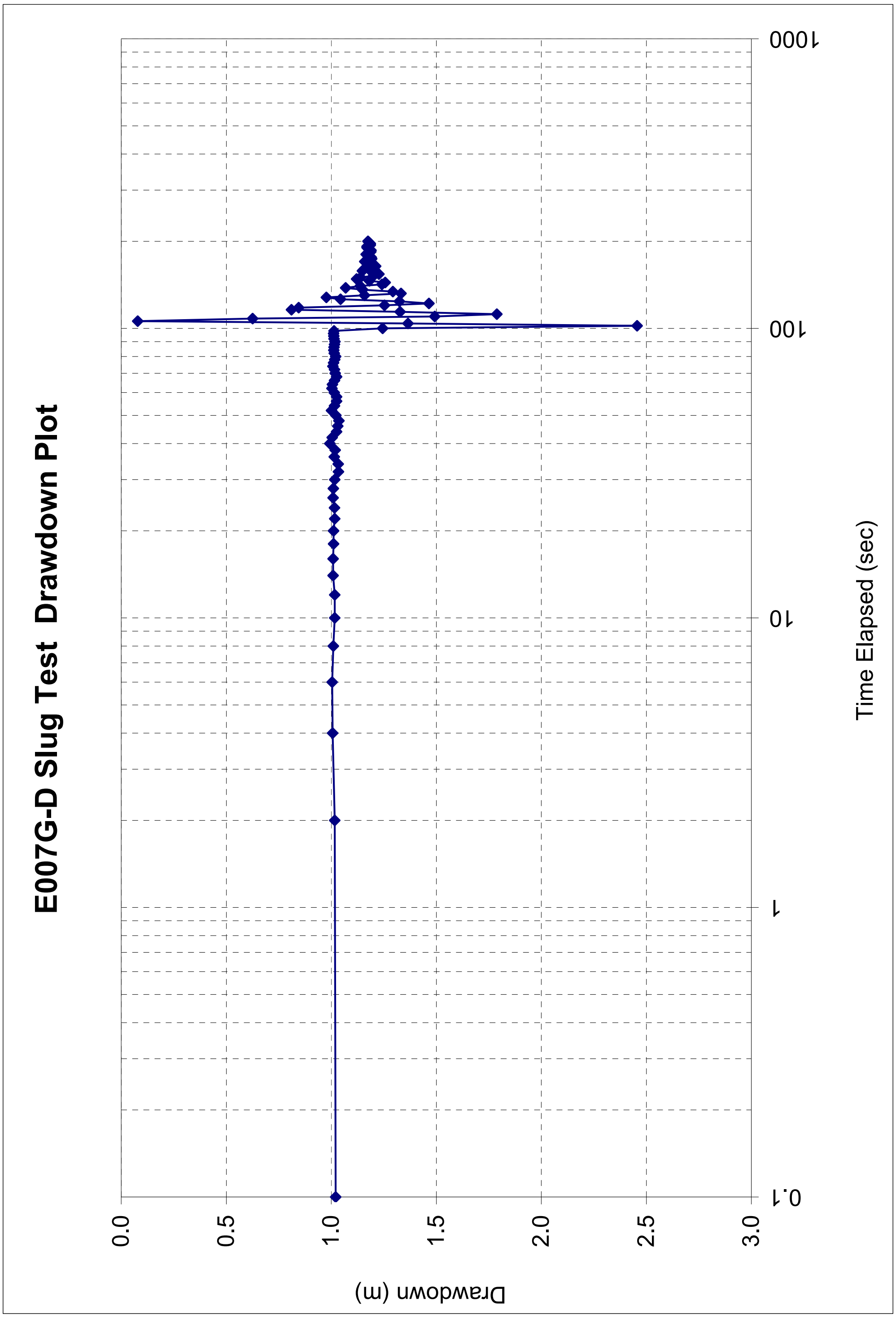

E002G-D Slug Test Raw Data Plot
Depth (m)
0
1
2
3
4
5
6
7
8
9
10
Time Elapsed (sec)
0
30
60
90
120
150
180
210
240
270
300
330
360

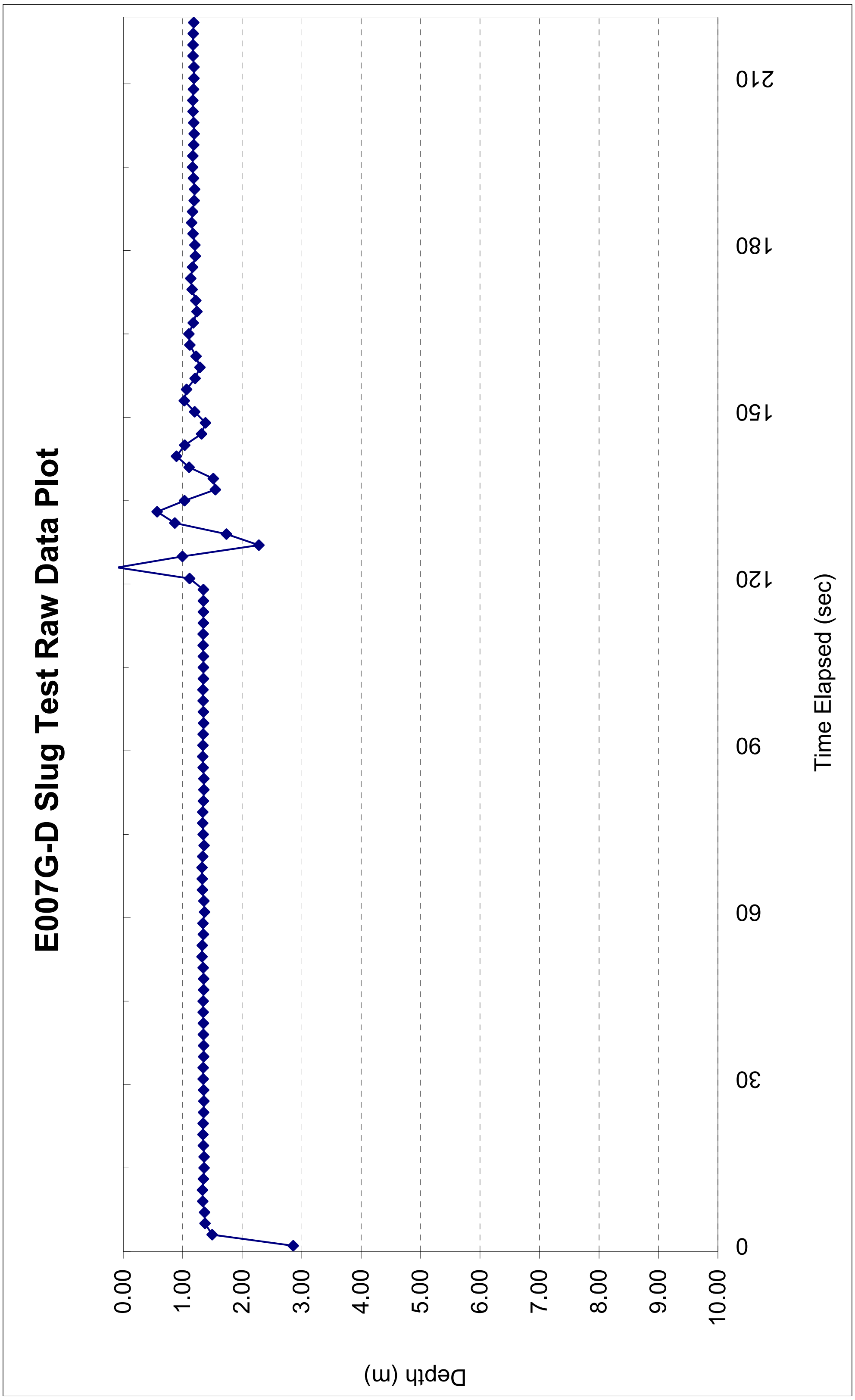

E005G-D Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100
1000

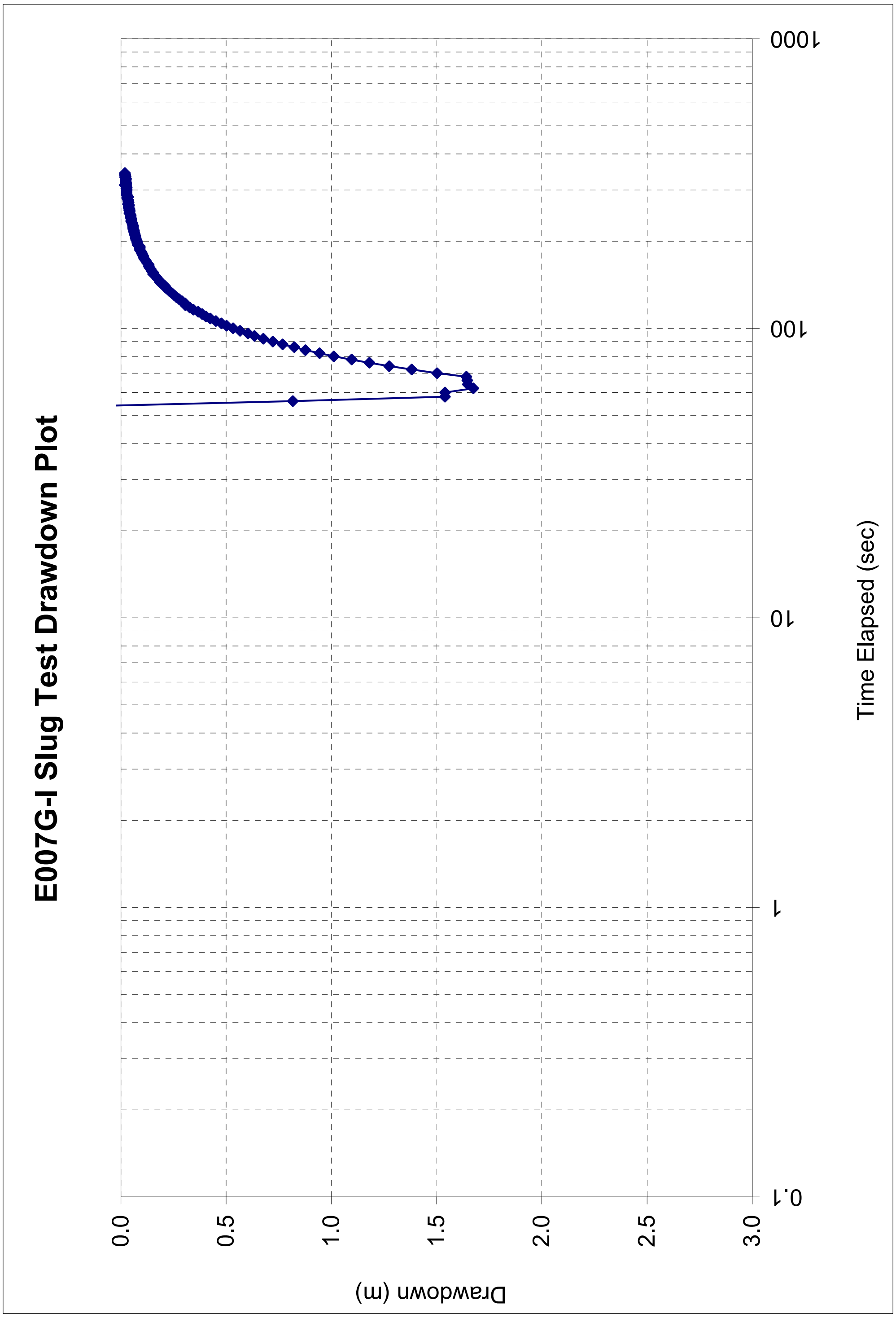

E005G-D Slug Test Raw Data Plot
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time Elapsed (sec)
0
30
60
90
120
150
180
210

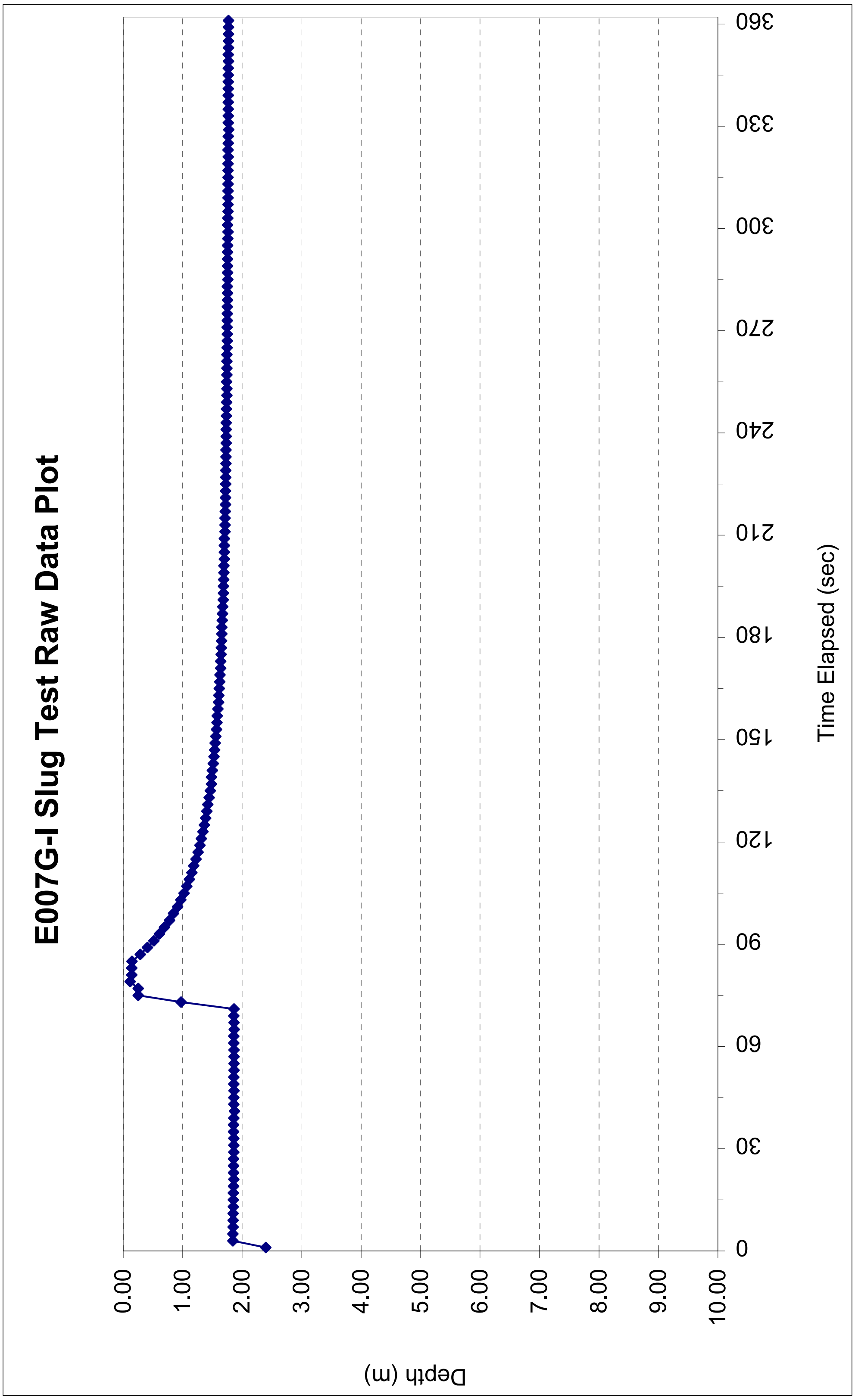

E005G-I Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100
1000

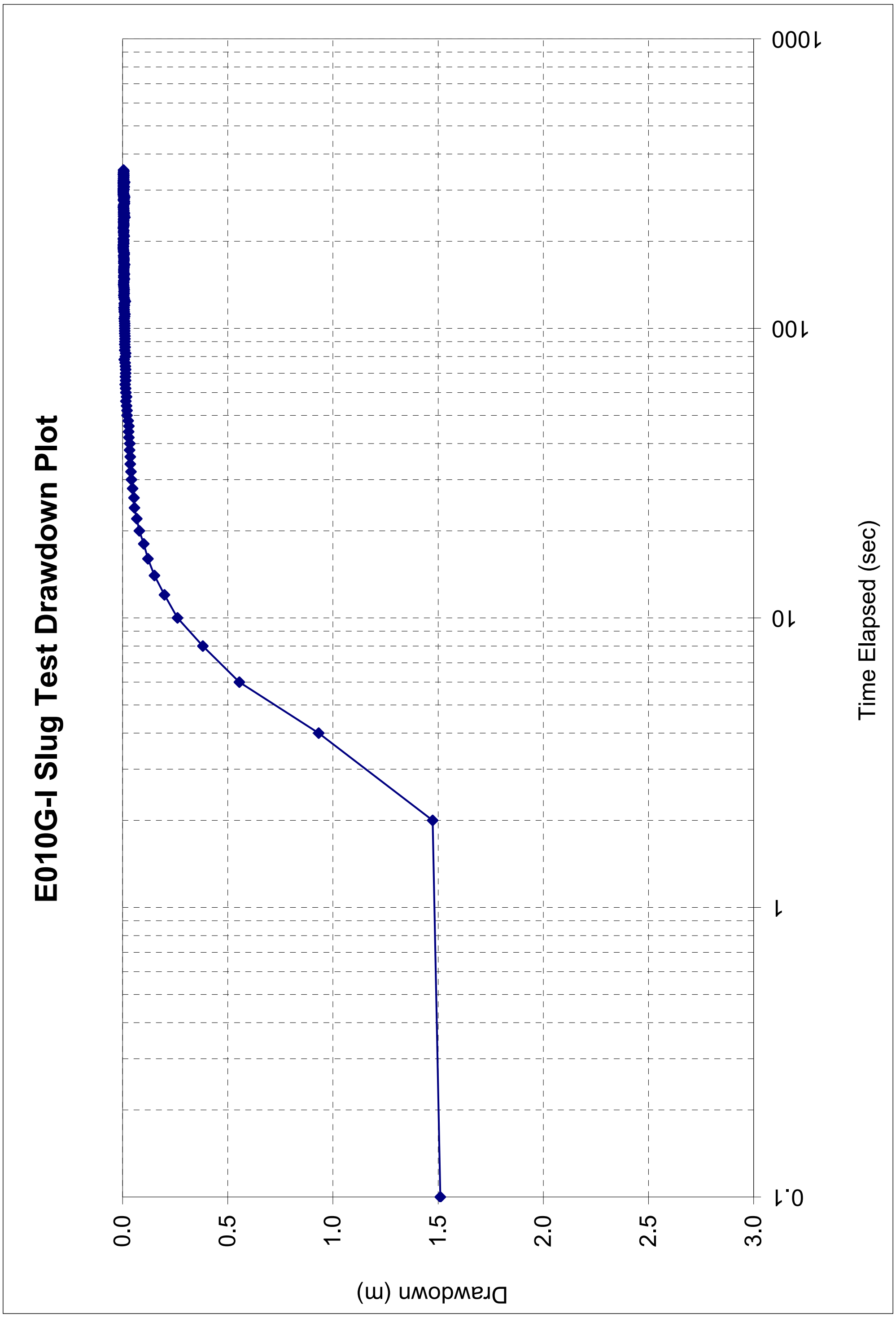

E005G-I Slug Test Raw Data Plot
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time Elapsed (sec)
0
30
60
90
120
150
180
210
240
270
300
330
360

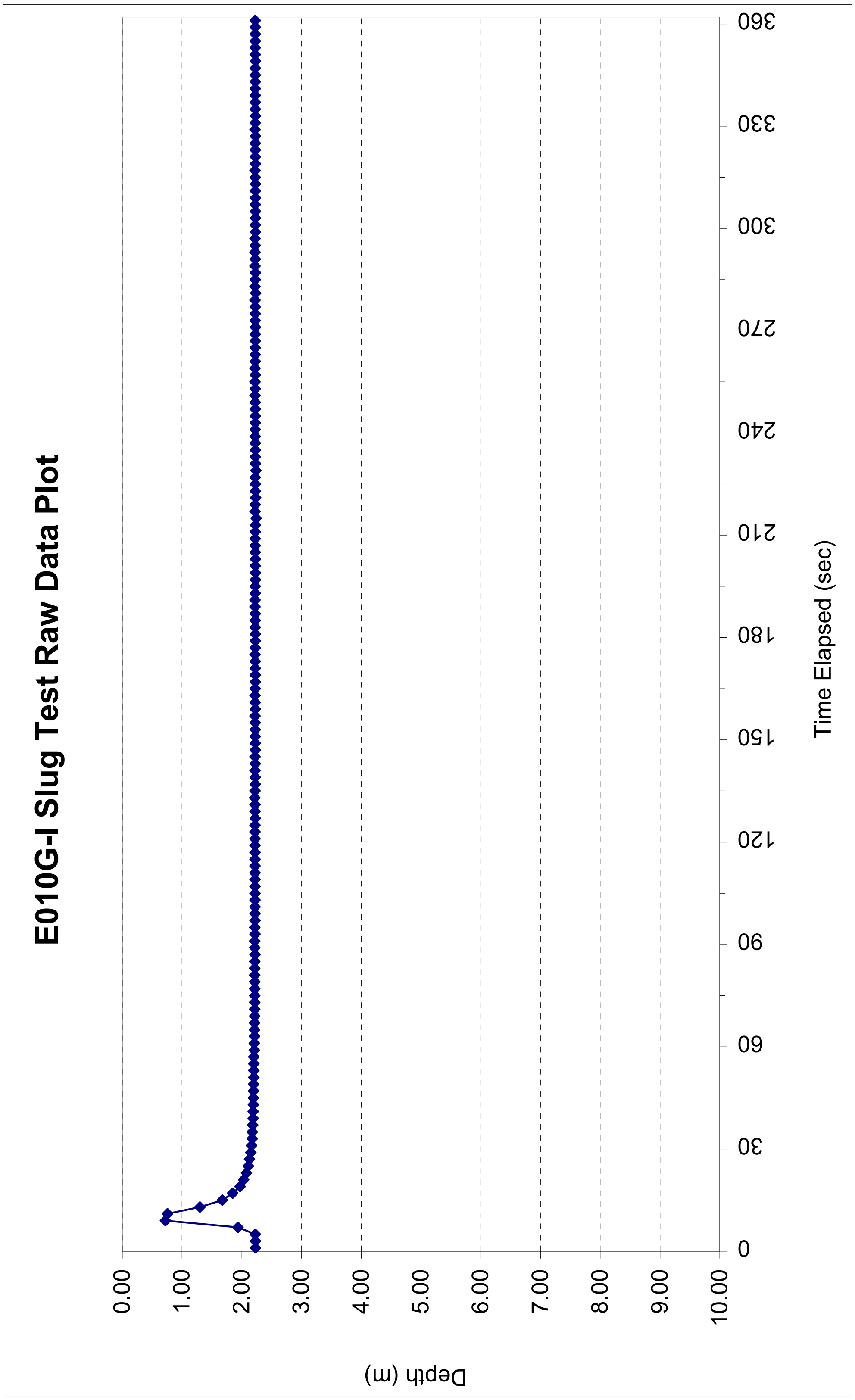

E007G-D Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100
1000

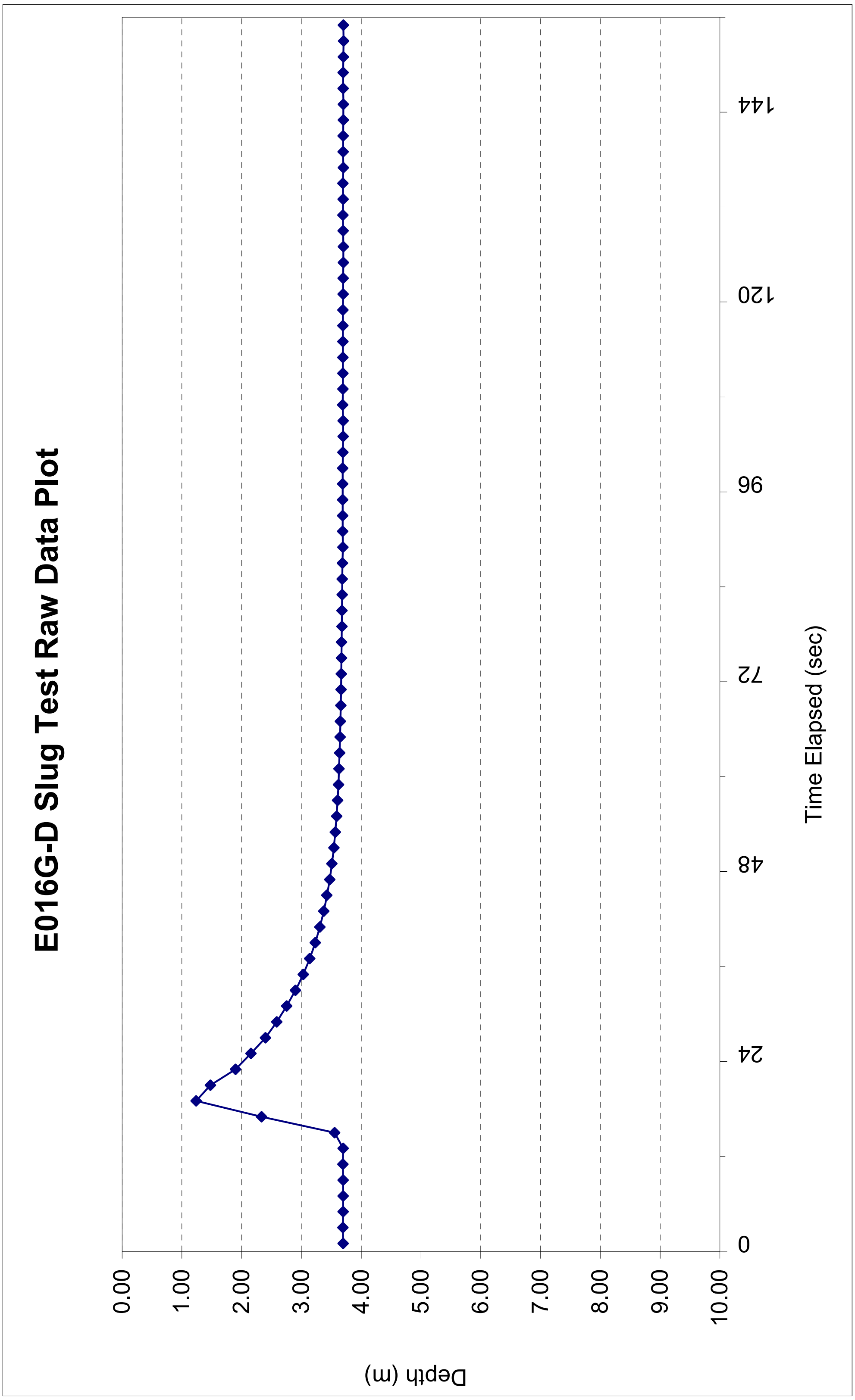

E007G-D Slug Test Raw Data Plot
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time Elapsed (sec)
0
30
60
90
120
150
180
210

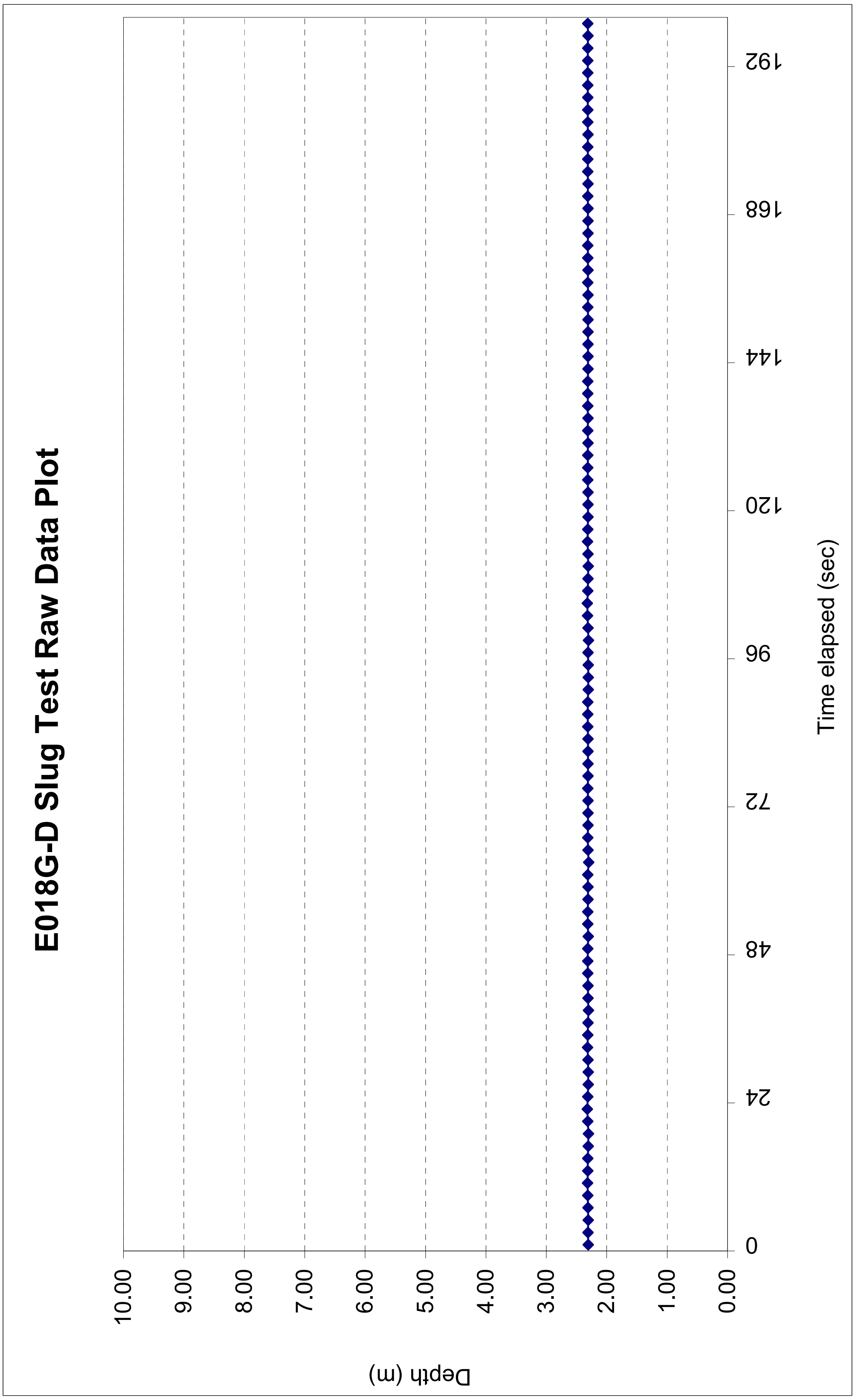

E007G-I Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100
1000

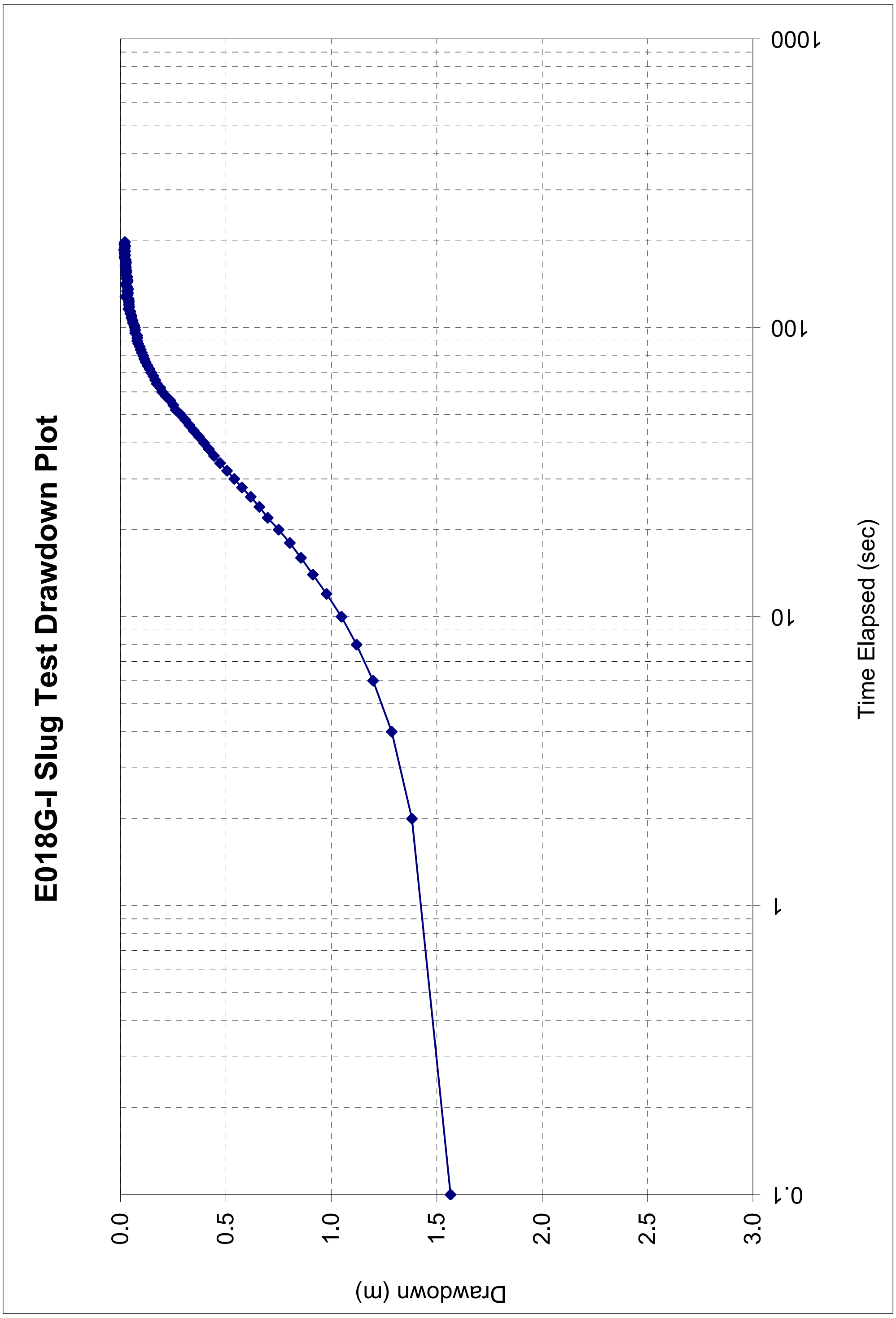

E007G-I Slug Test Raw Data Plot
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time Elapsed (sec)
0
30
60
90
120
150
180
210
240
270
300
330
360

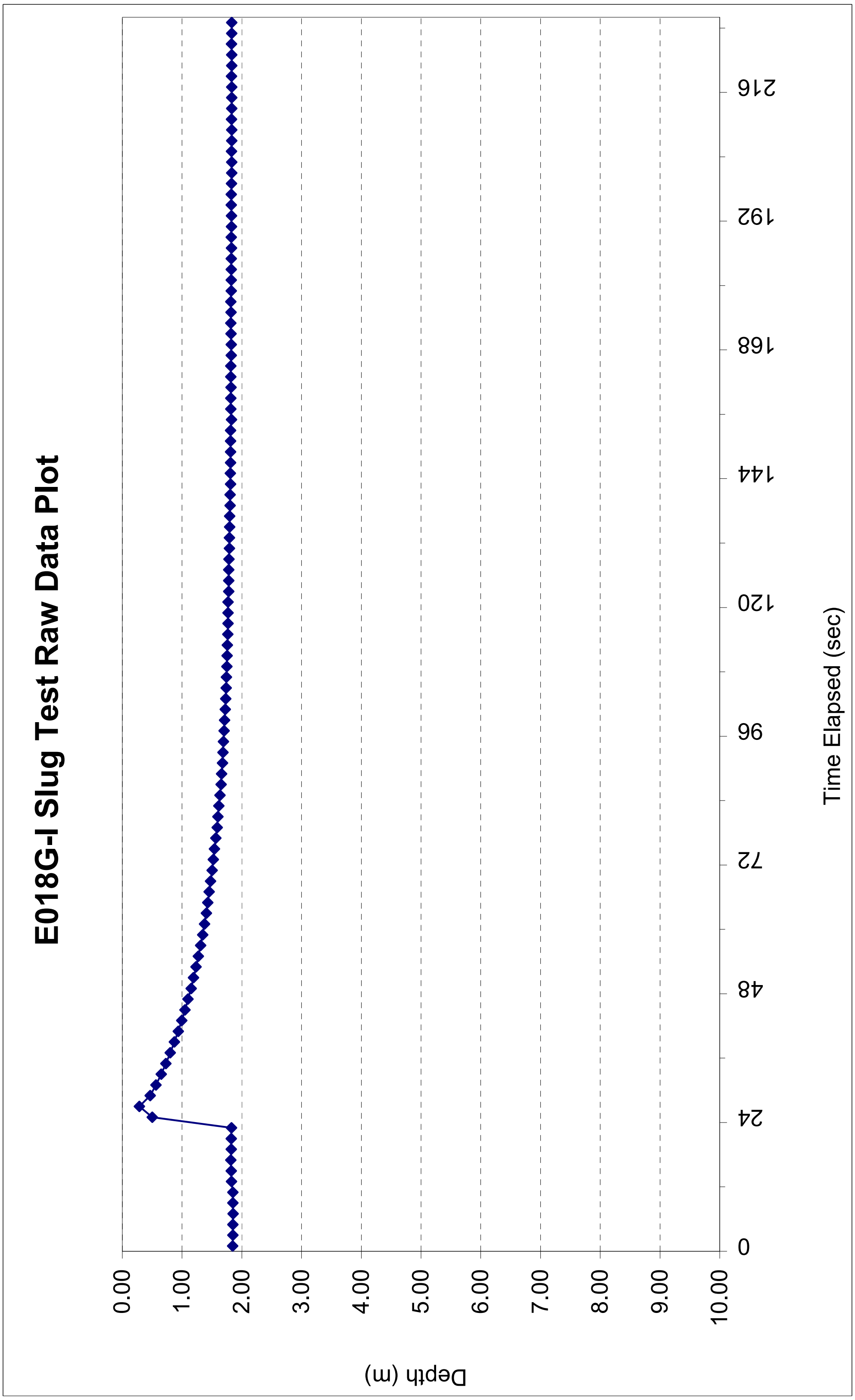

E010G-I Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100
1000

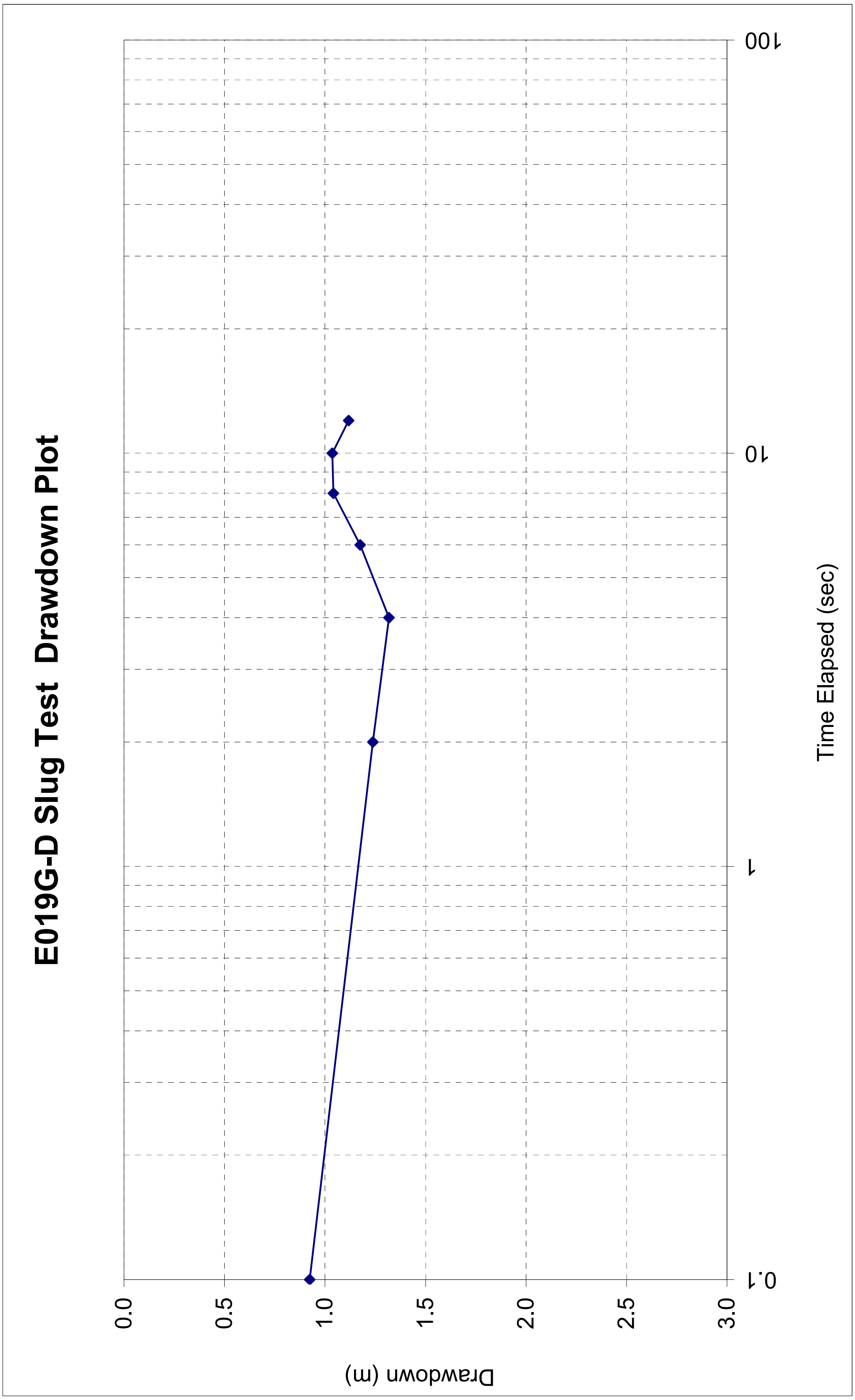

E010G-I Slug Test Raw Data Plot
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time Elapsed (sec)
0
30
60
90
120
150
180
210
240
270
300
330
360

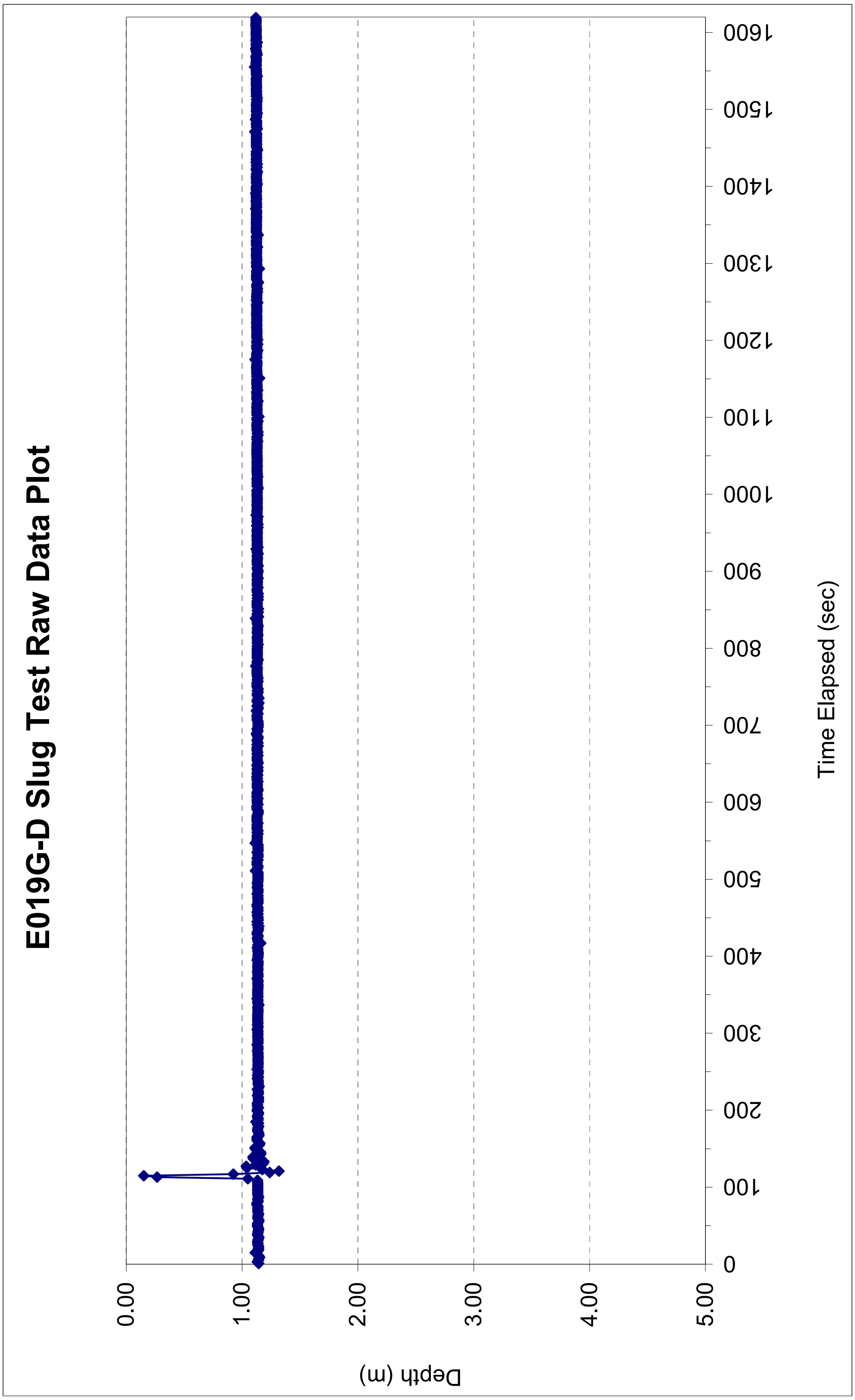

E016G-D Slug Test Raw Data Plot
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time Elapsed (sec)
0
24
48
72
96
120
144


E018G-D Slug Test Raw Data Plot
Depth (m)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Time elapsed (sec)
0
24
48
72
96
120
144
168
192

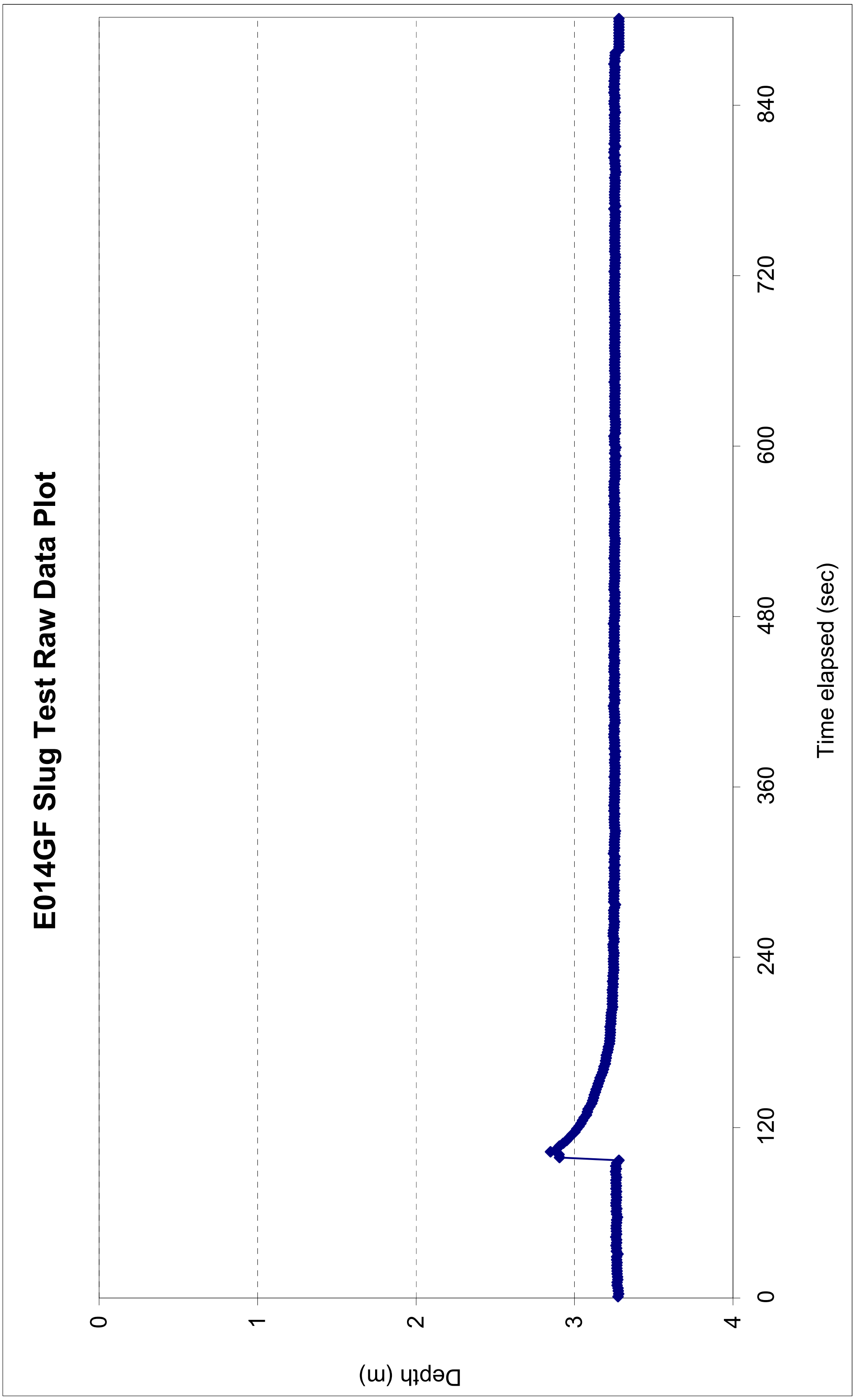

E018G-I Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100
1000

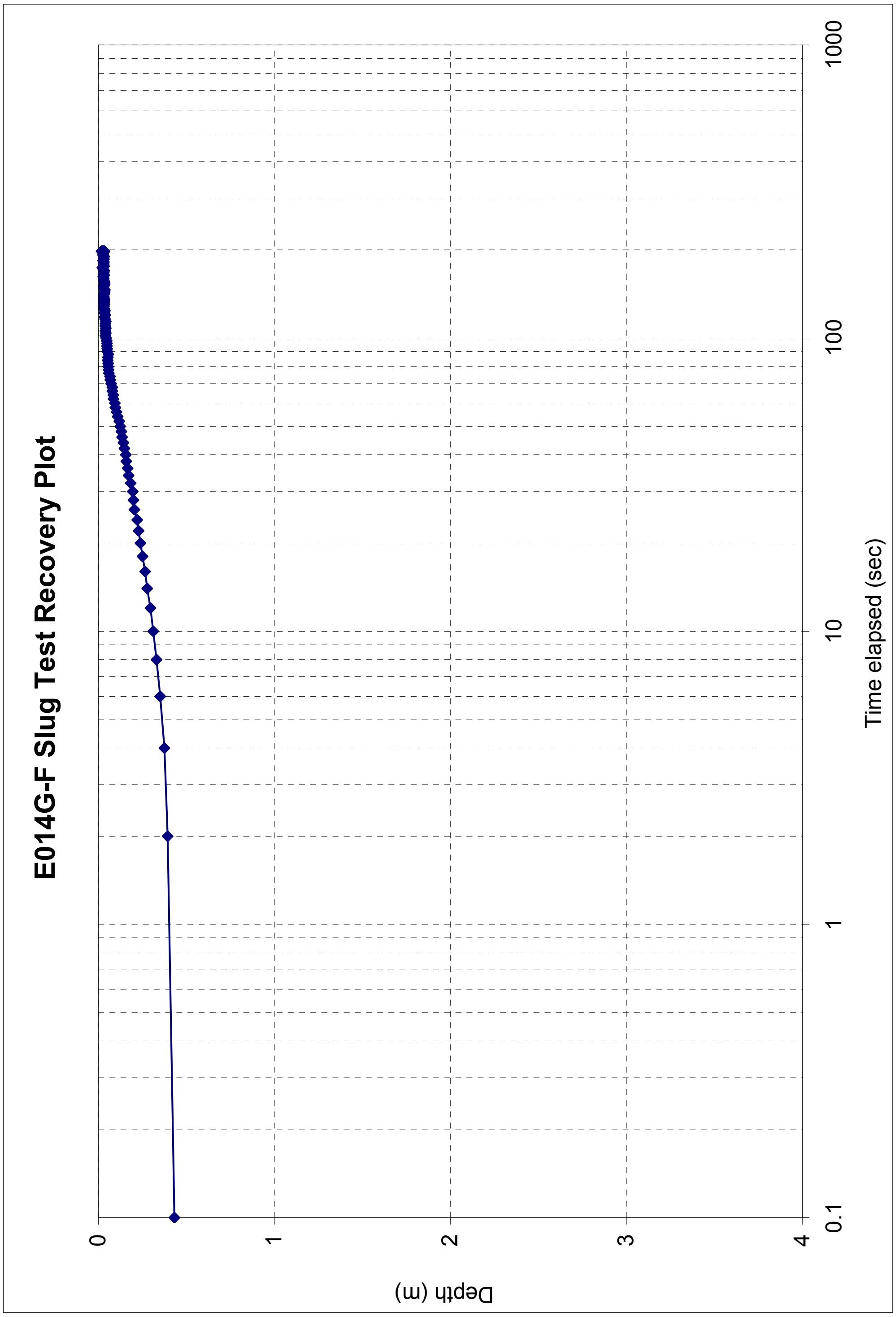

E018G-I Slug Test Raw Data Plot
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time Elapsed (sec)
0
24
48
72
96
120
144
168
192
216

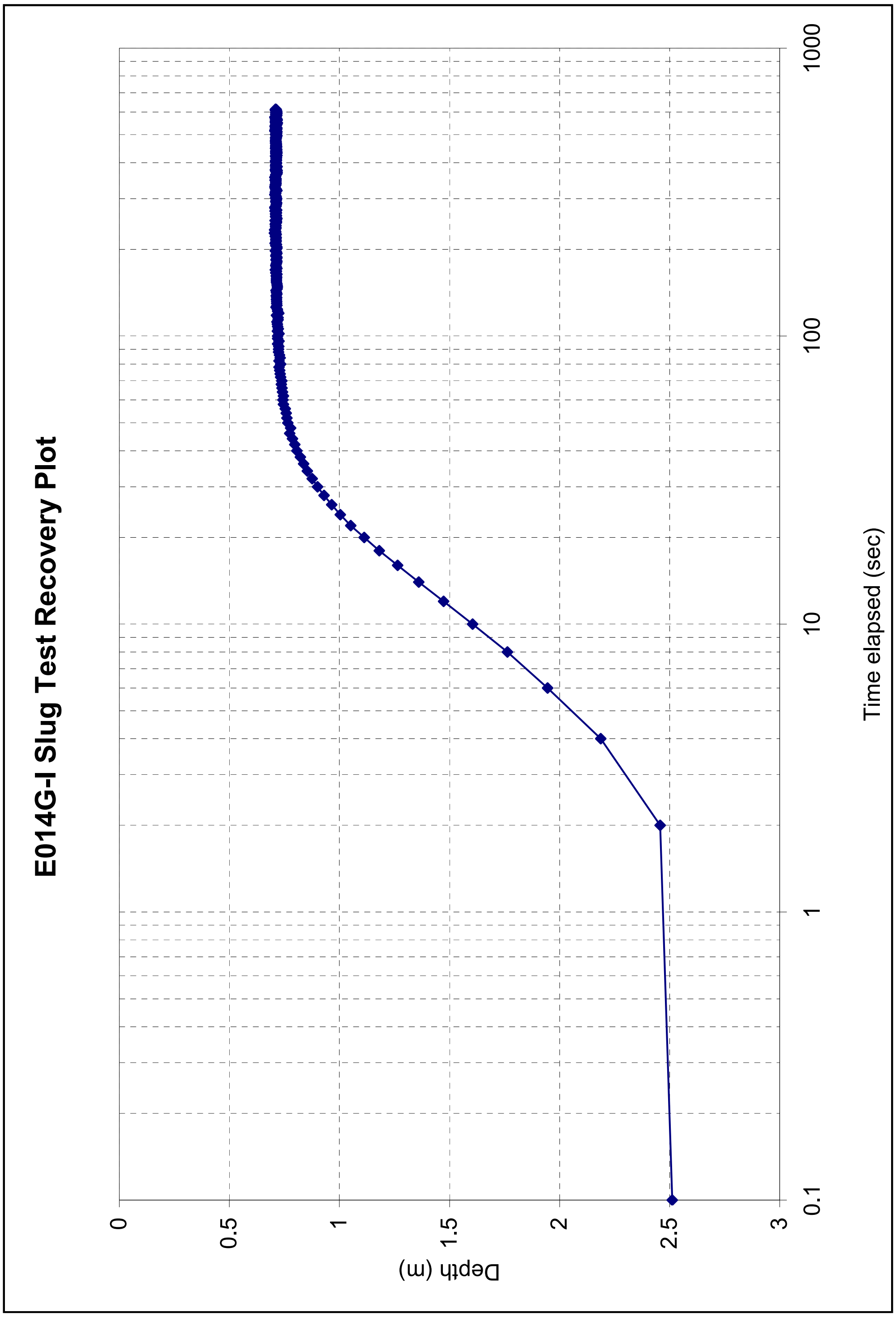

E019G-D Slug Test Drawdown Plot
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time Elapsed (sec)
0.1
1
10
100

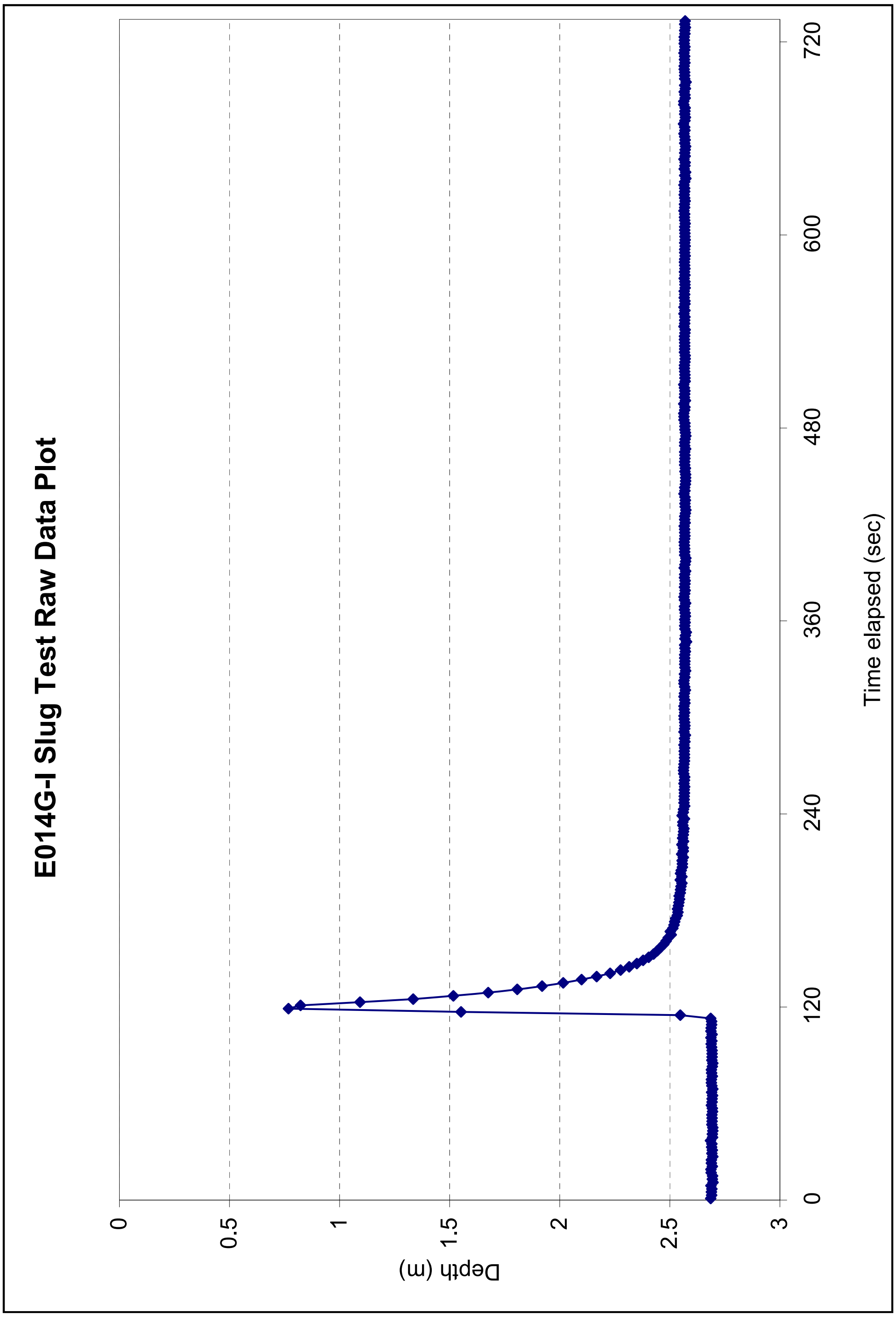


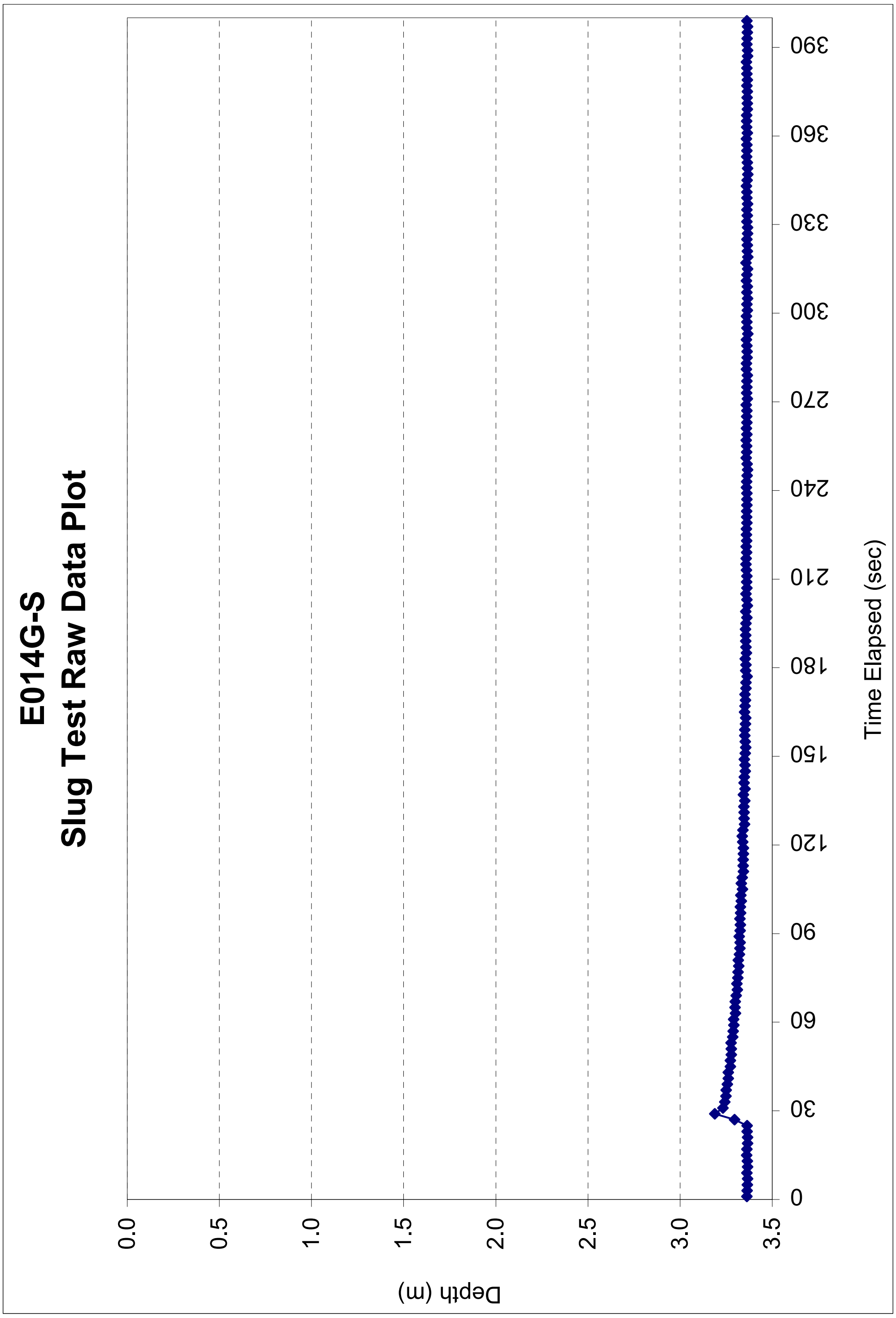
E019G-D Slug Test Raw Data Plot
Depth (m)
Time Elapsed (sec)
0.00
1.00
2.00
3.00
4.00
5.00
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600

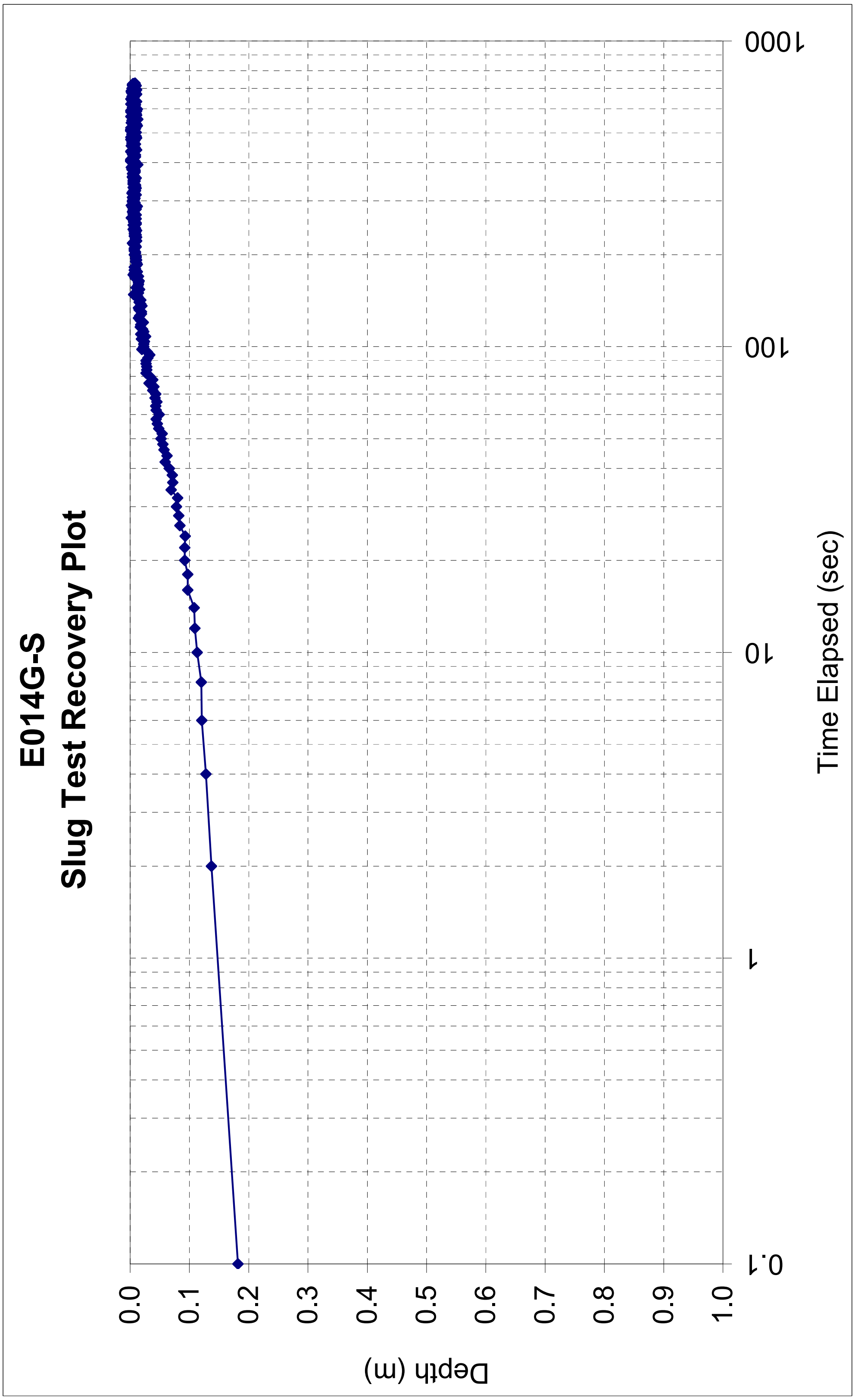

E014GF Slug Test Raw Data Plot
Depth (m)
0
1
2
3
4
Time elapsed (sec)
0
120
240
360
480
600
720
840

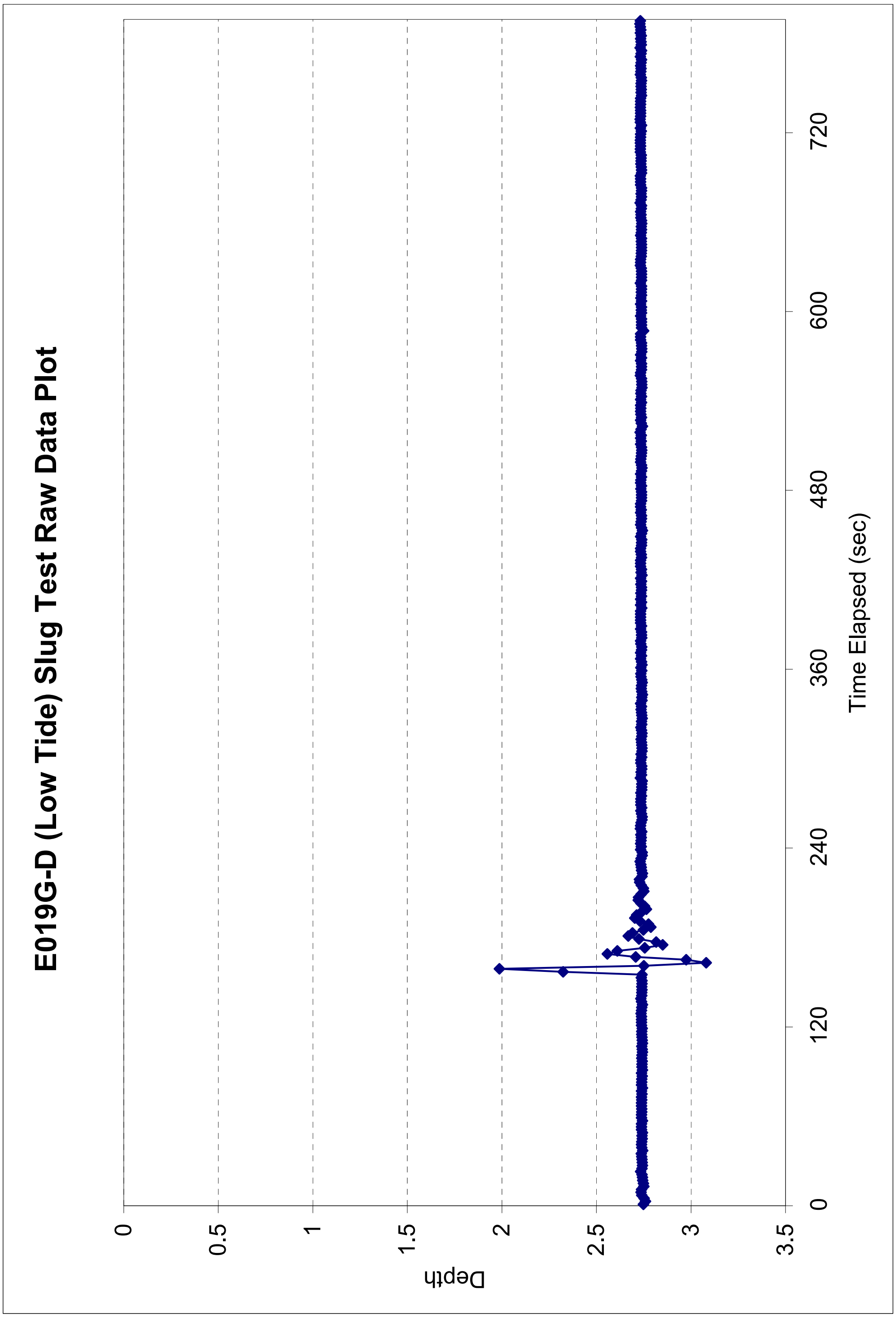

E014G-F Slug Test Recovery Plot
Depth (m)
0
1
2
3
4
Time elapsed (sec)
0.1
1
10
100
1000

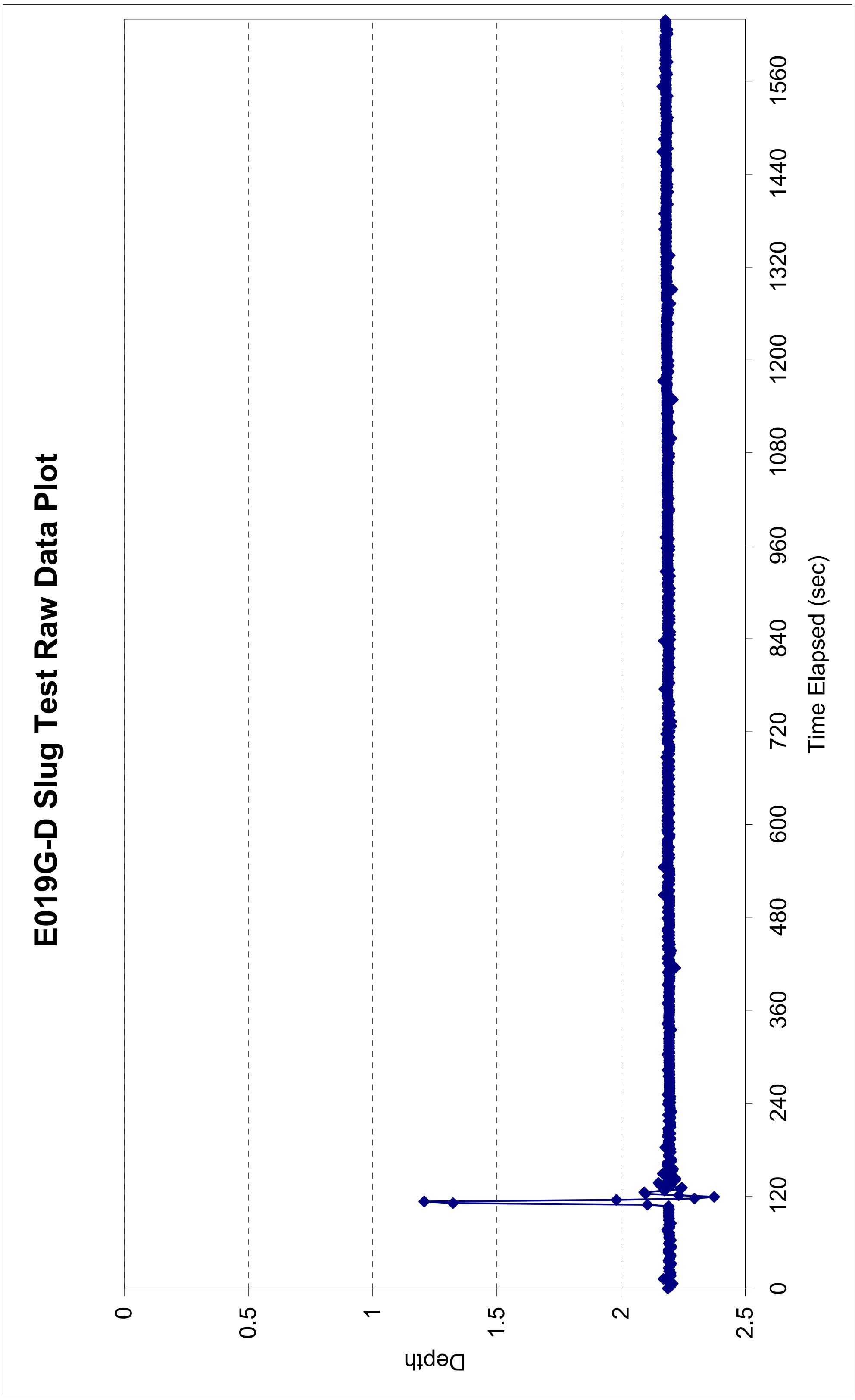

E014G-I Slug Test Recovery Plot
Depth (m)
0
0.5
1
1.5
2
2.5
3
Time elapsed (sec)
0.1
1
10
100
1000

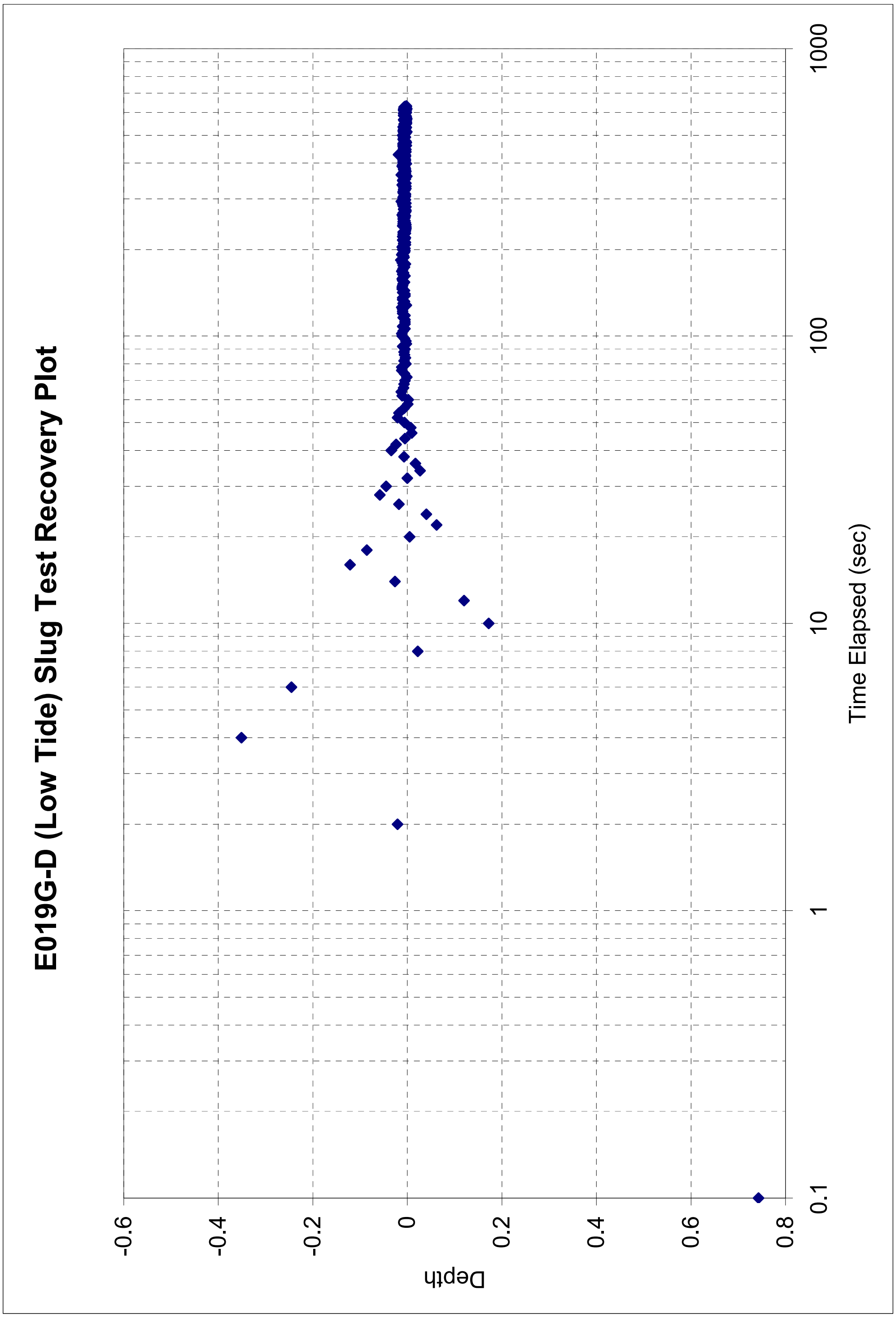

E014G-I Slug Test Raw Data Plot
Depth (m)
0
0.5
1
1.5
2
2.5
3
Time elapsed (sec)
0
120
240
360
480
600
720

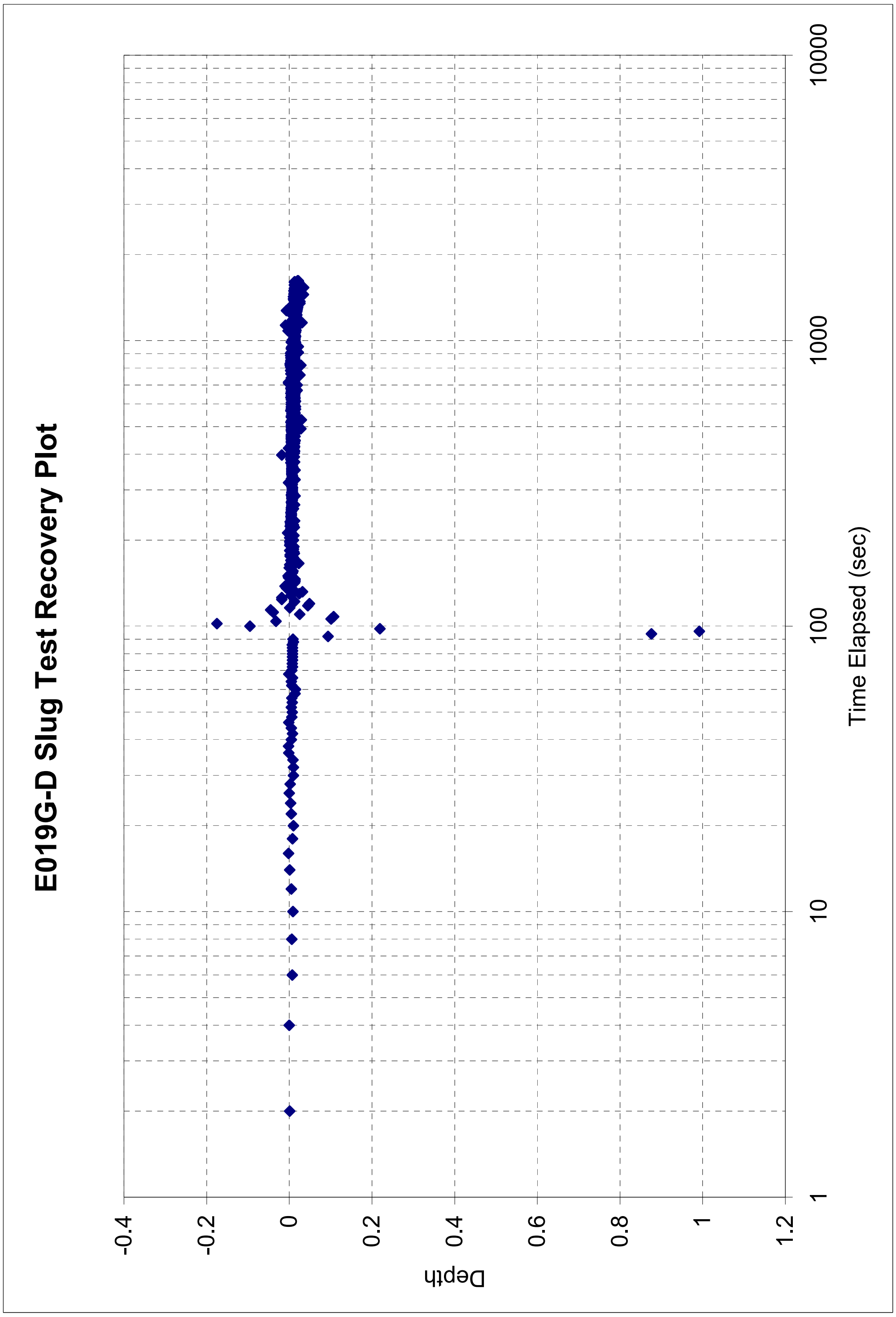

E014G-S
Slug Test Raw Data Plot
Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Time Elapsed (sec)
0
30
60
90
120
150
180
210
240
270
300
330
360
390

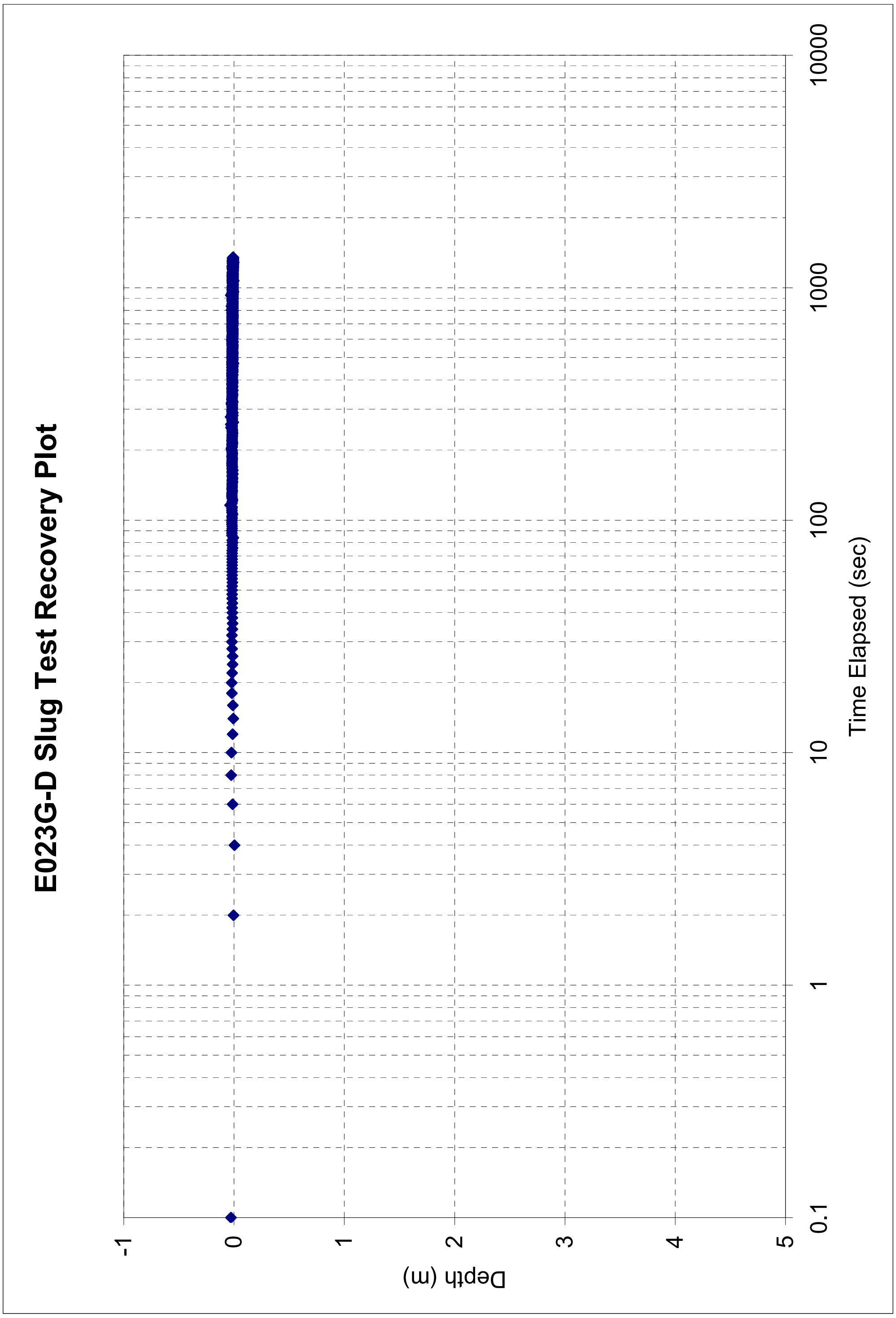

E014G-S
Slug Test Recovery Plot
Depth (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Time Elapsed (sec)
0.1
1
10
100
1000

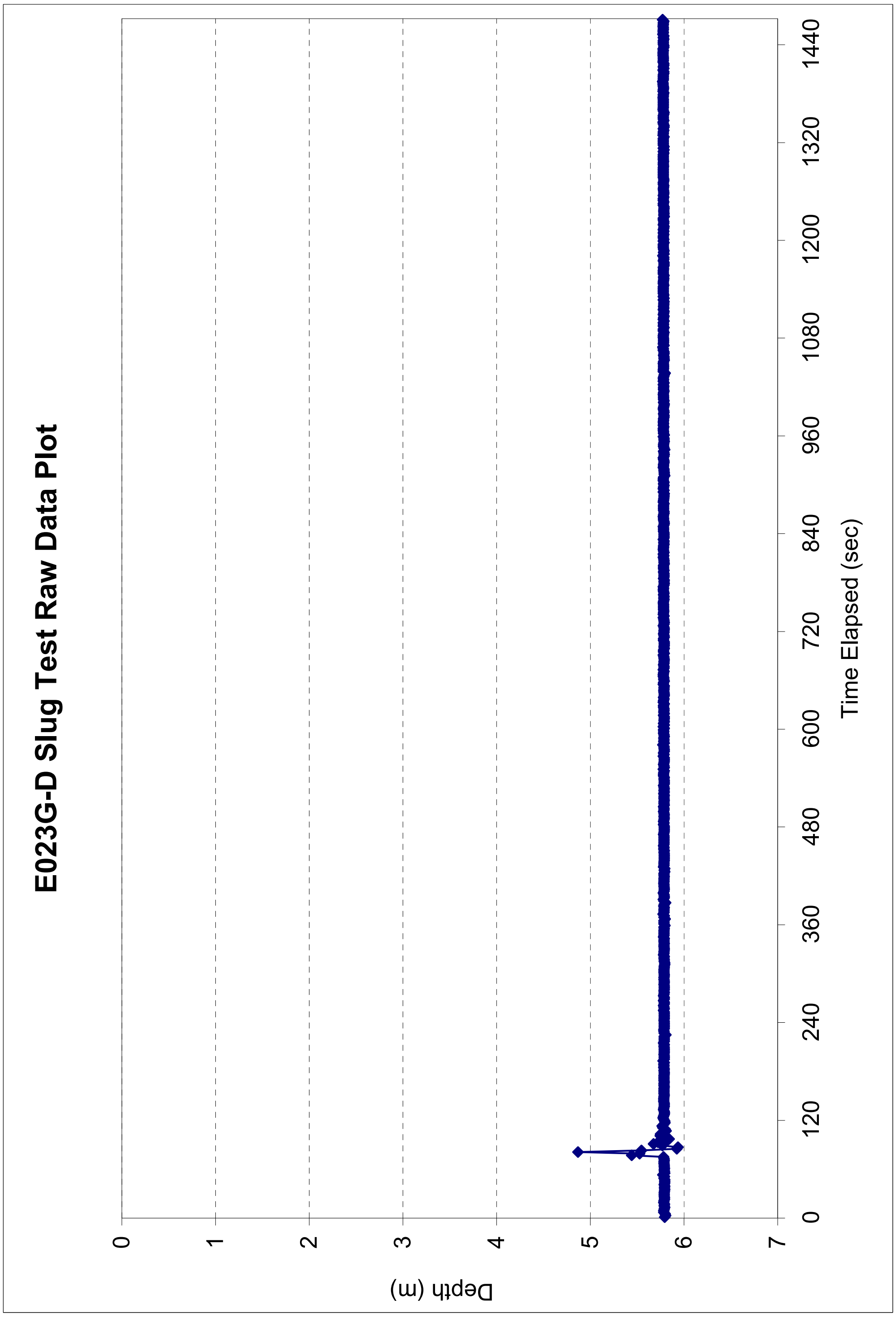

E019G-D (Low Tide) Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
3
3.5
Time Elapsed (sec)
0
120
240
360
480
600
720

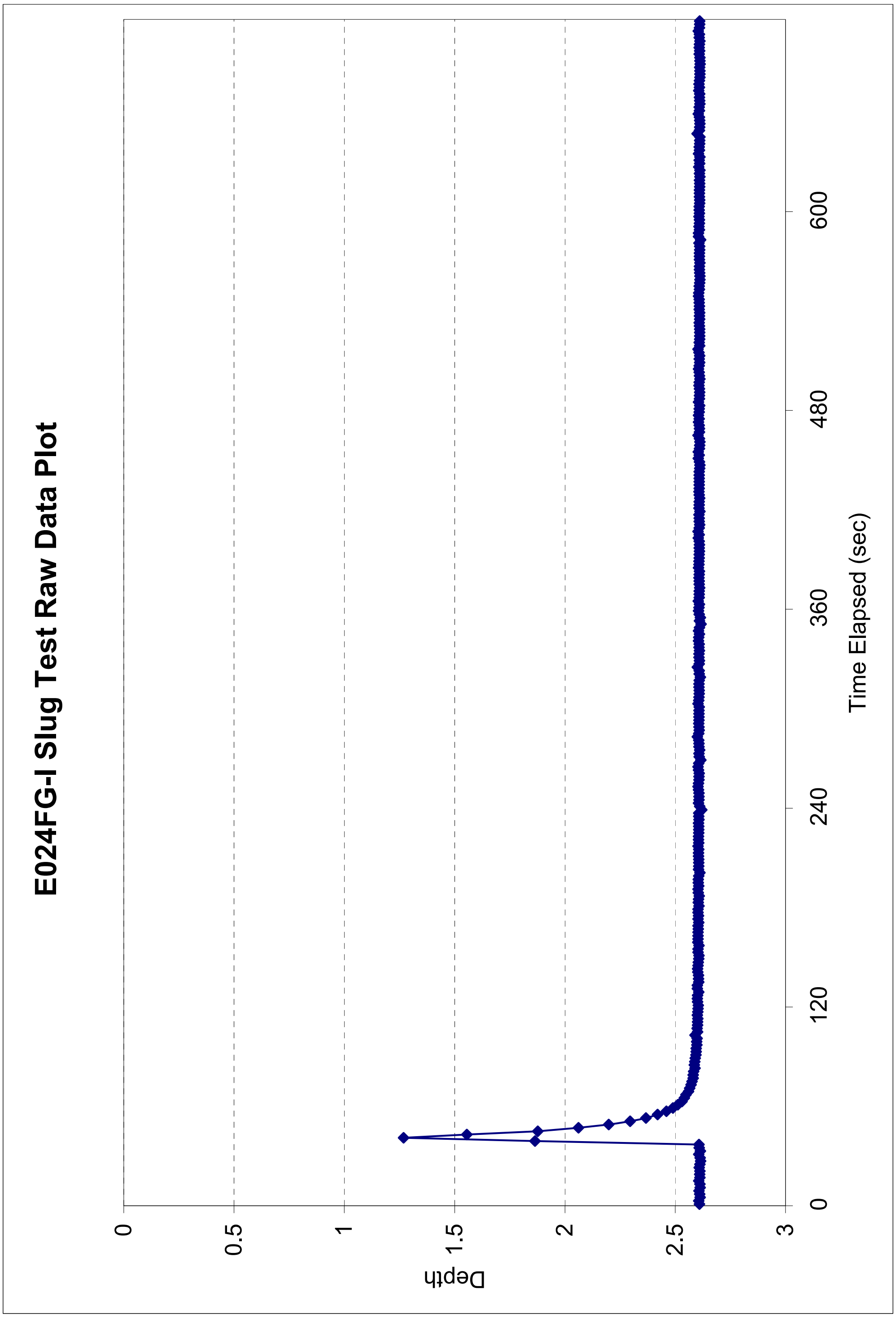

E019G-D Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560

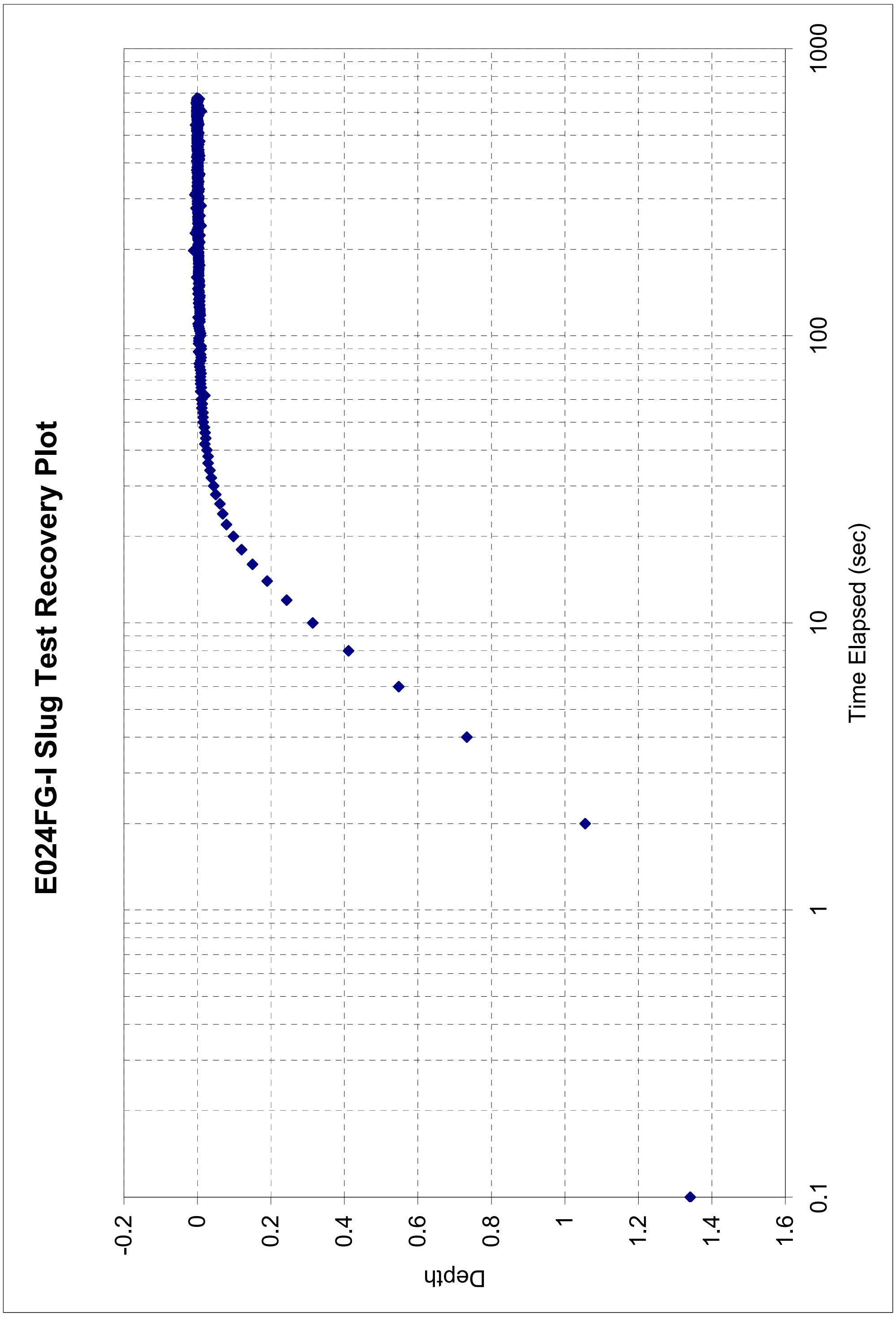

E019G-D (Low Tide) Slug Test Recovery Plot
Depth
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Time Elapsed (sec)
0.1
1
10
100
1000

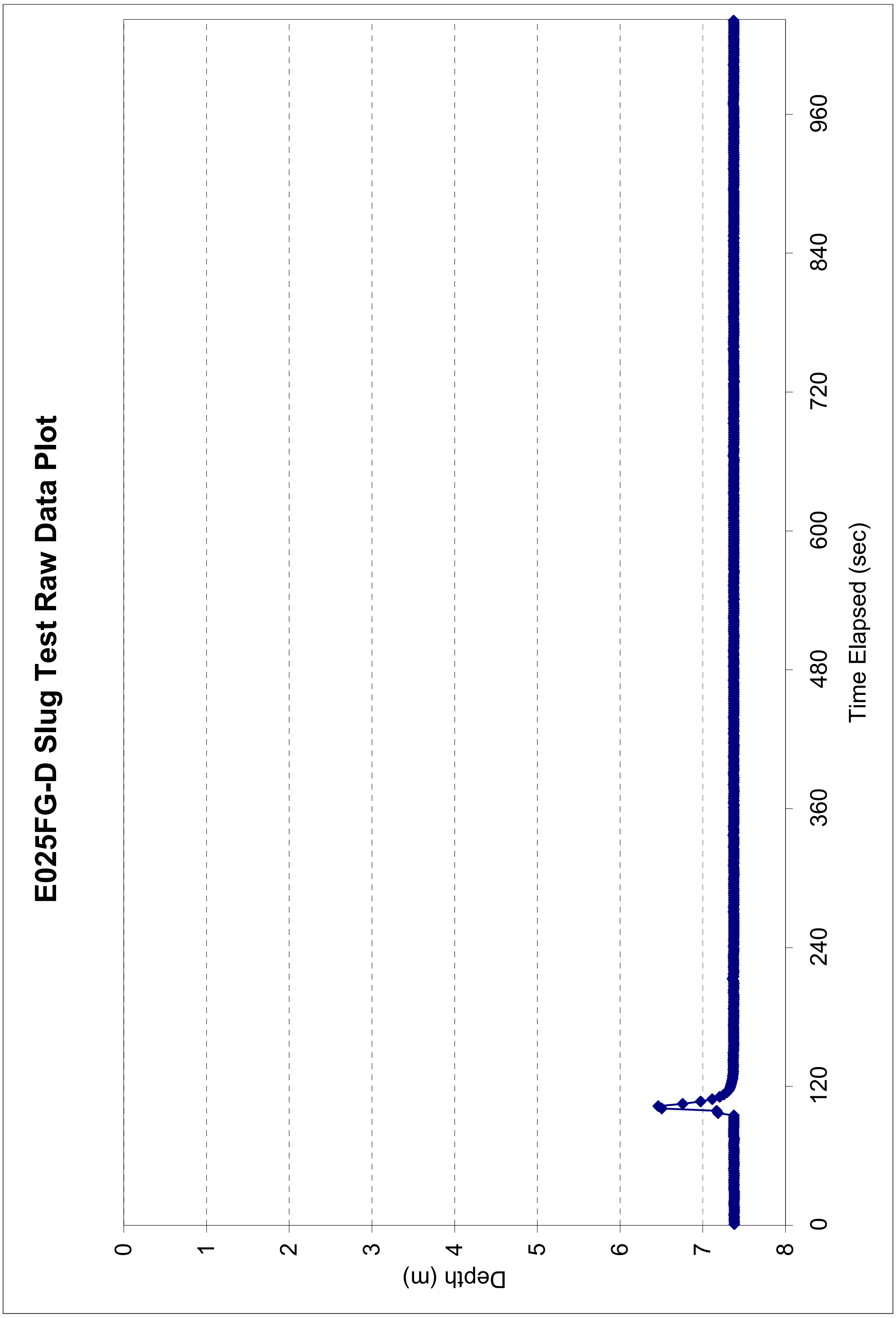

E019G-D Slug Test Recovery Plot
Depth
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
Time Elapsed (sec)
1
10
100
1000
10000

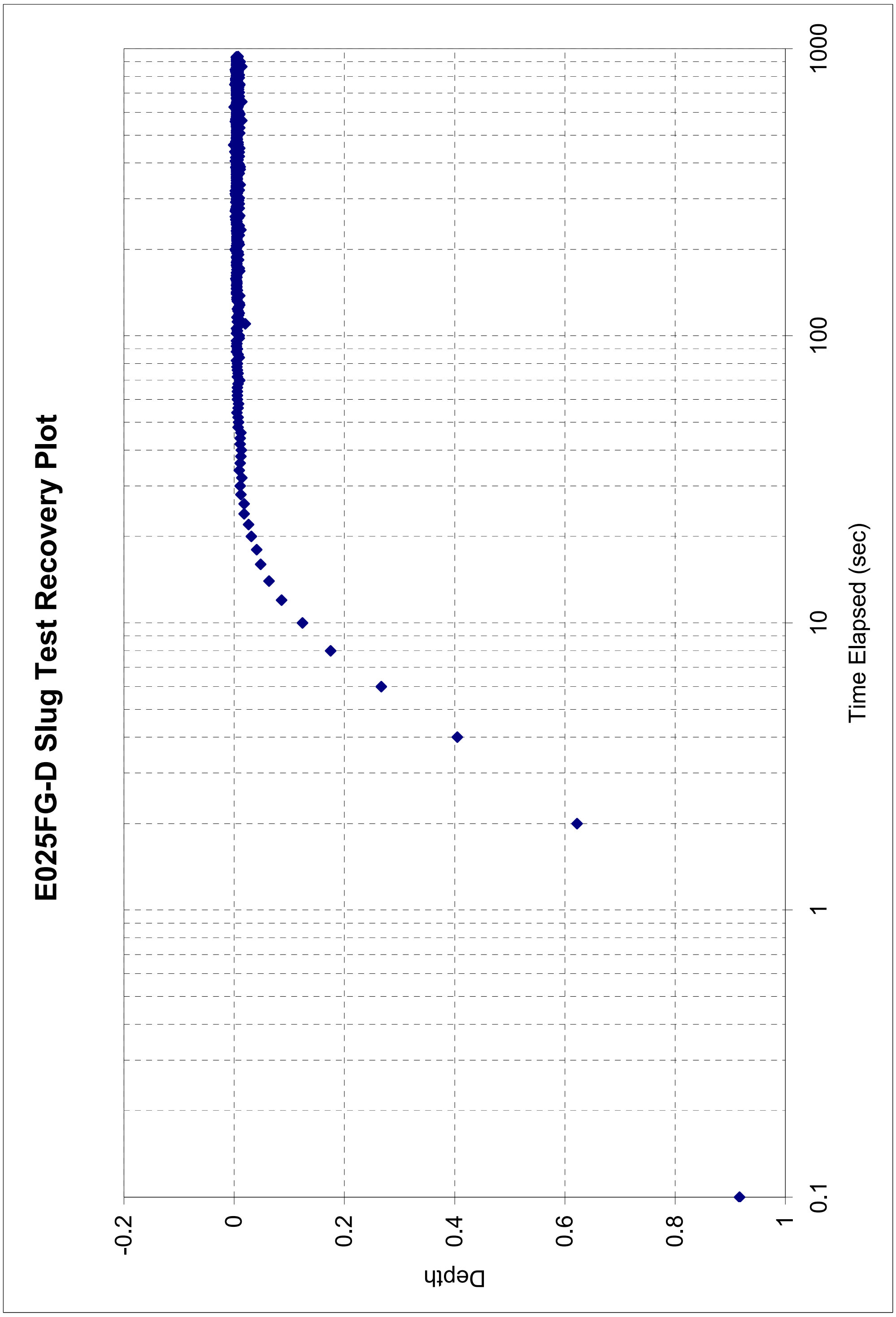

E023G-D Slug Test Recovery Plot
Depth (m)
Time Elapsed (sec)
-1
0
1
2
3
4
5
0.1
1
10
100
1000
10000

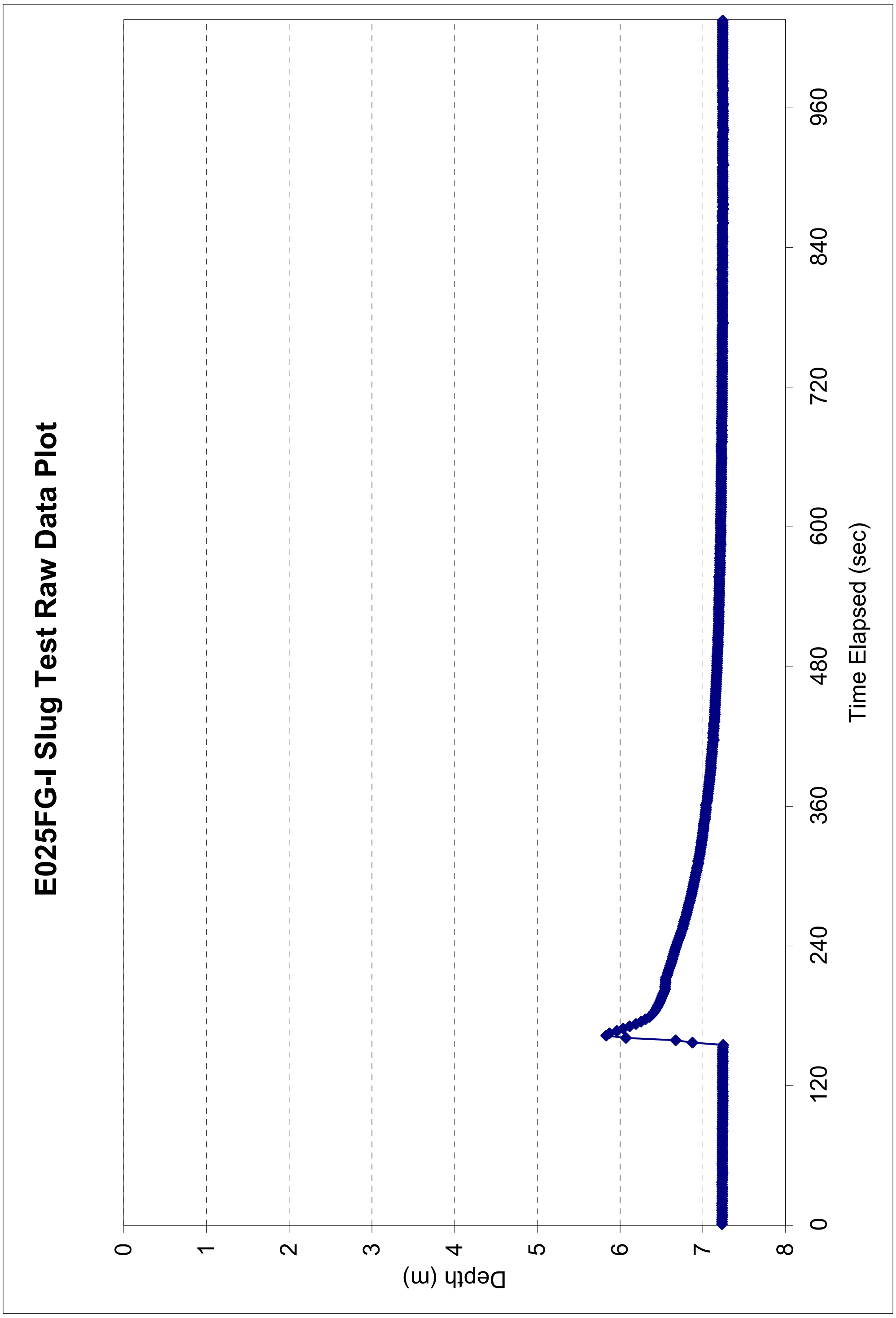

E023G-D Slug Test Raw Data Plot
Depth (m)
0
1
2
3
4
5
6
7
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440

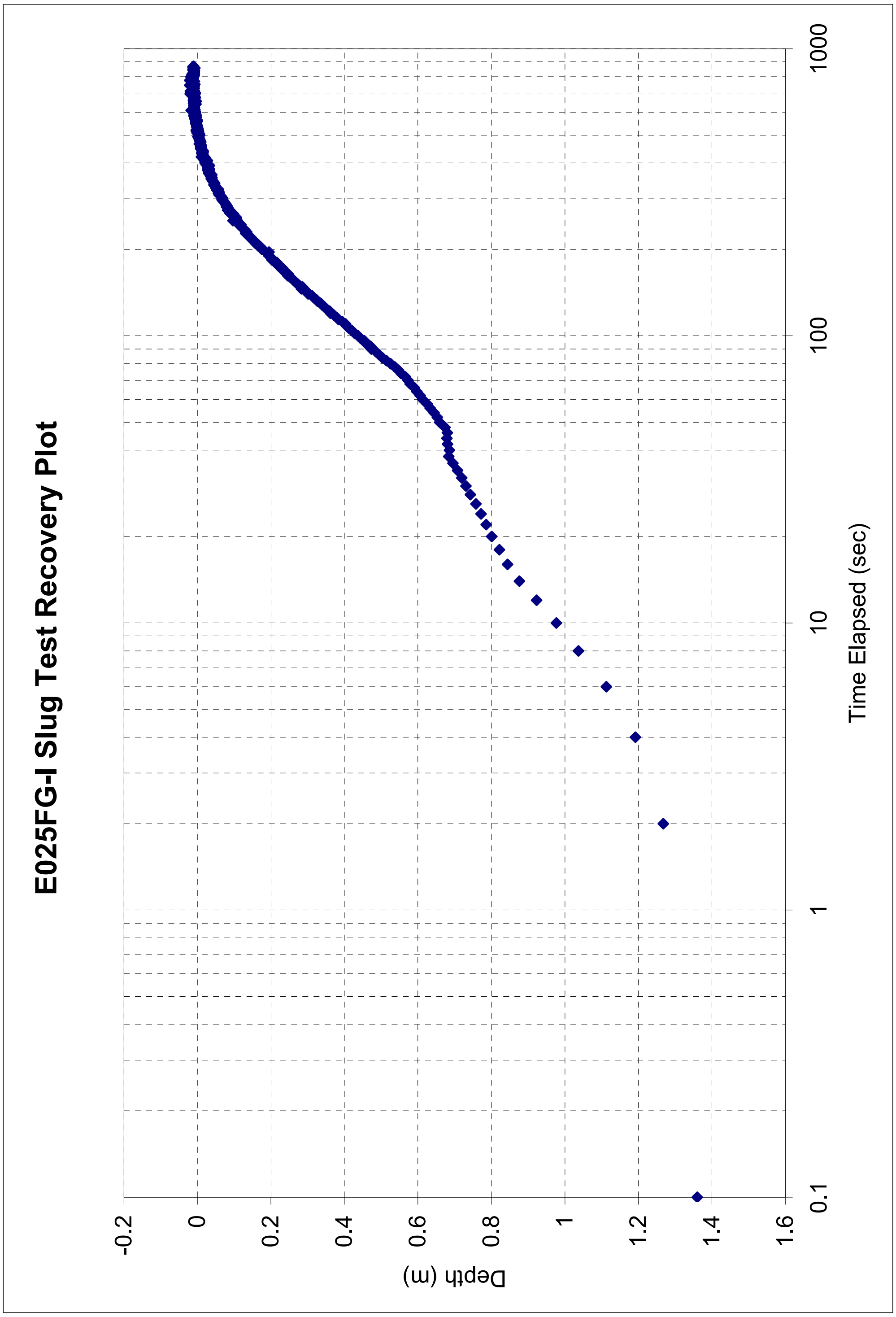

E024FG-I Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
3
Time Elapsed (sec)
0
120
240
360
480
600

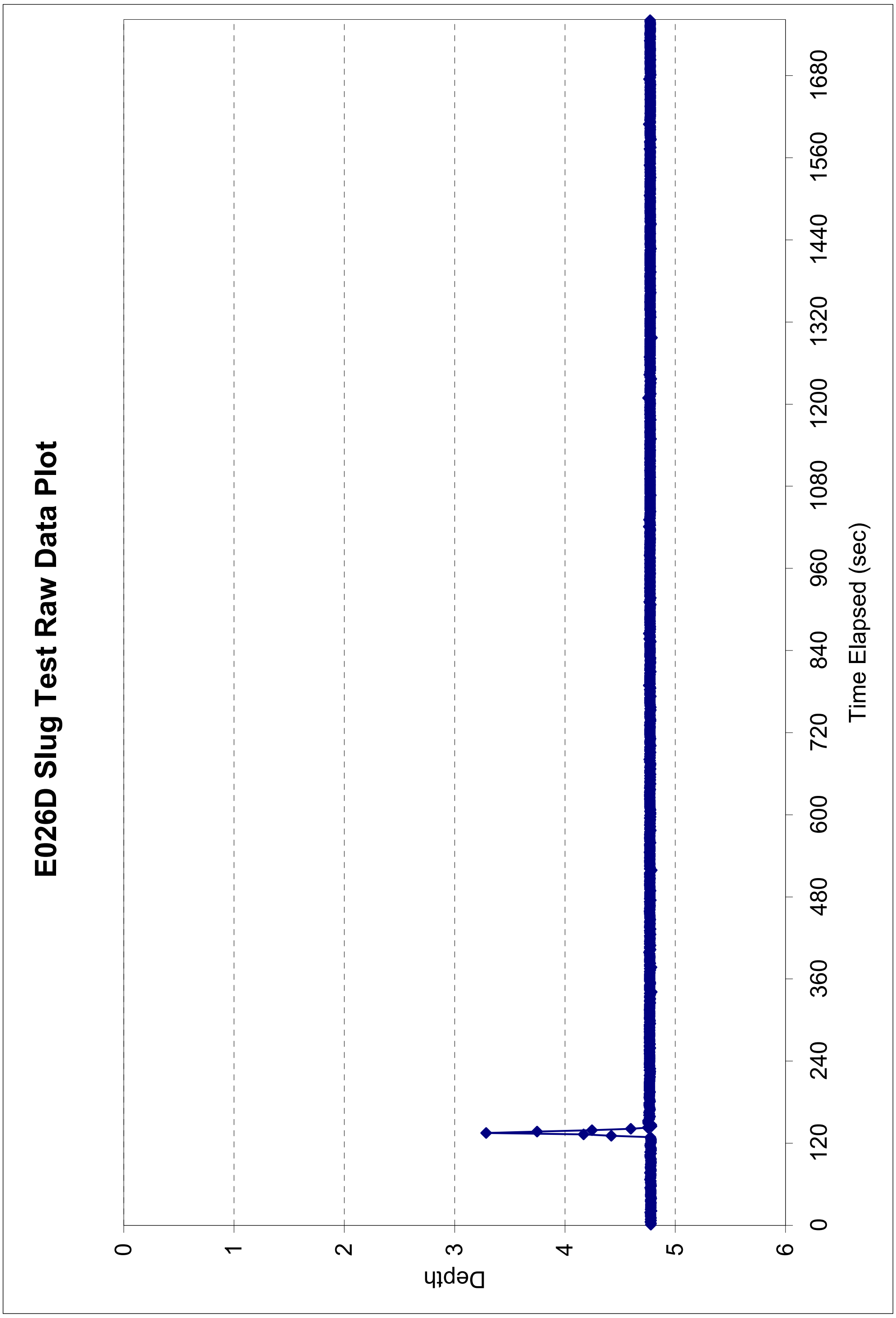

E024FG-I Slug Test Recovery Plot
Depth
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time Elapsed (sec)
0.1
1
10
100
1000

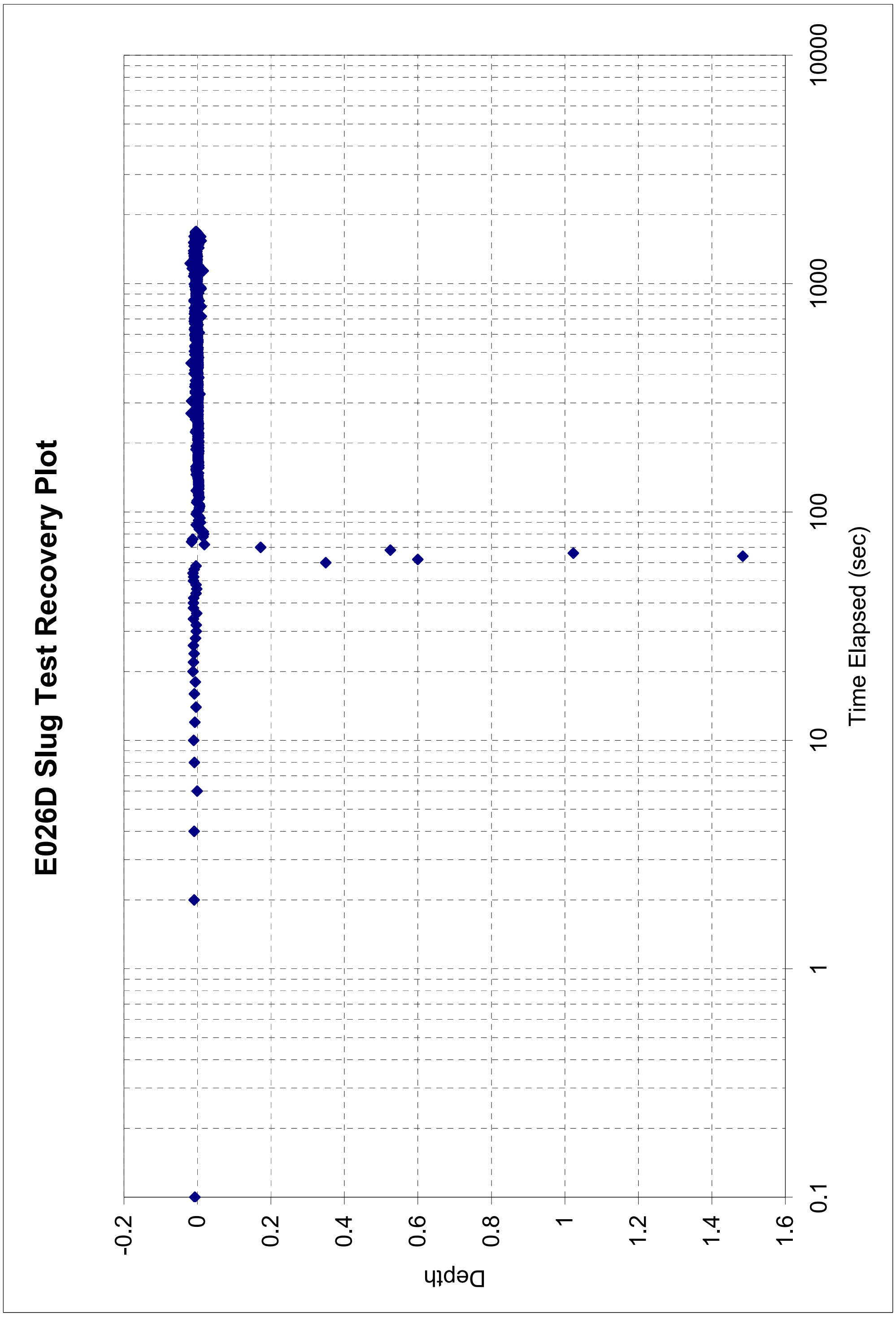

E025FG-D Slug Test Raw Data Plot
Depth (m)
0
1
2
3
4
5
6
7
8
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960

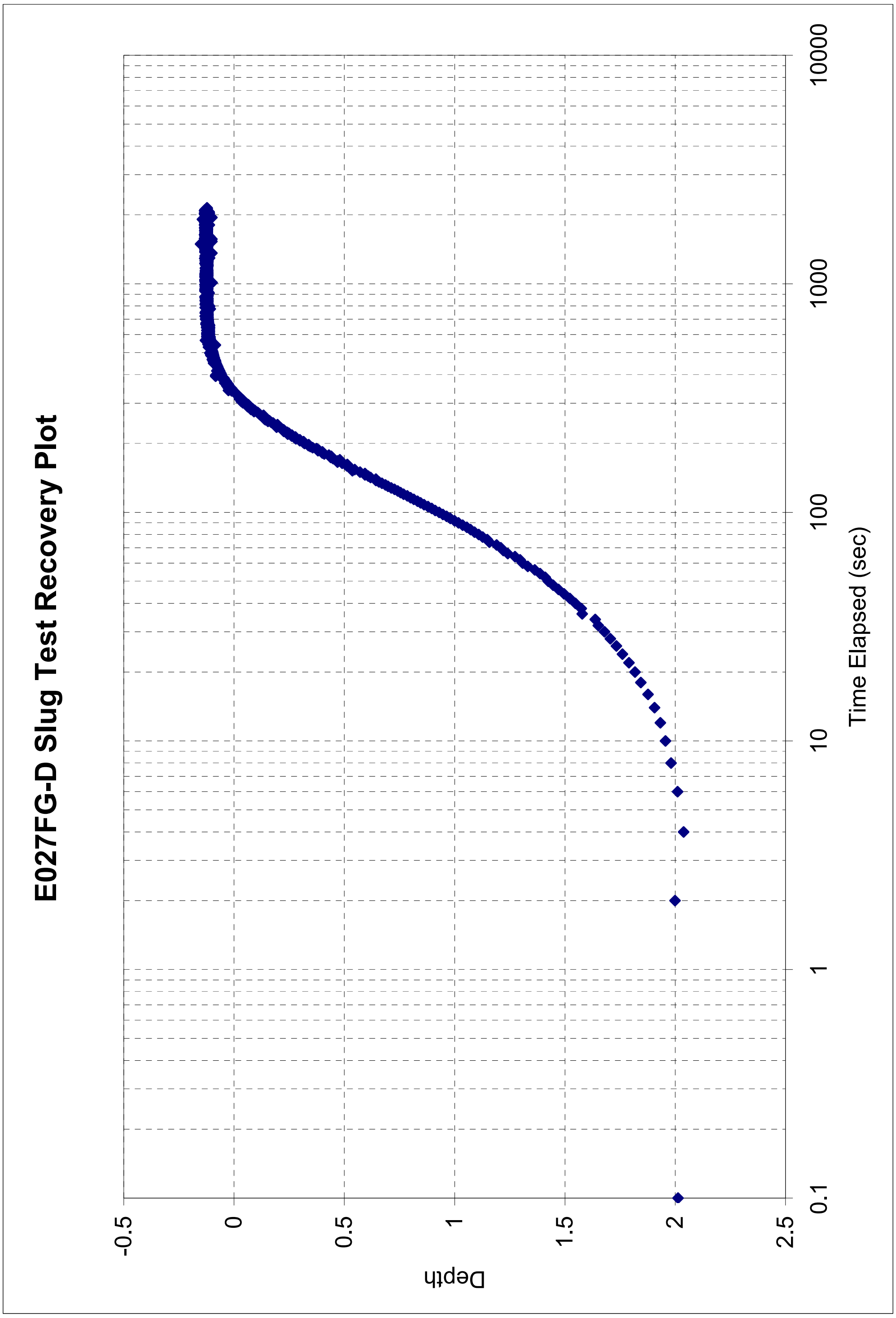

E025FG-D Slug Test Recovery Plot
Depth
-0.2
0
0.2
0.4
0.6
0.8
1
Time Elapsed (sec)
0.1
1
10
100
1000

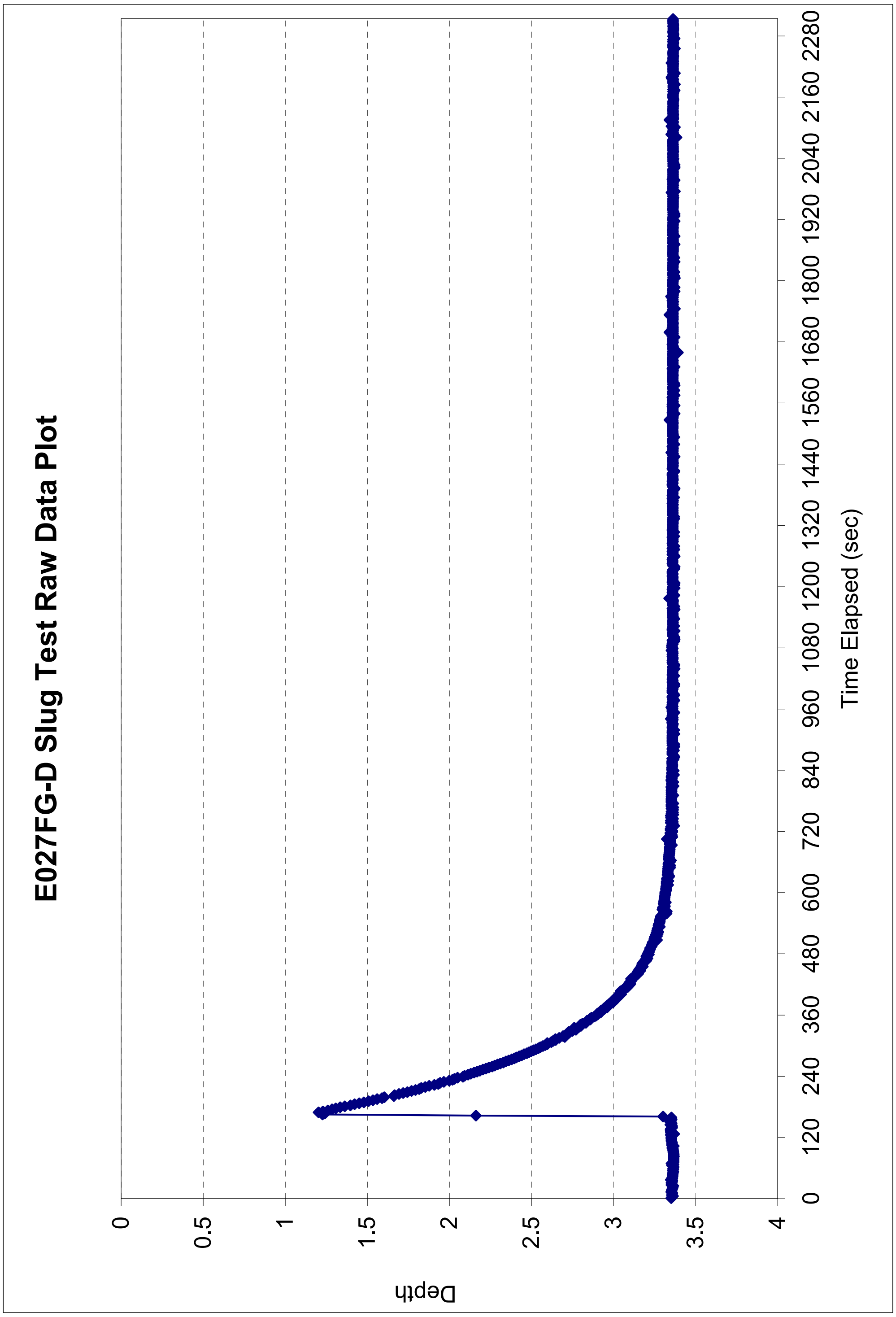

E025FG-I Slug Test Raw Data Plot
Depth (m)
Time Elapsed (sec)
0
1
2
3
4
5
6
7
8
0
120
240
360
480
600
720
840
960

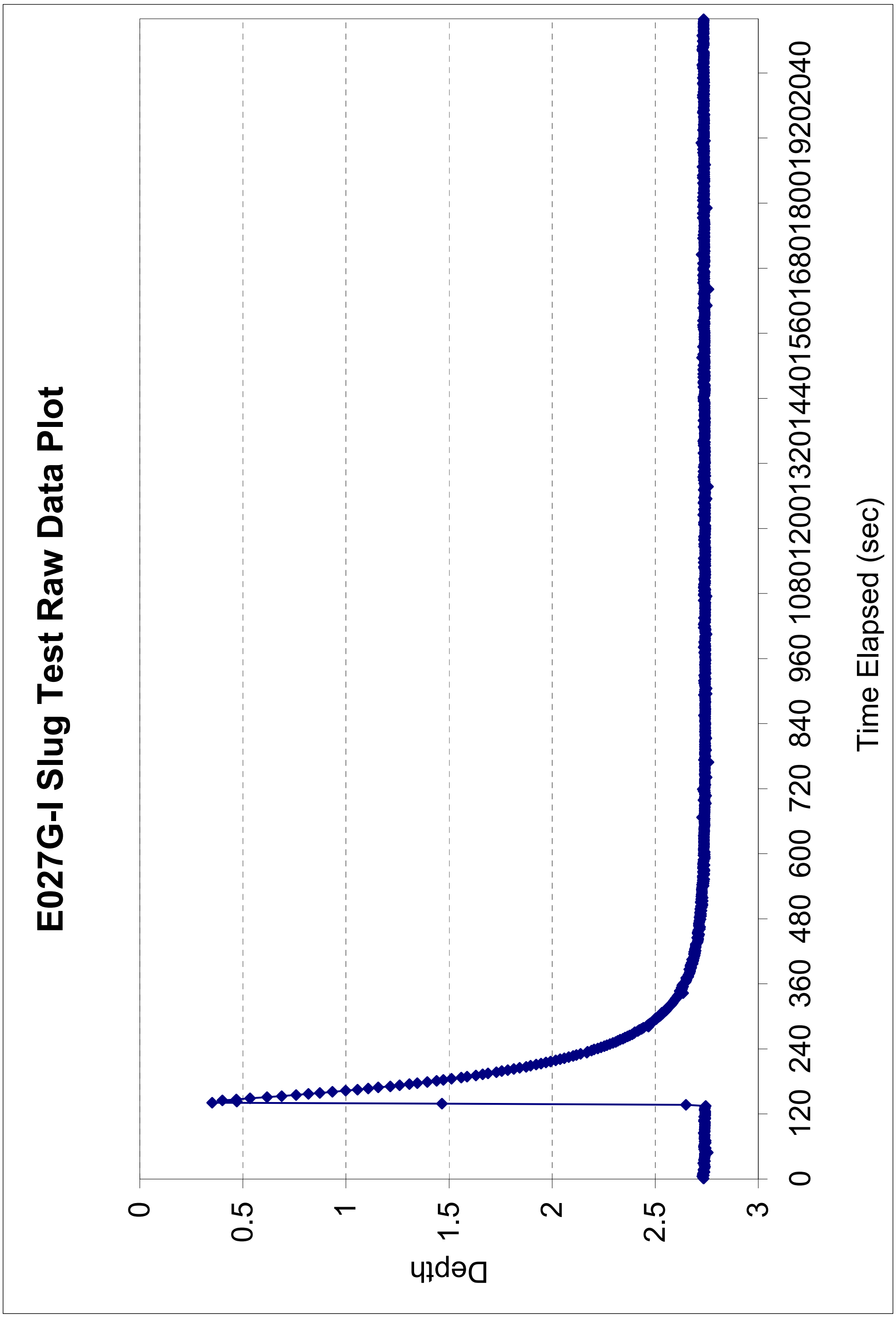

E025FG-I Slug Test Recovery Plot
Depth (m)
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time Elapsed (sec)
0.1
1
10
100
1000

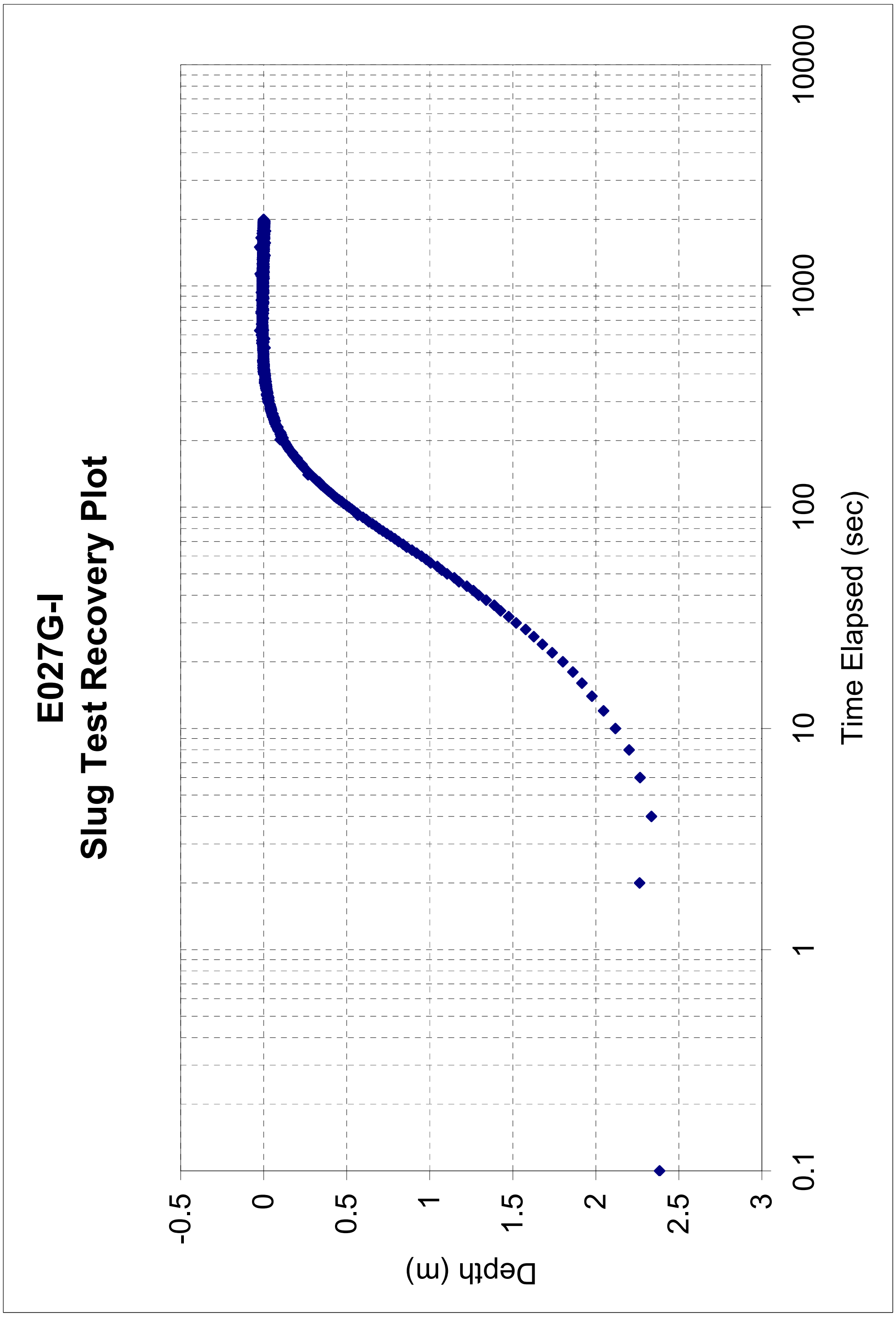

E026D Slug Test Raw Data Plot
Depth
0
1
2
3
4
5
6
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560
1680

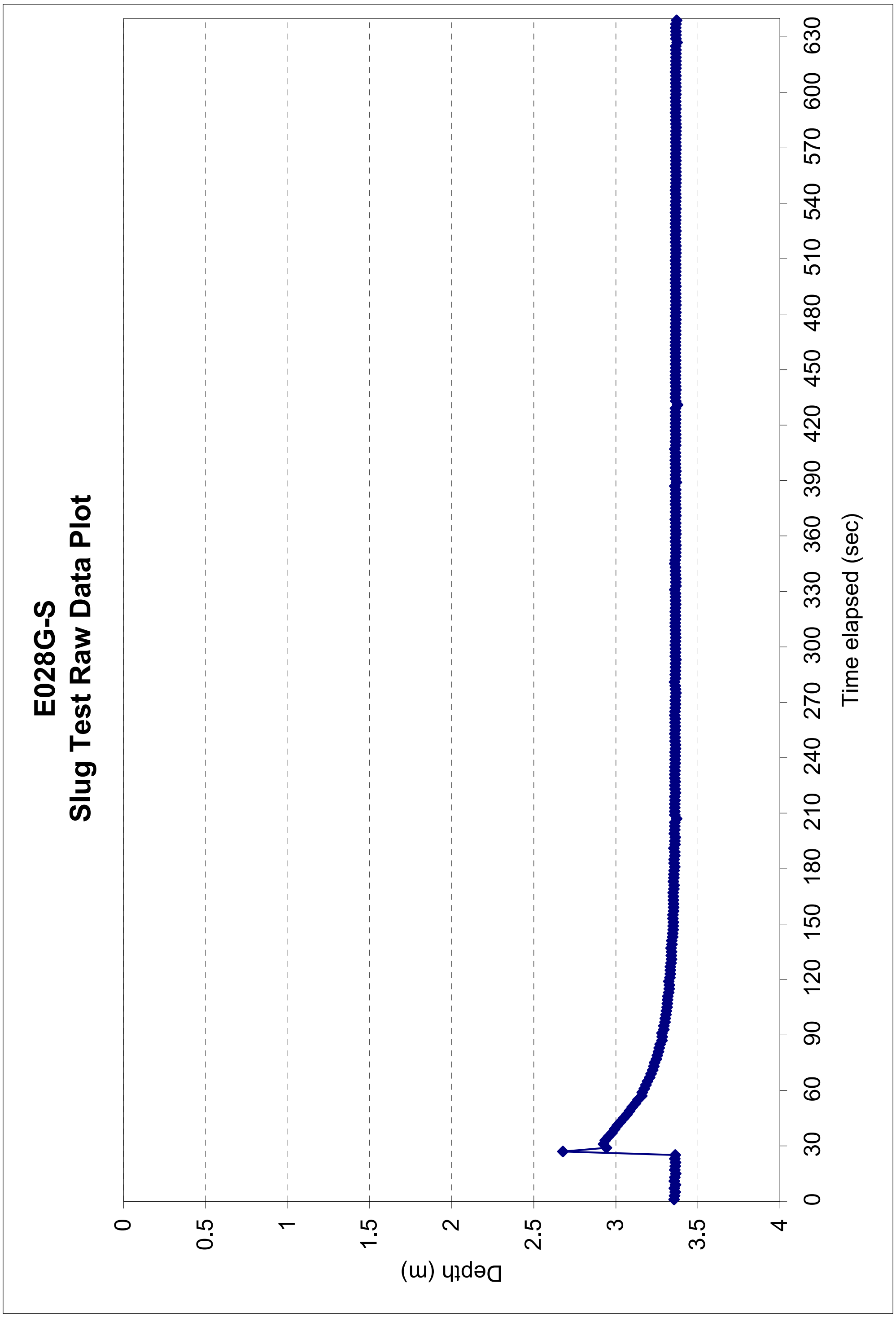

E026D Slug Test Recovery Plot
Depth
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time Elapsed (sec)
0.1
1
10
100
1000
10000

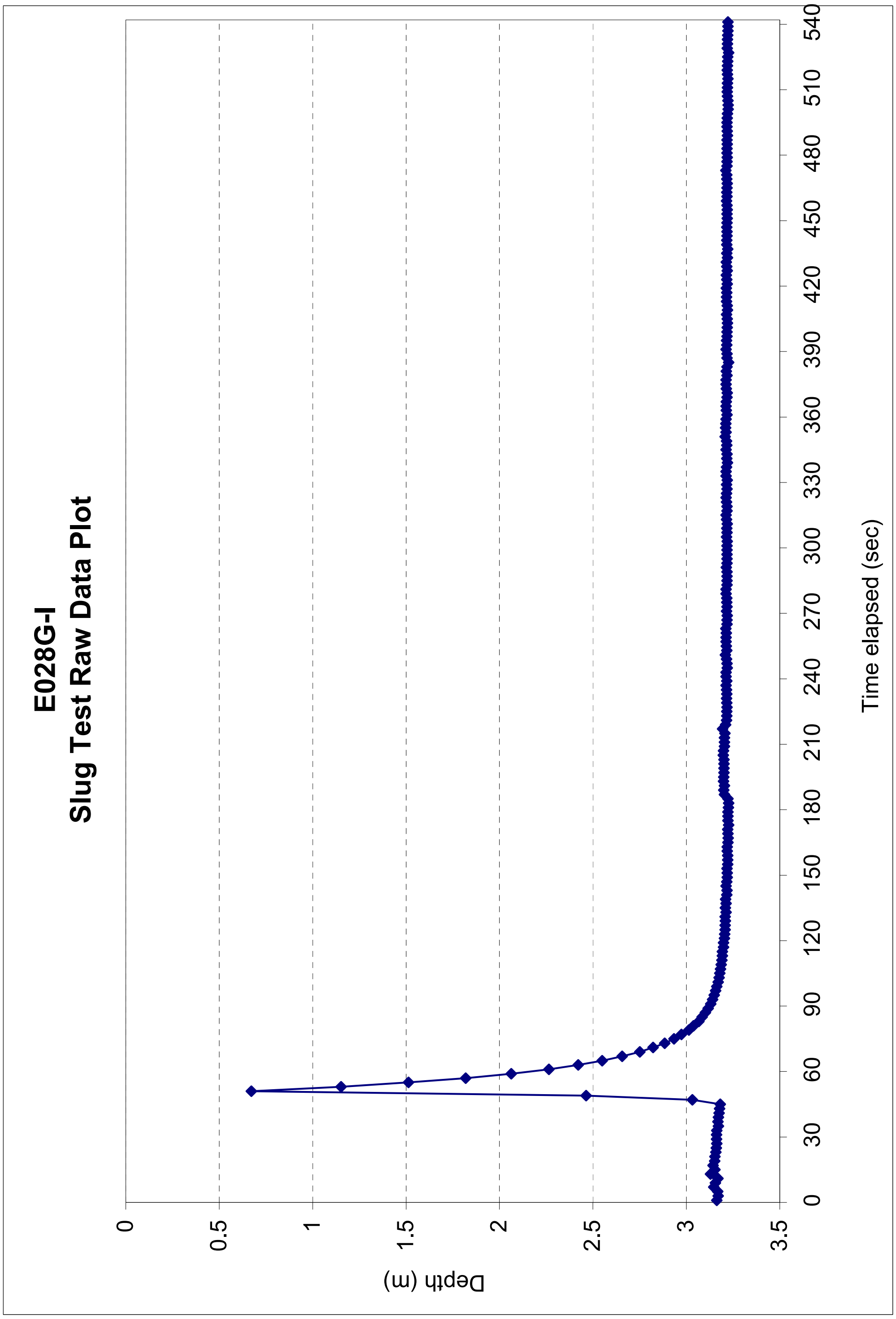

E027FG-D Slug Test Recovery Plot
Depth
-0.5
0
0.5
1
1.5
2
2.5
Time Elapsed (sec)
0.1
1
10
100
1000
10000

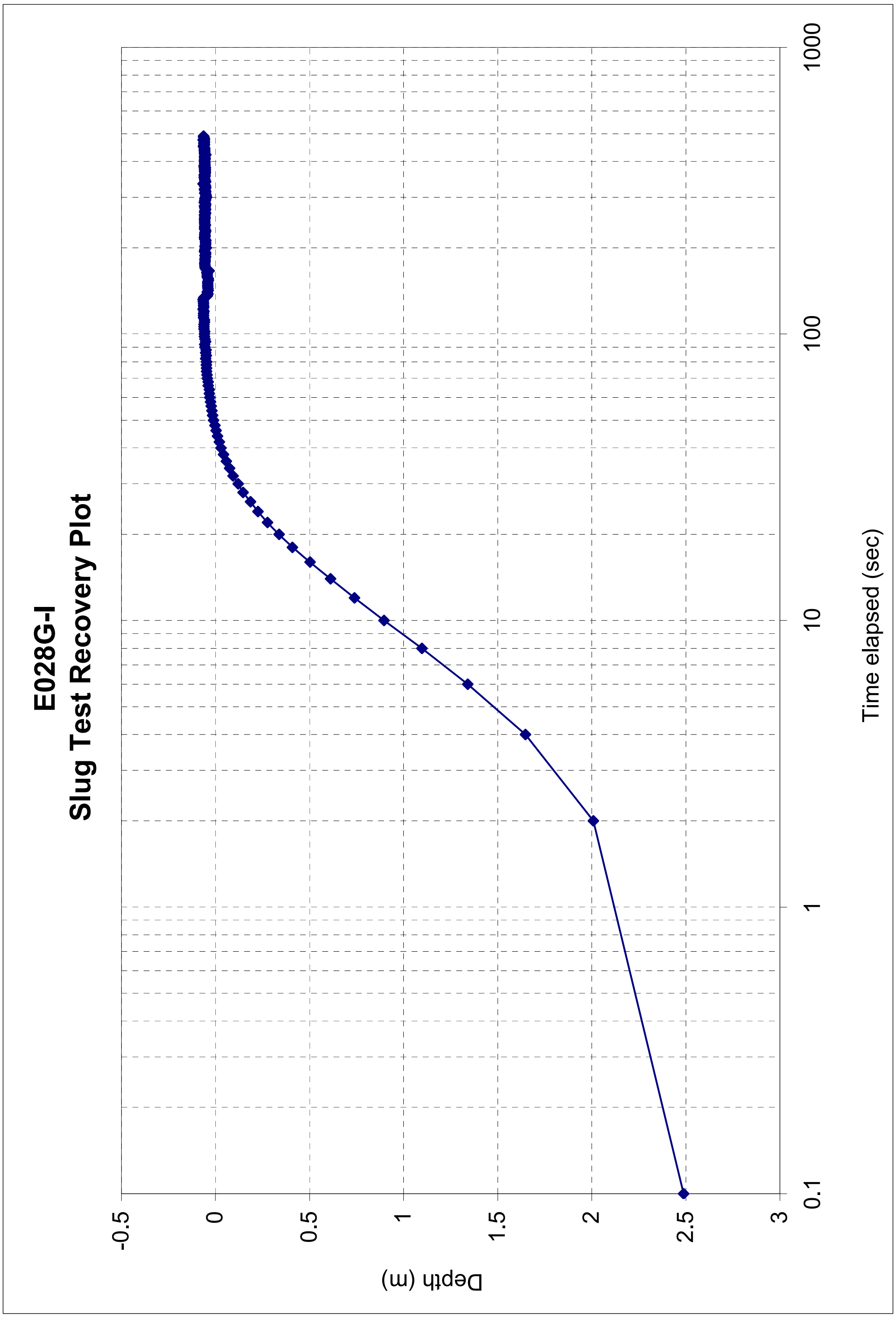

E027FG-D Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
3
3.5
4
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560
1680
1800
1920
2040
2160
2280

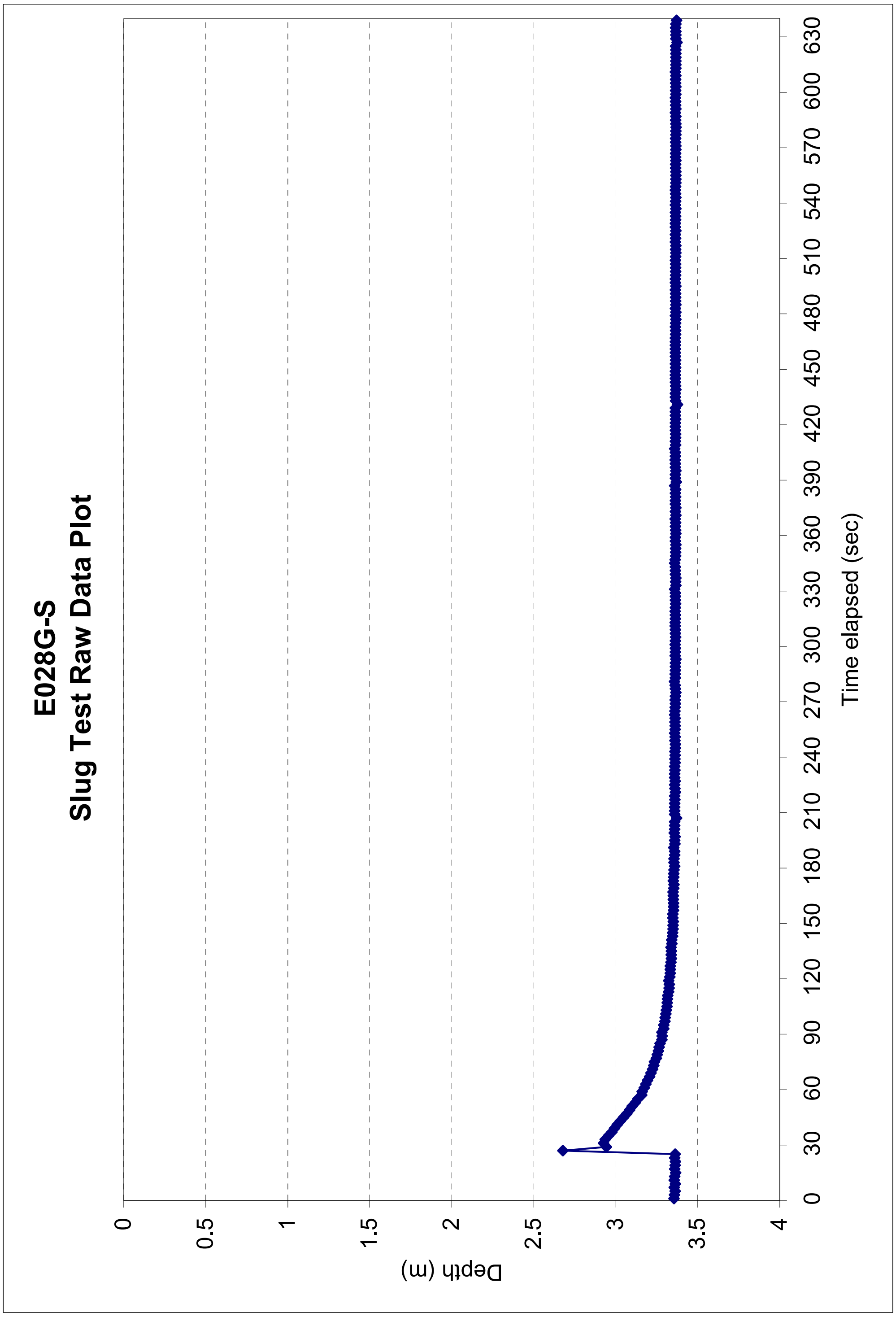

E027G-I Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
3
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560
1680
1800
1920
2040

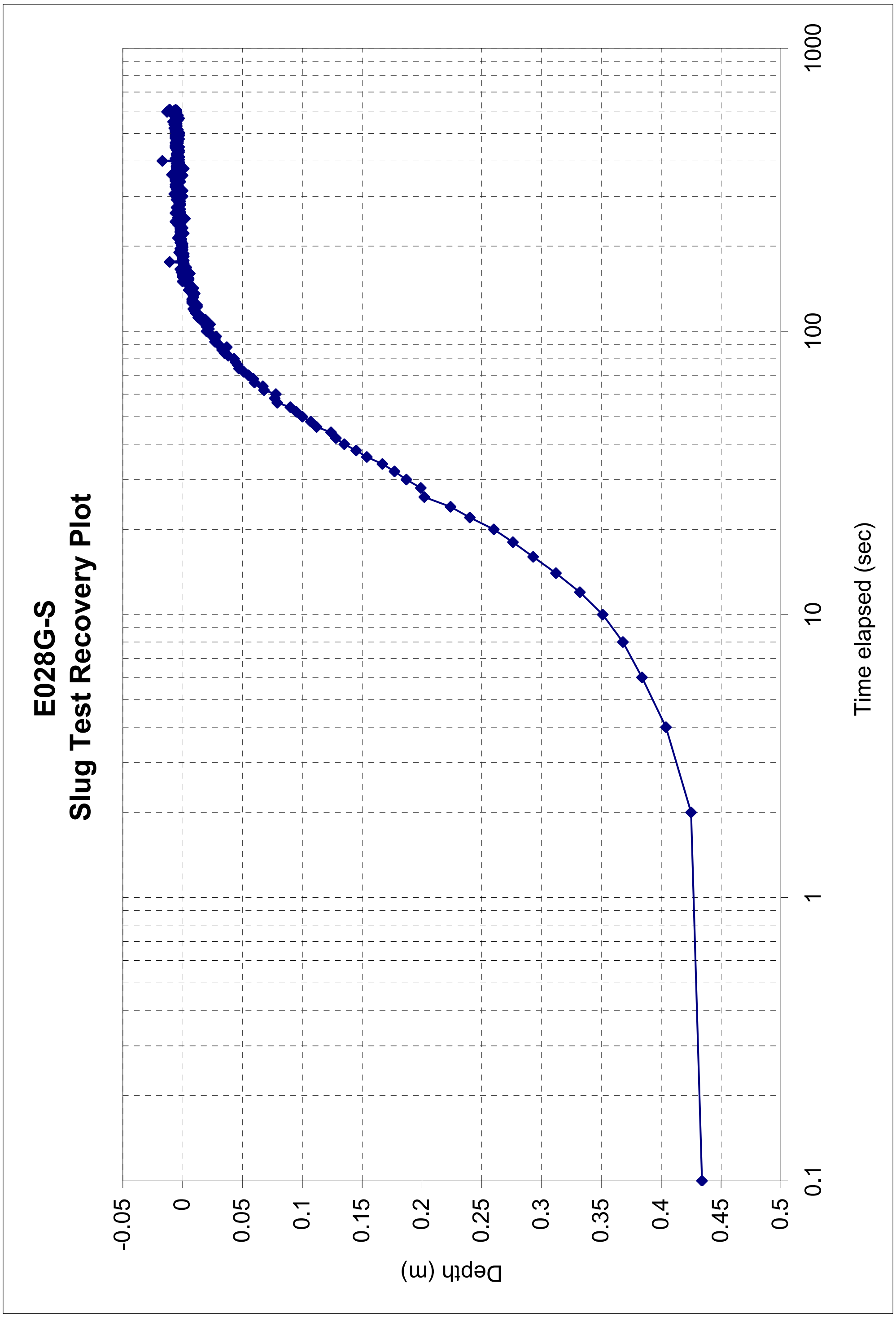

E027G-I
Slug Test Recovery Plot
Depth (m)
-0.5
0
0.5
1
1.5
2
2.5
3
Time Elapsed (sec)
0.1
1
10
100
1000
10000

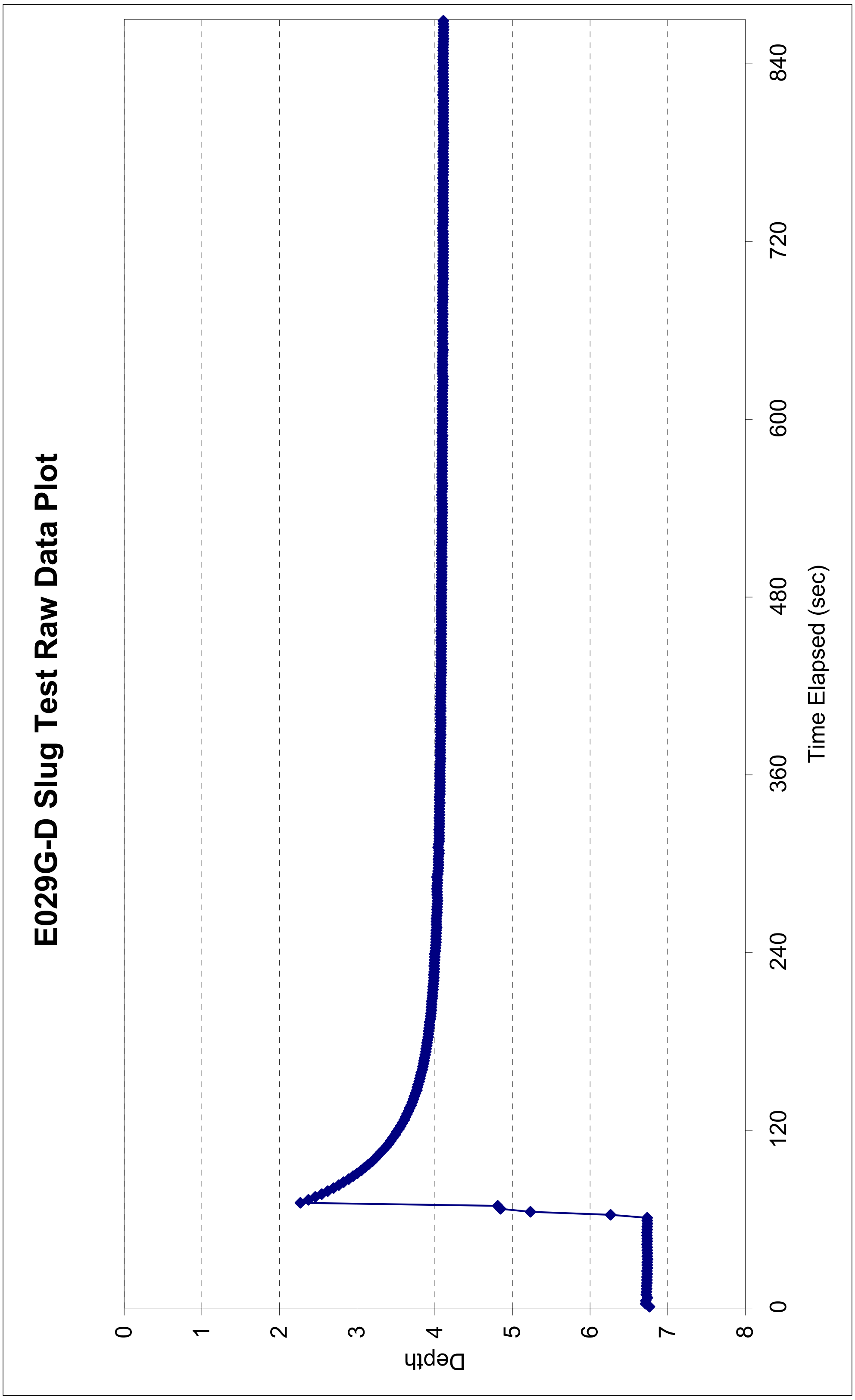

E028G-S
Slug Test Raw Data Plot
Depth (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
Time elapsed (sec)
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
480
510
540
570
600
630

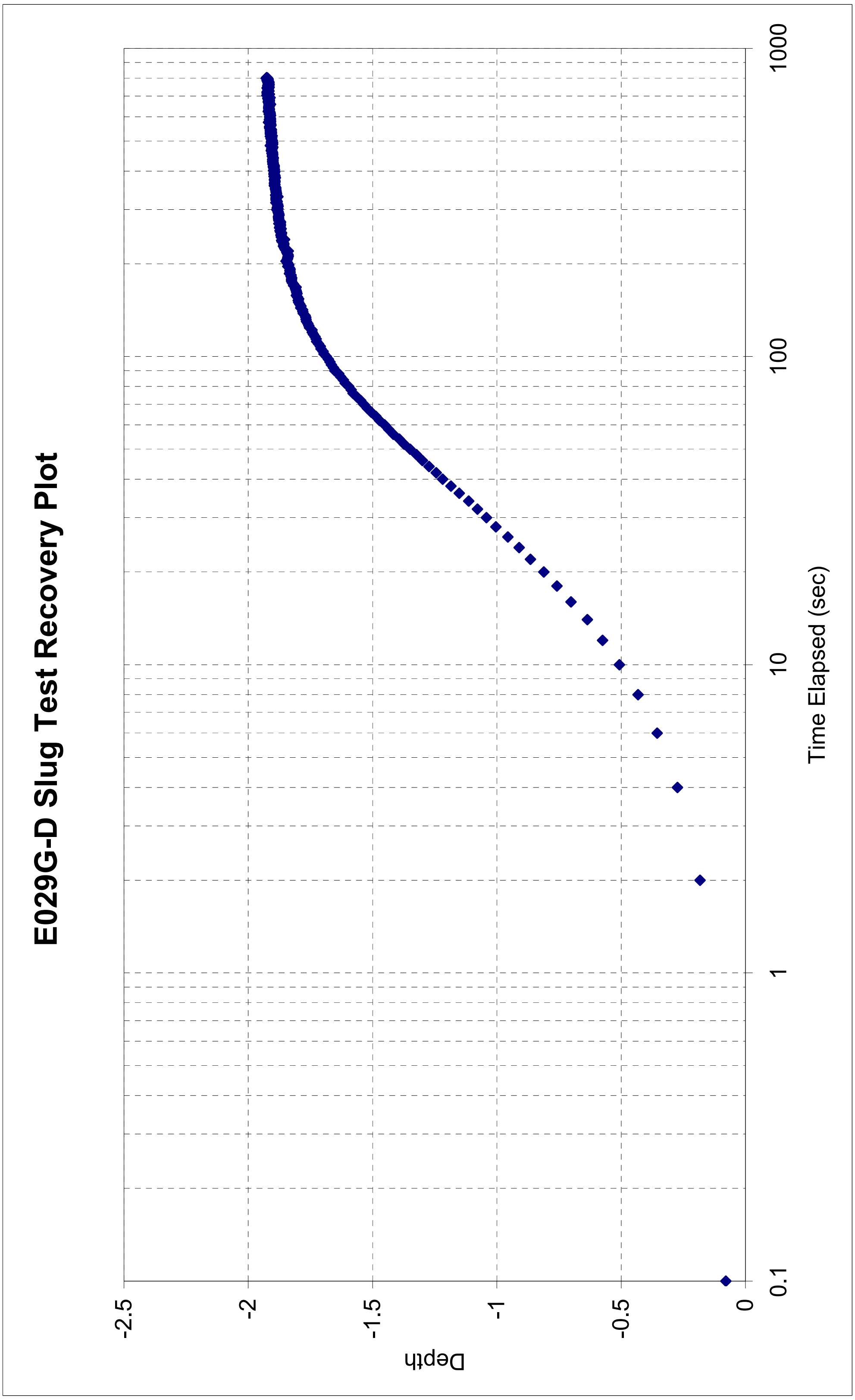

E028G-I
Slug Test Raw Data Plot
Depth (m)
0
0.5
1
1.5
2
2.5
3
3.5
Time elapsed (sec)
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
480
510
540

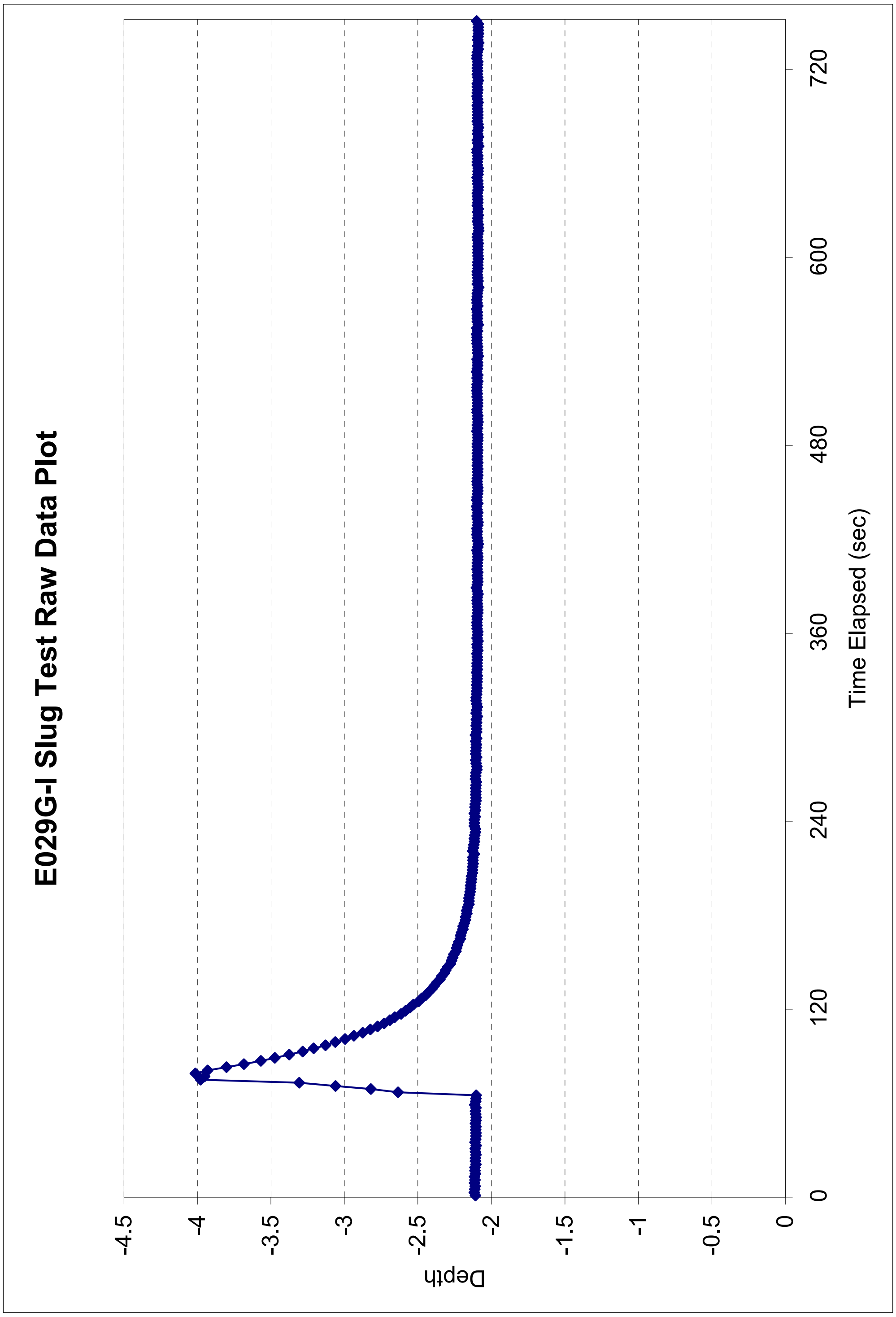

E028G-I
Slug Test Recovery Plot
Depth (m)
-0.5
0
0.5
1
1.5
2
2.5
3
0.1
1
10
100
1000
Time elapsed (sec)

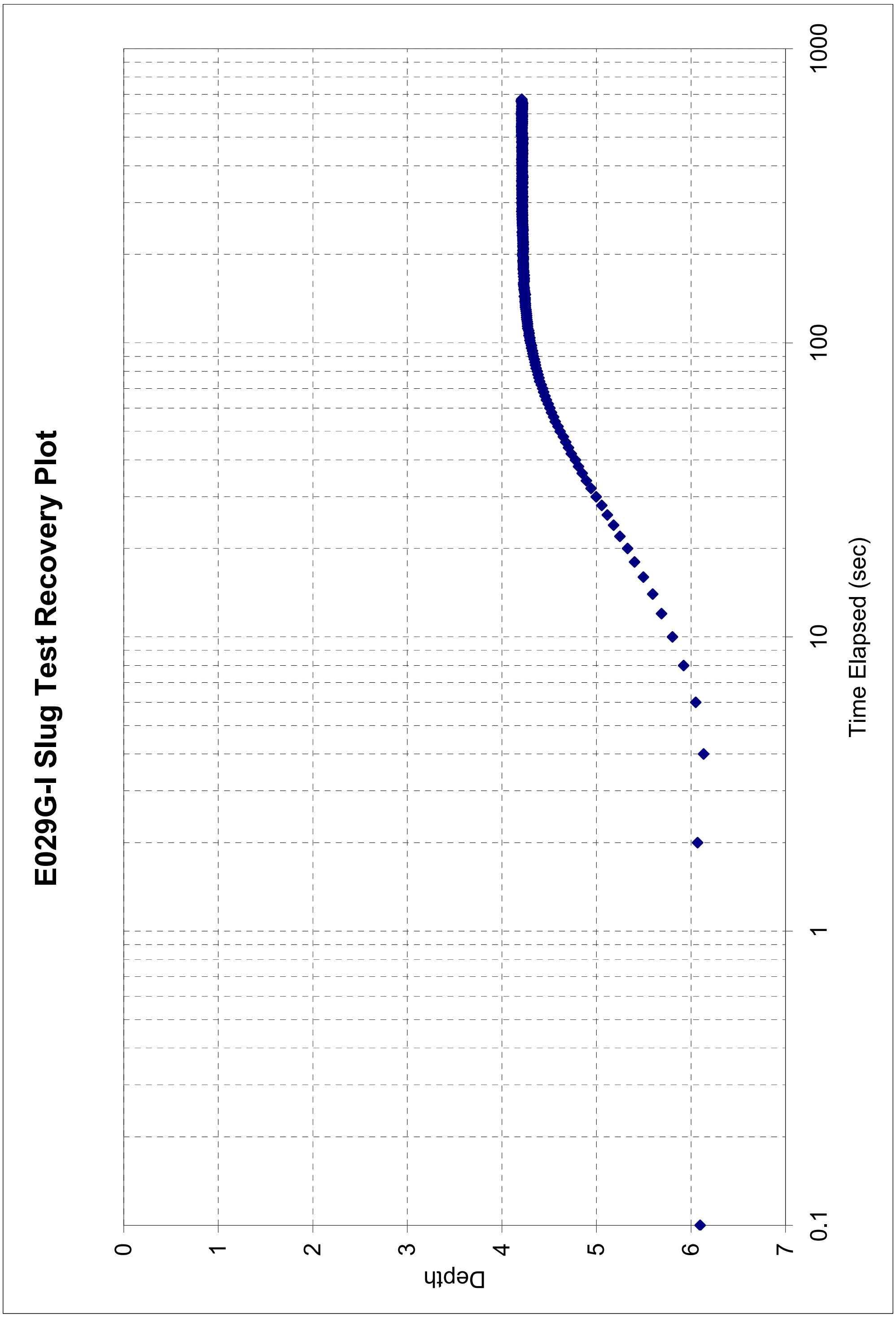

E028G-S
Slug Test Raw Data Plot
Depth (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
Time elapsed (sec)
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
480
510
540
570
600
630

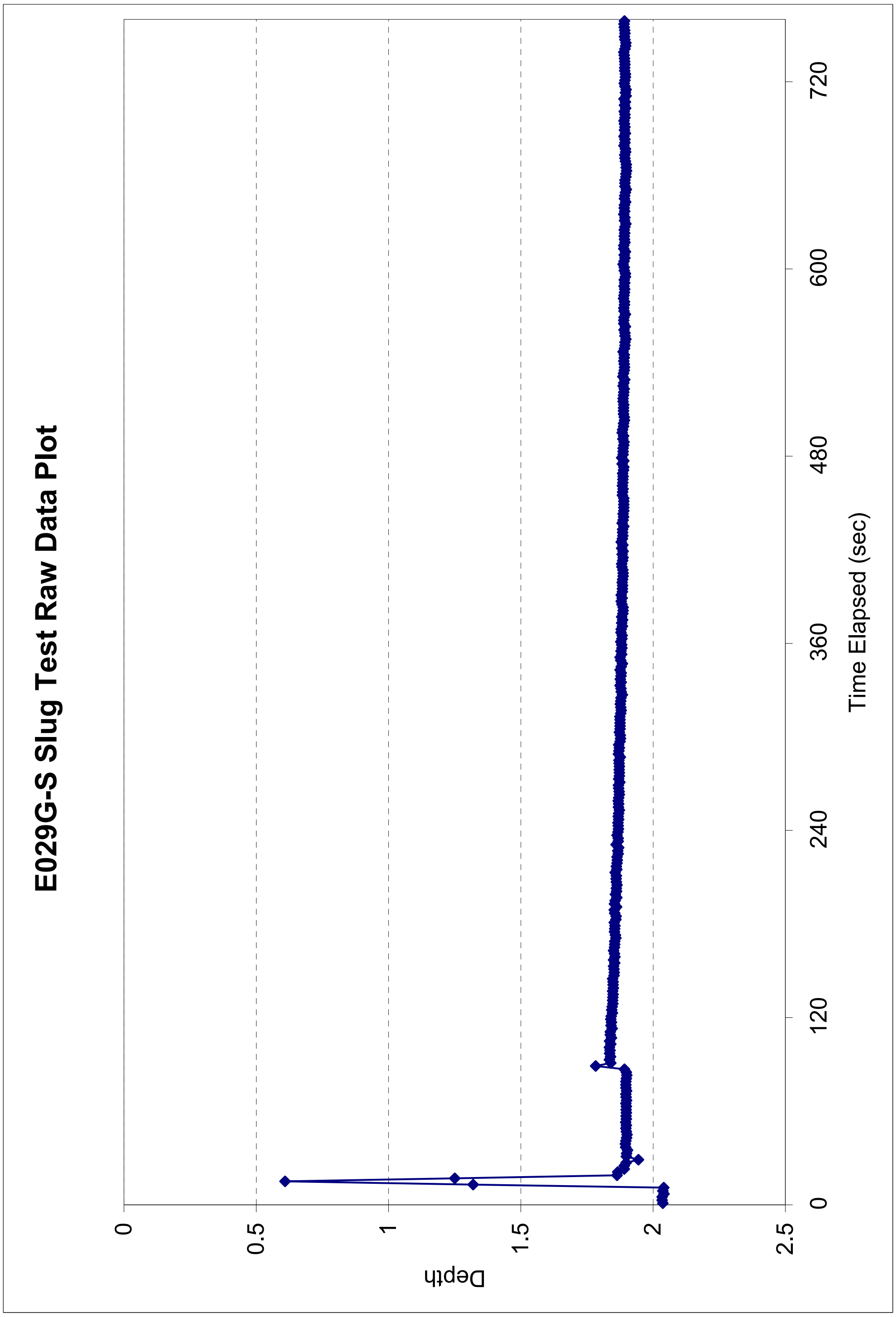

E028G-S
Slug Test Recovery Plot
Depth (m)
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.1
1
10
100
1000
Time elapsed (sec)

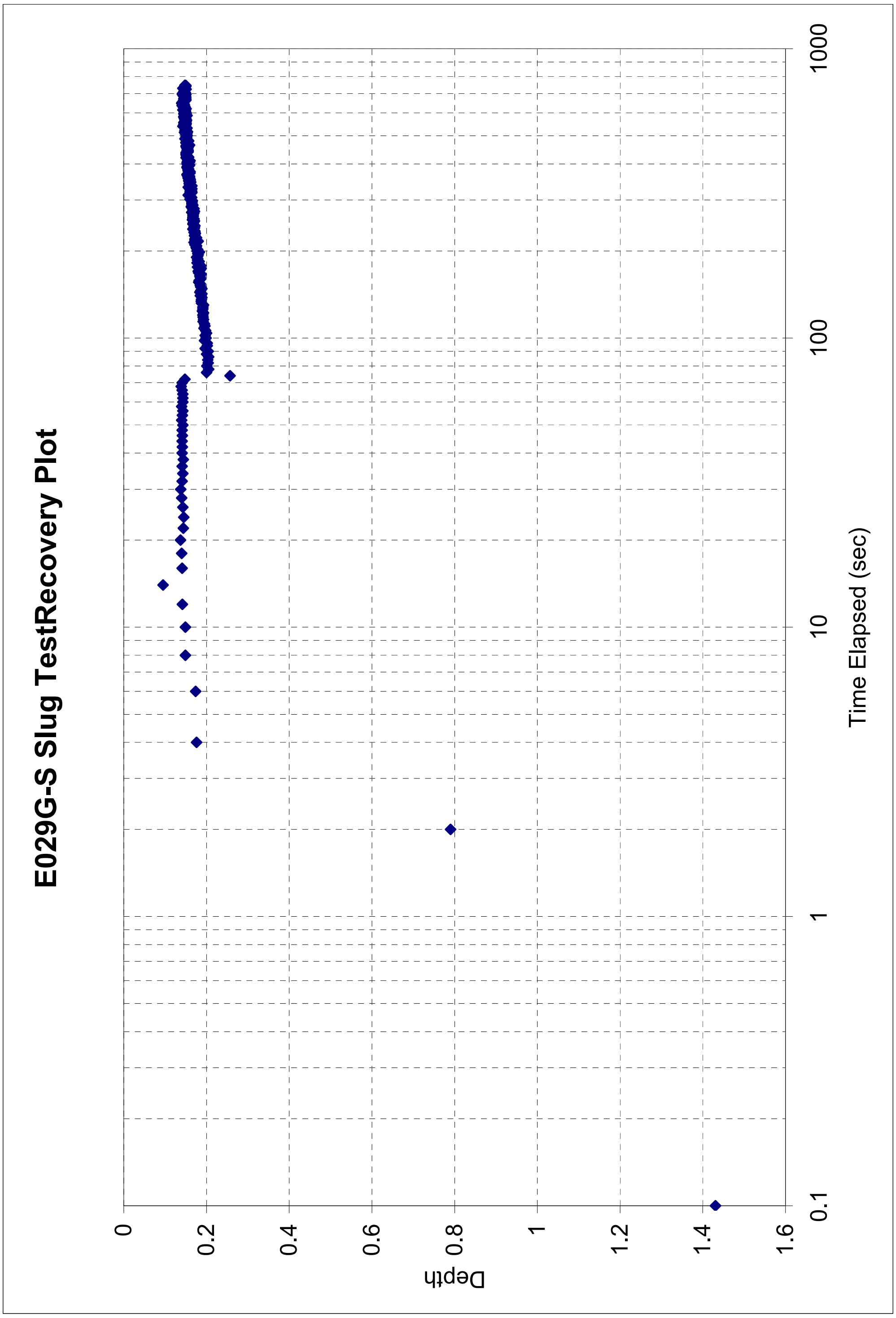

E029G-D Slug Test Raw Data Plot
Depth
0
1
2
3
4
5
6
7
8
Time Elapsed (sec)
0
120
240
360
480
600
720
840

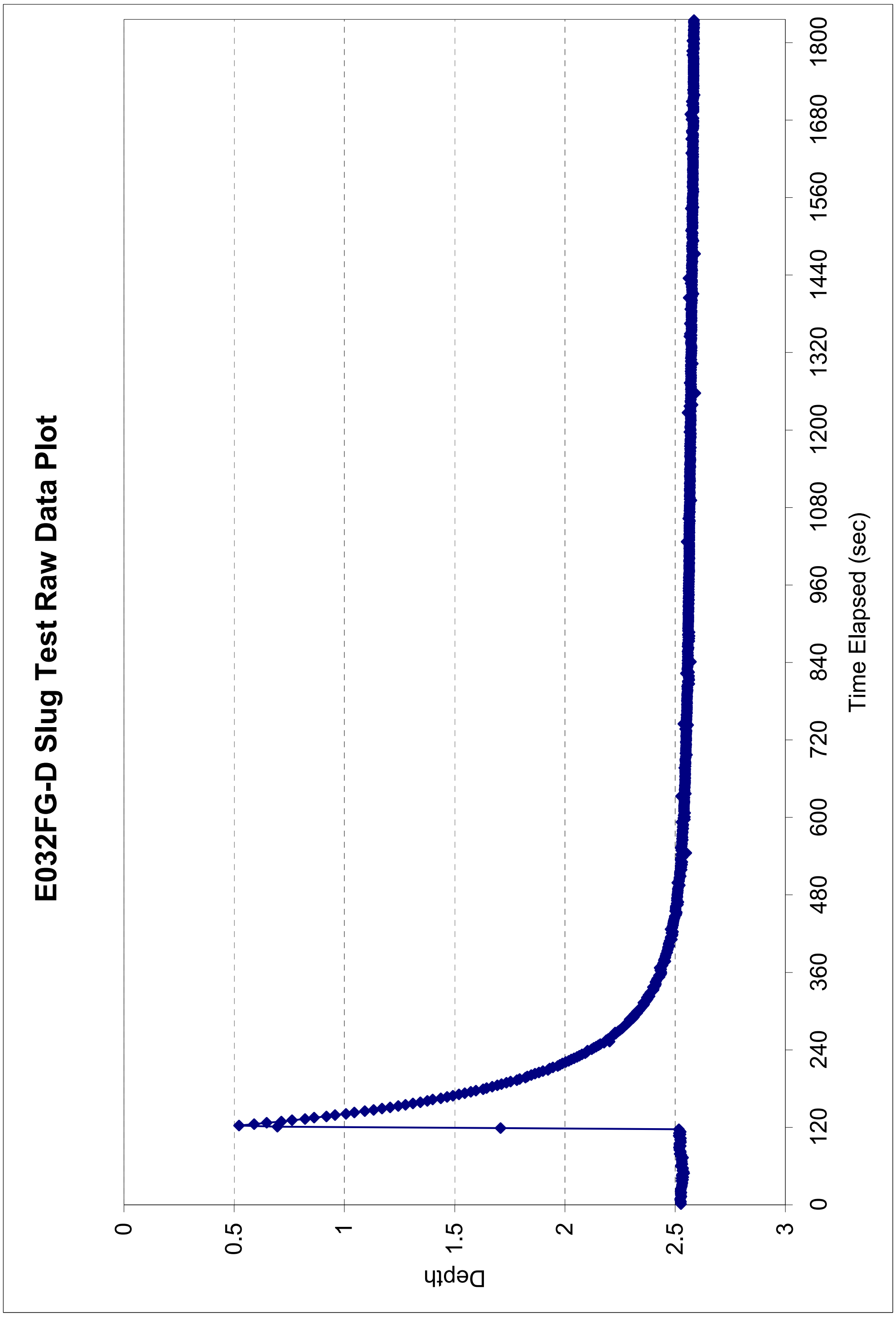

E029G-D Slug Test Recovery Plot
Depth
-2.5
-2
-1.5
-1
-0.5
0
Time Elapsed (sec)
0.1
1
10
100
1000

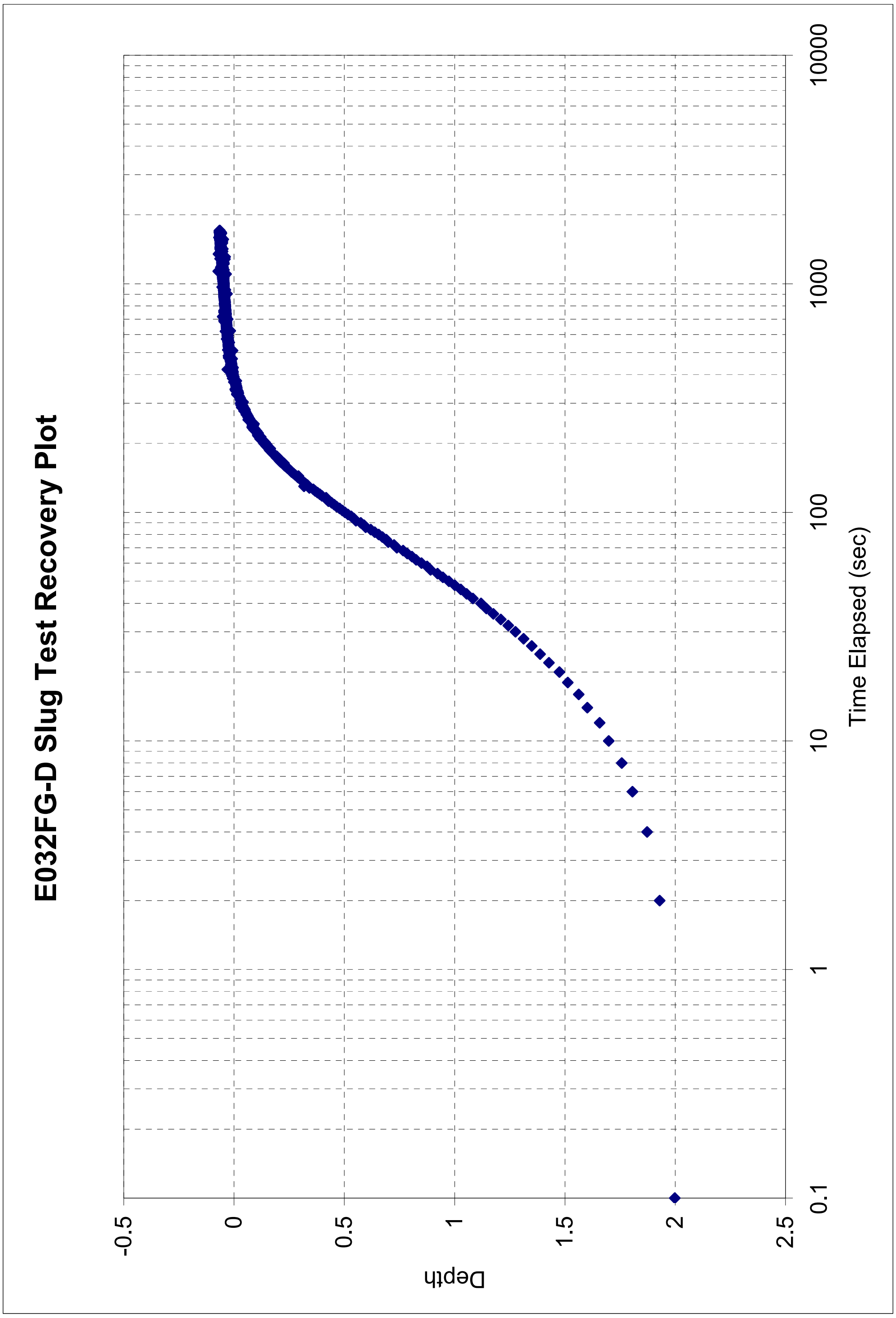

E029G-I Slug Test Raw Data Plot
Depth
-4.5
-4
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0
Time Elapsed (sec)
0
120
240
360
480
600
720

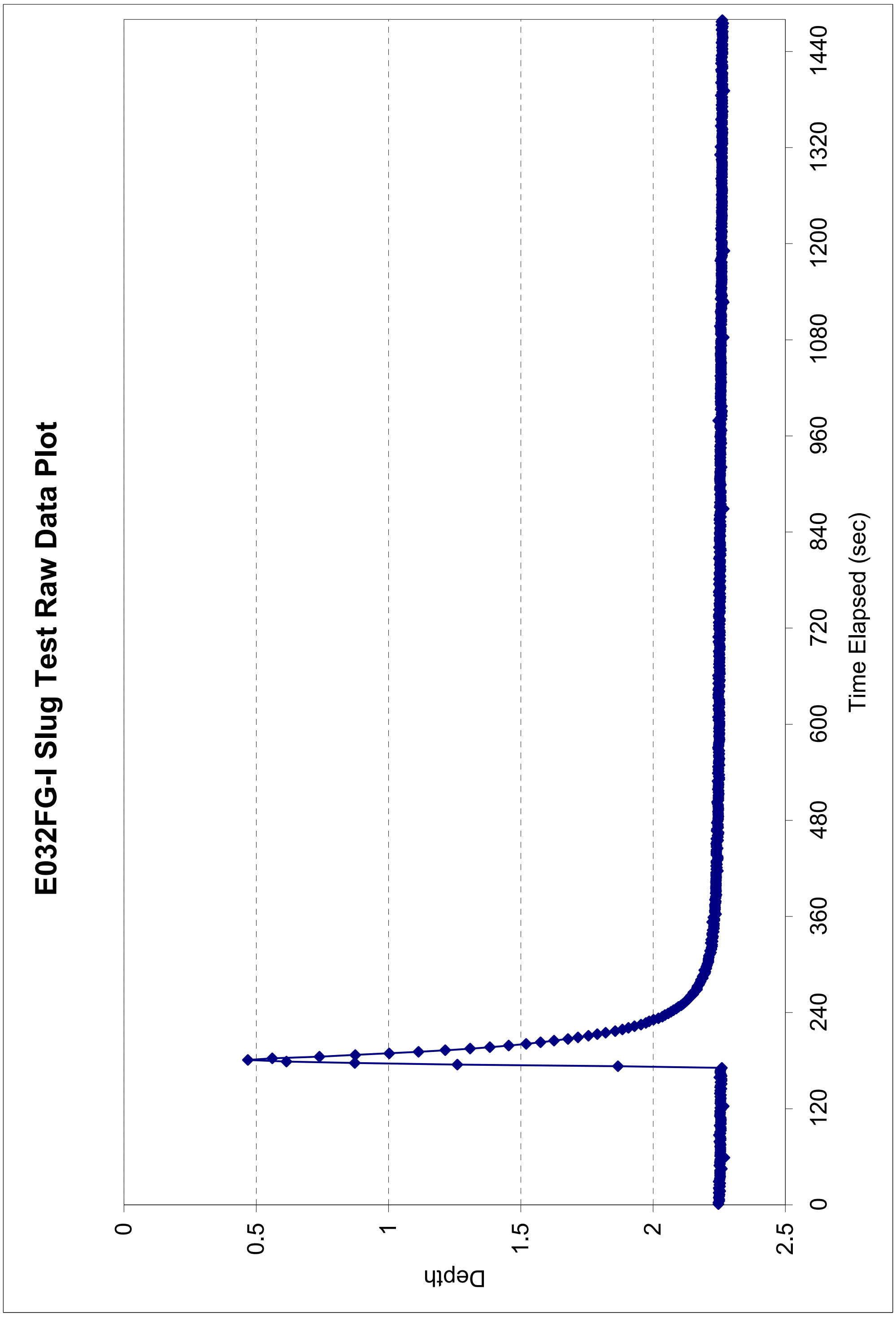

E029G-I Slug Test Recovery Plot
Depth
0
1
2
3
4
5
6
7
Time Elapsed (sec)
0.1
1
10
100
1000

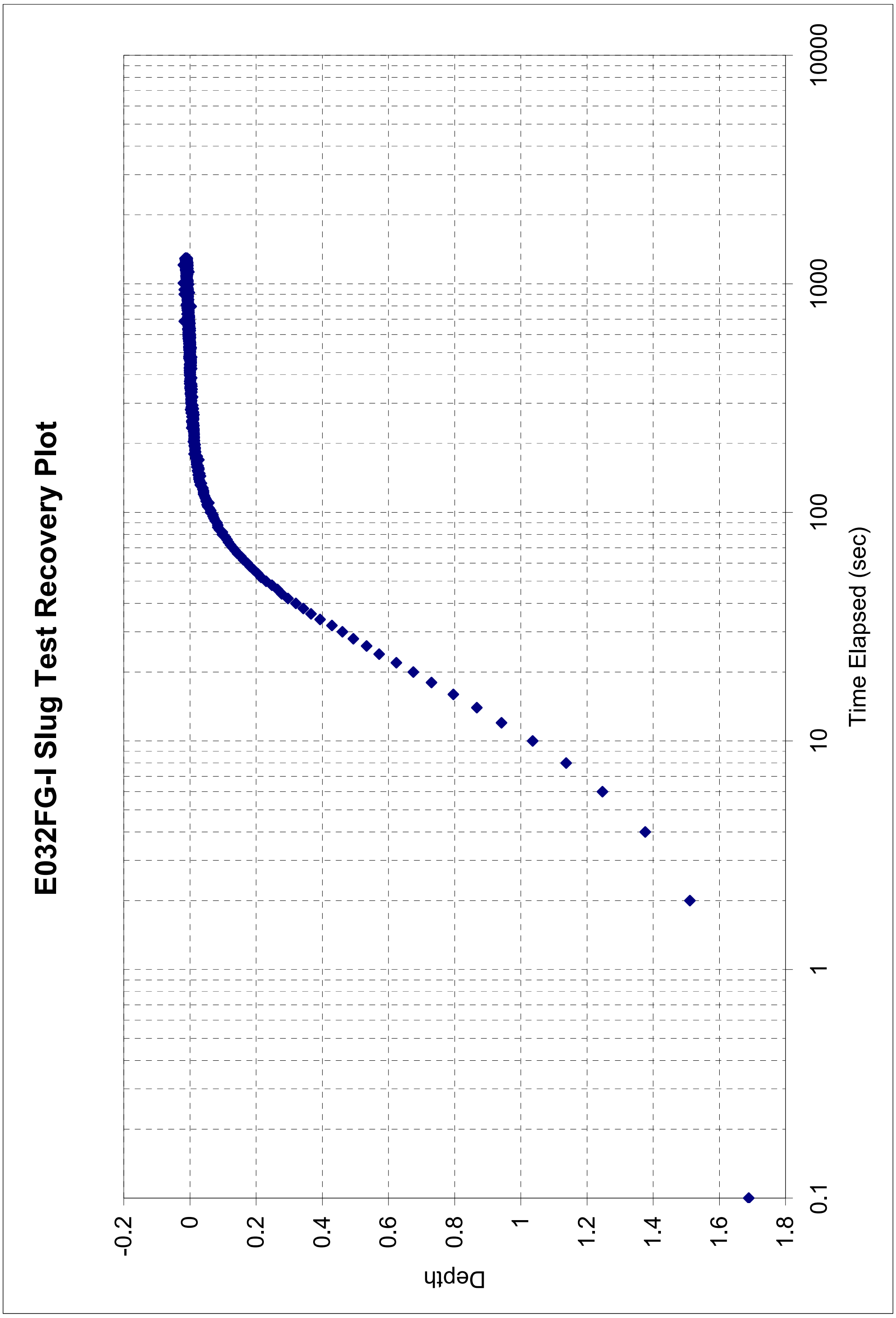

E029G-S Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
Time Elapsed (sec)
0
120
240
360
480
600
720

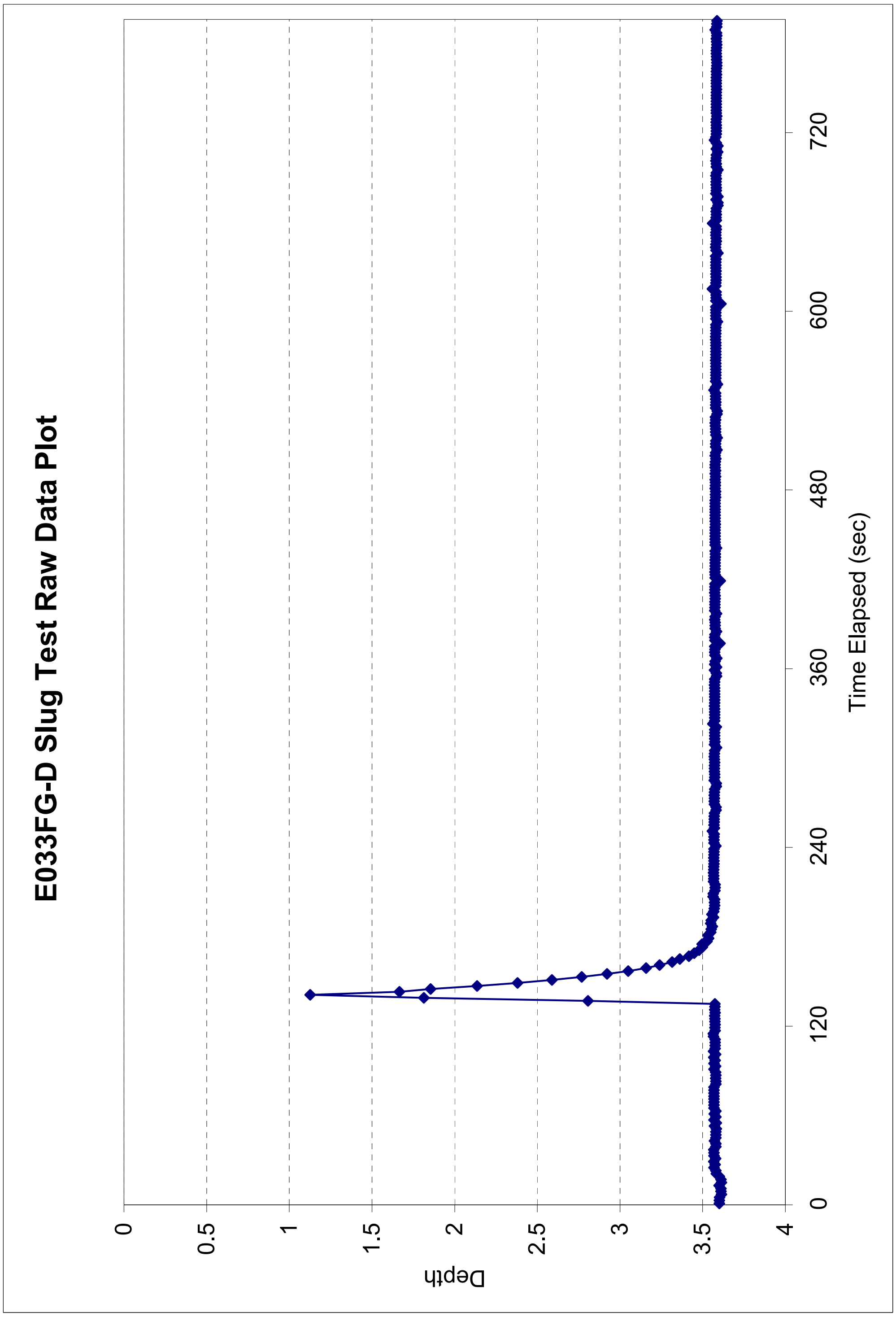

E029G-S Slug TestRecovery Plot
Depth
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0.1
1
10
100
1000
Time Elapsed (sec)

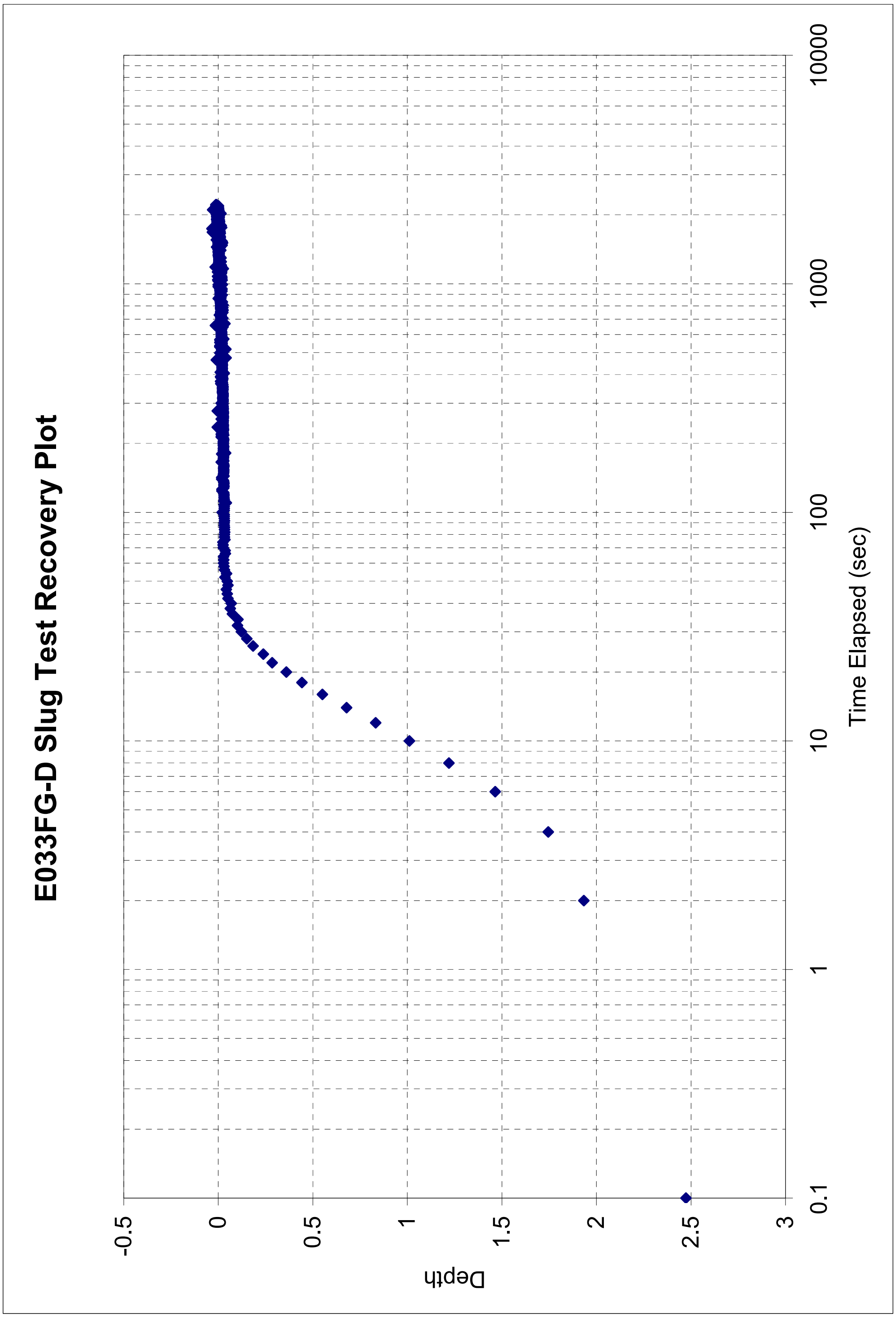

E032FG-D Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
3
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560
1680
1800

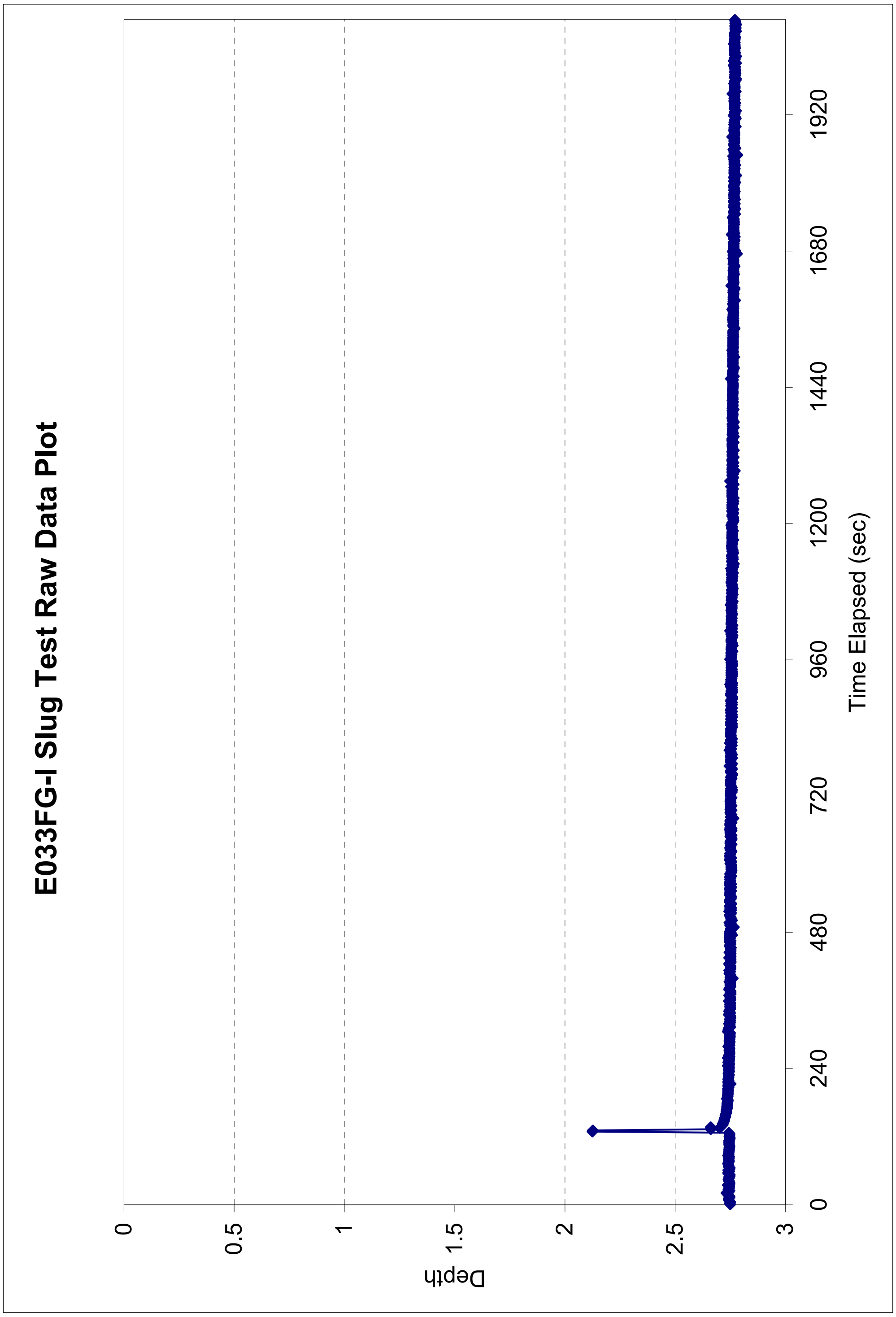

E032FG-D Slug Test Recovery Plot
Depth
-0.5
0
0.5
1
1.5
2
2.5
Time Elapsed (sec)
0.1
1
10
100
1000
10000

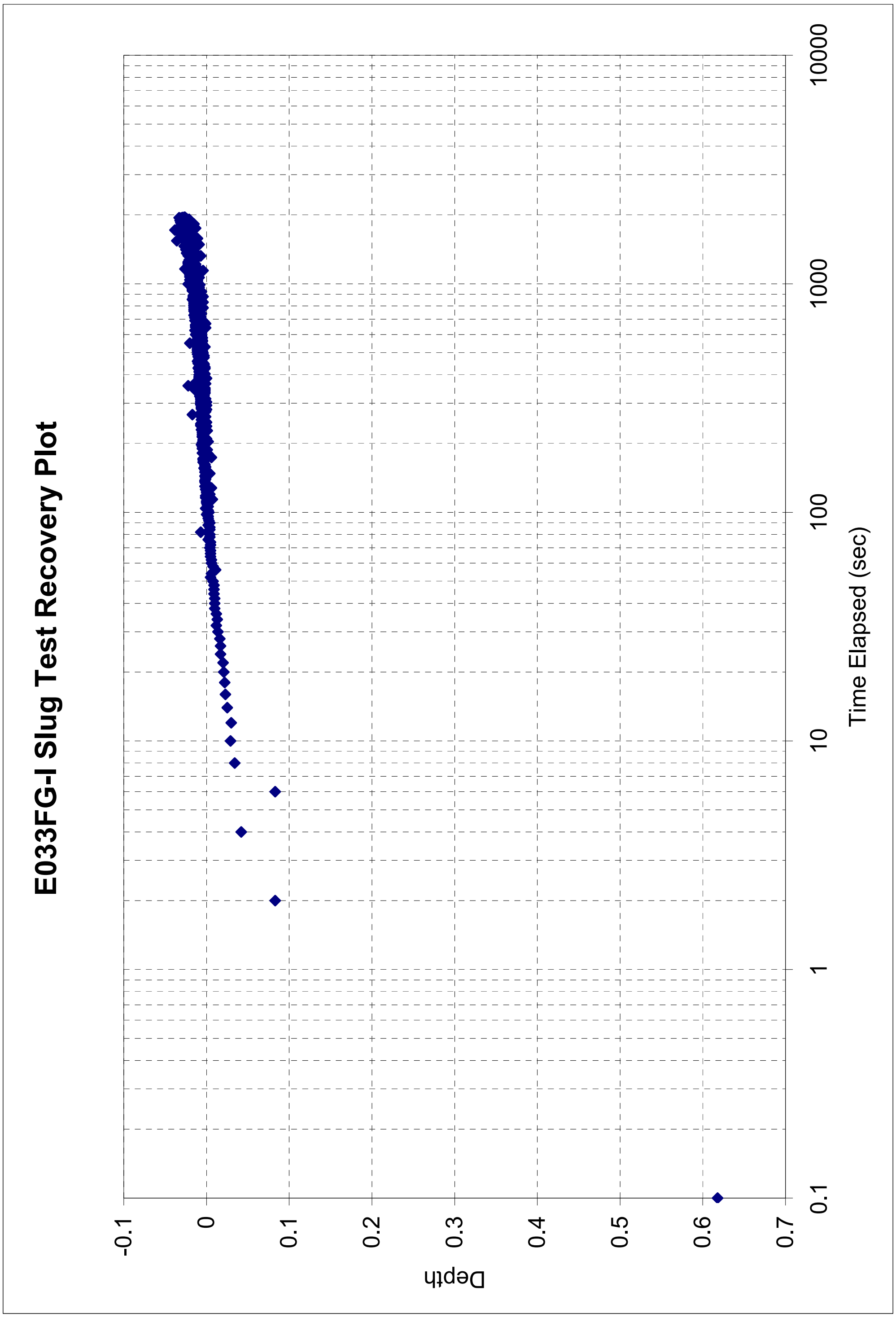

E032FG-I Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440

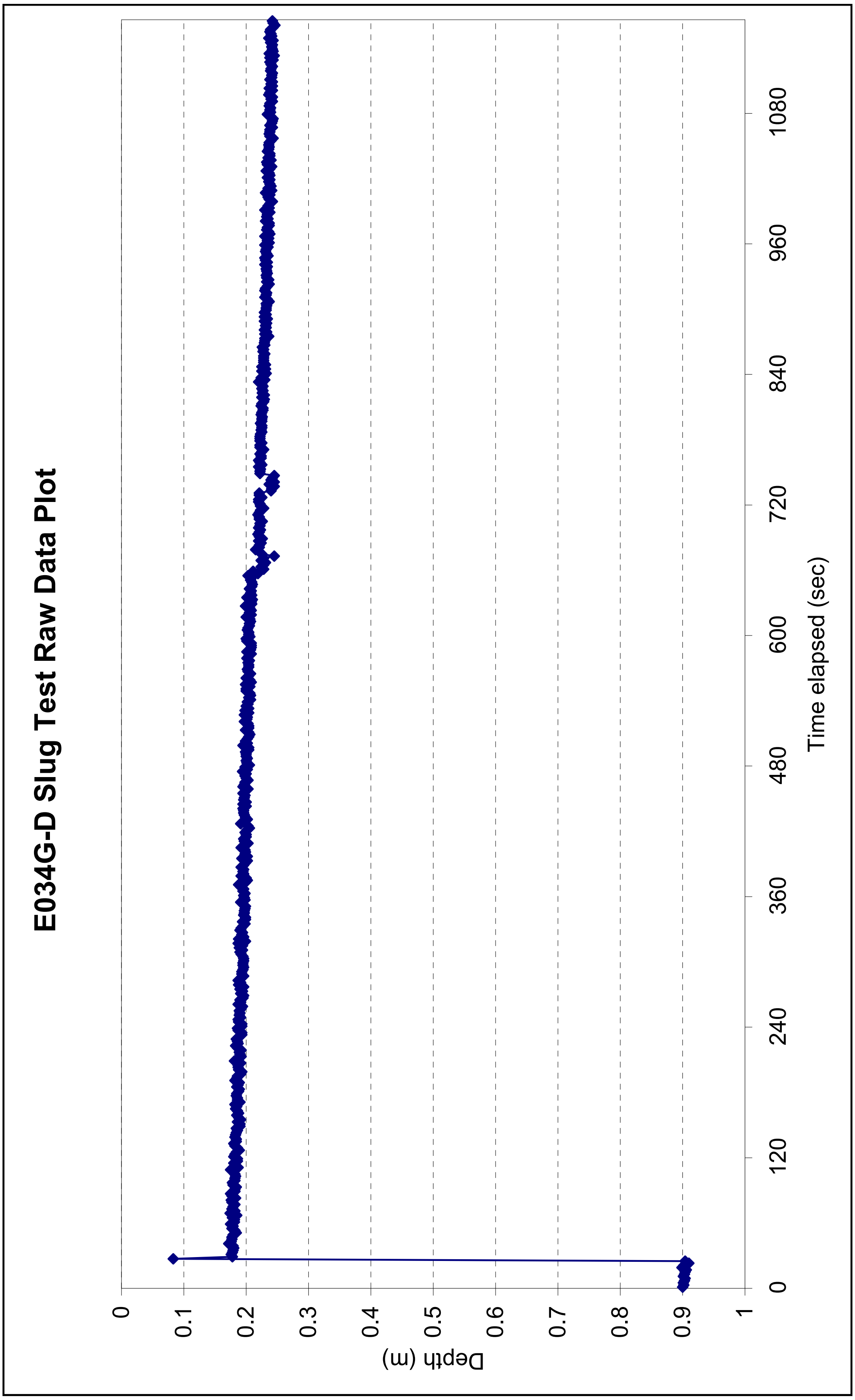

E032FG-I Slug Test Recovery Plot
Depth
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0.1
1
10
100
1000
10000
Time Elapsed (sec)

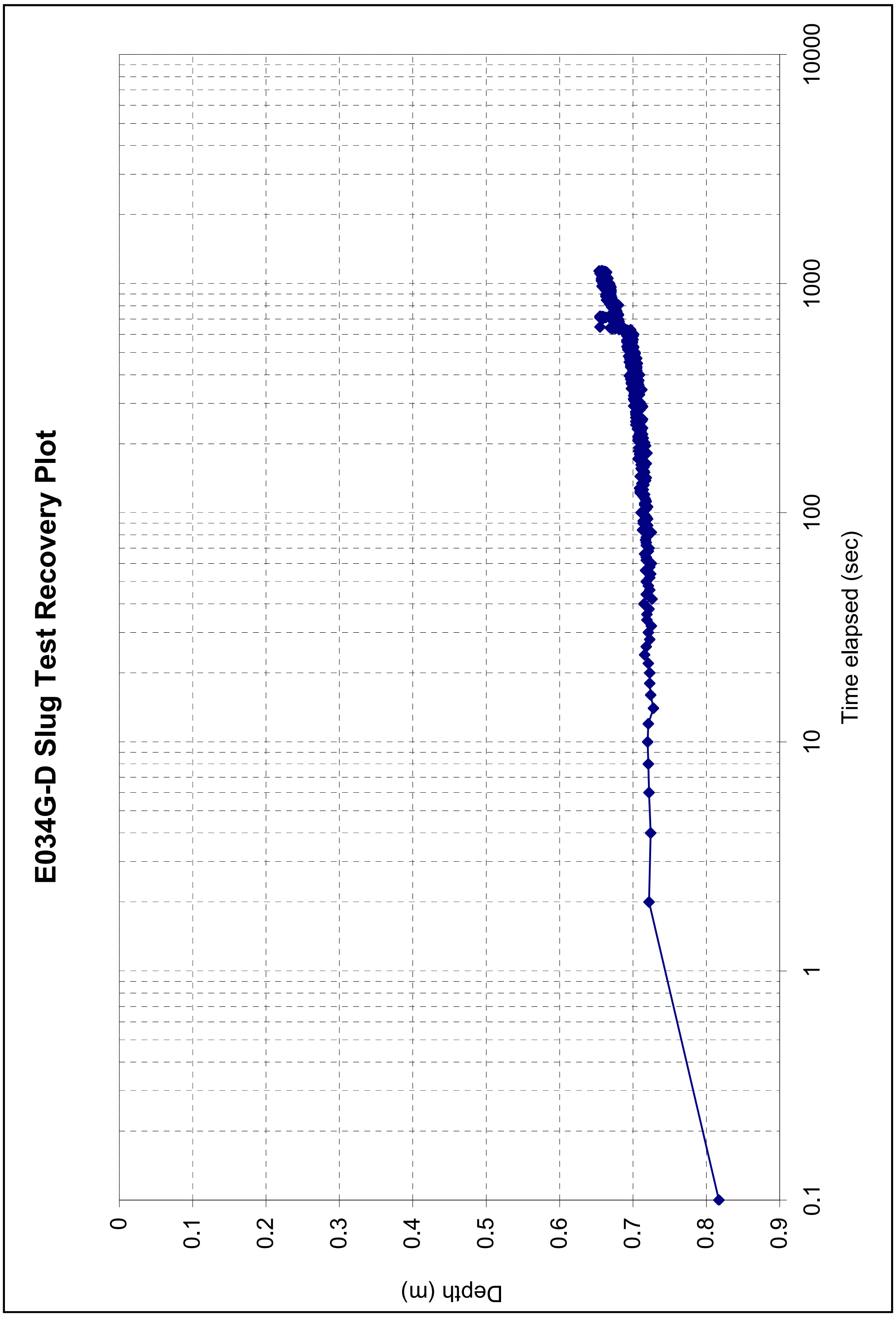

E033FG-D Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
3
3.5
4
Time Elapsed (sec)
0
120
240
360
480
600
720

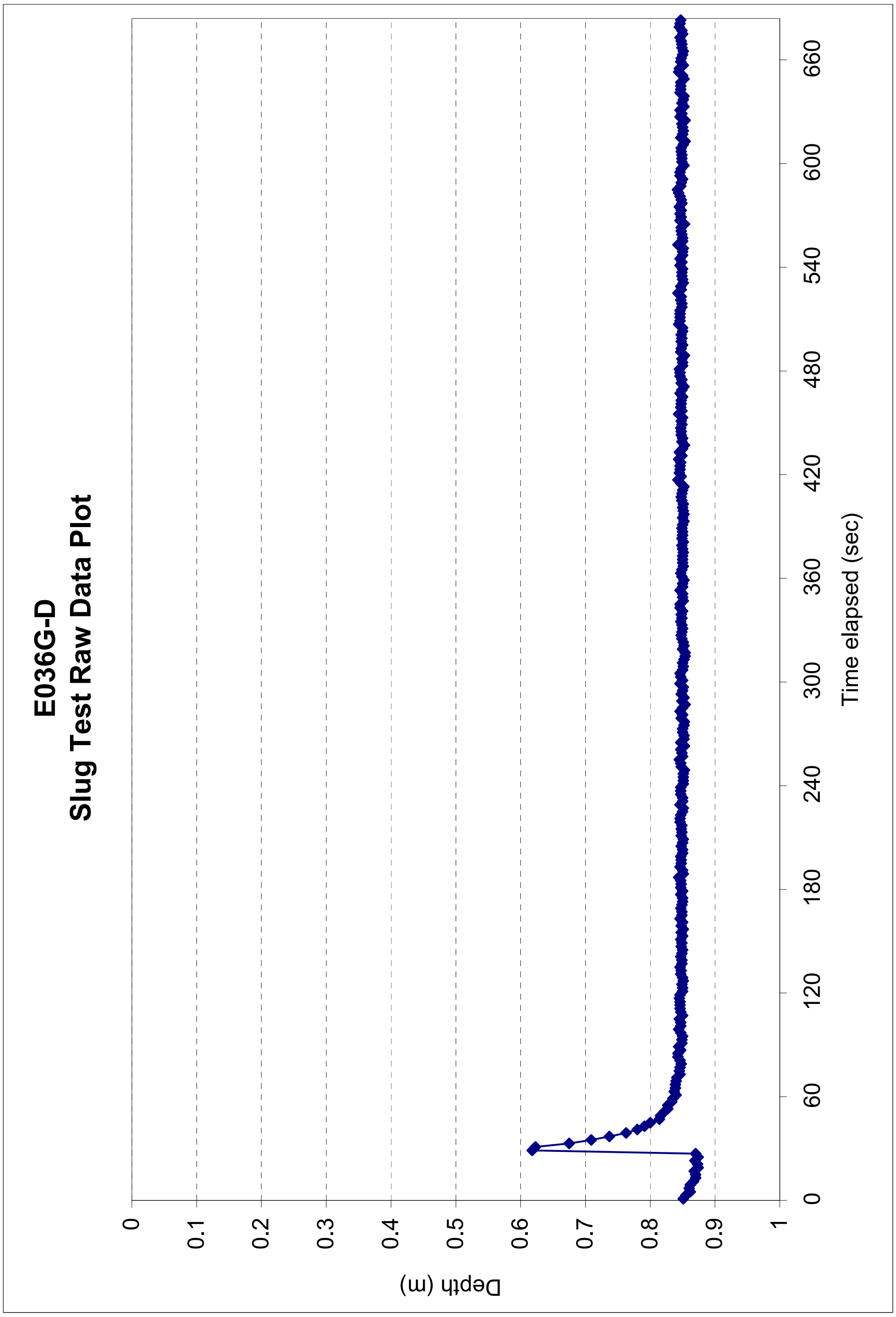

E033FG-D Slug Test Recovery Plot
Depth
-0.5
0
0.5
1
1.5
2
2.5
3
Time Elapsed (sec)
0.1
1
10
100
1000
10000

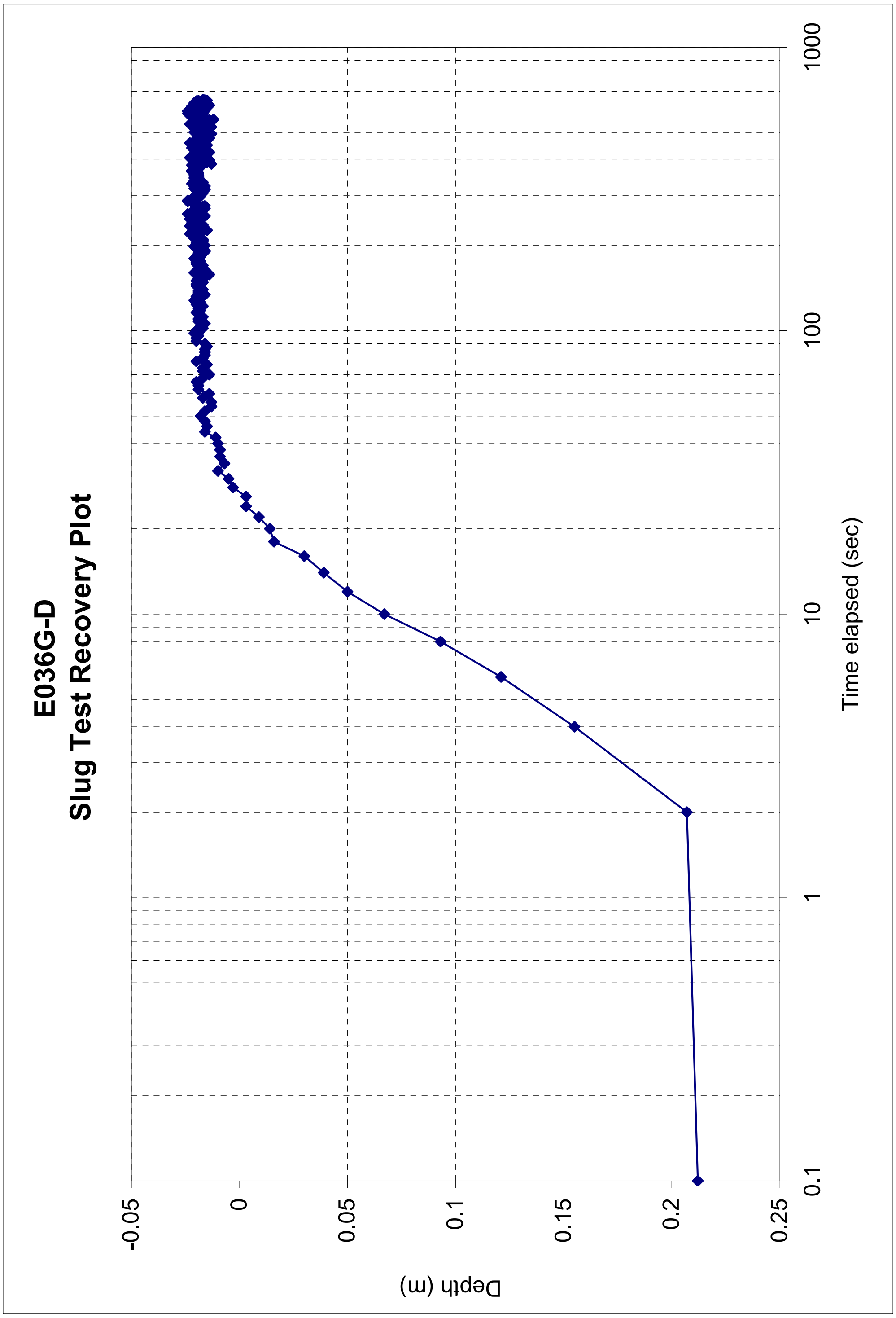

E033FG-I Slug Test Raw Data Plot
Depth
0
0.5
1
1.5
2
2.5
3
Time Elapsed (sec)
0
240
480
720
960
1200
1440
1680
1920

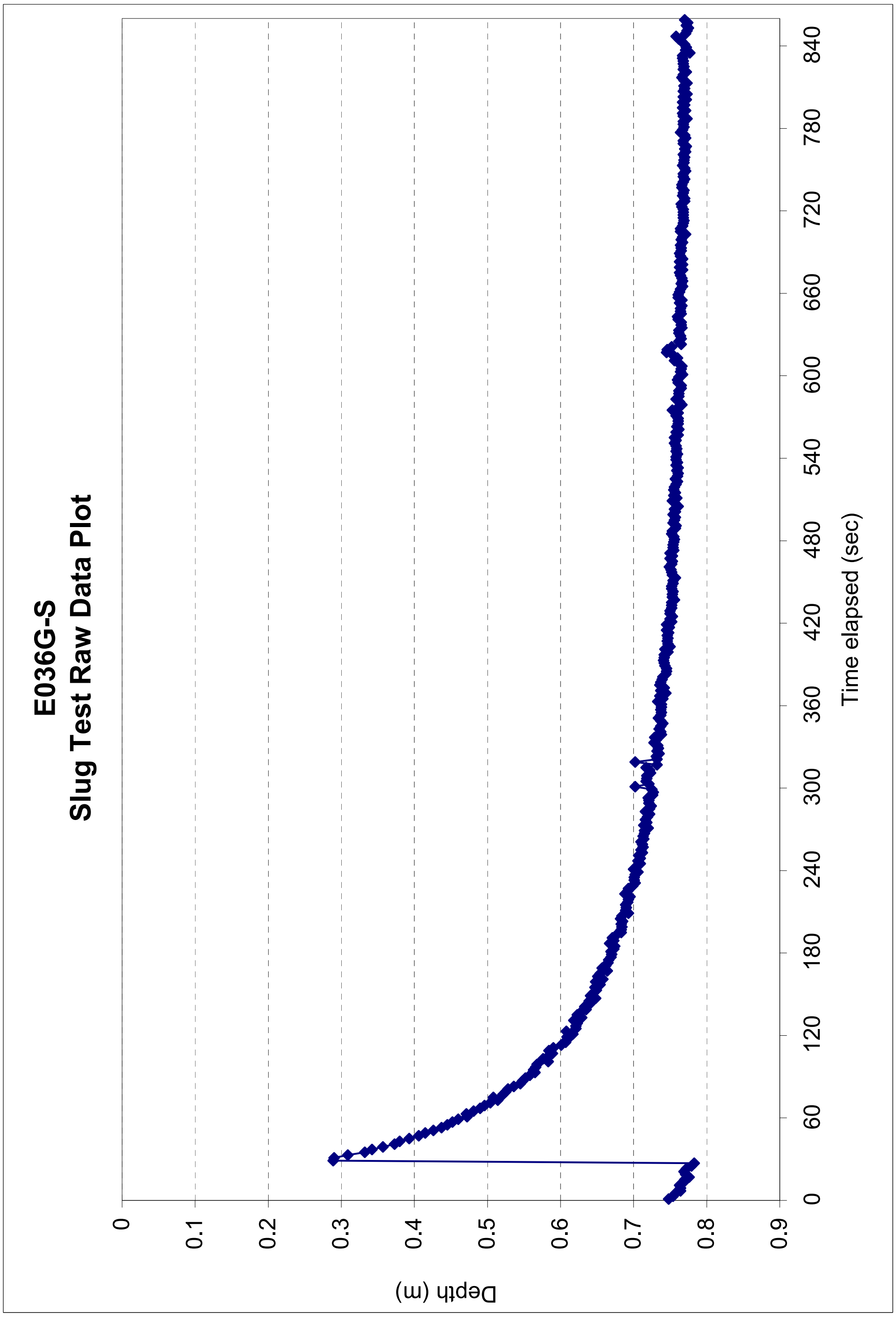

E033FG-I Slug Test Recovery Plot
Depth
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time Elapsed (sec)
0.1
1
10
100
1000
10000

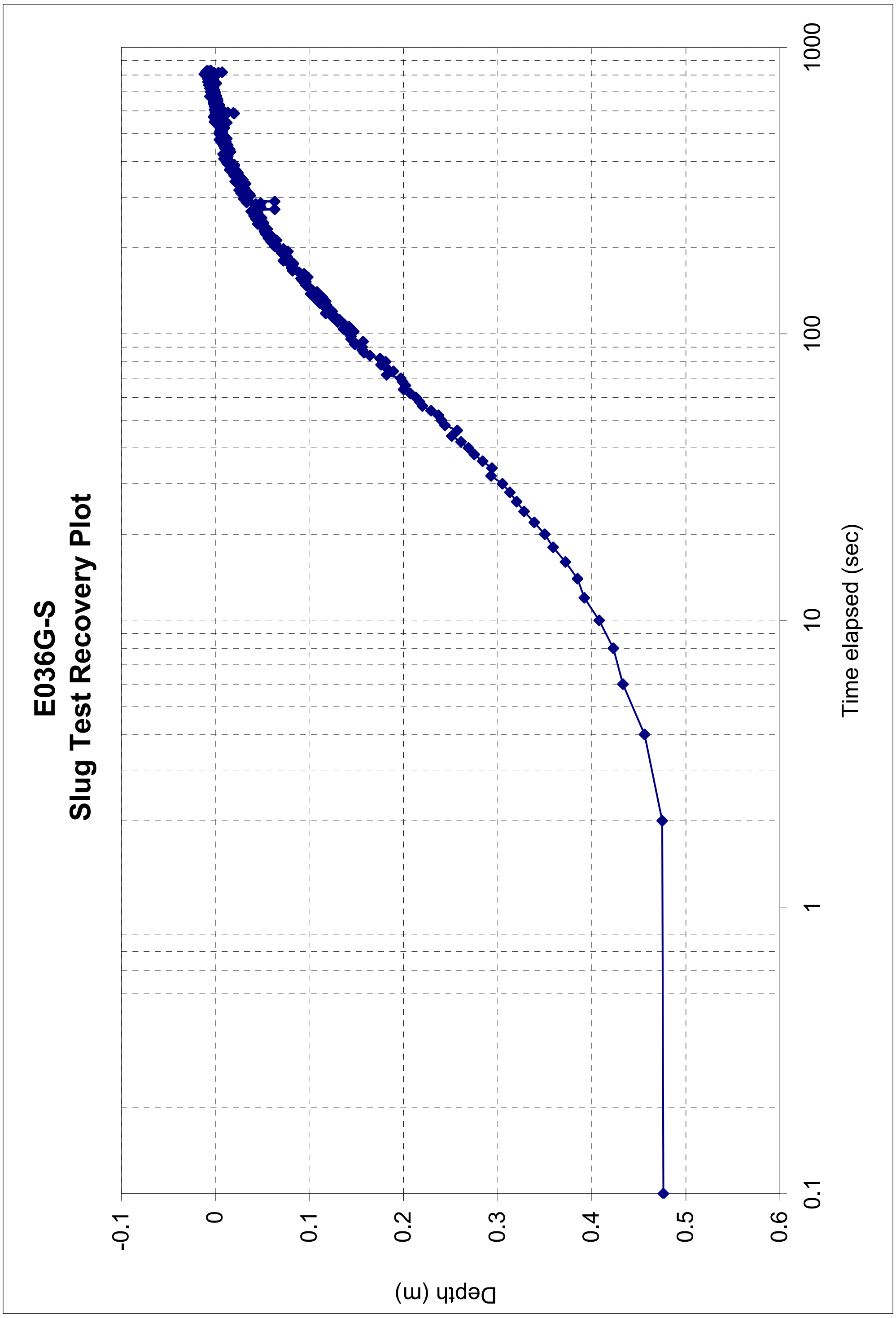

E034G-D Slug Test Raw Data Plot
Depth (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time elapsed (sec)
0
120
240
360
480
600
720
840
960
1080

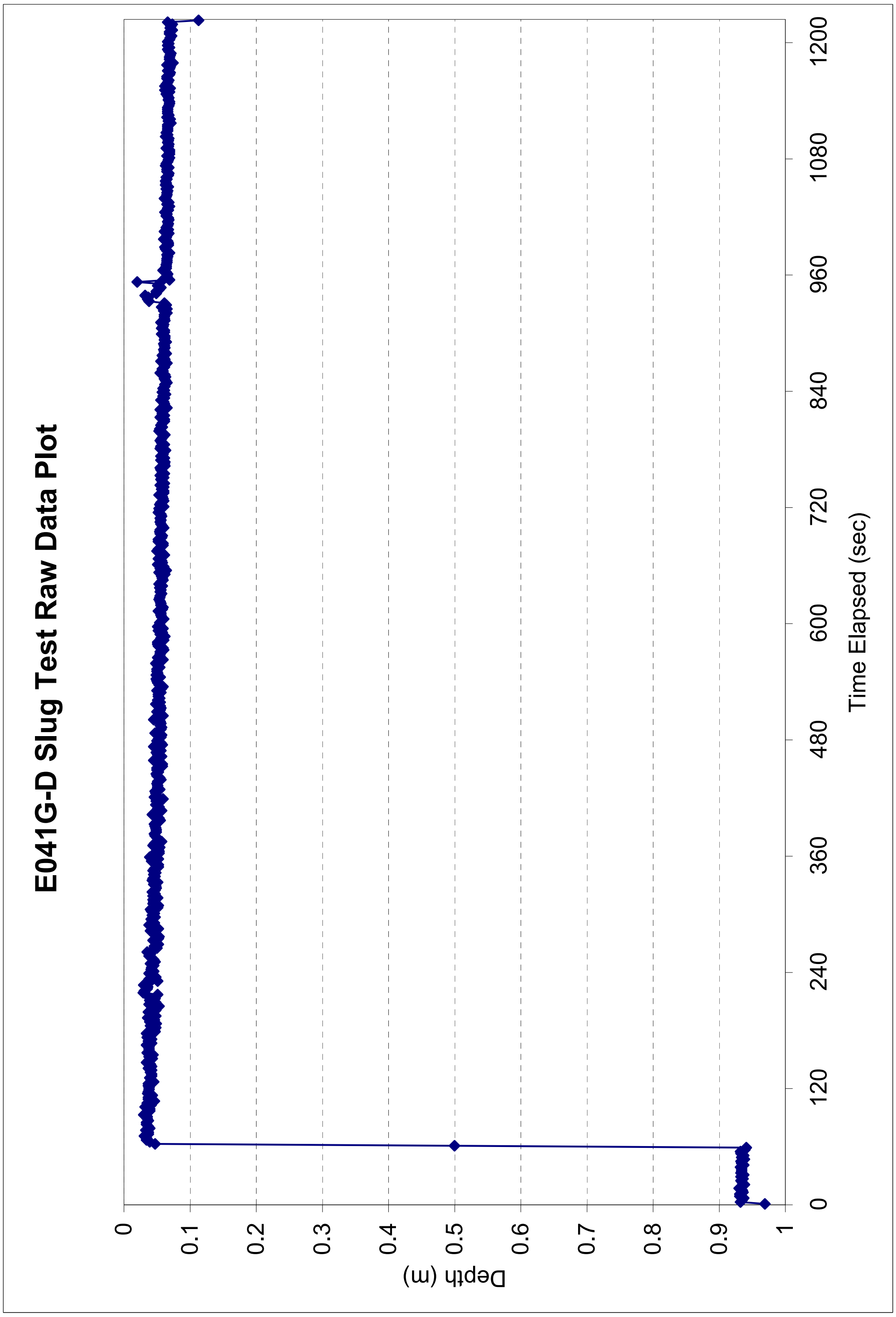

E034G-D Slug Test Recovery Plot
Depth (m)
Time elapsed (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.1
1
10
100
1000
10000

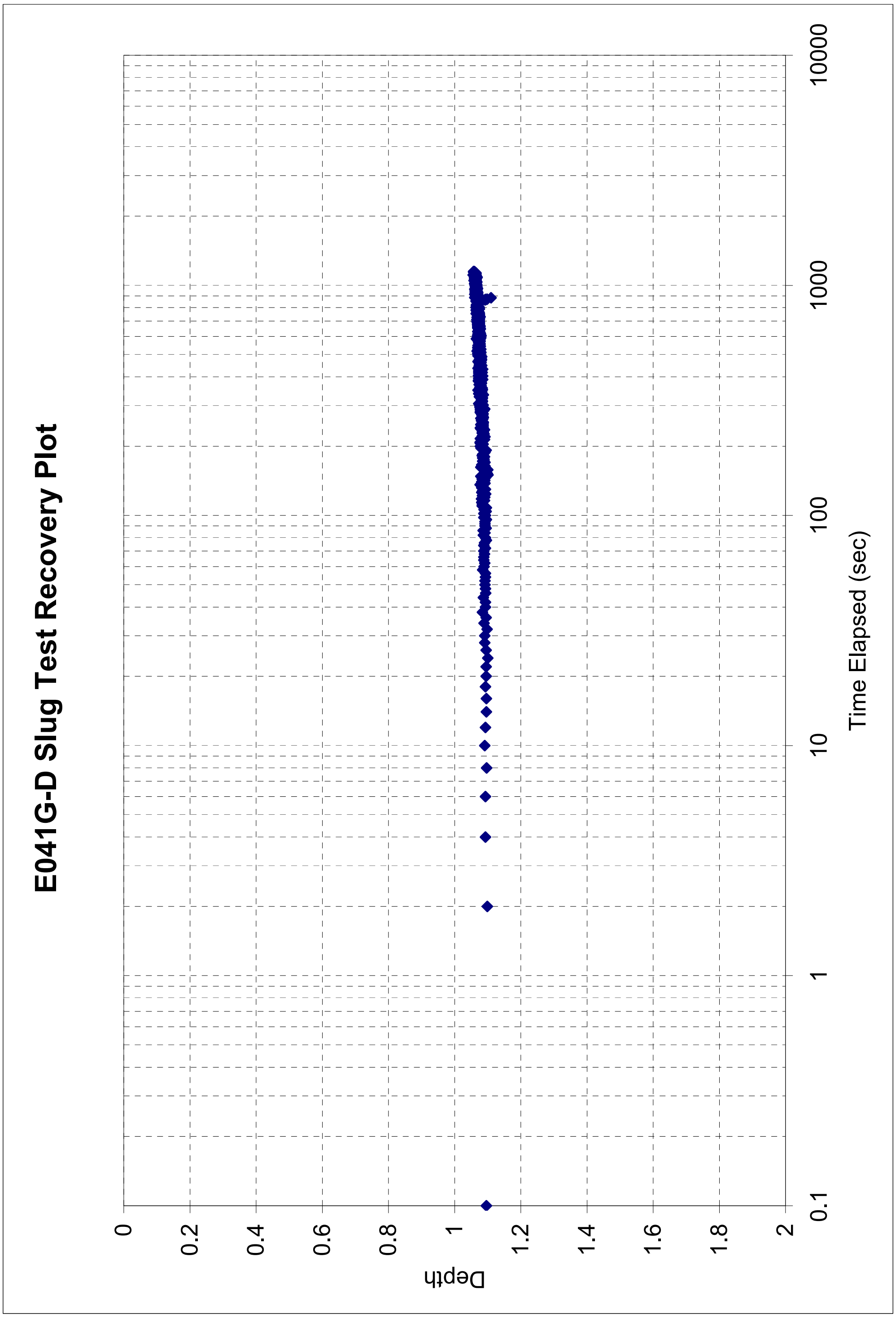

E036G-D
Slug Test Raw Data Plot
Depth (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time elapsed (sec)
0
60
120
180
240
300
360
420
480
540
600
660

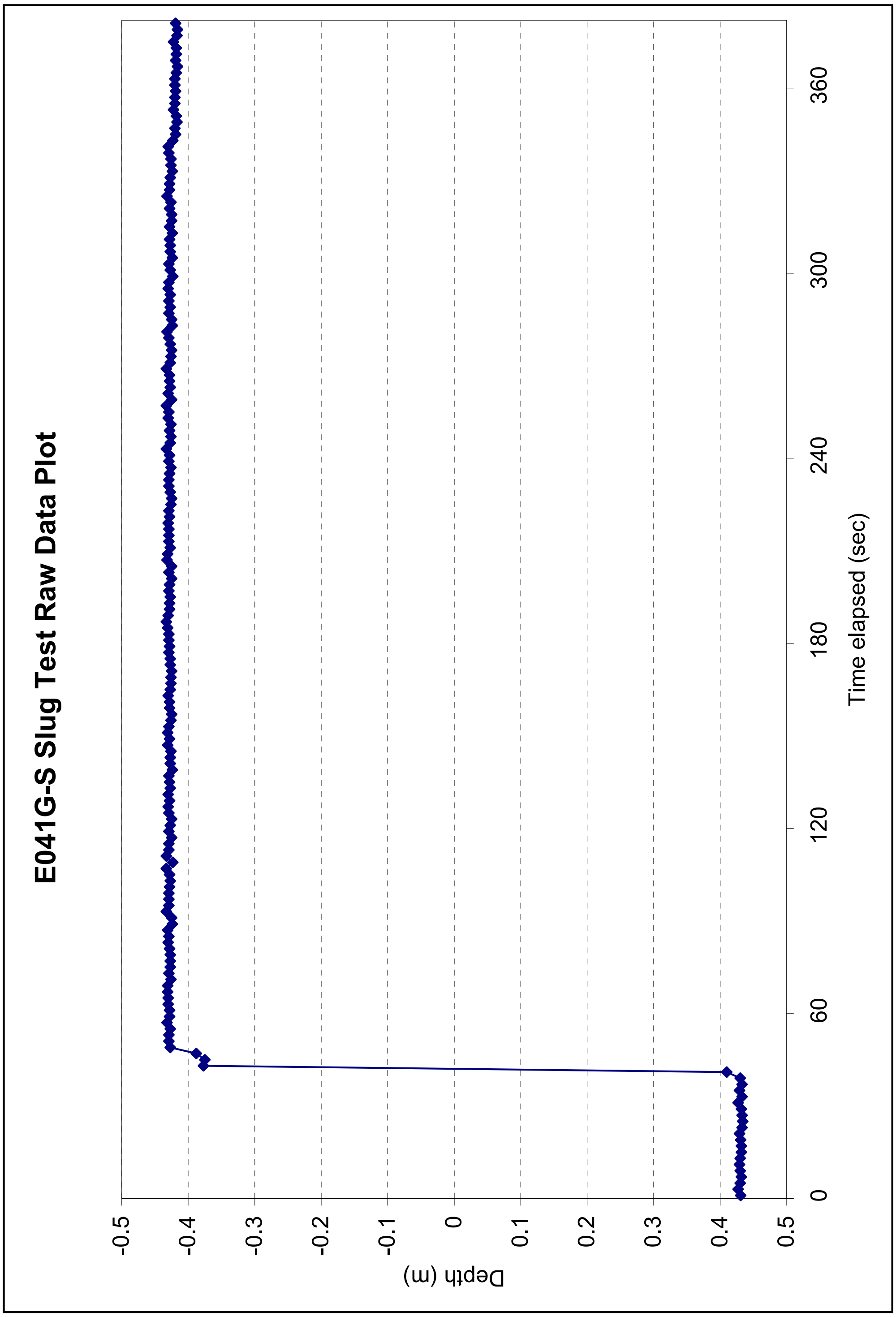

E036G-D
Slug Test Recovery Plot
Depth (m)
-0.05
0
0.05
0.1
0.15
0.2
0.25
Time elapsed (sec)
0.1
1
10
100
1000

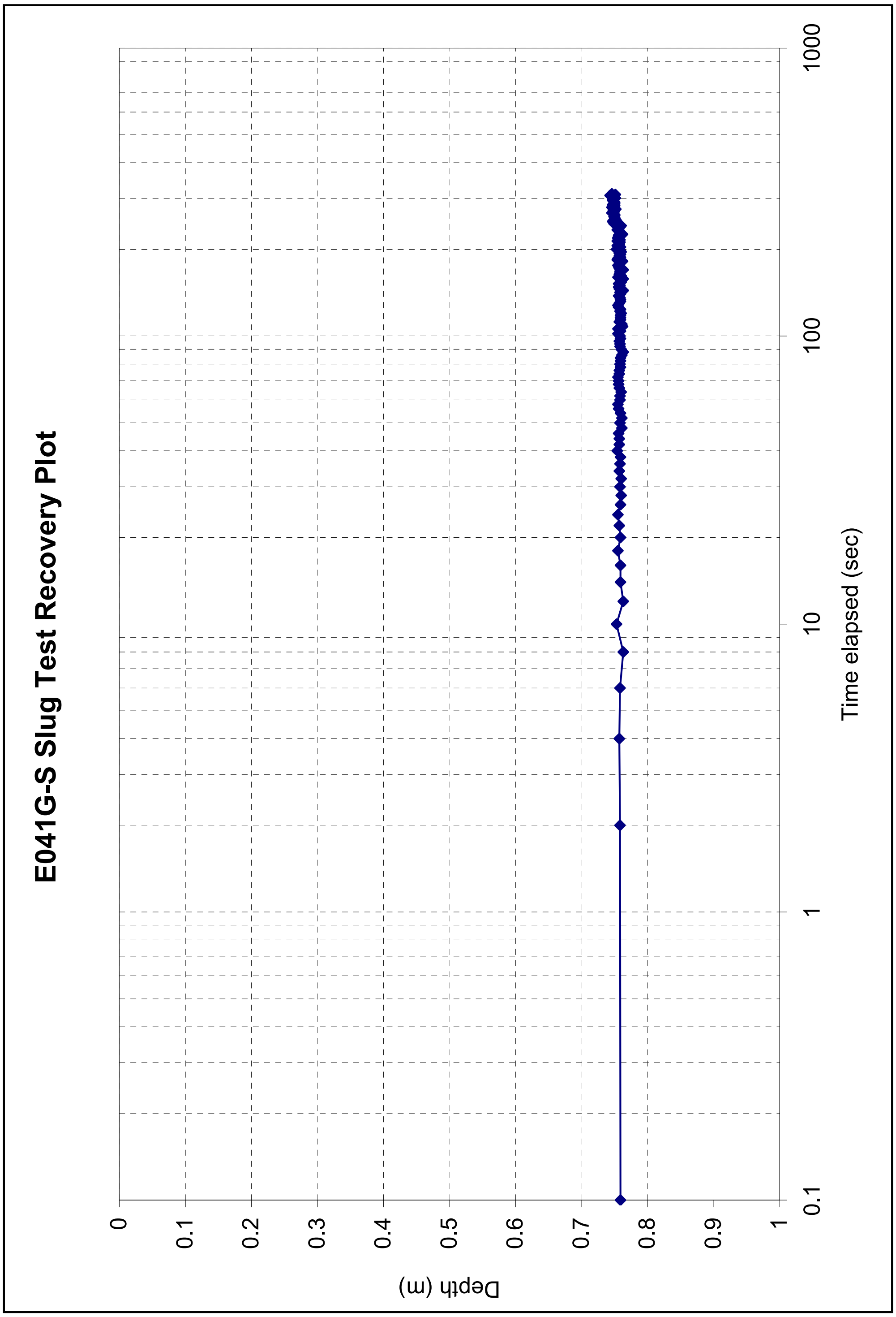

E036G-S
Slug Test Raw Data Plot
Depth (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Time elapsed (sec)
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840

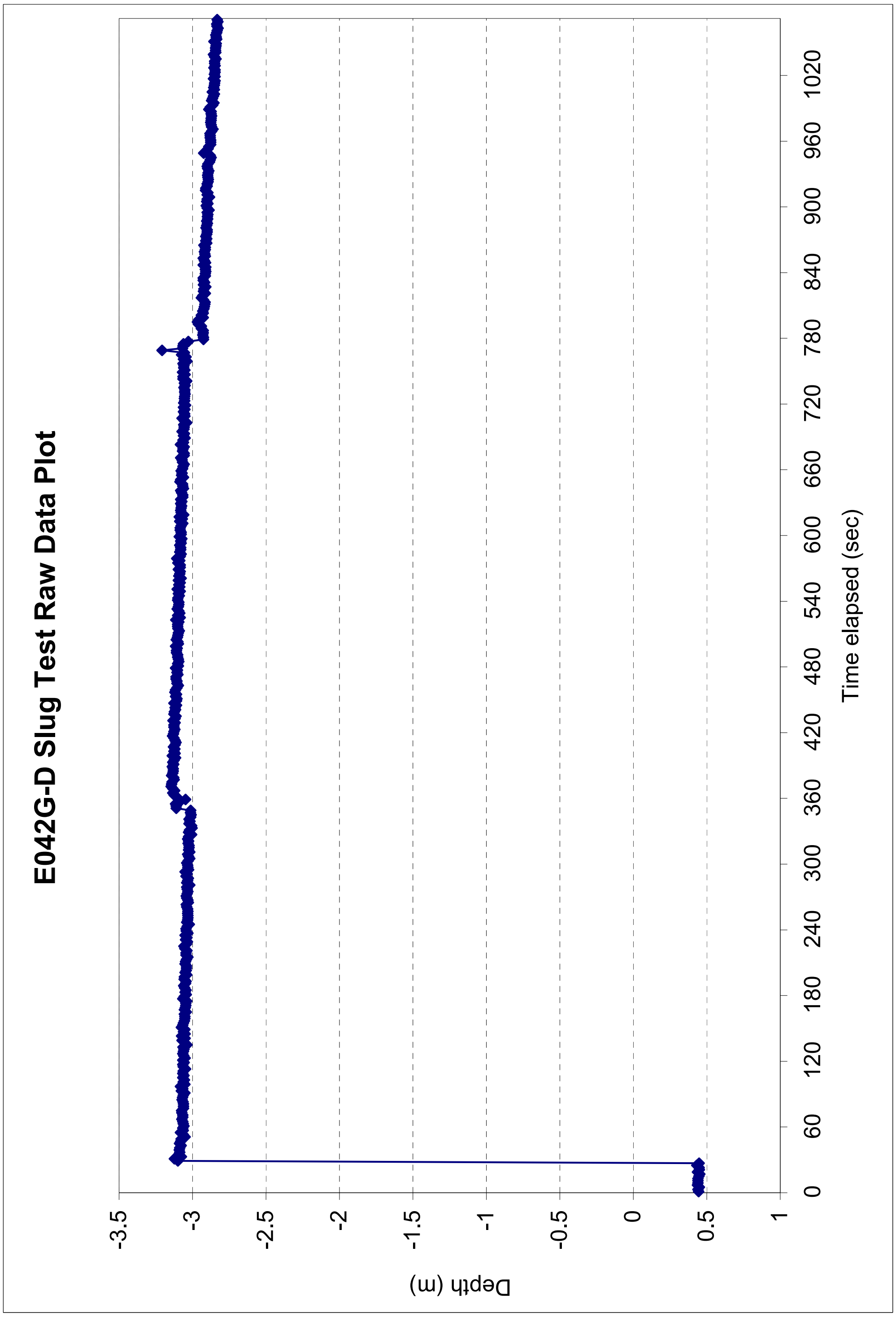

E036G-S
Slug Test Recovery Plot
Depth (m)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
Time elapsed (sec)
0.1
1
10
100
1000

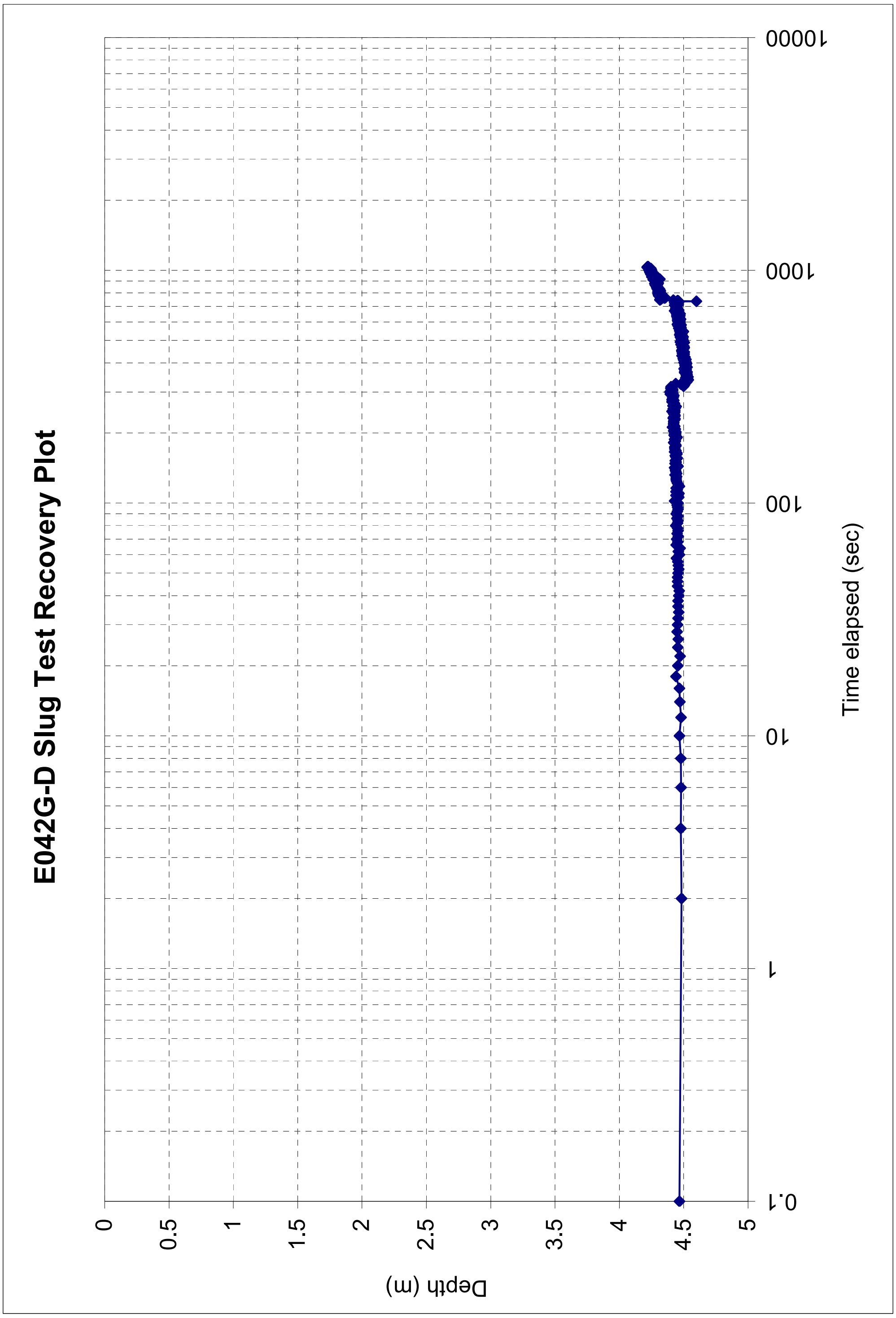

E041G-D Slug Test Raw Data Plot
Depth (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time Elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200

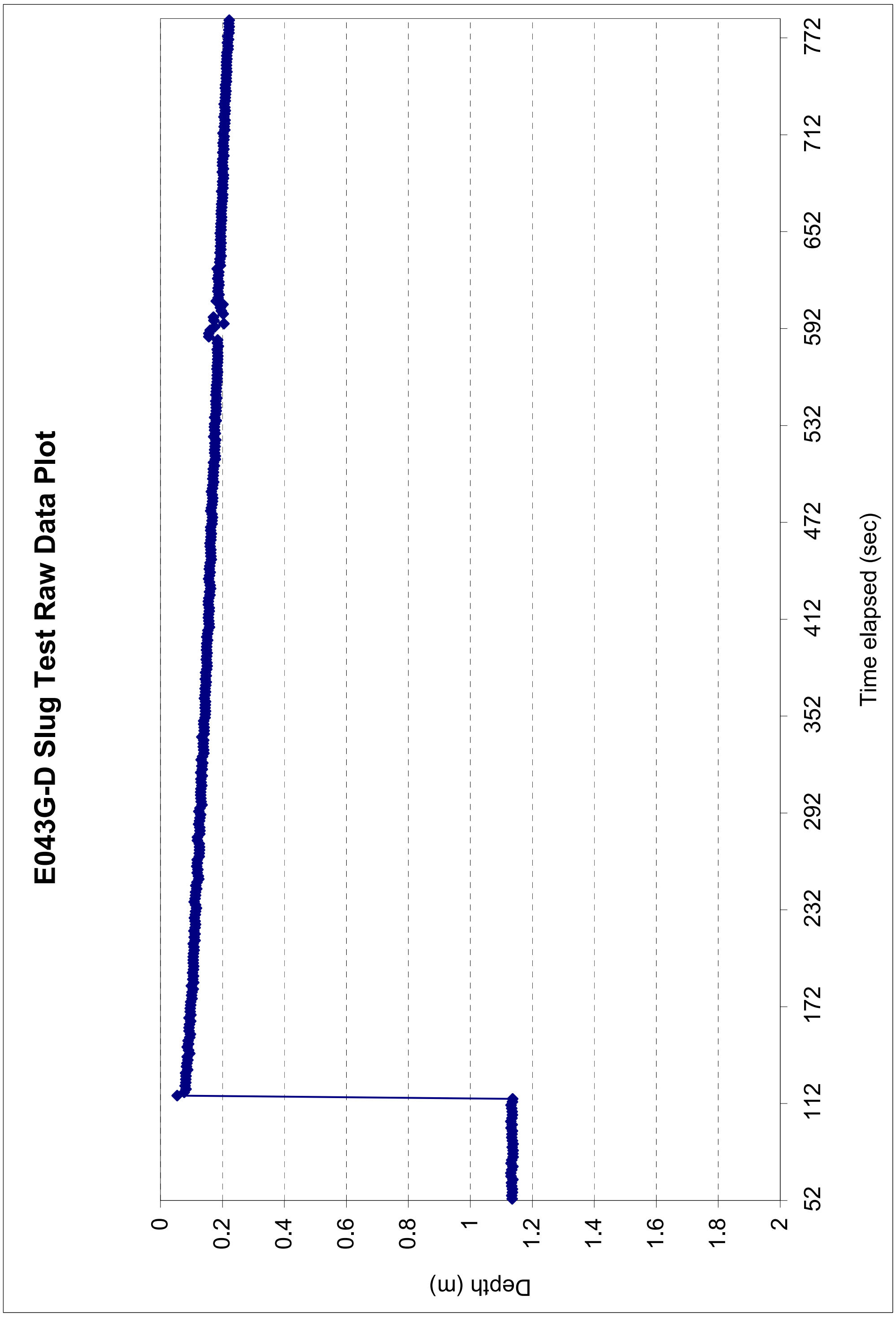

E041G-D Slug Test Recovery Plot
Depth
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time Elapsed (sec)
0.1
1
10
100
1000
10000

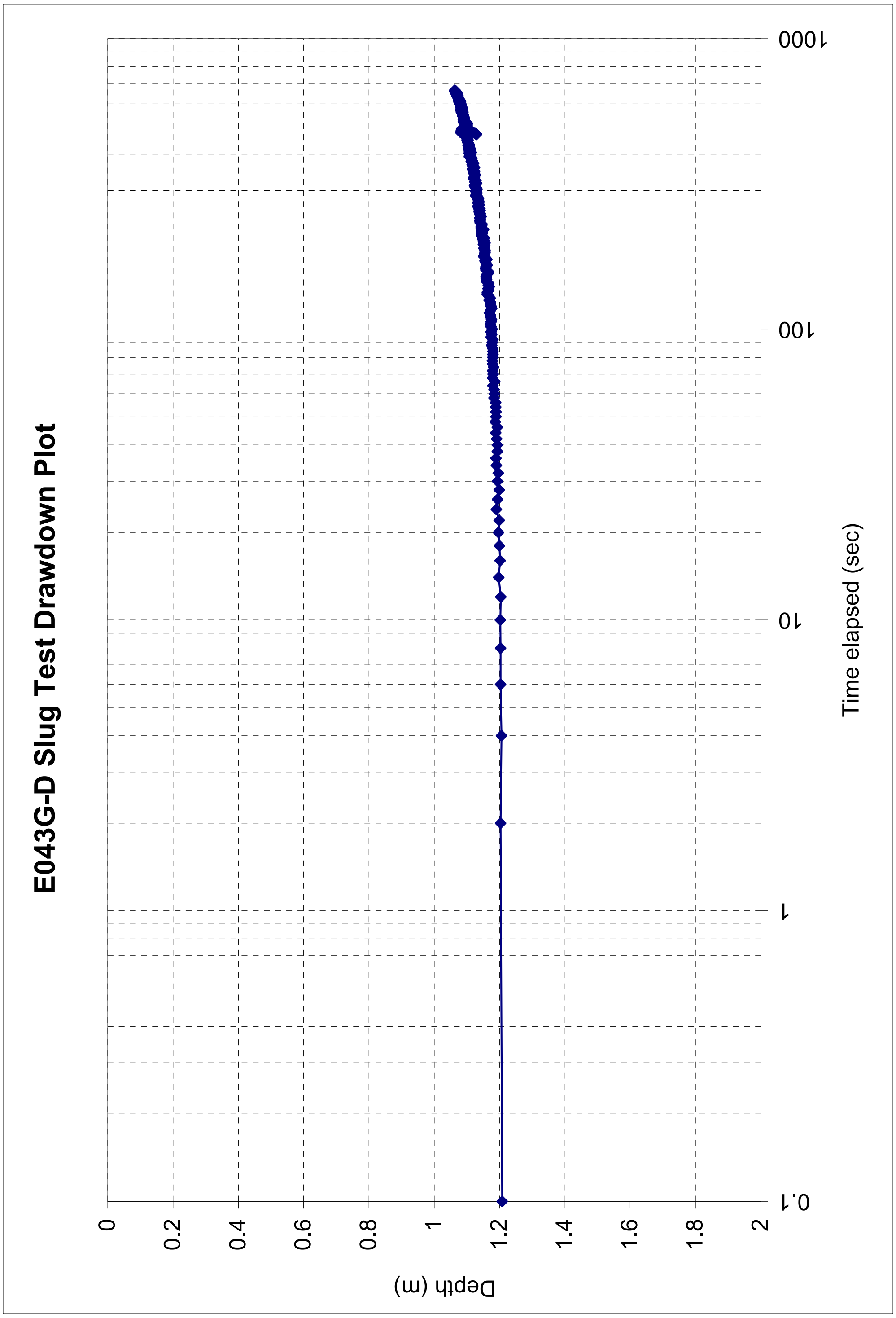

E041G-S Slug Test Raw Data Plot
Depth (m)
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0
60
120
180
240
300
360
Time elapsed (sec)

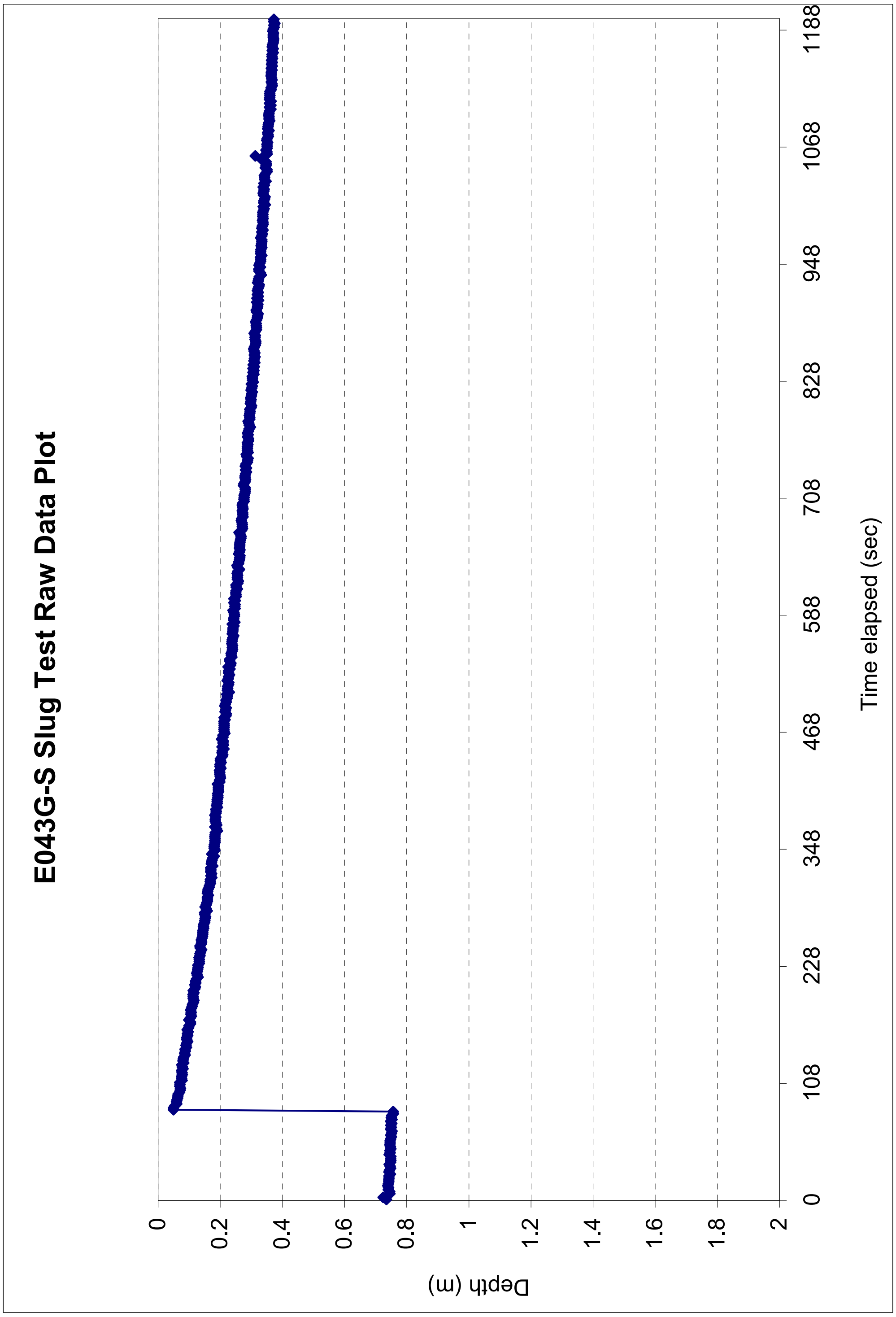

E041G-S Slug Test Recovery Plot
Depth (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time elapsed (sec)
0.1
1
10
100
1000

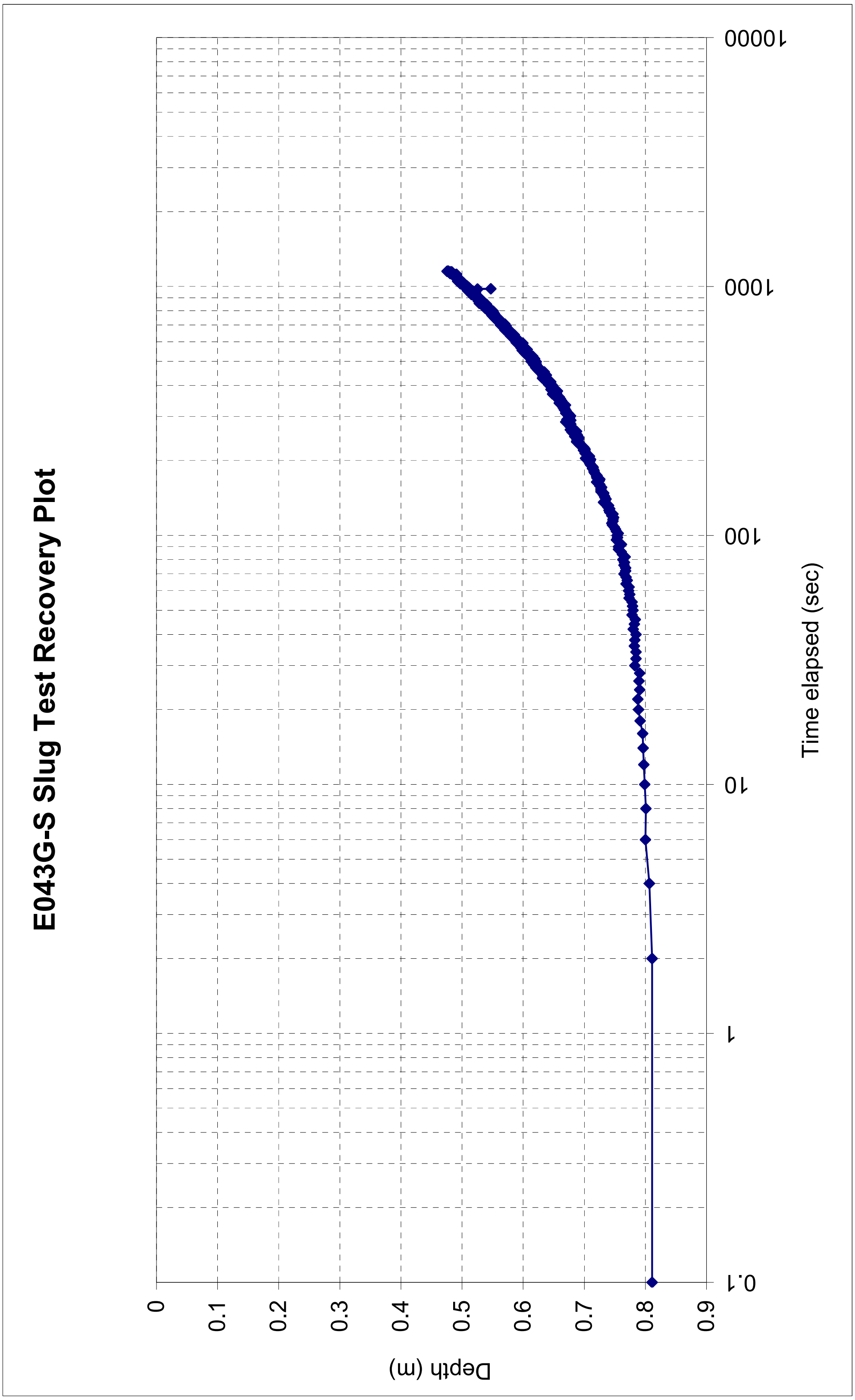

E042G-D Slug Test Raw Data Plot
Depth (m)
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
Time elapsed (sec)
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
960
1020

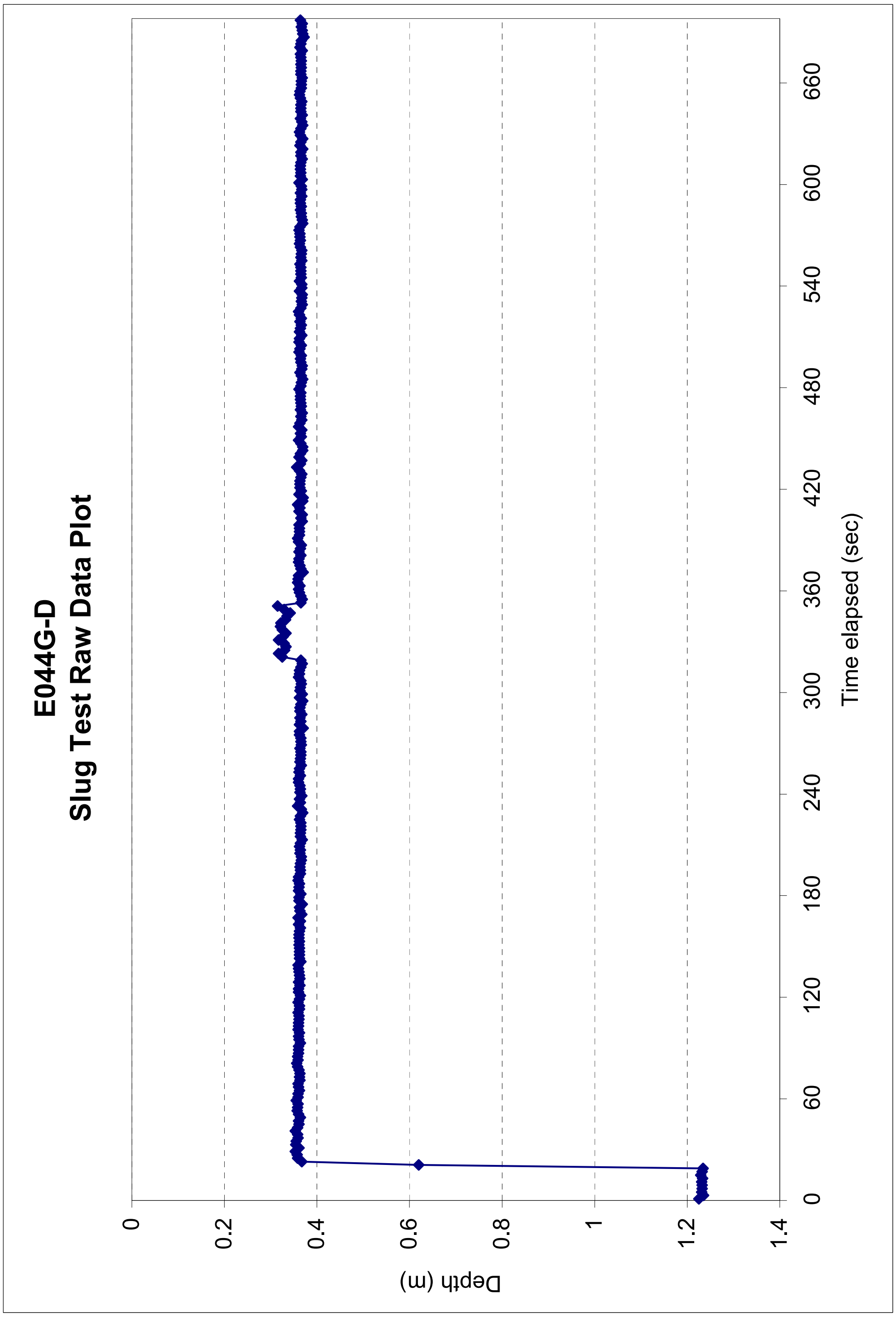

E042G-D Slug Test Recovery Plot
Depth (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time elapsed (sec)
0.1
1
10
100
1000
10000

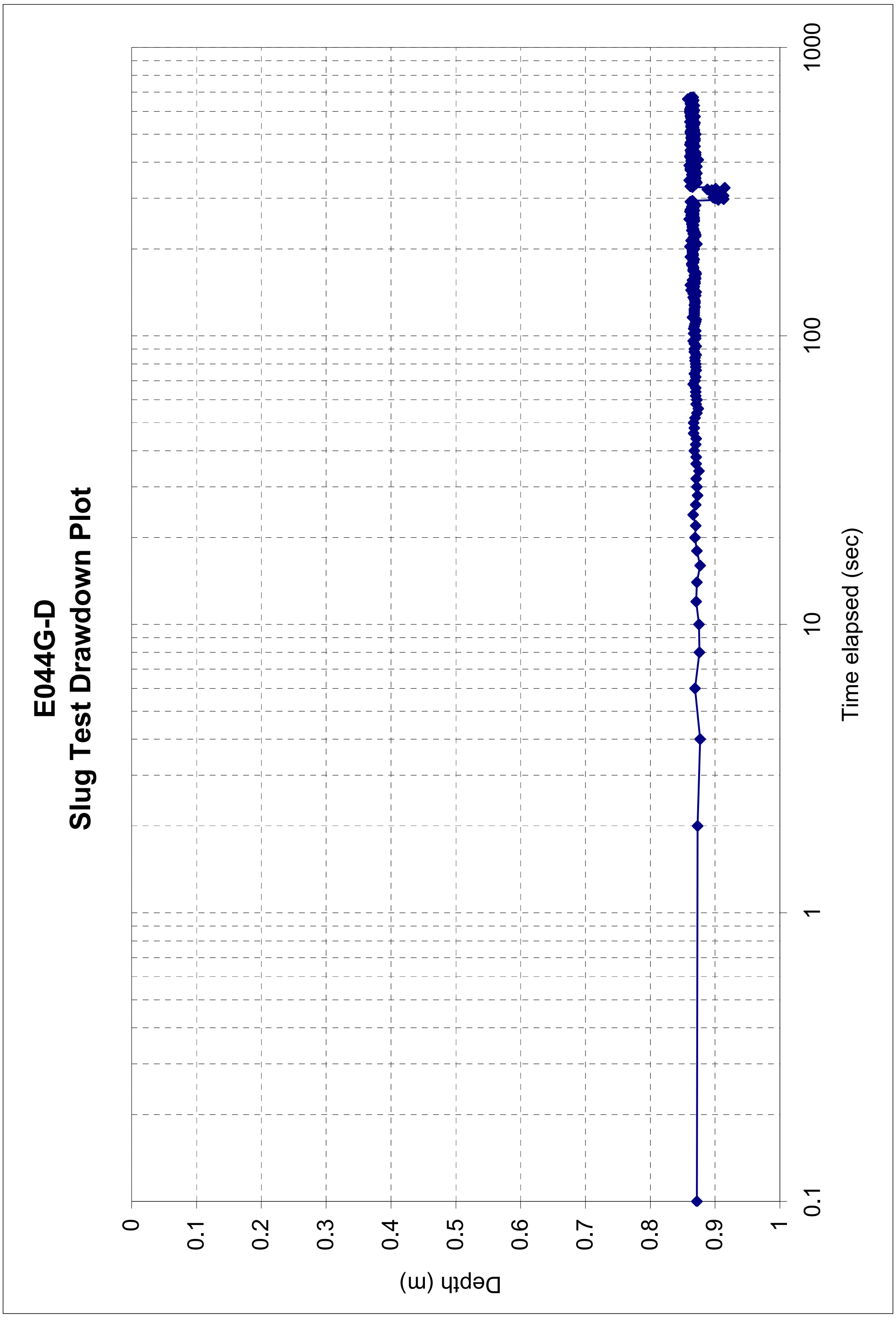

E043G-D Slug Test Raw Data Plot
Depth (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
52
112
172
232
292
352
412
472
532
592
652
712
772
Time elapsed (sec)

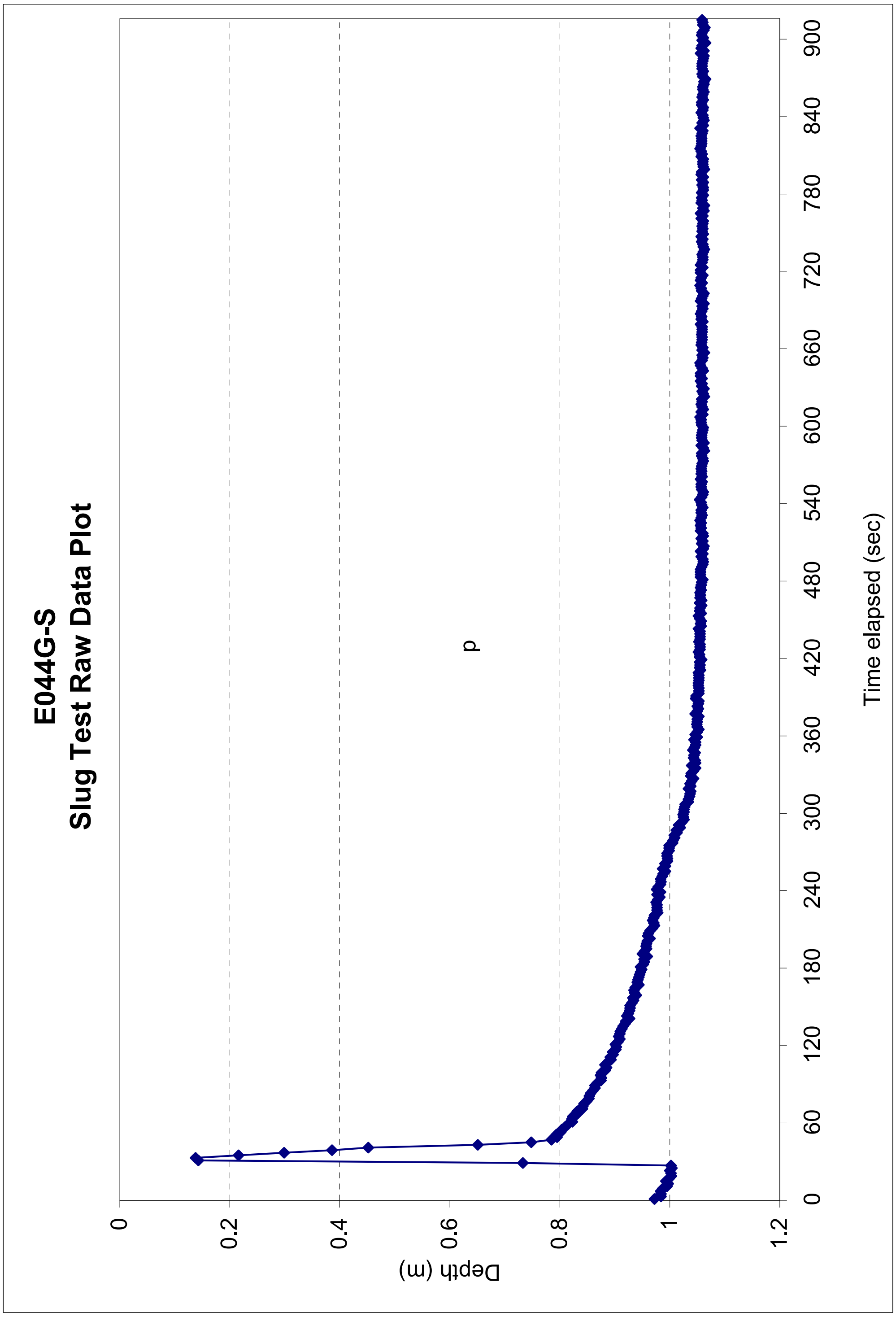

E043G-D Slug Test Drawdown Plot
Depth (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time elapsed (sec)
0.1
1
10
100
1000

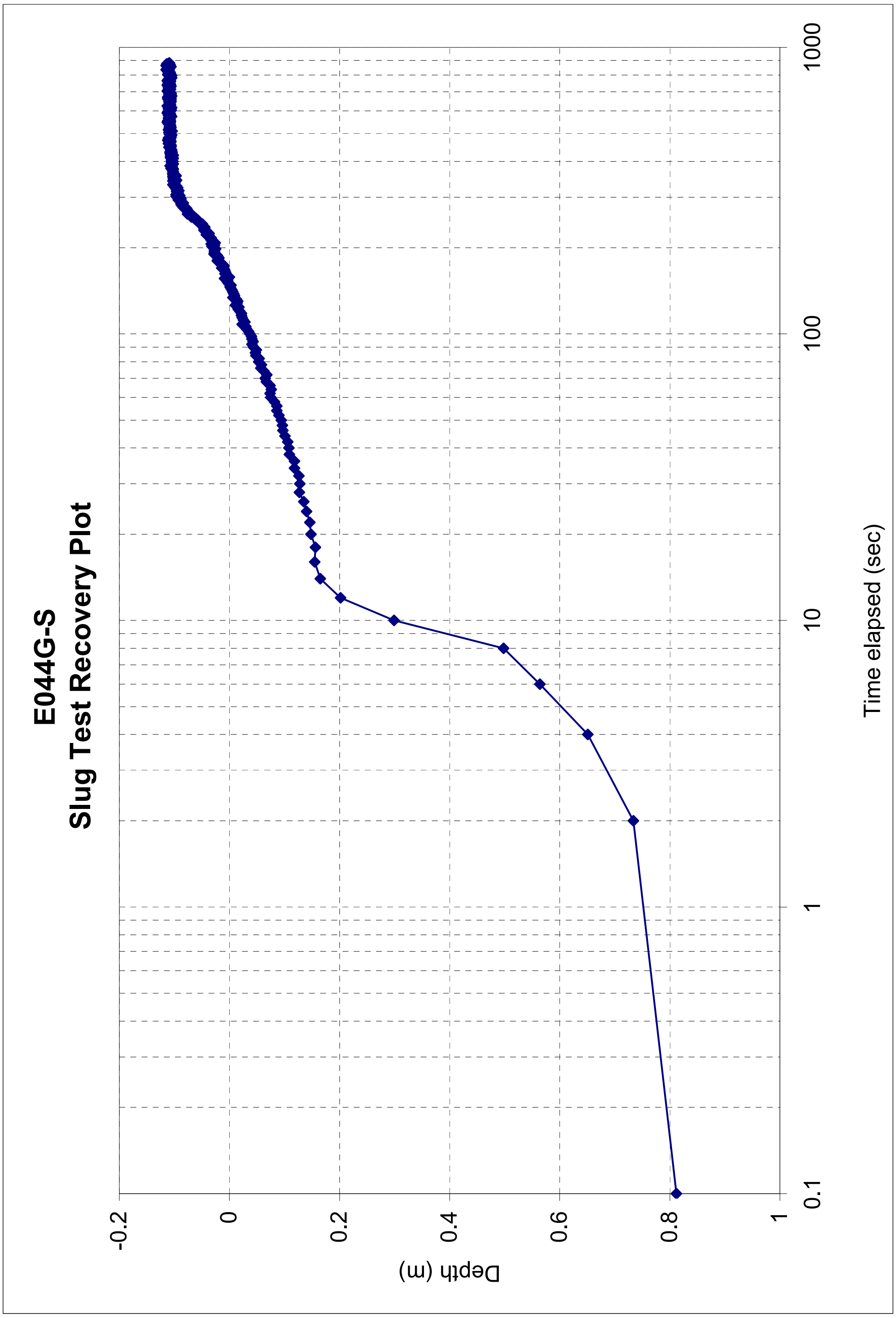

E043G-S Slug Test Raw Data Plot
Depth (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time elapsed (sec)
0
108
228
348
468
588
708
828
948
1068
1188

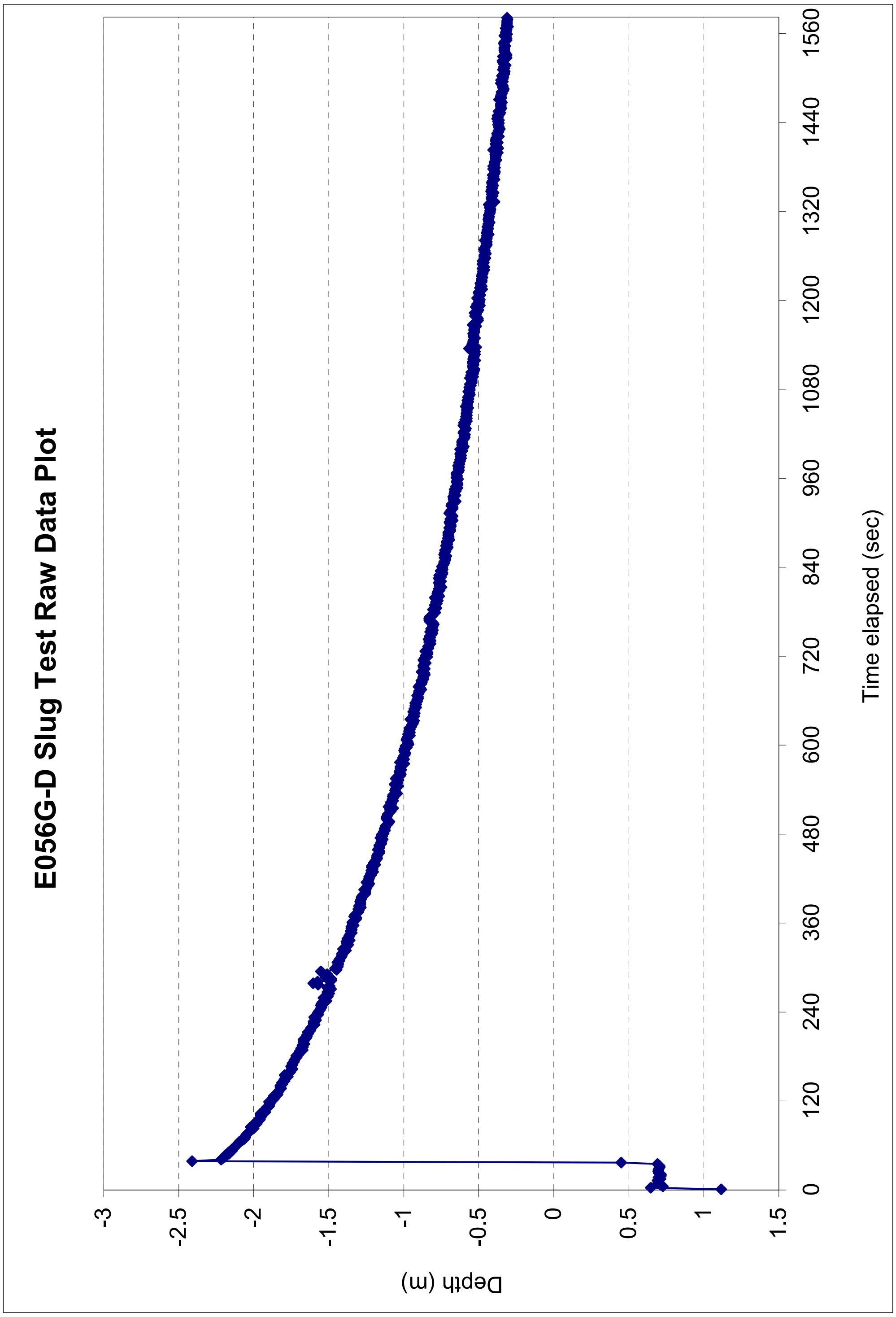

E043G-S Slug Test Recovery Plot
Time elapsed (sec)
Depth (m)
0.1
1
10
100
1000
10000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

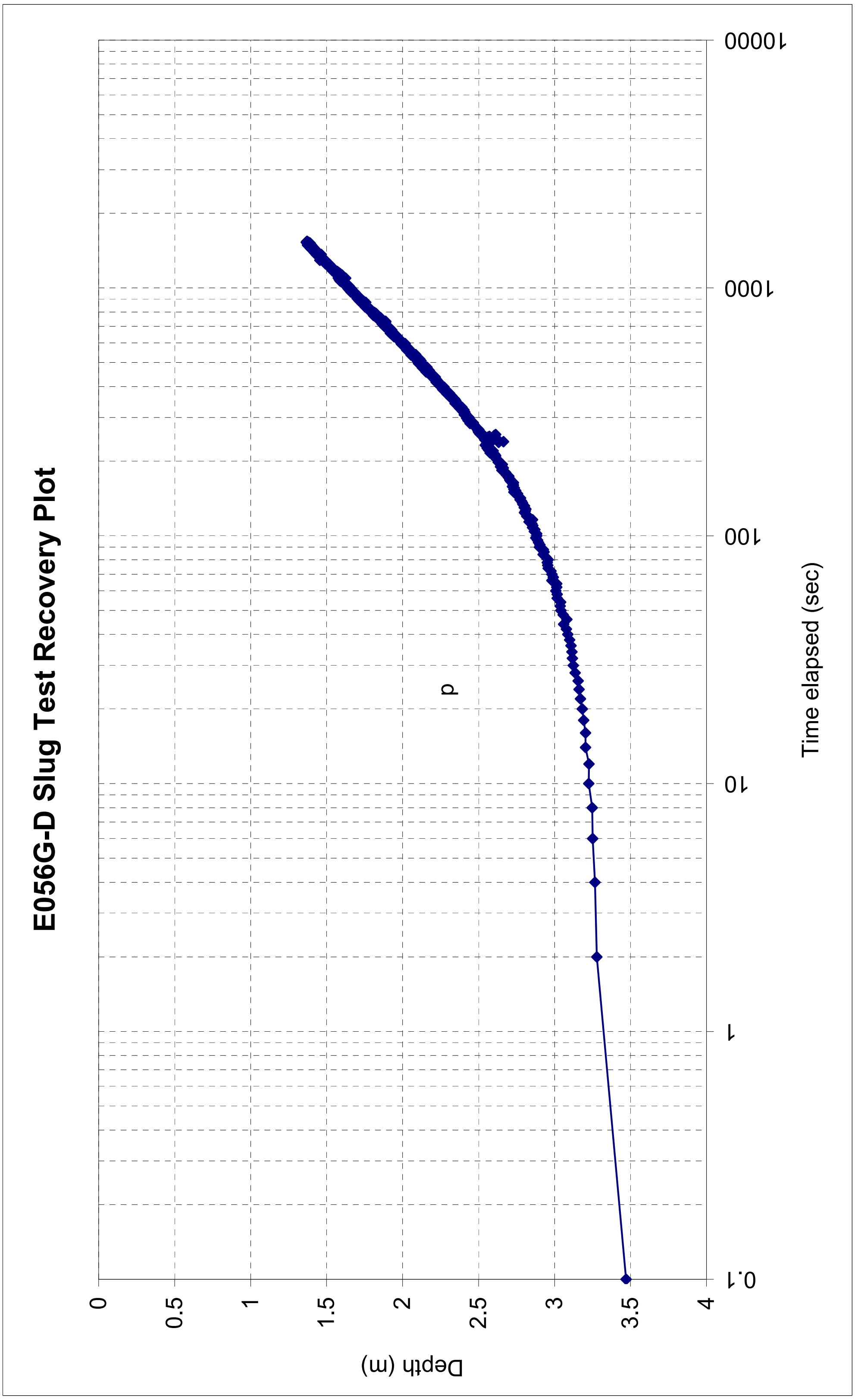

E044G-D
Slug Test Raw Data Plot
Depth (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Time elapsed (sec)
0
60
120
180
240
300
360
420
480
540
600
660

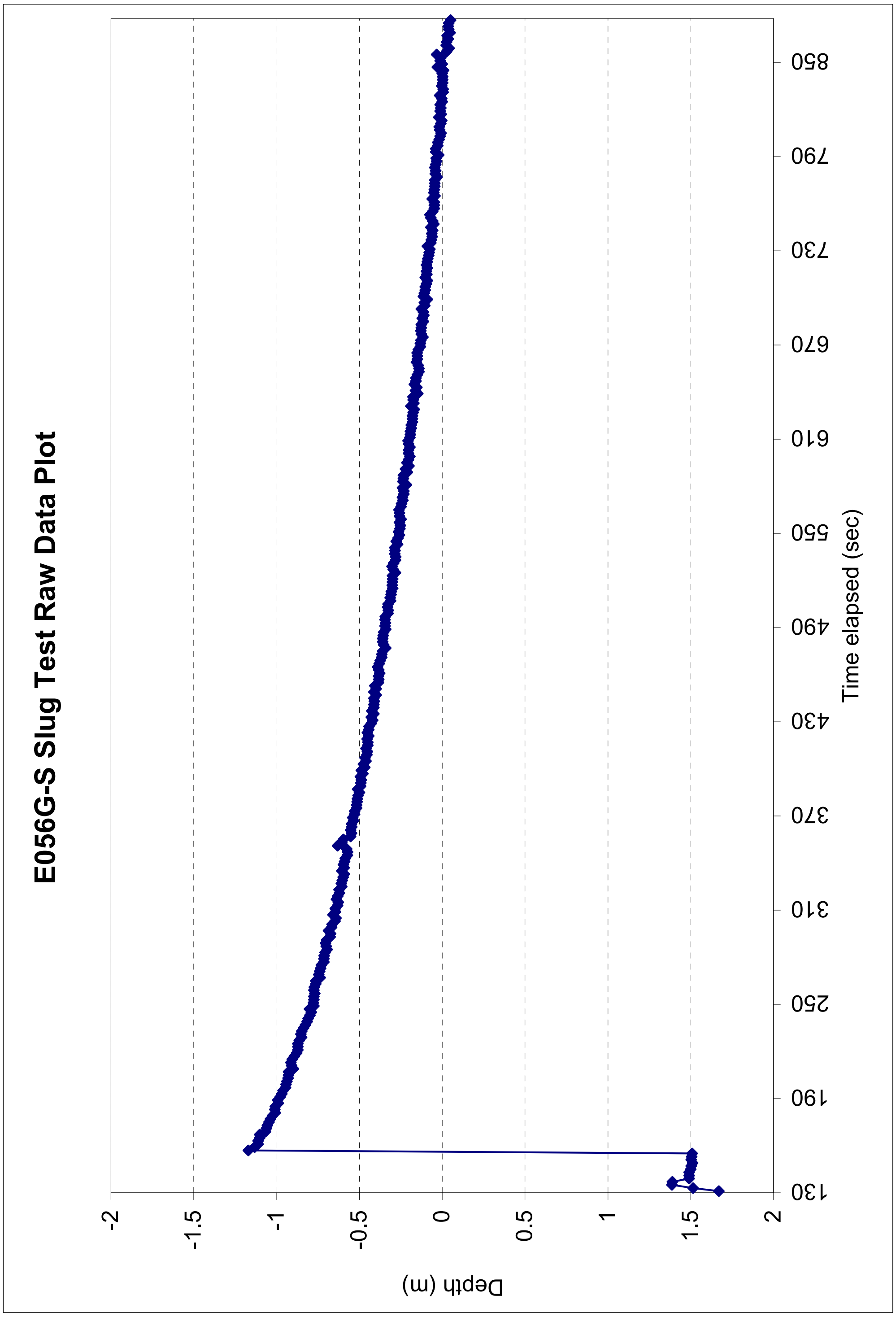

E044G-D
Slug Test Drawdown Plot
Depth (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time elapsed (sec)
0.1
1
10
100
1000

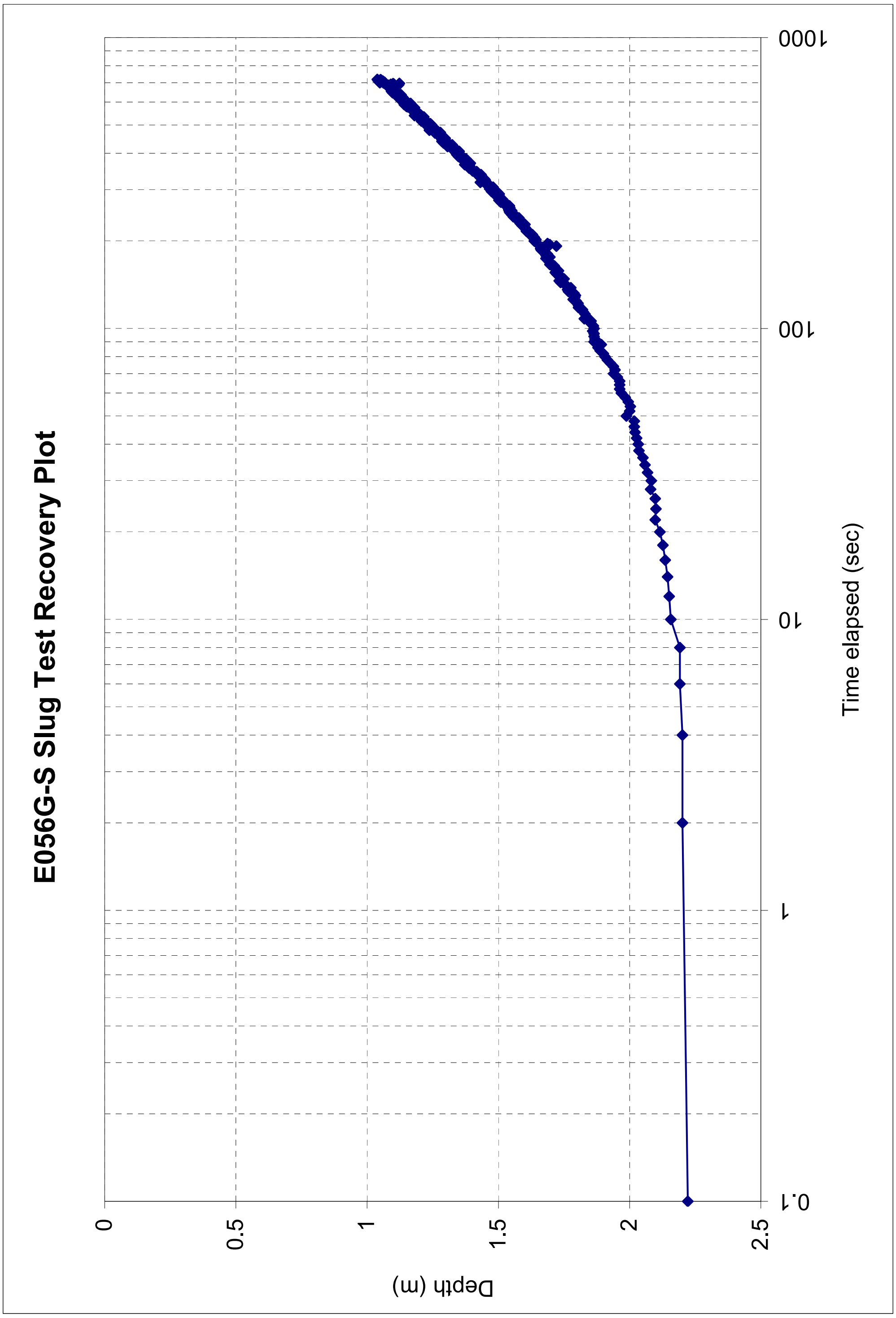

E044G-S
Slug Test Raw Data Plot
Depth (m)
0
0.2
0.4
0.6
0.8
1
1.2
Time elapsed (sec)
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
p


E044G-S
Slug Test Recovery Plot
Depth (m)
-0.2
0
0.2
0.4
0.6
0.8
1
0.1
1
10
100
1000
Time elapsed (sec)


E056G-D Slug Test Raw Data Plot
Depth (m)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
Time elapsed (sec)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560


E056G-D Slug Test Recovery Plot
Depth (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
Time elapsed (sec)
0.1
1
10
100
1000
10000
p


E056G-S Slug Test Raw Data Plot
Depth (m)
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Time elapsed (sec)
130
190
250
310
370
430
490
550
610
670
730
790
850


E056G-S Slug Test Recovery Plot
Depth (m)
0
0.5
1
1.5
2
2.5
Time elapsed (sec)
0.1
1
10
100
1000

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E

Appendix E Groundwater Quality Phase 1 and Phase 2

URS

42907466/WHST-STU-WA-RPT-0090/0

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0902086**	Page	: 1 of 5
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: DANIEL LACEY	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	: daniel_lacey@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0100	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
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 20-APR-2009
Sampler	: R.P / D.L	Issue Date	: 24-APR-2009
Site	: Wheatstone		
		No. of samples received	: 12
Quote number	: EN-001-08	No. of samples analysed	: 12

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Perth Inorganics
Scott James	Assistant Laboratory Manager	Perth Inorganics

Environmental Division Perth
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A Campbell Brothers Limited Company

Page	:	2 of 5
Work Order	:	EP0902086
Client	:	URS AUSTRALIA PTY LTD
Project	:	42907100

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Ionic Balance out of acceptable limits for various samples due to analytes not quantified in this report.**
- **TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.**

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Page : 3 of 5
Work Order : EP0902086
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

				E002G-D	E00G-S	E002F	E005G-D	E005G-I
			Client sample ID	**MB2A-airlift**	**MB2B-airlift**	**MB2C-airlift**	**MB5A**	**MB5B**
			Client sampling date / time	08-APR-2009 12:30	08-APR-2009 12:30	08-APR-2009 12:30	14-APR-2009 12:30	14-APR-2009 12:30
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902086-001**	**EP0902086-002**	**EP0902086-003**	**EP0902086-004**	**EP0902086-005**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.10	7.78	7.51	7.29	7.51
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	177000	62200	112000	154000	91900
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	188000	52600	102000	169000	82800
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	174	316	132	170	161
Total Alkalinity as CaCO3	----	1	mg/L	174	316	132	170	161
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	11200	5720	10800	7310	8520
^ Sulfur as S	----	1	mg/L	3750	1910	3590	2440	2840
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	118000	20600	40600	67800	35400
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	3000	1160	2220	4740	2530
Magnesium	7439-95-4	1	mg/L	6440	1290	3280	4660	2980
Sodium	7440-23-5	1	mg/L	52900	13300	26100	40500	19700
Potassium	7440-09-7	1	mg/L	2110	497	1200	1460	640
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	3560	708	1370	2070	1180
^ Total Cations	----	0.01	meq/L	3030	754	1540	2420	1240
^ Ionic Balance	----	0.01	%	8.03	3.15	5.94	7.82	2.67

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Page : 4 of 5
Work Order : EP0902086
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E005G-S	E005F	E015F	E017F	E016G-D
			Client sample ID	MB5C	MB5D	MB15A	MB17A	MB16A
			Client sampling date / time	14-APR-2009 12:30	14-APR-2009 12:30	14-APR-2009 12:30	13-APR-2009 12:30	13-APR-2009 12:30
				EP0902086-006	EP0902086-007	EP0902086-008	EP0902086-009	EP0902086-010
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.54	7.72	7.49	7.49	7.23
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	13200	71000	99700	104000	146000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	8500	58200	104000	102000	152000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	51	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	493	169	154	149	291
Total Alkalinity as CaCO3	----	1	mg/L	544	169	154	149	291
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	604	5310	8430	10200	9580
^ Sulfur as S	----	1	mg/L	201	1770	2810	3380	3190
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	4280	26700	49500	49800	86400
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<10	1390	3890	2520	3280
Magnesium	7439-95-4	1	mg/L	55	1790	3790	3230	4720
Sodium	7440-23-5	1	mg/L	3140	14700	22000	22900	39000
Potassium	7440-09-7	1	mg/L	<10	419	807	1070	1570
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	144	867	1580	1620	2640
^ Total Cations	----	0.01	meq/L	141	865	1480	1420	2290
^ Ionic Balance	----	0.01	%	1.06	0.14	2.97	6.70	7.17

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Page : 5 of 5
Work Order : EP0902086
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

E016G-S | E016F

Compound	CAS Number	LOR	Unit	MB16B	MB16C	----	----	----
			Client sample ID	**MB16B**	**MB16C**	----	----	----
			Client sampling date / time	13-APR-2009 12:30	13-APR-2009 12:30	----	----	----
				EP0902086-011	**EP0902086-012**	**----**	**----**	**----**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.85**	**7.47**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**43400**	**91500**	----	----	----
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	**36800**	**76600**	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**129**	**113**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**129**	**113**	----	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**2210**	**7310**	----	----	----
^ Sulfur as S	----	1	mg/L	**737**	**2440**	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**16900**	**42200**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**924**	**2710**	----	----	----
Magnesium	7439-95-4	1	mg/L	**1130**	**3110**	----	----	----
Sodium	7440-23-5	1	mg/L	**7950**	**19400**	----	----	----
Potassium	7440-09-7	1	mg/L	**328**	**871**	----	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**526**	**1340**	----	----	----
^ Total Cations	----	0.01	meq/L	**493**	**1260**	----	----	----
^ Ionic Balance	----	0.01	%	**3.23**	**3.26**	----	----	----

A Campbell Brothers Limited Company

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0902548**	Page	: 1 of 6
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: DANIEL LACEY	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	: daniel_lacey@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0100	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
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 13-MAY-2009
Sampler	: ----	Issue Date	: 22-MAY-2009
Site	: ----		
		No. of samples received	: 20
Quote number	: EN-001-08	No. of samples analysed	: 20

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Daniel Fisher	Inorganics Analyst	Perth Inorganics
Scott James	Assistant Laboratory Manager	Perth Inorganics

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A Campbell Brothers Limited Company

Page	:	2 of 6
Work Order	:	EP0902548
Client	:	URS AUSTRALIA PTY LTD
Project	:	42907100

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Ionic Balance out of acceptable limits for certain samples due to analytes not quantified in this report.**

A Campbell Brothers Limited Company

Page	:	3 of 6
Work Order	:	EP0902548
Client	:	URS AUSTRALIA PTY LTD
Project	:	42907100

Analytical Results

Sub-Matrix: **WATER**

				E007G-D	E013F	E018F	E012F	E007G-I
			Client sample ID	**MB07a**	**MB13a**	**MB18d**	**MB12a**	**MB07b**
			Client sampling date / time	21-APR-2009 15:00	28-APR-2009 15:00	28-APR-2009 15:00	25-APR-2009 15:00	21-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902548-001**	**EP0902548-002**	**EP0902548-003**	**EP0902548-004**	**EP0902548-005**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.98**	**7.64**	**7.63**	**7.46**	**7.38**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**173000**	**90400**	**112000**	**108000**	**129000**
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	**187000**	**77100**	**75700**	**97000**	**125000**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**165**	**165**	**233**	**133**	**126**
Total Alkalinity as CaCO3	----	1	mg/L	**165**	**165**	**233**	**133**	**126**
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**7760**	**3880**	**5510**	**5360**	**6980**
^ Sulfur as S	----	1	mg/L	**2580**	**1290**	**1840**	**1780**	**2330**
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**104000**	**39900**	**39000**	**50200**	**76700**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**992**	**566**	**771**	**748**	**1020**
Magnesium	7439-95-4	1	mg/L	**5300**	**2150**	**2420**	**2800**	**3640**
Sodium	7440-23-5	1	mg/L	**67200**	**24700**	**21200**	**30400**	**45500**
Potassium	7440-09-7	1	mg/L	**1750**	**790**	**665**	**965**	**1160**
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**3090**	**1210**	**1220**	**1530**	**2310**
^ Total Cations	----	0.01	meq/L	**3450**	**1300**	**1180**	**1610**	**2360**
^ Ionic Balance	----	0.01	%	**5.47**	**3.52**	**1.79**	**2.56**	**1.02**

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Page : 4 of 6
Work Order : EP0902548
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

				E008F	E018G-I	E018G-D	E011F	E006F
			Client sample ID	**MB08x**	**MB18b**	**MB18a**	**MB11a**	**MB6**
			Client sampling date / time	25-APR-2009 15:00	23-APR-2009 15:00	23-APR-2009 15:00	28-APR-2009 15:00	16-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0902548-006**	**EP0902548-007**	**EP0902548-008**	**EP0902548-009**	**EP0902548-010**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.47**	**7.45**	**7.31**	**7.76**	**7.36**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**121000**	**121000**	**151000**	**75700**	**126000**
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	**116000**	**112000**	**150000**	**59400**	**116000**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**100**	**162**	**166**	**141**	**96**
Total Alkalinity as CaCO3	----	1	mg/L	**100**	**162**	**166**	**141**	**96**
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**6510**	**6270**	**7290**	**3430**	**6730**
^ Sulfur as S	----	1	mg/L	**2170**	**2090**	**2430**	**1140**	**2240**
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**62800**	**69300**	**82900**	**36200**	**66400**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**1050**	**906**	**975**	**565**	**928**
Magnesium	7439-95-4	1	mg/L	**3290**	**3200**	**4270**	**1940**	**3500**
Sodium	7440-23-5	1	mg/L	**39100**	**33800**	**44200**	**19000**	**34000**
Potassium	7440-09-7	1	mg/L	**1110**	**1100**	**1410**	**612**	**1080**
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**1910**	**2090**	**2490**	**1090**	**2010**
^ Total Cations	----	0.01	meq/L	**2050**	**1810**	**2360**	**1030**	**1840**
^ Ionic Balance	----	0.01	%	**3.59**	**7.25**	**2.82**	**3.02**	**4.46**

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Page : 5 of 6
Work Order : EP0902548
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	MB10a	MB3a	MB04a	MB21a	MB10b
			Client sampling date / time	23-APR-2009 15:00	21-APR-2009 15:00	21-APR-2009 15:00	28-APR-2009 15:00	22-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	EP0902548-011	EP0902548-012	EP0902548-013	EP0902548-014	EP0902548-015
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.36	7.68	7.73	7.85	7.54
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	125000	97800	99300	79800	90200
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	123000	84400	88000	66600	74400
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	164	188	158	192	162
Total Alkalinity as CaCO3	----	1	mg/L	164	188	158	192	162
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	7030	4060	4300	4670	4480
^ Sulfur as S	----	1	mg/L	2340	1350	1430	1560	1490
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	73000	57600	52900	32200	46400
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1090	892	899	755	901
Magnesium	7439-95-4	1	mg/L	3640	2280	2400	2180	1940
Sodium	7440-23-5	1	mg/L	40000	33400	29100	18000	21000
Potassium	7440-09-7	1	mg/L	1230	712	770	655	808
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2210	1710	1580	1010	1400
^ Total Cations	----	0.01	meq/L	2120	1700	1530	1020	1140
^ Ionic Balance	----	0.01	%	1.99	0.32	1.82	0.42	10.4

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Page : 6 of 6
Work Order : EP0902548
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	E018G-S MB18c	E009F MB09a	E010F MB10c	E007F MB07d	E007G-S MB07c
			Client sampling date / time	23-APR-2009 15:00	25-APR-2009 15:00	22-APR-2009 15:00	21-APR-2009 15:00	21-APR-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	EP0902548-016	EP0902548-017	EP0902548-018	EP0902548-019	EP0902548-020
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.64	7.57	7.50	7.48	7.60
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	72600	123000	122000	132000	82100
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	62400	114000	118000	121000	71200
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	229	105	187	122	356
Total Alkalinity as CaCO3	----	1	mg/L	229	105	187	122	356
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	5410	6180	5710	6780	3800
^ Sulfur as S	----	1	mg/L	1800	2060	1900	2260	1260
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	33500	70200	67800	69900	40100
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	755	940	888	970	638
Magnesium	7439-95-4	1	mg/L	2160	3280	3120	3760	1920
Sodium	7440-23-5	1	mg/L	18100	37400	32800	38200	19900
Potassium	7440-09-7	1	mg/L	433	1110	1080	1250	722
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1060	2110	2040	2120	1220
^ Total Cations	----	0.01	meq/L	1010	1970	1760	2050	1070
^ Ionic Balance	----	0.01	%	2.38	3.48	7.42	1.54	6.32

A Campbell Brothers Limited Company

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0903304**	Page	: 1 of 13
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: DANIEL LACEY	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	: daniel_lacey@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0100	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
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 18-JUN-2009
Sampler	: B.P B.S D.C C.O C.W	Issue Date	: 25-JUN-2009
Site	: Onslow		
		No. of samples received	: 51
Quote number	: EN-001-09 BQ	No. of samples analysed	: 51

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Perth Inorganics
Scott James	Assistant Laboratory Manager	Perth Inorganics

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A Campbell Brothers Limited Company

Page	:	2 of 13
Work Order	:	EP0903304
Client	:	URS AUSTRALIA PTY LTD
Project	:	42907100

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Ionic Balance out of acceptable limits for various samples due to analytes not quantified in this report.**
- **LOR for some samples raised due to the high conductivity.**

A Campbell Brothers Limited Company

Page : 3 of 13
Work Order : EP0903304
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E09-A	E08-A	E07-C	E018-B	E032-C
Client sampling date / time				06-JUN-2009 11:30	05-JUN-2009 15:30	14-JUN-2009 13:45	14-JUN-2009 11:30	02-JUN-2009 16:00
				EP0903304-001	EP0903304-002	EP0903304-003	EP0903304-004	EP0903304-005
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.18	7.29	7.68	8.00	7.94
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	108000	110000	61300	32300	48300
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	101000	113000	49000	26400	39200
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	257	210	286	219	282
Total Alkalinity as CaCO3	----	1	mg/L	257	210	286	219	282
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	7450	1080	4470	1840	5460
^ Sulfur as S	----	1	mg/L	2480	359	1490	614	1820
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	49300	7470	25100	9930	15900
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1140	168	582	286	766
Magnesium	7439-95-4	1	mg/L	3480	499	1470	849	1750
Sodium	7440-23-5	1	mg/L	26200	3880	12300	6620	10800
Potassium	7440-09-7	1	mg/L	1170	197	651	346	612
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1550	237	806	323	567
^ Total Cations	----	0.01	meq/L	1510	223	702	381	669
^ Ionic Balance	----	0.01	%	1.19	3.03	6.92	8.28	8.25

A Campbell Brothers Limited Company

Page : 4 of 13
Work Order : EP0903304
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	E024-B	E013-C	E03-A	E032-B	E07-D
			Client sampling date / time	03-JUN-2009 15:20	14-JUN-2009 12:00	09-JUN-2009 13:30	02-JUN-2009 15:00	07-JUN-2009 11:45
Compound	*CAS Number*	*LOR*	*Unit*	EP0903304-006	EP0903304-007	EP0903304-008	EP0903304-009	EP0903304-010
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.99	7.93	7.58	7.73	7.46
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	52800	47400	69200	70300	101000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	43000	36000	54700	63600	96400
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	239	222	291	323	257
Total Alkalinity as CaCO3	----	1	mg/L	239	222	291	323	257
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	2920	3140	4060	6500	4570
^ Sulfur as S	----	1	mg/L	973	1050	1350	----	1520
Sulfur as S	----	1	mg/L	----	----	----	2170	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	14100	17100	25100	25200	35000
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	468	427	815	912	723
Magnesium	7439-95-4	1	mg/L	1100	1440	1900	2370	1930
Sodium	7440-23-5	1	mg/L	9800	10000	15900	15800	15900
Potassium	7440-09-7	1	mg/L	440	482	617	881	736
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	463	553	799	854	1090
^ Total Cations	----	0.01	meq/L	552	589	904	950	904
^ Ionic Balance	----	0.01	%	8.71	3.12	6.15	5.30	9.32

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Page : 5 of 13
Work Order : EP0903304
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E027-C	E013-A	E019-A	SURFACE WATER	E024-A
			Client sampling date / time	03-JUN-2009 11:30	04-JUN-2009 15:00	14-JUN-2009 11:00	14-JUN-2009 17:00	03-JUN-2009 14:55
				EP0903304-011	EP0903304-012	EP0903304-013	EP0903304-014	EP0903304-015
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.34	8.19	7.09	7.71	7.86
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	175000	23700	157000	25100	66100
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	198000	16700	168000	16700	55600
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	150	288	228	46	222
Total Alkalinity as CaCO3	----	1	mg/L	150	288	228	46	222
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	3940	1440	10200	2720	4300
^ Sulfur as S	----	1	mg/L	1310	480	3400	908	1430
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	38700	8270	75600	9160	27800
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	508	257	1310	905	612
Magnesium	7439-95-4	1	mg/L	2390	703	5720	518	1900
Sodium	7440-23-5	1	mg/L	19400	5570	42800	4500	13600
Potassium	7440-09-7	1	mg/L	866	278	1880	227	676
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1180	269	2350	316	878
^ Total Cations	----	0.01	meq/L	1090	320	2450	289	797
^ Ionic Balance	----	0.01	%	3.88	8.63	2.03	4.40	4.86

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Page : 6 of 13
Work Order : EP0903304
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E025-A	E027-B	SURFACE WATER	E033 - B	E019-A
			Client sampling date / time	10-JUN-2009 15:30	03-JUN-2009 12:15	13-JUN-2009 09:00	10-JUN-2009 14:30	08-JUN-2009 12:00
				EP0903304-016	EP0903304-017	EP0903304-018	EP0903304-019	EP0903304-020
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.97	7.42	7.50	7.66	7.37
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	65000	130000	232000	88500	154000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	56700	130000	362000	82200	169000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	240	103	136	212	217
Total Alkalinity as CaCO3	----	1	mg/L	240	103	136	212	217
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	3600	8840	2490	7730	10200
^ Sulfur as S	----	1	mg/L	1200	2950	830	2580	3400
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	28500	66100	47100	39700	82400
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	653	1160	155	1040	1260
Magnesium	7439-95-4	1	mg/L	1840	4250	2130	3050	5430
Sodium	7440-23-5	1	mg/L	12400	30800	22300	21700	41500
Potassium	7440-09-7	1	mg/L	601	1370	843	1050	1790
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	884	2050	1380	1280	2540
^ Total Cations	----	0.01	meq/L	737	1780	1170	1270	2360
^ Ionic Balance	----	0.01	%	9.09	7.06	8.18	0.44	3.63

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Work Order : EP0903304
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E012-A	E032-A	E016-A	E019-B	E017A
			Client sampling date / time	04-JUN-2009 11:26	02-JUN-2009 15:30	09-JUN-2009 16:00	08-JUN-2009 13:30	09-JUN-2009 12:00
				EP0903304-021	EP0903304-022	EP0903304-023	EP0903304-024	EP0903304-025
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.24	7.35	6.67	7.87	7.34
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	77400	120000	156000	34400	96600
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	70300	124000	182000	27200	93400
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	259	159	389	214	171
Total Alkalinity as CaCO3	----	1	mg/L	259	159	389	214	171
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	5620	8130	6190	1910	5880
^ Sulfur as S	----	1	mg/L	1870	2710	2060	637	1960
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	36600	60300	86700	12900	46500
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	832	1150	1850	295	1340
Magnesium	7439-95-4	1	mg/L	2260	3840	5030	884	2970
Sodium	7440-23-5	1	mg/L	17700	28700	42100	6900	22100
Potassium	7440-09-7	1	mg/L	904	1330	1500	349	1020
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1150	1870	2580	408	1440
^ Total Cations	----	0.01	meq/L	1020	1660	2380	396	1300
^ Ionic Balance	----	0.01	%	6.24	6.13	4.19	1.40	5.16

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Work Order	: EP0903304
Client	: URS AUSTRALIA PTY LTD
Project	: 42907100

Analytical Results

Sub-Matrix: WATER			Client sample ID	E027-A	E033-C	E07-B	E06-A	E015-A
			Client sampling date / time	03-JUN-2009 13:00	10-JUN-2009 00:00	07-JUN-2009 10:30	07-JUN-2009 13:30	09-JUN-2009 10:10
Compound	*CAS Number*	*LOR*	*Unit*	EP0903304-026	EP0903304-027	EP0903304-028	EP0903304-029	EP0903304-030
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.33	8.13	7.11	7.41	7.35
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	147000	12800	127000	80500	76800
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	164000	8660	134000	72100	76800
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	154	473	171	177	236
Total Alkalinity as CaCO3	----	1	mg/L	154	473	171	177	236
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	9630	1680	9300	5650	3950
^ Sulfur as S	----	1	mg/L	3210	561	3100	1880	1320
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	79200	4660	64300	39600	37900
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1330	162	1300	1010	1410
Magnesium	7439-95-4	1	mg/L	4950	519	4280	2120	2430
Sodium	7440-23-5	1	mg/L	39100	2260	31400	18200	15700
Potassium	7440-09-7	1	mg/L	1720	80	1360	1010	572
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2440	176	2010	1240	1160
^ Total Cations	----	0.01	meq/L	2220	151	1820	1040	967
^ Ionic Balance	----	0.01	%	4.67	7.57	5.07	8.60	8.88

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Analytical Results

Sub-Matrix: WATER			Client sample ID	E023-A	E019-C	E011-A	E021-A	E033-B
			Client sampling date / time	05-JUN-2009 12:20	10-JUN-2009 12:15	04-JUN-2009 16:15	08-JUN-2009 15:00	06-JUN-2009 14:00
Compound	*CAS Number*	*LOR*	*Unit*	EP0903304-031	EP0903304-032	EP0903304-033	EP0903304-034	EP0903304-035
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.25	7.62	7.89	7.70	7.47
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	139000	82600	40500	84000	85600
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	160000	79600	30700	84200	80500
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	268	153	219	232	236
Total Alkalinity as CaCO3	----	1	mg/L	268	153	219	232	236
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	8700	6290	2210	6680	7270
^ Sulfur as S	----	1	mg/L	2900	2100	737	2220	2420
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	74000	41100	14100	40300	41600
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1280	779	356	1040	1030
Magnesium	7439-95-4	1	mg/L	4480	2700	1040	2830	2830
Sodium	7440-23-5	1	mg/L	36600	18100	7580	18900	18700
Potassium	7440-09-7	1	mg/L	1550	862	374	923	968
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2270	1290	449	1280	1330
^ Total Cations	----	0.01	meq/L	2060	1070	443	1130	1120
^ Ionic Balance	----	0.01	%	4.90	9.45	0.71	6.27	8.54

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Work Order	: EP0903304
Client	: URS AUSTRALIA PTY LTD
Project	: 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E033-A	E07-A	E06-A	E017-A	E012-A
Client sampling date / time				06-JUN-2009 13:30	06-JUN-2009 16:00	07-JUN-2009 13:30	03-JUN-2009 12:00	04-JUN-2009 11:26
				EP0903304-036	EP0903304-037	EP0903304-038	EP0903304-039	EP0903304-040
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.27	7.00	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	149000	165000	----	----	----
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	174000	200000	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	180	233	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	180	233	----	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	11300	10000	----	----	----
^ Sulfur as S	----	1	mg/L	3770	3350	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	65600	98200	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1620	1330	----	----	----
Magnesium	7439-95-4	1	mg/L	5740	6120	----	----	----
Sodium	7440-23-5	1	mg/L	49400	49100	----	----	----
Potassium	7440-09-7	1	mg/L	2320	2020	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	----	----	<0.010	<0.021	<0.001
Cadmium	7440-43-9	0.0001	mg/L	----	----	0.0013	<0.0021	0.0001
Chromium	7440-47-3	0.001	mg/L	----	----	0.057	0.100	<0.001
Copper	7440-50-8	0.001	mg/L	----	----	0.031	0.040	0.039
Lead	7439-92-1	0.001	mg/L	----	----	<0.010	<0.021	<0.001
Nickel	7440-02-0	0.001	mg/L	----	----	0.024	0.050	0.005
Zinc	7440-66-6	0.005	mg/L	----	----	0.028	0.036	<0.005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	----	----	<0.0001	<0.0001	<0.0001
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2090	2980	----	----	----
^ Total Cations	----	0.01	meq/L	2760	2760	----	----	----
^ Ionic Balance	----	0.01	%	13.8	3.91	----	----	----

A Campbell Brothers Limited Company

Work Order : EP0903304
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E013-A	E07-A	E07-D	E015-A	E08-A
			Client sampling date / time	04-JUN-2009 15:00	06-JUN-2009 16:00	07-JUN-2009 11:45	09-JUN-2009 10:10	05-JUN-2009 15:50
				EP0903304-041	**EP0903304-042**	**EP0903304-043**	**EP0903304-044**	**EP0903304-045**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.052	<0.021	<0.010	<0.021
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	**0.0059**	<0.0021	<0.0010	<0.0021
Chromium	7440-47-3	0.001	mg/L	<0.001	**0.055**	**0.057**	**0.032**	**0.059**
Copper	7440-50-8	0.001	mg/L	**0.009**	**0.237**	**0.098**	**0.039**	**0.033**
Lead	7439-92-1	0.001	mg/L	<0.001	<0.052	<0.021	<0.010	<0.021
Nickel	7440-02-0	0.001	mg/L	**0.003**	**0.063**	**0.037**	**0.031**	**0.036**
Zinc	7440-66-6	0.005	mg/L	<0.005	**0.077**	**0.040**	**0.022**	**0.035**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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Page : 12 of 13
Work Order : EP0903304
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	**E07-B**	**E016-A**	**E019-B**	**E019-A**	**E07-C**
			Client sampling date / time	07-JUN-2009 10:30	09-JUN-2009 16:00	14-JUN-2009 11:30	14-JUN-2009 11:00	14-JUN-2009 13:45
Compound	*CAS Number*	*LOR*	*Unit*	**EP0903304-046**	**EP0903304-047**	**EP0903304-048**	**EP0903304-049**	**EP0903304-050**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.052	<0.052	<0.001	<0.021	<0.021
Cadmium	7440-43-9	0.0001	mg/L	<0.0052	<0.0052	<0.0001	<0.0021	**0.0022**
Chromium	7440-47-3	0.001	mg/L	**0.116**	**0.170**	**0.001**	**0.055**	**0.074**
Copper	7440-50-8	0.001	mg/L	**0.181**	**0.420**	**0.012**	**0.069**	**0.033**
Lead	7439-92-1	0.001	mg/L	<0.052	<0.052	<0.001	<0.021	<0.021
Nickel	7440-02-0	0.001	mg/L	**0.096**	**0.175**	**0.003**	**0.035**	**0.030**
Zinc	7440-66-6	0.005	mg/L	**0.064**	**0.102**	<0.005	**0.024**	**0.031**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

A Campbell Brothers Limited Company

Work Order : EP0903304
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E019-C	----	----	----	----
			Client sampling date / time	14-JUN-2009 12:00	----	----	----	----
				EP0903304-051	----	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.005	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0005	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	**0.075**	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.016**	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.005	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.033**	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.010**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0903591**	Page	: 1 of 5
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: DANIEL LACEY	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	: daniel_lacey@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0100	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
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 02-JUL-2009
Sampler	: ----	Issue Date	: 09-JUL-2009
Site	: ----		
		No. of samples received	: 12
Quote number	: EN-001-09 BQ	No. of samples analysed	: 12

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Perth Inorganics
Scott James	Assistant Laboratory Manager	Perth Inorganics
Stacey Hawkins	Senior Chemist - Acid Sulphate Soils	Perth Inorganics

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A Campbell Brothers Limited Company

Page	:	2 of 5
Work Order	:	EP0903591
Client	:	URS AUSTRALIA PTY LTD
Project	:	42907100

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Ionic Balance out of acceptable limits for various samples due to analytes not quantified in this report.**
- **Metals LOR for samples 10 and 11 raised due to the high conductivity and suppression of internal standard.**
- **TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.**

A Campbell Brothers Limited Company

Page : 3 of 5
Work Order : EP0903591
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	EO26G-D	EO14-F	EO18-G-I	Tidal	EO16-F
Client sampling date / time				22-JUN-2009 11:50	22-JUN-2009 10:48	18-JUN-2009 14:30	21-JUN-2009 09:30	17-JUN-2009 11:55
				EP0903591-001	EP0903591-002	EP0903591-003	EP0903591-004	EP0903591-005
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.87	7.35	6.82	7.86	7.20
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	151000	93200	119000	57200	60600
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	----	84700	119000	48700	56100
Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	100000	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	194	233	220	134	162
Total Alkalinity as CaCO3	----	1	mg/L	194	233	220	134	162
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	17000	10800	14400	6000	3740
^ Sulfur as S	----	1	mg/L	5670	3610	4790	2000	1250
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	71000	37200	53200	20100	22500
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1840	1250	1530	765	1150
Magnesium	7439-95-4	1	mg/L	6560	3720	4670	1990	2170
Sodium	7440-23-5	1	mg/L	50100	27200	34300	15000	14700
Potassium	7440-09-7	1	mg/L	2250	1460	1540	802	680
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2360	1280	1800	694	717
^ Total Cations	----	0.01	meq/L	2870	1590	1990	876	893
^ Ionic Balance	----	0.01	%	9.70	10.8	4.98	11.6	10.9

A Campbell Brothers Limited Company

Page : 4 of 5
Work Order : EP0903591
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: WATER

Compound	CAS Number	LOR	Unit	EO18-F	EO18-G-D	EO25FG-I	EO18G-S	EO14G-I
			Client sampling date / time	18-JUN-2009 16:35	18-JUN-2009 13:00	16-JUN-2009 12:35	19-JUN-2009 10:35	16-JUN-2009 13:35
				EP0903591-006	EP0903591-007	EP0903591-008	EP0903591-009	EP0903591-010
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.12	6.79	8.25	7.20	7.43
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	74200	156000	5890	58700	92400
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	65400	156000	3560	51900	85800
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	310	185	465	369	237
Total Alkalinity as CaCO3	----	1	mg/L	310	185	465	369	237
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	12600	16900	246	11200	10500
^ Sulfur as S	----	1	mg/L	4210	5620	82	3720	3500
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	27800	77800	1560	21100	40700
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1290	1720	32	1090	1210
Magnesium	7439-95-4	1	mg/L	3180	6810	115	2600	3600
Sodium	7440-23-5	1	mg/L	18900	53800	997	14900	25900
Potassium	7440-09-7	1	mg/L	728	2870	46	498	1430
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	----	----	0.045	----	<0.021
Cadmium	7440-43-9	0.0001	mg/L	----	----	0.0002	----	<0.0021
Chromium	7440-47-3	0.001	mg/L	----	----	0.084	----	0.062
Copper	7440-50-8	0.001	mg/L	----	----	0.253	----	<0.021
Lead	7439-92-1	0.001	mg/L	----	----	0.057	----	<0.021
Nickel	7440-02-0	0.001	mg/L	----	----	0.061	----	0.028
Zinc	7440-66-6	0.005	mg/L	----	----	0.105	----	0.564
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	----	----	<0.0001	----	<0.0001
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1050	2550	58.3	835	1370
^ Total Cations	----	0.01	meq/L	1170	3060	55.6	929	1520
^ Ionic Balance	----	0.01	%	5.20	9.04	2.34	5.30	5.12

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Page : 5 of 5
Work Order : EP0903591
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	EO14G-S	EO23FG-S	----	----	----
			Client sampling date / time	16-JUN-2009 15:00	22-JUN-2009 13:40	----	----	----
				EP0903591-011	EP0903591-012	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.78	8.09	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	59900	30500	----	----	----
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	50400	24400	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	232	267	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	232	267	----	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	5890	2550	----	----	----
^ Sulfur as S	----	1	mg/L	1960	850	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	22300	9600	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	780	479	----	----	----
Magnesium	7439-95-4	1	mg/L	1960	1120	----	----	----
Sodium	7440-23-5	1	mg/L	15900	7030	----	----	----
Potassium	7440-09-7	1	mg/L	820	362	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0010	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	0.082	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.010	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.012	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.038	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.011	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	757	329	----	----	----
^ Total Cations	----	0.01	meq/L	913	431	----	----	----
^ Ionic Balance	----	0.01	%	9.34	13.4	----	----	----

A Campbell Brothers Limited Company

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0904261**	Page	: 1 of 15
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: DANIEL LACEY	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	: daniel_lacey@urscorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0100	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
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 31-JUL-2009
Sampler	: Water Group(R.P,B.S)	Issue Date	: 11-AUG-2009
Site	: Ashburton North		
		No. of samples received	: 65
Quote number	: EN-001-09 BQ	No. of samples analysed	: 65

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Perth Inorganics
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A Campbell Brothers Limited Company

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Work Order	:	EP0904261
Client	:	URS AUSTRALIA PTY LTD
Project	:	42907100

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Ionic Balance out of acceptable limits due to analytes not quantified in this report.**
- **Poor metal matrix spike recoveries due to matrix effects.**
- **TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.**

A Campbell Brothers Limited Company

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E029G-S	E010-F	E030G-S	E029G-I	E033FG-S
Client sampling date / time				25-JUL-2009 13:00	26-JUL-2009 11:30	25-JUL-2009 15:00	25-JUL-2009 14:00	26-JUL-2009 15:00
				EP0904261-001	**EP0904261-002**	**EP0904261-003**	**EP0904261-004**	**EP0904261-005**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Cadmium	7440-43-9	0.0001	mg/L	<0.0052	<0.0052	<0.0052	<0.0052	<0.0052
Chromium	7440-47-3	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Copper	7440-50-8	0.001	mg/L	**0.060**	<0.052	<0.052	**0.086**	<0.052
Lead	7439-92-1	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Nickel	7440-02-0	0.001	mg/L	**0.329**	**0.084**	<0.052	<0.052	<0.052
Zinc	7440-66-6	0.005	mg/L	**0.109**	<0.052	<0.052	**0.062**	<0.052
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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Work Order : EP0904261
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	E031G-D	E019G-F	E029G-D	E033FG-D	E010-I
			Client sampling date / time	25-JUL-2009 15:00	26-JUL-2009 15:00	25-JUL-2009 15:00	26-JUL-2009 15:00	26-JUL-2009 10:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904261-006**	**EP0904261-007**	**EP0904261-008**	**EP0904261-009**	**EP0904261-010**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Cadmium	7440-43-9	0.0001	mg/L	<0.0052	<0.0052	<0.0052	<0.0052	<0.0052
Chromium	7440-47-3	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Copper	7440-50-8	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Lead	7439-92-1	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Nickel	7440-02-0	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Zinc	7440-66-6	0.005	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

A Campbell Brothers Limited Company

Work Order : EP0904261
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	E010-S	E019G-S	E019G-D	E033FG-I	E002G-D
			Client sampling date / time	26-JUL-2009 11:00	26-JUL-2009 15:00	26-JUL-2009 15:00	26-JUL-2009 15:00	20-JUL-2009 10:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904261-011**	**EP0904261-012**	**EP0904261-013**	**EP0904261-014**	**EP0904261-015**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Cadmium	7440-43-9	0.0001	mg/L	<0.0052	<0.0052	<0.0052	<0.0052	<0.0052
Chromium	7440-47-3	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Copper	7440-50-8	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Lead	7439-92-1	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Nickel	7440-02-0	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Zinc	7440-66-6	0.005	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

A Campbell Brothers Limited Company

Page : 6 of 15
Work Order : EP0904261
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**E030G-D**	**E005-F**	**E002-F**	**E005G-I**	**E016G-S**
			Client sampling date / time	21-JUL-2009 15:00	10-JUL-2009 15:00	20-JUL-2009 12:00	10-JUL-2009 11:55	20-JUL-2009 16:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904261-016**	**EP0904261-017**	**EP0904261-018**	**EP0904261-019**	**EP0904261-020**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Cadmium	7440-43-9	0.0001	mg/L	<0.0052	<0.0052	<0.0052	<0.0052	<0.0052
Chromium	7440-47-3	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Copper	7440-50-8	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Lead	7439-92-1	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Nickel	7440-02-0	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	<0.052
Zinc	7440-66-6	0.005	mg/L	<0.052	<0.052	<0.052	<0.052	**0.318**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

A Campbell Brothers Limited Company

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Work Order : EP0904261
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E002G-D	E010-F	E004-F	E005G-D	E010-F
			Client sampling date / time	11-JUL-2009 14:00	21-JUL-2009 15:00	11-JUL-2009 11:10	10-JUL-2009 11:05	26-JUL-2009 11:30
				EP0904261-021	EP0904261-022	EP0904261-023	EP0904261-024	EP0904261-025
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	----	----	----	----	**6.75**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	----	----	----	----	**119000**
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	----	----	----	----	**114000**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	----	----	----	----	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	----	----	----	----	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	----	----	----	----	**178**
Total Alkalinity as CaCO3	----	1	mg/L	----	----	----	----	**178**
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	----	----	----	----	**7700**
^ Sulfur as S	----	1	mg/L	----	----	----	----	**2560**
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	----	----	----	----	**51900**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	----	----	----	----	**1170**
Magnesium	7439-95-4	1	mg/L	----	----	----	----	**3100**
Sodium	7440-23-5	1	mg/L	----	----	----	----	**27100**
Potassium	7440-09-7	1	mg/L	----	----	----	----	**1050**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0052	<0.0052	<0.0052	<0.0052	----
Chromium	7440-47-3	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	----
Copper	7440-50-8	0.001	mg/L	<0.052	<0.052	<0.052	**0.061**	----
Lead	7439-92-1	0.001	mg/L	<0.052	<0.052	<0.052	<0.052	----
Nickel	7440-02-0	0.001	mg/L	**0.191**	**0.163**	**0.240**	**0.417**	----
Zinc	7440-66-6	0.005	mg/L	**0.521**	<0.052	**0.058**	**0.405**	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	----	----	----	----	**1630**
^ Total Cations	----	0.01	meq/L	----	----	----	----	**1520**
^ Ionic Balance	----	0.01	%	----	----	----	----	**3.48**

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Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	E019G-S	E031G-D	E030G-I	E026G-S	E026G-D
			Client sampling date / time	26-JUL-2009 15:00	24-JUL-2009 15:00	21-JUL-2009 15:00	24-JUL-2009 15:00	24-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	EP0904261-026	EP0904261-027	EP0904261-028	EP0904261-029	EP0904261-030
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.68	7.27	7.14	7.69	6.76
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	33500	146000	87600	41800	152000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	27400	156000	75400	30600	165000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	172	234	197	222	161
Total Alkalinity as CaCO3	----	1	mg/L	172	234	197	222	161
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	1890	4710	4240	2420	7860
^ Sulfur as S	----	1	mg/L	630	1570	1410	805	2620
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	10900	68700	36000	13600	73600
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	265	1660	940	372	1200
Magnesium	7439-95-4	1	mg/L	785	4150	1880	1010	4400
Sodium	7440-23-5	1	mg/L	7600	35300	20900	9490	37100
Potassium	7440-09-7	1	mg/L	274	1040	778	351	1450
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	350	2040	1110	439	2240
^ Total Cations	----	0.01	meq/L	415	1990	1130	524	2070
^ Ionic Balance	----	0.01	%	8.51	1.33	1.02	8.75	3.97

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E029G-I	E010-F	E033FG-D	E010G-S	E029G
Client sampling date / time				25-JUL-2009 14:00	21-JUL-2009 15:00	26-JUL-2009 15:00	21-JUL-2009 15:00	18-JUL-2009 15:00
				EP0904261-031	EP0904261-032	EP0904261-033	EP0904261-034	EP0904261-035
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.80	6.89	6.72	7.17	7.30
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	128000	116000	150000	77100	112000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	135000	119000	176000	72000	118000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	147	187	145	184	90
Total Alkalinity as CaCO3	----	1	mg/L	147	187	145	184	90
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	6070	7070	11800	4760	5160
^ Sulfur as S	----	1	mg/L	2020	2360	3930	1580	1720
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	60100	52200	72800	32900	52700
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1420	1210	1540	1030	1370
Magnesium	7439-95-4	1	mg/L	3670	3180	5880	1740	3230
Sodium	7440-23-5	1	mg/L	27800	26700	49000	16600	23200
Potassium	7440-09-7	1	mg/L	1040	1080	2140	628	837
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1820	1620	2300	1030	1600
^ Total Cations	----	0.01	meq/L	1610	1510	2750	935	1360
^ Ionic Balance	----	0.01	%	6.30	3.56	8.80	4.90	7.92

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Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E030-D	E029a	E033FG-I	E029G-S	E031G-D
			Client sampling date / time	18-JUL-2009 11:00	18-JUL-2009 15:00	26-JUL-2009 15:00	25-JUL-2009 13:00	28-JUL-2009 15:00
				EP0904261-036	EP0904261-037	EP0904261-038	EP0904261-039	EP0904261-040
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.16	7.14	7.17	6.79	6.51
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	157000	139000	82400	93300	150000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	182000	156000	79400	99300	185000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	189	158	175	261	219
Total Alkalinity as CaCO3	----	1	mg/L	189	158	175	261	219
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	5800	11100	5500	4840	5330
^ Sulfur as S	----	1	mg/L	1930	3690	1840	1610	1780
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	83700	69500	35900	42000	79200
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1340	1630	898	1430	1850
Magnesium	7439-95-4	1	mg/L	4260	5170	2300	3280	5090
Sodium	7440-23-5	1	mg/L	43400	43400	17000	22600	39700
Potassium	7440-09-7	1	mg/L	1180	1950	570	777	1180
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2480	2190	1130	1290	2350
^ Total Cations	----	0.01	meq/L	2340	2450	989	1340	2270
^ Ionic Balance	----	0.01	%	3.11	5.41	6.66	2.08	1.82

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Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E029G-D	E031G-S	E002G-S	E010G-S	E005G-S
			Client sampling date / time	25-JUL-2009 15:00	24-JUL-2009 15:00	11-JUL-2009 12:20	21-JUL-2009 15:00	11-JUL-2009 15:00
				EP0904261-041	EP0904261-042	EP0904261-043	EP0904261-044	EP0904261-045
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.81	7.30	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	136000	126000	----	----	----
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	160000	129000	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	169	132	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	169	132	----	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	9550	7410	----	----	----
^ Sulfur as S	----	1	mg/L	3180	2470	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	67600	55600	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1400	1080	----	----	----
Magnesium	7439-95-4	1	mg/L	4920	3960	----	----	----
Sodium	7440-23-5	1	mg/L	39300	31300	----	----	----
Potassium	7440-09-7	1	mg/L	1540	1240	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	----	----	<0.052	<0.052	<0.052
Cadmium	7440-43-9	0.0001	mg/L	----	----	<0.0052	<0.0052	<0.0052
Chromium	7440-47-3	0.001	mg/L	----	----	<0.052	<0.052	<0.052
Copper	7440-50-8	0.001	mg/L	----	----	<0.052	<0.052	<0.052
Lead	7439-92-1	0.001	mg/L	----	----	<0.052	<0.052	<0.052
Nickel	7440-02-0	0.001	mg/L	----	----	0.193	0.207	0.071
Zinc	7440-66-6	0.005	mg/L	----	----	0.117	<0.052	<0.052
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	----	----	<0.0001	<0.0001	<0.0001
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2110	1730	----	----	----
^ Total Cations	----	0.01	meq/L	2220	1770	----	----	----
^ Ionic Balance	----	0.01	%	2.58	1.29	----	----	----

Page : 12 of 15
Work Order : EP0904261
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E002G-S	E030G-I	E029C	E030G-I	E004F
			Client sampling date / time	20-JUL-2009 15:00	21-JUL-2009 15:00	18-JUL-2009 15:00	10-JUL-2009 11:30	11-JUL-2009 11:10
				EP0904261-046	EP0904261-047	EP0904261-048	EP0904261-049	EP0904261-050
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	----	----	7.22	7.59	7.56
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	----	----	126000	96500	59700
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	----	----	140000	90200	49800
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	----	----	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	----	----	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	----	----	131	123	269
Total Alkalinity as CaCO3	----	1	mg/L	----	----	131	123	269
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	----	----	6980	5360	2720
^ Sulfur as S	----	1	mg/L	----	----	2320	1790	906
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	----	----	56800	42000	24400
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	----	----	1580	1200	687
Magnesium	7439-95-4	1	mg/L	----	----	4110	2640	1370
Sodium	7440-23-5	1	mg/L	----	----	31000	26800	15700
Potassium	7440-09-7	1	mg/L	----	----	1210	982	438
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.052	<0.052	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0052	<0.0052	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.052	<0.052	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.052	<0.052	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.052	<0.052	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.118	0.125	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.052	<0.052	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	----	----	1750	1300	751
^ Total Cations	----	0.01	meq/L	----	----	1800	1460	840
^ Ionic Balance	----	0.01	%	----	----	1.33	5.97	5.58

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Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E010-S	E010-I	E005G-S	E019G-F	E026G-S
			Client sampling date / time	26-JUL-2009 11:00	26-JUL-2009 10:00	11-JUL-2009 10:00	26-JUL-2009 14:30	18-JUL-2009 12:20
				EP0904261-051	EP0904261-052	EP0904261-053	EP0904261-054	EP0904261-055
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.30	6.88	8.41	7.57	8.04
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	77500	121000	11400	62900	47500
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	71000	133000	6470	55800	39800
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	31	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	176	190	545	152	230
Total Alkalinity as CaCO3	----	1	mg/L	176	190	576	152	230
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	6160	8710	480	4620	2950
^ Sulfur as S	----	1	mg/L	2050	2900	160	1540	985
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	31800	54900	3450	26300	16900
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1280	1410	48	676	511
Magnesium	7439-95-4	1	mg/L	2100	3980	161	2060	1300
Sodium	7440-23-5	1	mg/L	20900	33400	2680	16800	11500
Potassium	7440-09-7	1	mg/L	877	1310	113	538	388
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1030	1730	119	842	542
^ Total Cations	----	0.01	meq/L	1170	1890	135	948	643
^ Ionic Balance	----	0.01	%	6.22	4.23	6.38	5.90	8.47

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Work Order : EP0904261
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	E030G-S	E00G-D	E002F	E002G-S	E019G-D
			Client sampling date / time	25-JUL-2009 15:00	20-JUL-2009 10:00	20-JUL-2009 12:00	20-JUL-2009 11:00	26-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	EP0904261-056	EP0904261-057	EP0904261-058	EP0904261-059	EP0904261-060
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.21	6.76	7.36	7.47	6.95
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	119000	178000	89700	63200	148000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	108000	228000	83600	56000	175000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	143	201	188	396	170
Total Alkalinity as CaCO3	----	1	mg/L	143	201	188	396	170
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	7900	8100	5740	4040	11200
^ Sulfur as S	----	1	mg/L	2640	2700	1910	1350	3740
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	50300	103000	38700	25800	71200
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1130	2030	1240	790	1610
Magnesium	7439-95-4	1	mg/L	3960	6350	2420	1400	5560
Sodium	7440-23-5	1	mg/L	33200	60300	23300	15200	46600
Potassium	7440-09-7	1	mg/L	1380	2100	920	500	2030
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1590	3080	1220	820	2240
^ Total Cations	----	0.01	meq/L	1860	3300	1300	827	2620
^ Ionic Balance	----	0.01	%	7.92	3.36	3.28	0.40	7.66

A Campbell Brothers Limited Company

Work Order : EP0904261
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E002G-S	E002G-D	E030G-D	E016G-S	E033FG-S
Client sampling date / time				11-JUL-2009 12:20	11-JUL-2009 14:00	21-JUL-2009 15:00	20-JUL-2009 16:00	26-JUL-2009 15:00
				EP0904261-061	EP0904261-062	EP0904261-063	EP0904261-064	EP0904261-065
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.50	6.82	6.85	7.75	7.96
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	63200	172000	158000	36500	22000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	49400	185000	204000	33500	17700
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	304	200	187	128	368
Total Alkalinity as CaCO3	----	1	mg/L	304	200	187	128	368
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	1350	6220	7530	934	2530
^ Sulfur as S	----	1	mg/L	450	2070	2510	311	844
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	26400	97000	81500	15000	6900
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	770	1800	1560	550	237
Magnesium	7439-95-4	1	mg/L	1350	6140	5150	1020	722
Sodium	7440-23-5	1	mg/L	14700	62900	56100	7230	3950
Potassium	7440-09-7	1	mg/L	500	1460	1570	297	115
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	778	2870	2460	444	255
^ Total Cations	----	0.01	meq/L	803	3370	2980	433	246
^ Ionic Balance	----	0.01	%	1.56	8.01	9.60	1.29	1.74

A Campbell Brothers Limited Company

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0904516**	Page	: 1 of 8
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: ANDREW MCTAGGART	Contact	: Michael Sharp
Address	: LEVEL 3, HYATT CENTRE 20 TERRACE RD EAST PERTH WA, AUSTRALIA 6004	Address	: 10 Hod Way Malaga WA Australia 6090
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Project	: 42907100	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: 213986 US		
C-O-C number	: ----	Date Samples Received	: 12-AUG-2009
Sampler	: ----	Issue Date	: 19-AUG-2009
Site	: ----		
		No. of samples received	: 27
Quote number	: EN-001-09 BQ	No. of samples analysed	: 27

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Perth Inorganics
Scott James	Assistant Laboratory Manager	Perth Inorganics

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A Campbell Brothers Limited Company

Work Order	: EP0904516
Client	: URS AUSTRALIA PTY LTD
Project	: 42907100

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

Page : 3 of 8
Work Order : EP0904516
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E036G-S	E028G-S	E028G-I	E030G-I	E023FG-D
			Client sampling date / time	03-AUG-2009 15:00	07-AUG-2009 15:00	07-AUG-2009 15:00	01-AUG-2009 15:00	01-AUG-2009 15:00
				EP0904516-001	EP0904516-002	EP0904516-003	EP0904516-004	EP0904516-005
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.50	7.57	7.33	7.32	6.90
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	101000	74700	102000	88500	153000
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	85300	49000	70000	78400	168000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	98	172	138	203	265
Total Alkalinity as CaCO3	----	1	mg/L	98	172	138	203	265
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	5410	3160	5180	3730	9400
^ Sulfur as S	----	1	mg/L	1800	1050	1730	1240	3130
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	41200	30100	43000	36100	74200
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	790	700	1100	930	1440
Magnesium	7439-95-4	1	mg/L	2380	1690	2680	1920	5230
Sodium	7440-23-5	1	mg/L	20500	15500	23700	19600	44600
Potassium	7440-09-7	1	mg/L	1260	680	1110	950	2380
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1280	919	1320	1100	2290
^ Total Cations	----	0.01	meq/L	1160	866	1330	1080	2500
^ Ionic Balance	----	0.01	%	4.74	3.02	0.35	1.00	4.29

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Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E014G-I	E0005F	E023FG-S	E032FG-D	E028G-I
			Client sampling date / time	29-JUL-2009 15:00	10-AUG-2009 15:00	01-AUG-2009 15:00	29-JUL-2009 15:00	06-AUG-2009 15:00
				EP0904516-006	EP0904516-007	EP0904516-008	EP0904516-009	EP0904516-010
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.24	7.94	7.87	7.12	7.60
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	94700	39700	28600	119000	99200
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	79200	29200	22500	127000	79800
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	234	388	252	161	138
Total Alkalinity as CaCO3	----	1	mg/L	234	388	252	161	138
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	5870	1430	1430	7670	4910
^ Sulfur as S	----	1	mg/L	1960	477	477	2560	1640
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	39800	15800	10700	53000	43700
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	980	350	300	1230	1060
Magnesium	7439-95-4	1	mg/L	2920	770	790	3680	2550
Sodium	7440-23-5	1	mg/L	22100	8170	5020	30000	22700
Potassium	7440-09-7	1	mg/L	1130	260	220	1610	1080
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	1250	485	336	1660	1340
^ Total Cations	----	0.01	meq/L	1280	443	304	1710	1280
^ Ionic Balance	----	0.01	%	1.20	4.54	5.10	1.55	2.38

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Work Order : EP0904516
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	**E030G-I**	**E030G-D**	**QC01**	**E028G-S**	**E024FG-I**
			Client sampling date / time	01-AUG-2009 15:00	01-AUG-2009 15:00	01-AUG-2009 15:00	06-AUG-2009 15:00	29-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904516-011**	**EP0904516-012**	**EP0904516-013**	**EP0904516-014**	**EP0904516-015**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.011**	**0.018**	**0.022**	**0.031**	**0.012**
Cadmium	7440-43-9	0.0001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.010	<0.010	**0.208**	<0.010
Copper	7440-50-8	0.001	mg/L	**0.058**	**0.118**	**0.082**	**0.141**	**0.028**
Lead	7439-92-1	0.001	mg/L	<0.010	<0.010	<0.010	**0.032**	<0.010
Nickel	7440-02-0	0.001	mg/L	**0.031**	**0.048**	**0.029**	**0.116**	**0.021**
Zinc	7440-66-6	0.005	mg/L	<0.010	**0.022**	<0.010	**0.147**	<0.010
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**E028G-S**	**E044G-D**	**E027FG-I**	**E014G-I**	**E026D-S**
			Client sampling date / time	08-JUL-2009 15:00	03-AUG-2009 15:00	28-JUL-2009 15:00	29-JUL-2009 15:00	24-JUL-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904516-016**	**EP0904516-017**	**EP0904516-018**	**EP0904516-019**	**EP0904516-020**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	**0.011**	<0.010	<0.010	<0.010
Cadmium	7440-43-9	0.0001	mg/L	<0.0010	**0.0012**	<0.0010	<0.0010	<0.0010
Chromium	7440-47-3	0.001	mg/L	<0.010	**0.747**	<0.010	<0.010	**0.014**
Copper	7440-50-8	0.001	mg/L	**0.036**	**0.145**	**0.083**	**0.049**	**0.010**
Lead	7439-92-1	0.001	mg/L	<0.010	**0.066**	<0.010	<0.010	<0.010
Nickel	7440-02-0	0.001	mg/L	**0.024**	**1.18**	**0.037**	**0.022**	**0.018**
Zinc	7440-66-6	0.005	mg/L	**0.018**	**0.186**	<0.010	<0.010	<0.010
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	E023FG-D	E032FG-D	E036G-S	E028G-I	E023FG-S
			Client sampling date / time	01-AUG-2009 15:00	29-JUL-2009 15:00	03-AUG-2009 15:00	07-AUG-2009 15:00	01-AUG-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904516-021**	**EP0904516-022**	**EP0904516-023**	**EP0904516-024**	**EP0904516-025**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	**0.014**	**0.150**	<0.010	<0.010
Cadmium	7440-43-9	0.0001	mg/L	<0.0010	**0.0029**	<0.0010	<0.0010	<0.0010
Chromium	7440-47-3	0.001	mg/L	<0.010	**0.010**	**0.398**	<0.010	<0.010
Copper	7440-50-8	0.001	mg/L	**0.080**	**0.071**	**0.178**	**0.054**	**0.020**
Lead	7439-92-1	0.001	mg/L	<0.010	**0.012**	**0.070**	<0.010	<0.010
Nickel	7440-02-0	0.001	mg/L	**0.028**	**0.043**	**0.198**	**0.022**	**0.026**
Zinc	7440-66-6	0.005	mg/L	**0.016**	**0.015**	**0.204**	<0.010	<0.010
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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Work Order : EP0904516
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	**E025FG-I**	**QC02**	----	----	----
			Client sampling date / time	01-AUG-2009 15:00	04-AUG-2009 15:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904516-026**	**EP0904516-027**	**----**	**----**	**----**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	<0.010	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0010	<0.0010	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.010	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.022**	<0.010	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.010	<0.010	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.019**	**0.013**	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.016**	<0.010	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----

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ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EP0904517**	Page	: 1 of 8
Client	: **URS AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: ANDREW MCTAGGART	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	: Andrew_McTaggart@URSCorp.com	E-mail	: michael.sharp@alsenviro.com
Telephone	: +61 08 9326 0100	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
Order number	: 213986 US		
C-O-C number	: ----	Date Samples Received	: 12-AUG-2009
Sampler	: ----	Issue Date	: 19-AUG-2009
Site	: ----		
		No. of samples received	: 28
Quote number	: EN-001-09 BQ	No. of samples analysed	: 28

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Perth Inorganics
Scott James	Assistant Laboratory Manager	Perth Inorganics

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Work Order	: EP0904517
Client	: URS AUSTRALIA PTY LTD
Project	: 42907100

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Ionic Balance out of acceptable limits for various samples due to analytes not quantified in this report.**

Work Order : EP0904517
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: WATER			Client sample ID	E005G-P	E024FG-1	E024FG-S	E014G-F	E044G-D
			Client sampling date / time	10-JUL-2009 15:00	29-JUL-2009 15:00	29-JUL-2009 15:00	29-JUL-2009 15:00	03-AUG-2009 15:00
Compound	CAS Number	LOR	Unit	EP0904517-001	EP0904517-002	EP0904517-003	EP0904517-004	EP0904517-005
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.03	7.54	7.75	7.48	7.37
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	148000	61500	48700	66500	74300
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	155000	50200	36400	57800	61000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	182	235	243	280	117
Total Alkalinity as CaCO3	----	1	mg/L	182	235	243	280	117
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	4760	4630	2770	3850	3780
^ Sulfur as S	----	1	mg/L	1590	1540	922	1280	1260
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	74900	25600	19500	29000	32400
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	2800	635	527	757	621
Magnesium	7439-95-4	1	mg/L	4530	1830	1320	2010	2280
Sodium	7440-23-5	1	mg/L	43800	14600	11800	17400	18800
Potassium	7440-09-7	1	mg/L	1700	815	411	553	602
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2220	824	613	906	995
^ Total Cations	----	0.01	meq/L	2460	838	660	973	1050
^ Ionic Balance	----	0.01	%	5.18	0.80	3.68	3.56	2.78

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Work Order : EP0904517
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E028G-S	E025FG-I	E005G-I	E032FG-I	E014G-S
			Client sampling date / time	06-AUG-2009 11:05	01-AUG-2009 15:00	10-JUL-2009 11:55	29-JUL-2009 15:00	29-JUL-2009 15:00
				EP0904517-006	EP0904517-007	EP0904517-008	EP0904517-009	EP0904517-010
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.82	8.20	7.43	7.57	7.97
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	75600	8460	52800	66700	45500
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	63000	5820	39100	59600	34600
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	159	274	98	318	430
Total Alkalinity as CaCO3	----	1	mg/L	159	274	98	318	430
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	3370	324	2520	6020	2520
^ Sulfur as S	----	1	mg/L	1120	108	841	2000	839
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	32600	2090	22200	26800	18200
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	905	83	748	845	317
Magnesium	7439-95-4	1	mg/L	1970	163	1360	1950	965
Sodium	7440-23-5	1	mg/L	19600	1580	11800	14800	10800
Potassium	7440-09-7	1	mg/L	579	95	284	590	423
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	993	70.7	680	888	574
^ Total Cations	----	0.01	meq/L	1070	86.4	669	864	578
^ Ionic Balance	----	0.01	%	3.88	9.98	0.84	1.37	0.29

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Work Order : EP0904517
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E021F	E030G-D	E032FG-S	E027FG-D	E026FG-D
Client sampling date / time				29-JUL-2009 15:00	01-AUG-2009 15:00	27-JUL-2009 15:00	28-JUL-2009 15:00	29-JUL-2009 15:00
				EP0904517-011	EP0904517-012	EP0904517-013	EP0904517-014	EP0904517-015
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.86	6.57	7.60	6.53	7.64
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	32300	160000	46400	161000	58200
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	24800	185000	38500	185000	48000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	207	213	302	145	217
Total Alkalinity as CaCO3	----	1	mg/L	207	213	302	145	217
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	3170	8160	4630	9430	3670
^ Sulfur as S	----	1	mg/L	1060	2720	1540	3140	1220
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	11900	90600	18500	87300	24500
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	452	1670	772	1450	761
Magnesium	7439-95-4	1	mg/L	1020	5530	1590	6160	1980
Sodium	7440-23-5	1	mg/L	6920	52400	11200	58000	15700
Potassium	7440-09-7	1	mg/L	286	2560	441	1890	546
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	406	2730	624	2660	772
^ Total Cations	----	0.01	meq/L	415	2880	670	3150	898
^ Ionic Balance	----	0.01	%	1.14	2.71	3.56	8.33	7.54

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Work Order : EP0904517
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	QC0	E027FG-S	E027FG-I	E014G-S	E021F
			Client sampling date / time	01-AUG-2009 15:00	28-JUL-2009 15:00	28-JUL-2009 15:00	12-AUG-2009 15:00	29-JUL-2009 15:00
				EP0904517-016	EP0904517-017	EP0904517-018	EP0904517-019	EP0904517-020
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.88	7.11	6.99	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	145000	119000	141000	----	----
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	GIS-210-010	5	mg/L	161000	127000	155000	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	265	176	143	----	----
Total Alkalinity as CaCO3	----	1	mg/L	265	176	143	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	9450	9660	9890	----	----
^ Sulfur as S	----	1	mg/L	3150	3220	3300	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	75000	55500	71300	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1500	1450	1510	----	----
Magnesium	7439-95-4	1	mg/L	5190	4350	5120	----	----
Sodium	7440-23-5	1	mg/L	50300	39400	42500	----	----
Potassium	7440-09-7	1	mg/L	1770	1450	2280	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	----	----	----	<0.010	0.012
Cadmium	7440-43-9	0.0001	mg/L	----	----	----	<0.0010	<0.0010
Chromium	7440-47-3	0.001	mg/L	----	----	----	<0.010	<0.010
Copper	7440-50-8	0.001	mg/L	----	----	----	<0.010	0.012
Lead	7439-92-1	0.001	mg/L	----	----	----	<0.010	<0.010
Nickel	7440-02-0	0.001	mg/L	----	----	----	0.018	0.021
Zinc	7440-66-6	0.005	mg/L	----	----	----	<0.010	0.011
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	----	----	----	<0.0001	<0.0001
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	2320	1770	2220	----	----
^ Total Cations	----	0.01	meq/L	2730	2180	2410	----	----
^ Ionic Balance	----	0.01	%	8.20	10.4	4.03	----	----

A Campbell Brothers Limited Company

Work Order : EP0904517
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	E028D-I	E032FG-I	E027FG-D	E025FG-D	E027FG-S
			Client sampling date / time	06-AUG-2009 15:00	29-JUL-2009 15:00	28-JUL-2009 15:00	29-JUL-2009 15:00	28-JUL-2009 15:00
				EP0904517-021	**EP0904517-022**	**EP0904517-023**	**EP0904517-024**	**EP0904517-025**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	**0.014**	<0.010	<0.010	**0.012**
Cadmium	7440-43-9	0.0001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.010	<0.010	<0.010	**0.116**
Copper	7440-50-8	0.001	mg/L	**0.043**	**0.029**	**0.089**	**0.027**	**0.128**
Lead	7439-92-1	0.001	mg/L	<0.010	<0.010	<0.010	<0.010	**0.025**
Nickel	7440-02-0	0.001	mg/L	**0.024**	**0.016**	**0.027**	**0.016**	**0.062**
Zinc	7440-66-6	0.005	mg/L	<0.010	<0.010	<0.010	<0.010	**0.082**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

A Campbell Brothers Limited Company

Work Order : EP0904517
Client : URS AUSTRALIA PTY LTD
Project : 42907100

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**E026G-D**	**E024FG-S**	**E014G-F**	----	----
			Client sampling date / time	24-JUL-2009 15:00	29-JUL-2009 15:00	29-JUL-2009 15:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP0904517-026**	**EP0904517-027**	**EP0904517-028**	**----**	**----**
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	<0.010	<0.010	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0010	<0.0010	<0.0010	----	----
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.010	<0.010	----	----
Copper	7440-50-8	0.001	mg/L	**0.101**	**0.022**	**0.025**	----	----
Lead	7439-92-1	0.001	mg/L	<0.010	<0.010	<0.010	----	----
Nickel	7440-02-0	0.001	mg/L	**0.024**	**0.014**	**0.018**	----	----
Zinc	7440-66-6	0.005	mg/L	<0.010	**0.022**	**0.012**	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----

CHAIN OF CUSTODY DOCUMENTATION

ALS Laboratory Group

CLIENT	URS	SAMPLER	BP/BS/GC/CO/CW
ADDRESS / OFFICE	Level 3, 20 Terrace Road, East Perth, 6004	MOBILE	
PROJECT MANAGER (PM)	Andrew McTaggart	PHONE	9326 0100
PROJECT NO	42907550	EMAIL REPORT TO	Garrett Lacey
SITE	Onslow	P.O. NO	[illegible]
RESULTS REQUIRED (Date)	[illegible]	QUOTE NO	[illegible]

Comments / special handling / storage or disposal: [illegible]

Notes: [illegible]

ALS ID	Sample ID	Matrix	Date	Time	Container type	Total bottles	TDS	EC	pH	Major ions
1	E07-F	GW	4/6	11:36	1	1	✓	✓	✓	✓
2	E08-A	"	5/6	3:50	"	"	✓	✓	✓	✓
3	E07-C	"	4/6	1:45	"	"	✓	✓	✓	✓
4	E08-B	"	4/6	11:30	"	"	✓	✓	✓	✓
5	E032-C	"	7/6	4:00	"	"	✓	✓	✓	✓
6	E024-B	"	3/6	3:25	"	"	✓	✓	✓	✓
7	E013-C	"	4/6	12:30	"	"	✓	✓	✓	✓
8	E03-A	"	9/6	1:30	"	"	✓	✓	✓	✓
9	E032-B	"	2/6	3:30	"	"	✓	✓	✓	✓
10	E07-D	"	7/6	4:55	"	"	✓	✓	✓	✓
11	E027-C	"	3/6	1:30	"	"	✓	✓	✓	✓
12	E013-A	"	4/6	3:00	"	"	✓	✓	✓	✓

Environmental Division
Perth
Work Order
EP0903304

RELINQUISHED BY		RECEIVED BY		METHOD OF SHIPMENT
Name	Date	Name	Date	Con' Note No
Of	Time	Of	Time	
Name	Date	Name	Date	Transport Co
Of	Time	Of	Time	

Water Container Codes: [illegible]

ALS LABORATORY GROUP

COC Page 3 of 6

[illegible]

CHAIN OF CUSTODY DOCUMENTATION

Client: URS	Sampler: 42907100/10/WA
Address / Office: Level 3, 20 Terrace Road, East Perth, WA	Mobile:
Project Manager: Andrew McTaggart	Phone: 9326 0100
Project ID: 42907100	Email Reports To: Daniel Lacey
Site: Onslow	Email Invoice To:
Results required (Date):	Analysis required

Comments / special handling / storage or disposal:

Lab ID	Sample ID	Matrix	Date	Time	Type / Code	Total Bottles	TDS	EC	pH	Major Ions
13	E019 - A	GW	14/6	11:00	P	1	✓	✓	✓	✓
14	Surface water	SW	14/6	5:00	"	"	✓	✓	✓	✓
15	E024 - A	GW	3/6	2:55	"	"	✓	✓	✓	✓
16	E025 - A	GW	4/6	3:30	"	"	✓	✓	✓	✓
17	E027 - B	"	3/6	8:35	"	"	✓	✓	✓	✓
18	Surface water	SW	13/6	9:00	"	"	✓	✓	✓	✓

Relinquished by		Received by		Method of shipment
Name:	Date:	Name:	Date:	Con'Note No:
Of:	Time:	Of:	Time:	
Name:	Date:	Name:	Date:	Transport Co:
Of:	Time:	Of:	Time:	

Water Container Codes: P = Unpreserved Plastic; ...

ALS LABORATORY GROUP

COC Page 6 of 6

FORM (2043)

CHAIN OF CUSTODY DOCUMENTATION

Client: URS
Address/Office: Level 3, 20 Terrace Road, East Perth, 6004
Project Manager (PM): Fabio [illegible] / Derek Jones
Project ID: Wheatstone 42907400
Site: Onslow
Results required (Date): [illegible]
Sampler: [illegible]
Phone: 9326 0100
Email Report to: Derek Jones

ALS Laboratory Group

Lab ID	Sample ID	Matrix	Date	Time	Type / Code	Total bottles	TDS	EC	pH	Major Ions
19	E033-B	GW	[illegible]	12:30	P	1	✓	✓	✓	✓
20	E019-A	GW	[illegible]	[illegible]	P	1	✓	✓	✓	✓
21	E012-A	GW	4/6	[illegible]	"	"	✓	✓	✓	✓
22	E032-A	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓
23	E016-A	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓
24	E011-B	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓
25	E017-A	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓
26	E022-A	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓
27	E032-SC	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓
28	E07-B	"	7/6	[illegible]	"	"	✓	✓	✓	✓
29	E06-A	"	7/6	[illegible]	"	"	✓	✓	✓	✓
30	E05-A	"	[illegible]	10:10	"	-	✓	✓	✓	✓

Relinquished by: Name / Of / Date / Time

Received by: Name / Of / Date / Time

Method of shipment: Con' Note No / Transport Co

Water Container Codes: [illegible]

ALS LABORATORY GROUP

COC Page 5 of 6

CHAIN OF CUSTODY DOCUMENTATION

ALS Laboratory Group

Client	URS
Address / Office	Level 3, 20 Terrace Road, East Perth
Project Manager	Andrew McTaggart
Project No	42907100
Site	Onslow
Sampler	MJBS/DJ/CQ/CW
Phone	9326 0100
Email Report to	David Lowry

Lab ID	Sample ID	Matrix	Date	Time	Type/Code	Total Bottles	TDS	EC	pH	Major Ions
31	E023 - A	GW	5/6	[illegible]	P	1	✓	✓	✓	✓
32	E019 - C	"	6/6	[illegible]	"	"	✓	✓	✓	✓
33	E011 - A	"	6/6	[illegible]	"	"	✓	✓	✓	✓
34	E021 - A	"	6/6	[illegible]	"	"	✓	✓	✓	✓
35	E033 - E	"	6/6	[illegible]	"	"	✓	✓	✓	✓
36	E033 - A	"	6/6	[illegible]	"	"	✓	✓	✓	✓
37	E07 - A	"	6/6	[illegible]	"	"	✓	✓	✓	✓

Relinquished by		Received by		Method of Shipment	
Name	Date	Name	Date	Con' Note No	
Of	Time	Of	Time		
Name	Date	Name	Date	Transport Co	
Of	Time	Of	Time		

Water Container Codes: [illegible]

ALS LABORATORY GROUP

COC Page 6 of 6

CHAIN OF CUSTODY DOCUMENTATION

ALS Laboratory Group

Client: URS
Address/Office: Level 3, 20 Terrace Road
Project Manager: Andrew McTaggart
Project ID: 42907100
Site: Onslow
Sampler: 09/6/P/CC/Cw
Phone: 9326 0100
Email reports to: Daniel Lacey

ALS ID	Sample ID	Date	Time	Type/Code	No. bottles	Total Metals
38	E06-A	6/6	11:30	P	1	✓
39	E07-C	3/6	12:00	"	"	✓
40	E012-C	6/6	11:25	"	"	✓
41	E013-A	5/6	3:00	"	"	✓
~~42~~	~~[illegible]~~	~~4/6~~	~~8:15~~	~~"~~	~~"~~	
~~43~~		~~5/6~~	~~1:36~~	~~"~~	~~"~~	
42 (~~44~~)	E07-A	6/6	4:00	"	"	✓
43 (~~45~~)	E07-D	3/6	11:45	"	"	✓
44 (~~46~~)	E015-A	9/6	10:10			

Relinquished by: Name / Of / Date / Time

Received by: Name / Of / Date / Time

Method of shipment: Con' Note No. / Transport Co.

ALS LABORATORY GROUP

COC Page 1 of 6

CHAIN OF CUSTODY DOCUMENTATION

CLIENT: URS
ADDRESS/OFFICE: Level 3, 20 Terrace Road, [illegible]
PROJECT MANAGER: Andrew McTaggart
PROJECT ID: 42907[illegible]
SITE: Onslow
PO NO:
RESULTS REQUIRED Date:
QUOTE NO:

SAMPLER: [illegible]
MOBILE:
PHONE: 9326 0100
EMAIL REPORT TO:
EMAIL INVOICE TO:
ANALYSIS REQUIRED:

[illegible]

Lab ID	Sample ID	Date	Time	Container Type	Total Bottles	Analysis
47	E28-A	[illegible]	3:56	P	1	✓
48	E07-A	[illegible]	10:31	P	1	✓
49	E06-A	9/[illegible]	14:05	"	"	✓
50	E019-B	[illegible]	[illegible]	"	"	✓
51	E019-A	"	[illegible]	"	"	✓
52	E07-C	"	[illegible]	"	"	✓
53	E019-C	"	[illegible]	"	"	✓

RELINQUISHED BY:
Name: Date:
Of: Time:
Name: Date:
Of: Time:

RECEIVED BY:
Name: Date:
Of: Time:
Name: Date:
Of: Time:

Water Container Codes: [illegible]

ALS LABORATORY GROUP

COC Page 2 of 5

SAMPLE RECEIPT INFORMATION & BOTTLE MAP

WORKORDER No: EP

Lab of Origin:

To Be completed by Sample Login Clerk

Receiving Details	Temperature Details	Packaging		Work Order Login Details	Work Order Sign-off	Comments
	Ambient Temp	Type	No.	Test Data Entry Commenced		
	Sample Temp					
	Chilling Process Order	Hard Esky		Time Date Logged		
		Other		Time Placed in Storage		
				Storing in Fridge (Log Time)		
		Receipt				

Sample Receipt Advice Comments – To be Completed by Sorting Staff | Tick

Samples have been received within recommended Holding Times

Please contact ALSE for further information.

CHAIN OF CUSTODY FORM

Sheet 1 of 2

FROM	URS Australia Pty Ltd
DATE	2/7/09
TO	ALS
Project No	[illegible]
Project Manager	[illegible]
Released to ALS by	[illegible]
Received in Laboratory by	[illegible]
Custody seal intact?	YES / NO
Sample cold?	YES / NO

Container Size, Type, Preservative and Analysis

Lab Identification	Date	Time	Matrix	Sample Number	Comments	TDS	EC	pH	Major Ions	Metals (dissolved)
[illegible]	22/6	11:50				✓	✓	✓	✓	
[illegible]	"	10:25				✓	✓	✓	✓	
[illegible]	18/6	14:30				✓	✓	✓	✓	
[illegible]	21/6	09:30				✓	✓	✓	✓	
[illegible]	17/6	11:55				✓	✓	✓	✓	
[illegible]	15/6	16:35				✓	✓	✓	✓	
[illegible]	18/6	15:00				✓	✓	✓	✓	
[illegible]	16/6	10:35				✓	✓	✓	✓	✓
[illegible]	19/6	12:15				✓	✓	✓	✓	
[illegible]	18/6	13:35				✓	✓	✓	✓	✓
[illegible]	21/6	15:00				✓	✓	✓	✓	✓
[illegible]	22/6	13:40				✓	✓	✓	✓	
TOTAL						12	12	12	12	

Environmental Division
Perth
Work Order
EP0903591

Remarks: [illegible]

Specify Turnaround Time

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

Courier Job No:

CHAIN OF CUSTODY FORM

Sheet 2 of 2.

FOR LAB USE ONLY

Job Code

Due Date

FROM: URS AUSTRALIA

DATE 21/1/09 TO: ALS

Project No: 42907030

Project Manager: [illegible]

Custody seal intact? YES NO

Sample cold? YES NO

Released for URS by: [illegible]

Date 21/1/09 Time

Received for Laboratory by: AC [illegible]

Date [illegible] Time [illegible]

Container Size, Type, Preservative and Analysis

Analysis: TDS, EC, pH, Major ions, Metals (total + filtered)

Lab identification	Date / Time	Matrix	Sample Number	Comments	Total no.	For required analysis
EC15G-D	15/1					✓
EC15G-S	19/1 [illegible]					✓
EC15E	16/1 [illegible]					✓
EC16F	[illegible]					✓
EC15G-I	[illegible]					✓
EC14F	20/1 [illegible]					✓
ED [illegible]	21/1 [illegible]					✓
[illegible]	21/1 [illegible]					✓
EC26C-D	21/1 [illegible]					✓

Remarks: [illegible]

TOTAL 9 … 9

* Container Type and Preservative Codes: P = Neutral Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar; S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS = Sulfuric Acid Preserved Vial; SG = Sulfuric Acid Preserved Glass Bottle; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle

Courier Job No.

Specify Turnaround Time

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY DOCUMENTATION

Client: URS
Address/Office: Level 3, 20 Terrace Road, East Perth WA
Project Manager: Andrew McTaggart
Phone: 4290700 (illegible)
Site: Ashburton North
Sampler: Walker George (K.G.)
Phone: 9326 0100
Email report to: Daniel Lopez

ALS Laboratory Group

Lab ID	Sample ID	Matrix	Date	Time	Type / Code	Total Bottles	Dissolved Metals
1	E02905 (illegible)	W	25/7	11:00	P	[illegible]	✓
2	E019-F (illegible)	W	25/7	11:30	"	"	✓
3	E0356-S	W	25/7		"	"	✓
4	E0296-I	W	25/7	11:00	"	"	✓
5	E0335G-S	W	25/7		"	"	✓
6	E0316-D	W	25/7		"	"	✓
7	E0196-F (illegible)	W	25/7		"	"	✓
8	E0296-S	W	25/7		"	"	✓
9	E033FG-D	W	25/7		"	"	✓
10	E016-I (illegible)	W	25/7	[illegible]	"	"	✓
11	E016-S (illegible)	W	25/7	9:00	"	"	✓
12	E0196-S (illegible)	W	25/7		"	"	✓

Environmental Division
Perth
Work Order
EP0904261

Received by: Name: [illegible] Date: 30/7/15 Time: 14:5[illegible]

ALS LABORATORY GROUP

COC Page 1 of 6

CHAIN OF CUSTODY DOCUMENTATION

CLIENT: URS
ADDRESS/OFFICE: Level 3, 20 Terrace Road, East Perth, 6004
PROJECT MANAGER (PM): Andrew McTaggart
PROJECT NO: 42907120
SITE: Ashburton North
RESULTS REQUIRED (Date):

SAMPLER: Water Group (RA, ES)
MOBILE:
PHONE: 9326 0100
EMAIL REPORT TO: Daniel Lacey
EMAIL INVOICE TO:
ANALYSIS REQUIRED

ALS Laboratory Group

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Type / Code	Total bottles	Total Metals
13	E0196-D Airlift	W	26/7		F	1	✓
14	E0385-I	W	26/7		"	"	✓
15	E0026-D Airlift	"	26/7	3:30	"	"	✓
16	E0306-F	"	27/7		"	"	✓
17	E005-F	"	5/7		"	"	✓
18	E002-F Airlift	"	29/7	13:30	"	"	✓
19	E0055-I	"	31/7	15:55	"	"	✓
20	E0395-I	"	30/7	16:05	"	"	✓
21	E0026-D	"	11/7	2:00	"	"	✓
22	E010-F	"	2/7		"	"	✓
23	E0076-F	"	11/7	11:10	"	"	✓
24	E0055-G	"	10/7	11:55	"	"	✓

RELINQUISHED BY:
Name: Date:
Of: Time:
Name: Date:
Of: Time:

RECEIVED BY:
Name: [illegible] Date: 31/7/[illegible]
Of: PAJ Time: [illegible]
Name: Date: Transport Co:
Of: Time:

Water Container Codes: [illegible]

ALS LABORATORY GROUP

COC Page 2 of ___

CHAIN OF CUSTODY DOCUMENTATION

Client: URS
Office: Level 3, 20 Terrace Road, East Perth, 6004
Project Manager: Andrew McTaggart
Project: 42907100
Site: Pilbara North

Sampler: Water Group (KP, RS)
Phone: 9326 0100
Email report to: Daniel Kasey

Analysis required: TDS, EC, pH, Major Ions

Lab ID	Sample ID	Matrix	Date	Time	Type/Code	Total bottles	TDS	EC	pH	Major Ions
25	E010-F (Pump Test)	W	26/2	1830	P	1	✓	✓	✓	✓
[illegible]	E0[illegible] ([illegible])	"	"		"	"	✓	✓	✓	✓
27	E031C-D	"	26/2		"	"	✓	✓	✓	✓
28	E0306-I (Pump Test)	"	27/2		"	"	✓	✓	✓	✓
29	E026-S	"	28/2		"	"	✓	✓	✓	✓
[illegible]	E026-D	"	28/2		"	"	✓	✓	✓	✓
[illegible]	E029C-I (Pump Test)	"	28/2	2:00	"	"	✓	✓	✓	✓
[illegible]	E010-F (Pump Test)	"	2/3		"	"	✓	✓	✓	✓
[illegible]	E035C-D	"	3/3		"	"	✓	✓	✓	✓
[illegible]	E016-I (Pump Test)	"	2/3		"	"	✓	✓	✓	✓
[illegible]	E029C	"	4/3		"	"	✓	✓	✓	✓
[illegible]	E030-C	"	4/3	11:00	"	"	✓	✓	✓	✓

Relinquished by: Name / Of / Date / Time
Received by: Name [illegible] / Of [illegible] / Date [illegible] / Time [illegible]
Method of shipment: Con'Note No / Transport Co

Water Container Codes: [illegible]

ALS LABORATORY GROUP

COC Page 5 of ___

CHAIN OF CUSTODY DOCUMENTATION

ALS Laboratory Group

CLIENT: URS

OFFICE: Level 3, 20 Terrace Road, East Perth

PROJECT MANAGER: Andrew McTaggart

PROJECT ID: 42907150

SITE: Ashburton North

SAMPLER: Waier Gap (URS)

PHONE: 9326 0100

EMAIL REPORT TO: Daniel Lowry

ANALYSIS REQUIRED including SUITES

LAB ID	SAMPLE ID	MATRIX	DATE	TIME	TYPE	TOTAL BOTTLES	TDS	EC	pH	Major Ions
37	E029a	W	18/7		P	1	✓	✓	✓	✓
38	E032A-1	"	23/2		"	"	✓	✓	✓	✓
39	E027C-S	"	25/7		"	"	✓	✓	✓	✓
40	E031G-C	"	25/7		"	"	✓	✓	✓	✓
41	E029G-C	"	25/7		"	"	✓	✓	✓	✓
42	E031G-S	"	26/7		"	"	✓	✓	✓	✓

RELINQUISHED BY: Name: Date: By: Time:

RECEIVED BY: Name: Date: 31/7/08 By: Time: 1400

METHOD OF SHIPMENT: Con' Note No: Transport Co:

ALS LABORATORY GROUP

COC Page 4 of ___

CHAIN OF CUSTODY DOCUMENTATION

ALS Laboratory Group

CLIENT: URS	SAMPLER: Water Group (RP, BS)
ADDRESS / OFFICE: Level 3, 20 Terrace Road, East Perth 6004	MOBILE:
PROJECT MANAGER (PM): Andrew McTaggart	PHONE: 9326 0100
PROJECT NO: 42907400	EMAIL REPORT TO: Daniel Hussey
SITE: Wheatstone North	EMAIL INVOICE TO: [illegible]
RESULTS REQUIRED (Date): [illegible]	ANALYSIS REQUIRED including SUITES: [illegible]

Analyses: TOTAL METALS; TDS; EC; pH; Major Ions

Notes: e.g. Highly contaminated samples; e.g. "High PAHs expected"; Extra volume for QC or trace LORs etc.

LAB ID	SAMPLE ID	MATRIX	DATE	TIME	TYPE CODE	TOTAL BOTTLES	TOTAL METALS	TDS	EC	pH	Major Ions
[illegible]	E0026-S	W	[illegible]	[illegible]	P	1	✓				
[illegible]	E010S-S [illegible]	"	[illegible]		"	"	✓				
[illegible]	E0056-S	"	[illegible]		"	"	✓				
[illegible]	E0026-S	"	[illegible]		"	"	✓				
[illegible]	E0300-I	"	[illegible]		"	"	✓				
[illegible]	E029C	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓	✓
[illegible]	E0305-I	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓	✓
[illegible]	E006F	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓	✓
[illegible]	E010-S [illegible]	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓	✓
[illegible]	E016-I [illegible]	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓	✓
[illegible]	E0056-S	"	[illegible]	[illegible]	"	"	✓	✓	✓	✓	✓
[illegible]	E019C-F [illegible]	"	[illegible]	[illegible]	"	"		✓	✓	✓	✓

RELINQUISHED BY		RECEIVED BY		METHOD OF SHIPMENT
Name:	Date:	Name: [illegible]	Date: [illegible]	Con' Note No:
Of:	Time:	Of:	Time: [illegible]	
Name:	Date:	Name:	Date:	Transport Co:
Of:	Time:	Of:	Time:	

Water Container Codes: [illegible]

ALS LABORATORY GROUP

COC Page 5 of ___

[illegible]

CHAIN OF CUSTODY DOCUMENTATION

ALS Laboratory Group

CLIENT: URS	SAMPLER: Water Group
ADDRESS/OFFICE: Level 3, 20 Terrace Road, East Perth, 6004	MOBILE:
PROJECT MANAGER (PM): Andrew McTaggart	PHONE: 9326 0100
PROJECT ID: 42907300	EMAIL REPORT TO: Daniel Lacey
SITE: Wheatstone North	P.O. NO.:
RESULTS REQUIRED (Date):	QUOTE NO.:

ALS ID	SAMPLE ID	DATE	TIME	TYPE CODE	TOTAL BOTTLES	TDS	EC	pH	Major Ions
55	E02GC-S	24/7	17:30	P	1	✓	✓	✓	✓
56	ED30G-S	25/7		"	"	✓	✓	✓	✓
57	E0GG-O [illegible]	"	25/7	12:00	"	"	✓	✓	✓	✓
58	E02GG-S	"	25/7		"	"	✓	✓	✓	✓
59	E0029-[illegible]	"	25/7	12:00	"	"	✓	✓	✓	✓
60	E0026-S [illegible]	"	25/7	15:00	"	"	✓	✓	✓	✓
61	E0106-[illegible]	"	25/7		"	"	✓	✓	✓	✓
62	E0026-S	"	25/7	12:30	"	"	✓	✓	✓	✓
63	E0026-D	"	25/7	2:30	"	"	✓	✓	✓	✓
64	E0356-D [illegible]	"	25/7		"	"	✓	✓	✓	✓
65	E0166-S [illegible]	"	25/7	6:00	"	"	✓	✓	✓	✓
66	E0336-S	"	25/7		"	"	✓	✓	✓	✓

RELINQUISHED BY: Name: / Of: / Date: / Time: / Name: / Of: / Date: / Time:

RECEIVED BY: Name: [illegible] / Of: ALS / Date: [illegible] / Time: [illegible] / Name: / Of: / Date: / Time:

METHOD OF SHIPMENT: Con' Note No: / Transport Co:

Water Container Codes: [illegible]

ALS LABORATORY GROUP

COC Page 6 of 6

CHAIN OF CUSTODY FORM

Sheet: 1 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS AUSTRALIA [illegible]

DATE: 12/8/09 TO: ALS

Lab Code: [illegible] 09

Due Date:

Project No: 42907180

Project Manager: Sam [illegible]

Custody seal intact? YES / NO

Sample cold? YES / NO

Released by URS: Date: Time:

Received by Laboratory: Linda W. Date: 12-8 Time: 1410

Container Size, Type, Preservative and Analysis

Analyses: TDS, EC, pH, Major Ions

Lab Identification	Date	Time	Matrix	Sample Number	Comments	TDS	EC	pH	Major Ions
1	25/7/09	[illegible]		E005G-P		✓	✓	✓	✓
2	25/7/09	—		E02[illegible]FC-I		✓	✓	✓	✓
3	29/7/09			E014FC-S		✓	✓	✓	✓
4	29/7			E014G-F		✓	✓	✓	✓
5	3/8			E044G-D		✓	✓	✓	✓
6	15/8	[illegible]		E018G-S		✓	✓	✓	✓
7	[illegible]			E015FG-I		✓	✓	✓	✓
8	10/7	[illegible]		E005G-I		✓	✓	✓	✓
9	25/7			E032FC-I		✓	✓	✓	✓
10	29/7			E014G-S		✓	✓	✓	✓
11	29/7			E02-F		✓	✓	✓	✓
12	[illegible]			E030G-D		✓	✓	✓	✓

TOTAL: 12

Remarks

Environmental Division Perth

Work Order

EP0904517

Telephone: [illegible]

Courier Job No. Specify Turnaround

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet 2 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS AUSTRALIA, ACN 000 691 690, [illegible]

DATE: 12/8/09 TO: ALS

Job Code:

Due Date:

Project No: 42907-00

Project Manager: A. [illegible]

Custody seal intact? YES / NO

Sample cold? YES / NO

Relinquished by: Date: Time:

Received for Laboratory by: CW Date: 12-8 Time: 14:10

Container Size, Type, Preservative and Analyses

Container Identification

Analyses: TOTAL/DISSOLVED METALS, TDS, EC, pH, Major Ions

Lab Identification	Date	Time	Matrix	Sample location	Comments	Total no.	TOTAL/DISSOLVED METALS	TDS	EC	pH	Major Ions
15	27/7			EC22FC-S				✓	✓	✓	✓
16	28/7			EC27FC-D				✓	✓	✓	✓
17	28/7			EC26FC-D				✓	✓	✓	✓
18	1/8			QC2				✓	✓	✓	✓
19	29/7			EC27FC-S				✓	✓	✓	✓
20	28/7			EC21FC-I				✓	✓	✓	✓
21				EC4C-S			✓				
22	29/7			EC21F			✓				
23	2/8			EC38D-1			✓				
24	29/7			EC32FC-BI			✓				
25	28/7			EC27FC-D			✓				
26	29/7			EC25FC-D			✓				

Remarks:

TOTAL 12

[illegible] Container Type and Preservative Codes: [illegible]

Courier details: Specify Turnaround time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

Form [illegible]

CHAIN OF CUSTODY FORM

Sheet 3 of 3

THIS COLUMN FOR LAB USE ONLY	FROM: URS AUSTRALIA; ACN [illegible] (insert your office address here)	DATE: 12/8/09 TO: ALS
Job Code:		
Due Date:	Phone: / Project No: 42907100 / Project Manager: [illegible] / Samplers:	Fax: / Sampler(s): / Checked:
Custody Seal Intact? YES / NO; Sample Cold? YES / NO	Released by URS by: / Date: / Time:	Received for Laboratory by: [illegible] / Date: 12-8 / Time: 1410

Container: Size, Type, Preservation and Analysis; Container Identification

Analyses: TOTAL METALS

Lab Identification	Date	Time	Matrix	Sample Number	Comments	Total no.	Test required as ticked
25	24.7			EO27FG-S			✓
26	24.7			EO26G-D			✓
27	24.7			EO26FG-S			✓
28	24.7			EO45-F			✓

Remarks:

TOTAL: 4

* Container Type and Preservative Codes: P = Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar; S = Solvent Washed Acid Rinsed Glass Bottle; HC = Hydrochloric Acid Preserved Vial; VS = Sulfuric Acid Preserved Vial; SS = Sulfuric Acid Preserved Glass Bottle; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle

Turnaround time: Specify Turnaround Time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet 3 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS (AUSTRALIA) [illegible]

DATE: 12/8/09

TO: ALS

Job Code:

Insert work office address here

Ph: Fax:

Due Date:

Project No: 42907[illegible]

Project Manager:

Sampled by:

Signature:

Courier:

Custody seal intact? Yes / No

Sample cold? Yes / No

Relinquished for URS by: Date: Time:

Received for Laboratory by: [illegible]

Date: 12-8 Time: 14:10

Container Size, Type, Preservative and Analysis

Container Identification

Lab identification	Date	Time	Matrix	Sample number	Comments	Total no	Total metals	TDS	EC	pH	Major Ions
1	3/8			EO 36C-S				✓	✓	✓	✓
2	7/8			EO 28G-S				✓	✓	✓	✓
3	7/8			EO 23G-I				✓	✓	✓	✓
4	1/8			EO 30G-I				✓	✓	✓	✓
5	1/8			EO 13FG-D				✓	✓	✓	✓
6	29/7			EO 14G-I				✓	✓	✓	✓
7	30/7			EO 05F				✓	✓	✓	✓
8	1/8			EO 13FG-S				✓	✓	✓	✓
9	29/7			EO 32FG-D				✓	✓	✓	✓
10	6/8			EO 28G-I				✓	✓	✓	✓
11	1/8			EO 30G-I			✓				
12	1/8			EO 30G-D			✓				

TOTAL: 12

Environmental Division Perth

Work Order

EP0904516

Telephone: [illegible]

Container and Preservative Codes: [illegible]

Relinquished Time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet 2 of 3

THIS COLUMN FOR LAB USE ONLY

FROM URS AUSTRALIA

DATE 12/5/04

TO: ALS

Project No: 42906003

Analyses: TOTAL METALS

Received by Laboratory by: [illegible]

Date: 12-5 Time: 1410

Lab identification	Date	Time	Matrix	Sample Number	Comments	Total No.	Tick required analyses
13	11/8			GC01			✓
14	6/8			EC28G-S			✓
15	24/7			EC24FG-I			✓
16	8/7			EC28G-S			✓
17	31/8			EC44G-D			✓
18	25/7			EC27FG-I			✓
19	24/7			EC14G-DI			✓
20	28/7			EC26D-S			✓
21	1/8			EC23FG-D			✓
22	28/7			EC30FG-D			✓
23	3/8			EC36G-S			✓
24	7/8			EC28G-I			✓

Remarks:

TOTAL 12

* Container Type and Preservation Codes: [illegible]

Specify Turnaround Times

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet 3 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS AUSTRALIA

DATE: 12/8/09

TO: ALS

Job No: 4290 ...

Total Metals

ID	Date	Sample Number	Total Metals
25	1/8	EQ23FG-S	✓
26	1/8	EQ25FG-T	✓
27	1/8	QC02	✓

TOTAL: 3

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet 3 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS [illegible]

DATE: 12/8/09

TO: ALS

Job Code: [illegible]

Due Date:

Project No.: 42907000

Project Manager: [illegible]

Cooler seal intact? Yes

Sample cold? Yes

Received for Laboratory by: [illegible]

Date: 12-8

Time: 14:10

Container Size, Type, Preservative and Analyses

Lab Identification	Date	Time	Matrix	Sample Number	Comments	Total No.	Total Metals	TDS	EC	pH	Major Ions
1	3/8			EO 36C-S				✓	✓	✓	✓
2	7/8			EO 28C-S				✓	✓	✓	✓
3	7/8			EO 28G-I				✓	✓	✓	✓
4	1/8			EO 30G-I				✓	✓	✓	✓
5	1/8			EO 13FG-D				✓	✓	✓	✓
6	29/7			EO 14G-I				✓	✓	✓	✓
7	[illegible]			EO OSF				✓	✓	✓	✓
8	1/8			EO 13FG-S				✓	✓	✓	✓
9	29/7			EO 32FG-D				✓	✓	✓	✓
10	6/8			EO 28G-I				✓	✓	✓	✓
11	1/8			EO 30G-I			✓				
12	1/8			EO 30G-D			✓				
					TOTAL:	12					

Environmental Division Perth

Work Order

EP0904516

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet 2 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS AUSTRALIA

DATE: 12/8/09

TO: ALS

Project No.: 42906100

Project Manager: [illegible]

Relinquished to Laboratory by: [illegible]

Date: 12-8 Time: 1410

Analysis: TOTAL METALS

Lab Identification	Date	Time	Matrix	Sample Number	Comments	Total No.	Tick required analyses
13	11/8			GC01			✓
14	6/8			EC28G-S			✓
15	[illegible]			EC24FG-I			✓
16	5/7			EC28G-S			✓
17	3/8			EC44G-D			✓
18	25/7			EC27FG-I			✓
19	24/7			EC14G-DI			✓
20	23/7			EC4D-S			✓
21	1/8			EC23FG-D			✓
22	26/7			EC37FG-D			✓
23	3/8			EC36G-S			✓
24	7/8			EC28G-I			✓

Remarks:

TOTAL 12

* Container Type and Preservative Codes: P = Neutral Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar; S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS = Sulfuric Acid Preserved Vial; BS = Sulfuric Acid Preserved Glass Bottle; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle

Specify Turnaround Time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet 3 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS AUSTRALIA

DATE: 12/8/09

TO: ALS

Project No: 4290 1100

Analyses: TOTAL METALS

Lab Identification	Date	Time	Sample Number	Total No.	Test required analyses
25	11/8		EG23FG-S		✓
26	11/8		EG23FG-T		✓
27	11/8		QCO2		✓

TOTAL 3

Remarks

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet: 1 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS AUSTRALIA [illegible]

DATE: 12/8/09 TO: ALS

Project No: 42907:50

Project Manager: Sam Taggart

Custody seal intact? Yes / No

Sample cold? Yes / No

Received for laboratory by: Linda W

Date: 12-8 Time: 1410

Analyses: TDS, EC, pH, Major Ions

Lab identification	Date	Time	Matrix	Sample Number	Containers	TDS	EC	pH	Major Ions
1	[illegible]			E005G-P		✓	✓	✓	✓
2	[illegible]			E02[illegible]FC-1		✓	✓	✓	✓
3	[illegible]			E015FC-S		✓	✓	✓	✓
4	[illegible]			E014G-F		✓	✓	✓	✓
5	[illegible]			E044G-D		✓	✓	✓	✓
6	[illegible]			E018G-S		✓	✓	✓	✓
7	[illegible]			E015FG-I		✓	✓	✓	✓
8	[illegible]			E005G-I		✓	✓	✓	✓
9	[illegible]			[illegible] FG-I		✓	✓	✓	✓
10	[illegible]			E014G-S		✓	✓	✓	✓
11	[illegible]			E02-F		✓	✓	✓	✓
12	[illegible]			E030G-D		✓	✓	✓	✓

Remarks:

TOTAL: 12

Environmental Division Perth

Work Order

EP0904517

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

CHAIN OF CUSTODY FORM

Sheet 2 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS (AUSTRALIA) [illegible]

DATE: 12/8/09 TO: ALS

Job Code:

Due Date:

Project No: 42907-CC

Project Manager: [illegible]

Custody seal intact? YES / NO

Sample cold? YES / NO

Released by: Date: Time:

Received by Laboratory: CW Date: 12-8 Time: [illegible]

Container Size, Type, Preservative and Analysis

Container Identification

Analyses: TOTAL METALS, TDS, EC, pH, Major Ions

Lab Identification	Date	Time	Matrix	Sample Identification	Comments	Total No	TOTAL METALS	TDS	EC	pH	Major Ions
[illegible]	27/7			EC22 FC-S				✓	✓	✓	✓
[illegible]	28/7			EC27FC-D				✓	✓	✓	✓
[illegible]	29/7			EC26FC-D				✓	✓	✓	✓
[illegible]	[illegible]/8			[illegible]				✓	✓	✓	✓
[illegible]	[illegible]/7			EC27 FC-S				✓	✓	✓	✓
[illegible]	28/7			EC21 FC-I				✓	✓	✓	✓
[illegible]				EC4C-S			✓				
[illegible]	29/7			EC21F			✓				
[illegible]	[illegible]/8			EC28D-1			✓				
[illegible]	29/7			EC32FC-DI			✓				
[illegible]	28/7			EC27FC-D			✓				
[illegible]	29/7			EC25FC-D			✓				

Remarks:

TOTAL 12

Container Type and Preservative Codes: [illegible]

Courier Details:

Specify Turnaround time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

[illegible]

CHAIN OF CUSTODY FORM

Sheet 3 of 3

THIS COLUMN FOR LAB USE ONLY

FROM: URS AUSTRALIA, ACN 000 691 690, [Insert your office address here]

DATE: 12/8/09 TO: ALS

Job Code:

Due Date:

Phone: Fax:

Project No.: 42907100 Sampler(s):

Project Manager: N. O'Toole Shipment:

Condition: Checked:

Custody Seal Intact? YES / NO

Sample Cold? YES / NO

Received by Lab: Date: Time:

Released for Laboratory by: [illegible] Date: 12-8 Time: 1410

Analyses: TOTAL METALS

Container Size, Type, Preservation and Analysis — Container Identification

Lab Identification	Date	Time	Matrix	Sample Number	Comments	Total no.	Tick required analyses (TOTAL METALS)
25	26/7			EO27FG-S			✓
26	24/7			EO26G-D			✓
27	28/7			EO24FG-S			✓
28	29/7			EO24G-F			✓

Remarks:

TOTAL: 4

* Container Type and Preservative Codes: [illegible]

Turnaround Time: Specify Turnaround Time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

F

Appendix F EC Profiles Phase 1 and Phase 2

42907466/WHST-STU-WA-RPT-0090/0

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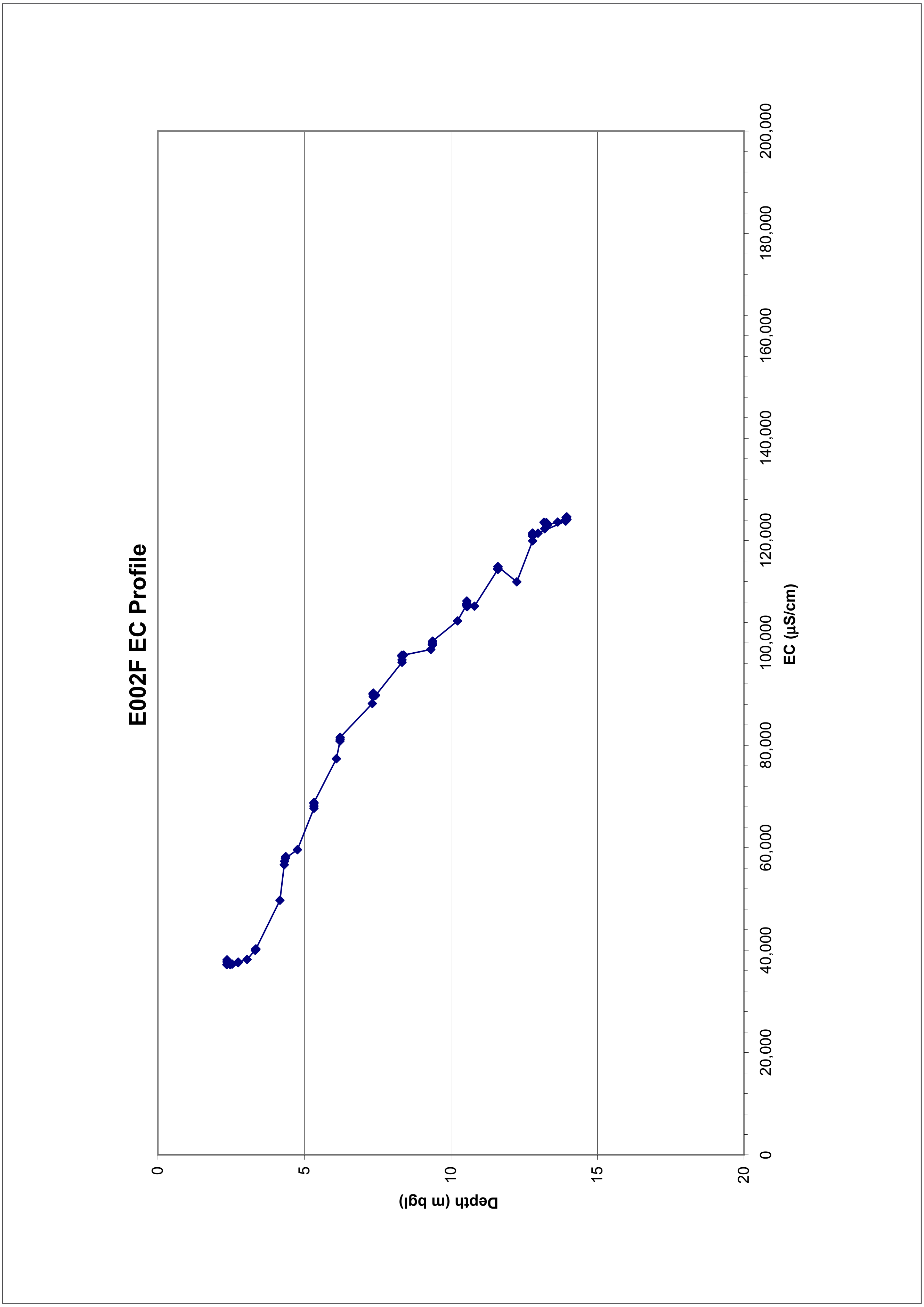

E002F EC Profile
Depth (m bgl)
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5
10
15
20
EC (µS/cm)
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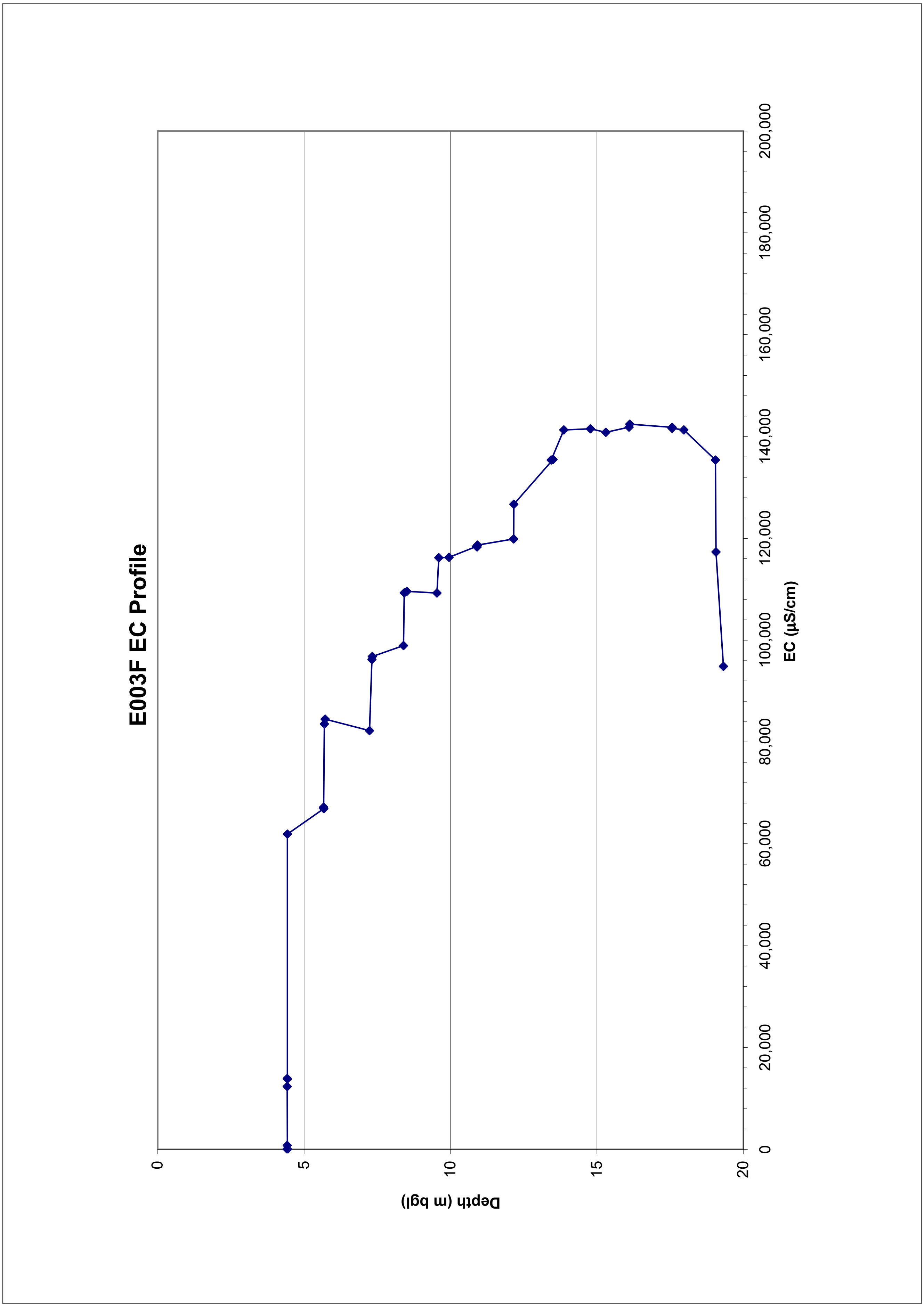
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000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10
15
20
EC (µS/cm)
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40,000
60,000
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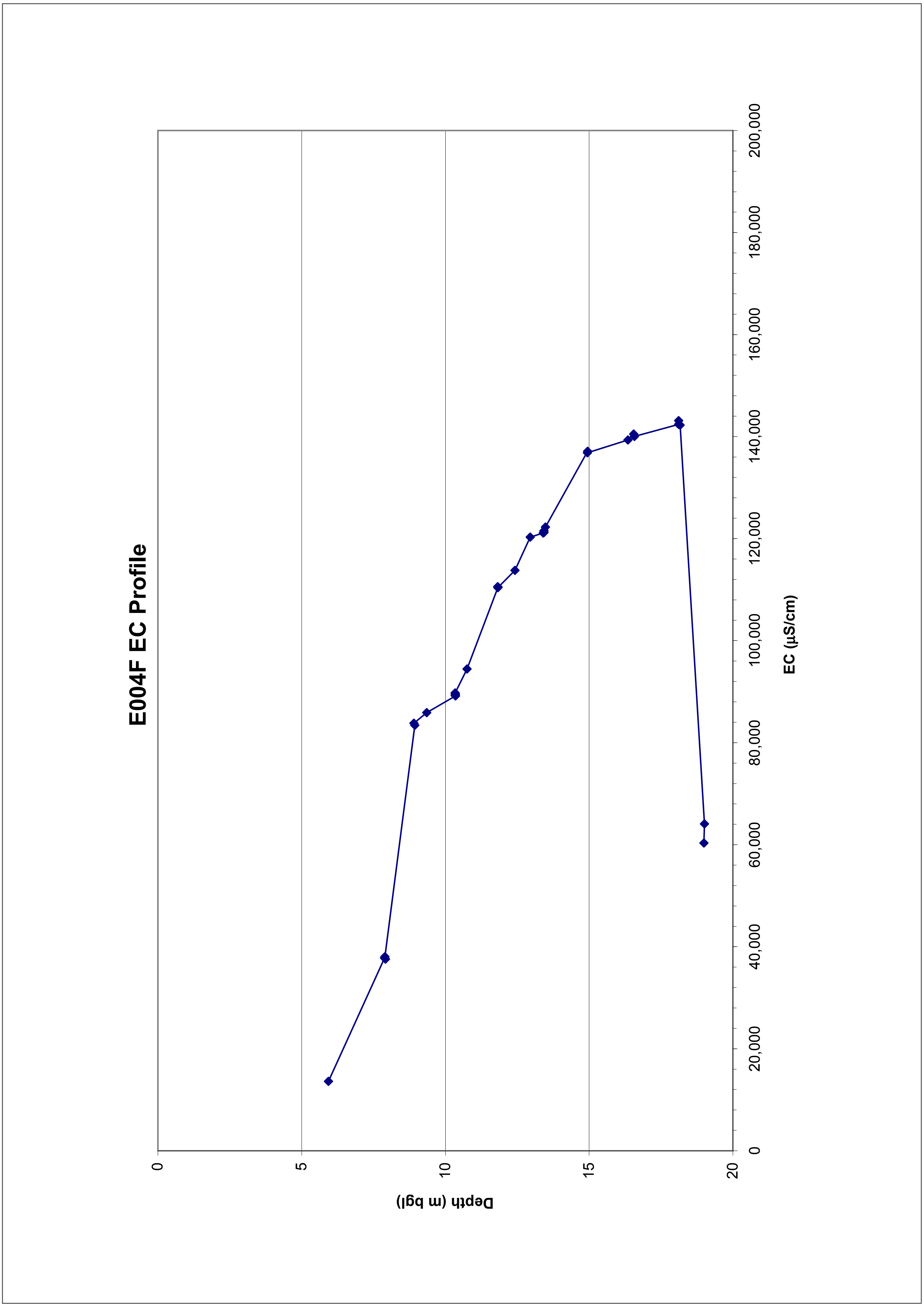
160,000
180,000
200,000


E004F EC Profile
EC (µS/cm)
Depth (m bgl)
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20,000
40,000
60,000
80,000
100,000
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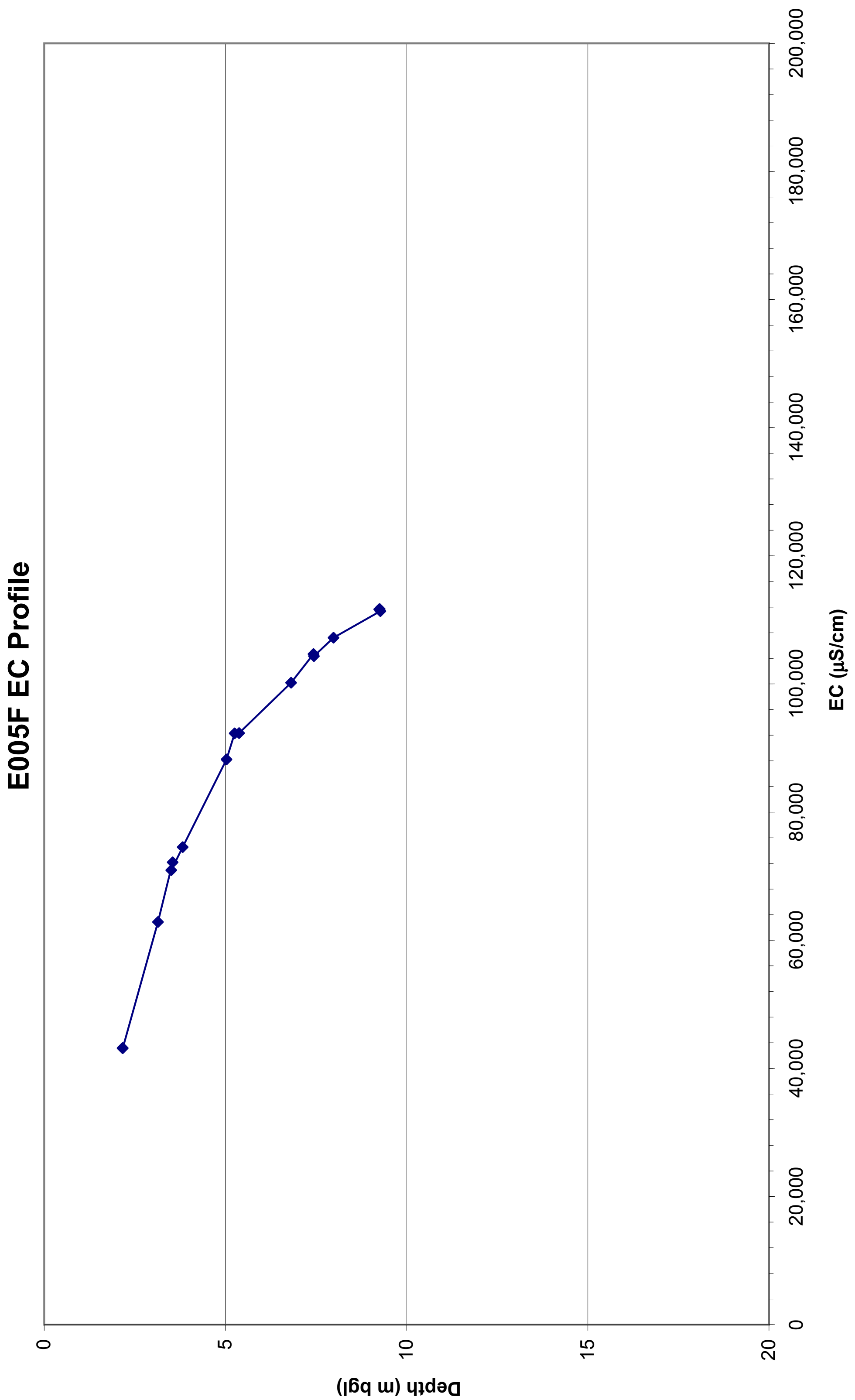
140,000
160,000
180,000
200,000
0
5
10
15
20


E005F EC Profile
EC (µS/cm)
Depth (m bgl)
0
20,000
40,000
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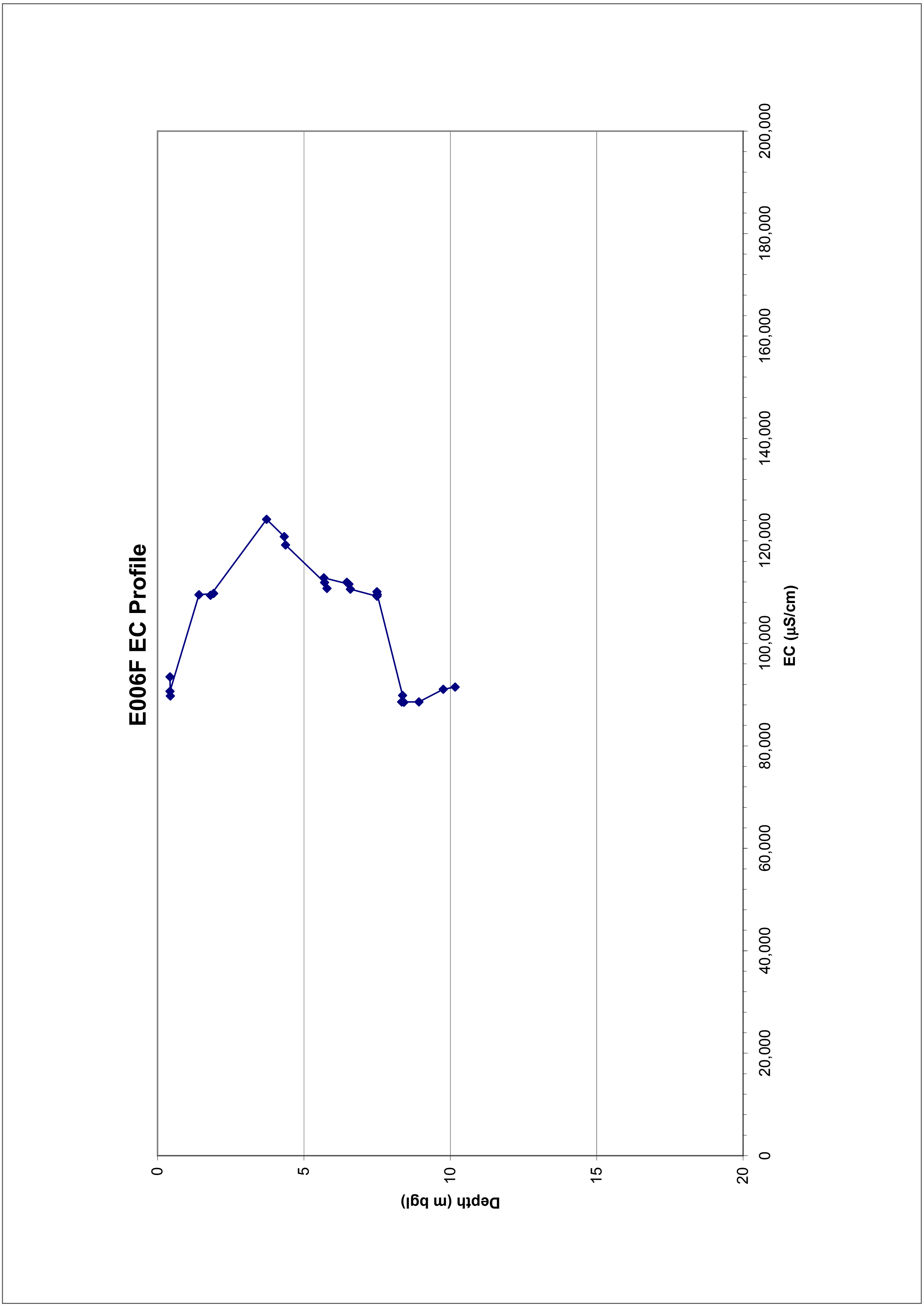
10
15
20


E006F EC Profile
Depth (m bgl)
EC (µS/cm)
0
5
10
15
20
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20,000
40,000
60,000
80,000
100,000
120,000
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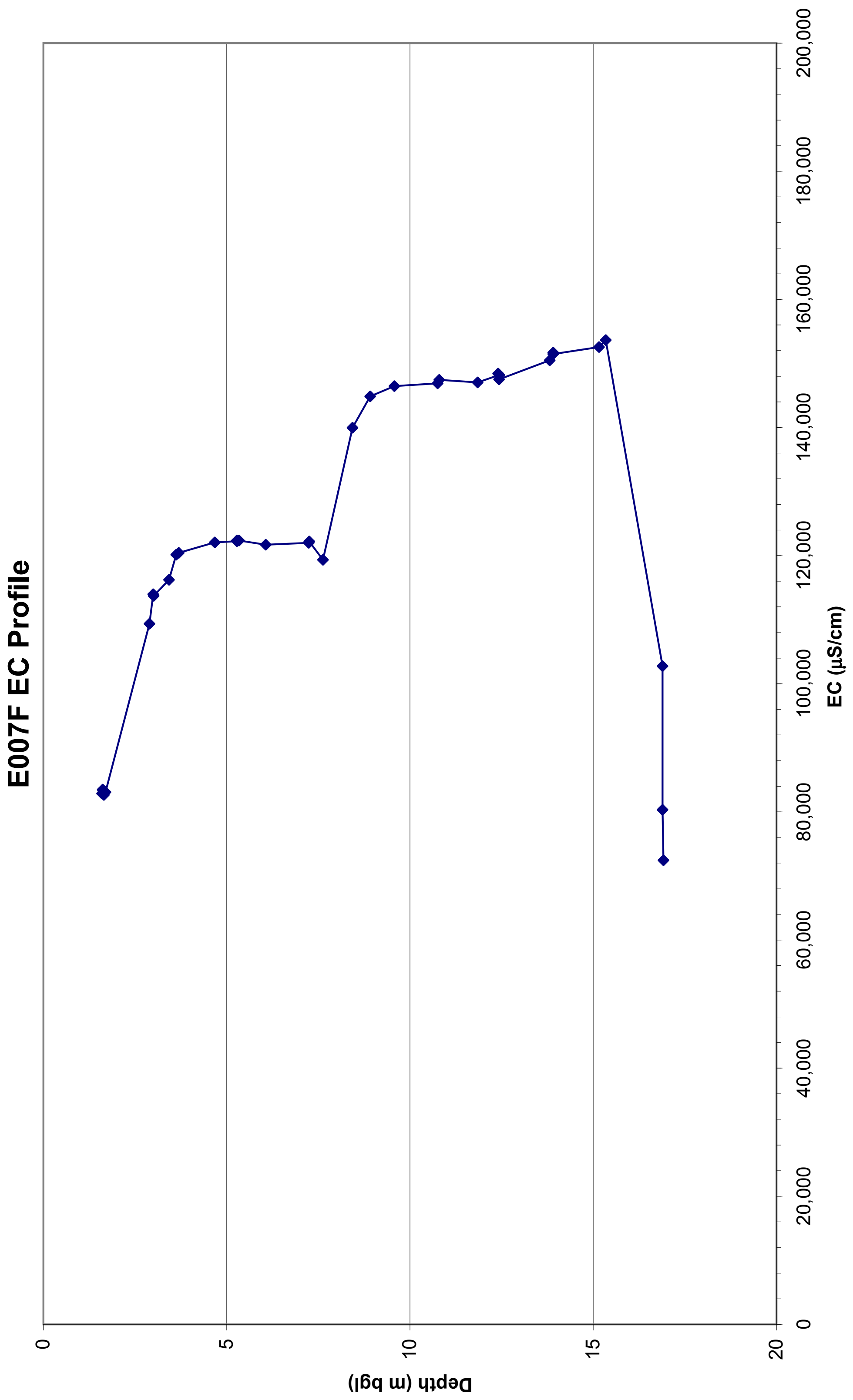
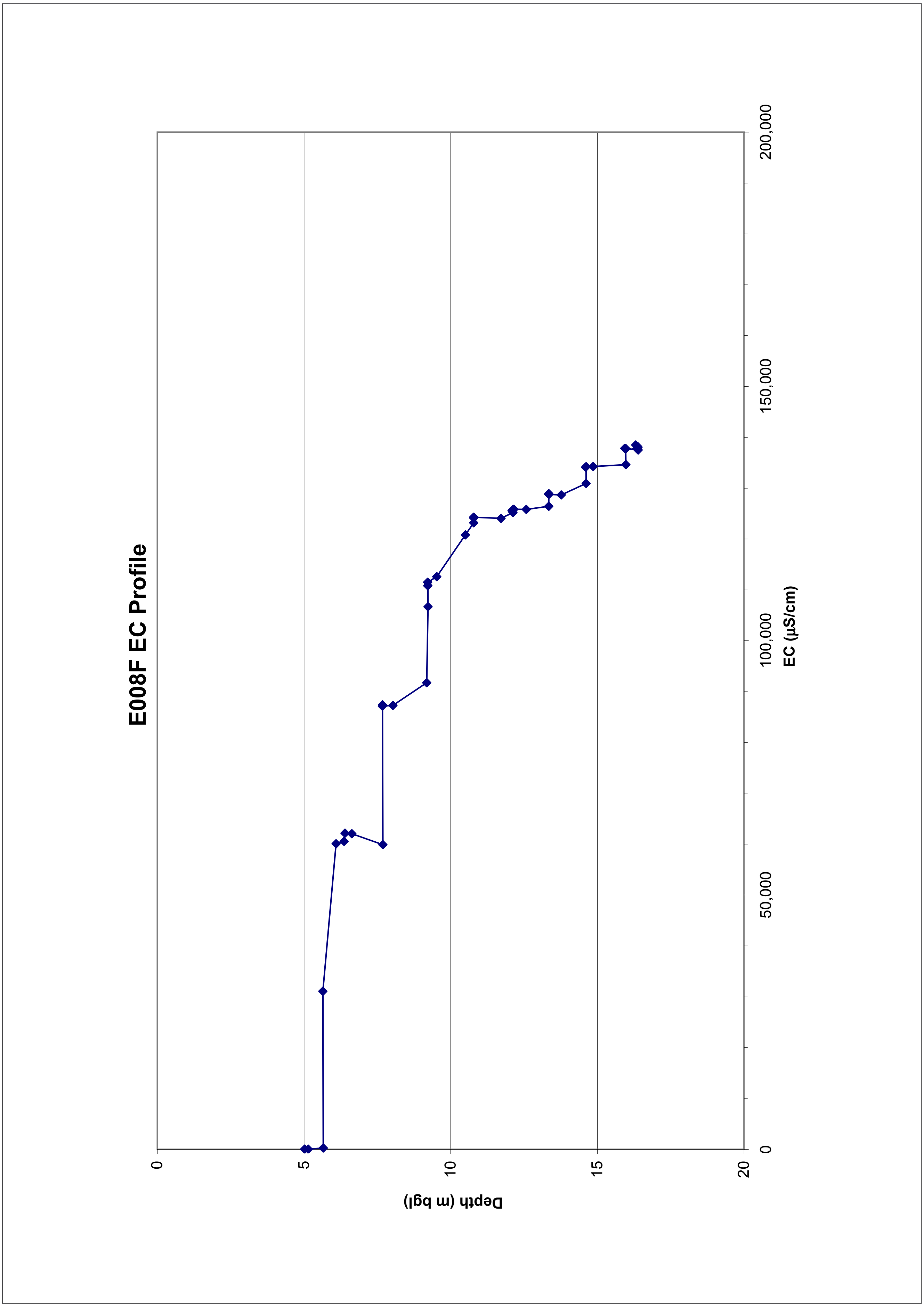
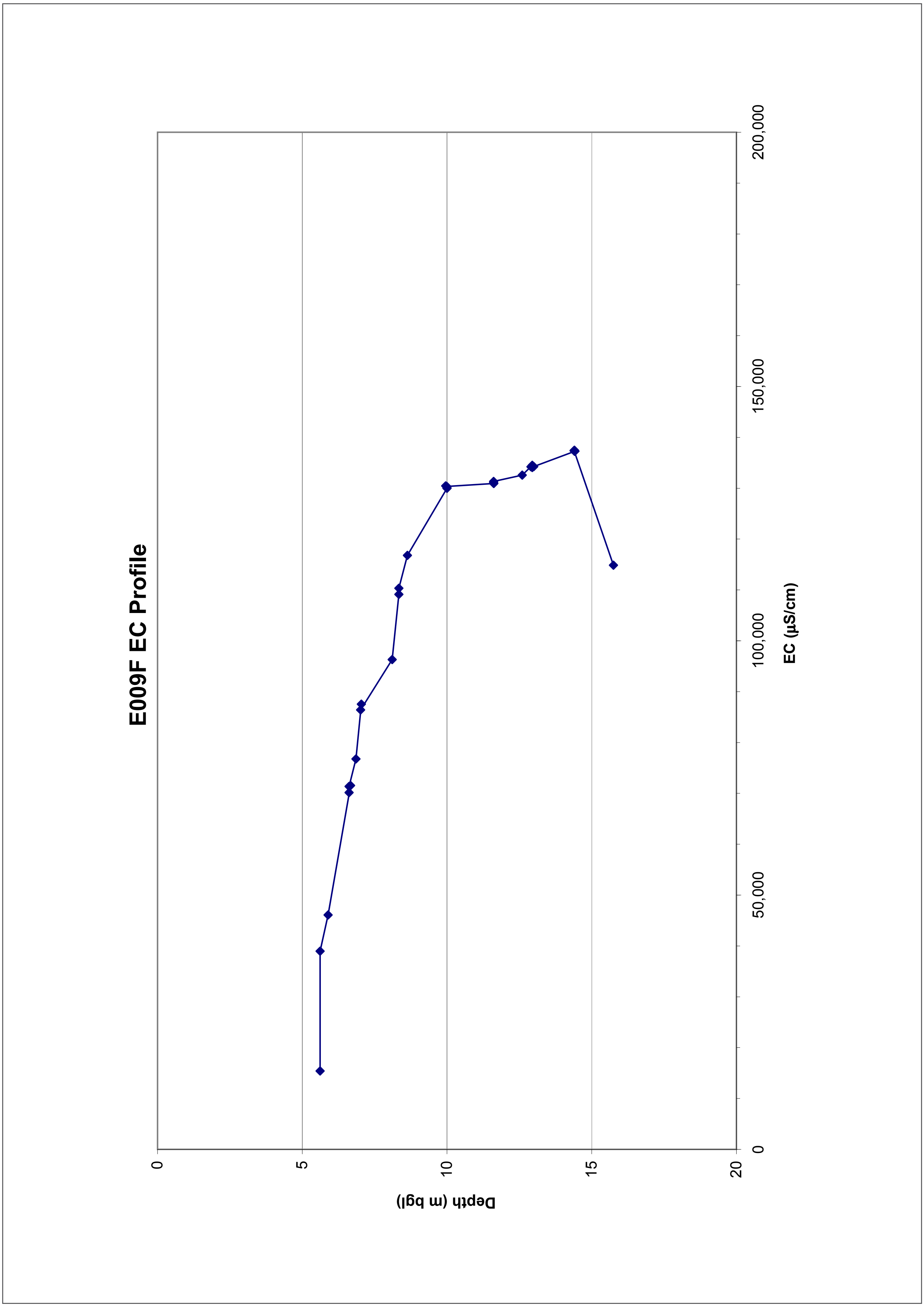
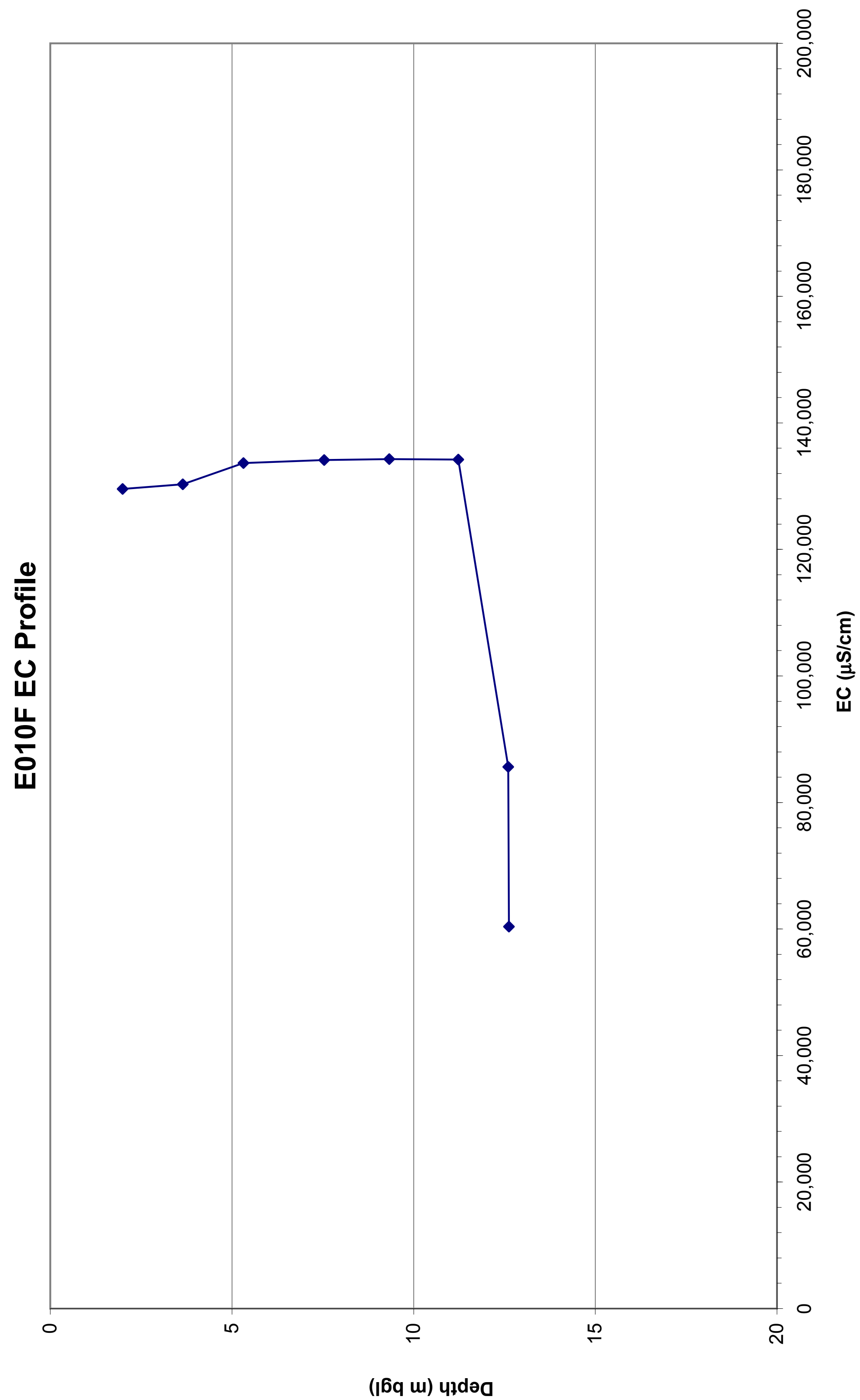
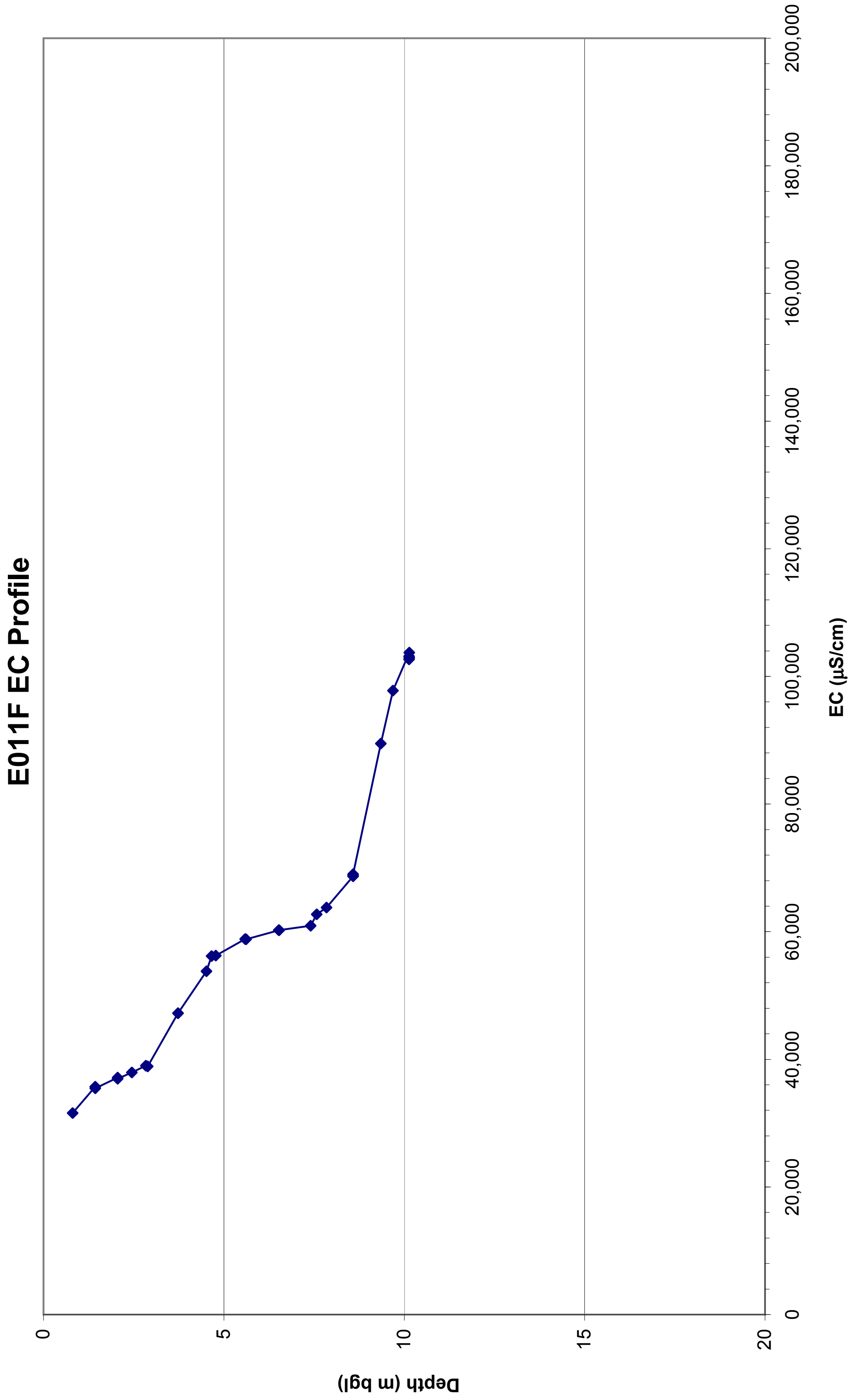
160,000
180,000
200,000

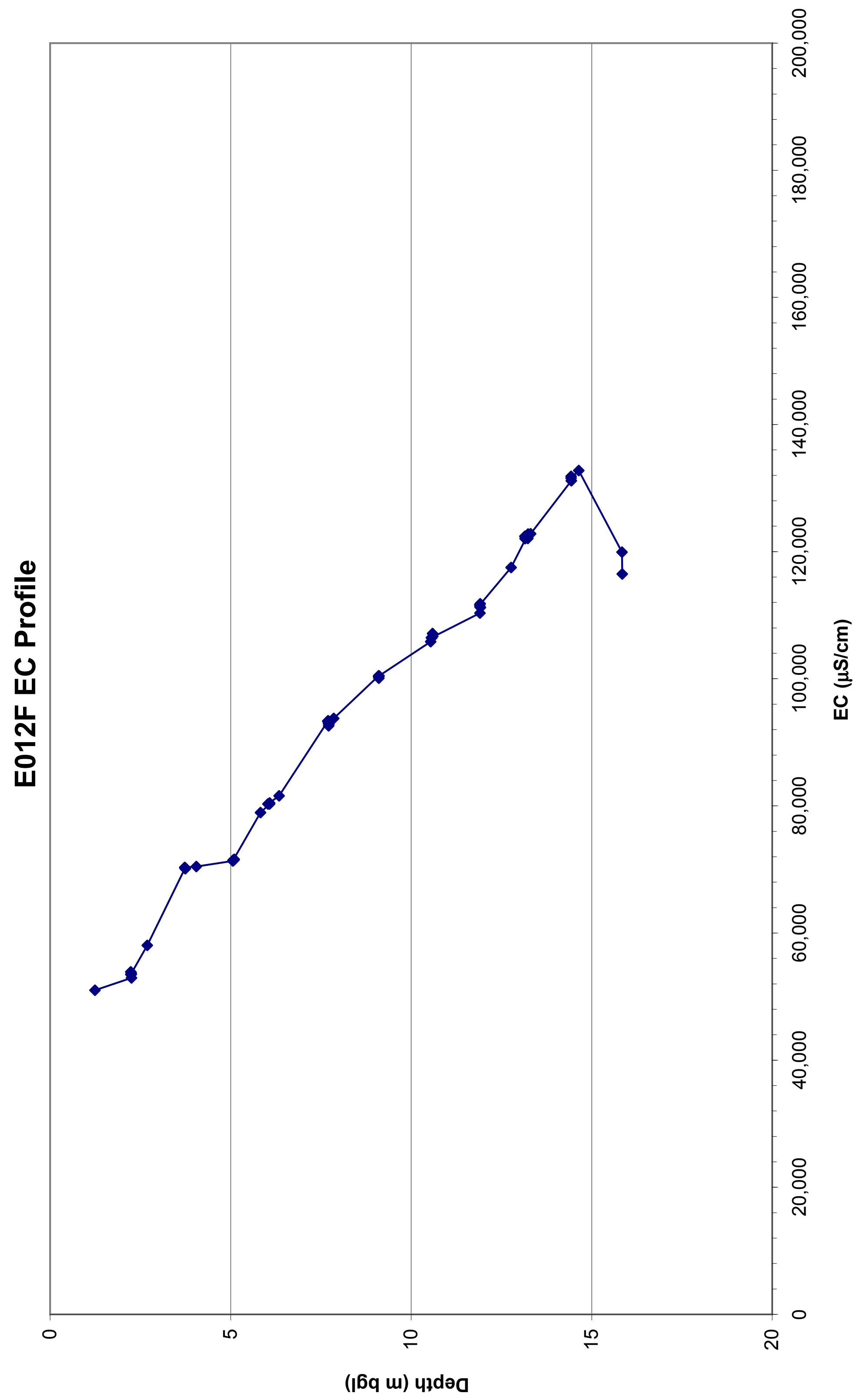

E007F EC Profile
EC (µS/cm)
Depth (m bgl)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
0
5
10
15
20


E008F EC Profile
Depth (m bgl)
0
5
10
15
20
EC (µS/cm)
0
50,000
100,000
150,000
200,000

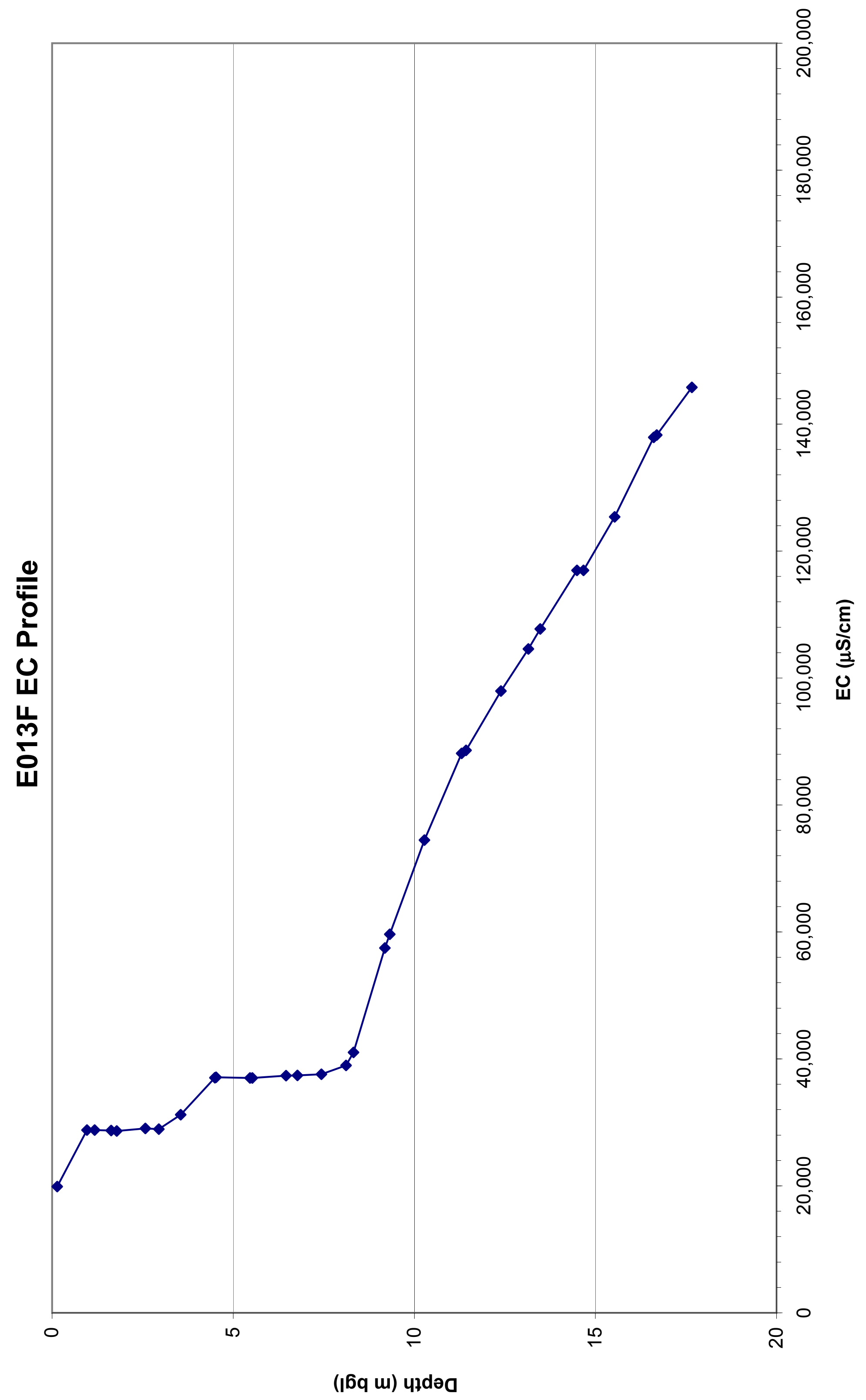

E009F EC Profile
EC (µS/cm)
Depth (m bgl)
0
50,000
100,000
150,000
200,000
0
5
10
15
20

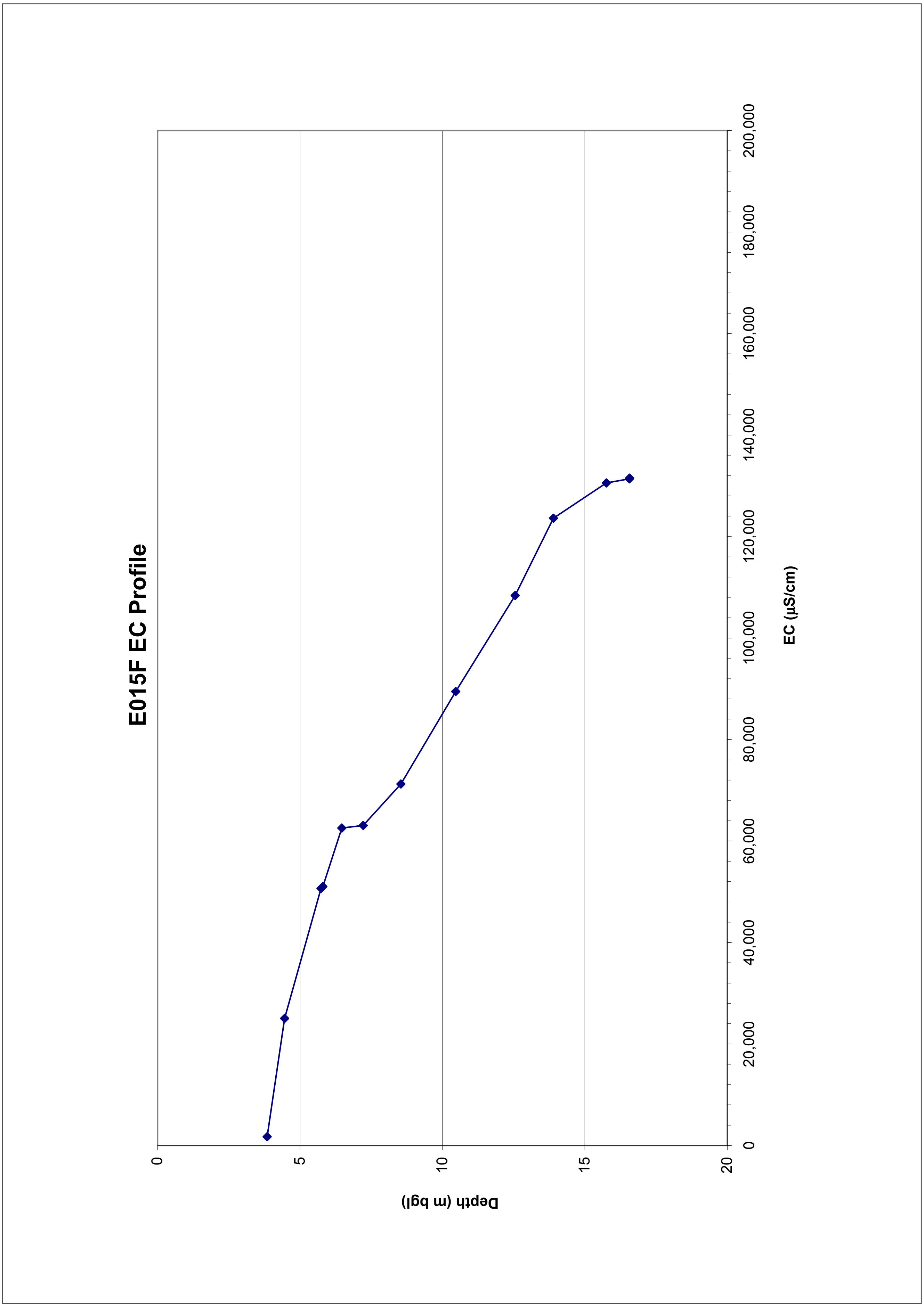

E010F EC Profile
EC (µS/cm)
Depth (m bgl)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
0
5
10
15
20

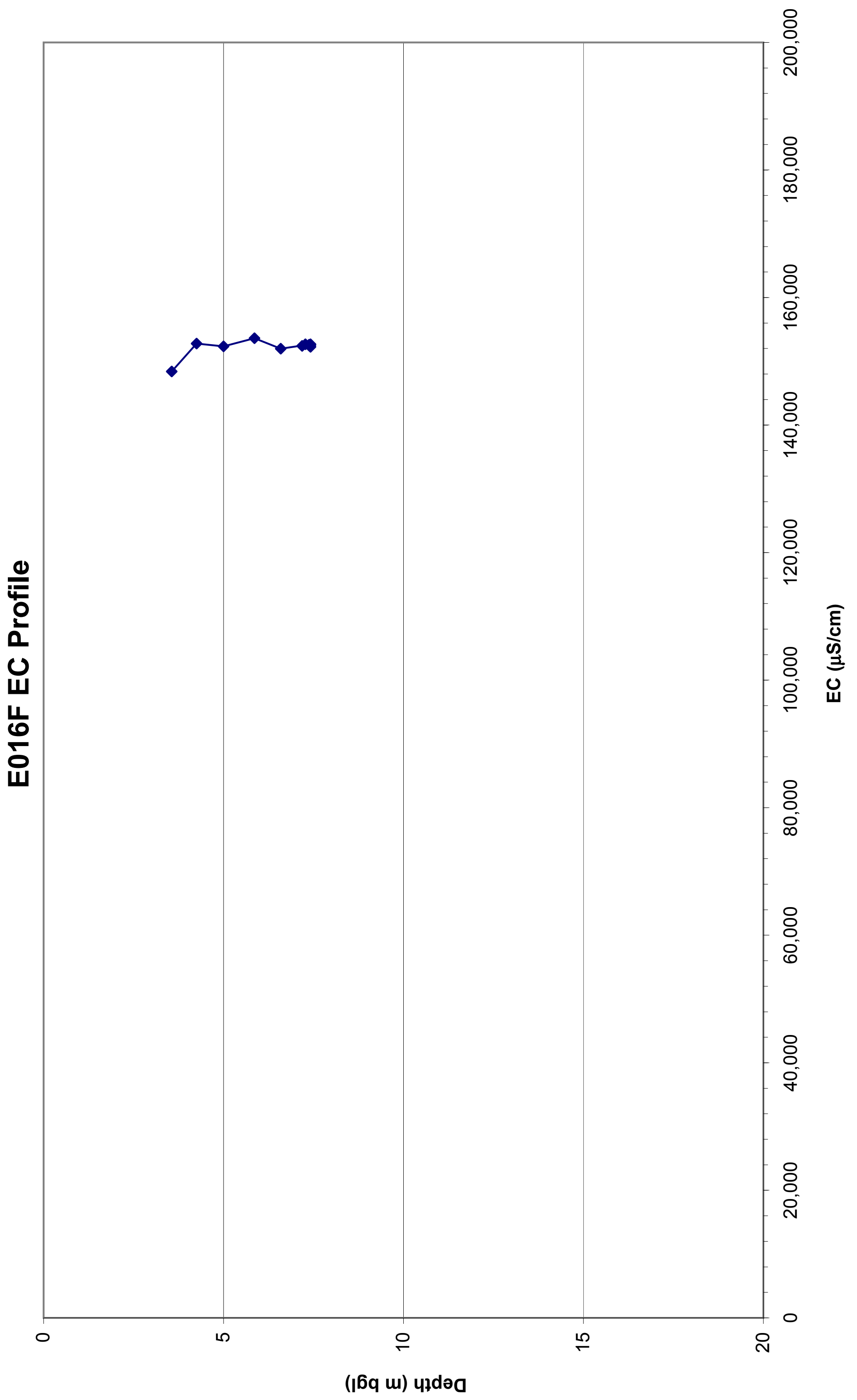

E011F EC Profile
Depth (m bgl)
0
5
10
15
20
EC (µS/cm)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000

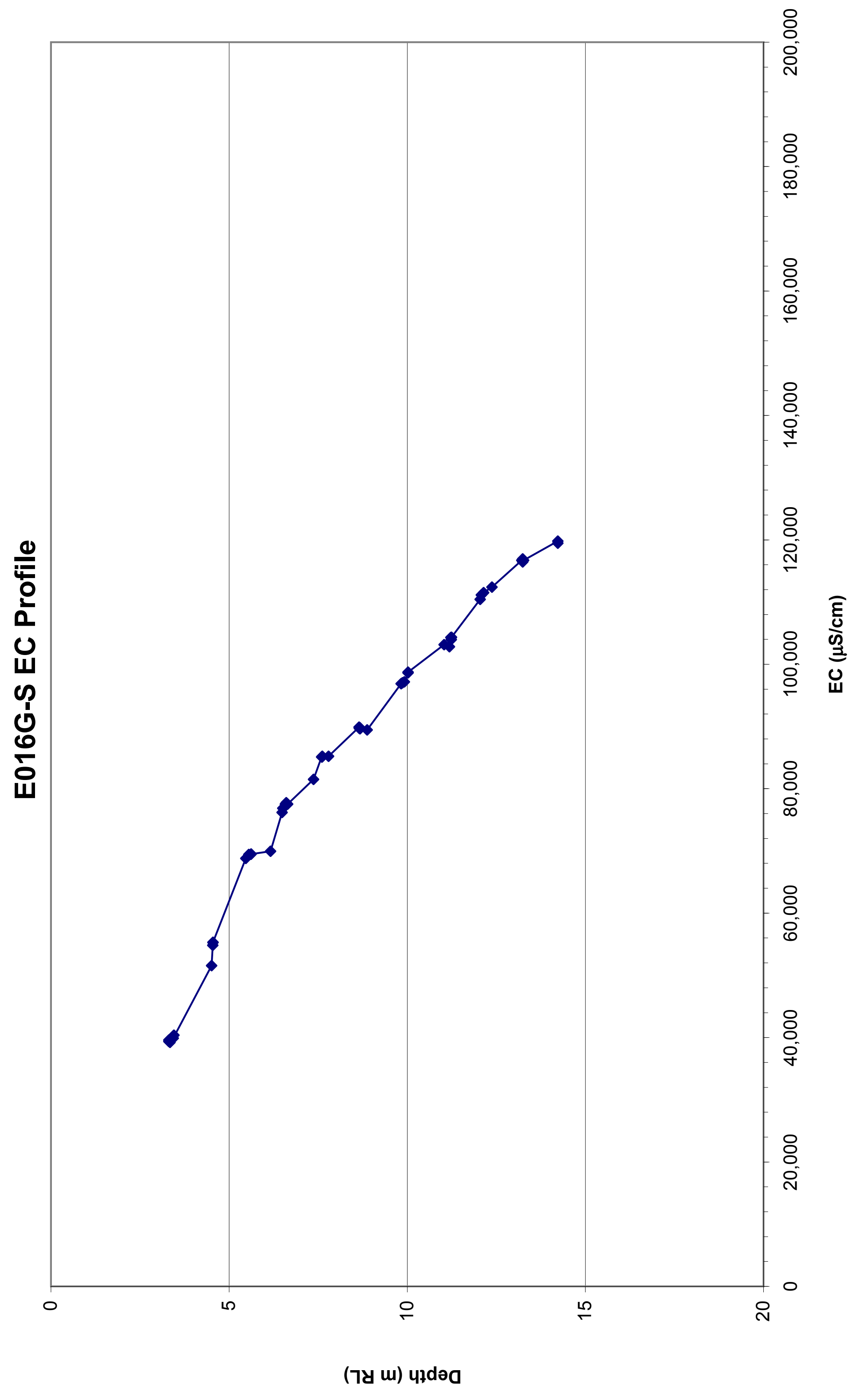


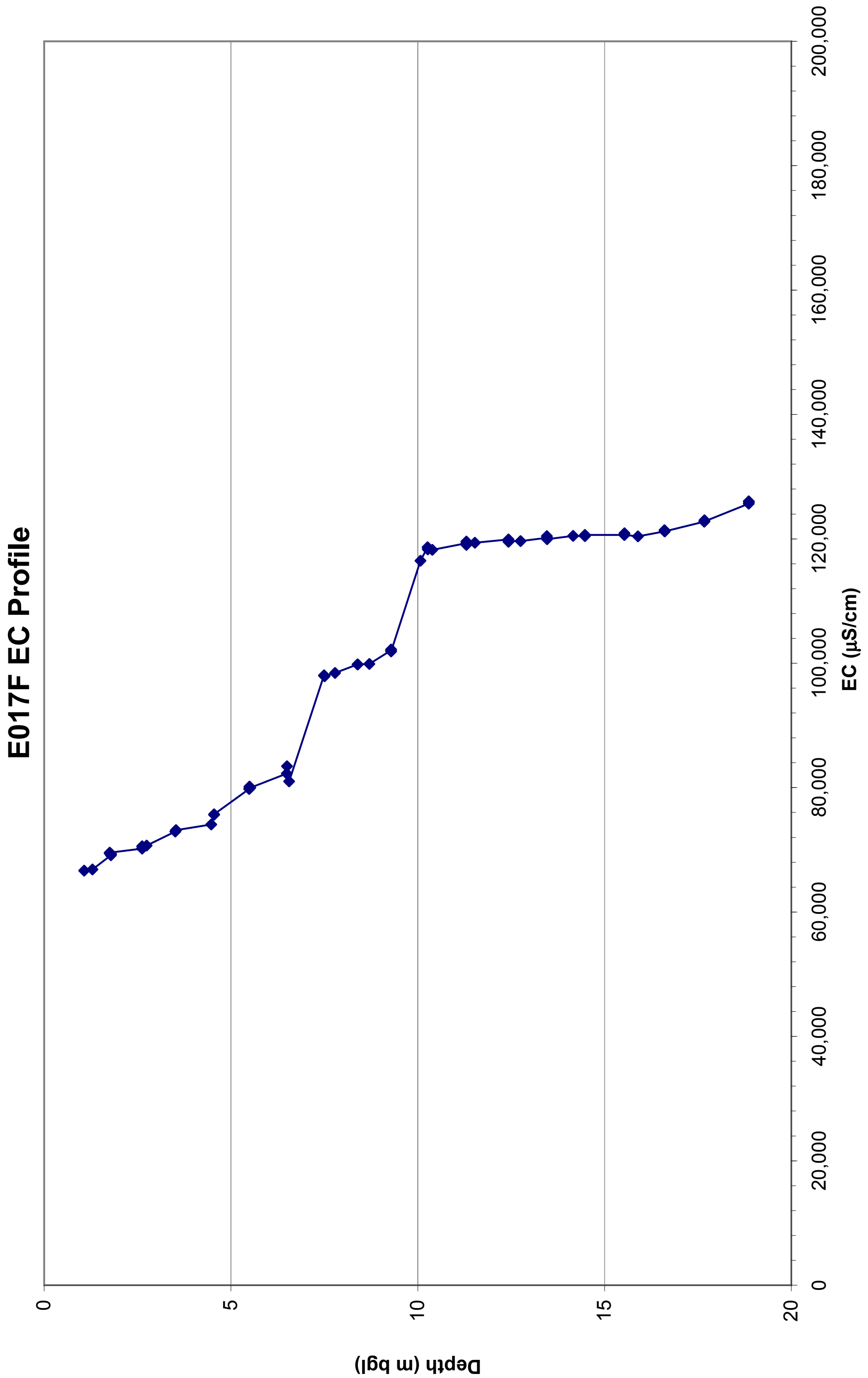
E012F EC Profile
Depth (m bgl)
0
5
10
15
20
EC (µS/cm)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000

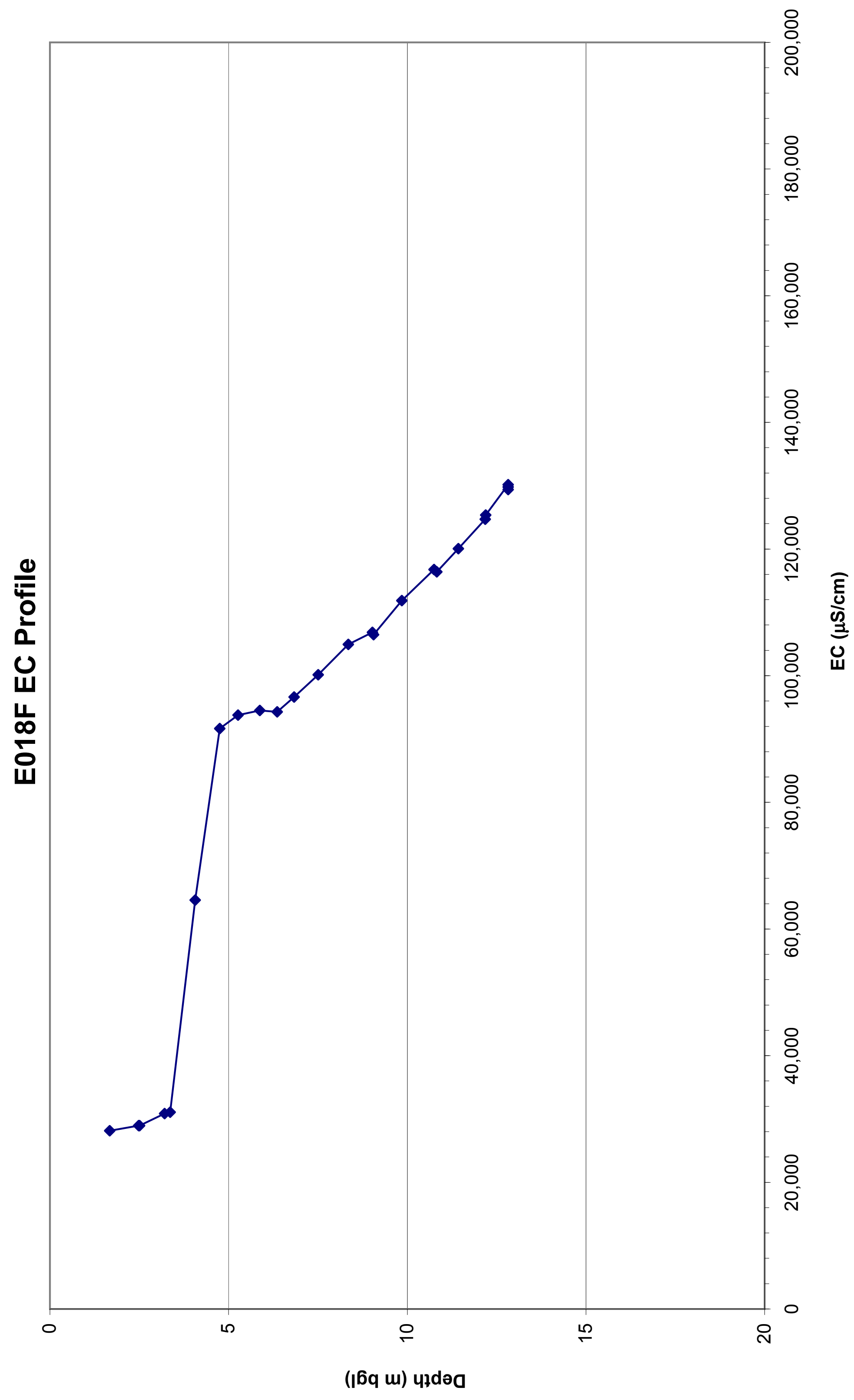

E013F EC Profile
Depth (m bgl)
0
5
10
15
20
EC (µS/cm)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000

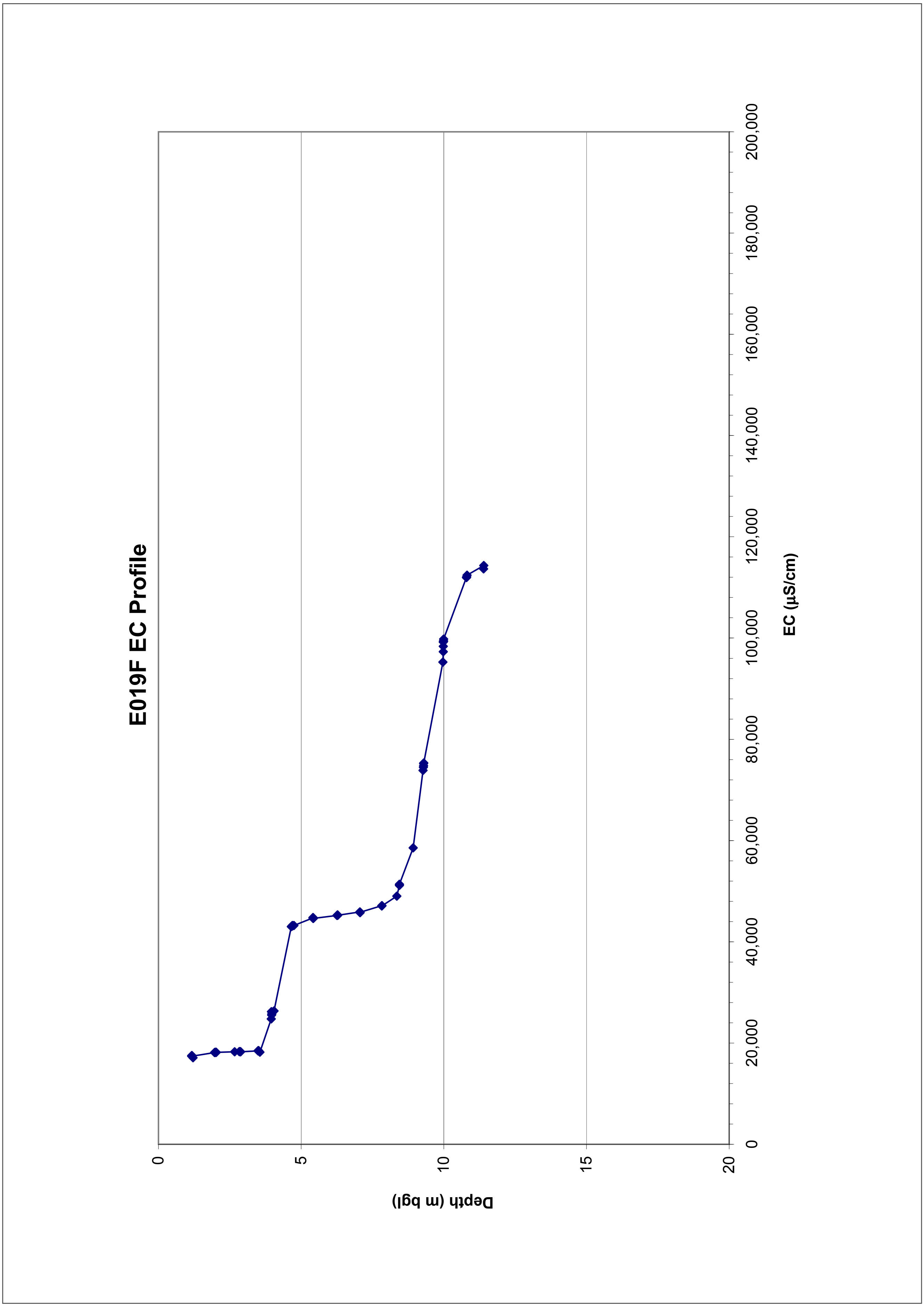

E015F EC Profile
EC (µS/cm)
Depth (m bgl)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
0
5
10
15
20

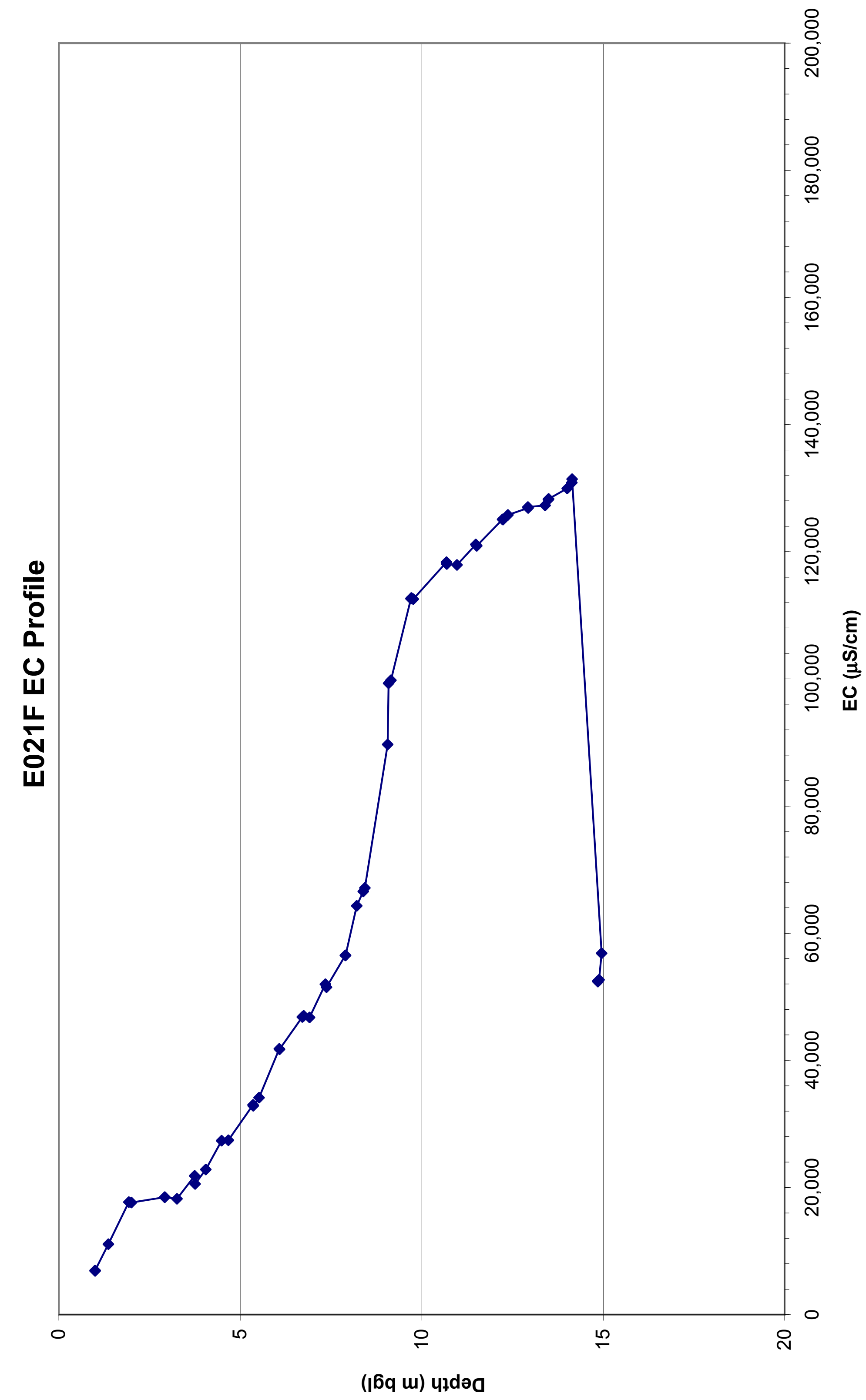

E016F EC Profile
EC (µS/cm)
Depth (m bgl)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
0
5
10
15
20


E016G-S EC Profile
Depth (m RL)
0
5
10
15
20
EC (µS/cm)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000

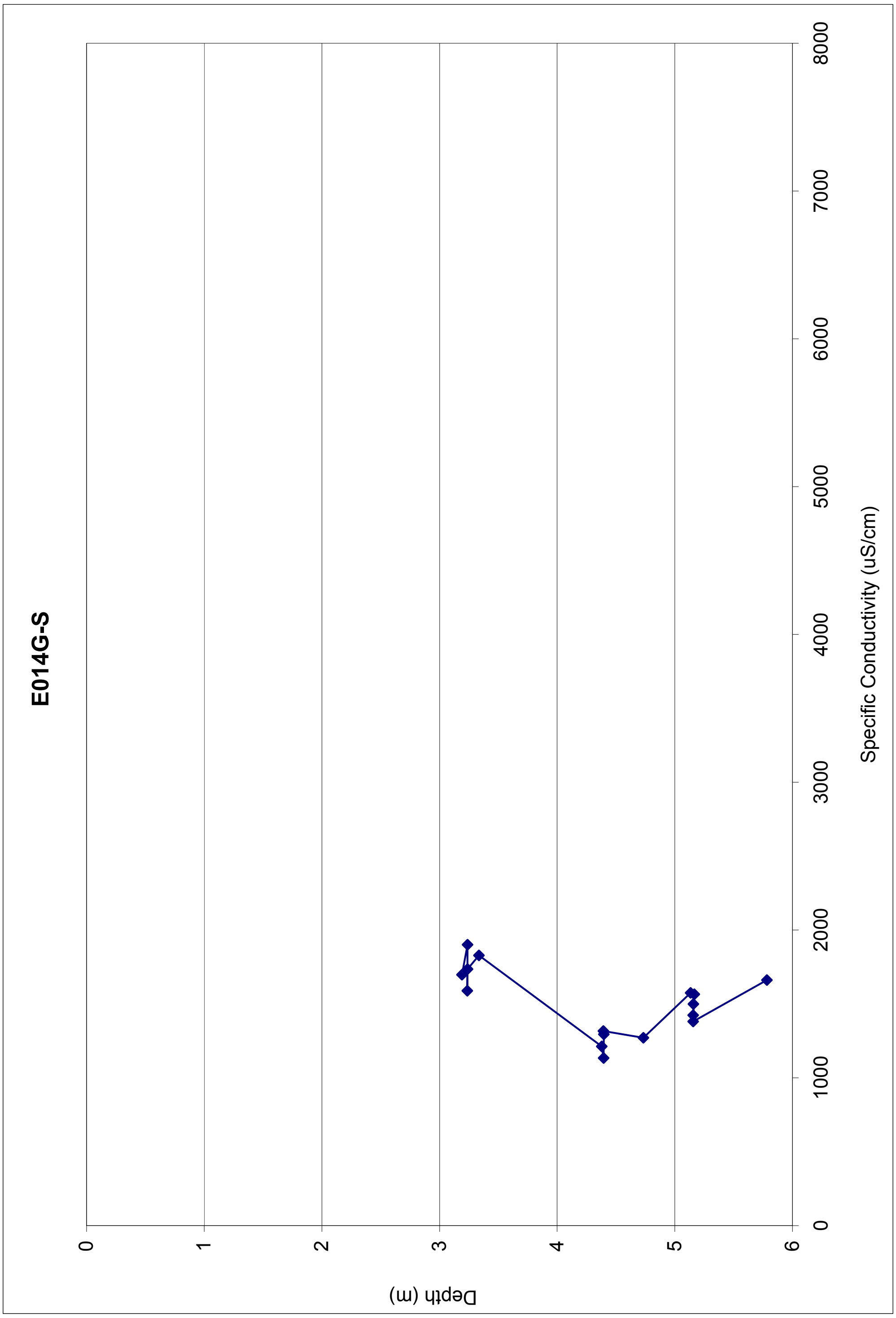

E017F EC Profile
EC (µS/cm)
Depth (m bgl)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
0
5
10
15
20

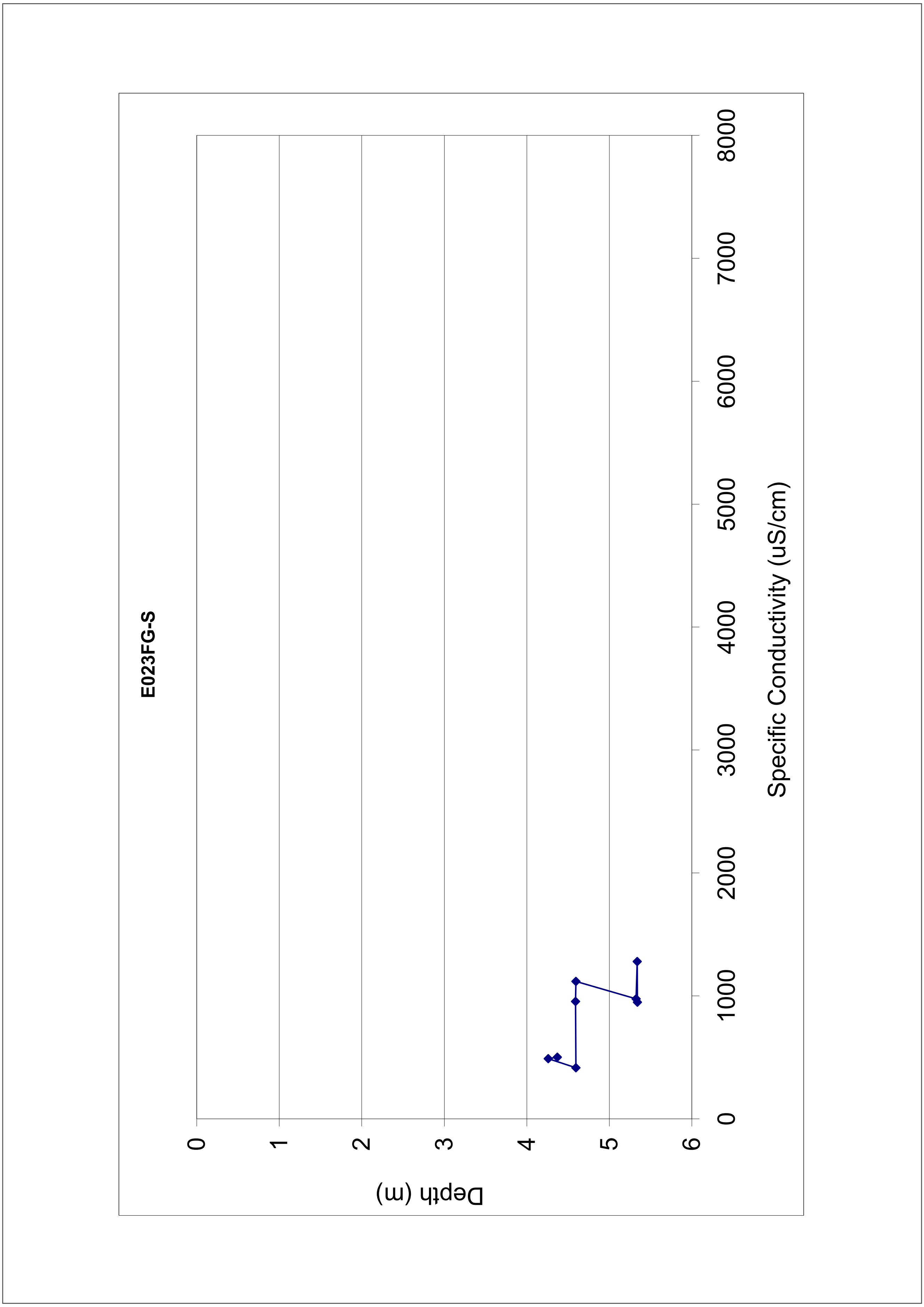

E018F EC Profile
Depth (m bgl)
0
5
10
15
20
EC (µS/cm)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000

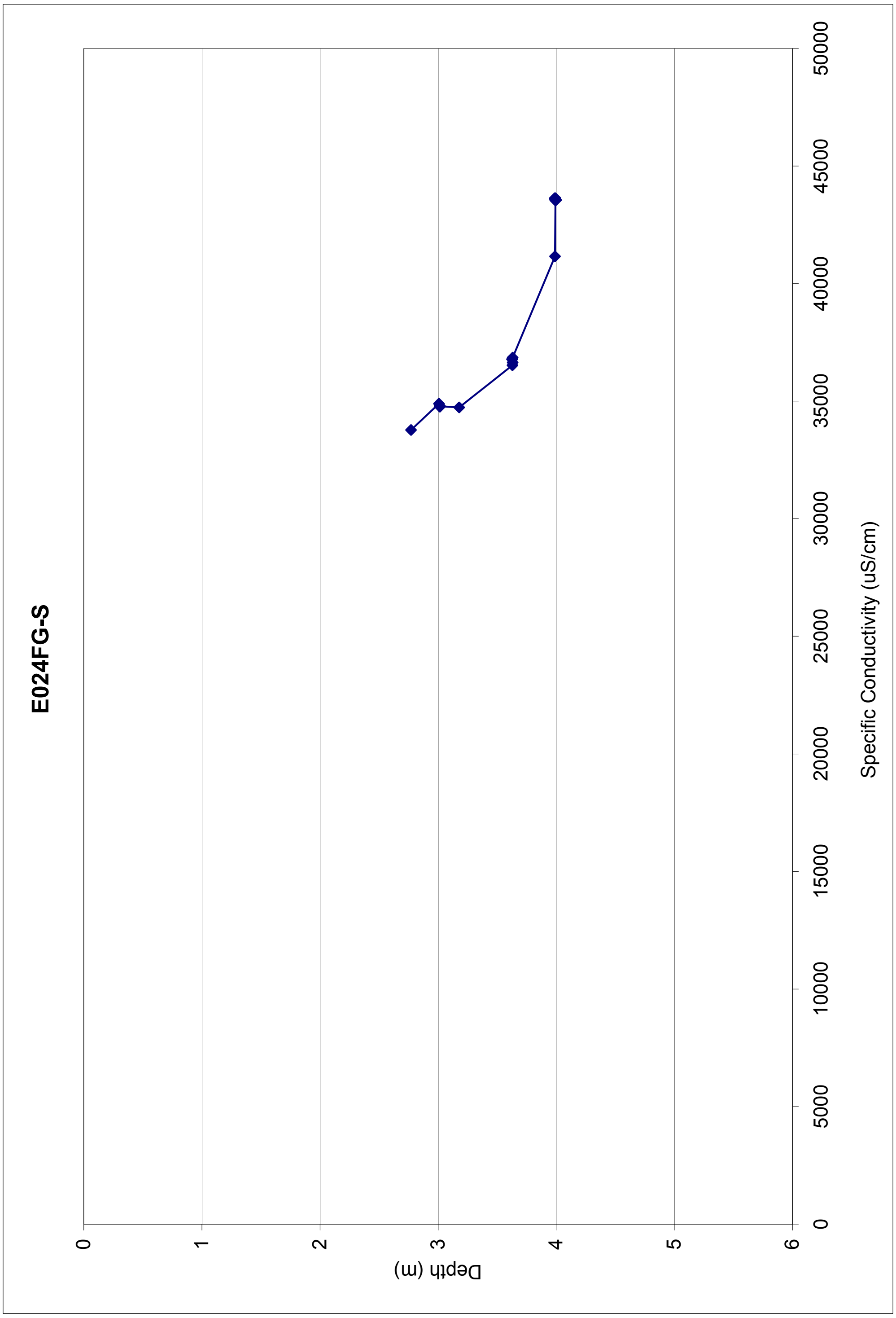

E019F EC Profile
EC (µS/cm)
Depth (m bgl)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
0
5
10
15
20


E021F EC Profile
EC (µS/cm)
Depth (m bgl)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
200,000
0
5
10
15
20

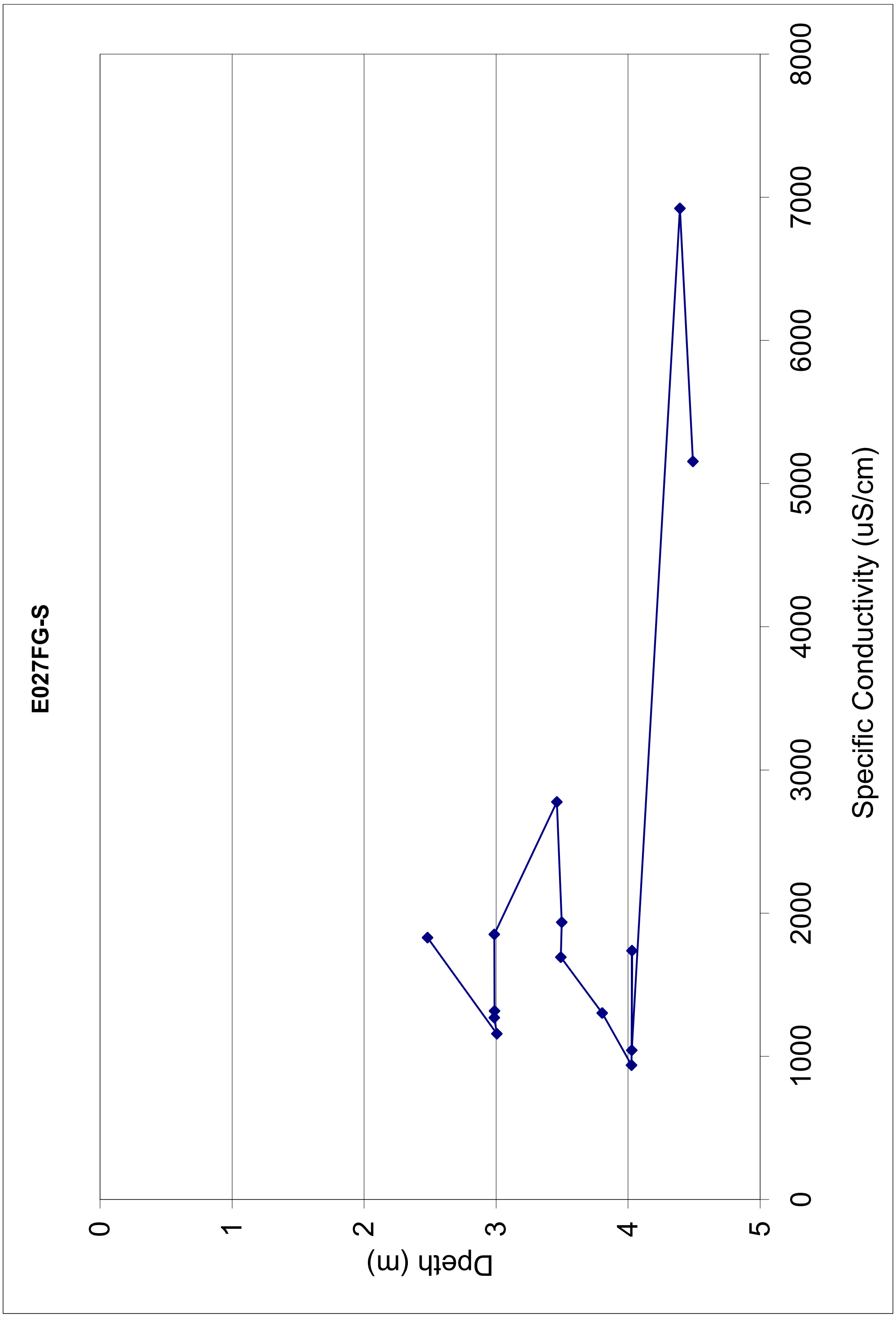

E014F
Depth (m)
0
1
2
3
4
5
6
7
8
9
Specific Conductivity (uS/cm)
0
1000
2000
3000
4000
5000
6000
7000
8000

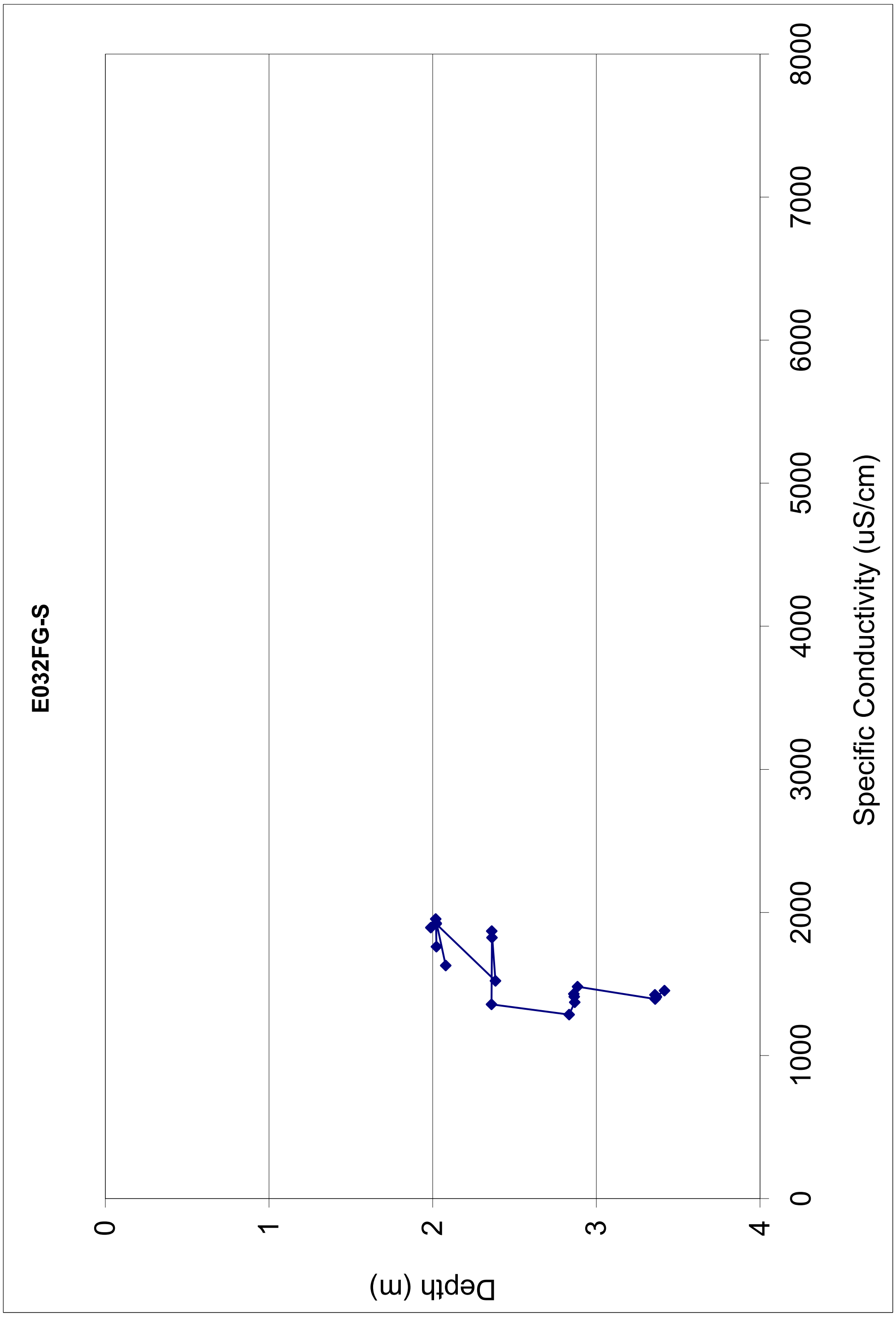

E014G-S
Depth (m)
0
1
2
3
4
5
6
Specific Conductivity (uS/cm)
0
1000
2000
3000
4000
5000
6000
7000
8000

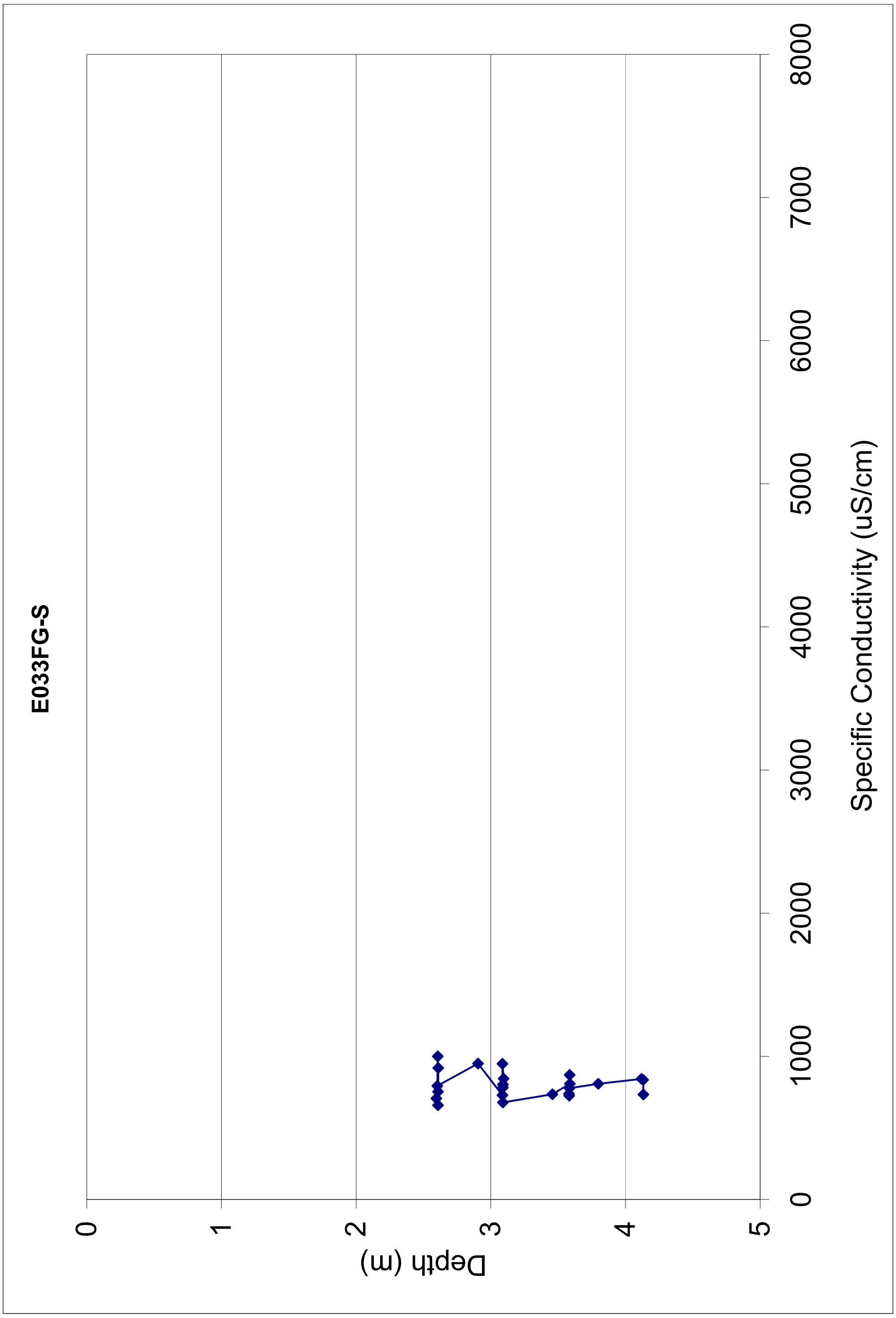

E023FG-S
Depth (m)
0
1
2
3
4
5
6
Specific Conductivity (uS/cm)
0
1000
2000
3000
4000
5000
6000
7000
8000


E024FG-S
Depth (m)
0
1
2
3
4
5
6
Specific Conductivity (uS/cm)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000


E026FG-D
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
0
1000
2000
3000
4000
5000
6000
7000
8000
Specific Conductivity (uS/cm)


E027FG-S
Dpeth (m)
0
1
2
3
4
5
0
1000
2000
3000
4000
5000
6000
7000
8000
Specific Conductivity (uS/cm)


E032FG-S
Depth (m)
0
1
2
3
4
Specific Conductivity (uS/cm)
0
1000
2000
3000
4000
5000
6000
7000
8000


E033FG-S
Depth (m)
0
1
2
3
4
5
Specific Conductivity (uS/cm)
0
1000
2000
3000
4000
5000
6000
7000
8000

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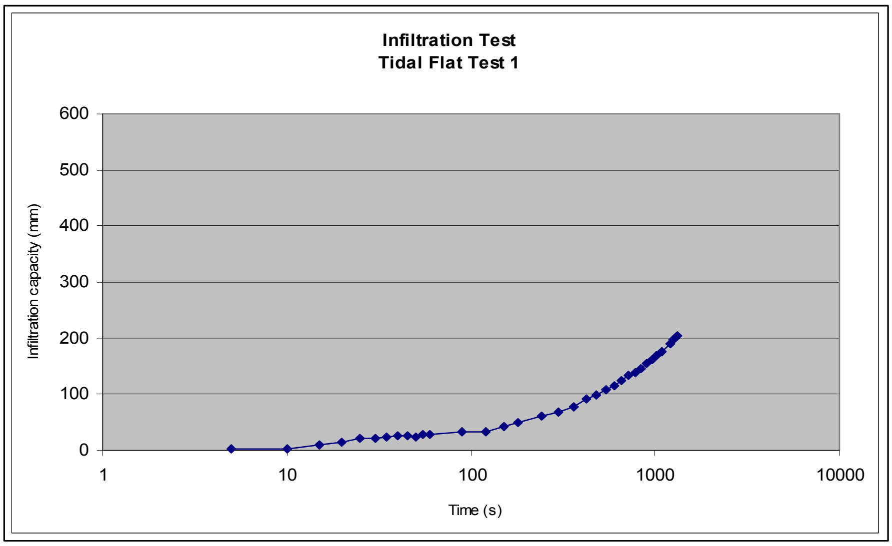
G

Appendix G Infiltration Tests

URS

42907466/WHST-STU-WA-RPT-0090/0



Tidal Flat Test 2

Variables

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1= 0.342
h_2= 0.215

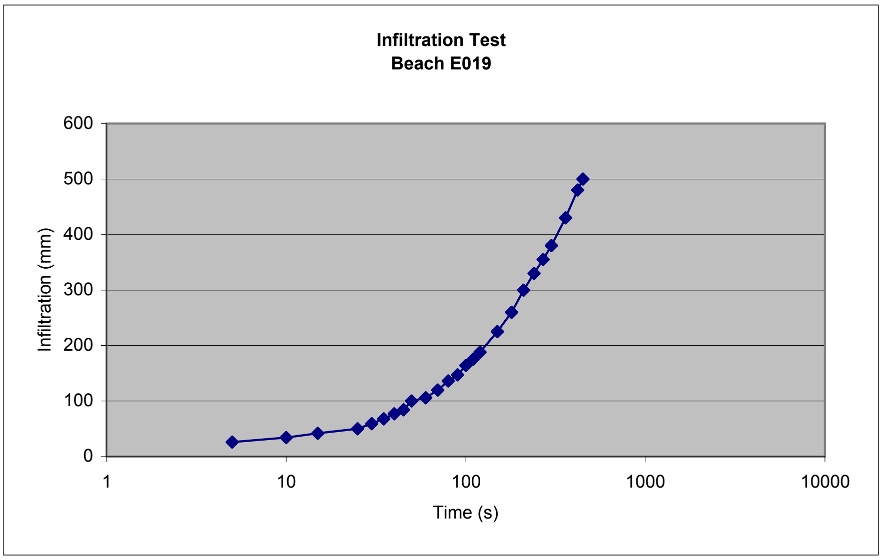
DD_1= 0.008 m
DD_2= 0.135 m
T_1= 0.08
T_2= 22

$$K = \frac{0.15708}{241.12} \; 0.464$$

= 0.000302 m/min

K= **0.43544 m/day**

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**	**Appendix E**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies	URS
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Tidal Flat Test 2	



Beach E019

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.392699 \quad 3.879}{92.4}$$

= 0.016488 m/min

K= **23.74246 m/day**

Variables

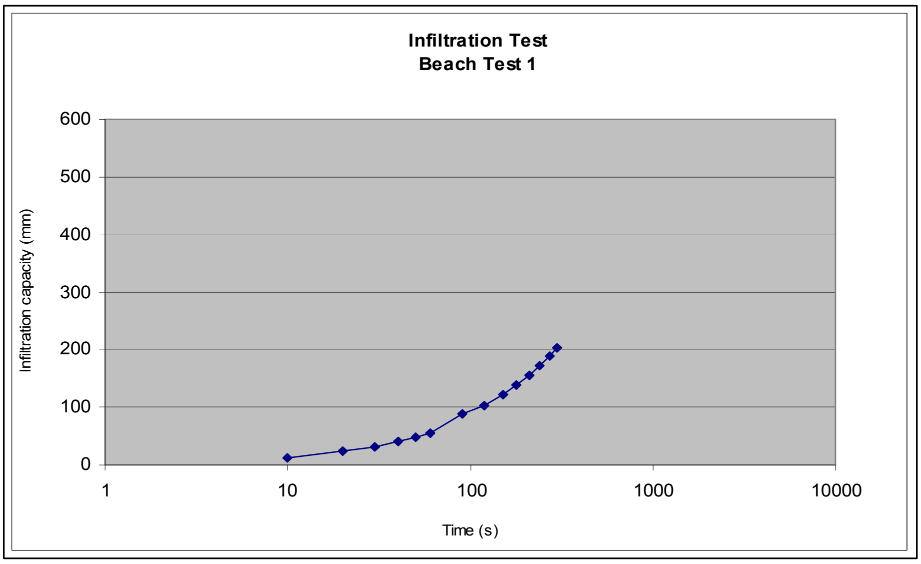
D= 0.125 m
Total Depth= 0.45 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1= 0.448
h_2= 0.395

DD_1= 0.002 m
DD_2= 0.055 m
T_1= 0.33
T_2= 10

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**	**Appendix E**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies	
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Beach E019	URS



Beach Test 1

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.15708}{90.893}\ 2.133$$

= 0.003686 m/min

K= **5.307809 m/day**

Variables

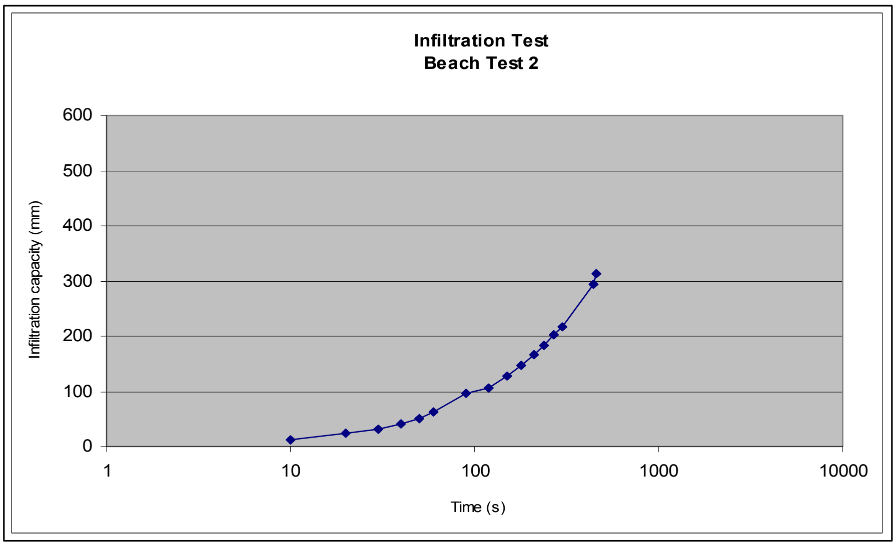
D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1= 0.346
h_2= 0.041

DD_1= 0.004 m
DD_2= 0.309 m
T_1= 0.167
T_2= 8.43

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**	**Appendix E**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies	
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Beach Test 1	URS



Beach Test 2

Variables

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.15708 \quad 2.218}{89.1}$$

= 0.00391 m/min

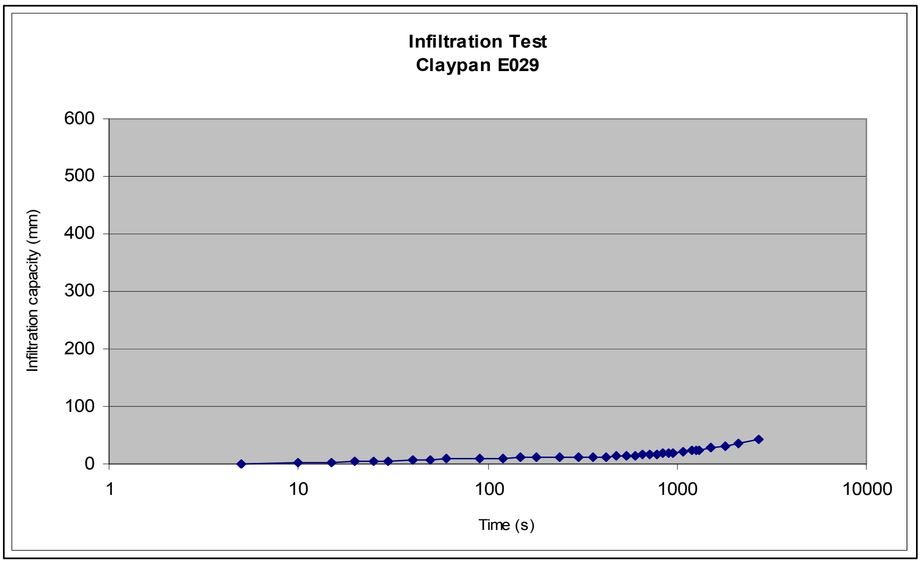
K= **5.630815 m/day**

D=	0.05	m
Total Depth=	0.35	m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1=	0.34	
h_2=	0.037	
DD_1=	0.01	m
DD_2=	0.313	m
T_1=	0.167	
T_2=	8.267	

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**	**Appendix E**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies	URS
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Beach Test 2	



Claypan E029

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.15708 \quad 0.128}{494.12}$$

= 4.08E-05 m/min

K= **0.058697 m/day**

Variables

D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

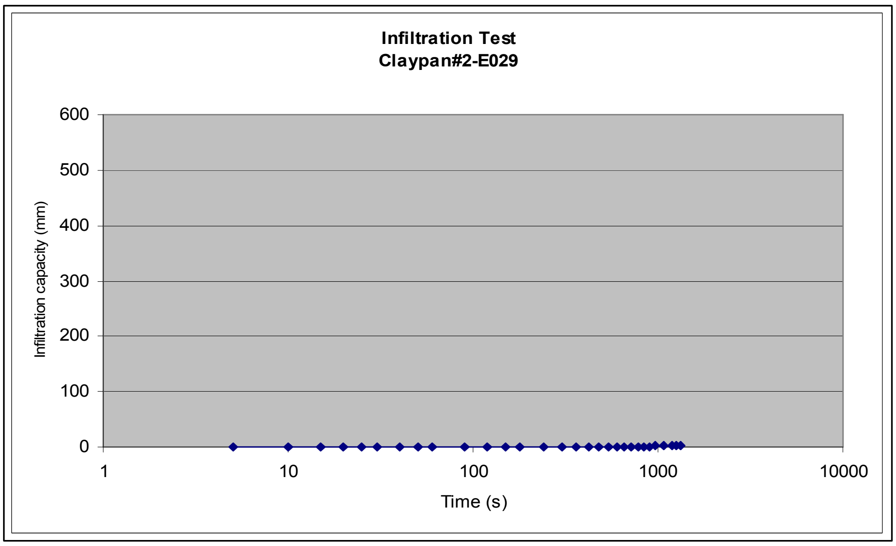
h_1= 0.349
h_2= 0.307

DD_1= 0.001 m
DD_2= 0.043 m
T_1= 0.08
T_2= 45

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Claypan E029

Appendix E

URS



Claypan#2-E029

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

Variables

D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1= 0.349
h_2= 0.348

DD_1= 0.001 m
DD_2= 0.002 m
T_1= 0.5
T_2= 22

$$K = \frac{0.15708}{236.5} \; 0.003$$

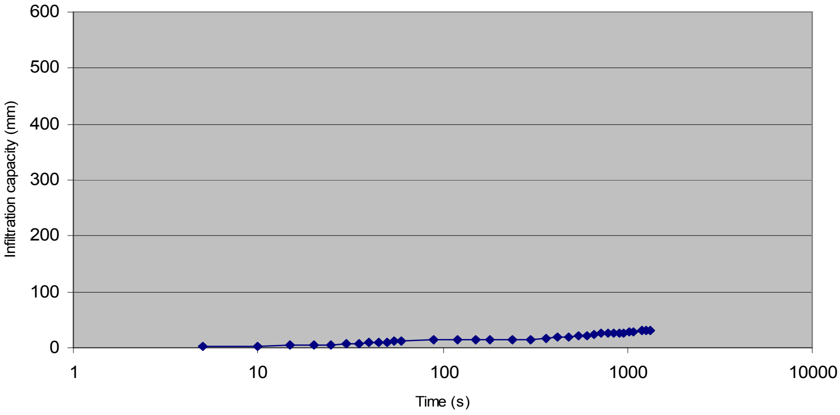
= 1.91E-06 m/min

K= **0.002744 m/day**

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Claypan#2-E029

Appendix E

URS



Claypan#3-Dune8

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.15708}{241.12}\ 0.084$$

= 5.46E-05 m/min

K= **0.078689 m/day**

Variables

D=	0.05	m
Total Depth=	0.35	m

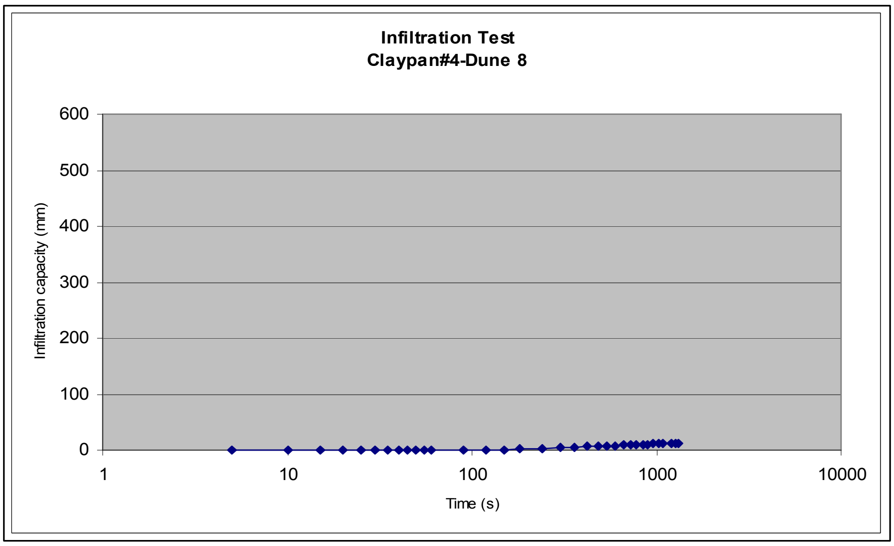
h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1=	0.348	
h_2=	0.32	
DD_1=	0.002	m
DD_2=	0.03	m
T_1=	0.08	
T_2=	22	

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Claypan#3-E029

Appendix E

URS



Claypan#3-Dune8

Variables

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1= 0.349
h_2= 0.338

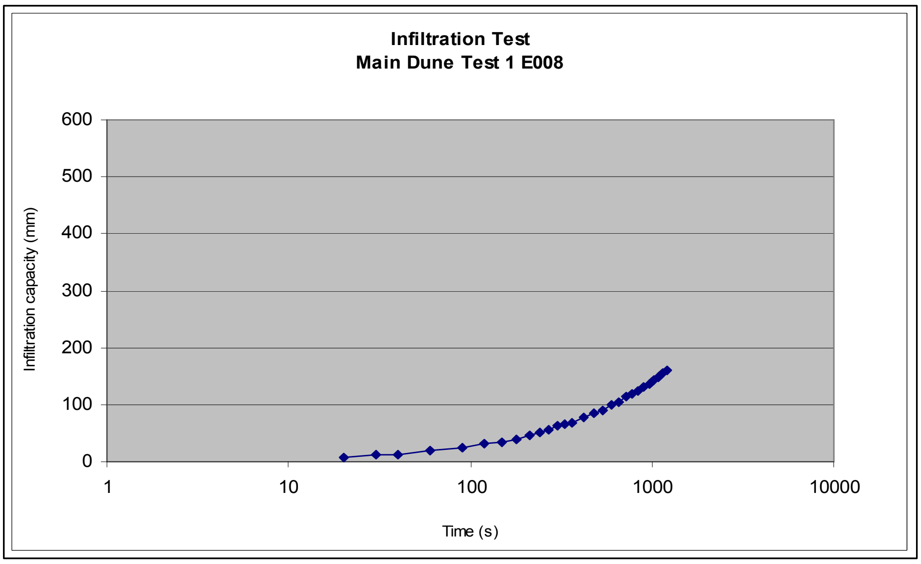
DD_1= 0.001 m
DD_2= 0.012 m
T_1= 0.92
T_2= 22

$$K = \frac{0.15708}{231.88} \; 0.032$$

= 2.17E-05 m/min

K= **0.031241 m/day**

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**	Appendix E
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies	
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Claypan#4-E029	URS



Main Dune Test 1 E008

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.15708}{216.37}\ 0.383$$

= 0.000278 m/min

K= **0.400183 m/day**

Variables

D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

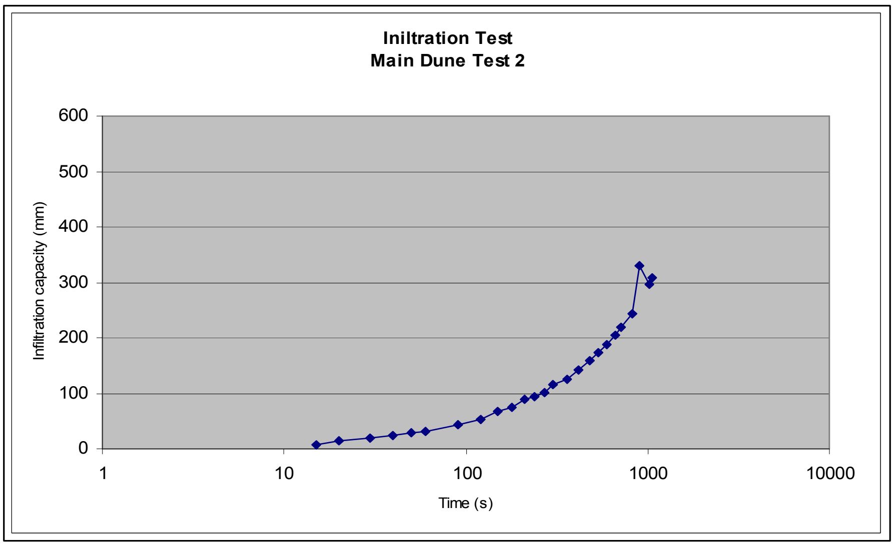
h_1= 0.349
h_2= 0.238

DD_1= 0.001 m
DD_2= 0.112 m
T_1= 0.33
T_2= 20

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Main Dune Test 1 E008

Appendix E

URS



Main Dune Test 2 E008

Variables

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1= 0.344
h_2= 0.021

DD_1= 0.006 m
DD_2= 0.329 m
T_1= 0.25
T_2= 15.83

$$K = \frac{0.15708}{171.38} \; 2.796$$

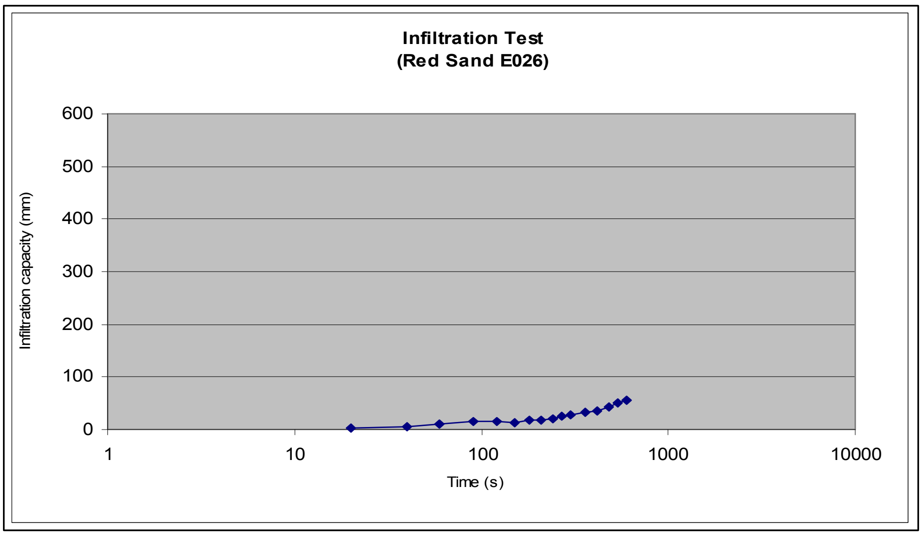
= 0.002563 m/min

K= **3.690435 m/day**

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Main Dune Test 2 E008

Appendix E

URS



Red Sand E026

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

K= 0.392699 / 106.37 0.126
= 0.000465 m/min
K= **0.669352 m/day**

Variables

D= 0.125 m
Total Depth= 0.45 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

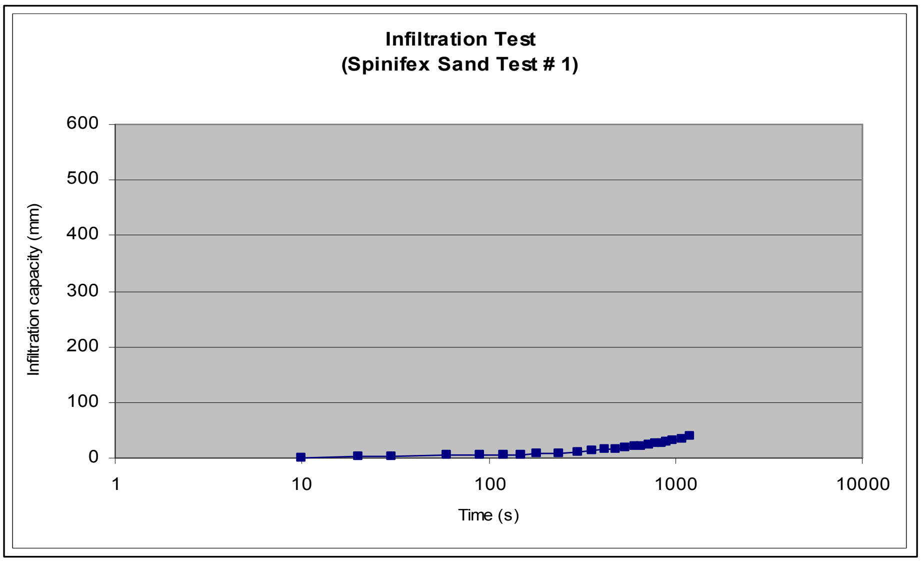
h_1= 0.448
h_2= 0.395

DD_1= 0.002 m
DD_2= 0.055 m
T_1= 0.33
T_2= 10

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Red Sand E026

Appendix E

URS



Spinifex Sand # 1

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.15708}{218.163} \; 0.115$$

= 8.3E-05 m/min

K= 0.119523 m/day

Variables

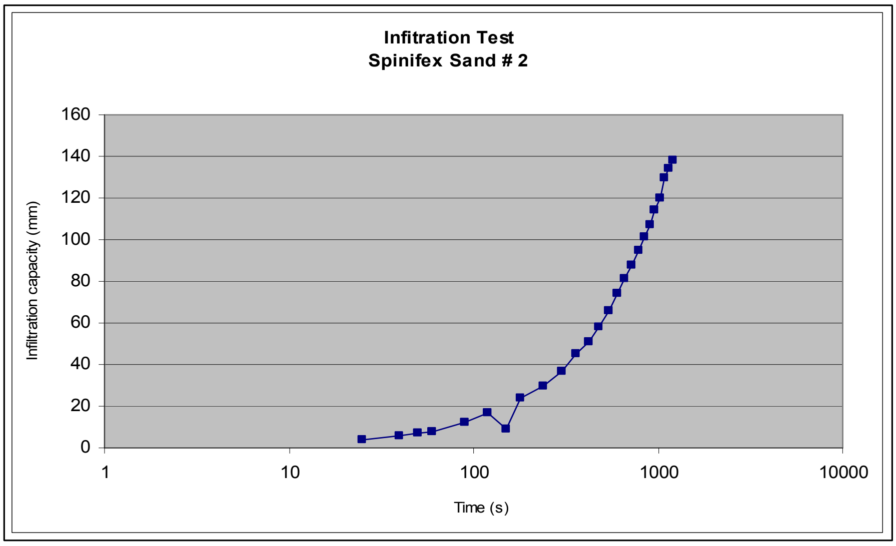
D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1= 0.349
h_2= 0.311

DD_1= 0.001 m
DD_2= 0.039 m
T_1= 0.167
T_2= 20

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**	**Appendix E**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies	
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Spinifex Sand # 1	URS



Spinifex Sand # 2

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.15708}{215.38} \quad 0.49$$

= 0.000357 m/min

K= **0.514449 m/day**

Variables

D=	0.05	m
Total Depth=	0.35	m

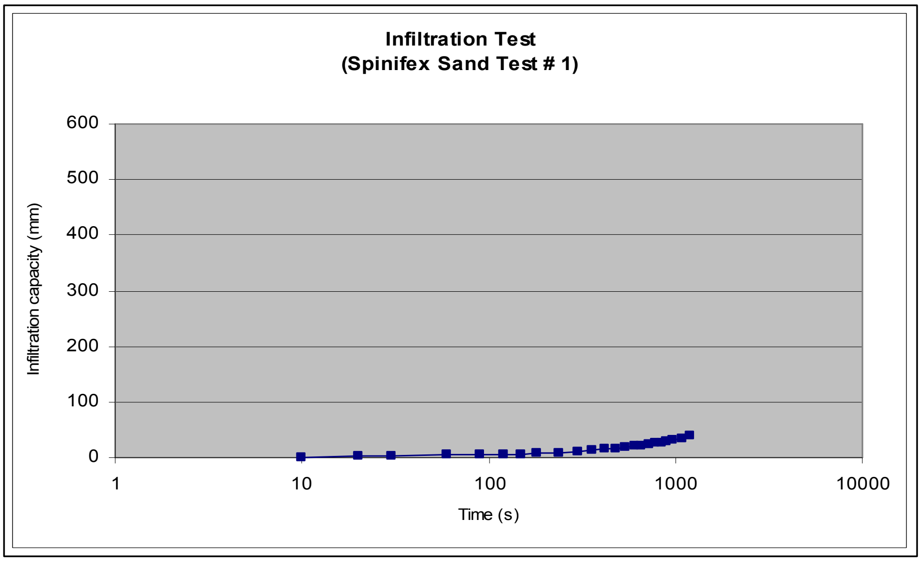
h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1=	0.349	
h_2=	0.311	
DD_1=	0.001	m
DD_2=	0.039	m
T_1=	0.167	
T_2=	20	

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Spinifex Sand # 2

Appendix E

URS



Spinifex Sand # 1

$$K = \frac{\pi D}{11(T_2 - T_1)} \times \ln(h_1/h_2)$$

K: m/day
D: m
T_1: mins
T_2: mins
h_1: m
h_2: m

$$K = \frac{0.15708}{218.163} \; 0.115$$

= 8.3E-05 m/min

K= **0.119523 m/day**

Variables

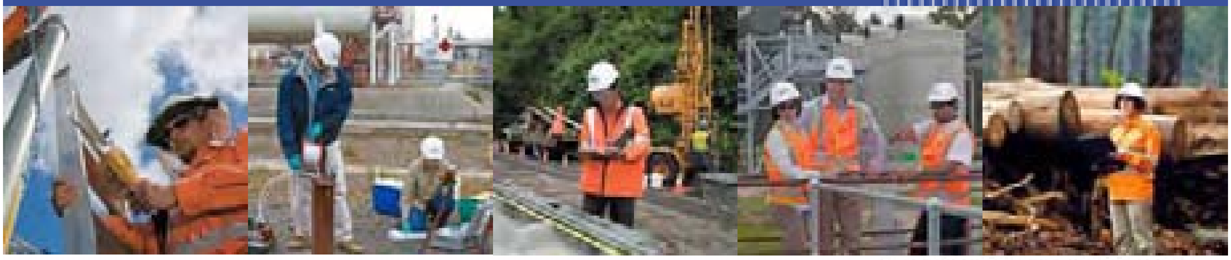
D= 0.05 m
Total Depth= 0.35 m

h_1= Total depth - DD_1
h_2= Total depth - DD_2

h_1= 0.349
h_2= 0.311

DD_1= 0.001 m
DD_2= 0.039 m
T_1= 0.167
T_2= 20

Job No.	42907100		Client: **CHEVRON AUSTRALIA PTY LTD**	**Appendix E**
Prep. By	BP	22 Sep. '09	Project: Wheatstone Groundwater Studies	
Chk'd By	IGB	22 Sep. '09	Infiltration Test Analysis Plots: Spinifex Sand # 1	URS



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