GORGON
AUSTRALIAN GAS

ENVIRONMENTAL, SOCIAL AND ECONOMIC REVIEW of THE GORGON GAS DEVELOPMENT on BARROW ISLAND

TECHNICAL APPENDICES

FEBRUARY 2003

APPENDIX A

THE GORGON GAS DEVELOPMENT
ENVIRONMENTAL, SOCIAL AND ECONOMIC REVIEW
SCOPING DOCUMENT

The Gorgon Gas Development

Environmental, Social and Economic Review Scoping Document

ChevronTexaco Australia Pty Ltd
ACN 086 197 757

250 St George's Terrace
GPO Box S1580
Perth WA 6845
Australia

Telephone: 08 9216 4000
Facsimile: 08 9216 4444
Email: gorgon.info@chevrontexaco.com

ABBREVIATIONS

AMEEF	Australian Minerals and Energy Environment Foundation
APPEA	Australian Petroleum Production and Exploration Association
CALM	The Western Australian Department of Conservation and Land Management
CCWA	Conservation Commission of Western Australia
CO_2	Carbon dioxide
EP Act	The Western Australian *Environmental Protection Act 1986*
EPA	The Western Australian Environmental Protection Authority
EPBC Act	The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
ESE Review	Environmental, Social and Economic Review
GTL	Gas-to-liquids
ha	Hectare
km	Kilometre(s)
LNG	Liquefied natural gas
MPR	The Western Australian Department of Mineral and Petroleum Resources
NWS	North West Shelf
R&D	Research and development
SES Study	Social, Economic and Strategic Study
SIAC	Standing Interagency Committee of Chief Executive Officers
Tcf	Trillion cubic feet
WA	Western Australia
WAPET	West Australian Petroleum Pty Limited

Executive Summary

ChevronTexaco is the operator of the Gorgon area natural gas fields located some 130km off the north-west coast of Western Australia. The company and its co-venturers, Shell and ExxonMobil (the Gorgon Participants), are investigating a range of development options for Gorgon gas including liquefied natural gas (LNG) and gas-to-liquids (GTL) opportunities.

Central to the commercial viability of the development of the Gorgon area gas fields is the siting of gas processing facilities on Barrow Island. Barrow contains one of Australia's most important onshore oilfields, which has operated since 1967. It is also a Class A Nature Reserve, particularly important as a refuge for rare wildlife species.

The Gorgon Participants are seeking in-principle approval to access Barrow Island for an initial gas development. Such approval will provide the certainty required to progress commercial, engineering and environmental work necessary to develop markets for Gorgon gas and to allow a detailed development proposal to be assessed under the Western Australian *Environmental Protection Act 1986* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

After approaches to the Western Australian Government by the Gorgon Participants in 2001, the Minister for State Development has indicated the government is prepared to consider examining the restricted use of Barrow Island for the initial development of the Gorgon gas resources, after considering the environmental, social, economic and strategic ramifications and provided there are net conservation benefits.

The Gorgon Participants therefore propose to review these issues at a strategic level in order to provide the government with the information to make an informed in-principle decision. In this regard, the Environmental, Social and Economic Review (the ESE Review) will address the ability of the Gorgon development to achieve a range of environmental, social, economic and strategic objectives.

The environmental aspects of the ESE Review are being coordinated through the Environmental Protection Authority in order to provide advice to the Minister pursuant to Section 16(e) of the *Environmental Protection Act*. The social, economic and strategic aspects of the ESE Review are being coordinated through the Department of Mineral and Petroleum Resources.

The scoping process for the ESE Review commenced in January 2002. The Gorgon Participants plan to conduct the sustainability studies over the next six months and release the ESE Review in the fourth quarter 2002 for a six-week public comment period. At this stage, it is anticipated that the government will

decide on the in-principle acceptability of the development in the second quarter 2003.

The purpose of this document is to obtain Western Australian Government endorsement for the planned scope of the ESE Review investigations. This Scoping Document has been prepared using the Environmental Protection Authority *Environmental Impact Assessment (Part IV Division 1) Administrative Procedures (2002)* as a model, and provides:

- background to the Gorgon gas development and an outline of the broad development concept
- an overview of the existing environmental and social setting
- a summary of those environmental, social, economic and strategic aspects considered important at this stage of the ESE Review
- a preliminary assessment of impacts
- an outline of the proposed scope of investigations to be conducted as part of the ESE Review
- indicative management strategies, and
- an outline of the plans for stakeholder consultation.

This Scoping Document will be available to the public. In addition, the Department of Mineral and Petroleum Resources has issued guidelines specific to the social, economic and strategic aspects, which are available at www.mpr.wa.gov.au.

As part of the ESE Review itself, the Gorgon Participants will coordinate a range of specialist studies that will include desktop reviews, field reconnaissance surveys, interviews and preliminary modelling. Information obtained and assessed will be at a high level, consistent with the in-principle approval being sought. In broad terms the studies will:

- describe the existing conditions
- describe the proposed development
- identify, and where appropriate, quantify potential impacts and benefits
- identify strategies to mitigate (and possibly offset) adverse impacts, and to improve on potential benefits,
- identify potential net conservation benefits, and
- comment on the significance of the resultant impacts and benefits.

Throughout the investigations, the Gorgon Participants will consult widely with all relevant stakeholders. The findings will be integrated within a sustainability framework, commenting on the ability of the development to meet its stated commercial, environmental, social, economic and strategic objectives.

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1 Introduction

ChevronTexaco is the operator of the Gorgon area natural gas fields located some 130km off the north-west coast of Western Australia (see Figure 1). The Gorgon field is the largest gas field ever discovered in Australia and together with the other fields in the area represents a world class natural gas resource, currently estimated at over 40 trillion cubic feet[1]. ChevronTexaco and its Gorgon co-venturers, Shell and ExxonMobil (the Gorgon Participants) are investigating a range of initial development options for Gorgon area gas, including liquefied natural gas (LNG) and gas-to-liquids (GTL) opportunities.

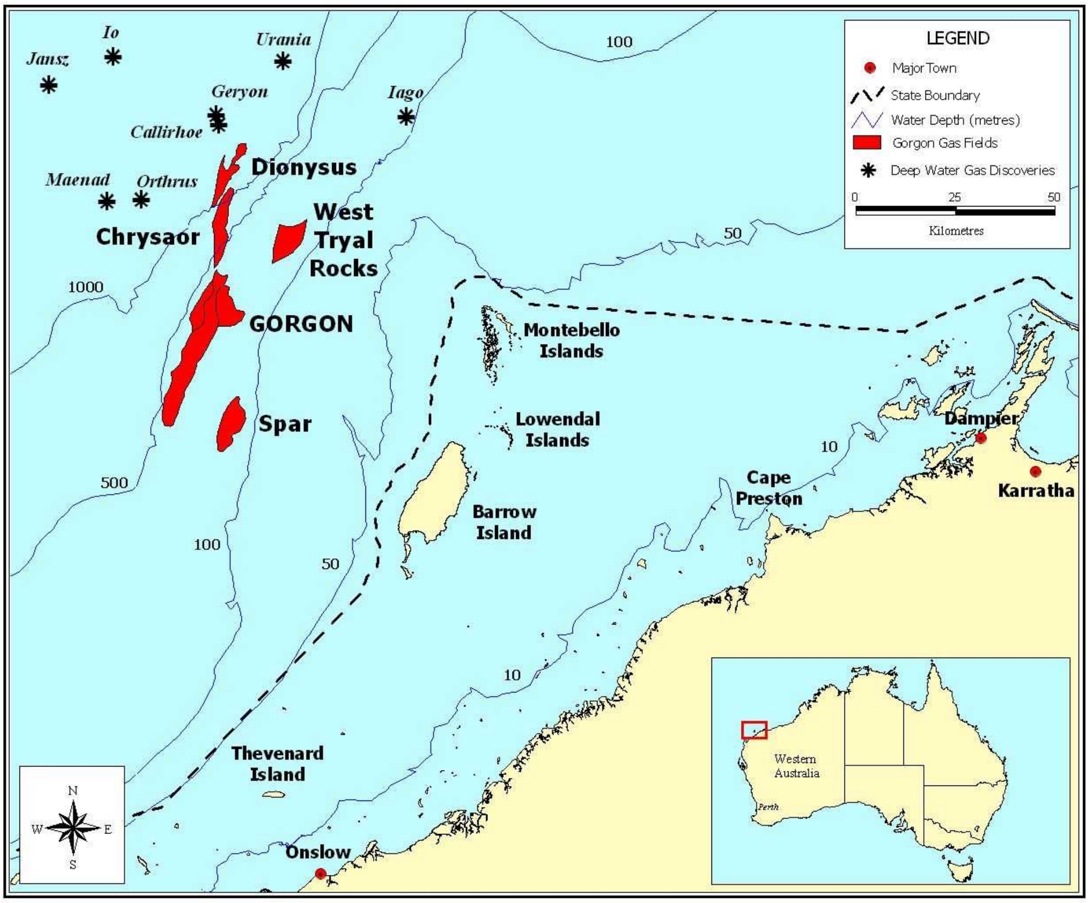

Figure 1: Gorgon Gas Development Location Map

Gorgon is a remote gas field that requires LNG or a large-scale industrial gas user to underpin its initial development. This initial investment will facilitate future developments in the region, and will further benefit Western Australia through greater availability, security and competition in the domestic gas market.

The development of Gorgon area gas will be one of the nation's most significant resource developments, rivalling the North West Shelf. It will generate substantial social and economic benefits to Australia. Depending on the development concept selected, the development will attract several billion dollars of initial investment, generate substantial export income and tax

[1] The Gorgon area gas fields have approximately twice the reserves underpinning the existing North West Shelf development north of Dampier.

payments over the next 30 years, and be a major creator of jobs - both directly and indirectly.

Central to the commercial viability of the development of the Gorgon gas resources is the siting of gas processing facilities on Barrow Island, the second largest island off the coast of Western Australia. The island is the site of one of Australia's most important onshore oilfields, operating since 1967. Since then, almost 900 wells have been drilled and almost 300 million barrels of oil produced[2]. Barrow was gazetted as a Class A Nature Reserve in 1910 and is a refuge for rare wildlife species, some of which are endemic to Barrow Island and some of which are extinct (or near extinct) on the mainland. In selecting Barrow Island as the location for an initial development, ChevronTexaco understands the importance of the island as a conservation resource and is committed to maintaining its excellent record in protecting the environmental and conservation values of the island as it has done for the last three and a half decades.

1.1 The Need for an Innovative Approach

Gorgon is Australia's largest gas field and its development offers substantial economic and social benefits. However, it is remote gas that presents many commercial, technical, and environmental challenges. The complexity of these challenges in many critical development aspects (most importantly the location of the development, the type of gas processing and the timeframe for commercialisation) has held the development in abeyance.

In Western Australia, there are well-established, effective processes for evaluating the environmental acceptability (or otherwise) of a proposal through the *Environmental Protection Act 1986*. However, there has been no formal, transparent process to assess the relationship between the environmental, social and economic costs and benefits of significant development proposals.

The Review of the Project Development Approvals System[3] recently conducted by a State Government appointed independent review committee recommended that for major projects, the Government should consider overall impact within a sustainability context. To do this the Committee recommended that proponents prepare a sustainability statement to address the economic, social and environmental aspects of the project.

In the case of the proposal to develop Gorgon gas, the Gorgon Participants initially approached the Western Australian Government with a request for an in-principle decision as to whether Barrow Island could be used as a site for gas processing facilities. The Gorgon Participants and the Government have worked closely to devise an approach to this question that fulfils the requirements of all stakeholders.

The Minister for State Development has indicated that the government is prepared to consider the restricted use of Barrow Island for the initial development of the Gorgon gas resources, after considering the environmental, social, economic and strategic ramifications and provided there are net conservation benefits. Such in-principle approval, if granted, would enable the Gorgon Participants to proceed with detailed development planning and commercial market representations ahead of detailed evaluation pursuant to the provisions of Part IV of the *Environmental Protection Act* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the *EPBC Act*).

The Environmental, Social and Economic Review (the ESE Review) will address the development's ability to mitigate potential on-site impacts and generate social and economic

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2 This represents nearly one-quarter of all oil produced in Western Australia.

3 Independent Review Committee (Apr 2002). Review of the Project Development Approvals System – Final Report. Govt of Western Australia.

benefits for the region, state and the nation. The ESE Review will also aim to demonstrate that the development could meet a range of broad strategic criteria and achieve net conservation benefits.

1.2 The Purpose of this Document

The purpose of this ESE Review Scoping Document is to establish the necessary actions and investigations to be undertaken by the Gorgon Participants to enable the Government to make an in-principle decision regarding access to Barrow Island.

The scope of the ESE Review has been developed in two parts:

- the Department of Mineral and Petroleum Resources (MPR) has coordinated the development of guidelines for the social, economic and strategic elements to the ESE Review, and
- the environmental component of the ESE Review has been developed by the Gorgon Participants in accordance with the requirements of the Administrative Procedures for a Scoping Document[4] for endorsement by the EPA.

To place the proposed scope in context, this document also provides background to the Gorgon gas development. In particular, it outlines the broad development concept and identifies those environmental, social, economic and strategic aspects considered important at this stage of the ESE Review process. A preliminary, high level assessment of the impacts and benefits is also provided.

1.3 The Proponent

The Gorgon gas field is operated by ChevronTexaco, the fifth largest energy company in the world with over 53,000 employees in over 180 countries. ChevronTexaco has been involved in the Australian energy industry since the 1950s and is a participant in the North West Shelf project.

ChevronTexaco is the operator of the Barrow Island oilfield. The company assumed operatorship of the oilfield in February 2000. Prior to this, and since its discovery in the early 1960's, West Australian Petroleum (WAPET) operated the field. As a principal member of the WAPET consortium, Chevron has provided senior management and technical support during nearly 40-years of operation. During the transfer of operatorship from WAPET to ChevronTexaco, the majority of the key management and operations personnel have been retained.

Environmental Performance on Barrow Island

ChevronTexaco's operations on Barrow Island are widely recognised as a model for coexistence of petroleum development and the protection of biodiversity. Rather than jeopardise the island's flora and fauna, ChevronTexaco's efforts have done much to preserve the unique ecosystem. The success of ChevronTexaco's rigorous environmental management program is evident in the continuing health and stability of the island's ecosystem, prevention of entry of foreign animals and plants and the fact that the full suite of native species remains. This success has been formally recognised by the receipt of a number of environmental awards including the AMEEF and APPEA awards for environmental excellence in 1994 and 2001, respectively.

[4] WA Government (Feb 2002). Environmental Impact Assessment (Part IV Division 1) Administrative Procedures 2002. *Western Australian Government Gazette, No.26 Special*.

2 ESE Review and Assessment Process

The following sections outline the proposed approach to, and schedule for:

- the ESE Review to be conducted by the Gorgon Participants, and
- the assessment and the decision making process to be conducted by the Western Australian Government.

2.1 Overall Approach

The ESE Review and assessment process involves the following phases and key activities:

Phase	Key activities
Scoping	▪ Identification of key, high level environmental aspects associated with the development by the Gorgon Participants ▪ Development of a proposed scope of work to address environmental aspects (as incorporated into this ESE Review Scoping Document) ▪ Development of guidelines for the social, economic and strategic evaluation of the development by MPR – also incorporated in this document ▪ Integration of the social, economic and strategic guidelines and the environmental scope of work to form the ESE Review Scoping Document ▪ Endorsement of the environmental aspects of the ESE Review Scoping Document by the EPA ▪ ESE Review Scoping Document made available to the public ▪ Stakeholder consultation to be conducted by the Gorgon Participants during this phase
Investigation	▪ Review and refinement of sustainability objectives ▪ Baseline investigations involving desktop reviews, field reconnaissance surveys, interviews and preliminary modelling ▪ Identification and broad quantification of potential impacts and benefits ▪ Development of possible strategies to mitigate (and possibly offset) adverse impacts and improve on potential benefits ▪ Identification of net conservation benefits associated with the development ▪ Integration of the findings regarding the environmental, social, economic and strategic issues within a sustainability framework ▪ Print and distribute ESE Review document for agency and public comment ▪ Stakeholder consultation to be conducted by the Gorgon Participants during this phase
Assessment	▪ The public will have a six-week period to provide comment on the ESE Review ▪ The Gorgon Participants will conduct stakeholder consultation during this phase and will respond to public comment ▪ In a whole of government approach, the evaluation will be coordinated through the Standing Interagency Committee of Chief Executive Officers (SIAC). Members of SIAC represent all the Western Australian Government agencies with responsibility for project assessment and decision making ▪ In this coordinating role, SIAC will receive all public comments on the ESE Review Document ▪ The EPA will evaluate the environmental aspects under the provisions of Section 16(e) of the *Environmental Protection Act* and produce a Bulletin documenting its advice ▪ MPR will evaluate the social, economic and strategic matters in harmony with and parallel to the EPA's Section 16(e) environmental assessment and will produce a Bulletin documenting its advice ▪ The Conservation Commission of Western Australia will provide independent advice to the Minister for Environment ▪ All three of these documents will be publicly available ▪ An integrated document with the three individual Bulletins forming appendices will be prepared under SIAC's supervision in the form of a ESE Assessment report ▪ The ESE Assessment will be publicly available for a six-week period before being considered by the Western Australian Government
Decision	▪ Western Australian Government will consider the ESE Assessment and any other documentation and advice it considers relevant ▪ Western Australian Government will decide in-principle on the acceptability (or otherwise) of an initial gas development on Barrow Island.

Should in-principle approval be granted for the establishment of an initial development on Barrow Island, formal project approval would still be required under Part IV of the *Environmental Protection Act* and the *EPBC Act*[5]. This ESE Review does not circumvent this process. The timing of a project specific environmental impact assessment would be determined by the timetable for the development. In the meantime, the Gorgon Participants would be able to proceed with the necessary technical, engineering, environmental and commercial investigations with the greater certainty and confidence provided by the in-principle decision of the sustainability review process.

The process of review and assessment is summarised in Figure 2.

2.2 The Approach to the ESE Review

The investigations that contribute to the ESE Review will be coordinated by the Gorgon Participants and involve a range of specialist studies. The studies will include baseline investigations involving desktop reviews, field reconnaissance surveys, interviews and preliminary modelling. Information obtained and assessed will be at a high level, consistent with the in-principle approval being sought. However, the investigations that contribute to the ESE Review will also provide substantial input to the *EP Act* (Part IV) and *EPBC Act* assessment.

The scope of the studies is discussed in detail in Section 6. In broad terms the studies will:

- describe the existing conditions
- describe the proposed development
- identify, and where appropriate quantify, potential impacts and benefits
- identify strategies to mitigate (and possibly offset) adverse impacts and to improve on potential benefits
- identify potential net conservation benefits, and
- comment on the significance of the resultant impacts and benefits

Throughout the investigations, the Gorgon Participants will consult widely with relevant stakeholders.

The findings will be integrated within a sustainability framework, commenting on the ability of the development to meet its stated commercial, environmental, social, economic and strategic objectives. The information will be compiled in an ESE Review document, which will be available to the public for a six-week comment period.

2.3 Stakeholder Consultation

The active involvement of government and non-government stakeholders is critical to the success of the ESE Review. The Gorgon Participants have begun consultation with a wide range of organisations and key individuals through briefing sessions and presentations. These discussions have provided the Gorgon Participants with an opportunity to obtain feedback and comment about the development and to clarify issues and sensitivities of particular interest to the various stakeholder groups.

There will be a six-week public review period during which all stakeholders will have an opportunity to provide formal input into the ESE Review process and comment on its findings. The Gorgon Participants plan to continue its pro-active approach to consultation and to increase its activities during the ESE Review. The program will include consultation with:

- State and Commonwealth Ministers, members of Parliament and their advisers
- State and Commonwealth Government agencies
- Local Government representatives

[5] Likely EPBC Act triggers include endangered species and migratory species.

- industry and regional development groups
- conservation organisations
- local and regional community groups
- indigenous groups
- employees and contractors
- potential customers and suppliers, and
- the general public.

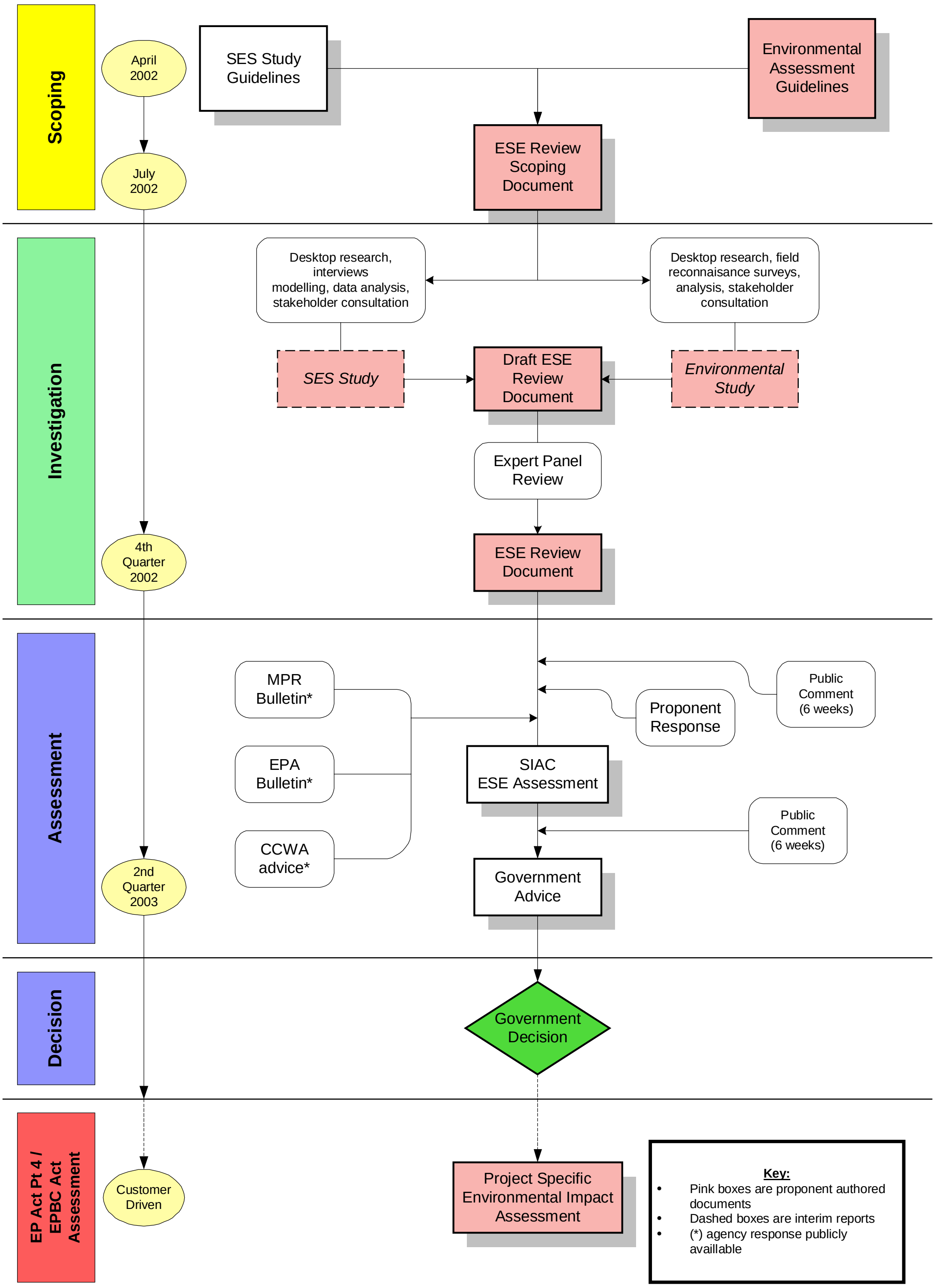

Figure 2: Summary of the ESE Review and Assessment Process

Over the coming months the Gorgon Participants will continue to meet with these stakeholders and provide briefing materials and updates. The Gorgon Participants will actively seek comments from stakeholders on the development and the process of review. The Gorgon Participants aim to obtain technical information and clarify issues to ensure that all relevant aspects of the development are appropriately addressed in the ESE Review.

2.4 Expert Panel Review Process

In accordance with the EPA suggestions, the Gorgon Participants intend to engage an Expert Panel to review the findings and conclusions of the investigations. The purpose of the Expert Panel review is to assist the Gorgon Participants to ensure that the investigations meet the requirements of this ESE Review Scoping Document and to verify the validity of the conclusions. The Gorgon Participants are in the process of establishing a small group of experts with an appropriate mix of knowledge and experience to address the breadth of issues to be canvassed in the ESE Review. The Expert Panel members will have standing in the community and possess a range of expertise including environment and socio-economic.

The specialists who are chosen to participate in the Expert Panel will be selected in consultation with the EPA and MPR.

3 Description of the Gorgon Gas Development

This section outlines the broad development concept being considered, the alternative gas processing options and strategic importance of Barrow Island to the commercial viability of the Gorgon gas development.

3.1 Why Barrow Island?

In 1998 the Gorgon Participants proposed a two LNG Train development on the Burrup Peninsula, to be supplied with gas via a 230km pipeline from the Gorgon field. As a result of the Asian economic crisis, the LNG market contracted and it became clear that a more flexible and lower cost development concept was required if the Gorgon development was to be commercially competitive.

After evaluating a number of development concepts and locations, such as the Montebello Islands, Varanus Island and the Burrup Peninsular, Barrow Island emerged as the option most likely to allow the Gorgon development to compete in the marketplace. The island, only 70km from the field, is the nearest landfall to Gorgon gas. Landing gas on the island will allow cost-effective sub-sea technology to be used in the field development and minimise the length of specialised corrosion resistant pipeline required. Barrow Island also provides existing infrastructure and access to deep sheltered water necessary for the development.

The establishment of an initial development on Barrow Island increases the certainty of supplying Gorgon gas to customers in the domestic market via a pipeline to the mainland. The Gorgon Participants are actively seeking a domestic market for the gas and are working with potential customers and the government to achieve an economically viable domestic gas supply as soon as practicable.

In line with global and national efforts to reduce greenhouse gas emissions, the Gorgon Participants are exploring a range of possible greenhouse gas mitigation/sink options, including greenhouse gas efficient design and sequestration options such as geological storage of CO_2. Subject to the results of research into its technical and commercial feasibility, the selection of Barrow Island as a site for gas processing offers a unique opportunity for the re-injection of reservoir CO_2 into the deep saline aquifers beneath the island.

The Gorgon Participants recognise the importance of clearly demonstrating the need for an initial development on Barrow Island and will ensure that this issue is incorporated into the scope of the ESE Review and adequately addressed in the proposed studies.

3.2 The Broad Concept

The Gorgon development is based on the largest gas field ever discovered in Australia and one of the world's premier hydrocarbon resources. In the Gorgon area, *proved* levels of reserves are 13.8Tcf of recoverable gas. At the *proved, probable plus possible* level, there is 21.5Tcf of recoverable gas. Recent deep water discoveries indicate there are resources in excess of 40Tcf in the Gorgon area, representing a significant proportion of Australia's discovered gas resources. The broad concept for the development of these resources is shown schematically in Figure 3.

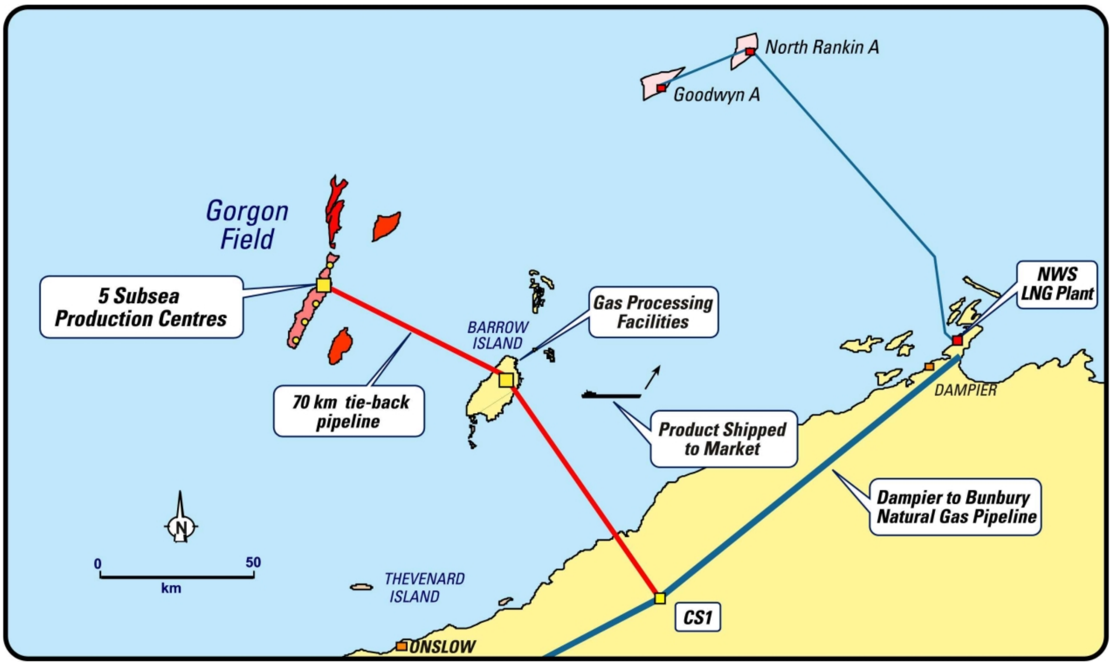

Figure 3: The Gorgon Development Concept

Gas Recovery

The current development concept for gas recovery involves a sub-sea gas gathering system as portrayed in Figure 4. The main features are:

- a sub-sea gas gathering system initially involving a number of wells, flowlines and sub-sea manifolds, and
- a 70km sub-sea pipeline from the field to Barrow Island.

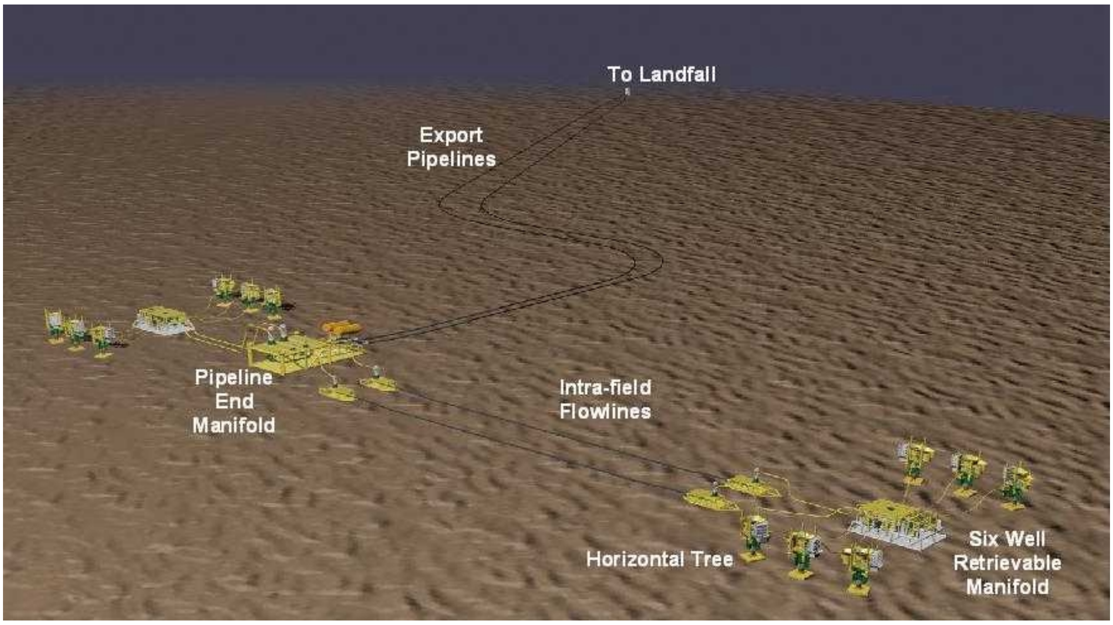

Figure 4: Sub-sea Development Concept

On Barrow Island

Once landed on Barrow Island, water, condensate and inert gases (such as CO_2) would be removed. If technically and commercially feasible CO_2 would be reinjected into a sealed saline aquifer, more than 2000m below the surface.

While the scope of the development on Barrow Island will ultimately be determined by market factors, current market activities and development planning work are focussed on LNG, GTL or an integrated facility producing both products. Such facilities may require up to 300ha – about 1.3% of the island.

The liquid hydrocarbon product(s) would be transported from the island to market via ship.

3.3 Development Activities

The activities associated with the construction and operation of the Gorgon gas development broadly include:

- dredging of a shipping channel
- installation of a jetty
- earthworks at the plant site
- import and temporary storage of material (such as rubble)
- fabrication and installation of pipe work, process vessels, control systems, buildings etc
- transport and accommodation of the workforce
- gas processing
- product generation, storage and off-loading, and
- generation of wastes and emissions.

These aspects and their broad implications are listed in Appendix 1.

3.4 Objectives of the Gorgon Gas Development

The Gorgon Participants aim to achieve a range of commercial, environmental, social, economic and strategic objectives in the development of the Gorgon gas fields. The purpose of the ESE Review is to demonstrate the ability of the Gorgon Participants to achieve these objectives. Through the ESE Review's scoping, consultation, investigation and assessment phases, the public and all other stakeholders will have opportunities to comment on the appropriateness of these objectives.

Commercial Objectives

The commercial objective of the development, which is fundamental to the project proceeding, is to establish a world competitive gas development that captures markets for its products and delivers the necessary commercial benefits to its investors and customers.

Environmental Objectives

It is ChevronTexaco's goal to be recognised and admired worldwide for environmental excellence[6]. The company believes that no new development should be established on Barrow Island unless it can be demonstrated the development is sustainable and continues to preserve the conservation values the company has helped to protect and maintain.

Specifically the environmental objectives of the development are to:

- protect the terrestrial, subterranean, marine and intertidal ecological values from significant adverse impact

6 ChevronTexaco Policy on Health, Environment and Safety. (www.chevrontexaco.com)

- maintain the integrity of ecological processes potentially impacted by the development
- protect local and regional air quality
- minimise the net greenhouse gas impact of the development, and
- achieve net conservation benefits.

Social Objectives

The Gorgon gas development may result in a number of social changes. Specifically the social objectives of the development are to:

- maximise opportunities to enhance the benefits to society offered by the development, and
- minimise and mitigate any potential adverse effects on people's lifestyle, culture and community.

Economic Objectives

The development of Gorgon gas will result in significant economic benefits, including regional development, employment, income to Government and economic growth. The economic objectives of the development are to:

- deliver benefits to regional, state and national economies
- provide opportunities for direct employment on the development, and indirect employment in other areas of the economy, and
- contribute to State and Commonwealth Government revenues.

Strategic Objectives

Strategic benefits will also flow to Western Australia and Australia from development of Gorgon gas. The strategic objectives of the Gorgon gas development are to:

- unlock the value of the natural gas resources in the Gorgon area gas fields
- encourage the development of major new value-adding industries for Western Australia and Australia
- develop technology and expertise for the benefit of Australia
- make Gorgon gas available to domestic customers on an economically viable basis, and
- increase security of, and competition in, the gas supply to Western Australia and Australia.

4 The Regional Setting

The following sections provide an overview of the characteristics of the region of relevance to the Gorgon gas development. The purpose is to introduce the key environmental and social features, as a basis for discussion of potential impacts, to allow informed consideration of the scope of the investigation.

4.1 Biophysical Environment

The Pilbara Region

Situated in the north-west of Western Australia, the Pilbara Region covers over 500,000 square kilometres extending from the Indian Ocean to the Northern Territory border.

Thought to be around 2.8 billion years old, the Pilbara contains some of the earth's oldest rock formations and most important mineral deposits.

The Pilbara is a semi-arid region characterised by high temperatures, low and variable rainfall and high evaporation. Temperature ranges are generally greater in inland districts away from the moderating effects of onshore winds common to the coastal districts.

Barrow Island

Barrow Island is the largest of a group of islands, located off the Pilbara coast, 85km north-north-east of the town of Onslow (refer to Figure 1). Barrow is Western Australia's second largest island, being some 25km long and 10km wide, covering an area of approximately 234 square kilometres. Figure 5 provides an indication of the size of Barrow Island relative to Perth and surrounding suburbs. The island experiences an arid climate with a highly variable rainfall (the average is about 320mm per annum).

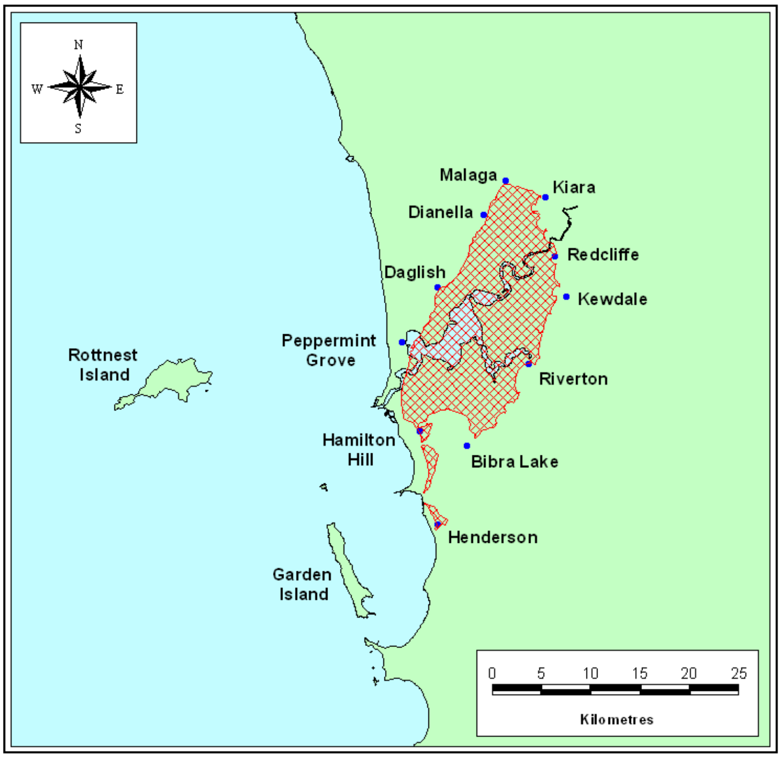

Figure 5: Relative Size of Barrow Island

Isolation from the mainland, freedom from introduced plants and animals and the absence of European pastoral influence continue to make Barrow Island an important remnant of the natural ecology of the Pilbara region.

In 1910, Barrow Island was designated as a Class A Nature Reserve. The Class A status of the island reflects its importance as a refuge for wildlife species, some of which are endemic to Barrow Island and some of which are extinct, or near extinction, on the mainland. The Reserve is vested in the Conservation Commission of Western Australia (CCWA) and managed by the Department of Conservation and Land Management (CALM) for the purpose of wildlife and landscape conservation, scientific study and preservation of features of archaeological, historic and scientific interest.

Barrow Island is the centre for ChevronTexaco's oil operations in Western Australia. It has been operating as a producing oilfield since 1967. The conservation value of the island has long been recognised by the oilfield operators, who have maintained a strict environmental program which has enabled these values to be preserved during nearly 40 years of operation.

Flora

Barrow Island supports a variety of significant plant species and vegetation associations. There are 8 major habitat units on the island and more than 250 plant species.

One flora species is listed as endangered (*Corchorus* sp. *Barrow*) and a number of vegetation associations have restricted distributions. Figure 6 shows those vegetation associations that are restricted to 1500ha or less on the island[7].

Fauna

The significance of Barrow Island to terrestrial fauna has been acknowledged for many years. Because of its isolation from the mainland, restricted access and quarantine procedures, it represents one of the few remaining areas in Western Australia that has not been subject to the broadscale impact of introduced foxes, cats, rats, mice, rabbits, stock animals, frequent wildfires and broadscale pastoral activity. As a direct result, the island supports a large number of species which are considered to be under threat or extinct on the adjacent mainland, but are secure on the island. Through isolation, some native animals have evolved into distinct sub-species restricted to the island. Some of the mammal species of particular importance include the burrowing bettong (*Bettongia lesueur)*, the black-flanked rock wallaby (*Petrogale lateralis lateralis*), the Barrow Island euro (*Macropus robustus isabellinus*), the spectacled hare-wallaby (*Lagorchestes conspicillatus conspilillatus*), the golden bandicoot (*Isoodoon auratus barrowensis*) and the Barrow Island mouse (*Pseudomys nanus ferculinus*).

Ten species of birds are covered by the migratory provisions of the Commonwealth *EPBC Act* (in the marine, intertidal or wetlands categories). In addition the Barrow Island black and white fairy wren is listed as 'rare or likely to become extinct' under the *Wildlife Conservation Act 1950* and as vulnerable under the *EPBC Act*.

Subterranean Fauna

Investigations by the Western Australian Museum have identified the presence of terrestrial invertebrate fauna (troglobites) and aquatic fauna (stygofauna), in subterranean caverns on Barrow Island. The Western Australian Museum considers the aquatic fauna to be significant, as there is no known counterpart elsewhere in Australia. The terrestrial cave fauna is endemic to the north-west of Western Australia, although it has affinities across northern Australia.

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[7] Based on: Mattiske EM and Assoc (1993). *Flora and Vegetation – Barrow Island*. Unpublished Report to WAPET

Figure 6: Restricted Vegetation Associations

The cave fauna has a considerable genetic diversity, and includes shrimps, millipedes, cockroaches, spiders and microwhip scorpions. The fauna are highly adapted to the cave conditions, including water quality, humidity and temperature. The fauna is considered to be an important component of Australian biodiversity and some species are listed under the *Wildlife Conservation Act*.

Marine Areas

The marine and intertidal areas surrounding Barrow Island possess considerable conservation significance. The Class A Nature Reserve status of Barrow Island extends to the low water mark and several areas have been identified as possible future marine reserves. The Barrow Island Marine Area is currently on the Interim List of the Register of the National Estate. The waters contain a number of marine fauna, including whales, dolphins, dugongs, sea turtles and certain fish species, which are protected by the Western Australian *Wildlife Conservation Act* and / or the *EPBC Act*. Intertidal and subtidal areas also contain important flora species and fauna habitats.

4.2 Regional Socio-economic Structure

This section outlines the social and economic characteristics of the region. While there are no towns or permanent settlements on Barrow Island itself, the ESE Review will need to address potential effects to regional communities and industries.

Regional Demographics

The population of the Pilbara is approximately 43,000 (2001 Census), or about 2.3% of Western Australia's population. The majority of the population live in the western third of the region, in the towns of Port/South Hedland, Karratha, Newman and Tom Price. There are also a number of Aboriginal communities scattered across the region, with resident populations of between 50 and 300 people.

The census revealed that the population is relatively young, fluctuates according to major resource projects and contains a high proportion of Aboriginal and Torres Strait Islanders relative to the rest of Western Australia.

Regional Economic Issues

The Pilbara Region makes a significant contribution to Western Australia's economy by providing the overwhelming majority of Western Australia's three largest exports - natural gas and gas liquids, crude oil and condensate, and iron ore.

In 1999/2000 the value of production from the Pilbara's petroleum and mining industries was nearly $12 billion. While these industries dominate the region's economy, accounting for almost 90% of its investment and approximately 30% of its employment, other industries also make important contributions. The proportions of value of production attributable to industry sectors are illustrated in Figure 7.

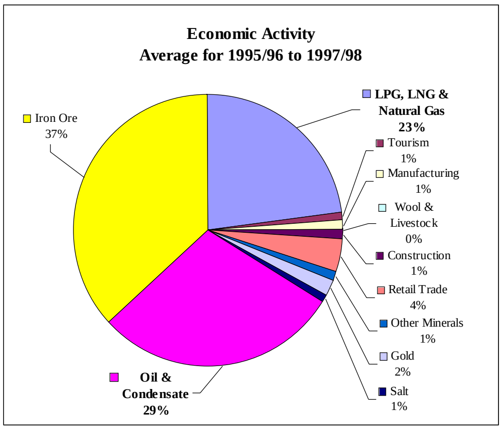


Figure 7: Regional Economic Activity, average for 1995/96-1997/98

Mining (including the petroleum industry) is by far the single most significant employer in the region. The contributions of each sector to employment in the region are illustrated in Figure 8.

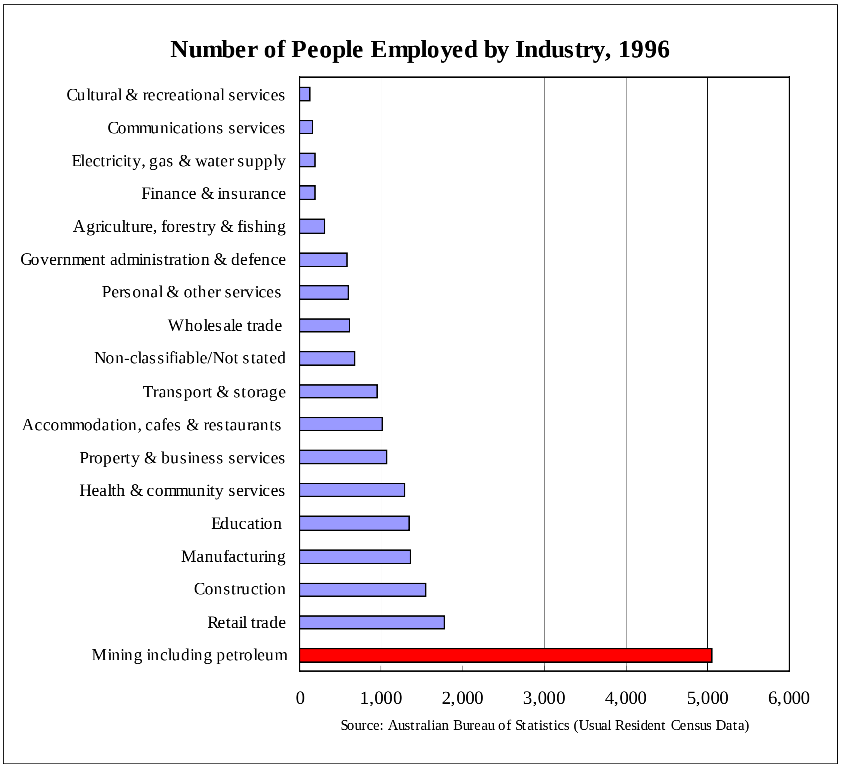


Figure 8: Regional Employment by Industry, 1996

Petroleum

The Pilbara is Australia's leading petroleum region with production valued at more than $7.5 billion per year. There are four main producers that access the Carnarvon Basin reserves: Woodside Offshore Petroleum (and its NWS Venture project partners) produces mainly natural gas and liquefied natural gas (LNG) and condensate, ChevronTexaco, Apache Energy and BHP Billiton produce mainly crude oil.

The North West Shelf Venture Project has created a range of economic, social, industrial and environmental benefits for Australia. These have resulted from capital investments during construction of the Venture assets through to export revenue, royalty payments, economic stimulation and job growth from ongoing operations. Economic benefits from the North West Shelf Project include annual export revenues in excess of $3 billion, annual royalty payments to Government in the order of $300 million and capital expenditure to date in excess of $13 billion.

It is anticipated that the petroleum industry will continue to grow with the current North West Shelf Project expansion to double the production from the North West Shelf Project and the Gorgon Participant's plans for development of the Gorgon area gas.

Iron Ore

Western Australia produces almost one third of the world's seaborne traded iron ore, with all but a small amount coming from mines in the Pilbara. In 1999/2000 total iron ore production was 143.3 million tonnes and was valued at $3.7 billion.

Downstream Processing

The Pilbara is the focus of a drive to increase downstream processing to add value to its mineral and energy resources. A number of proposals are currently under consideration, including iron ore processing and production of petrochemicals. The success of many will be directly or indirectly influenced by access to secure competitively priced energy or gas feedstock such as that provided by Gorgon gas development.

Pilbara Coast – Resource Developments

There are a considerable number of resource developments being considered in the region that could compete with the Gorgon development for construction and operating resources.

In iron ore processing, these include Austeel's Fortescue (Cape Preston) mine and HBI plant, and the iron ore mines of BHP Billiton's Mining Area C, Hamersley Iron's Nammuldi and Hope Downs. HiTec Energy Limited has a proposed manganese dioxide project near Port Hedland at Boodarie.

In addition to the North West Shelf oil and gas expansion, there are five petrochemicals/chemicals prospects in the region: two gas-to-liquids plants, Sasol Chevron's and Syntroleum's (Sweetwater); two methanol proposals, Methanex and GTL Resources, Burrup Fertilisers' ammonia plant, the Plenty River Corporation's ammonia urea plant; and Japan DME's dimethyl ether project. These projects could also be customers for Gorgon gas, as could industrial and electricity generation developments in the Mid West and South West regions.

Shipping

The Pilbara has a well-developed transport infrastructure network. The ports in the Pilbara handle tonnages far in excess of any other ports in Western Australia, with export trade dominating. The Pilbara's three large industrial ports are located at Dampier, Port Hedland and Port Walcott (Cape Lambert). A total of 184 million tonnes of cargo was exported through these three ports in 1999/2000. Annual shipments from the main ports currently run at around 144 million tonnes.

Tourism

Tourism is a small but valuable contributor to the region's economy. The sector provides the necessary facilities for both business and holiday travel. Key attractions include the spectacular gorge country in the Karijini National Park, the tropical oasis at the Chichester-Millstream National Park and the historic settlements of Marble Bar and Cossack. The region's coastline and the islands of the Dampier Archipelago and off the Onslow coast also provide opportunities for aquatic-type activities.

There were 355,000 overnight domestic visitors to the region in 2001.

Other Industry Sectors

Other industry sectors contributing to the regional economy include gold, salt, fishing and aquaculture, construction, manufacturing, public administration and community services, commerce and pastoral.

Barrow Island:

Land Tenure

Barrow Island has undergone a series of tenure variations since it was first set aside as a "Hospital for Aboriginals", in March 1908. The island was never used for this purpose and in November of the same year, approval was received for the island to become a reserve for the purpose of "Protection of Flora and Fauna". In 1910, it was classified as a Class A Reserve. The classification changed again in 1979, when the island was designated a "Nature Reserve" and in 1984, the purpose was altered from "Protection" to "Conservation". The following year, the island was vested in what was then known as the National Parks and Nature Conservation Authority (now CCWA) although management responsibility remained with CALM. At the same time the boundaries of the reserve were extended to the low water mark. Since that time, Barrow Island, along with all of Western Australia's National Parks, conservation parks, nature reserves, forest and timber reserves have been vested in the Conservation Commission of Western Australia, which was formed in November 2000. The Conservation Commission reports to the Minister for Environment and Heritage. The mission of the Commission is to conserve Western Australia's biological diversity and to ensure the conservation estate, for which it has responsibility, is managed in an ecologically sustainable manner.

In 1966 a Petroleum Lease (PL1H) was granted by the Western Australian Government to WAPET to govern the company's petroleum exploration and production activities. The lease overlies all but two small areas of the island[8].

Native Title

While the location on Barrow Island is not expected to result in the occurrence of native title issues, such issues may arise as a consequence of a pipeline extension to the mainland. The region has seen mixed experiences in terms of relations between resource explorers and developers and indigenous communities. ChevronTexaco aims to maximise social enhancement opportunities dependant on the development while minimising and mitigating adverse impacts. This will involve not only ensuring compliance with relevant legislation, both State and Commonwealth, but also engaging in constructive dialogue with relevant indigenous communities. Early consultation with the Yamatji Barna Baba Maaja Land and Sea Council, the Native Title Representative Body for the Pilbara, will be undertaken to initiate the process. The aim will be to resolve any issues and to maximise the potential for positive effects.

Land Use

Land use on Barrow Island primarily comprises either industrial usage associated with the exploration for, or production and export of, oil in those areas leased to WAPET, now held by ChevronTexaco, or to conservation associated with the nature reserve. There is no tourist use of Barrow Island.

Cultural Heritage

In Western Australia all objects, sites and areas of Aboriginal origin or of significance to Aboriginal people are protected under the *Aboriginal Heritage Act, 1972* (and amendments 1980 and 1995). Barrow Island is considered to be of low sensitivity in regard to Aboriginal heritage. The island has been separated from the mainland for at least 8,000 years and has not been utilised by indigenous populations since this time, with the exception of minor pearling activities around the turn of the century.

[8] ChevronTexaco holds exploration permits EP 61 and EP 62 over these two areas.

Economic Activity

Barrow Island was first visited by geologists from West Australian Petroleum (WAPET) in 1954 with oil being discovered by the Barrow-1 well in 1963 and first commercial production in 1967. Since that time, some 900 wells have been drilled on the island and nearly 300 million barrels of oil have been produced. At its peak, the field was producing at a rate of 53,000 barrels per day and is the largest onshore field ever developed in Australia.

Currently, the Barrow Island oilfield is producing at around 9,000 barrels of oil per day and is maintained by a rotational workforce of about 150 staff and contractors. The existing petroleum development is shown in Figure 9. As stated earlier, petroleum exploration and production has been successfully conducted over a period of nearly forty years in a manner that has protected and maintained the conservation values of the island.

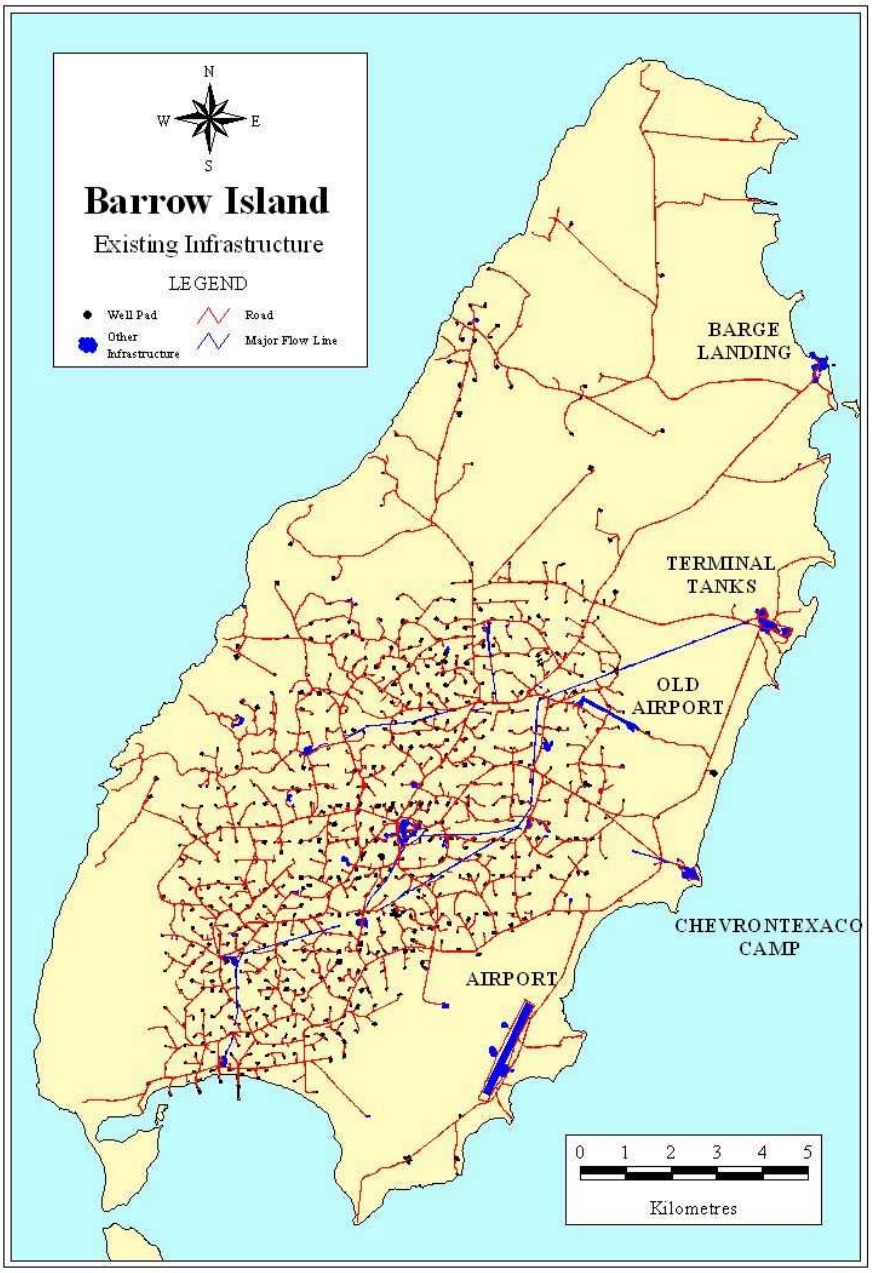


Figure 9: Petroleum Infrastructure on Barrow Island

5 Preliminary Assessment of Impacts and Benefits

The construction and operation of the Gorgon development has the potential to result in a range of environmental, social, economic and strategic impacts and benefits. While it is the purpose of the ESE Review to identify and discuss these at a more detailed level, the following section presents a summary of the key issues, as currently understood, to serve as a basis for consideration of the scope of the investigations.

The Gorgon Participants are confident that a range of options exist to address the potential issues and to achieve the agreed objectives. An overview of some of the key strategies to be investigated is provided in Appendix 1. The strategies outlined are not fixed and are certainly not exhaustive, but intended as examples of the options available. These will be dealt with in detail in the ESE Review.

5.1 Commercial Aspects

Several factors are necessary for the establishment of a commercially viable, world competitive gas development. The most significant of these are:

- the ability to capture markets for Gorgon gas or its products within the context of regional competition and favourable economic conditions
- the management of potential technical and engineering constraints, so ensuring competitive product costs, and
- the adoption of regulatory processes and government policies that allow reasonable development costs to be maintained.

The ESE Review will identify and address issues that may enhance or inhibit the commercial viability of the development.

5.2 Environmental Aspects

Activities associated with the construction and operation of a gas processing facility and its associated infrastructure on Barrow Island have the potential to impact the local terrestrial, subterranean, intertidal and marine environments, local air quality and wider atmospheric conditions. The Gorgon Participants are confident that the majority of such impacts can be avoided or appropriately mitigated. While considered to be highly unlikely, the following potential impacts, were they to occur, are considered critical to the in-principle acceptability of the use of Barrow Island for the development. Therefore, these will be the focus of the environmental component of the ESE Review.

- The introduction of exotic plants, animals and diseases as a result of the import of materials and the movement of vessels, equipment and personnel.

- Extensive disturbance to significant vegetation or wildlife habitats particularly during construction earthworks or as a result of hydrocarbon or chemical spills.

- Extensive disturbance to sensitive marine habitats (such as corals and sea grass areas) particularly during dredging operations.

- Significant contamination of the marine environment as a result of accidental hydrocarbon spills.

- Significant greenhouse gas emissions associated with the separation of hydrocarbons from reservoir CO_2 and as a result of gas processing.

5.3 Social Aspects

There are likely to be long-term regional benefits as the project will act as a catalyst for greater industrial development. This could well extend beyond the Pilbara into other regions. Development on Barrow Island will have a limited direct impact on the Pilbara region in terms of demographic changes and social and economic impacts. During the construction phase direct effects are likely to be more significant, although transient, because of the numbers of people and movement of construction material involved.

The development may generate significant social benefits related to both direct and indirect employment, particularly in small business, both in the region and in Perth. Technology transfer to local business can result in significant growth outside the direct influence of the development.

Some effects on social infrastructure may result from the construction and operational phases. Impacts that may be of particular concern include the potential to place strains on social infrastructure including:

- local and regional health and welfare services
- emergency response facilities
- transport, and
- accommodation.

5.4 Economic Aspects

The development of Gorgon gas will result in significant economic benefits including regional development, employment, income to the Government and economic growth.

Most economic consequences of the development are intrinsic to the economic activity of constructing and operating the gas field and processing facilities, or are induced by bringing a competitive gas supply into the market. Economic consequences, particularly during the construction phase, include:

- the potential to engage local, state and national contractors to provide goods and services to the development
- the potential to invest in training, education and R&D, and
- the potential impact on the operations of other enterprises.

Benefits to the economy, to be quantified during the review, include:

- significant direct and indirect employment during construction
- significant sustained direct and indirect employment during operations
- stimulation of small and medium enterprises through direct work on the development, indirect provision of goods and services, and technology transfer enabling expansion of business into other areas
- tax revenues to both the Western Australian and Commonwealth Governments either enhancing Government expenditure in the community or lessening the tax burden
- improved efficiency of existing oil production on Barrow Island associated with operational synergies offered by the Gorgon gas development, and
- stimulation of the economy through the provision of increased competition in the gas market.

5.5 Strategic Aspects

Development of the Gorgon gas resource offers significant strategic benefits. The following strategic aspects are considered the highest priority for assessment:

- the potential the development offers to unlock the value of these gas resources
- the potential for new investment in value-adding industries that is induced by developing these gas resources

- the additional security of energy supply offered by developing the gas resources
- the opportunity to establish a gas-to-liquids industry with potential environmental and strategic benefits, and
- the potential to increase competition in energy markets in Western Australia and Australia.

6 Scope of the ESE Review

The ESE Review will be conducted at the strategic level, focusing on issues critical to the determination of the sustainability of a Gorgon area gas development on Barrow Island. The ESE Review will provide sufficient high-level data and analysis to allow:

- the public to arrive at an informed view
- the Department of Mineral and Petroleum Resources, the Environmental Protection Authority, the Conservation Commission of Western Australia and the Standing Interagency Committee of Chief Executive Officers to make proper evaluations, and
- the Western Australian Government to make a holistic informed decision on the issues involved with access to Barrow Island.

A subsequent assessment will be conducted under Part IV of the *Environmental Protection Act* and the *Environment Protection and Biodiversity Conservation Act*, but it is the expectation of the EPA that all issues fundamental to Barrow Island access will be addressed in the ESE Review. The subsequent project specific environmental impact assessment will provide technical, project specific detail in support of the in-principle decision.

The scope for the ESE Review is outlined in the Appendix 1. The proposed content and structure of the ESE Review is summarised in Appendix 2. The following sections provide an outline of the key elements of the scope.

6.1 General Content

The main focus of the ESE Review will be the ability of the Gorgon gas development to achieve a range of commercial, environmental, social, economic and strategic objectives. To enable this, the document will also need to present sufficient background information to allow readers to understand the context of the development. The ESE Review will address the following issues:

Preface:

The ESE Review will describe:

- the purpose of the document, and
- the process for public comment.

Introduction

The ESE Review will identify and describe:

- the key aspects of the development (eg. scope, activities, location and schedule)
- the objectives of the development (ie. commercial, environmental, social, economic and strategic objectives), and
- the proponent (ie. background to ChevronTexaco and the Gorgon Participants).

Development Description

The ESE Review will provide:

- a more detailed description of what is being proposed, eg.
  - the scope of the development – including the sub-sea gathering system, the type of development (ie. LNG, GTL etc), facilities on Barrow Island and the ability to deliver gas to the mainland
  - key activities and processes – including field development, construction, operation and decommissioning
  - the areas involved in the development
  - the schedule for planning, construction and operation

- a discussion of the alternatives to the development, including alternative locations such as the Montebello Islands, Varanus Island and the mainland, and a comparative assessment of the selected development concept
- a discussion of the 'no development' alternative, and
- an outline of the process for site selection on Barrow Island.

The ESE Review Process

The ESE Review will:

- describe the process being adopted for the ESE Review by the Gorgon Participants, and
- describe the process for public comment, assessment and decision making by the Western Australian Government.

6.2 Environmental Issues

The investigations into the biophysical environment will address the terrestrial, subterranean, marine, intertidal and atmospheric issues. Investigations will involve:

- desktop research
- liaison with relevant stakeholders
- reconnaissance surveys (as required), and
- preliminary modelling (where relevant).

Existing Environment

The ESE Review will:

- describe the existing biophysical environment, in particular
  - marine habitats and species
  - intertidal habitats
  - terrestrial vegetation types including their composition and distribution
  - subterranean habitats
  - fauna habitats and species
- broadly identify the significant issues, in particular
  - key species including marine mammals, migratory species and rare and endangered fauna and subterranean species
  - important habitats
  - areas of instability (eg. dunes, karst areas)
- broadly identify areas or times of year that will influence the significance of impacts.

Potential Effects

The ESE Review will:

- identify and broadly describe the type and magnitude of potential impacts, including cumulative effects, and
- provide a preliminary assessment of the significance of potential impacts.

Mitigation and Management

The ESE Review will:

- identify likely mitigation strategies with comment on their effectiveness, and
- identify a range of potential net conservation benefit strategies under consideration.

6.3 Social Issues

In broad terms the ESE Review will identify and demonstrate how the development is likely to affect communities, at a local, regional and state level.

Demographics

The ESE Review will:

- define the study area in terms of what settlements are to be included in the ESE Review and provide justification for this:
    - the study area will include locations that provides a base for the workforce, or houses and infrastructure connected with the development
- establish baseline demographic data for relevant local and regional areas
- predict potential population changes resulting from the development
- identify origins and locations of potential workforce
- quantify potential workforce movements resulting from the development
- detail the preferred workforce method:
    - assessing alternative means, if any, of sourcing labour (with reference to local labour market), and
- propose response measures.

Livelihood and Lifestyle Effects

The ESE Review will:

- identify community structures and lifestyles that may be affected by the development
- describe the effects of the development on local and any other affected communities
- predict both the benefits of the development to livelihoods and any potential issues to be managed
- assess the potential for the development to cause changes to people's way of life, their sources of income and opportunities for development
- identify any impacts on the existing Barrow Island workforce
- identify any significant issues for indigenous communities in the study area and discuss any impacts on these issues (for example, health, employment, education) from the development, and
- propose response measures.

Social Infrastructure

The ESE Review will:

- identify existing social infrastructure in the study region
- undertake a strategic needs assessment to identify needs of the incoming population
- identify any potential shortfalls in service provision, or structural changes required to accommodate the workforce
- identify how shortfalls in social infrastructure may be met
- identify how the development may benefit the provision of social infrastructure in the areas of greatest impact, and
- propose response measures.

Native Title

The ESE Review will:

- identify any potential native title matters
- identify potential impacts and proposed management measures, and
- propose response measures.

Cultural Heritage

The ESE Review will:

- identify any indigenous and non-indigenous heritage issues
- identify any cultural groups or land to be impacted by the development
- identify potential impacts and proposed management measures, and

- propose response measures.

Work Practices

The ESE Review will:

- identify how the development will meet all legislative requirements regarding workers entitlements, workers compensation and employment practices.

Health and Safety

The ESE Review will:

- identify potential health risks to the workforce and local community
- describe how potential risks to health and safety of workers and local communities will be managed, and
- identify any social issues arising from constraints due to quarantine, development location or environment.

Conservation

The ESE Review will:

- demonstrate how the proponent will manage local, state and national communities' ongoing conservation amenity in relation to Barrow Island.

Community Development

The ESE Review will:

- describe the investment in human capital (training, community education), research and development and other investments likely to result from the development, and
- describe benefits to community development through regional job creation, support of local community or other initiatives.

6.4 Economic Issues

The economic assessment will address strategic economic development and involve economic analysis. Baseline data will be presented at a regional, state and national level.

Strategic Economic Development

Gorgon gas resources have the potential to underpin the future economic development of the region, state and nation. The scope of the assessment of this issue will be to:

- describe the strategic economic benefits of the development
- quantify the expenditure associated with the development at each stage of implementation
- assess the ability to deliver gas to the mainland, and
- describe how the development will contribute to economic development at a regional, state and national level.

Economic Analysis

Using regional specific and computable general equilibrium models, the scope of the assessment of the economic analysis will be to:

- quantify the development's potential contribution to gross domestic product, gross state product and gross regional product
- quantify direct, indirect and induced employment at each stage of any development
- quantify the value added aspects of the development (direct, indirect and consumption induced)

- quantify the value added to conservation programs above and beyond regulatory functions directly associated with the development, including but not limited to, the value added by accelerating or bringing forward conservation programs which would otherwise be funded from consolidated revenue
- quantify the projected Government revenue at various stages of the development
- forecast any potential impacts on price and cost changes at a regional or state level resulting from the development, and
- the scope of analysis will include the initial construction phase of the development and the future operations of the development.

6.5 Strategic Value

The strategic assessment will examine those benefits that flow to the region, state and the nation as a result of the development creating a significant community energy resource that can underpin growth in other sectors of the economy.

The scope of the assessment of strategic factors will be to define, assess, describe and where relevant, quantify:

- the implications of this proposal for the realisation of the development of the Gorgon gas resources
- the implications for energy security of Western Australia
- the impact on gas competition in Western Australia and in the eastern states, and
- the transfer of technology and skills developed from the Gorgon gas development to other hydrocarbons projects and to the petroleum industry service sector.

Legislation and Policy

The ESE Review will:

- identify areas where the development may conflict with, is consistent with, or enhances relevant policies and legislation
- discuss how the development is relevant to policy objectives on local content, regional development and others that may be relevant (local, regional, state and national), and
- discuss response and management measures that may be required.

Appendix 1:

Relevant Environment, Social and Economic Aspects

Table A1: Relevant Aspects - Biophysical Environment

Aspect	Key Attributes	Objective	Development Activities		Potential Impacts / Issues	Management Options for Consideration	ESE Review Scope of Studies	Project Specific Environmental Impact Assessment Scope of Studies[A]
Terrestrial Ecology	▪ Significant habitats – breeding, shelter & feeding areas for significant species (eg. bettong warrens) – subterranean habitats – areas of high habitat diversity – restricted habitats (ie. those under 1500ha) ▪ EPBC listed species or species protected under State legislation, eg: – burrowing bettong – black-flanked rock-wallaby – euro – spectacled hare wallaby – golden bandicoot – Barrow island mouse – black and white fairy wren – stygofauna and troglobitic fauna – listed flora species ▪ Absence of exotic species on Barrow Island ▪ Areas subject to instability or with poor rehabilitation potential ▪ Ground and surface water quality	To protect the terrestrial and subterranean ecological values from significant adverse impact and maintain the integrity of ecological processes	Construction (plant and associated infrastructure)	Import of equipment, personnel and materials	▪ Introduction of exotic plants, animals or diseases	▪ Upgrade existing quarantine protocols and implement ▪ Adopt rigorous incident response procedures ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Outline impact avoidance strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Liaise with relevant stakeholders regarding technical issues ▪ Undertake an environmental risk assessment ▪ Provide a detailed description of potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Document detailed impact avoidance procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations
				Earthworks / blasting	▪ Vegetation clearing ▪ Habitat loss / disturbance ▪ Surface instability (erosion / sedimentation) ▪ Accidental fire	▪ Avoid critical areas, where practicable ▪ Minimise 'footprint' ▪ Avoid critical times of year, where practicable ▪ Prohibit vegetation clearance for temporary purposes ▪ Rationalise access ▪ Select appropriate equipment and methods ▪ Adopt strict construction procedures ▪ Rehabilitate areas progressively ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Conduct a reconnaissance ecological field survey ▪ Broadly identify significant habitats and species ▪ Broadly describe spatial and temporal sensitivities ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Propose likely mitigation strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations Specific requirements: ▪ Propose broad fire prevention strategies and comment on their effectiveness	General requirements: ▪ Conduct detailed ecological field survey(s) ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and describe significant habitats and species in detail ▪ Describe spatial and temporal sensitivities in detail ▪ Undertake an environmental risk assessment ▪ Provide a detailed description of potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Develop and document detailed impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations Specific requirements: ▪ Conduct a blasting impact study ▪ Propose fire prevention procedures and comment on their effectiveness
				Construction camp	▪ Earthworks ▪ Habitat loss / disturbance ▪ Quarantine issues ▪ Waste production ▪ Workforce 'recreation'	▪ Maximise use of existing facilities ▪ Avoid disturbance to critical habitat areas ▪ Adopt strict workforce access and management procedures ▪ Implement quarantine procedures (see above) ▪ Implement waste management procedures (see below) ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above	General requirements: ▪ As above
				Waste storage and handling	▪ Soil and groundwater contamination ▪ Localised habitat destruction ▪ Damage to cave habitats ▪ Habitat for pests ▪ Food / shelter for native fauna	▪ Avoid critical habitats ▪ Contain wastes, prevent leaching and spills ▪ Adopt strict management procedures ▪ Adopt comprehensive spill response procedures ▪ All construction wastes transported to the mainland for disposal ▪ Avoid accumulation of wastes ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above Specific requirements: ▪ Propose likely spill prevention strategies and comment on their effectiveness ▪ Propose broad emergency response procedures and comment on their effectiveness	General requirements: ▪ As above Specific requirements: ▪ Propose spill prevention procedures and comment on their effectiveness ▪ Propose emergency response procedures and comment on their effectiveness
			Production and processing	Condensate / Liquid hydrocarbon product production and transfer	▪ Spills ▪ Soil and groundwater contamination ▪ Localised habitat destruction ▪ Damage to cave habitats	▪ Avoid critical areas, where practicable ▪ Design plant and equipment to prevent spills ▪ Adopt strict operating procedures ▪ Adopt comprehensive spill response procedures ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above Specific requirements: ▪ Propose likely spill prevention strategies and comment on their effectiveness ▪ Propose broad emergency response procedures and comment on their effectiveness	General requirements: ▪ As above Specific requirements: ▪ Propose spill prevention procedures and comment on their effectiveness ▪ Propose emergency response procedures and comment on their effectiveness

Aspect	Key Attributes	Objective	Development Activities		Potential Impacts / Issues	Management Options for Consideration	ESE Review Scope of Studies	Project Specific Environmental Impact Assessment Scope of Studies[A]
Terrestrial Ecology (continued)			Production and processing (continued)	Waste storage and handling	▪ Soil and groundwater contamination ▪ Localised habitat destruction ▪ Damage to cave habitats ▪ Habitat for pests ▪ Food / shelter for native fauna	▪ Avoid critical habitats ▪ Design plant and equipment to contain wastes, prevent leaching and spills ▪ Adopt strict management procedures ▪ All hazardous and all solid wastes transported to the mainland for disposal ▪ Avoid unnecessary accumulation of wastes ▪ Adopt comprehensive spill response procedures ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above Specific requirements: ▪ As above	General requirements: ▪ As above Specific requirements: ▪ As above
				Import of equipment, personnel and materials	▪ Introduction of exotic plants, animals or diseases	▪ Upgrade existing quarantine protocols and implement ▪ Adopt rigorous incident response procedures ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Outline impact avoidance strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Liaise with relevant stakeholders regarding technical issues ▪ Undertake an environmental risk assessment ▪ Provide a detailed description of potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Document detailed impact avoidance procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations
				Physical presence of plant, equipment and personnel	▪ Habitat loss / disturbance ▪ Changes to water movement ▪ Fauna disturbance by light or noise	▪ Design structures to minimise footprint and rationalise access for operations ▪ Design and operate facilities to minimise light and noise emissions ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above	General requirements: ▪ As above Specific requirements: ▪ Noise modelling
				Air emissions	▪ Acute / chronic impacts to wildlife health	▪ Design and operate plant to minimise emissions and to facilitate adequate dispersion to avoid harmful concentrations ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above	General requirements: ▪ As above Specific requirements: ▪ Air emissions modelling
Marine Ecology	▪ Significant habitats (seagrass areas, reefs, coral) ▪ Areas of high habitat diversity ▪ EPBC listed species (cetaceans, turtles, marine birds, fish etc) ▪ Species protected under State legislation ▪ Water quality ▪ Local current / flow characteristics	To protect marine ecological values from significant adverse impacts and maintain the integrity of ecological processes	Offshore construction	Dredging	▪ Sediment plumes ▪ Smothering of benthic communities ▪ Introduction of foreign marine organisms	▪ Avoid critical areas, where practicable ▪ Avoid critical times of year, where practicable ▪ Select appropriate vessels and equipment ▪ Adopt strict construction procedures ▪ Adopt the AQIS (2001) Australian Ballast Water Management Requirements ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Conduct a reconnaissance field survey ▪ Broadly identify significant habitats and species ▪ Broadly describe spatial and temporal sensitivities ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Propose likely mitigation strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Conduct detailed field survey(s) ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and describe significant habitats and species in detail ▪ Describe spatial and temporal sensitivities in detail ▪ Undertake an environmental risk assessment ▪ Provide a detailed description of potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Develop and document detailed impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations Specific requirements: ▪ Conduct sediment plume modelling
				Vessel movements	▪ Fuel spills ▪ Contamination of water and possibly sediments ▪ Lethal impacts to marine flora and fauna ▪ Chronic impacts to marine flora and fauna	▪ Prohibit fuel transfer in critical habitat areas ▪ Select appropriately designed vessels and equipment ▪ Adopt strict operating procedures ▪ Adopt comprehensive emergency response procedures ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above	General requirements: ▪ As above Specific requirements: ▪ Conduct oil spill trajectory modelling ▪ Undertake a quantitative environmental risk assessment
			Production and processing	Presence of infrastructure (eg. jetty)	▪ Habitat modification ▪ Current modification	▪ Design structures to accommodate required current characteristics ▪ Design structures to limit detrimental colonisation by marine species ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above	General requirements: ▪ As above (excluding environmental risk assessment)

Aspect	Key Attributes	Objective	Development Activities		Potential Impacts / Issues	Management Options for Consideration	ESE Review Scope of Studies	Project Specific Environmental Impact Assessment Scope of Studies[A]
Marine Ecology (continued)			Production and processing (continued)	Cooling water discharges	▪ Reduction in water quality ▪ Habitat modification	▪ Prohibit discharge of cooling water to the marine environment ▪ Design water collection, treatment and disposal systems to minimise the risk of spills to the marine environment ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Propose likely mitigation strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Develop and document detailed impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations
				Condensate / Liquid hydrocarbon product transfer	▪ Spills ▪ Contamination of water and possibly sediments ▪ Lethal impacts to marine flora and fauna ▪ Chronic impacts to marine flora and fauna	▪ Avoid critical habitat areas for condensate loading ▪ Select appropriately designed vessels and equipment ▪ Adopt strict operating procedures ▪ Adopt comprehensive emergency response procedures ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Conduct a reconnaissance field survey ▪ Broadly identify significant habitats and species ▪ Broadly describe spatial and temporal sensitivities ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Propose broad spill prevention strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Conduct detailed field survey(s) ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and describe significant habitats and species in detail ▪ Describe spatial and temporal sensitivities in detail ▪ Provide a detailed description of potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Develop and document detailed impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations Specific requirements: ▪ Conduct condensate spill trajectory modelling ▪ Undertake a quantitative environmental risk assessment
			Shipping	Ballast water transfer	▪ Introduction of exotic marine organisms or diseases	▪ Adopt the AQIS (2001) Australian Ballast Water Management Requirements ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Broadly describe spatial and temporal sensitivities ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Outline management strategies and comment on their expected effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Liaise with relevant stakeholders regarding technical issues ▪ Describe spatial and temporal sensitivities in detail ▪ Undertake an environmental risk assessment ▪ Provide a detailed description of potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Outline in detail the impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations Specific requirements: ▪ Undertake an environmental risk assessment
				Vessel fouling and treatment	▪ Introduction of exotic marine organisms or diseases ▪ Tributyltin (TBT) contamination	▪ Adopt the ANZECC Code of Practice for Anti-fouling and In-water Hull Cleaning and Maintenance ▪ Adopt International Maritime Organisation standards regarding anti-fouling treatments ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above	General requirements: ▪ As above Specific requirements: ▪ As above
				Collision	▪ Fuel spills ▪ Contamination of water and possibly sediments ▪ Lethal impacts to marine flora and fauna ▪ Chronic impacts to marine flora and fauna	▪ Avoid critical areas, where practicable ▪ Select appropriately designed vessels and equipment ▪ Adopt strict operating procedures ▪ Adopt comprehensive emergency response procedures ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Conduct a reconnaissance field survey ▪ Broadly identify significant habitats and species ▪ Broadly describe spatial and temporal sensitivities ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Propose likely mitigation strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Conduct detailed field survey(s) ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and describe significant habitats and species in detail ▪ Describe spatial and temporal sensitivities in detail ▪ Provide a detailed description of potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Develop and document detailed impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations Specific requirements: ▪ Conduct condensate spill trajectory modelling ▪ Undertake a quantitative environmental risk assessment

Aspect	Key Attributes	Objective	Development Activities		Potential Impacts / Issues	Management Options for Consideration	ESE Review Scope of Studies	Project Specific Environmental Impact Assessment Scope of Studies[A]
Intertidal Ecology	▪ Significant habitats (seagrass areas, mangrove areas, rock platforms, breeding & feeding areas for significant species etc) ▪ Areas of high habitat diversity ▪ EPBC listed species (turtles, wading birds, fish etc) ▪ Species protected under State legislation ▪ Areas subject to instability ▪ Water quality ▪ Local current / flow characteristics	To protect the ecological values of intertidal areas from significant adverse impacts and maintain the integrity of ecological processes	Construction	Earthworks	▪ Substrate disturbance ▪ Shoreline instability ▪ Habitat loss / disturbance	▪ Avoid critical areas, where practicable ▪ Minimise 'footprint' ▪ Avoid critical times of year, where practicable ▪ Rationalise access ▪ Select appropriate equipment ▪ Adopt strict construction procedures ▪ Rehabilitate areas progressively ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Conduct a reconnaissance ecological field survey ▪ Broadly identify significant habitats and species ▪ Broadly describe spatial and temporal sensitivities ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Propose likely mitigation strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Conduct detailed ecological field survey(s) ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and describe significant habitats and species in detail ▪ Describe spatial and temporal sensitivities in detail ▪ Undertake an environmental risk assessment ▪ Provide a detailed description of potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Develop and document detailed impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations
			Production and processing	Presence of infrastructure (eg. jetty and processing plant)	▪ Habitat loss / disturbance ▪ Changes to water movement ▪ Fauna disturbance by light or noise	▪ Design structures to minimise footprint and rationalise access for operations ▪ Design and operate facilities to minimise light and noise emissions ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ As above	General requirements: ▪ As above
Atmospheric Issues	▪ Local air quality parameters (NO_x, SO_x, CO, particulates etc) ▪ Regional / global concentrations of greenhouse gases (CO_2, CH_4 etc)	To protect local and regional air quality and to minimise the net greenhouse gas impact of the development	Production and processing	Air emissions	▪ Reduction in local air quality	▪ Design plant to (as a minimum) meet statutory air quality standards ▪ Adopt strict operating procedures ▪ Implement comprehensive training, inspection, monitoring, auditing and reporting programs	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and broadly describe the type and magnitude of potential impacts ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Propose likely mitigation strategies and comment on their effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Collate existing meteorological data ▪ Collate generic plant design data ▪ Liaise with relevant stakeholders regarding technical issues ▪ Conduct air emission modelling ▪ Describe potential impacts (including cumulative impacts) ▪ Assess the significance of impacts ▪ Develop and document detailed impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations
				Greenhouse gas emissions	▪ Climate change	▪ Develop and implement a comprehensive greenhouse gas management strategy that may include: ▪ plant design and operation to maximise energy and greenhouse efficiency ▪ plant design and operation to minimise fugitive emissions of greenhouse gases ▪ adoption of technically feasible and economically viable CO_2 disposal methods ▪ adoption of viable sequestration options	General requirements: ▪ Undertake desktop research ▪ Liaise with relevant stakeholders regarding technical issues ▪ Identify and broadly describe the type and magnitude of potential impacts (on a lifecycle basis) ▪ Provide a preliminary assessment of the significance of potential impacts ▪ Outline potential management strategies and comment on their likely viability and effectiveness ▪ Report on results, conclusions and recommendations	General requirements: ▪ Collate generic plant emission data ▪ Liaise with relevant stakeholders regarding technical issues ▪ Describe potential impacts (including cumulative impacts) of greenhouse gas emissions (on a life cycle basis) ▪ Assess the significance of impacts ▪ Develop and document detailed impact mitigation procedures and management systems ▪ Prepare a detailed report of findings. Document and justify conclusions. Provide detailed and substantiated recommendations

A - Note: The scope of studies for the project specific environmental impact assessment is not intended to be comprehensive at this stage (as it will be a revised as a result of the work conducted during the ESE Review). It is however intended to provide an indication of the proposed timing of the assessment work and the differences in detail between the ESE Review and the subsequent assessment.

Table A2: Relevant Social Aspects

Aspect	Key Attributes	Objective	Development Activities		Potential Impacts / Issues	Management Options for Consideration	ESE Review Scope of Studies

Demographics	▪ Potential changes in population
	▪ Sources of the workforce and its movements
		Maximise social enhancement opportunities dependant on the development while minimising and mitigating adverse impacts	Construction and operational phases	▪ Fly-in-fly-out employees and contractors
				▪ Accommodating workforce and contractors
					▪ Temporary population increases in construction phase
					▪ Permanent increases likely in the operational phase
					▪ The fly-in-fly-out impacts on social infrastructure placing strains on those unable to expand to meet new requirements
					▪ Price increases for locally provided services including accommodation, food, and entertainment
					▪ Pressures on local and regional health and welfare services, emergency response facilities, transport and the other services could be stretched beyond capacities to cope
						▪ Provision of accommodation on site or in the region
						▪ Provision of social infrastructure used directly by the workforce
						▪ Contributing to the social infrastructure used by both the development workforce and the local/regional community
						▪ Seed funding to facilitate local businesses forming or expanding to respond to the increased needs for infrastructure and goods and services
							▪ Define the development study area in terms of what settlements are to be included in the ESE Review and provide justification for this:
							  ▪ The study area will include any location that provides a base for the workforce, or houses and infrastructure connected with the development
							▪ Establish baseline demographic data for relevant local and regional areas
							▪ Predict potential population changes resulting from the development
							▪ Identify origins and locations of potential workforce
							▪ Quantify potential workforce movements resulting from the development
							▪ Detail the preferred workforce method:
							  ▪ Assessing alternative means, if any, of sourcing labour (with reference to local labour market)
							▪ Propose response measures

Government policy and legislation	▪ The extent to which the development meets current government policies and in particular furthers development policies ▪ How the development is consistent with or enhances these relevant government policies and legislation	Maximise social enhancement opportunities dependant on the development while minimising and mitigating adverse impacts Measures that may be required to mitigate or remove inconsistencies or negative impacts Impacts on the economic and social development locally and of the region, state and nation	Construction and operational phases	▪ All activities ▪ Relevant legislative provisions will need to be identified	▪ Enhancement of economic development through broadening and deepening of availability of jobs in the locality and region ▪ Increasing availability of education and training in the region ▪ Social pressures from the introduction of transient populations ▪ Increased exports of gas and gas related products ▪ Enhanced prospects for future increased competition in the domestic gas supply industry	▪ Means of further enhancing some of these developments, for example, such as through mentoring schemes and life skills training to increase the prospects of local people gaining employment on the development	▪ Identify areas where the development conflicts with, is consistent with, or enhances relevant policies and legislation ▪ Discuss management measures that may be required ▪ Discuss how the development is relevant to policy objectives on local content, regional development and others that may be relevant (local, regional, state and national) ▪ Propose response measures
Livelihood and Lifestyle Impacts	▪ Changes to people's way of life, their sources of income and opportunities for development ▪ Measures that may be required to mitigate or remove inconsistencies or negative impacts ▪ Impacts on the economic and social development locally and of the region, state and nation	Maximise social enhancement opportunities dependant on the development while minimising and mitigating adverse impacts	Construction and operational phases	• All activities	▪ Increase significantly the opportunities for employment potentially available locally and in the region	▪ A range of assistance and cooperative ventures to assist local communities in taking up these opportunities. Such issues as education and training in life skills and basic literacy and numeracy will be included	▪ Describe the impacts of the development on local and any other affected communities ▪ Identify community structures and lifestyles that may be affected by the development ▪ Predict both the benefits of the development to livelihoods and any potential issues to be managed ▪ Identify any impacts on the existing Barrow Island workforce ▪ Identify any significant issues for indigenous communities in the study area and discuss any development impacts on these issues (for example, health, employment, education) ▪ Propose response measures
Social Infrastructure	• Changes to demand for schools, hospitals, roads, health services, law and order and recreation	Maximise social enhancement opportunities dependant on the development while minimising and mitigating adverse impacts	Construction and operational phases	• Influx and movement of employees and contractors	• Shortfalls in planned construction of facilities such as schools and medical facilities	▪ A range of options including the issue of public versus private or joint provision of social infrastructure	▪ Identify existing social infrastructure in the study region ▪ Undertake a strategic needs assessment to identify needs of the incoming population ▪ Identify any potential shortfalls in service provision, or structural changes required to accommodate the workforce ▪ Identify how shortfalls in social infrastructure may be met ▪ Identify how the development may benefit the provision of social infrastructure in the areas of greatest impact and ▪ Propose response measures
Native Title and Cultural Heritage	• Impact on Indigenous communities regarding native title and cultural heritage	Maximise social enhancement opportunities dependant on the development while minimising and mitigating adverse impacts	Construction and operational phases	▪ Compliance with relevant legislation, both State and Commonwealth ▪ Addressing issues related to indigenous or cultural heritage	▪ Cultural heritage on Barrow Island ▪ Should there be a pipeline extension onshore, both native title and cultural heritage issues would arise	▪ Compliance with relevant legislation ▪ Constructive dialogue with relevant indigenous communities to resolve any issues and to maximise the potential for positive impacts	▪ Identify any potential native title matters ▪ Identify any indigenous and non-indigenous heritage issues ▪ Identify any cultural groups or land to be impacted by the development ▪ Identify potential impacts and proposed management measures ▪ Propose response measures

Aspect	Key Attributes	Objective	Development Activities		Potential Impacts / Issues	Management Options for Consideration	ESE Review Scope of Studies
Work Practices	▪ Worker entitlements ▪ Employment practices	Maximise social enhancement opportunities dependant on the development while minimising and mitigating adverse impacts	Construction and operational phases	▪ All activities ▪ Relevant legislative provisions will need to be identified	▪ Comply with all legislative requirements regarding worker's entitlements, workers compensation and employment practices	• The proponent's experience in the North West Shelf project and on Barrow Island will be relevant in both identifying issues that could arise in this area and the management measures considered resolving them	▪ Identify relevant work practice legislation ▪ Identify potential impacts and management measures ▪ Propose response measures
Health and Safety	▪ Remote area location ▪ Climate ▪ Seasonal conditions ▪ Quarantine requirements	Maximise social enhancement opportunities dependant on the development while minimising and mitigating adverse impacts	Construction and operational phases	• All activities	▪ Potential health risks to the workforce ▪ Health or safety risks to the local population ▪ Issues from constraints on the workforce due to, development location or the environment	• The proponent's experience in the North West Shelf project and on Barrow Island will provide a substantial contribution to identifying and addressing management of the issues potentially involved	▪ Identify any potential health risks to the workforce due to location, climate, seasonal conditions ▪ Identify any health or safety risks to the local population ▪ Identify any social issues arising from constraints on the workforce due to quarantine requirements, development location and environment ▪ Propose response measures
Conservation	• Changes to the conservation estate and the societal amenity in that estate	Appropriately mange the local, state and national communities' ongoing conservation amenity in relation to Barrow Island	Construction and operational phases	• All activities	• Refer to Table A1 of this Appendix	• Refer to Table A1 of this Appendix	▪ Refer to Table A1 of this Appendix ▪ Plus and examination of potential net conservation strategies

Table A3: Relevant Economic Aspects

Aspect	Key Attributes	Objective	Development Activities		Potential Impacts / Issues	Management Options for Consideration	ESE Review Scope of Studies
Strategic Economic Development	▪ Potential for economic development	Maximise the contribution to economic development of the region, state and nation	Construction and operational phases	• All activities	• Competitive position of Gorgon gas	▪ Market disposition ▪ Marketing strategies ▪ Competitor analysis	General requirement: ▪ Assess the extent to which this development will further the economic development of the region, state and nation ▪ Quantify development expenditure at each stage of the development ▪ Describe how the development will contribute to economic development at a regional, state and national level
Economic analysis	▪ Gross domestic, state and regional product ▪ Employment ▪ Value added ▪ Royalties, taxes and other government revenues ▪ Local and regional price cost changes	Maximise the contribution to economic development of the region, state and nation	Construction and operational phases	• All activities	▪ Local content ▪ Impact on other businesses	▪ Maximising the opportunity for local, state and national contractors ▪ Schedule operations to minimise the impact on the operations of other enterprises (for example, fishing and tourism)	General requirement: ▪ Quantify the development's potential contribution to gross domestic product, gross state product and gross regional product ▪ Quantify direct and indirect and induced employment at each stage of any development ▪ Quantify the value added aspects of the development (direct, indirect and consumption induced) ▪ Quantify the value added to conservation programs above and beyond regulatory functions directly associated with the development, including but not limited to, the value added by accelerating or bringing forward conservation programs which would otherwise be funded from consolidated revenue ▪ Quantify the projected payments to various levels of government at various stages of the development ▪ Forecast any potential impacts on price and cost changes at a regional or state level resulting from a development
Community Development	▪ Human capital, training, local community investment	Maximise the contribution to economic development of the region, state and nation	Construction and operational phases	• All activities	▪ Training and R&D ▪ Community support	▪ Examine opportunities for investing in human capital, education and R&D ▪ Examine opportunities for contributing to community cohesion	General requirement: ▪ Describe investment in human capital (training, community education), research and development and other investments state-wide and locally as a result of the development ▪ Describe benefits to community development through regional job creation, support of local community or other initiatives

Appendix 2:

Proposed Contents and Structure ~ ESE Review

Executive Summary

Introduction

Preface
- Document context
- Purpose of document
- Process for Public comment

Introduction
- Development overview
- Objectives
- Proponent

Development Description
- Development components and scope
- Development alternatives
- Site selection

Legislation Review Process
- Key State and Commonwealth legislation
- ESE Review and Assessment Process

Existing Environmental and Social Setting

Description of the existing conditions, key issues and sensitivities:

Environment
- Marine and intertidal ecology
- Terrestrial ecology
- Atmospheric issues

Socio-Economic
- Demographics
- Regional industry
- Cultural heritage
- Land tenure and land use

Economic
- Regional economic isues

Potential Impacts and Benefits

Environment
- Quarantine issues
- Vegetation clearance
- Habitat disturbance
- Impacts to key species
- Sediment plumes/ smothering
- Contamination and pollution
- Air quality issues
- Greenhouse issues

Social
- Employment
- Training
- Local content
- Disturbance to heritage sites
- Land tenure/use issues
- Impact to native title rights
- Workforce management

Economic
- Gross domestic, state and region product
- Regional economic development
- Royalties export income

Strategic
- Security of supply
- Ability to deliver gas to mainland
- Gas-on-gas competition

Maximising Benefits, Minimising Impacts

Environment
- Minimising, managing and mitigating impacts
- Net conservation benefit strategies

Social
- Minimising impacts
- Maximising benefits

Economic
- Maximising local, regional, state and national benefits

Strategic
- Maximising state and national benefits

Conclusion

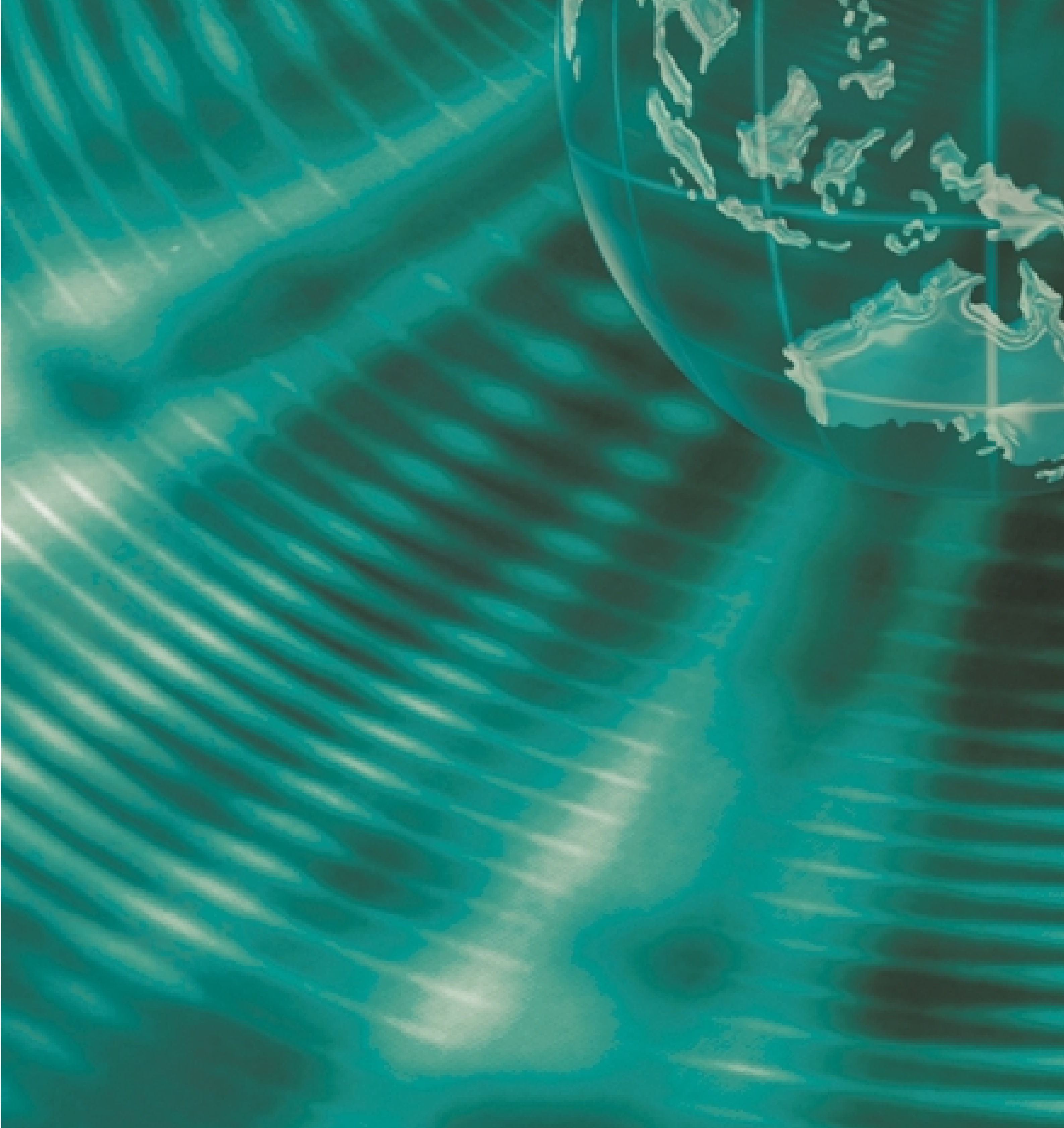
Summary of key findings

Can objectives be achieved?

Next steps

Technical Appendices

Proposed Contents and Structure ~ ESE Review



APPENDIX B

GUIDELINES FOR THE SOCIAL, ECONOMIC AND STRATEGIC EVALUATION OF THE GORGON GAS DEVELOPMENT PROPOSAL

Department of
Mineral and Petroleum Resources

Guidelines for the Social, Economic and Strategic Evaluation of the Gorgon Gas Development Proposal

30th May 2002

CONTENTS

1 INTRODUCTION

1.1 OBJECTIVE

The Government of Western Australia has determined that a high level evaluation of the Gorgon Gas Proposal (*the Proposal*) is required to allow it to make an informed decision on whether to reject or, to provide 'in principle' approval for, the use of Barrow Island as the location for a gas processing complex as part of the initial development of the Gorgon gas project.

This proposal, for the limited use of Barrow Island, is a unique proposal of State significance to Western Australia. This significance stems from the size and potential economic value of the Gorgon project gas fields, the high conservation values (including biodiversity) of Barrow Island and the social importance of these economic and conservation values.

The objective of these Guidelines is to provide a framework for the social, economic and strategic evaluation of this proposal.

1.2 BACKGROUND

In Western Australia, there is no formal process to assess the relationship between the environmental, social and economic costs and benefits of significant development proposals.

The State Sustainability Strategy, currently under development, will provide a Sustainability Assessment Framework and the necessary arrangements to enable this to occur. The Sustainability Assessment Framework will also make clear the relationship and differences between Environmental, Social & Economic Assessment and Sustainability Assessment. The former provides separate assessments on the social, economic and environmental factors. The later will integrate these factors at the start and throughout the assessment process.

Therefore, in the absence of an formalised Sustainability Assessment Framework, the evaluation of the Gorgon Gas Proposal should be considered an Environmental, Social & Economic assessment.

There are well established, effective processes for evaluating the environmental acceptability (or otherwise) of a proposal through the Environmental Protection Act. However, this process is conducted in isolation from consideration of the direct or downstream economic and/or social costs and/or benefits that may accrue locally, to the State or nation from a proposal. Accordingly, the Government is often not able to demonstrate in a transparent manner, how it has considered the balance between social, economic and environmental factors when determining whether to approve a proposal.

Prior to making a decision about whether to reject or, to provide in-principle approval to, the limited use of Barrow Island for the development of the

Gorgon gas field, Government is seeking information on the strategic, social, economic and environmental aspects of the Proposal. The Environmental Protection Authority (*EPA*) will provide advice on environmental matters and Government has asked the Department of Mineral and Petroleum Resources (*MPR*) to provide advice on the social, economic and strategic aspects of the Proposal. The advice will be made public. The Government has also sought advice from the Conservation Commission of WA, in which Barrow Island Nature Reserve is vested.

These Guidelines for the Social, Economic and Strategic (*SES*) evaluation have been prepared to provide clear guidance to Chevron Australia Pty Ltd (*ChevronTexaco*) as the manager of the Gorgon Gas Joint Venture and developer of this proposal, as to the form and scope of this part of the evaluation.

The preparation of these Guidelines has been assisted by Environmental Resources Management Australia (*ERM*). ERM has provided advice in relation to benchmark issues examined during similar evaluations in other jurisdictions in Australia and elsewhere, and conducted consultation with key stakeholders to determine issues of relevance in the current context. Sections 2 and 3 of these Guidelines represent the outcome of this work by ERM.

It should be noted that these Guidelines, and associated process, are not intended to set a precedent for other project assessments or proposals of this nature. The evaluation is being undertaken to respond to a specific need of Government in relation to a unique proposal by the Gorgon Gas Joint Venture.

1.3 EVALUATION PROCESS

1.3.1 Overview

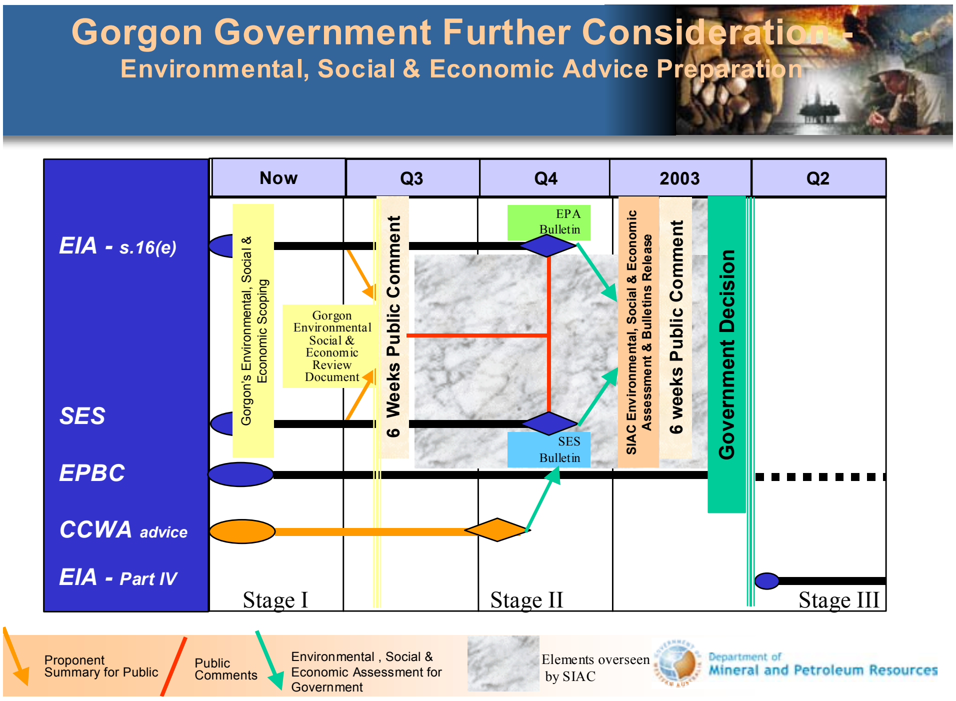
A diagram outlining the overall process for the high level evaluation of the Gorgon Gas Proposal is shown in *Figure 1.*

The Environmental Protection Authority will evaluate environmental aspects under the provisions of Section 16(e) of the Environmental Protection Act. The EPA will deal with all potential environmental impacts, high level management commitments and environmental offsets.

The SES evaluation will be undertaken in harmony with and parallel to the EPA's Section 16(e) environmental assessment.

In a whole of government approach, the SES evaluation will be co-ordinated through the Standing Interagency Committee of Chief Executive Officers (*SIAC*).

Figure 1.



In this co-ordinating role, SIAC will receive all public comments on the Proponent's ***Environmental, Social & Economic Review Document*** and act as a clearing house to ensure that comments concerned with environmental issues are dealt with by the EPA, while those concerned with social, economic or strategic aspects are dealt with by MPR.

The Standing Interagency Committee of Chief Executive Officers (SIAC) comprises core representation by:-

- The Department of Land Administration
- The Department of Treasury and Finance
- The Environmental Protection Authority
- The Department of Environment, Water and Catchment Protection
- The Department of Planning and Infrastructure.
- The Department of Mineral and Petroleum Resources, with
- Other relevant agencies invited to participate as appropriate to co-ordinate specific project approvals or issues.
- MPR acts as the secretariat to SIAC.

SIAC has operated for more than 2 years to advise the Minister for State Development on whole of government strategic and approvals matters relating to major resource development projects.

In respect to Gorgon, SIAC is expanded through the addition of representation from the Department of the Premier and Cabinet, and from the Department of Conservation and Land Management and the Conservation Commission of WA to ensure a co-ordinated whole of government evaluation is available for the WA State Government.

The detailed information on environmental, social, economic and strategic issues prepared by ChevronTexaco will be presented within a single ***Environmental, Social & Economic Review*** document. This document will be released to the public for review and comment for a period of six (6) weeks. Following receipt of public submissions the EPA will prepare a ***Bulletin*** documenting its advice on the Proposal. MPR will prepare a separate evaluation document, or ***Bulletin***, on the social, economic and strategic aspects. Government will also be advised on nature conservation matters relating to the Proposal by the Conservation Commission of WA. The Commission will formulate its advice at the same time as the EPA and SES Bulletins are prepared.

A single overarching ***Environmental, Social & Economic Assessment*** report will then be prepared under SIAC's supervision. This overarching ***Assessment*** report will then be packaged with the two individual ***Bulletins*** and the Commission's. This package will be publicly available for a six (6) week period before being considered by the WA State Government.

These Guidelines have been developed in consultation with key stakeholders and are being made publicly available for information purposes only.

1.3.2 Consultation

Consultation with stakeholders during the scoping and preparation of the ***Environmental, Social & Economic Review*** is important. ChevronTexaco should ensure that the consultation process includes Government and non-government stakeholders at the local, regional, State and national levels. These stakeholders should represent the interests of the whole community and include:

- Local, State and Federal government;
- Regional development and social welfare agencies;
- Local and industry business groups;
- Indigenous groups; and
- Conservation groups.

The ***Environmental, Social & Economic Review*** should clearly identify the consultation processes used to engage stakeholders, the stakeholders that have been consulted and the key issues raised by each group. The ***Environmental, Social & Economic Review*** should seek to identify how these issues can be addressed and proposed processes for ongoing community engagement.

1.4 *PROPOSAL DESCRIPTION*

The Gorgon gas field is located off the north-west coast of Western Australia. The three partners in the Gorgon joint venture include Chevron Australia Pty Ltd, Texaco Australia Pty Limited (operating together as ChevronTexaco), Shell Development (Australia) Proprietary Limited and Mobil Australia Resources Company Pty Ltd. The Joint Venture is pursuing consideration of Barrow Island as a siting location to support the initial development associated with the Gorgon gas field.

The current proposal involves piping gas from the Gorgon gas field to Barrow Island, a Class A Nature Reserve, with high conservation values and site of an existing oil field operation. The Proposal would involve the construction of a subsea pipeline from the Gorgon gas field and establishment of gas processing facilities on Barrow Island that the proponent states are required to establish the viable development of the Gorgon gas resources at this time.

An important consideration from the WA State Government's viewpoint in the evaluation will be the level of commitment by the Gorgon Joint Venture to the delivery of gas to the Western Australian mainland.

2 GUIDELINE FRAMEWORK

2.1 AIMS AND OBJECTIVES

2.1.1 General

The Proponent's Social, Economic and Strategic (SES) review within the ***Environmental, Social & Economic Review Document*** should consider the development, construction, operation and decommissioning stages of the Proposal. Notwithstanding the high level nature of the evaluation, Government will require sufficient detail in the ***Environmental, Social & Economic Review*** to make an informed decision about this proposal to use Barrow Island. This information should be provided at local (within the local government authority), regional (Pilbara), State and National levels, where appropriate.

It is generally accepted practice that socio-economic reviews for new operations should involve analysis of the potential effects of proposals on the community and economy at local, state and national levels, along with the development of strategies to manage these effects. Many of the identified social, economic and strategic issues will overlap with aspects and issues to be examined by the EPA during its separate, but parallel and synchronised, evaluation.

The general objectives of a socio-economic evaluation are to:

- Develop and build an understanding of the needs of communities and other stakeholders;
- Estimate the socio-economic costs and benefits of the development;
- Propose means to limit, adverse socio-economic impacts of new developments; and
- Propose means which seek to increase socio-economic benefits of new developments.

2.1.2 Social

Proposals may result in social changes that affect:

- people's way of life (how they live, work, play and interact with one another on a day to day basis);
- their culture (shared beliefs, customs and values); and

- their community (its cohesion, stability, character, services and facilities). (Armour, 1992)

Therefore, a social evaluation must assess the effect that a new proposal may have in relation to any of the above aspects, either on an individual or on a community. It is a process for predicting change that may result from a proposal. It must be recognised that this change can be either positive or negative.

2.1.3 *Economic*

The aim of an economic evaluation is to measure the costs and benefits of the proposal to the potentially affected local, regional, state and national economies that are additional to what would have occurred otherwise.

A particular component of this review should be the understanding and estimation of benefits that might accrue from enhanced availability, security and competition in the WA domestic gas industry in general. It is anticipated that the review will also highlight additional benefits derived from export of processed products produced from Gorgon gas feedstock.

2.1.4 *Strategic*

The strategic part of the evaluation will examine those benefits and costs that flow to the State as an indirect result of the Proposal enabling or causing growth in other areas. These strategic issues may be social, economic or environmental.

There may also be issues that represent the integration of social, economic and environmental elements, for example greenhouse gas emissions, contribution to competition in the WA gas market and inter-generational equity.

2.2 *REVIEW REQUIREMENTS FOR SOCIAL, ECONOMIC AND STRATEGIC FACTORS*

2.2.1 *Structure*

The social, economic and strategic review should include the following components:

- What the Proposal is intended to achieve (objective);
- A scoping of the Proposal;
- Baseline studies;
- Impact identification, analysis and evaluation for the Proposal, taking into account future scenarios;

- Comparative assessment of potential project locations (alternatives to Barrow Island); and

- Development of management or mitigation strategies, and as appropriate, measures to gauge the success of these strategies.

2.2.2 *Proposal Description*

The review should include a clear description of the Proposal, including physical, social, and economic context.

The project description(s) may include disclosure of the profile of the organisation(s) and the technical aspects of the Proposal, consisting of (but not limited to):

- a description of the location, infrastructure and the full range of proposed technologies forming part of the Proposal;

- the proposed demographics of the workforce for the Proposal and the basis for a working regime (eg. fly in–fly out) during construction and operation;

- the economic value of the Proposal; and

- corporate structure and partnership/joint venture relationships of the proponent(s).

2.2.3 *Proposal Alternatives*

The proponent should identify all reasonable project locality options considered, and provide a comparative assessment of these that adequately demonstrates for the Government, the merits associated with the selection of Barrow Island as the proposed site for the initial land based elements of the Proposal.

The review should, as part of this comparative assessment, also consider the no development alternative.

2.3 *EVALUATION APPROACH*

2.3.1 *Scope - Issues Identification And Selection*

An initial scoping of the Proposal issues has been undertaken through consultation with various stakeholders during the development of these Guidelines. ChevronTexaco should expand on this information and identify all issues relevant to the Proposal and, through further consultation with relevant stakeholders, ensure that the list of issues is complete and appropriate alternatives are addressed in the comparative assessment.

2.3.2 *Baseline Studies*

In order to understand potential impacts resulting from the Proposal, it is necessary to provide a baseline of the social and economic conditions prior to commencement. Baseline data should be presented at a regional, state and national level.

The baseline data may be available through government and other sources, or primary data collection and modelling may need to be commissioned. The data collated and reviewed at this point can provide a reference point for a detailed project assessment.

2.3.3 *Methodology for Impact Identification and Assessment*

There are a variety of qualitative and quantitative methodologies that can be applied to the assessment of social and economic factors. The proponent may select the methodologies most appropriate to responding to the objectives and issues outlined in Section 3.

Sufficient high-level data and analysis should be provided that will allow the public to arrive at an informed view, SIAC to make a proper evaluation and the WA State Government to make an informed decision on the issues involved.

2.3.4 *Mitigation*

The potential for any negative impacts to occur and opportunities to enhance the benefits of the Proposal should be identified and, where required, mitigation and monitoring measures should be included in the report. There should be consultations with stakeholders on mitigation options and realistic strategies presented.

2.4 *FACTORS FOR ASSESSMENT*

The social and economic factors to be considered in the Proponent's review are outlined in *Table 3.1* and *Table 3.2*. The tables identify the objectives and broad scope of work for each of the factors. The requirements to draw out the factors of strategic State significance are outlined in Section 3.3.

Where information is not available due to the high level nature of the Proposal, the review should identify how these factors would be considered in the future.

3 FACTORS FOR ASSESSMENT

3.1 SOCIAL

Table 3.1 Social Issues

CONTENT		SCOPE OF WORK	
Factor	**Issue**	**Objective**	**Suggested Scope of Work for Social Assessment**
Demographics	Impact of workforce and contractors on relevant settlements	Identify potential changes in population Predict impacts resulting from changes Identify workforce sources and movements	Define the Proposal Study Area (what settlements are to be included in the Proponent's review and provide justification for this). The Study Area should include any location that provides a base for the workforce or houses and infrastructure connected with the Proposal
			Establish baseline demographic data for relevant local and regional areas
			Predict potential population changes resulting from the Proposal
			Identify origins and locations of potential workforce and quantify potential workforce movements resulting from the Proposal
			Detail the preferred workforce method and assess alternative means, if any, of sourcing labour (with reference to local labour market)
			Propose response measures
Government policy and legislation	The extent to which the Proposal meets current government policies and in particular furthers development policies	Demonstrate how the project is consistent with or enhances relevant Government policies and legislation, and to the extent that it may not be, what measures may be required	Identify areas where the Proposal conflicts with, is consistent with, or enhances relevant policies, programs and legislation
			Discuss how the Proposal meets policy objectives

CONTENT		SCOPE OF WORK	
		Identify and predict how the Proposal will impact on the economic and social development of the region, state and nation	Discuss management measure that may be required
			Discuss how the Proposal is relevant to policy objectives on local content, regional development and others that may be relevant (local, regional, state and national)
			Propose responses by the proponent to identified impacts
Livelihood and lifestyle impacts	Changes to people's way of life, sources of income, opportunities for development	Demonstrate how the Proposal affects local communities, as well as at a regional and state level	Describe the impacts of the Proposal on local and any other communities
			Identify community structures and lifestyles that may be affected by the Proposal
			Predict both the benefits of the Proposal to livelihoods and any potential issues to be managed
			Identify any impacts on existing Barrow Island workforce
			Identify any significant issues for indigenous communities in the Study Area and discuss any Proposal impacts on these issues (eg. health, employment, education)
Social Infrastructure	Changes to demand for schools, hospitals, roads, health services, law and order and recreation	Identify requirements for social infrastructure changes in population numbers or composition	Identify existing social infrastructure in the study region
			Undertake a strategic needs assessment to identify needs of the incoming population
			Identify any potential shortfalls in service provision, or structural changes required to accommodate the workforce
			Identify how shortfalls in social infrastructure may be met

CONTENT		SCOPE OF WORK	
			Identify how the Proposal may benefit the provision of social infrastructure in the areas of greatest impact
Native Title and Cultural heritage	Indigenous communities, native title, cultural heritage	Demonstrate how proponent will ensure compliance with relevant legislation (state and federal)	Identify any potential Native Title matters
			Identify any indigenous and non-indigenous heritage issues
		Demonstrate how the proponent will address issues related to indigenous or cultural heritage	Identify any cultural groups or land to be impacted by the Proposal
			Identify potential impacts and proposed management measures
Work Practices	Worker entitlements and employment practices	Identify how the project will meet all legislative requirements regarding worker's entitlements, workers compensation, employment practices.	Identify relevant work practice legislation
			Identify potential impacts and management measures
Health and Safety	Disease, risks, isolation and remote areas	Describe how potential risks to health and safety of workers and local communities will be managed	Identify any potential health risks to the workforce due to location, climate, seasonal conditions
			Identify any health or safety risks to the local population
			Identify any social issues arising from constraints on workforce due to quarantine requirements, project location and environment
Conservation, including Biodiversity	Changes to the conservation estate and the societal amenity in that estate	Demonstrate how the proponent will manage the local, State and Federal communities' ongoing conservation amenity in relation to Barrow Island	Identify range and extent of proposed management measures intended to provide a net conservation benefit.

CONTENT		SCOPE OF WORK	
Alternative locations	Social and societal comparison	Demonstrate what changes to social and societal costs and benefits would occur if the Proposal developed at an alternative location	Identify all reasonable project locality options considered, and provide a comparative assessment of these that adequately justifies for the Government the selection of Barrow Island as the proposed site for the initial land based elements of the Proposal.

3.2 *ECONOMIC*

Table 3.2 Economic Issues

CONTENT		SCOPE OF WORK	
Factor	**Issue**	**Objective**	**Suggested Scope of Work for Economic Assessment**
Strategic Economic Development	Potential for economic development	To assess the extent to which this Proposal will further the economic development of the region, state and Australia	Describe the strategic economic benefits of the Proposal Quantify Proposal expenditure at each stage of the development Describe how the Proposal will contribute to economic development at a regional, state and national level Quantify the impact on domestic industry resulting from the addition of a further major gas supply source, including regional, state and national benefits resulting therefrom
Economic analysis	Gross Domestic, state and regional product	Outline the economic impacts of the Proposal to the regional, state and national economy	Quantify the Proposal's potential contribution to gross domestic product, gross state product and gross regional product
	Employment		Quantify direct and indirect and induced employment at each stage of any development
	Value added		Quantify the value added aspects of the Proposal (direct, indirect and consumption induced)

CONTENT			SCOPE OF WORK
			Quantify the value added to conservation programs above and beyond regulatory functions directly associated with the Proposal, including but not limited to, the value added by accelerating or bringing forward conservation programs which would otherwise be funded from consolidated revenue
	Royalties, Taxes and other Government Revenue		Quantify the projected payments to various levels of government at various stages of the Proposal
	Local and Regional Price Cost Changes		Forecast any potential impacts on price and cost changes at a regional or state level resulting from a project development
Community Development	Human capital, training, local community investment	Describing the broader benefits the Proposal may bring to the region	Describe investment in human capital (training, community education), research and development and other investments state wide and locally as a result of the Proposal
			Describe benefits to community development through regional job creation, support of local community or other initiatives
Alternative locations	Economic comparison	Demonstrate what changes to economic costs and benefits would occur if the Proposal developed at an alternative location	Identify all reasonable project locality options considered, and provide a comparative assessment of these that adequately justifies for the Government the selection of Barrow Island as the proposed site for the initial land based elements of the Proposal.

3.3 STRATEGIC

The proponent should separately identify the issues of strategic State significance relevant to the Proposal. These strategic aspects may be social, economic or environmental.

Key issues include (but are not limited to) the implications of this proposal for the timing and the consequential development of the greater Gorgon gas fields and associated changes to the physical and social environment; the impact on domestic gas competition; the ability to deliver gas to the mainland;

Greenhouse Gas matters (taking into account local, national and global aspects); effects on maintenance of living standards; import substitution of petroleum fuels and other products; the potential for availability of "clean" fuels; and broader conservation costs and benefits.

Specifically addressing relevant aspects of strategic State significance will enable Government to balance its decision from a more holistic view of the Proposal. However, care should be taken to ensure that impacts are not double counted nor costs and benefits compounded.

3.4 OUTPUTS

A report, including sources of data, modelling assumptions, conclusions and mitigation measures should be prepared that addresses the social, economic and strategic aspects of the Proposal. Where modelling is undertaken, the relevant parameters used and assumptions made should be fully detailed, including the level of precision attributable to outputs in the modelling. The information should be incorporated in a single document with a specific section that addresses the integration between economic, social and environmental factors.

3.5 CONCLUSION

The document should clearly describe and assess all social, economic and strategic impacts as outlined in the guidelines that the Gorgon Proposal may have at a local, regional, state or national level. The review must include the overall life of the Proposal from construction to decommissioning.

The comparative assessment of alternative site locations, to adequately demonstrate the relative merits associated with the potential use of Barrow Island, must be made.

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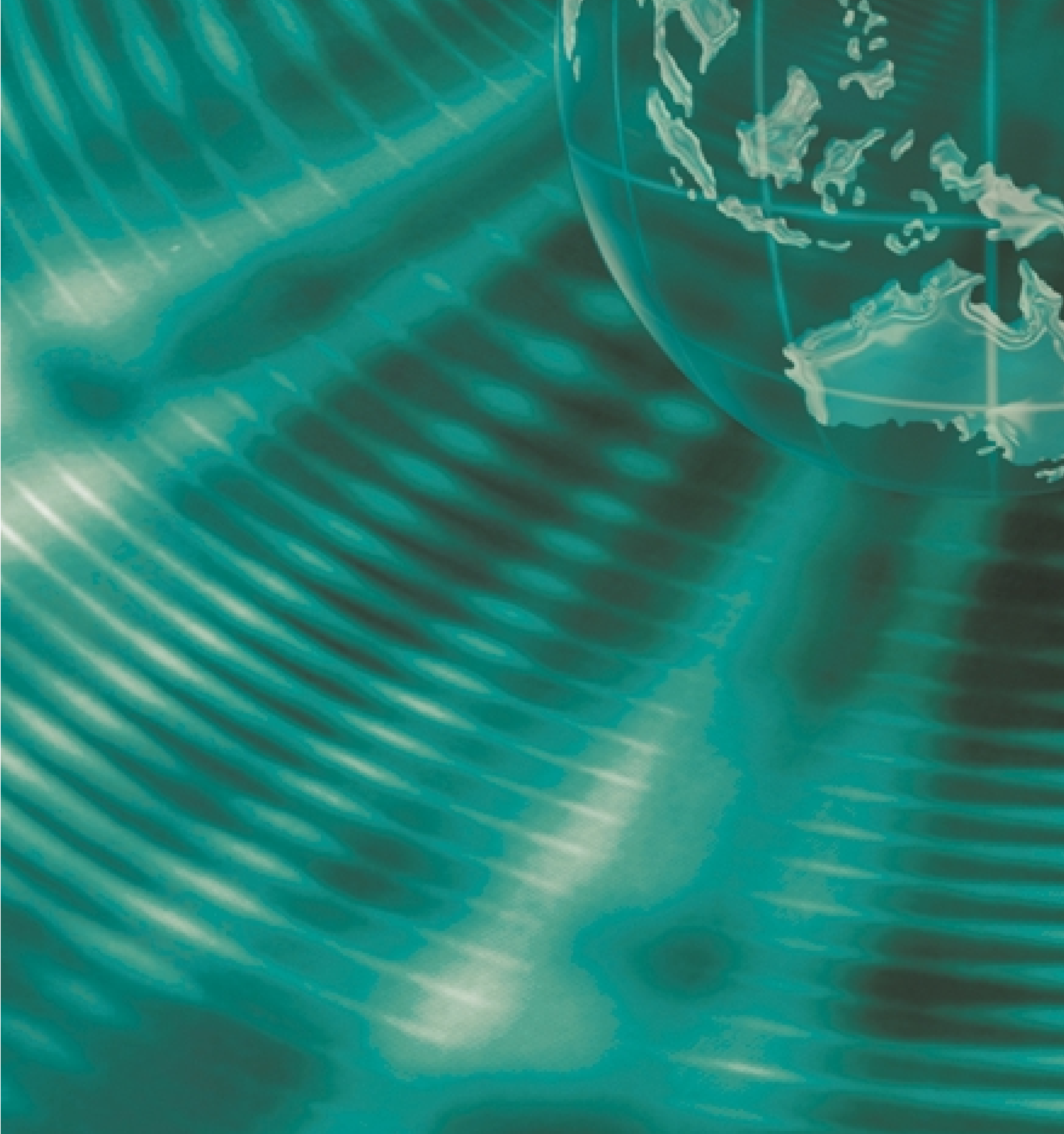
REFERENCES

Armour, A. (1992)



APPENDIX C

IDENTIFICATION OF SUITABLE LOCATIONS FOR A LAND-BASED GAS PROCESSING FACILITY LINKED TO THE GORGON GAS FIELD

(URS AUSTRALIA PTY LTD)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

1.1 OBJECTIVES OF THIS STUDY

This study has been undertaken to identify suitable onshore locations at which a site for the development of a gas processing facility (GPF) and export facilities to service the Gorgon gas field, offshore north-western Australia (Figure 1.1) could be established. Environmental, social, logistic, economic and regional planning limitations have been investigated to identify locations having low levels of overall constraint.

It is important to emphasise the difference between a 'location selection' study versus a 'site selection study'. The differences are principally in terms of methodology and intent. A 'location selection' study is a regional planning methodology for the purpose of scanning a very large geographic area at a regional scale over which data availability is either variable in quality, or limited. In planning or spatial analysis terms, the location selection is termed a **coarse** level of regional assessment, intended to identify areas meeting specified criteria. In this case these criteria are the basic requirements suitable for locating a large natural resource processing plant, together with appropriate navigable access for export shipping.

The outcome of this study process is to identify locations within a broad region where it may be possible to identify specific development sites based on further detailed site specific technical and financial investigations.

This study is based on a previous confidential location and site selection study undertaken in 1998 for Mobil Exploration & Production Australia and Texaco Australia Pty Ltd, but that was not proceeded with at that time. It has been updated to incorporate new information which has become available since 1998.

1.2 REGION OF INTEREST

This location identification study focused on the region within 200 kilometres (km) radius of the Gorgon gas field on Western Australia's North West Shelf. This study boundary was used in recognition of the economic and logistic limitations of piping gas from offshore to a land-based processing facility. To be viable, the project must be profitable. In general terms, the closer the plant site to the gas field, the more cost effective the development will be due to the high cost of large diameter sub-sea gas pipelines, the length of which is the cost limiting factor. If no suitable location could be identified within 200 km, then it was considered unlikely that a greenfield project would be economically viable.

The mainland limits of the study area are approximately bounded by the Burrup Peninsula to the north and the Exmouth Peninsula to the south (Figure 1.1).

1.3 BROAD STAKEHOLDER CONCERNS

It is recognised that selecting a location for a GPF involves careful consideration of stakeholder concerns, including local and state government, industry groups, public interest groups and the wider community. These concerns include a broad range of environmental and socio-economic issues.

Tue 21 Jan 03

Job No.	50374-003-562		ChevronTexaco GPF LOCATION SELECTION STUDY **REGION OF INTEREST**	**Figure 1.1**	
Prep. By	JS	10 Sept 02		URS	
Chk'd By	JS	10 Sept 02			
Revision No.		0			

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In regional planning terms, state and local government have consistently indicated that they wish to see major new industrial development in the Pilbara established in locations either strategically nominated for industry, or in suitable proximity to existing settlements where the benefits of local investment and spending will be felt (Pilbara Development Commission 1997; Western Australian Planning Commission 1998a,b). However, there are various other considerations to be addressed in a thorough location selection process.

Complying with regional planning initiatives and avoiding social and environmental complications are as much practical considerations for proponents as they are concerns of government and the community. For industry, it is simpler to avoid environmental or social problems than try to mitigate and remediate after a problem occurs. Environmental protection is also legislated to ensure that a development will cause a minimal level of impact.

The Pilbara coast and its nearshore islands are recognised as having high environmental value. These values are reflected in an extensive network of existing and proposed conservation areas which include Ningaloo Marine Park, Cape Range National Park, Barrow Island Nature Reserve, Great Sandy Islands Nature Reserve, (proposed) Barrow-Montebello-Lowendal marine management area, (proposed) Cape Preston Marine Reserve, (proposed) Dampier Archipelago Marine Reserve and (existing) Nature Reserves. Location selection for a GPF plant therefore requires careful consideration of the natural environment, both in terms of protected and unprotected areas of conservation significance.

Integration with, and maintenance of, lifestyle and community cohesion have met variable success during previous large-scale Pilbara developments. This location selection process considers impacts associated with a range of social issues that have historically shown to be problematic when such developments are implemented, particularly during the construction stage.

High social values of recreational resources (particularly scenic landscapes, fishing areas and swimming beaches) and historical sites are also recognised, and form a significant component of the location selection analyses.

Another critical component determining project success is the minimisation of risk and hazards to the public and adjacent land uses.

1.4 INFORMATION SOURCES

Location selection data were derived from an extensive list of published reports (including planning strategies, EIA reports, regional development plans, government policies, EPA guidelines and reports) and unpublished oil industry research documents. In addition, several members of the study team are very familiar with the region as a result of various work assignments during the last 20 years.

The most frequently referenced documents used in this location selection study were:

- *Pilbara 21: Final Strategy Report* (Pilbara 21 Study Group June 1992 [Department of Planning and Urban Development (DPUD)]);
- *Pilbara/Gascoyne Islands Ecotourism Management Strategy* (Higgins Wood & Associates 1995);
- *Gorgon LNG Greenfield Site Selection Study* (Shell Development Pty Ltd [Shell] 1996);
- *State Planning Strategy* (Western Australian Planning Commission [WAPC] Nov. 1996),
- *Gorgon LNG Greenfield Site Assessment* (West Australian Petroleum Pty Ltd [WAPET] 1997);
- *Pilbara Land Use Strategy* (Pilbara Development Commission [PDC] July 1997);
- *LNG Plant Site Selection Study* (Mobil Exploration & Production Australia and Texaco Australia Pty Ltd, 1998);

- *Karratha Area Development Strategy* (WAPC 1998);
- *Exmouth – Learmonth (North West Cape) Structure Plan* (WAPC Apr. 1998);
- *Housing and Land Snapshot Update* (PDC 2002).

All references quoted or referred to in this report are listed in Section 6.

1.5 STRUCTURE OF THIS REPORT

Section 1 introduces the proposal and area of interest for the location selection study, as well as identifying the main sources of information for the study.

Section 2 briefly describes the key elements of the proposed development, focusing on aspects of a GPF and supporting infrastructure which most significantly influence the choice of a development location.

Section 3 outlines the semi-quantitative methodology used to select a shortlist of locations and, eventually, to rank them in order of least overall constraint. This section includes the theory and practice behind the use of multi-criteria analyses in planning studies. The study was undertaken in three steps.

Section 4 presents the methods and results of Step 1, the GIS-based regional constraints analysis aimed at identifying potential development locations.

Section 5 presents the methods and results of Step 2, a panel-based selection of feasible sites based on engineering constraints.

Section 6 presents the methods and results of Step 3, an impact assessment workshop on each potential site to produce a multi-criteria matrix index of site sensitivity.

Section 7 compares the best site options to current regional planning strategies and policies to confirm overall suitability in planning terms.

Section 8 presents the references cited in the document, and **Section 9** acknowledges the individuals who contributed to the study.

2. SUMMARY DESCRIPTION OF PROPOSED DEVELOPMENT

This section provides a brief overview of the essential components of the proposed GPF and its supporting infrastructure. The information provided herein is not intended to be a comprehensive description of a GPF, but highlights important elements of the facility which determine the site restrictions and thus influence the location selection study.

2.1 FACILITIES AND INFRASTRUCTURE

The major components of a GPF plant and necessary infrastructure include:

- a supply, or 'feed gas', pipeline from the gas field to the processing plant;
- a GPF plant (comprising processing facilities to remove impurities and treat the natural gas);
- storage tanks for treated gas and liquids;
- a sheltered GPF load-out pipeline and jetty;
- a sheltered materials handling dock or jetty;
- product storage tanks;
- a shipping channel and turning basin;
- waste treatment and storage facilities;
- workforce and office facilities (including accommodation and workshops); and
- access roads, airstrip, etc., as required.

2.2 SITE REQUIREMENTS

2.2.1 Land Requirements

The plant itself, including storage tanks, waste treatment facilities, offices, fencing and gas processing modules, requires an area of approximately 200 hectares (ha). Space for on-site workforce accommodation and construction laydown areas will also be required, particularly during the construction stage (~100 ha). A total area of 300 ha has therefore been assumed to be the land requirement. Ease of construction requires that the land be relatively flat (<5° slope) and elevated to at least 5 metres (m) AHD (Australian Height Datum) to protect it from storm surge flooding.

2.2.2 Marine Requirements

Access to shipping facilities requires that the plant be preferably no more than 10 km from loading facilities. In addition, docking facilities are required to be in sheltered, navigable waters, no more than 5 km from the 10 m isobath.

3. APPROACH AND METHODS

3.1 SUMMARY OF APPROACH

This section details the approach and methodology applied for selecting a potential development location within the region of interest.

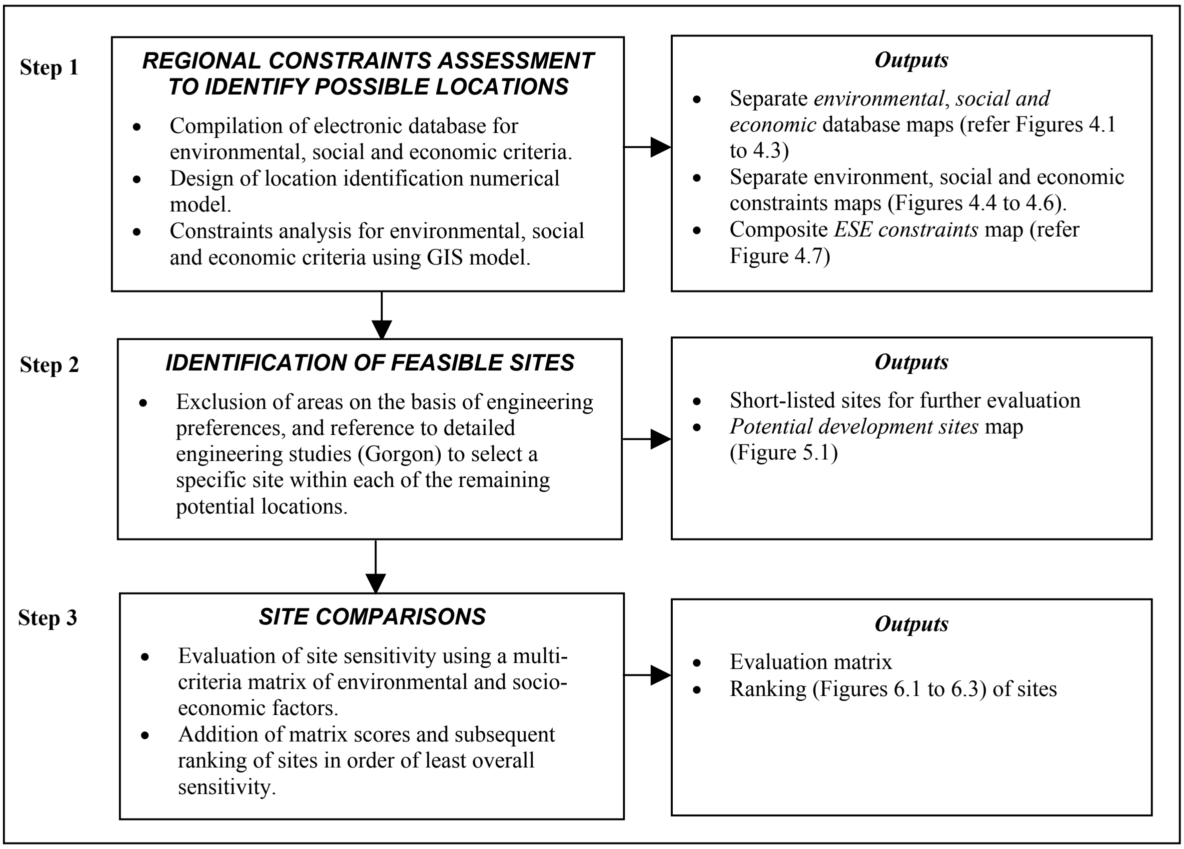
The approach and methods applied to this study are summarised in Figure 3.1. The study comprised three steps or components of work. The first step was aimed at identification of potential locations for the project. The second step involved an in-house review of these locations to confirm their feasibility and identify potential development sites. The third step was a comparison between short-listed locations to rank them in order of least overall constraint. Methods used for each step were as follows.

Step 1 involved GIS analyses of a range of environmental, social and economic and engineering criteria to broadly assess the relative suitability of all coastal areas within the study region for the possible siting of a GPF;

Step 2 required evaluation by an expert engineering panel of data from Step 1, and reference to previous engineering site selection studies and regional planning documents to select a short-list of feasible development sites; and

Step 3 involved an impact assessment workshop of each of the short-listed sites using a multi-criteria matrix of environmental and socio-economic factors to rank the potential sites in order of least overall sensitivity.

Figure 3.1 Location Identification Methodology



3.2 BACKGROUND ON METHODS OF MULTI-CRITERIA ANALYSIS

Location or site selection is a process of determining the location of suitable sites for a given development or activity within a chosen region. This definition implies that numerous factors influence location/site selection, including those which are required by the development or activity itself (in a logistic or practical sense), and those which are inherent in the region being investigated (such as environmental values and socio-economic uses which may conflict with the development or activity).

There are a range of tools and methods available for identifying and selecting potential locations for a GPF. These can be considered to fall within two broad categories: Scientific-Analytical approach and Delphic-Judgmental approach. The Scientific Analytical approach to site selection uses existing spatial data and objective numerical techniques to evaluate a range of constraints and identify favourable areas. The Delphic-Judgmental approach involves stakeholders or an expert group making decisions using a list of criteria and objectives that reflect the range of values and interests.

Two forms of multi-criteria analysis have been employed for this study:

- firstly, a Scientific Analytical-based spatial constraints and opportunities analysis has been performed using a Geographic Information System (GIS) to determine potential development locations; and

- secondly, a Delphic Judgmental-based 2-dimensional matrix evaluation has been used to differentiate between (or rank) the short-listed sites.

"Constraints Analyses" are widely used for spatial decision-making in planning and design disciplines. McHarg (1969) first articulated the technique of thematically mapping spatial factors (in terms relevant to the study being conducted) and overlaying them, either selectively or in combination, to obtain an overview of the region. Historically, these multi-criteria analyses were limited to a small number of criteria for the simple reason that manual calculations and their spatial representation were time consuming and difficult to undertake, modify or repeat. Modern use of integrated, computerised mapping and database systems (GIS) enables the analysis of virtually unlimited numbers of criteria, and allocation of various weighting and priority systems. GIS technology has created a powerful analytical tool which has made site selection a more transparent, repeatable and thorough process, thereby improving the professional acceptability and usefulness of detailed site selection processes. It has enabled a wider range of information to be integrated and analysed, taking a greater number of influential factors into consideration.

At a regional level, constraints analysis provides a coarse planning assessment, identifying general **locations** which *may* encompass suitable sites. These locations then require detailed technical assessment to determine their suitability and to define specific **sites** within their broad boundaries. Given that specific methods can give different results and broad-scale information has been used, there is no guarantee that any location within the regional analysis will stand up to detailed scrutiny. The identified locations simply offer a number of areas on which further investigation should focus.

Two-dimensional, multi-criteria matrices have been used in regional strategic planning for at least 30 years. They are frequently used to compare positive and negative effects or values against a list of relevant criteria to determine preferred strategies or locations.

The strength of multi-criteria analysis is the accountable manner in which unquantifiable and intangible factors (such as loss of amenity to a community or 'existence value' of wilderness) can be integrated with strictly measurable data. The reality of land use planning and environmental and social impact assessment is that decisions on these matters invariably include unquantifiable and intangible factors. When issues cannot be measured it does not mean that they are irrelevant or unimportant. In fact, these issues are often the determining criteria for project or strategy success.

The selection and weightings of each criteria in the analyses remain subjective, but are clearly stated and debated by individuals with relevant expertise within a delphic forum. For this project, a team of senior biologists, planners and engineers combined to determine which factors were important on a regional scale and the scores, weightings and appropriate buffers for each. Their combined experience totals around 100 years of professional practice and the model development process encouraged extended debate of the model formula. As with all general planning tools and methods, there is still room for modification but, in general terms, it is considered that the model derived was suitable for the broad-scale identification of locations with development potential. This process concluded with the establishment of a 'peer review panel' to test the validity of the process, the factors selected in the matrix comparison, and the imputed values.

4. STEP 1: REGIONAL CONSTRAINTS ASSESSMENT

4.1 OBJECTIVE AND SCOPE OF WORKS

The objective of this first step of work was to identify broad locations along the coast within the study area where development of a GPF may be engineeringly feasible, and social and environmental constraints manageable. The analysis of environmental, social and economic/engineering constraints was undertaken using a GIS, and involved the following process:

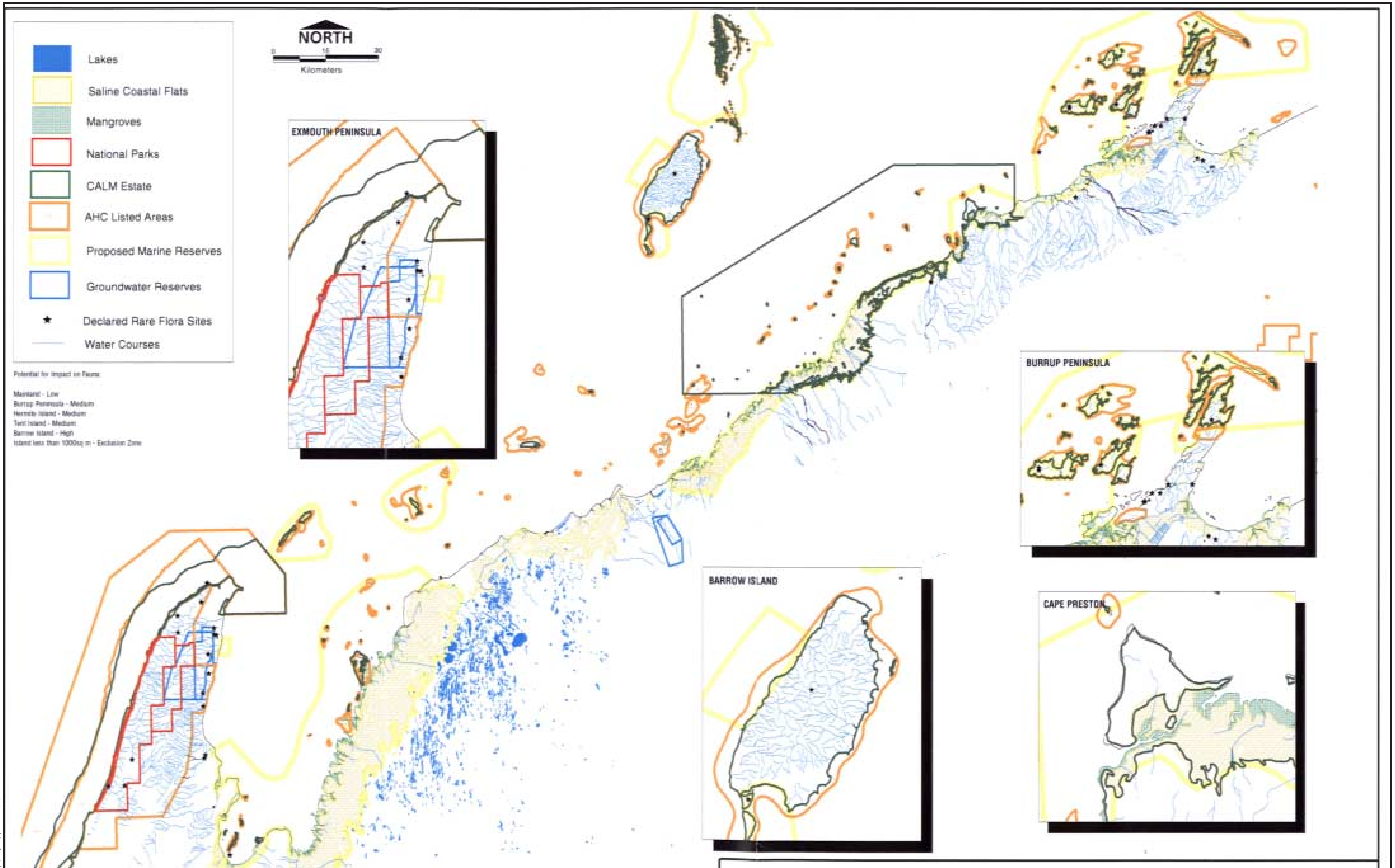
- collation of regional information which was readily available on government electronic databases for the region within approximately 200 km of the Gorgon gas field and up to 10 km inland of the coast;
- production of database maps for environmental, social and economic/engineering criteria (Figures 4.1 – 4.3);
- formulation of a site identification model, determining environmental, social, and economic criteria, and suitable buffers and constraint weightings;
- execution of the model to produce maps showing the level of constraint (from least to most) for environmental factors (Figure 4.4), social factors (Figure 4.5) and economic/engineering factors (Figure 4.6). Each of these maps incorporated some criteria which were considered unsuitable for development and were therefore designated ‘exclusion zones’ (refer Tables 4.1 – 4.3); and
- generation of a composite ESE constraints map by overlaying Figures 4.4 to 4.6 on each other to produce Figure 4.7. Figure 4.8 illustrates this methodology. Figure 4.7 was the output of Step 1 of the location identification process and became the base for Step 2 of the process.

4.2 GIS DATABASE AND MODEL

The GIS model combined eight environmental constraint factors (or data sets), seven social data sets and eight economic data sets. All 23 spatial data sets were divided into a 500 m grid which covered the study area, comprising more than 17,000 grid cells for the study area.

Numeric values were applied to each of the grid cells in each of the data sets to represent levels of constraint. Values ranged between 1 (low constraint) and 10 (high constraint) for each factor. Where a constraint was so severe that development should not reasonably be considered, an extreme value (999) was assigned to indicate an exclusion area.

Data sets were then digitally overlain and constraint values were added to provide a total numeric indicator of constraint. Figure 4.9 below, illustrates this approach for two constraint factors over a 3 x 3 cell grid.



This figure has been produced by Dames & Moore using a variety of digital and mapped data collected by Dames & Moore or derived from published and unpublished sources.

The data represented in this map are for information purposes only. Dames & Moore does not warrant the accuracy of the data and shall not be liable for any consequences of the use of the figure.

Job No.	50374-003-562		ChevronTexaco GPF LOCATION SELECTION STUDY **GPF PLANT SITE SELECTION STUDY ENVIRONMENTAL CRITERIA BASE DATA**	**Figure 4.1** URS
Prep. By	JS	10 Sept 02		
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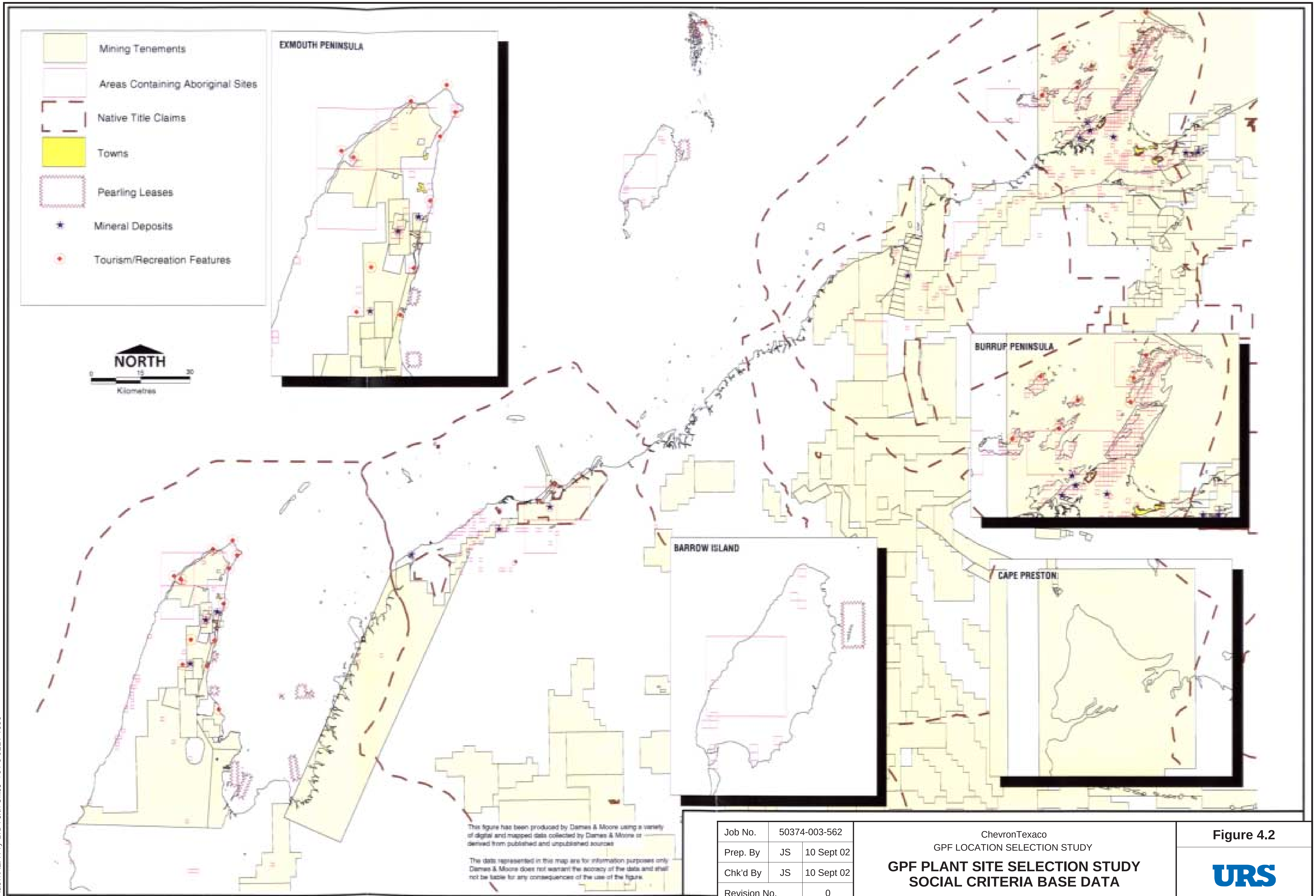

Job No.	50374-003-562		ChevronTexaco GPF LOCATION SELECTION STUDY **GPF PLANT SITE SELECTION STUDY** **SOCIAL CRITERIA BASE DATA**	**Figure 4.2** URS
Prep. By	JS	10 Sept 02		
Chk'd By	JS	10 Sept 02		
Revision No.		0		

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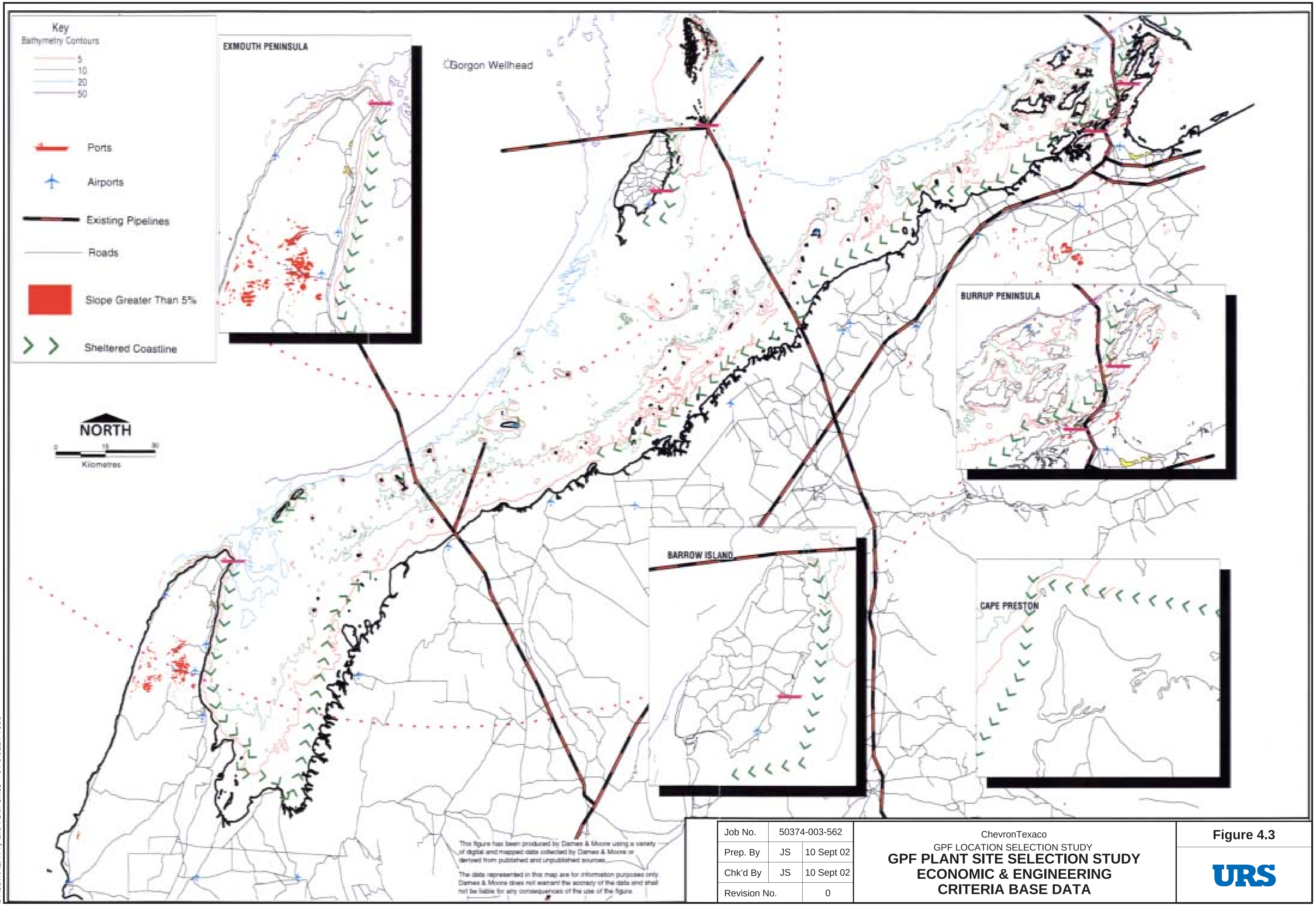

Job No.	50374-003-562	
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GPF PLANT SITE SELECTION STUDY ECONOMIC & ENGINEERING CRITERIA BASE DATA

Figure 4.3

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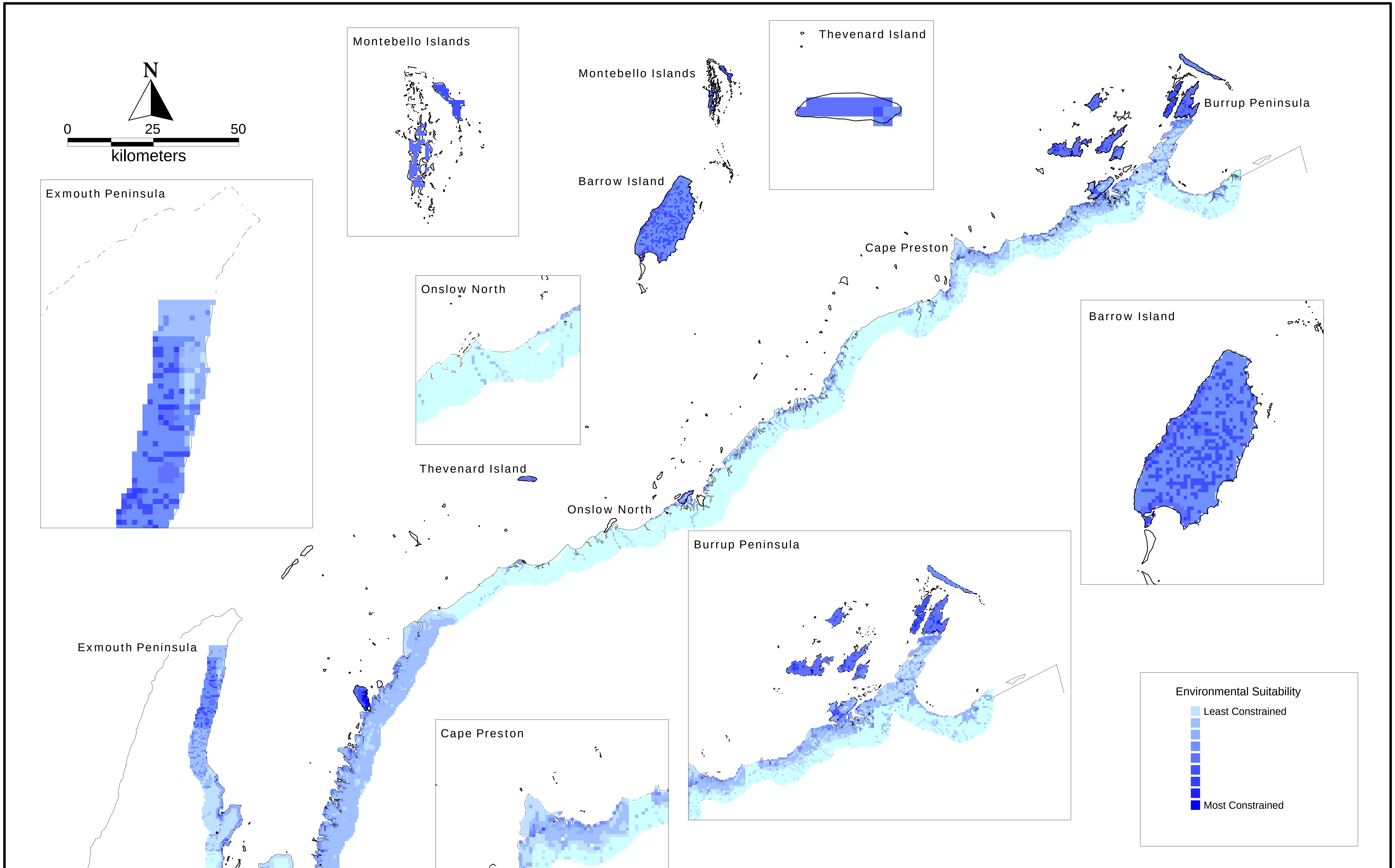

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Prep. By	JS	10 Sept 02	**ENVIRONMENTAL CONSTRAINTS**	URS
Chk'd By	JS	10 Sept 02		
Office	Perth, Western Australia Phone: +61 8 9221 1630			

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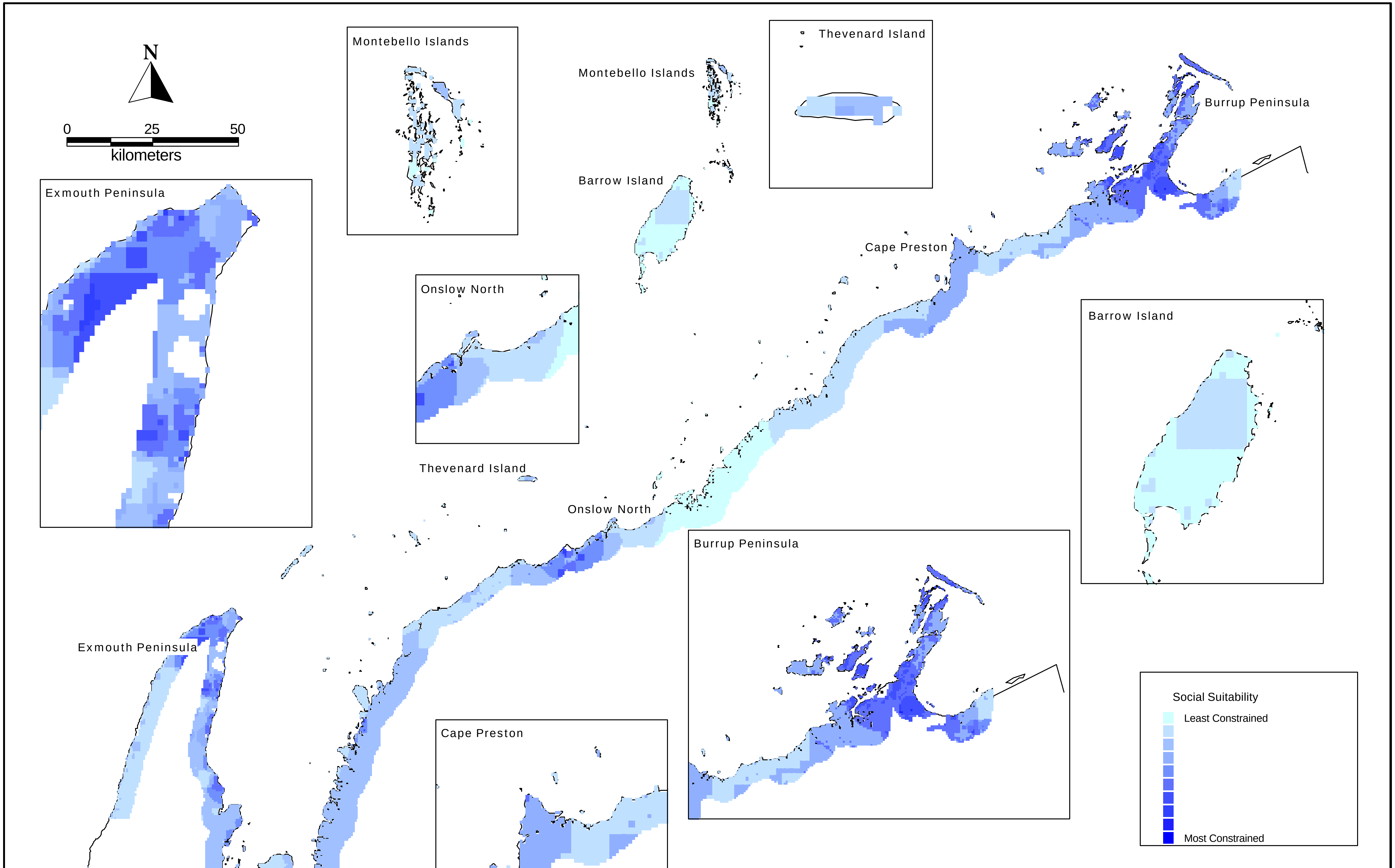

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SOCIAL CONSTRAINTS

Figure 4.5

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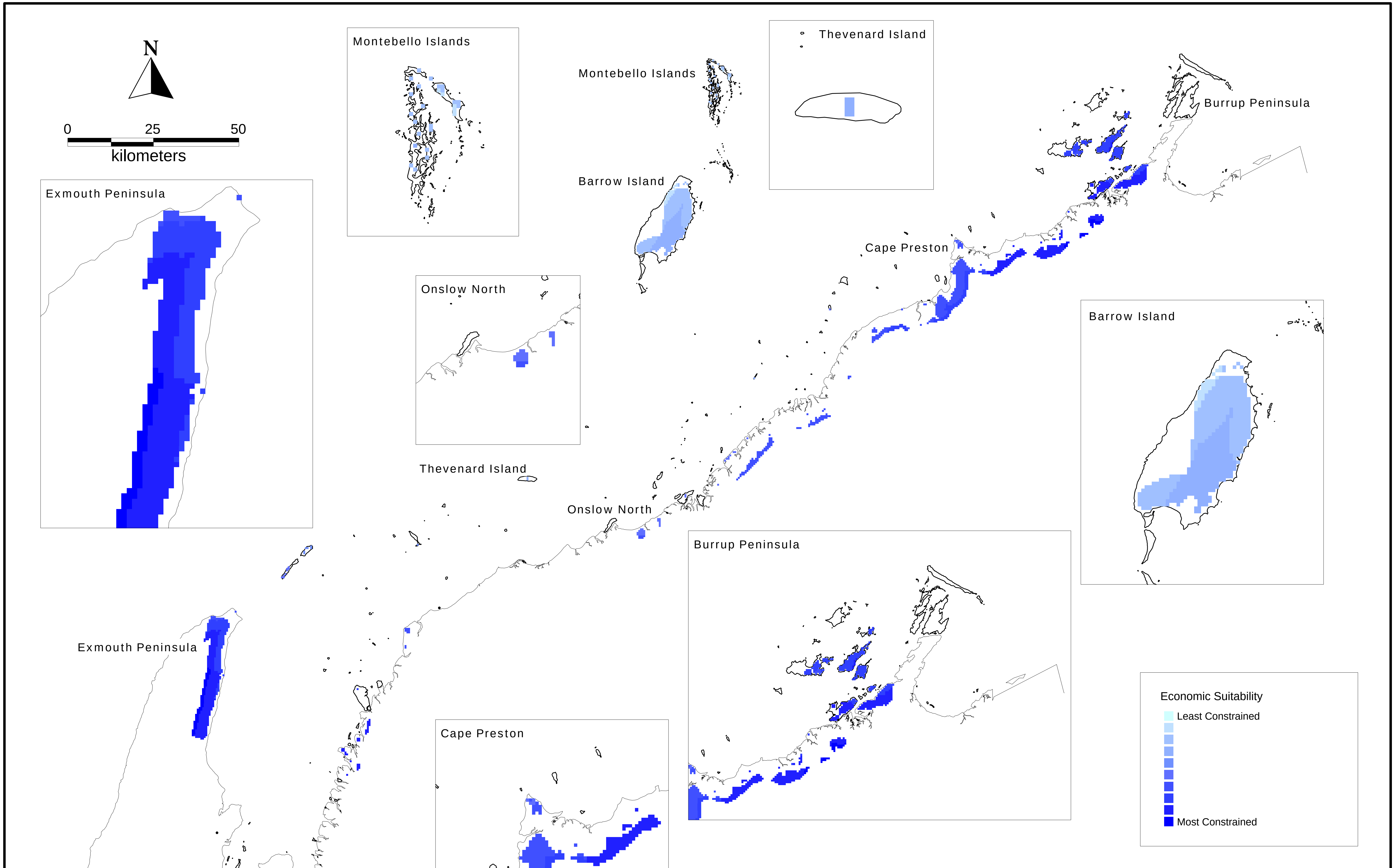

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Prep. By	JS	10 Sept 02	**ECONOMIC / ENGINEERING CONSTRAINTS**	URS
Chk'd By	JS	10 Sept 02		
Office	Perth, Western Australia Phone: +61 8 9221 1630			

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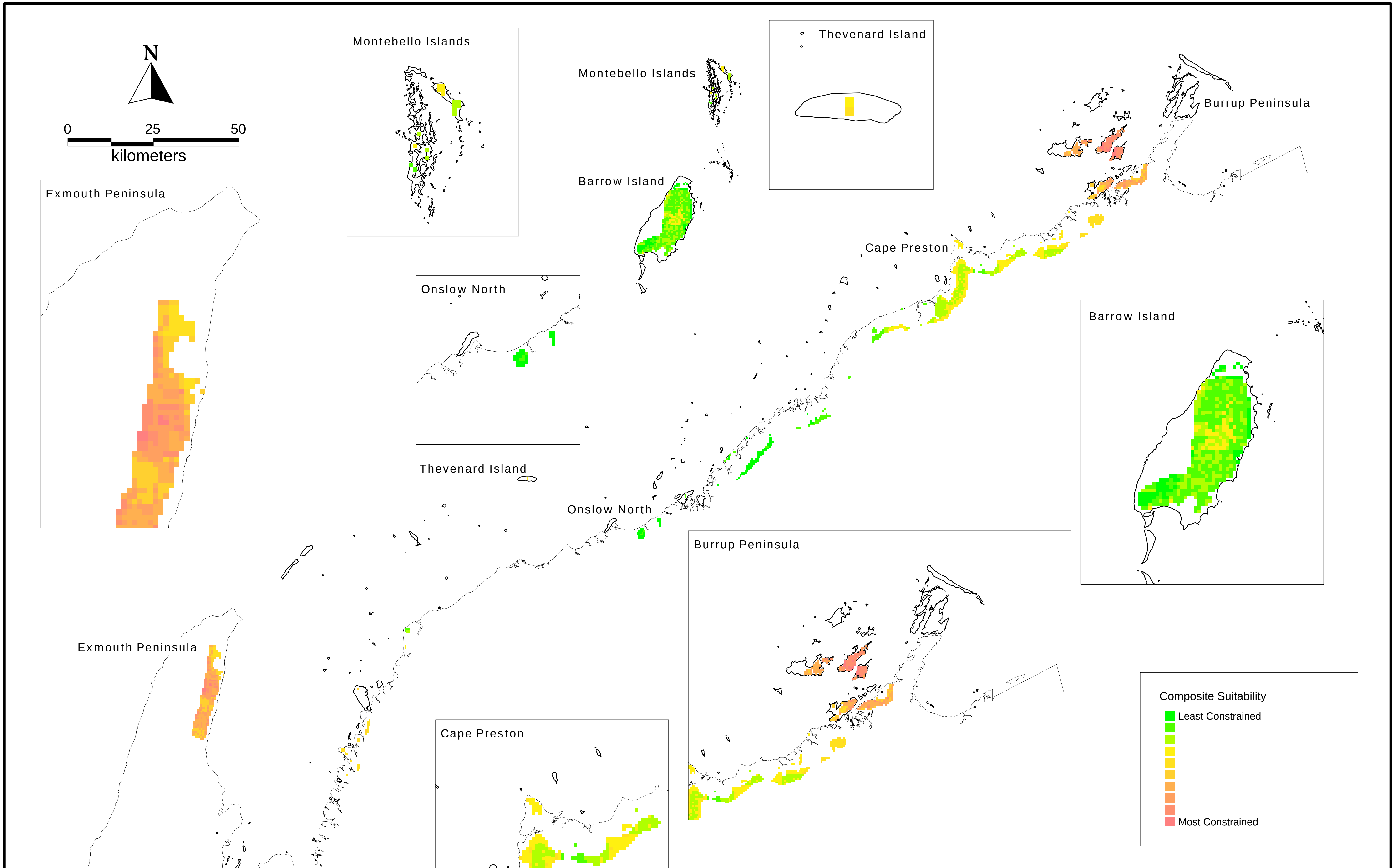

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COMPOSITE ESE CONSTRAINTS

Figure 4.7

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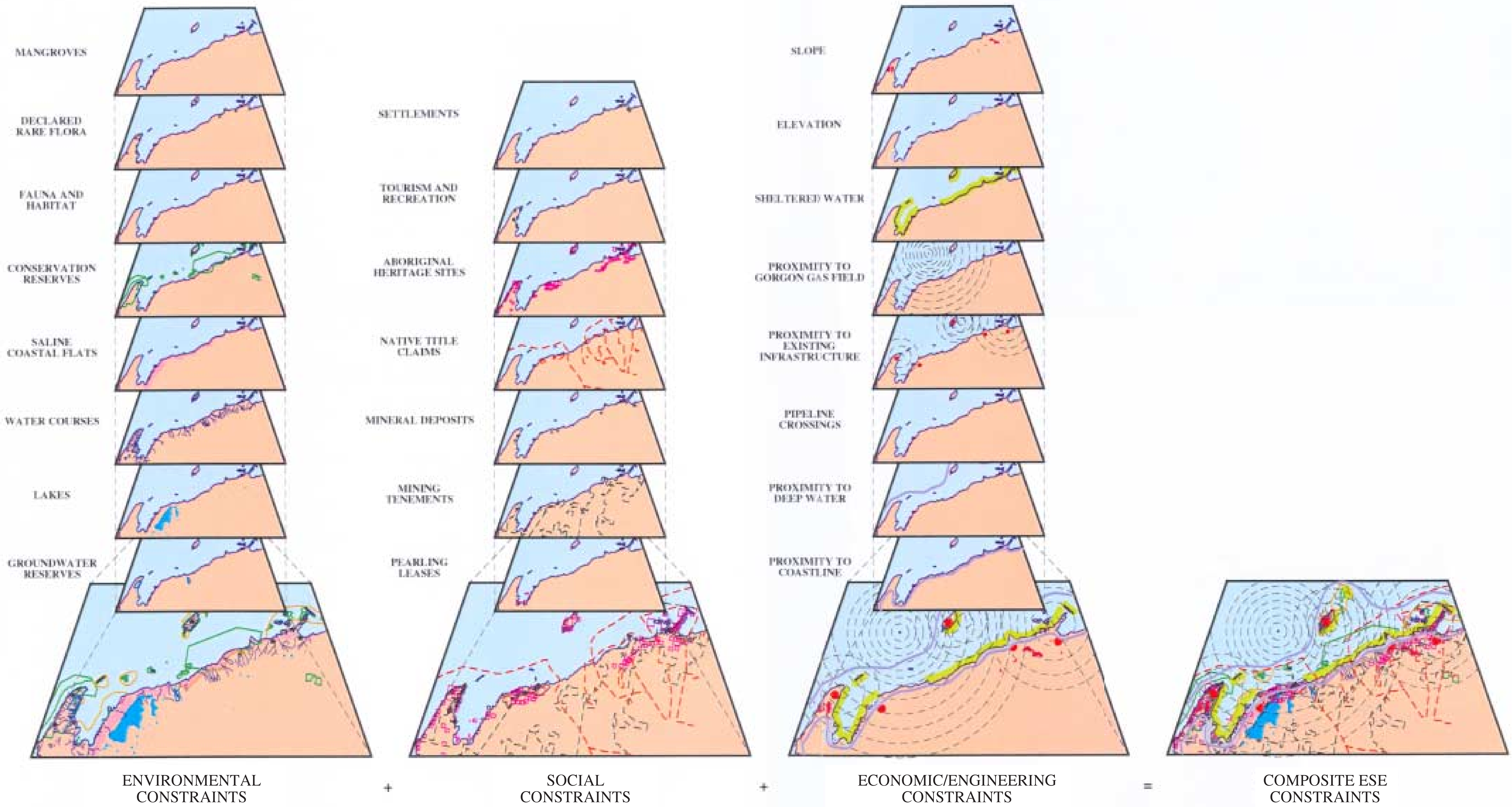

Job No.	50374-003-562	
Prep. By	JS	10 Sept 02
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ILLUSTRATED METHODOLOGY FOR ENVIRONMENTAL, SOCIAL AND ECONOMIC/ENGINEERING CONSTRAINTS ANALYSIS

Figure 4.8

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Figure 4.9 Principle of Environmental, Social and Logistic Overlay Analysis

0	5	5
999	5	0
999	5	0

Constraint #1,
e.g. mangroves

+

3	0	3
3	0	3
0	3	0

Constraint #2,
e.g. water courses

=

3	5	8
1 002	5	3
999	8	0

Scores for the two constraints are added together. The result represents the overall level of constraint.

4.2.1 Criteria, Buffers and Weightings

The selection of suitable regional criteria, or constraints, for Phase 1 of the regional assessment involved:

- review of standard development feasibility assessment procedures;
- discussions with ChevronTexaco representatives (see acknowledgements in Section 9);
- review of Western Australian EPA bulletins and EPA guidelines for previous resource development projects;
- review of previous Western Australian EIA and regional planning reports;
- review of documented Federal government EIA approaches; and
- review of Northern Territory Department of Land Planning and Environment Guidelines for similar projects previously completed in Darwin.

The constraints criteria chosen and the weightings and buffers assigned to them are detailed in Tables 4.1 – 4.3. A further description and justification of these values is provided in the text immediately following Tables 4.1 – 4.3.

Table 4.1 Environmental Criteria

***** Ratings : 1 (low constraint) - 10 (high constraint).

Criteria	Details	Constraint Factor *	Buffer Width	Buffer Constraint Factor *
Mangroves	Important habitat and key primary producers. High level of protection generally recommended by environmental agencies.	10	200 m	5
Declared Rare Flora	Important species for protection.	3	1 km	3
Fauna and Habitat (special considerations)	1) Small islands (<1 000 ha) have limited capacity for loss of habitat without significant impact on natural balance. 2) Larger islands (>1 000 ha) still have limited capacity for habitat loss 3) Barrow Island is >1 000 ha, but has no introduced species, thus providing a habitat for rare native species. Also noted for rare subterranean fauna. 4) Mainland generally has greater flexibility for loss of habitat. 5) Exmouth Peninsula has known subterranean fauna habitats of high conservation significance.	exclusion 5 8 2 5	- - - - -	- - - - -
Conservation Reserves	1) National Parks and Marine Parks (land is also excluded if nearest coast is adjacent to a marine park, i.e. beside Ningaloo) 2) Conservation reserves, nature reserves, AHC listed reserves. 3) Proposed marine reserves	exclusion 5 4	- -	-
Saline Coastal Flats	Moderate habitat value but extensive coverage in the region.	2	-	-
Water Courses	Construction on or near watercourses has potential to disrupt natural drainage patterns, leading to erosion and loss of habitat.	5	100 m	5
Lakes	Significant habitat value.	exclusion	-	-
Groundwater Reserves	Exmouth Town Groundwater Reserve (21 000 ha immediately south of Exmouth).	5	-	-

Table 4.2 Social Criteria

* Ratings : 1 (low constraint) - 10 (high constraint).

Criteria	Details	Constraint Factor *	Buffer Width	Buffer Constraint Factor *
Settlements	Consideration of amenity, visual impact, pollution potential, disturbance, risk/hazard.	exclusion	3 km	5
Tourism and Recreation Resources	Consideration of amenity and landscape values. (Due to existing industrial presence, Burrup Peninsula was not constrained by this factor.)	exclusion	3 km	exclusion
Aboriginal Heritage Sites	In accordance with data from the Department of Aboriginal Affairs, accurate locations are not available, a reasonable buffer is required.	5	500 m	5
Native Title Claims	Acknowledges delays and difficulties in resolving Native Title issues:	One claim over area=3 More than one claim over area=5	- -	- -
Mineral Deposits	Preference that development should not sterilise a mineral resource	2	2 km	2
Mining Tenements	Conflicting land use and compensation requirements	3	-	-
Pearling Leases	Potential for marine activities and discharges to disrupt pearling activities	5	2 km	5

Table 4.3 Economic (Engineering and Development Cost) Criteria

Criteria	Details	Constraint Factor*	Constraint Value	Weighting Factor
Proximity to Gorgon Gas Field	Pipeline length, and costs, will be reduced by minimising distance of the plant site from the gas source. A sliding scale was used that reflects an increasing level of constraint as the distance to the gas source increases.	>200 km 180 - 200 160 - 180 140 - 160 120 - 140 100 - 120 80 - 100 60 - 80 40 - 60 20 - 40 0 - 20	exclusion 10 9 7.6 6.2 4.8 3.4 2 1 1 1	70%
Proximity to Existing Infrastructure (ports, roads, airport)	Use of existing infrastructure will provide economies in development costs and a more efficient use of resources. A sliding scale was used that reflects an increasing level of constraint as the distance to infrastructure facilities increases.	180 - 200 160 - 180 140 - 160 120 - 140 100 - 120 80 - 100 60 - 80 40 - 60 20 - 40 0 - 20	10 9 8 7 6 5 4 3 2 1	4.5%

Table 4.3 Economic (Engineering and Development Cost) Criteria (cont'd)

Criteria	Details	Constraint Factor*	Constraint Value	Weighting Factor
Slope	Areas with greater than 5% slope	<5% slope >5% slope	0 10	1%
Elevation	Saline coastal flats and other areas below 5 m AHD (low elevation, poor drainage, poor foundations, exposure to storm surge)	Exclusion	-	-
Sheltered Water	Coast with no sheltered water for shipping access	Exclusion	-	-
Pipeline Crossings	Crossing of existing sub-sea pipelines	No crossing Crossing	0 10	0.5%
Proximity to Deep Water	Areas closer to deep water require less dredging for shipping channels. The distance to the 10 m isobath and the distance to the 5 m isobath were both considered, and an index developed reflecting the distance to these features.	>5.5 km to 10m isobath 5 to 5.5 km distance 4.5 to 5 4 to 4.5 3.5 to 4 3 to 3.5 2.5 to 3 2 to 2.5 1.5 to 2 1 to 1.5	10 9 8 7 6 5 4 3 2 1	12%
Proximity to Coastline	Plant to ship pipeline length, and costs, will be reduced by minimising distance of the plant site from the shipping berth. A sliding scale was used that reflects an increasing level of constraint as the distance from the coast increases.	>10 km 9 km – 10 km 8 km – 9 km 7 km – 8 km 6 km – 7 km 5 km – 6 km 4 km – 5 km 3 km – 4 km 2 km – 3 km 1 km – 2 km 0 – 1 km	exclusion 10 9 8 7 6 5 4 3 2 1	12%

4.2.2 Rationale for Criteria, Buffers and Weightings

The following provides the rationale applied in the determination of criteria, buffers and weightings for the regional (GIS-based) constraints and opportunities analysis, as shown in the previous tables.

Buffer constraint factors range between 1 (low constraint) and 10 (high constraint) for each Environmental and Social criterion or buffer area. Areas containing significant environmental or engineering restrictions were considered unsuitable for development and were designated as 'exclusion zones'. In the case of economic (engineering and development cost) criteria, an additional weighted rating is applied based on approximate capital expenditure for specific engineering/infrastructure requirements. This is further explained in Appendix A.

4.2.2.1 Environmental criteria

Mangroves

Mangroves occur extensively throughout the study area, fringing the coast. Areas supporting mangroves were considered unsuitable for development on the basis of their important function as key primary producers in tropical coastal environments and the significance given to mangrove systems by environmental protection agencies such as the WA EPA and Environment Australia.

Mangroves were therefore given a high constraint level of 10. In addition, a 200 m buffer around mangroves was also applied (where development suitability was considered to be low) and these areas were assigned a constraint index of 5.

Declared Rare Flora

Known locations of Declared Rare Flora (DRF) were obtained from the CALM database. This database identifies the locations at which DRF have been found to occur. While collection of DRF in the past does not guarantee that the plant is still present at this location, it is considered more likely, and a lower level of suitability was therefore assigned to confirmed sites. A 1 km buffer was applied around each site to account for variable accuracy in the original data and the need to protect the broad habitat. A constraint of 3 was assigned to reflect the lower suitability of these sites and buffer areas, but acknowledged that they were unlikely to be a significant constraint.

Fauna and Habitat

Fauna are generally mobile and information on fauna habitats is not available at a useful scale or coverage for the entire study area. In order to reflect potential impact on fauna, the following levels of constraint were adopted:

- islands less than 1 000 ha were considered exclusion zones on the basis that the land-take of a GPF plant and associated infrastructure would have a severe impact on fauna habitats within such a relatively confined area;
- islands over 1 000 ha were assigned a moderate constraint (5), on the basis that the land-take of a GPF plant and associated infrastructure could more easily be accommodated by the island, without severe impact upon fauna habitats;
- Barrow Island was assigned a higher constraint (8) than other large islands to reflect the known presence (but undetermined extent) of rare subterranean fauna and the absence of introduced species (with a correspondingly high habitat value for rare native fauna); and
- the mainland was assigned a low constraint (2) on the basis that that there is greater flexibility to accommodate the land-take of a GPF plant, thus reducing impact upon fauna habitats. Exmouth Peninsula was assigned a moderate constraint (5) due to the known presence of rare subterranean fauna.

Conservation Reserves

National Parks (such as Cape Range on the Exmouth Peninsula) and Marine Parks (Ningaloo) were identified as exclusion zones in recognition of their high conservation, recreational and social values. Coastal land directly adjacent to Ningaloo Marine Park was also considered an exclusion zone due to the need for marine port facilities at the GPF plant and the subsequent marine use conflict.

Suitability was considered moderate (constraint of 5) in all other declared Conservation Reserves, Nature Reserves and AHC listed areas. Proposed marine reserves have also been allocated a constraint of 4 to reflect their recognised importance and potential future conservation status.

Saline Coastal Flats

Saline coastal flats were considered to be moderately unsuitable due to habitat value. However, because of their extensive coverage along the Pilbara coast, it was considered unlikely that the loss of 300 ha would have a significant impact on the regional habitat. Therefore, they were allocated a low level of constraint (2).

Water Courses

Permanent, seasonal or intermittent watercourses were considered less suitable for development. The construction of a GPF plant across a water course would be a direct impact which would disrupt natural surface drainage patterns. Such changes to drainage pattern could result in large, localised impacts to a restricted habitat type although, in reality, impacts would be minimised through management. Water courses were given a buffer of 100 m and assigned a constraint of 3.

Lakes

Lakes (permanent, seasonal or intermittent) were considered exclusion areas due to their significance as waterfowl habitats and their limited distribution in the region. Lakes within the study area occur mainly in the south, inland from the Exmouth Gulf, and are generally saline.

Groundwater Reserves

The only groundwater reserve to occur in the study area is the Exmouth Town Groundwater Reserve. Given the relative scarcity of potable water in the region, this was considered a significant constraint, and was assigned a constraint index of 5.

4.2.2.2 Social criteria

Settlements

Suitability of heavy industrial development in or near settlements was considered low. Although it is an advantage to be within reasonable proximity of a settlement and related infrastructure, a 3 km exclusion zone was applied around any town site. A further 10 km buffer and a constraint of 5 was applied around settlements to avoid visual, noise, safety and amenity impacts.

Tourism and Recreation

Tourism and recreational features were considered exclusion zones. To avoid conflicting land use and impacts on amenity, wilderness and landscape values, a constraint of 5 was assigned to areas within 3 km of significant tourism or recreation areas.

Although existing industrial facilities at Burrup Peninsula are also considered to be a tourism feature, they were not considered to lower the suitability of the area for further industrial expansion.

Aboriginal Heritage Sites

Areas that contain sites of Aboriginal archaeological or ethnographic significance were considered a moderate constraint (5). As the precise locations of these sites are not released by the Department of Aboriginal Affairs, a 500 m buffer (equal to the grid size used in the regional analysis procedure) was applied to ensure that coverage was appropriate.

Native Title Claims

Native title claims as of September 2002 were obtained from the Native Title Claims Mapping Unit of the Department of Land Information. Areas with one Native Title claim were assigned a constraint of 3 and areas with two or more were assigned a constraint of 5, indicating the potential for extended negotiation and compensation which may delay land acquisition and plant construction.

Mineral Deposits

Areas with mineral deposits were considered less suitable, on the basis that development in these areas may lead to the sterilisation of a mineral resource. A constraint of 2 was applied where a mineral resource was identified within 2 km. The presence of mineral deposits does not reflect any currently proposed extraction, nor the economic feasibility of extraction.

Mining Tenements

Mining tenements were obtained from the Department of Minerals and Energy in September 2002. Areas subject to a current lease were considered less suitable on the basis that the use of the land would involve some form of compensation to the holder of the tenement. A constraint of 3 was assigned to existing mining tenements.

Pearling Leases

Boundaries for current pearling leases were obtained from Fisheries Western Australia. Lease areas and a 2 km buffer were given a moderate constraint value of 5 on the basis that pearling is a high value industry and disturbance to the beds (in terms of wave energy or turbidity) may have a significant impact on production.

4.2.2.3 Economic (engineering and development cost) constraints

Proximity to Gas Source

Proximity to the Gorgon gas field was considered to be a major factor in selection of suitable areas. The length of the pipe required to transport the gas has a significant impact on project costs. The constraint was assigned, based on proximity to the gas field. Areas outside a 200 km limit were considered exclusion zones. A sliding index was applied to the remainder of the study area, with the more distant areas (180 – 200 km) assigned the maximum constraint of 10, through to the closer areas (0 – 60 km) which were assigned a constraint of 1. This does not imply that costs are linear with distance of pipe, but gives a generalised rating of preference. A weighting of 70% (equivalent to $70 million for each constraint point) was applied (refer Appendix A).

Proximity to Existing Infrastructure

A level of constraint was assigned based on distance from potentially beneficial infrastructure facilities (such as ports and roads). Areas closer to existing facilities such as ports implied potentially lower project development costs and were considered to improve regional synergies. A sliding scale was applied, where the most distant areas (180 – 200 km) were assigned the maximum constraint of 10, through to the closest areas (0 – 20 km) which were assigned a constraint of 1. A weighting of 4.5% (equivalent to $4.5 million for each constraint point) was applied.

Slope

Areas with slope greater than 5^{o} were considered less suitable due to increased erosion potential and construction complexity and were assigned a constraint of 10. These occurred only in small areas on the Exmouth Peninsula and Burrup Peninsula. A weighting of 1% (equivalent to $1 million for each constraint point scored) was applied.

Elevation

Areas of low elevation (below 5 AHD), such as coastal flats, were considered exclusion zones due to exposure to storm surge and because of poor foundation conditions.

Sheltered Water

Large tankers require berthing facilities protected from extreme wind and wave action. Areas not offering sheltered waters were considered exclusion zones.

Pipeline Crossings

While crossing of submarine pipelines by shipping channels and other pipelines is technically possible, a higher development cost is implied. A low constraint (0) has been assigned to distinguish in favour of those sites that can be reached without crossing another pipeline. Areas which could be accessed only by crossing another pipeline (e.g. East Spar) were allocated a constraint of 10. A weighting factor of 0.5% (equivalent to \$0.5 million for each constraint point) was applied.

Proximity to Deep Water

Deep water is required to enable access for large tankers. Extensive shallow waters would require substantial dredging at high cost. Large dredging programs also imply higher potential for environmental impacts from turbidity and spoil disposal. The constraint used in the regional GIS model reflected both the distance to the 5 m and 10 m isobaths. A sliding index was applied at 0.5 km distance increments, up to the 10 m isobath, which was assigned the maximum level of constraint of 10, through to the closest areas (1-1.5 km) which were assigned 1. A weighting factor of 12% (equivalent to \$12 million for each constraint point) was applied.

Proximity to Coastline

Pipeline length from the plant to the ship-loading facilities is a constraint factor due to gas handling and cost limitations. Beyond 10 km was considered an exclusion zone due to temperature management requirements for the gas whilst in the pipeline, and general engineering cost. A sliding scale was used that reflected an increasing level of constraint as the distance increased from the coast (maximum of 10 km, rated 1 – 10 using 1 km increments). A weighting factor of 12% (equivalent to \$12 million for each constraint point) was applied.

4.3 RESULTS OF REGIONAL CONSTRAINTS ANALYSIS

The outcome of the regional constraints assessment is presented in a series of figures as follows:

Figure 4.1 presents the environmental criteria database;
Figure 4.2 presents the social criteria database;
Figure 4.3 presents the economic and engineering criteria database;
Figure 4.4 shows the level (least to most) of constraint presented by the environmental criteria;
Figure 4.5 shows the level of constraint presented by the social criteria;
Figure 4.6 shows the level of constraint presented by the economic and engineering criteria and the parts of the coast excluded by various engineering requirements; and
Figure 4.7 presents the combined level of ESE constraints achieved by overlaying Figures 4.4 to 4.6.

Notable features shown on these figures include:

- the large amount of CALM estate and proposed marine parks throughout the region (Figure 4.1);
- the extensive occurrence of mangroves and saline coastal flats in the region (Figure 4.1);
- the widespread distribution of mining tenements, Aboriginal sites and Native Title claims in the region (Figure 4.2);
- the shallowness of nearshore waters along much of the coast, and the volume of oil and gas infrastructure (pipelines and ports) already present in the region (Figure 4.3);

- the location of greatest environmental constraint tended to occur on offshore islands, in the vicinity of Exmouth and on the eastern side of the Exmouth Gulf (Figure 4.4);
- the location of greatest social constraint tended to occur in the vicinity of settlements and recreation areas, and areas supporting a high abundance of Aboriginal sites and mining tenements (Figure 4.5); and
- substantial areas of coastline were excluded by the economic and engineering constraints (Figure 4.6). Figure 4.6 shows that large parts of the coastline within 10 km of the shore are excluded because of low elevation, lack of shelter for shipping or distance to deep water. Coloured areas meet the economic and engineering critera. Dark blue areas have the highest level of constraint and occur at greatest distance from Gorgon (e.g. Burrup, Cape Preston and Exmouth). The offshore islands of Barrow, Thevenard and Montebellos rated well in the economic/engineering constraints analysis.

Figure 4.7 presents the outcome of Step 1 of the study process. Orange-red areas reflect locations with the greatest level of constraint and have least suitability for development of a GPF. Such areas included the islands of the Dampier Archipelago, Burrup Peninsula and Exmouth South. Yellowish areas indicate a moderate level of constraint. Such areas include Maitland Industrial Estate, Thevenard Island, and parts of the Montebello Islands. Finally, the figure shows Barrow Island mainly green in colour which is the lowest constraint value of all locations.

Figure 4.7 therefore identifies broad locations where:

(1) GPF development has been excluded by one or more selection criteria (areas of no colour);
(2) GPF development is possible but highly constrained, mainly by cost, distance from Gorgon and some social criteria (areas coloured orange-red);
(3) GPF development is possible, and least to moderately constrained (areas coloured green and yellow, respectively).

Figure 4.7 therefore forms the first broad brush identification of potential locations for further analysis and screening. As such, it forms the basis for Step 2 of the process.

5. STEP 2 – IDENTIFICATION OF FEASIBLE SITES

The objective of this step was to identify a number of engineeringly feasible sites for further evaluation. The composite ESE constraints map (Figure 4.7) resulted in the identification of a number of locations along the coast where development was potentially possible. This map was reviewed by the ChevronTexaco engineering team to:

(1) confirm the feasibility of each general location identified;
(2) exclude locations that did not meet the feasibility criteria; and
(3) identify potential development sites within each feasible location.

The key feasibility criteria applied by the ChevronTexaco engineering team were as follows:

- area had to be safe from flooding and storm surge;
- distance to deep (sheltered) water (>10 m) no further than 10 km from GPF plant;
- land was legally available and unencumbered; and
- land not close to socially sensitive locations.

The outcome of this review resulted in the exclusion of the following areas.

Dampier Archipelago islands: These islands are all nature reserves and occur within the proposed Dampier Archipelago Marine Park. They support holiday shacks and are a highly popular recreation area for the people of Dampier and Karratha. Considered too socially sensitive.

Dampier environs: Most of this land is owned by Hamersley Iron and supports its infrastructure. It was excluded due to unavailability and closeness to Dampier.

Cape Preston: Most of this land is not available and is protected by mining tenements owned by organisations associated with the recently-approved Austeel project. Inland from Cape Preston was considered too far from deep water and poorly sheltered from a shipping perspective.

North of Onslow: This land was considered too far from deep water, prone to flooding and storm surge, and adjacent to extensive mangrove and tidal flat environments which occurred within the Great Sandy Islands Nature Reserve.

Onslow North: This land was also considered too far from deep navigable water which occurs some 20 km offshore. The location has been identified by the GIS process because there occurs a small 10 m deep basin within 5 km of the coast.

Exmouth Gulf East: A few scattered sites on islands in the salt flats along the eastern shore of the gulf were too small, remote from access, and potentially socially sensitive as a result of conflict with the prawn fishing industry.

Exmouth North: This small area of land was excluded because of its proximity to existing infrastructure (town site, camping grounds, radio bases) and Ningaloo Marine Park. Generally considered too socially sensitive.

The above exclusions resulted in the following locations being available for further consideration:

- West Intercourse Island;
- Maitland Industrial Estate and West Intercourse Island (combined);
- Exmouth South;
- Thevenard Island;
- Montebello Islands; and
- Barrow Island.

The next phase of work in Step 2 required the identification of feasible development sites within each of the above locations. Previously published reports and engineering documents were reviewed to identify development sites with a minimum area of 300 ha. The reports referred to for this part of the study included:

- The Pilbara Land Use Strategy (PDC 1997);
- The Gorgon LNG Greenfield Site Selection Study (Shell 1996);
- The Gorgon LNG Draft EIS (Chevron 1998; unreleased);
- The Maitland Industrial Estate Report (Woodward Clyde 1994); and
- Review of Site Locations on Barrow Island (Chevron 2002).

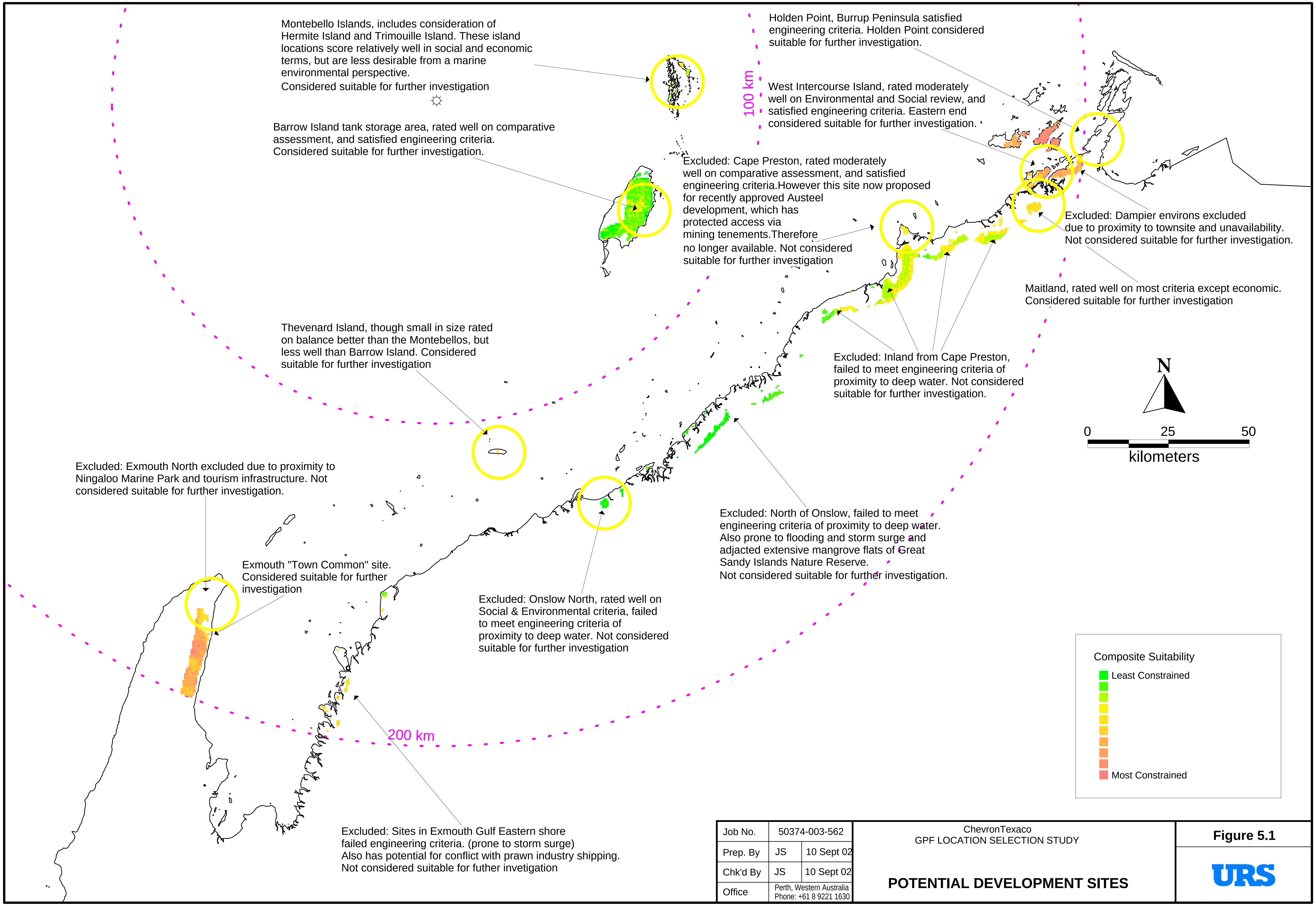
This review identified the following feasible sites at each location:

- eastern end of West Intercourse Island;
- Maitland Industrial Estate/eastern end of West Intercourse Island;
- Exmouth Town Common;
- Thevenard Island west of Saladin facilities;
- Hermite and Trimouille Islands in the Montebellos; and
- Barrow Island tank farm.

It should be noted that the Maitland Industrial Estate can only be considered as a potential site in combination with Intercourse Island, as the latter is essential for storage, jetty and shiploading requirements (i.e. coastal access).

The review also identified a further site for consideration at Holden Point on the Burrup Peninsula. This area had been excluded by the GIS analysis because it was further than 200 km from Gorgon. However, it has been seriously evaluated previously by Chevron and hence was included in this assessment.

Figure 5.1 summarises the outcome of this portion of investigation and shows the location of potential development sites considered suitable for further investigations. It also shows the sites which were excluded and provides the main reason for their exclusion.



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6. STEP 3: SITE COMPARISONS AND RANKING

6.1 OBJECTIVE AND SCOPE OF WORKS

The objective of this phase of work was to compare the relative sensitivity of each site from the perspective of potential social and environmental impacts of construction and operation of the proposed development. This task was achieved by firstly reviewing available environmental and social information about each site, and secondly by undertaking an impact assessment workshop for each site to produce a multi-criteria impact matrix. The details of the matrix evaluation subsequently provided an indication of the potential environmental and social sensitivity of each site, and hence enabled their ranking in order of least to most sensitivity or potential constraint.

Prior to describing the detail of the matrix evaluation technique and the criteria assessed, it is necessary to understand the relative social and environmental attributes of each site. The key social and environmental attributes of each site are summarised in the following section and the accompanying comparison (Table 6.1), and greater detail is provided in Appendix B.

6.2 LOCATION DESCRIPTION – PRIMARY ATTRIBUTES FOR A GPF

6.2.1 Exmouth South

The Exmouth peninsula provides a flat coastal plain on the eastern side of Cape Range and adjacent to Exmouth Gulf that is suitable for development in general. Exmouth South was identified as an available site with suitable tenure, and a locality thought to be largely free of important flora and fauna. Exmouth also features extensive infrastructure development, including good communications, the largest town in the Gascoyne region and an airport. Exmouth is just within the 200 km zone from the Gorgon gas field, with sheltered and sufficiently deep water access for major shipping and loading. All these attributes make Exmouth South a potential location for a GPF.

On the negative side, the possible site(s) at Exmouth are relatively close to the existing settlement and close to the major highway to the Cape. The coastal plain is an open landscape with high visibility. These present problems both in terms of impact on the Exmouth community, road safety issues during the construction phase, and the high visibility of any GPF development in the landscape. The presence of such a facility would also be directly in conflict with the primary 'natural environment and tourism' destination attractions of the area, and the stated intention of the State Planning Strategy to build on these values for the future. In addition, the presence of the Ningaloo Reef close to the required loading jetty for export tankers is considered a highly constraining factor.

6.2.2 Burrup Peninsula – Holden Point

Burrup Peninsula has the main attribute of being an established centre of the natural resource processing industry in the Pilbara. The site features a landscape of generally precipitous terrain extending out to sea and hence offers relatively good deep water access for major shipping. Sufficiently level sites are available for development, of which Holden Point is one. Environmental values are high in general terms, but are also site specific, and Holden Point is free of any known significant flora and fauna values. Further attributes of Burrup Peninsula-Holden Point include the presence of good infrastructure (communications, access, etc.) and the availability of accommodation for workforce and support services.

Constraining attributes include the distance from Gorgon, and a number of social issues and potential land use conflicts that affect the Burrup in general. These include such matters as the loss of further beaches suitable for swimming, navigational hazards, and harbour management issues concerned with narrow navigational channels that have to accommodate increasing ship movements. Additionally, owing to the Burrup's exceptional wealth of Aboriginal rock art and important Aboriginal sites, the incremental loss of beaches and impact on landscape/scenic values, there continues to be controversy over specific development proposals. Furthermore, the community of Karratha has in the past experienced high impacts and inconvenience resulting from the sudden influx of workforce to the region, with consequent effects on accommodation rentals and availability of community services.

6.2.3 West Intercourse Island

West Intercourse Island was set aside for industry and mining related developments in 1978 and is administered by the Department of Land Administration with this intention in mind. The island is characterised by hardrock and boulder landscape with varying relief to 60 m elevation, surrounded by mangroves and tidal mudflats. The flora and fauna of the island are not outstanding and close proximity to the mainland has resulted in infestation by weed species and pests. There are therefore no major flora, fauna or habitat constraints to development on the island. Access to the island by sea would need to be by a dredged navigable channel linking to existing channels, and similar issues with respect to navigation logistics and safety mentioned for the Burrup Peninsula also apply. Social issues are not significant for West Intercourse Island as it is far enough from Dampier and Karratha for a practical buffer to exist, yet near enough for workforce accommodation and to provide support services. The main factor mitigating against West Intercourse Island is distance from Gorgon, and cost of providing infrastructure to a specific development site, because at present the island is not connected to the mainland.

6.2.4 Maitland Industrial Site and West Intercourse Island

Maitland industrial area has been formally set aside through the planning process and has the potential for development of a GPF, but only if considered in conjunction with West Intercourse Island which would provide the site for storage, jetty and shiploading. Maitland itself is a low-lying site some 15 km west of Karratha, rising to a height of 20 m AHD. The site is largely free of flora and fauna values of concern, with mainly a presence of seasonal wading and waterbirds that take advantage of the existing and nearby creek lines and alluvial channels, one of which dissects the location. Maitland's main attributes for a major resource processing facility is that it has been set aside for such a purpose. However, the negative attributes are the distance of the location from Gorgon, and the distance of the site itself from both the coast and the nearest potential ship loading point, which would be at West Intercourse Island. Navigation and dredging issues pertaining to West Intercourse Island and the Burrup therefore also apply. A further concern with Maitland is that it is as yet undeveloped and unproven as an industrial zone, and hence there is currently no infrastructure (power, communications, access, etc.) provided to the site. These represent further hurdles to development and operation of a facility at Maitland.

6.2.5 Barrow Island

The principal positive attributes of Barrow Island for a GPF include good proximity to the Gorgon gas fields, existing industry infrastructure on the island and an excellent record in environmental management and protection of the island's outstanding ecological/biological values, good access to deep water for shipping access, and the prospect for re-injecting CO_2 into the saline reservoir under the oil/gas wells on the island. Furthermore, Barrow Island is of sufficient size to allow a GPF footprint to be selected and located without intruding on any of the island's key flora or fauna values/habitats. Barrow Island is also devoid of competing or conflicting human activities or other industries (such as tourism) and Native Title claims.

Despite these outstanding positive attributes, on the negative side Barrow Island is a Class A reserve for the protection of flora and rare fauna, albeit legally accommodating the presence of industry, and has gained the reputation of an internationally significant conservation site. Some of the fauna present are either endemic to the island or have become extinct on the mainland. A principal value of the vegetation on the island is its vital habitat function for the various important fauna species. Barrow also features a biodiverse marine environment with varied marine habitats, including corals on the interdidal and subtidal platforms that surround it. These values make Barrow a controversial possible location, even though industry has proven to be highly compatible with these values, and has actually contributed significantly to preserving those values up to the present time.

6.2.6 Montebello Islands

The Montebello Island group is comprised of some 265 individual islands, of which Trimouille and Hermite are possibly large enough to accommodate a GPF development. The islands have a range of terrestrial wildlife, but these are limited in conservation value owing to past introduction of pests and feral animals, the presence of some human activities and industry, and the past impacts of nuclear weapons testing. Sheltered waters and reasonably good access to deep water are further positive attributes.

The Montebellos have high marine environmental and wilderness values, and these are becoming progressively important in conservation terms and also as a potential eco-tourism attraction. The narrow channels and diverse marine habitat with abundant coral reef systems with their associated habitat value to marine fauna, are of concern with respect to the introduction of large ship movements that would be associated with a loading facility. Existing recreational boat and yachting activity, as well as pearling industry and commercial fishing activities within and near the island group, also present potential human use conflicts.

6.2.7 Thevenard Island

Thevenard Island is some 5 km long and 1 km wide and currently supports a C Class reserve and an oil processing facility and a small tourism (recreational fishing) resort. The island therefore also has some essential infrastructure, including an airstrip. The island environment is dominated by shrub and grass habitat, with only one native mammal present. Thevenard Island is a moderate distance from the Gorgon gas field and, being relatively unconstrained, offers some potential for development of a GPF.

The negative attributes of Thevenard for a GPF include the limited size of the island, and hence the high impact level on both the existing resort facility (and other occupants on the island) and the frequent recreational fishermen and boat users who visit the island and its waters. Thevenard also supports a rich marine environment. A further deficiency of is the lack of sheltered waters, and hence difficulty in establishing an operational ship loading facility.

Table 6.1 Comparison of Key Attributes for Possible Locations

Constraints	Short Listed Locations						
	Montebello Islands (Trimouille Island)	**Thevenard Island**	**Barrow Island**	**Maitland Estate/ West Intercourse Island**	**Burrup Peninsula (Holden Point)**	**Exmouth**	**West Intercourse Island**
Technical/Cost							
• Pipeline distance to Gorgon gas field	Approx. 90 km	Approx. 120 km	Approx. 70 km	Approx. 250 km	Approx. 230 km	Approx. 200 km	Approx. 200 km
• Sufficient available area	Area available for development is extremely restricted	Area available for development is limited	Sufficient area available for development requirements	Sufficient area available for development requirements	Sufficient area available for development requirements	Sufficient area available for development requirements	Sufficient area available for development requirements
• Proximity to coastline	Immediately adjacent to coast	Immediately adjacent to coast	Immediately adjacent to coast	Maitland Estate 10 km inland, coastal access via West Intercourse Island	Immediately adjacent to coast	Coastal	Immediately adjacent to coast
• Proximity to deep water	Good access to deep water	Good access to deep water	Moderate access to deep water	Moderate access to deep water	Moderate access to deep water	Moderate access to deep water	Moderate access to deep water
• Sheltered water	Limited sheltered waters	Limited sheltered waters	Sheltered waters	Sheltered waters	Sheltered waters	Sheltered waters	Sheltered waters

Table 6.1 Comparison of Key Attributes for Possible Locations (cont'd)

Constraints	Short Listed Locations						
	Montebello Islands (Trimouille Island)	**Thevenard Island**	**Barrow Island**	**Maitland Estate/ West Intercourse Island**	**Burrup Peninsula (Holden Point)**	**Exmouth**	**West Intercourse Island**
• Slope	Stable soils and minimal amount of earthworks required	Stable soils and minimal amount of earthworks required	Stable soils and minimal amount of earthworks required	ME - stable soils and minimal amount of earth-works required WII – moderate geotechnical conditions	Difficult geotechnical conditions at site	Stable soils and minimum earthworks required	Moderate geotechnical conditions at site
• Elevation	No elevation constraints	No elevation constraints	No elevation constraints	ME - low lying site WII – no elevation constraints	No elevation constraints	No elevation constraints	No elevation constraints
• Proximity to existing infrastructure	No existing infrastructure	Adjacent to existing oilfield infrastructure	Adjacent to existing oilfield infrastructure	No existing infra-structure at site. Good regional infrastructure	Site is adjacent to the NWS LNG development. Good regional infrastructure	No infrastructure at site. Good regional infrastructure	No existing infrastructure Good regional infrastructure
• Pipeline crossings	No	No	Yes	Yes	Yes	No	Yes
Environment							
• Mangroves	No mangroves	No mangroves	Relatively few areas of mangroves	WII – surrounded by mangroves	No mangroves	No mangroves.	Surrounded by mangroves.
• Declared rare flora	Locality has relatively few significant flora	Locality has relatively few significant flora	Locality has relatively few significant flora	Locality has relatively few significant flora	Locality has relatively few significant flora	Locality has relatively few significant flora	Locality has relatively few significant flora

Table 6.1 Comparison of Key Attributes for Possible Locations (cont'd)

Constraints	Short Listed Locations						
	Montebello Islands (Trimouille Island)	**Thevenard Island**	**Barrow Island**	**Maitland Estate/ West Intercourse Island**	**Burrup Peninsula (Holden Point)**	**Exmouth**	**West Intercourse Island**
• Fauna species and habitats	Locality has relatively few significant terrestrial fauna and habitats High marine environmental and habitat values	Locality has relatively few significant terrestrial fauna and habitats High marine environmental and habitat values	High ecological values. Several fauna that are endemic to Barrow Island High marine environmental and habitat values	Locality has relatively few significant terrestrial fauna and habitats Presence of seasonal wading and water birds	Locality has relatively few significant fauna and habitats	Locality has relatively few significant fauna and habitats High marine environmental and habitat values	Locality has relatively few significant fauna and habitats
• Conservation reserves	Class A Conservation Park Surrounding waters considered for a Marine Park	Class C Nature Reserve	Class A Nature Reserve Surrounding waters considered for a Marine Management Park	None	None	Close proximity of loading jetty to Ningaloo Marine Park	None
• Saline coastal flats	No saline coastal flats	No saline coastal flats	No saline coastal flats	WII surrounded by tidal mudflats	No saline coastal flats	No saline coastal flats	Surrounded by tidal mudflats
• Water courses	No water courses	No water courses	Water courses exist (intermittent)	Water courses exist	Water courses exist	Water courses exist	Limited numbers of watercourses exist
• Groundwater reserves	No prescribed groundwater reserves	None	None	None	None	Prescribed groundwater reserve exists	None

Table 6.1 Comparison of Key Attributes for Possible Locations (cont'd)

Constraints	Short Listed Locations						
	Montebello Islands (Trimouille Island)	**Thevenard Island**	**Barrow Island**	**Maitland Estate/ West Intercourse Island**	**Burrup Peninsula (Holden Point)**	**Exmouth**	**West Intercourse Island**
Social							
• Settlements	No settlements	Small tourist resort accommodation	No settlements	Relatively close to Dampier	Relatively close to Dampier	Relatively close to existing settlements and major highway	Relatively close to Dampier
• Tourism and recreation reserves, attractions or activities.	Existing recreational boating and yachting activity. Islands support increasing tourism.	Existing recreational boat and yachting activity. Island also supports tourism	No tourism or recreation	No tourism or recreation	Area used extensively for recreation and tourism	High regional tourism activity and high tourism industry growth potential	No island tourism or recreation Nearby recreational fishing occurs
• Aboriginal heritage sites	Relatively few Aboriginal heritage sites exist	One Aboriginal heritage site	Relatively few registered Aboriginal heritage sites	Many Aboriginal heritage sites recorded	High occurrence of Aboriginal heritage sites	Aboriginal heritage sites in general area	High occurrence of Aboriginal heritage sites
• Native Title claims	No Native Title claims	Native Title claim exists	No Native Title claims	Native Title claims settled	Native Title claims settled	Native Title claim exists	Native Title claims settled
• Mineral deposits	No mineral deposits	No mineral deposits	No mineral deposits	No mineral deposits	No mineral deposits	No mineral deposits	No mineral deposits
• Mining tenements	No mining tenements	No mining tenements	No mining tenements	No mining tenements	No mining tenements	Some mining tenements	No mining tenements
• Pearling leases	Several existing pearling leases in adjacent waters	Pearling leases	Pearling lease in adjacent waters on east coast of Island	No pearling leases in adjacent waters	No pearling leases in adjacent waters	No pearling leases in adjacent waters	No pearling leases in adjacent waters

6.3 MATRIX EVALUATION TECHNIQUE

The short-listed sites described briefly above were then compared in greater detail using a multi-criteria matrix evaluation technique. The matrix evaluation technique considered potential impacts during both the **construction** and **operation** stages of the development.

This assessment was based on environmental and socio-economic factors, and does not directly consider commercial cost/benefit aspects. A simple ranking system in increments of 0.5 where appropriate, ranging from +2 (major positive) to -2 (major negative) was used to evaluate each criteria. The assignment of number values for each criterion has been subjective, based upon reference documents and the professional judgement and consensus of the consultant team working on the project. Scores were added to produce an overall ranking for each site, and then normalised (as a percentage of the total score possible) to allow comparison.

The strength of this approach is the robustness and transparency of the final outcome. As presented, the matrix evaluation does not include any deliberate weighting of the values.

6.4 EVALUATION CRITERIA FOR SITE COMPARISONS

Thirty-eight (38) criteria were used in the evaluation. Fifteen (15) of these related to environmental issues, twenty three (23) to socio-economic issues. A comparison of certain hazard/risk issues is also included in the matrix evaluation.

Factors evaluated and their general definitions for the purpose of this study are presented in Tables 6.2 – 6.4. Further definition of each factor and justification for the scores allocated to each is provided in Appendix C.

The numerical results of the matrix have been presented both for separate categories (e.g. environmental or socio-economic), as a composite score for all categories and as ‘normalised’ scores, enabling overall and component comparisons to be made. The scores are also illustrated in the accompanying bar charts (Figures 6.1 – 6.3).

A preferred site was identified from the matrix evaluation on the basis of lowest negative score (or least level of overall constraint).

Table 6.2 Environmental Factors

Category	Factor	Definition
Chemical and Physical	Pollution	Atmospheric pollution, odour and noise. Illumination. Light pollution. Water pollution/effluent discharges.
Terrestrial Biological	Habitat	Physical (vegetation, terrain). Agreements (JAMBA/CAMBA).
	Flora	Declared, rare.
	Fauna	Declared, endangered, priority.
Marine Biological	Habitats	Corals, mangroves, seagrass meadows.
	Notable species	Whale, dugong, turtle, whale shark.
Ecological Risk/hazard	Fire/explosion	With regard to system terrestrial ecosystem.
	Transport accident	With regard to marine ecosystem.
	Spill discharge	With regard to marine ecosystem. With regard to terrestrial ecosystem.
	Quarantine	With regard to terrestrial ecosystem.

Table 6.3 Socio-economic Factors

Category	Criteria	Definition
Urban	Aesthetics/landscape	Visual quality and landscape value.
	Amenity	Sense of place and pleasantness for locals.
	Social/lifestyle	Structure and social dynamics; local customs.
	Capacity	Ability to accommodate new influx of people in relation to housing, services and infrastructure.
	Proximity	Distance to accommodation and services.
	Disruption	Such as traffic, access to services, etc.
Community	Community services	Medical, education, emergency services, etc.
Land and Marine Use	Recreation and tourism	Commercial or not; local, regional, national and international interests and their losses or inconveniences.
	Other industry	Inconvenience. Obstruction or inefficiencies imposed on all sections of industry through new development.
	Infrastructure	Conflict with pipelines, rail, road, etc.
	Marine use conflicts	Conflict of shipping with other shipping, fishing activities and recreational boating.
Economic Activity	Expenditure	Direct or indirect.
	Employment	Employment of local residents.
Perception	Local perception	Acceptance of proposed development.
	National perception	National acceptance of development on proposed site.
Tenure	Leases/reserves	Negotiation possible but perhaps time consuming.
	Native Title	Extensive delays possible.
Linkages	Industry synergy	Added value and mutual benefits.
Heritage	European	Generally relates to structures or relics.
	Aboriginal	Archaeological and ethnographic.

Table 6.4 Hazard and Risk to the Community

Category	Factor	Definition
Construction Stage	Accident or emergency	Hazard to settlements, other industry or natural.
Operation Stage	Fire/explosion	Hazard to human/social system.
	Transport accident	Hazard to human/social system.
	Spill discharge	Hazard to human/social system.
	Breach of quarantine	Hazard to natural resource-based primary industry.

6.5 RESULT OF SITE COMPARISONS

Tables 6.5 and 6.6 present the multi-criteria matrix evaluation of the short-listed sites against environmental, socio-economic and hazard/risk categories. Justification of the scores is provided in Appendix C. Figures 6.1 – 6.3 present graphically the outcome of Tables 6.5 and 6.6.

Figure 6.1 presents graphically the Normalised Total score presented on the bottom line of Table 6.5 and shows the relative levels of environmental constraint between potential development sites. Interestingly, the figure shows that most sites have roughly similar levels of environmental constraint. Barrow Island and Exmouth (South) have the highest level of environmental constraint, as expected. The figure also shows that all sites have similar or greater levels of environmental constraint during the operations phase of development compared to the construction phase of development.

Figure 6.2 graphically shows the Normalised Total score presented on the third line from the bottom on Table 6.6. It enables comparison of the level of socio-economic constraints applicable to each potential development site. This figure shows that Exmouth and the Montebello Islands sites have the greatest level of socio-economic constraint, whilst Barrow Island has the least. Interestingly, the figure shows that, for most sites, the construction phase of development is the major contributor to the levels of constraint recorded while, by comparison, the operations phase is positive for Burrup, West Intercourse (and Maitland) and Barrow, but significantly negative for Exmouth and the Montebello Islands.

Figure 6.3 graphically shows the Normalised Combined Total score presented on the bottom line of Table 6.6. It shows the overall level of ESE constraint for each potential development site.

It is noted that Maitland Industrial Estate by itself would have scored highly with the least level of environmental and socio-economic constraint, however, the essential requirement for Maitland to be considered jointly with West Intercourse Island denies this potential benefit in the scoring. The area is appropriately zoned for GPF development, has low environmental sensitivity and benefits from access to high levels of social infrastructure in nearby Dampier and Karratha.

Exmouth recorded the highest overall ESE constraint levels, particularly during the construction phase. Exmouth is principally a tourism and recreation centre servicing a region of high conservation value and limited potable water.

The Montebello Islands also scored poorly in this evaluation, reflecting its current use for recreational fishing and diving, and commercial pearling, its high environmental sensitivity and conservation value as a wilderness area.

The remaining sites all recorded a similar level of overall ESE constraint with little to distinguish between them. In essence, this means that these remaining sites (e.g. Barrow Island, Thevenard Island, West Intercourse Island and the Burrup Peninsula) all share similar levels of ESE constraint.

In regional planning terms, development of a GPF at Exmouth would be a highly conflicting land use in the context of the objectives contained in the adopted State Planning Strategy. Given this and the high level of constraint identified by this analysis, it is recommended that this location be excluded from further evaluation.

In conclusion, Figure 6.4 illustrates the outcome of a lengthy and intense assessment presented in this study; that of those locations considered, Barrow Island and Thevenard Island all record the lowest constraint outcome, while the Montebello Islands, Burrup Peninsula and Exmouth Peninsula record the highest.

Table 6.5 Multi-criteria Comparison of Possible Development Sites (Environmental Factors)

Physical/Chemical/Biological (refer back to Table 6.1)	**Burrup Peninsula** construction	Operations	**West Intercourse** construction	operations	**Barrow Island** construction	operations	**Exmouth (South)** construction	operations	**Montebello Isls** construction	operations	**Thevenard** construction	operation	**Maitland/West Intercourse Island** construction	operations
POLLUTION														
Air Pollution, Odour, Noise	-1	-2	-1	-1	-1	-0.5	-2	-1.5	-1	-2	-1	-1	-1	-0.5
Illumination	0	-1	-1	-1	-1	-1.5	-1	-2	-1	-2	-1	-2	-1	-1
Effluent/Water	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Sub Total	**-2**	**-4**	**-3**	**-3**	**-3**	**-3**	**-4**	**-4.5**	**-3**	**-5**	**-3**	**-4**	**-3**	**-2.5**
TERRESTRIAL BIOLOGY														
Habitats														
Physical (vegetation, terrain)	-1	0	-1	0	-1	0	-1	0	-1	0	-1	-1	-0.5	0
Agreements (CAMBA, JAMBA)	-1	-1	-1	-1	-1	-1	-1	-1	-0.5	-0.5	-0.5	-0.5	-1	-1
Threatened Ecological Communities	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flora														
(declared, rare and mangroves)	-2	0	-2	0	-0.5	0	-1	0	0	0	0	0	-2	0
Fauna														
(declared, endangered, priority)	-2	0	-1	0	-2	-1	-2	0	-0.5	-0.5	-1	-1	-0.5	0
Sub Total	**-6**	**-1**	**-5**	**-1**	**-4.5**	**-2**	**-5**	**-1**	**-2**	**-1**	**-2.5**	**-2.5**	**-4**	**0**
MARINE BIOLOGY														
Habitats	-2	-1	-2	-1.5	-2	0	-1	-0.5	-2	0	-0.5	0	-2	-1
Notable Species (whale, turtle, dugong	-1	0	-2	-1	-2	-1	-1	-2	-2	-1.5	-1	-0.5	-2	-1
Sub Total	**-3**	**-1**	**-4**	**-2.5**	**-4**	**-1**	**-2**	**-2.5**	**-4**	**-1.5**	**-1.5**	**-0.5**	**-4**	**-2**
RISK/HAZARD														
Fire/Explosion														
Biological System		-2		-1		-2		-2		-0.5		-0.5		-0.5
Transport Accident														
Biological (Marine) System		-1		-1		-1		-1		-2		-1		-1
Spill Discharge														
Biological (Marine) System		-2		-2		-2		-2		-2		-2		-2
Biological (Terrestrial) System		-1		-1		-2		-2		-1		-1		-0.5
Quarantine														
Biological (Terrestrial) System	0	0	0	0	-2	-1	0	0	-0.5	-0.5	-1	-0.5	0	0
Sub Total	**0**	**-6**	**0**	**-5**	**-2**	**-8**	**0**	**-7**	**-0.5**	**-6**	**-1**	**-5**	**0**	**-4**
TOTAL	-11	-12	-12	-11.5	-13.5	-14	-11	-15	-9.5	-13.5	-8	-12	-11	-9.5
Normalised Total	**-36.7**	**-40**	**-40**	**-38.3**	**-45**	**-46.6**	**-36.7**	**-50**	**-31.6**	**-45**	**-26.7**	**-40**	**-36.7**	**-31.7**

Table 6.6 Multi-criteria Comparison of Possible Development Sites (Socio-economic Factors)

Socio-Economic	**Burrup Peninsula**		**West Intercourse**		**Barrow Island**		**Exmouth (South)**		**Montebello Isls**		**Thevenard**		**Maitland**	
(refer back to Tables 6.2 and 6.3)	construction	operations	construction	operations	construction	operations	construction	operations	construction	operations	operations	construction	construction	operations
URBAN														
Aesthetics/Landscape	-1	-0.5	-1	-0.5	-1	-0.5	-2	-2	-1	-2	-0.5	-1	-1	-0.5
Amenity	-1	0	-1	0	0	0	-2	-1	-0.5	-2	-0.5	-1	-1	0
Social/Lifestyle	-1	1	-1	1	0	0	-2	1	-0.5	-0.5	0	0	-2	1
Capacity (e.g. housing)	-2	1	-2	1	0	0	-2	1	0	0	-1	-1	1	1
Proximity	1	1	1	1	-2	0	1	1	-2	-2	-2	-2	-1	0
Disruption	-1	0	-1	0	0	0	-1	0	0	0	-0	0	-2	1
COMMUNITY SERVICES	-2	1	-2	1	0	0	-2	1	0	0	0	0	-1	1
Sub Total	**-7**	**3.5**	**-7**	**3.5**	**-3**	**-0.5**	**-10**	**1**	**-4**	**-6.5**	**-4**	**-5**	**-7**	**2.5**
LAND USE CONFLICTS														
Recreation/Tourism	-1	0	-1	0	0	0	-2	-2	-2	-2	-2	-2	-1	0
Other Industry	-2	-2	-1	-1	0	0	0	-1	0	0	0	0	-1	-1
Infrastructure	-1	2	-1	1	-2	1	1	0	-2	-1.5	-1.5	-1	-1	1
POTENTIAL INDUSTRY SYNERGY	1	2	0	1	1	2	0	0	0	0	0	0	0	0
MARINE USE CONFLICTS														
Shipping Channels, Navigation	-2	-2	-2	-2	-1	0	-2	-1	0	0	0	0	-2	-2
Recreation Fishing, Boating	-1	-1	-1	-1	0	0	-1	-1	-1	-1	0	0	-1	-1
Commercial Fishing	0	0	0	0	0	0	-2	-2	-1	-0.5	0	0	0	0
Sub Total	**-6**	**-1**	**-6**	**-2**	**-2**	**3**	**-6**	**-7**	**-6**	**-5**	**-3.5**	**-3**	**-6**	**-3**
ECONOMIC ACTIVITY														
Expenditure (direct/indirect)	2	2	2	2	1	1	2	2	1	1	1	1	2	2
Employment (direct)	2	2	2	2	1	1	1	2	1	1	1	1	2	2
PERCEPTION														
Local Perception	1	0	1	0	-1	0	-2	-1	-1.5	-1.5	0	0	2	1
National Perception	1	0	1	0	-1	0	-2	-2	0	0	0	0	0	0
Sub Total	**6**	**4**	**6**	**4**	**0**	**2**	**-1**	**1**	**0.5**	**0.5**	**2**	**2**	**6**	**5**
TENURE														
Leases and Reserves	0	0	0	0	-2	0	-1	0	-2	0	-1	0	0	0
Native Title	-2	-1	-2	-1	0	0	-2	-1	0	-1	0	0	-2	-1
HERITAGE														
European	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aboriginal Sites	-2	0	-2	0	-1	0	-2	0	0	0	0	0	-1.5	0
Sub Total	**-4**	**-1**	**-4**	**-1**	**-3**	**0**	**-5**	**-1**	**-2**	**-1**	**-1**	**0**	**-3.5**	**-1**
RISK/HAZARD														
Settlements	-1		-1		0		-1		0		0	0	-1	0
Industry	-2		0		0		0		0		0	0	0	0
Sub Total	**-3**	**0**	**-1**	**0**	**0**	**0**	**-1**	**0**	**0**	**0**	**0**	**0**	**-1**	**0**
TOTAL	-14	5.5	-12	4.5	-8	4.5	-23	-6	-11.5	-12	-6.5	-6	-11.5	3.5
Normalised Score	**-29.2**	**-11.4**	**-25**	**-9.4**	**-16.7**	**-9.4**	**-47.9**	**-12.5**	**-23.9**	**-25**	**-13.5**	**-12.5**	**-24.0**	**-7.3**
Combined Totals (Tables 4.2 and 4.3)	**-25**	**-6.5**	**-24**	**-7**	**-21.5**	**-9.5**	**-34**	**-21**	**-21**	**-25.5**	**-14.5**	**-18**	**-22.5**	**-6**
Normalised Combined Total	**-32**	**-8.3**	**-30.8**	**-8.9**	**-27.6**	**-12.2**	**-43.6**	**-26.9**	**-26.9**	**-32.7**	**-18.6**	**-23.1**	**-28.8**	**-7.7**

Figure 6.1 Comparison of Level of Environmental Constraints between Potential Development Sites

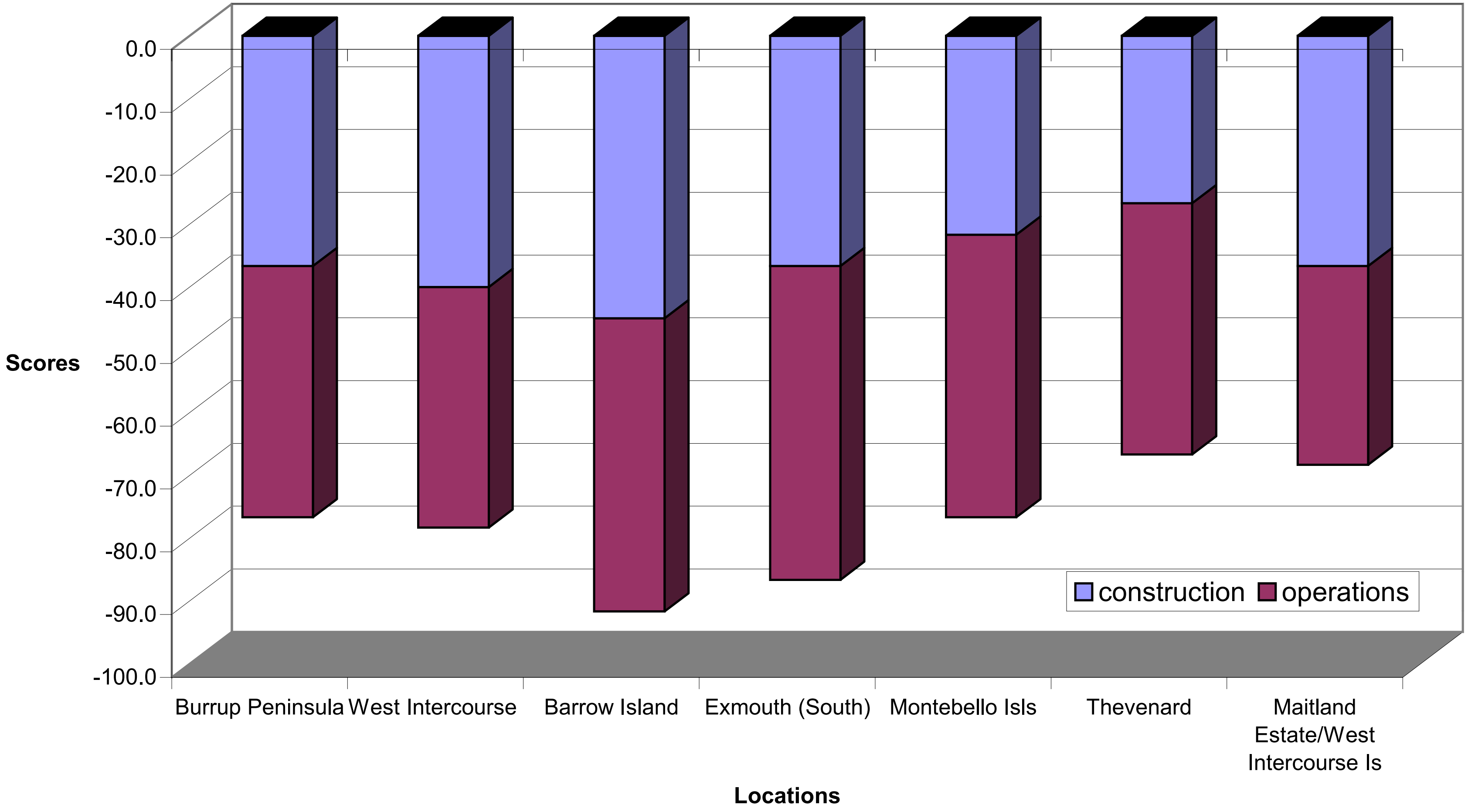


Figure 6.2 Comparison of Level of Socio-Economic Constraints between Potential Development Sites

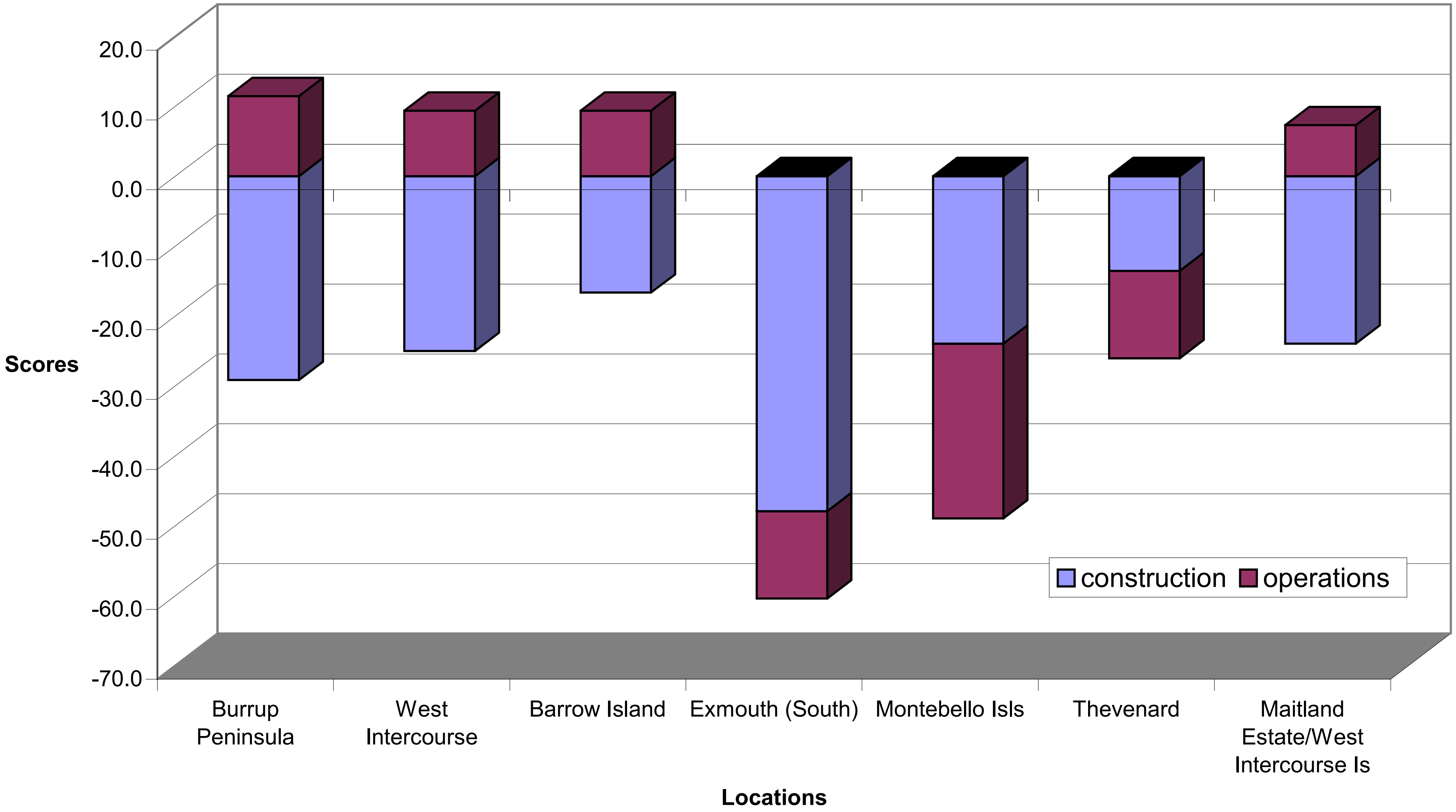


Figure 6.3 Comparison of Level of Total Environmental and Socio-Economic Constraints between Potential Development Sites

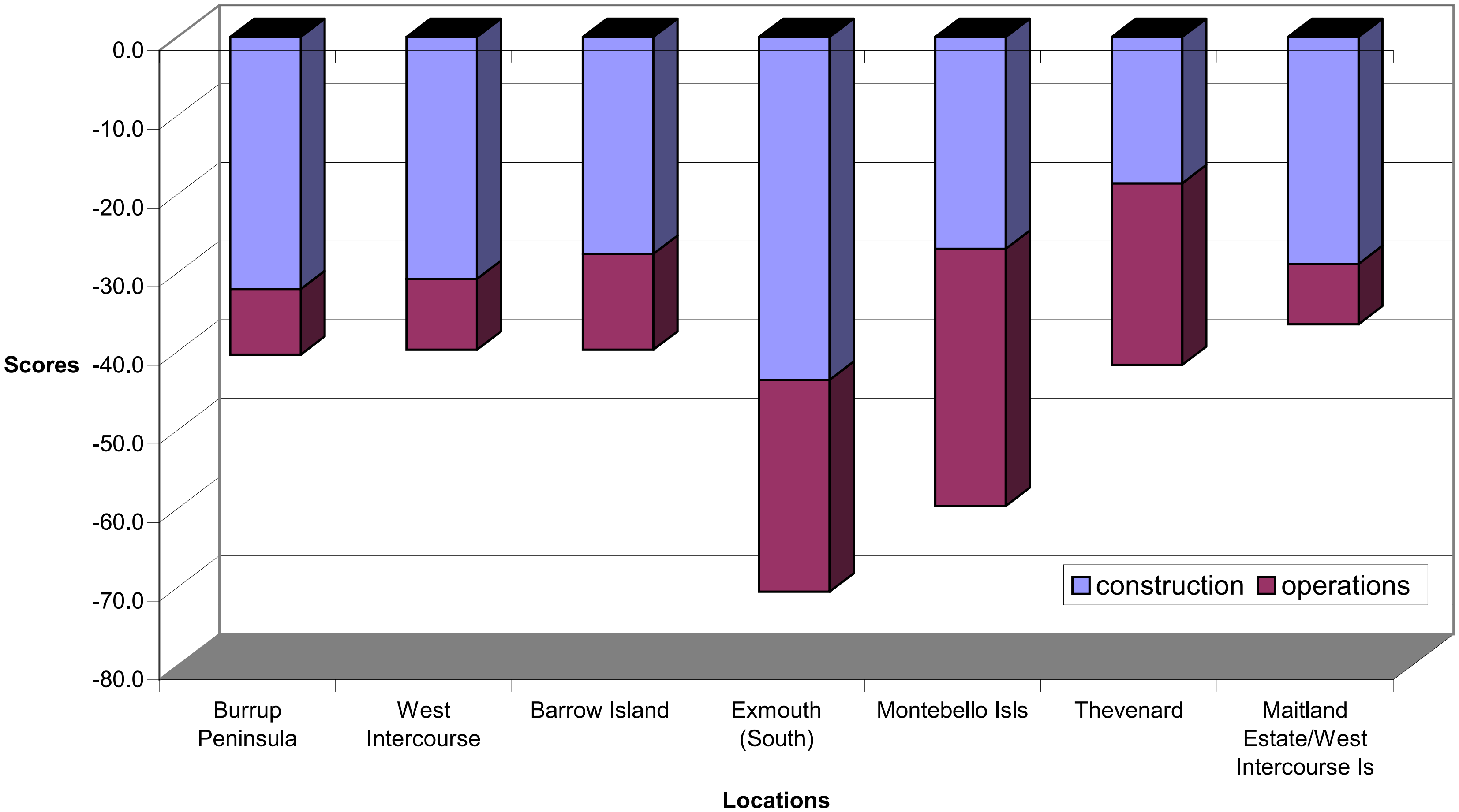
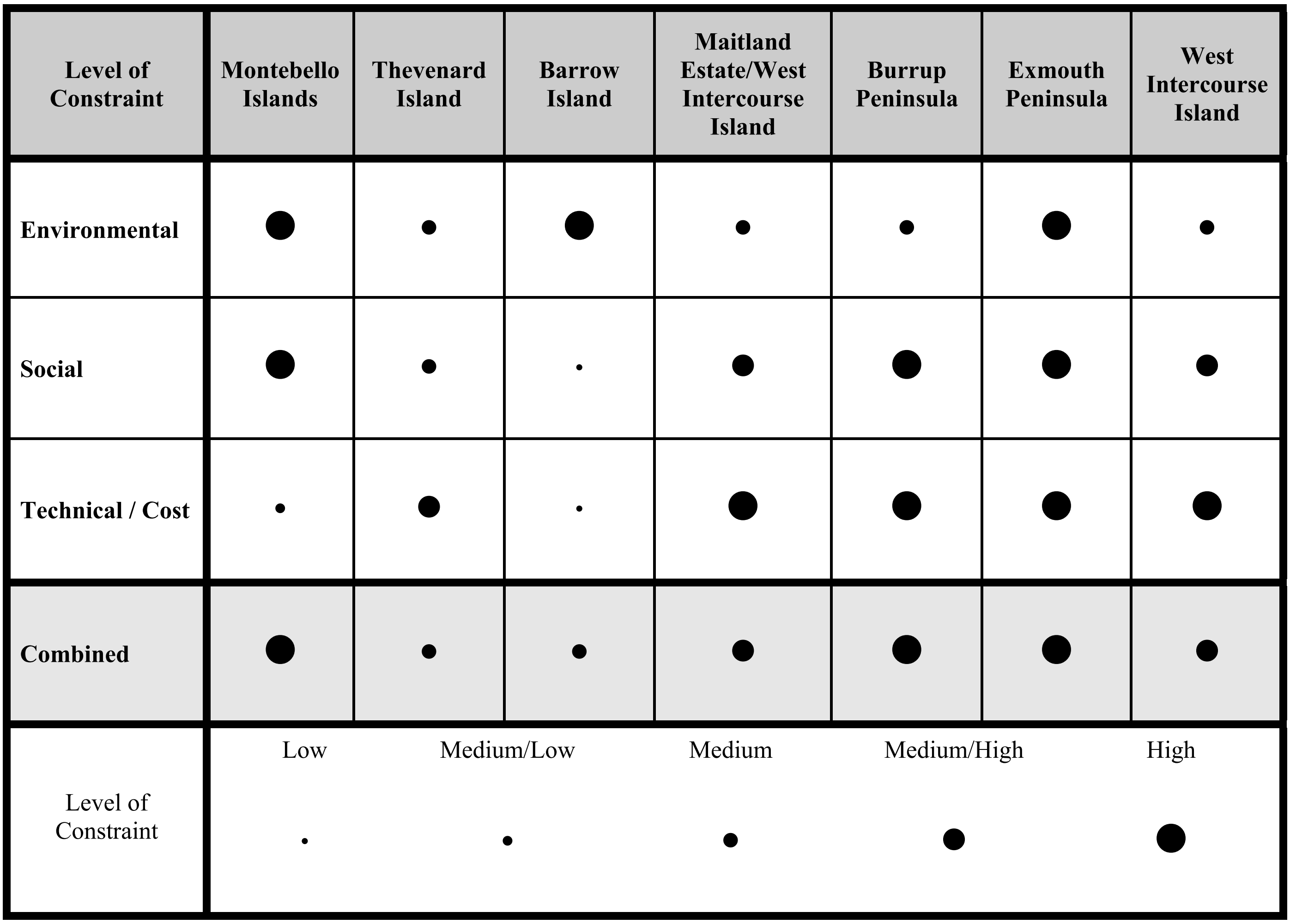


Figure 6.4 Summary of Location Comparison



7. REGIONAL PLANNING REVIEW

7.1 INTRODUCTION

The study area lies across the boundary of the Western Australian planning and administrative regions of Gascoyne and Pilbara. The Gascoyne region includes areas generally to the south and west of the Exmouth Gulf (incorporating Exmouth Peninsula). The Pilbara region includes the region generally north and east of the Exmouth Gulf (incorporating Barrow Island, the Montebello Islands, Onslow, Burrup Peninsula, Karratha and Dampier).

It was considered important to review the results of this site selection study in relation to previously determined (or proposed) land use plans. Not only does this accommodate community and government expectations, but it also ensures that existing research (at a more detailed scale) has been employed to check and confirm regional quantitative and qualitative data.

The most significant regional reports incorporated into this review are:

- Exmouth-Learmonth (North West Cape) Structure Plan (WAPC 1998a);
- Karratha Area Development Strategy (WAPC 1998b);
- Pilbara Land Use Strategy (PDC 1997);
- State Planning Strategy (WAPC 1996);
- Pilbara/Gascoyne Islands Ecotourism Management Strategy (Higgins Wood & Associates 1995); and
- Pilbara 21: Final Strategy Report (Pilbara 21 Study Group 1992).

7.2 REGIONAL PLANNING RECOMMENDATIONS

The Pilbara Land Use Strategy (PDC 1997) identifies three primary and three secondary areas for potential industrial development that lie within the study area for the site selection study. These areas are as follows:

Primary	Maitland (near Karratha); West Intercourse Island; and Burrup Peninsula.
Secondary	Barrow Island (for petroleum processing industry); Cape Preston (for iron ore and petroleum processing industries); and Onslow (for salt, petroleum processing and petrochemical industries).

The Karratha Area Development Strategy (WAPC 1998b) also supports the identification of secondary industrial sites in strategic coastal locations if necessary for particular industry needs. However, it is believed that this would be a tertiary preference, of lower preference than the sites listed above.

7.3 MULTIPLE-USE PLANNING

In 1992, the Western Australian State Cabinet endorsed the *Pilbara 21 Final Strategy Report* (Pilbara 21 Study Group 1992), which included as one of its key recommendations that the Pilbara Land Use Strategy (PLUS) be prepared, based on the principle of multiple land use. The PLUS was finalised in 1997 (PDC 1997) and clearly recognised that no development is possible without some degree of impact, but that the challenge is to devise a balance of land uses which represents sensible compromise. Further, it suggested that “wherever possible, the use of land should not be exclusive, but planning and development strategies adopted to facilitate the long-term joint use by multiple users, including conservation” (PDC 1997: p.17). ChevronTexaco’s operations and environmental management on the Class A Reserve at Barrow Island are a clear example of how this multi-use principle can be successfully applied with the petroleum industry and conservation.

The State Planning Strategy (WAPC 1997) recommended the endorsement of the PLUS as the framework for regional development needs for the Pilbara, thereby recognising the benefits of multi-use development strategies. Other regional planning documents also recognise the need to incorporate multiple land use and the principle of ecologically sustainable development (WAPC 1998a,b).

In addition, the report, *Potential Arrangements for Multiple Use Management in the Montebello Islands to Barrow Island Region* [Australian Petroleum Production & Exploration Association Limited (APPEA) 1997], recommended the establishment of a multiple use marine reserve to both protect the conservation values of the region while providing greater certainty for industry. This report has been endorsed by both the Commonwealth and Western Australian Governments. In endorsing the APPEA initiative, the then Commonwealth Minister for the Environment, Senator Robert Hill said that it “has the potential to become an important model for ‘off reserve’ measures in areas where the protection of conservation values can be achieved alongside economic uses such as the petroleum industry” (Joint Media Release by the Federal Minister for the Environment, Western Australian Minister for the Environment and Chairman of the Australian Petroleum, Production and Exploration Association, 11 March 1998).

Thus the compatibility of petroleum industry activities with the conservation values of the region is accepted at the highest level of government.

7.4 COMPARISON OF RESULTS

Comparison of the above regional planning outcomes with the findings of this GPF location selection study indicates substantial agreement between the two sources of information. All of the primary and tertiary development areas were identified in the regional GIS analysis, except Exmouth.

The Onslow area (two areas north of the town) was identified as suitable on environmental, social and logistic grounds, but was discounted on economic considerations, specifically with regard to distance to the 10 m isobath and the subsequent requirement for extensive dredging.

Overall, the current site selection study has shown high general agreement with regional planning documents and strategies. Therefore, no major conflicts with regional planning recommendations are evident in the findings to this point.

7.5 CONCLUSION: WHERE TO FROM HERE?

This report has undertaken an assessment of environmental, social and economic/engineering constraints to GPF development within the North West Shelf coastal region between North West Cape and Burrup Peninsula to identify potential development sites for a GPF plant linked to the Gorgon gas field.

The sites identified compare favourably with sites indicated in available regional planning documents, and many of the sites share similar levels of environmental constraint and overall ESE constraint.

No one site stands out as having the least level of sensitivity or potential community opposition, although Maitland Estate/West Intercourse attains marginally the lowest overall constraint. However, this evaluation has been conducted at a broad level of detail and assuming similar development concepts for each site. In reality, each site will require a different development concept to cater for the differences in nearshore bathymetry, and topography and foundation conditions at each location.

Figure 6.4 summarises the outcome of the overall study process described in this document, and indicates the final judgement reached on the relative level of development constraint for a GPF for the short-listed locations.

In order to select the ultimate site for GPF development, each site will need to be technically assessed for engineering and financial feasibility. Such a task is beyond the scope of this report and rightfully is a task that can be conducted only by ChevronTexaco.

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9. ACKNOWLEDGEMENTS

9.1 STUDY TEAM

The URS Australia study team comprised:

Ian LeProvost	Senior Principal Environment	Project Director
Jim Singleton	Principal Planner	Project Manager
Peter Collins	Associate (Marine Biologist)	
Katrina Burke	Environmental Scientist	
Tonya Carter	Environmental Scientist	
William Blackshaw, Justin Dwyer	Cartographers	GIS and figure production
Jill Regazzo	Project Coordinator	Report editing and production

9.2 CHEVRONTEXACO TECHNICAL TEAM

Ian Binnie
Ian Grose
Russell Lagdon
Mark Watson
Ken Dean
Ian Satchwell (ASIL TASMAN)
Mike Kuzich

9.3 PEER REVIEW PANEL

The following 'Impact Assessment Workshop Team' undertook a comprehensive review of the constraint values assigned in the matrix evaluation. Individuals were selected for their expertise and, in the case of three panel members, the fact that they were not project team members and could provide independent judgments.

Peter Farrell	Independent Environmental Consultant	
Ian Baxter	Principal Marine Environmental Scientist	URS
Ian LeProvost	Senior Principal Environment	URS
Peter Collins	Associate (Marine Biologist)	URS
Jim Singleton	Principal Stratetic Planner	URS
Dr Tony Rouphael	Marine Biologist	URS

Appendix A

Explanation of Cost Basis for Weighting

EXPLANATION OF WEIGHTINGS USED IN ECONOMICS COMPONENT OF REGIONAL CONSTRAINTS ANALYSIS

The economic component of the regional constraints analysis includes a weighting of constraint scores. The regional level economic evaluation assigns a numerical score to grid cells throughout the region based on eight economic criteria. The eight criteria that have been applied are listed within Table 1. Clearly the costs associated with each of these criteria will vary significantly, for example, the costs of pipeline construction are vastly different to the costs associated with dredging a channel for shipping. It is necessary, therefore, that the regional level economic constraints analysis contains a consideration of the relative levels of cost impost associated with each criterion. This has been achieved by applying a weighting factor to the constraint score assigned for each criterion that reflects the approximate cost associated with that criterion.

The method by which the weighting for each criterion has been set can best be illustrated by example. Using the cost to construct a pipeline as the example, the maximum pipeline length is 200 km, the cost impost of which is estimated to be approximately AUD 700 million. The maximum constraint score for the criteria is 10; therefore the ratio of maximum cost (in AUD million) to maximum constraint score is 700:10 which can simplified to 70:1. The weighting applied to each assigned constraint point is the multiple of the Maximum Cost to Maximum Score ratio, which in this example is 70.

The ratio of estimated maximum cost to maximum constraint score for all eight economic criteria and the weightings used are listed in Table 1 below.

Table 1 Determination of Weightings Applied to Economic Criteria in Regional Site Selection Model

Criteria	Approximate Maximum Cost (AUD million)	Maximum Constraint Factor	Maximum Cost to Maximum Score Ratio	Weighting Applied per Point
Proximity to Gorgon gas field	700	10	70:1	70
Proximity to existing infrastructure	45	10	4.5: 1	4.5
Slope	10	10	1: 1	1
Elevation*	N/A	N/A	N/A	N/A
Sheltered water*	N/A	N/A	N/A	N/A
Pipeline crossing	2	2	1:1	1
Proximity to deep water	120	10	12:1	12
Proximity to Coastline	120	10	12:1	12

* These criteria are exclusion criteria, that is if the requirements for elevation above 5 m AHD and sheltered water cannot be met then the area is excluded from further consideration.

Appendix B

Environmental and Social Characteristics of Potential Development Sites

ENVIRONMENTAL AND SOCIAL CHARACTERISTICS OF POTENTIAL DEVELOPMENT SITES

INTRODUCTION

A broad physical and biological description of the potential development sites is provided below.

The coastal Pilbara region has a subtropical arid climate characterised by extremes in temperature, high evaporation rates, and unpredictable, often torrential rainfall. Rainfall is mostly associated with tropical cyclones occurring in mid to late summer, although the region does receive some winter rainfall. Tropical cyclones occur between November and April, developing to the north and track down the coast. An analysis of the occurrence of tropical cyclones passing within 150 km of the Cape Preston area undertaken by WNI Science and Engineering (1996) indicated that up to four cyclones typically occur per year.

Mean daily temperatures in summer are usually above 30^{o}C and often exceed 40^{o}C. The winds are typically westerly and temperatures moderated in the afternoon by the sea breeze. The mean daily temperatures are moderated in the winter months, which are dominated by easterly and north-easterly winds.

A summary of descriptions of the main locations within which sites are identified, based on a literature review of published and unpublished research documents, is provided below. Prior to each description, an overview of environmental conditions is provided to assist readers unfamiliar with the North West of Western Australia (Pilbara coast and offshore islands).

Burrup Holden Point

The geology of the Burrup Peninsula is dominated by an intrusive Proterozoic outcrop called the Gidley Granophyre. A differentiated, coarse-grained gabbro forms the base of the intrusion. Dykes of dense, blue grey to medium fine dolerite exist on the Burrup. There are recent surface veneers of Pleistocene silty sands, these occur around the bays, coves and low-lying central neck of the peninsula. Mud and silt has been deposited within the intertidal zone (Geological Survey of Western Australia 1980).

The topography of the Burrup Peninsula is rugged, with large areas of steep, bare-rock piles devoid of vegetation except in isolated entrapped soil pockets. There are four major types of topographic units on the Burrup. These are scree slope terrain (58%), undulating terrain (18%), low coastal terrain (14%) and disturbed land areas (10%). The Burrup reaches a maximum elevation of 120 m.

The flora in the Burrup Peninsula region is within the Fortescue Botanical District, which is part of the biogeographical region known as the Eremaean Botanical Province. The vegetation of this area is extremely varied, and rich in diversity and the number of species present. The vegetation of the botanical province is predominantly open grassy plains or mixed grass and spinifex with shrub steppe occurring further inland on the granite plains. A total of 393 species of vascular plants have been recorded on the Burrup Peninsula representing 67 families and 184 genera. Two species are listed as Priority 4 on the Department of Conservation and Land Management. Also, 33 plants have not been identified past generic level and eight have questionable taxonomic status.

The area is uniquely rich in vertebrate fauna including 20 mammal, 47 reptile, two amphibian and 121 bird species. In addition to the mammal species recorded, the mounds of the Pebble Mound Mouse (*Pseudomys chapmani*) were located. This species was thought to be locally extinct.

Marine fauna of the area has been recorded. Vertebrates recorded include dugong, whales, dolphins, turtles and seasnakes. The Dugong, Blue Whale, Humpback Whale, Loggerhead, Green and Hawksbill turtles are protected under the *Wildlife Conservation Act (WA) 1959* and the

Commonwealth Endangered Species Protection Act 1992. Of the fish in the area, none are local endemic species. A wide range of invertebrates occur, including molluscs, crustaceans, echinoderms, worms, corals, sponges and ascidians. No invertebrates are of local endemic distribution.

The peninsula contains an extremely rich diversity of Aboriginal rock engravings and archaeological sites. It also includes areas that are culturally significant to Aboriginal people who claim a traditional association with the area. Approximately 30% of the land area of the Burrup Peninsula has been surveyed for archaeological sites. The surveys have identified and recorded Aboriginal sites of outstanding scientific significance. A total of eight heritage places were listed on the Register of the National Estate. These sites are protected under the *Aboriginal Heritage Act 1972*.

The Burrup Peninsula has been inhabited by people for approximately the last 7,000 years, with the impact on the environment being minor. In the 1970s, with the development of natural resources, towns were built and ports were constructed. Mineral exports such as iron ore, petroleum, salt, gold and manganese make the Pilbara one of the richest mineral areas of the world. The area is a significant industrial and port site, due to its nearness to natural resources and its excellent port facilities. A wide range of recreation activities exist in the area, most of which are based along the coast. Tourism is increasing on the peninsula due to the unique environment and Aboriginal rock art that exists.

The Burrup Peninsula contains areas of significant conservation value, which were identified as requiring management in the *Burrup Peninsula Land Use and Management Strategy*. Through this process, 62% of the peninsula was allocated for conservation, heritage and recreation purposes. The proposed Dampier Archipelago Marine Park is also of conservation value.

The Burrup Peninsula is located within the Shire of Roebourne which has a population of 15 974 (The Australian Bureau of Statistics 2001 Basic Community Profile and Snapshot population data). Development on the peninsula is most pertinent to the townships of Karratha and Dampier as they are the nearest population centres to the area. Due to possible future industrial developments in the region, the population of the Shire is expected to increase significantly.

Maitland

The Maitland area as described by Appleyard (1993) is underlain by a thin veneer of superficial sediments of Quaternary age, overlying weathered Archaean granite. A white sandy clay, derived from weathering of the granite, is thought to lie between the granite and the Quaternary sediments. Fresh Achaean age granite outcrops occur in several small areas on the site, and form as a low permeability basement.

The Maitland site is located on the silty sand coastal plain. The site is typified by low relief, rising from close to sea level in the north of the site, to a maximum elevation of 20 m AHD. The coastal plain is dissected by a series of alluvial channels, predominantly flowing north-west.

The Maitland River is the main alluvial channel to dissect the area. Minor ephemeral surface water channels are also present in the area and mostly run north-west.

The direction of groundwater flow in the area is to the north and north-west towards the ocean and the Maitland River, however this flow pattern may reverse when the Maitland River floods. The depth to groundwater is expected to exceed 2 m, except in alluvial sediments and creeks where groundwater may occur at shallower depths. The quality of the groundwater is variable between fresh and saline.

The Maitland area lies in the Fortescue Botanical District of the Pilbara Region, which forms a part of the Eremaean Botanical Province. However, portions of the area exhibit characteristics of the Northern Botanical District. Species composition for the mainland industrial site is dominated by the families of Poaceae (grasses), Mimosaceae (shrubs and trees of *Acacia* sp) and Papilionaceae (peas and low shrubs) (E M Matiske and Associates 1994).

Five vascular plant species classified on the “Declared Rare and Priority Flora List” and three Priority Three Species are known to occur in the region.

A survey conducted by Mattiske Consulting Pty Ltd (1994) recorded 24 bird species; with intense seasonal surveys, a further 166 species would be expected to occur, including a number of wading and waterbirds. Three mammal species were recorded and a further 31 would be expected to occur, including three introduced species. Ten species of reptile and frog were recorded and a further 116 would be expected to occur in the area.

The nearest centres which would be affected by any development activity (Karratha and Dampier) are located in the Shire of Roebourne. The population of the Shire of Roebourne at the 2001 census was 15 974 (Australian Bureau of Statistics 2002).

The majority of the town workforce is employed in the resources industry, including Hamersley Iron, Dampier Salt and the Woodside Offshore Petroleum Ltd North West Shelf Gas Project, and support industries, commercial and administrative services.

Archaeological sites have been recorded in the area. A survey conducted by McDonald, Hales and Associates (1994), recorded artefact scatters, middens-artefact scatters, quarries, a ‘tree’, stone arrangements, and engravings. Consultations with Aboriginal people in the area revealed that there may not be any ethnographic sites (Woodward-Clyde 1994). A review of literature undertaken by Woodward-Clyde (1994) concluded that there is little evidence of European heritage in the Maitland area. European heritage in the regions mainly related to early exploration activities and the pearling industry. It is understood that Walter Padbury settled in the area in 1863. Three pastoral leases were granted in 1918 and the land was subsequently utilised by Karratha Station for sheep grazing [Pilbara 21 Steering Committee (1992) cited by Woodward-Clyde (1994)].

West Intercourse Island

West Intercourse Island is vacant Crown Land (2 300 ha), which was set aside by Cabinet in 1978 for future industrial or mining use. The island is administered by the Department of Land Administration (DOLA).

West Intercourse Island is a boulder and rock landform, comprising three main landmasses, separated by intertidal mudflats. The island rises from sea level to an elevation of over 60 m AHD in the south-east. Jointed Archaean granite and gneissic granite, and Proterozoic gabbro and granophyre outcrop occur over most of the West Intercourse Island (Geological Survey of Western Australia 1980). All of these Precambian rock are cut by Proterozoic dolerite. A thin veneer of Holocene sediments, likely to be less than 5 m in thickness, overlies the igneous rocks on the western part of the island (Geological Survey of Western Australia 1980).

A number of small, ephemeral streams drain the elevated areas of West Intercourse Island following heavy rain. A tidal channel less than 1 km in length dissects the tidal flats in the western part of the island, separating the three main landmasses of the islands.

The plant communities identified at West Intercourse Island during April 1994 and August 1994 surveys (E.M. Mattiske and Associates 1994; Mattiske Consulting 1994) included hummock grasslands and tussock grasslands with scattered shrubs and trees, tussock grasslands with seasonal ephemerals, coastal mudflats of chenopods and grasses, and sandy coastal plain of hummock grassland, primary rock outcrops with hummock grasslands, secondary rock slopes with emergent shrubs, sandy dunes with *Acacia* sp., mangroves on coastal mudflats and narrow drainage lines with valleys of *Eucalyptus* sp. A total of 310 species of flora have been recorded from sections of the Burrup Peninsula (Woodside Petroleum Development Pty Ltd 1979). The majority of these were angiosperms (flowering plants). The rocky slopes and hilltops of West Intercourse Island are vegetated by *Triodia pungens*, *Triodia wiseana* with emergent shrubs of

Ficus platypoda, *Grevillea pyramidalis*, *Hakea suberea*, *Acacia coriacea*, *Bracychiton acuuminatus* and *Acacaia ampliceps.*

Mangrove assemblages of the Dampier Archipelago (West Intercourse Island) system include muddy tidal flat, spit/chenier, tidal creek bank assemblages, simple rocky shore assemblages, mid-tidal alluvial fan assemblages and high-tidal alluvial fan assemblages.

Twelve species of native mammal, including species of marsupial and five species of rodent and four species of bat have been recorded in the islands in the Dampier Archipelago. Forty-one species of terrestrial reptile are known in the Dampier Archipelego. Four species of marine turtle use the beaches of the archipelago for resting during the summer months. Introduced species,(such as cats, mice, foxes and rats), are known to occur on West Intercourse Island.

The main intertidal habitats present within the West Intercourse Islands include mangals, sand and mudflats, rocky shores, sandy beaches and reef flats. Mangals in the vicinity of West Intercourse Island are backed by mudflats and fronted by sandy intertidal flats. These habitats support populations of crabs, molluscs, shorebirds, wading birds, and fish and stingrays when covered by water.

The mudflats are usually inundated only on spring high tides, and are characterised by a high salinity. Due to the high salinity, the mudflats do not support mangroves, but mats of blue-green algae.

The marine environment of the Dampier Archipelago has been impacted by commercial and recreational fishing, recreational activities, industry and shipping activities.

As with Maitland, the nearest centres which would be affected by any development activity are Karratha and Dampier.

Ethnographic and archaeological studies on West Intercourse Island have been limited (Woodward-Clyde 1994), however it is understood that engravings are present on the island which are of ethnographic significance. Two extensive mound midden complexes have been found on the island, which are considered to have great archaeological significance. A review of literature undertaken by Woodward-Clyde (1994) concluded that there is little evidence of European heritage on the island.

Montebello Islands

A detailed description of the Montebello Islands is provided by the Australian Petroleum Production & Exploration Association Limited (APPEA 1997) from which the following summary has been obtained. The Montebello Islands are a Class A reserve created in 1992, vested in the Conservation Commission (previously National Parks and Nature Conservation Authority) and administered by CALM. Proposals exist for reservation of the surrounding waters.

The Montebello Islands are a group of some 265 islands, smaller islets and rocky stacks situated on a broad sublittoral limestone platform. The islands in the main are low lying, comprised of Pleistocene limestone with a variable thickness of overlying sand. The majority of the smaller islets and stacks are rocky with negligible sand (and hence vegetation) cover, while North West and Trimouille have a substantial sand cover which in places forms high dunes with elevations up to 40 m.

The vegetation is largely comprised of spinifex and low shrubs on the sandier parts of the islands and herbs in sand pockets of the rocky islands and islets. Mangroves occur in a number of the small bays, with a more extensive and diverse population found in the sheltered lagoon within Hermite Island.

Two species of marsupial, the Spectacled Hare Wallaby and Golden Bandicoot, are known to have inhabited the Montebello Islands until early in the twentieth century, when they became extinct, possibly as a result of predation. Feral animals, notably cats and rats have been present on some of the islands, but an ongoing programme of eradication has been undertaken and there are plans to re-introduce native mammals to the islands.

More than 20 species of seabird breed on the islands, including North West and Trimouille where Wedge-tailed shearwater colonies are present.

Macroalgae and seagasses occur in the shallows surrounding the islands. Corals are found throughout the area, with the greatest development occurring to the west of the island chain where a fringing reef occurs.

Highly varied fish and marine mollusc communities have been identified in the diverse habitats found within and around the island group. Turtles and dugong are observed in the shallow waters surrounding the islands, while Green and Hawksbill turtles use most of the sandy beaches for nesting. The western humpback whale northward and southward migration route lies immediately to the north and west of the island group.

The site of the historic shipwreck *Tryal* lies to the north of North West Islands.

A pearling lease was held over the waters surrounding the islands between 1903 and 1913. The island chain came to public notice in the 1950s when it was the site of nuclear weapons tests. In 1966 an oil exploration well was drilled on Trimouille Island. Currently, there is a large cultured pearl aquaculture industry based around the protected waters found within the island group. Mainland-based fishermen also use the waters for recreational and commercial fishing, while diving charters are becoming more common.

Only two of the islands, Hermite (970 ha) and Trimouille (450 ha), meet the 300 ha land area requirement for a gas processing facility, however, the convoluted shape of Hermite is such that it is unlikely to provide a sufficient consolidated area for practical planning and establishment of a GPF.

Barrow Island

Both the marine and terrestrial components of the physical and biological environments of Barrow Island are of high conservation value. In particular, the terrestrial environment is an important refuge for rare species of wildlife, some of which are endemic to the island, or extinct or near extinct on the mainland. For this reason, Barrow Island was declared as a Class A reserve for the protection of flora and fauna in 1910.

There are 14 known terrestrial native mammal species on Barrow Island, of which five species are considered endangered due to their localised island population and restricted distribution. Endangered fauna species include the Burrowing Bettong (*Bettongia lesueur*), the Rock Wallaby (*Petrogale lateralis lateralis)*, the Spectacled Hare Wallaby (*Largorchestes conspicullatus conspicullatus*), the Golden Bandicoot (*Isoodon auratus*) and the Barrow Island Euro (*Macropus robustus isabellinus)*.

Unlike the fauna of Barrow Island, the vegetation of Barrow Island is generally well-represented on the mainland, being dominated by *Triodia* hummock grasslands common to much of the Pilbara. Much of the island's vegetation is also similar to that occurring on the North West Cape. The conservation value of the island's flora relates to its critical role in providing food and shelter to its fauna. In addition, there are 28 restricted or significant plant species on the island.

In recent years, the discovery of Troglobitic organisms inhabiting the limestone caves of Barrow Island has lead to these environments also being identified as an endangered community. At this stage, many features of these communities, including their composition and distribution, remain unknown.

The marine environment of Barrow Island is largely influenced by the tidal patterns common to much of northern Australia, with exposure of large sections of reef a daily occurrence. The island is located within the migratory zones of both cetacean species and turtles. In addition, turtles use the island's western beaches for breeding and nesting on a seasonal basis. Dugongs graze on the seagrass meadows that occur widely throughout the eastern waters of Barrow Island.

Oil has been produced for over 30 years on Barrow Island, which has lead to the modification of natural landforms, clearing of vegetation and placement of infrastructure in parts of the island. Producing oil wells are located over almost half of the island. Infrastructure present includes many hundreds of kilometres of gravel roads, Lufkin wells, separator stations, water injection wells, workshop and storage areas, administration and accommodation buildings and the terminal tanks that are located on the eastern side of the island. The vast majority of aggregate and sand used for construction of oil production facilities has been sourced from the island which has lead to disturbance for the purpose of gravel and sand pits.

Prior to the commencement of oil production, Barrow Island had never experienced permanent resident populations of either Aboriginal or European origin, however there are some areas that contain some archaeological material.

Human activity on Barrow Island is limited to that related to oil production or to maintenance of, and research within, the nature reserve. There is a strong awareness of the island's natural attributes amongst oil company personnel, many of whom have worked there for some years, and consequently a strong sense of stewardship amongst workers. Fishing, swimming, surfing and other recreational activities are commonly pursued by workers on the island.

The Barrow Island airport located in the south-eastern part of the island services not only Barrow Island-based activities, but also numerous offshore oil and gas platforms and smaller islands in the region.

Thevenard Island

The major part (western three-quarters) of Thevenard Island is a Class C (No. 33174) reserve administered by CALM. The remainder is the processing facility for the Saladin and adjacent oil fields and the Mackerel Islands Resort. An airstrip, which services the oil industry and the resort, is located toward the eastern end of the island.

Thevenard is a sand island approximately 5 km in length and 1 km wide, situated on an intertidal/shallow subtidal limestone platform. The island has a subtropical arid climate, characterised by high summer temperatures, moderate winter temperatures, low and variable rainfall and high evaporation. Tropical cyclone activity occurs between November and March. There is no permanent surface water or water courses present on the island, and freshwater occurs as a thin groundwater lens overlying saline water.

The vegetation is largely comprised of open shrubland dominated by *Acacia coriacea* with *Rhagodia preissii, Threlkeldia diffusa* and *Sarcostemma australe*, found within the central portions, and with a narrow fringe of mixed *Spinifex longifolius* grassland occurring immediately above the beachline.

One native mammal, Forrest's mouse, *Pseudomys forresti*, occurs on the island. One feral animal species, the domestic mouse *Mus musculus,* is also present on the island, but an ongoing programme of management is in place to control its numbers. Domestic cats have also been recorded on the island in the recent past. A number of land and sea birds occur on the island, some of which breed there. These species are common on the mainland and none is rare or endangered.

Corals occur on the intertidal/subtidal platform and around its outer fringe. Macroalgae and seagrasses are also common on the shallow platform.

Turtles and dugong are observed in the shallow waters surrounding the island, while the sandy beaches are used by turtles for nesting.

In addition to the oil processing and storage facilities and resort development previously described, the waters surrounding the island are also used for recreational and commercial fishing by Onslow-based fishermen, while diving is also a popular pastime.

Exmouth South

The geology of the North West Cape is dominated by Tertiary sediments comprising the northern part of the Canarvon Basin geological province. The region is a depositional environment reflecting the geomorphology of the coastal region and is dominated by karst features characteristic of limestone and carbonate environments.

Cape Range reaches a maximum elevation of 300 m. The uplifting of the range also produced alluvial fans which cover a large portion of the coastal plain. The depositional environments of recent sediments vary from sandy beach dune to the north of the peninsula to the flat tidal mangal development in the southern and eastern parts of the Exmouth gulf.

The flora in the Cape Range area is species-rich and contains both tropical and temperate floras that are largely confined to the Cape Range Peninsula. The peninsula is situated in the Carnarvon basin area, falling into the Eremaean Botanical Province, dominated by an arid, perennial shrub association. The vegetation complexes south of Shothole Canyon have been degraded through grazing.

The area is uniquely rich in vertebrate fauna including 30 mammal, 84 reptile, five amphibian and 200 bird species. Fauna species found in the area such as the Black Footed Wallaby (*Petrogale lateralis*) and the Night Parrot (*Pezoporus occidentalis*) are considered to be rare and under threat. Underground limestone karst environments are habitats for a great diversity of subterranean aquatic animals called stygofauna, many species of which are found only in the Cape Range peninsula.

The Ningaloo Marine Park is located on the west coast of the North West Cape and covers an area of 43 000 km^2. The North West Cape accommodates a number of land uses including conservation, commercial, residential, Commonwealth (including Defence land), industrial, recreation and tourism, and pastoral. Major industries include oil and gas, energy generation, fishing and tourism. The Cape Range National Park is also located on the western side of the North West Cape and encompasses 50 581 ha. It is a Class A reserve vested in the Conservation Commission.

The Western Australian Museum has evidence of Aboriginal occupation of the North West Cape dating back at least 25 000 years continuously to about 400 years ago. There are 110 known registered Aboriginal sites on the North West Cape, which are protected under Western Australian legislation. Other sites have historic significance for European settlement of the area.

The Exmouth town site is one of the largest settlements in the Gascoyne region. The population at the 2001 census was 4 267, with 175 overseas visitors (ABS 2002). The main employers in Exmouth are local small businesses and business directly associated with tourism. Sectors of the North West Cape economy with economic growth potential include horticultural and pastoral, aquaculture, export industries (such as prawning and pearling), mining and extractive industries, and tourism. In conclusion, and most importantly, the Exmouth Peninsula is promoted strongly as a tourism and conservation orientated land zone in the Western Australian State Planning Strategy.

Appendix C

Site Comparison : Matrix Evaluation

SITE COMPARISON: MATRIX EVALUATION

METHODOLOGY

The short-listed locations identified through the location selection procedure (Sections 3 and 4) were compared using a multi-criteria matrix evaluation technique. The methodology considered the potential environmental and socio-economic impacts during both the construction and operation stages of the GPF development. The assessment did not directly consider commercial cost/benefit aspects.

A simple ranking system, ranging from +2 (major positive) to -2 (major negative) with increments of 0.5 was used to evaluate each criterion within the matrix. Scores for each criterion were summed to produce an overall ranking for each site. These scores were then normalised (as a percentage of the total score possible for each site) to allow comparison.

The assignment of numerical values to a subjective assessment of environmental effect is a recognised and accepted planning process. It is important to point out that this is not a quantitative or scientific technique. Rather, it is qualitative and subjective, providing transparent judgments of various ‘value’ estimates. The end point of the process is a set of ranking that provides an indicative comparison between sites. Scoring of each criterion was done individually through a “Delphi” procedure which included reference to available literature, professional judgment and consensus of the consultant team working on the project.

Criteria were divided into two categories:

- physical/chemical/biological; and
- socio-economic.

The detailed criteria included under these two broad categories were selected on the basis that they were both relevant, and capable of being judged in a subjective manner by a team of professionals with expertise in the various subjects. There is no pretence to argue the criteria as exhaustive - merely that those selected are sufficiently broad in scope and representative so that a reasonable comparison between the locations could be achieved.

PHYSICAL/CHEMICAL/BIOLOGICAL

Pollution

For the purpose of the two evaluations, pollution is defined as including:

- air pollution (gaseous emissions, dust and particulates), odour or noise;
- illumination; and
- effluent or other liquid/solid discharges.

<u>Scoring</u>: While it is accepted that GPF are relatively ‘clean’, some minor pollution can be expected during both the construction and operation stages. Pollution impacts of concern are those that affect nearby land users (and workforce), settlements, or animal behaviour (e.g. illumination of beaches affecting turtle reproduction success).

The construction phase would result in minor negative impacts (-1) across the three pollution categories at all sites except for air pollution at Exmouth (-2) where dust and noise of construction traffic may be of greater impact on the local community.

During the operations phase, cumulative effects with the existing gas treatment plant on Burrup Peninsula have resulted in a score of –2 for air pollution. Areas where turtles are known to nest on the beaches score –1 for illumination impacts as, although these impacts can be significant on turtle populations, management of illumination can be effectively achieved.

Terrestrial Biological

Terrestrial biology is categorised in the matrix under the values of:

- habitat (two sub-categories : physical vegetation/terrain value and special significance relating to international migratory bird agreements);
- flora (declared, rare and priority flora and mangroves); and
- fauna (rare and priority fauna).

Scoring: The main concern is for the loss of vegetation and habitat, and loss of, or harm to, specific flora and fauna. The construction stage involves an intense period of site modification and therefore results in a higher overall level of negative scores in the matrix. All sites score highly on terrestrial biology, as all are known to support significant flora or fauna species. Once cleared, further impact is minimal on the site during the operations phase. Effects on nearby habitats, fauna or flora are, however, possible during operations.

During operation, Barrow Island is more constrained than the other sites, due to the presence of important fauna known to be in the vicinity of the site, as well as the presence of bird habitats protected under JAMBA and CAMBA treaties. On the other hand, current operations demonstrate clearly that, with good management, potential impacts are greatly reduced and controlled, establishing that the operational phase is far less problematic than might otherwise be assumed.

Marine Biological

Marine biology is categorised in the matrix under the categories:

- habitat; and
- notable species.

Habitat includes the marine environment generally extending from the shoreline, through the nearshore intertidal zone and the offshore subtidal zone into deeper water. This incorporates all habitats that could be potentially affected by marine traffic or by development of marine structures.

The most significant concern is the loss of productive habitats which either have limited extent or which provide a significant food or shelter resource for other species (eg. coral reefs, seagrass meadows and limestone platforms).

Notable species of fauna include whale, dugong and turtle, locally prevalent species of which are protected under the *Environment Protection and Biodiversity Conservation Act 1999* or the WA *Wildlife Conservation Act 1950*.

Scoring: It was considered that the construction stage would be more destructive than the operation stage, particularly for those sites with major dredging requirements (Burrup Peninsula, Montebello Islands, West Intercourse Island and Maitland). While the operation stage has reduced impact, maintenance dredging and ship movements will cause some disruption to remaining habitats, flora and fauna.

SOCIO-ECONOMIC CRITERIA

Urban

Impacts upon amenity, lifestyle/social dynamics, capacity (housing, infrastructure, services, facilities) and increased levels of general disruption were considered relevant to nearby settlements. Differences between the settlements concerned was taken into account: for example, Karratha and Dampier as towns established in relatively close proximity to rapidly expanding industry, and Exmouth as a ‘tourism’ orientated town. The definitions of each ‘urban’ criteria and the scoring rationale is provided below.

Aesthetics/landscape or Seascape

This refers to the visual quality of the various locations, and is dependent on the measurable features of the landscape/seascape. These include the visual qualities derived from topography or terrain, variation in features (e.g. sea and land, hills, ridges and flats, etc.), vegetation cover (type, texture and density) and special features (e.g. islands, cliffs, beaches, coral reef platforms, shorelines, etc.). The various locations under consideration have varying degrees of intrinsic landscape or aesthetic quality, ranging from very high (e.g. Montebellos and Burrup) to relatively low (e.g. Exmouth South). The matrix therefore sought to place a value of the impact of a GPF on the various sites/locations.

<u>Scoring</u>: For all sites except the Montebellos and Thevenard Island, the construction impacts were considered to score higher than, or equal to, operational impacts. The latter two gained high scores for the operational due to the impact on ongoing tourism (fishing, yachting) and their popularity as sailing/boating destinations. Exmouth scored the highest, partly due to the tourist visitor expectation of a major tourism destination area.

Amenity

Amenity is defined as ‘pleasantness’ of a place and, in land planning terms, is initially based on the physical (the basic physical elements of the landscape), visual (what can be seen) and aesthetic (human judgment employing notions of beauty or attractiveness) characteristics of the environment, combined with familiarity of those surroundings and a ‘sense of place’. In total, amenity is a community’s ‘comfort’ and ‘fondness’ for the place in which they live, part of which is derived from the ‘consistency’ and ‘reliability’ of those surroundings. Amenity may not be apparent to outsiders and a location does not have to be visually attractive to have amenity.

<u>Scoring</u>: Introduction of large-scale construction activities in or near a settlement would be expected to impact amenity in many different ways: the increase in heavy vehicle movements, dust, parked vehicles, more cars, together with the possible establishment of storage depots, transportable premises, new building sites and general change in the surroundings. In the matrix evaluation, such changes were rated as ‘negative’ for the construction phase in the context of all settlements and as a ‘major negative’ for Exmouth, which is a small tourism settlement and has no major industrial activity nearby. A ‘lesser’ impact was allocated during the operation stage for all sites, except Exmouth, Montebello Islands and Thevenard Island.

Social/lifestyle

Social or lifestyle is defined as the structure and social dynamics of a community and the quality of life resultant upon the cohesion of the community, including its familiar ways of doing things (i.e. culture).

<u>Scoring</u>: Community structure, social dynamics and lifestyle of small communities can be severely impacted by the introduction of large numbers of outsiders, particularly itinerants comprised significantly of ‘single’ persons. In the matrix evaluation, Burrup Peninsula and West Intercourse sites scored ‘minor negatives’ for the construction stage, due to the prior existence of industrial land use in the vicinity of the settlements and familiarity with change and itinerant workers. Exmouth would be severely impacted by an influx of itinerants for the construction stage.

During the operation stage, a much smaller workforce would live in or near the affected settlements, thereby becoming part of the community and supposedly adding to it. Positive scores are therefore given.

Capacity

Capacity is defined as the capacity of the facilities, services and infrastructure of a settlement to accommodate extra population. This criterion particularly refers to housing but also includes infrastructure such as water supply, effluent and waste disposal.

Scoring: Major negative scores are given for all sites except Barrow Island, Montebello Islands and Thevenard Island during the construction phase, on the assumption that most, if not all, of the construction workforce would be accommodated in or near the available settlements which would place pressure on existing accommodation, rentals and general services. Minor positive scores are given to West Intercourse Island and Exmouth for the operation stage due to an expected expansion of capacity to subsequently meet the level of demand for various facilities, services and infrastructure.

Proximity

Proximity is defined as the relative position of a settlement to the identified site. This is essentially concerned with minor trip distance (30 minutes or less) for convenience of access to essential town facilities (e.g. banks, health care, police, shops and accommodation) yet sufficient distance separation to avoid land use conflict and other impacts.

Scoring: The Burrup Peninsula, Exmouth, Maitland and West Intercourse Island sites are in close proximity to nearby settlements and score 'minor positive'. Barrow Island, Montebello Islands and Thevenard Island score 'major negatives', although for different reasons. It should be noted that the Barrow Island site has good proximity to the WAPET facility where a number of essential and non-essential 'support' facilities do exist and could be made available.

Disruption

Disruption is defined as the general level of functional inconvenience caused by the proposed development. It refers to the outcome of extra activities occurring in a settlement that cause the local community to adapt and change against their choice. This may include such things as extra supervision of children due to higher traffic volumes on local roads, changing shopping or banking habits due to peak demand periods and inconvenience in various other aspects of life.

Scoring: A 'minor negative' score was given to the Burrup Peninsula, West Intercourse Island and Exmouth sites during the construction stage only. Disruption was not considered to be a problem for the Barrow Island site and is not anticipated to significantly affect any of the sites during the operation stage. Thevenard, however, has a major negative score due to the impact on existing island tourism activities.

COMMUNITY SERVICES

Community services are always limited in small, isolated settlements, particularly so in the north west of Western Australia. It has been shown with previous, large-scale developments in remote areas of WA that the influx of a large workforce and their families places enormous pressure on existing services. It is very difficult to plan for and accommodate these requirements prior to the development taking place, thus disadvantaging local people until service provisions increase to meet demand. In reality some settlements (such as Karratha) have a greater community service capacity than others (such as Exmouth).

Community services are defined as the range of essential services that any community requires, including education, medical, banking, communications, law enforcement, social services (welfare), emergency services (fire fighting, ambulance), and local government administration and services (waste disposal, health). Essential services are mainly provided by the public sector and expansion of the service capacity is typically not responsive to sudden increases in user demand.

Scoring: For the construction stage all sites except Barrow Island, Montebello Islands and Thevenard Island score ‘major negative’: the influx of up to 2000 workers would easily exceed the capacity of existing community services. Barrow Island, Montebello Islands and Thevenard Island receive a neutral score due to the expectation of either fly-in fly-out to Perth, which has adequate servicing capacity, or fly-in fly-out to a range of Pilbara and Gascoyne settlements, hence spreading the demand for services.

Burrup Peninsula, Exmouth, West Intercourse Island and Maitland were allocated ‘minor positive’ scores during the operation phase due to the anticipated expansion of services to accommodate demand. No impact was anticipated for Montebello Islands, Thevenard or Barrow islands.

LAND AND MARINE USE

This includes criteria for land use and marine use conflicts.

Land Use Conflicts

Potential land use conflict arising from the establishment of resource processing industry plant is a legitimate land use planning concern. They are defined as the outcome (potential or existing) of current or proposed land uses either adjacent or in close proximity that results in danger, inconvenience, inefficiency, obstruction or any other perceived adverse condition. Land use conflict can also be caused by an under-supply of land for particular activities, as well as land use competition itself.

Particular conflict situations in the study area relevant to the GPF development include:

- recreation and tourism activities;
- other industrial development;
- infrastructure; and
- tenure.

Pastoral conflicts were initially considered but subsequently dropped from the matrix when research indicated that it was not a significant issue in the region of interest.

Recreation and tourism activities are defined as those dependent on fixed facilities or natural resources, whether or not involving commercial or non-commercial organisations, and that provide for the diverse leisure pursuits of the local, regional, national or international community.

Other industry is defined as all industry sector activities, including other plant and installations associated with the oil and gas industry.

Infrastructure includes all physical support services to either industry or urban areas and includes pipelines, wires, roads, rail, ports (air and sea), together with their associated ancillary plant and equipment (e.g. pump stations, depots, terminuses, etc.).

Scoring: In general, land use conflicts are anticipated to be more negative before or during the construction stage than during the operation stage. Barrow Island attracts the least negative score due to the relative absence of other activities.

During the operation stage ‘positive impacts’ are indicated for the Burrup Peninsula, West Intercourse Island and Barrow Island sites, due to the availability of various support infrastructure. Exmouth, Montebello Islands and Thevenard Island attract major negative scores owing to a significant conflict with regional recreation and tourism.

Certain documents reviewed indicate that the Burrup Peninsula industrial area is not without land use conflict issues. There are many constraining factors on the Burrup Peninsula and it is profiled in various reports, such as the Pilbara Land Use Strategy (PDC 1997), as an area of increasing land use competition and conflict.

Regional land use conflict issues arise on the Exmouth Peninsula, particularly given the strategic objectives identified in the State Planning Strategy (WAPC 1996) and the Exmouth-Learmonth (North West Cape) Structure Plan (WAPC 1998a).

In the case of Barrow Island, a similar strategic land use conflict may be claimed based on the conservation status of the island. However, for Barrow Island, the following considerations apply:

- Barrow Island (and its surrounds) are already a recognised gas/oil field;
- the oil industry activities are formally accommodated within existing lease arrangements;
- regional planning documents such as the Pilbara Land Use Strategy (PDC 1997) identify it as a potential development site for petroleum processing industry;
- it is recognised as a successful multi-use area (conservation and industry); and
- existing industry environmental management has maintained the quarantine status of the island.

Marine Use Conflicts

Potential marine use conflicts are recognised in association with the proliferation of shipping channels, channel dredging, ship movements in confined areas, recreational fishing, commercial fishing, recreational diving and general boating.

Marine use conflict is defined as the danger, inconvenience, inefficiency, obstruction or other perceived adverse outcome of conducting any activity in the marine environment, as a result of the siting of a GPF. Subcategories of this criterion include shipping channels/navigation, recreation fishing/boating and commercial fishing.

Scoring: Negative values were allocated for the dredging of new channels, taking into account the amount of dredge material involved and distance to dredge spoil disposal sites. Increased ship movements during the operation stage were viewed in the context of raising the risk of accidents and general environmental disturbance, as well as issues of constraint and interference with other marine users. All sites score a negative impact for the construction stage, with Barrow Island the lowest due to the distance from community settlements.

Recreational fishing is widespread in the Pilbara and has a very high rate of overall community participation. A high lifestyle value is placed on recreational fishing, and it is a popular activity in the Dampier Archipelago. Recreational fishing and boating could be affected to some degree by exclusion zones associated with a GPF at all mainland coastal sites. Commercial fishing in the Exmouth Gulf is a relevant factor for the Exmouth site. Barrow and Thevenard islands are accorded the lowest level of conflict for marine activities.

ECONOMIC ACTIVITY

Establishment of a large resource processing plant results in a general level of benefit to the regional economy both in terms of direct capital expenditure with procurement of local goods and services, and also in the form of a multiplier effect derived from employment and local employee domestic expenditure.

Two sub-categories are used in the matrix: expenditure (direct/indirect) and employment.

Economic activity is defined as direct and indirect expenditure in the local/regional economy, and as direct employment. Expenditure (direct and indirect) includes direct purchase of goods and services during either the construction or operation stage, as well as the multiplier effect. The latter includes indirect employment, business growth and subsequent use of disposable incomes in the local economy.

Scoring: All sites would benefit the region in this regard, with Barrow Island, Montebello Islands and Thevenard Island the least, on the assumption of a 'fly-in/fly-out workforce' exclusively to the Perth region. It should be noted, however, that one possible option for Barrow Island, Montebello Islands and Thevenard Island is to arrange fly-in/fly-out accommodation to certain North West towns, ensuring that the economic multiplier effect is retained in the immediate region and, furthermore, spread to various centres. This option could make Barrow Island, Montebello Islands and Thevenard Island the most favourable rather than the least favourable for this criteria.

Employment relates to direct recruitment in the local area for the construction and operation stages of the project.

PERCEPTION

Local Perception

Local perception is defined as the personal and collective feeling of the immediate and regional population toward both the idea of the development and the tangible (observable) presence of the development. Local perception can be important: if there is to be significant opposition, it will very likely arise in the local community.

National Perception

National perception is defined as above, but from the viewpoint of the national population. This sector of the public will generally be poorly informed, and will be influenced by ideology and political positioning.

Scoring: The values indicated are of course subjective, although they take into account the relative position, character and predominant function of the nearest settlements as important factors which influence local perception of the project. The matrix therefore reflects a positive local and national perception of a GPF at Burrup Peninsula, Maitland and West Intercourse Island during the construction stage, indicating the positive attitude to industrial development within a designated industrial area. A negative perception has been allocated for the other sites, with the highest negative score being recorded for Exmouth, principally due to the proximity of the Cape Range National Park and Ningaloo Reef Marine Park. This perception may also apply for Barrow Island, which has both a national and international conservation reputation.

In the case of either local or national/international perception, the construction stage is the most significant and potentially contentious.

TENURE

Tenure is defined as the legal control over land, whether in terms of ownership or other claim. This criterion included the categories of leases/reserves and Native Title. The definition assumes that ownership in fee simple would not normally be a constraining factor. Issues of tenure may not be insurmountable, but can take time to resolve.

Scoring: Tenure in terms of lease arrangements were considered an important issue for the Barrow Island site. All sites except Barrow Island are considered to face significant constraints concerning Native Title, and it is possible that resolution of this tenure issue may extend through to the operation stage, although very recent announcements (January 2003) indicate that final agreements concerning Native Title claims at the Burrup Peninsula may have been achieved..

LINKAGES

Industry Synergy

An important consideration in the location of any industrial plant is the potential for synergies with other operators/industry, allowing significant commercial advantage to be realised. Industry synergy is defined as the potential for added value, downstream processing and mutually beneficial shared use of processing facilities or support infrastructure.

Scoring: In this regard, both Barrow Island and Burrup Peninsula offer potential for industrial synergy and gain major positive scores for the operations phase. Barrow Island also gains a positive score for the construction period due to the strategic advantage of WAPET facilities; an advantage that would not normally be expected for a remote island site.

HERITAGE

Heritage is defined as the existence, or potential existence, of sites of historical or contemporary importance that signify culture or cultural values. Heritage value can involve sites containing structures and artefacts, through to modified or unmodified landscapes. The categories for this criterion are European and Aboriginal heritage. The former generally involves structures or buildings, the latter involves archaeological sites (with or without artefacts) as well as past, recent, or contemporary ethnographic (cultural) sites.

Scoring: All sites are affected, or potentially affected, to varying degrees by Aboriginal heritage issues. Due to considerable archaeological research that has been carried out on Barrow Island, there is relative certainty this is the least affected site. European heritage appears not to be an issue for any sites. All sites except Barrow Island were therefore allocated a major negative score for Aboriginal sites during the construction stage.

HAZARD AND RISK CRITERIA

It was considered important to compare 'accident, hazard and emergency conditions' aspects for each of the sites. In this evaluation, the consequences, not the probability (risk), are considered. These are variously considered in terms of the resultant impact potential on either the marine or terrestrial biological environment, or on the social/human/built environment.

Construction Stage

Accidents or emergencies were defined as the occurrence of mishap, accident or injury as a result of construction activities that would affect local settlements (road accidents due to higher traffic volumes), that would affect industry (fire, transport accident, helicopter/aircraft crash, severed gas pipeline), or that would affect the natural environment (fire, breach of quarantine).

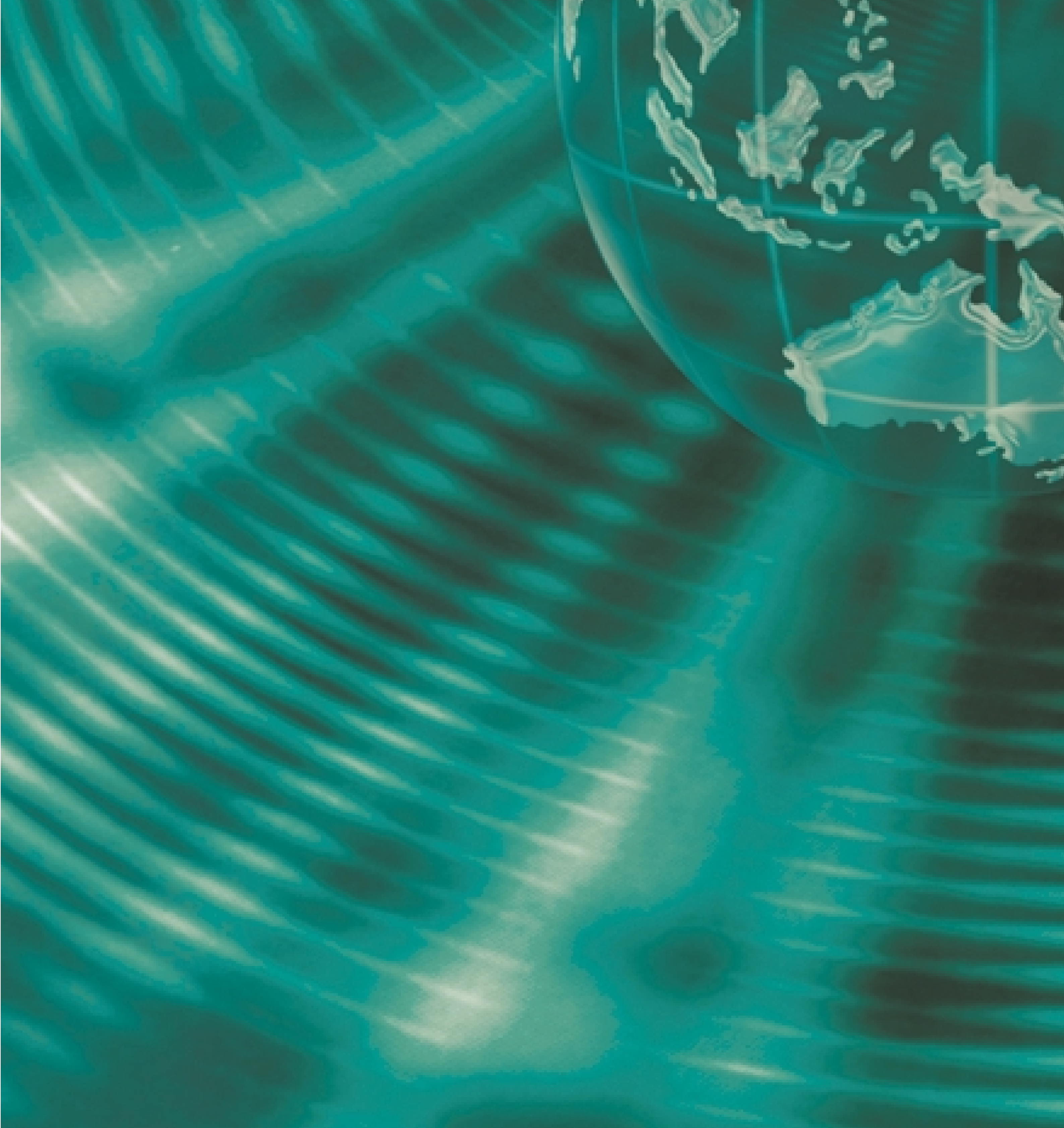
Scoring: For the construction stage assessment of accident and hazard, the Burrup Peninsula and West Intercourse Island sites were allocated highest negative scores due to the proximity of settlements and/or industry. Barrow Island scored a major negative (-2) major impact on the natural environment, while Exmouth has the same overall score due to potential minor impact on both the natural environment and nearby settlement.

Operations Stage

Categories of risk or hazard identified for the operation stage were:

- fire/explosion;
- transport accident;
- spill discharge; and
- breach of quarantine.

Scoring: For the operation stage the highest accident or emergency impact potential is considered to be for the Exmouth site where the proximity of settlement and marine conservation areas (such as Ningaloo Marine Park) implied a higher sensitivity. The Burrup Peninsula, Montebello Islands and Barrow Island sites also scored relatively highly against hazard/risk. In particular, Barrow Island scored highly negative for potential breach of quarantine and subsequent impact on the biological system, whereas the Montebello Islands and Thevenard Island scored minor negative.



APPENDIX D

MARINE AND INTERTIDAL ENVIRONMENTAL SURVEY FOR THE GORGON GAS DEVELOPMENT ON BARROW ISLAND

(BOWMAN BISHAW GORHAM)

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1.0 INTRODUCTION

ChevronTexaco Australia Pty Ltd (ChevronTexaco), on behalf of the Gorgon Venture Participants, proposes to develop a gas processing facility on Barrow Island for the Gorgon gas development. Marine infrastructure for the proposed development would have elements on both the east and west coast of Barrow Island, comprising:

- a gas pipeline from the offshore Gorgon gas field to the west coast of Barrow Island with a shore crossing at Flacourt Bay,
- a materials offloading facility (MOF) and associated barge access channel on the east coast,
- a pile jetty from Town Point to an offshore product offloading (tanker) facility with shipping channel and turning basin,
- a gas pipeline from the east coast to the mainland for exporting domestic gas.

ChevronTexaco engaged Bowman Bishaw Gorham to survey marine benthic and intertidal habitats and assemblages in the area of the proposed development to assist in preliminary assessment of the environmental implications of the proposal. This report describes the results of the surveys and previous surveys in the area in relation to potential impacts associated with the proposed development.

Dredging of the channels to the offshore product offloading facility and MOF would require disposal of the dredged materials to a designated spoil ground. The dredge spoil ground would be sited and assessed within the procedures of a dredging licence application under the *Environment Protection (Sea Dumping) Act 1981* and is not addressed in this report.

2.0 METHODS

The survey comprised a review of the available information describing the marine environment of the area and specific field surveys at the location of proposed infrastructure. Assessment of potential impacts from the Gorgon gas development was based on the results of field observations, general knowledge of the area from previous surveys and literature on the area.

2.1 Field Surveys

Field surveys were undertaken during August 2002 and January 2003 to identify any areas of high conservation significance within the areas of potential impact from the proposed Gorgon gas development. The surveys covered the subtidal, intertidal and immediate supratidal areas on both the east and west coasts at the locations that would be affected by the proposed marine facilities and surrounding areas.

2.1.1 Subtidal Surveys

Subtidal, benthic marine habitats and assemblages were surveyed using a combination of towed underwater videography and snorkel diver surveys.

Video surveys involved towing an underwater video camera behind the survey vessel to assess seabed features along, and in the areas adjacent to, the proposed west coast pipeline corridor and the east coast jetty and shipping areas. Marine biologists assessed the videography as it was captured to characterise the benthic habitats and assemblages. Positional accuracy along the survey routes was monitored using GPS receivers and GIS and navigation software.

Snorkel diver surveys involved marine biologists ‘bounce’ diving to examine and photograph apparent seabed features that were identified in existing aerial photography of the area.

2.1.2 Intertidal Surveys

Benthic habitats and assemblages within the intertidal areas on the west and east coast that are likely to be affected by the proposed development were surveyed at low tide. Marine biologists qualitatively surveyed the intertidal zone habitats and assemblages to facilitate assessment of their conservation significance.

2.2 Habitat Mapping

Preliminary habitat maps for the east and west coast development areas were created from aerial photography (1:40,000) flown in October 2001. Ground-truth data collected during the August 2002 and January 2003 surveys were used to validate specific areas of the maps (Figure 1) and to assist in characterising habitats apparent in other areas from the aerial photography. Mapping of habitats from the aerial photography in areas beyond the ground-truthed survey area also incorporated field data from previous surveys (Bowman Bishaw Gorham, 1996) and an existing regional habitat map (Bancroft and Sheridan, 2000). The habitat map was revised to incorporate the new ground truth data following the January 2003 survey which examined areas of discrepancy between the initial habitat map and the Bancroft and Sheridan (2000) map. These data were also provided to the Department of Conservation and Land Management for revision of their regional marine GIS database.

3.0 REGIONAL MARINE ENVIRONMENT

3.1 Introduction

The Rowley Shelf is a large sedimentary shelf in the West Pilbara, mainly in the geological province known as the Carnarvon Basin. Barrow Island, the Montebello Islands and the Lowendal Islands are the most offshore of the Rowley Shelf islands. These islands are separated from the inner part of the Rowley Shelf by the Flinders Fault and collectively form the Barrow-Montebello Complex (Wilson *et al.*, 1994).

3.2 Intertidal Environment

The wide range of physical and geological conditions on the Rowley Shelf has supported the development of a wide diversity of intertidal habitats. The shallow limestone shelf contains numerous small sand cays and islands, often surrounded by expansive intertidal areas. Habitat zonation is favoured by the moderate tidal range (approximately 3-4 m at Barrow Island), while the diversity of physical conditions (ranging from the energetic western edge of the shelf to the turbid coastal zones) supports a large variety of intertidal communities.

The intertidal habitats on the Rowley Shelf can be broadly separated into six categories:

- Rock platforms
- Upper intertidal notches
- Sandy beaches
- Mangals
- Coral reefs
- Sand flats

These are briefly discussed in the following.

3.2.1 Rock Platforms

Limestone shores typically erode into wave cut benches in the intertidal zone, known as rock platforms or flats. These habitats are well developed around the shores of many of the Rowley Shelf islands, including Barrow Island, and occupy approximately the 1m to 0m above lowest astronomical tidal levels. They may be backed by beach slopes or by notched rocky headlands.

Barrow Island is the largest of the islands in tropical Western Australia and there are distinct differences between the west coast and east coast rock platforms. Rock platforms on the west coast usually have a discrete outer edge that bears the brunt of moderate to high wave action at low tide. Typically, the outer edge is at or very close to the datum (low spring tide) level. Most rock platforms on the east coasts grade imperceptibly into the sublittoral zone and there is no distinct edge and little wave action (except during storm events).

Rock platforms may slope gradually from the upper intertidal level down to low tide level or there may be distinct steps or changes of slope that commonly mark abrupt changes in biota. Rock platforms on the west coast are typically deeply and irregularly guttered along the outer edge. There are also drainage gutters, usually sand filled, in the upper intertidal zone.

The rock pavement may be bare or covered with an algal turf or a veneer of sediment. Most commonly, the outer part of the platform is moderately to densely vegetated with *Sargassum* and other macroalgae. The middle flat usually has more sparse algal growth that is often short, forming a low turf mixed with sediment. The inner flat, which may be affected by brackish seepage from the beach, usually has a silty sand veneer and little macroalgae.

Many invertebrates live on the surface of the rock pavement, among the macroalgal thalli or in the superficial sediment. Some species exhibit trends for horizontal zonation on the reef flat. Generally, the species richness is higher in the lower intertidal zone. For example, corals may be common and diverse in the lower intertidal, but few species live at higher levels. The harsh environmental conditions in intertidal areas generally cause corals to grow as stunted ecomorphs. The large opisthobranch slugs, *Dolobella* sp. and *Aplysia* sp., are typically found in pools at the upper levels of the reef.

Microhabitat diversity and species diversity are higher where there are irregularities in the rock pavement surface such as loose stones, pools, gutters, fissures and ledges. The relatively barren inner flat may support a diverse fauna of cryptic invertebrates if there are loose stones and pools.

Where there are high rocks in the mid to lower intertidal zone, barnacles and molluscs may occur that are otherwise restricted to the upper intertidal zone. For example, the mussel *Brachidontes ustulatus* and the rock oyster *Saccostrea*, which normally live in a band in the upper intertidal zone, occur on high rocks in the mid to lower intertidal zones.

Beach sand may be eroded away to expose the beach rock at the base of the beach slope. When beach rock is exposed for extended periods, it is colonised by some of the suite of molluscs and barnacles that otherwise live in the intertidal notch habitats. However, the vertical zoning patterns that are characteristic of the notch habitats are often poorly defined in exposed beach rock habitats.

The more exposed rock platforms of the west coast of Barrow Island tend to support dense algal turfs and a rich middle and outer flat fauna. Their outer edges are dominated by *Sargassum* and there are relatively few corals. The more sheltered rock platforms of the east coast tend to have more sparse vegetation and a relatively high diversity of corals at and near low tide level.

West coast rock platforms often have a relatively wide zone of sediments on the inner flat with associated infaunal and epifaunal communities. These flats are uncommon on the east coast.

Related to these physical differences in habitat, there are significant differences in species assemblages occupying the west and east coast rock platforms. Although the majority of species occur on both coasts, some species are restricted to one coast. Three molluscan genera that illustrate this pattern are included in Table 1.

Table 1: Species of three intertidal molluscan genera that are restricted to either the east coast or the west coast of Barrow Island.

Genus	**West coast**	**East coast**
Conus	*C. textile*	*C. victoriae*
	C. geographus	*C. novaehollandiae*
	C. vexillum	*C. monachus*
	C. miles	
	C. lividus	
Modiolus	*M. auriculatus*	*M.* sp. nov.
Rhinoclavis	*R. bituberculatum*	*R. vertagus*

This pattern may be observed throughout the West Pilbara region and is the basis of the distinction between the *Offshore Pilbara Region* and the *Nearshore Pilbara Region* made in the Marine Parks and Reserves Working Group Report (Wilson *et al.,* 1994) and in the ecosystem-based classification of IMCRA (1998). The west and east coasts of Barrow Island represent the offshore and nearshore regional sub-provinces respectively.

3.2.2 Upper intertidal notch

Limestone shores in the West Pilbara region are typically double-notched in the upper intertidal zone. The double notches are created by erosion of the cliff face above and below the protective or accretionary band of oysters in the central zone. The depth of the eroded lower notch in some areas is increased by burrowing invertebrates. The most important of these are the barnacle *Lithotrya* and the bivalves *Petricola* and *Lithophaga.*

Two species of littorinid gastropod are ubiquitous in the upper notch at Barrow Island. *Nodilittorina pyramidalis* extends up into the supralittoral zone and *N. millegrana* extends down to the upper edge of the oyster zone. At most west coast sites there may also be one or more of *N. australis, N. nodosa* and *Littoraria undulata* in the upper notch. These latter species are rare at east coast sites.

The alga, *Bostychia tenella*, is usually present in the oyster zone and the lower part of the upper notch. One of two species of the pulmonate snail genus, *Ophiocardula*, may be present among the algae.

The oyster zone is composed of clusters of the rock oyster *Saccostrea cuccullata*, possibly in association with a second species in some more sheltered sites. The oyster zone provides habitat for the gastropod *Planaxis sulcatus and* a variety of other invertebrates, most of them nestlers rather than borers. These animals are not restricted to the oyster zone and also extend onto the rock surfaces above and below it.

The lower notch is habitat for several species confined to that zone, for example the grazing gastropods *Cellana radiata, Monodonta labio* and *Turbo cinerea*, the boring bivalves *Lithophaga malaccana* and *Petricola lapicida* and the boring barnacle *Lithotyra valentiana.*

A variety of species inhabit both the lower notch and the inner part of the rock platform. For example, the molluscs *Nerita chamaeleon*, *N. albicilla*, *Siphonaria* sp. and *Onchidium* sp. and the two large chitons, *Acanthopleura spinosa* and *A. gemmata* are conspicuous in these habitats. *A. spinosa* sometimes extends up into the lower part of the upper notch and the latter sometimes extends out onto the inner rock platform. Cemented barnacles are also an important element of intertidal notch communities. Three or four species of barnacles are usually present in Barrow - Montebello Complex notch habitats.

The composition of the species assemblage in intertidal notch sites varies among sites and not all of the typical species are always present. Sand scouring is an obvious cause of absence of some species in the lower notch. In general, intertidal notches on the wave exposed west coast shores of Barrow Island tend to be more species-rich than comparable habitats of the more sheltered east coast shores.

3.2.3 Sandy Beaches

Sandy beaches on the Rowley Shelf islands are generally wide and steep on wave exposed shores and relatively narrow and less steep on sheltered shores. They are generally species poor in comparison with other intertidal habitats. The ghost crab *Ocypode* sp. is a common inhabitant of the middle and upper beach slope. The bivalves *Donax cuneata* and *Paphies striata* burrow in the sand of the lower slope, the latter confined to less wave exposed beaches.

The importance of sandy beaches in the region is primarily related to their significance for turtle and seabird nesting.

Turtles nest in the supratidal beach sand and only use the beach slopes as a conduit between the ocean and the nest sites. The beaches in the region are very important sites for turtle nesting. Sandy beaches on the west coast of Barrow Island are heavily utilised by green turtles, while beaches in the Montebello and Lowendal Islands groups are important hawksbill nesting sites. Flatback turtles are also known to nest on the east coast of Barrow Island.

Seabirds such as terns and oyster catchers nest on sandy beaches on islands in the Montebello and Lowendal Islands groups, including Barrow Island.

3.2.4 Mangals

The large mangrove forests (mangals) along the Pilbara coastline are composed of up to six different mangrove species. Mangals on the offshore islands tend to be small and are monospecific stands of the white mangrove *(Avicenia marina*). *A. marina* mangals grow at several localities on the protected south and east coasts of Barrow Island. Consistent with their limited size and floral diversity, the faunal assemblage associated with these mangals is usually species poor.

3.2.5 Coral Reefs

Coral communities are generally subtidal, however, many coral species are very tolerant of exposure and, in places, form reefs which extend into the lower intertidal. Many of the intertidal platforms which surround the islands of the Rowley Shelf contain small emergent reefs, and there are at least two large intertidal coral reefs in the region:

- unnamed reef on the southwest side of Thevenard Island.
- Biggada Reef on the west coast of Barrow Island.

The intertidal coral reef on the south west side of Thevenard Island is about 5 km long and is largely exposed during spring low tides over much of its length (Bowman Bishaw Gorham, 1995). The intertidal coral reef at Biggada Reef in Turtle Bay on the west coast of Barrow Island extends approximately 1.5 km northward and 0.5 km offshore from Biggada Creek. Surveys of the intertidal component of this coral community in 1995 revealed a diverse fauna, including 64 species of hard coral, 32 species of echinoderm and 75 species of shelled mollusc (Bowman Bishaw Gorham, 1996).

3.2.6 Sand Flats

Large intertidal sand flats are uncommon on the offshore Rowley Shelf. There are sand sheets and bars on the northern end of Thevenard Island and at Barrow Island. The fauna of the Thevenard Island sand flats is depauperate in comparison with other West Pilbara areas (Bowman Bishaw Gorham, 1995).

Intertidal sand flats at southern Barrow Island and north and east of Surf Point at northern Barrow Island have not been extensively studied, but are expected to support different faunal assemblages to those on the rock platforms and pools.

3.3. Subtidal Environment

The Rowley Shelf is a shallow (less than 20 m) submarine limestone shelf up to 80 km wide and composed mainly of Pleistocene limestone. The limestone is overlain in places by sediments of various thickness and particle size. The large variety of oceanographic and physical conditions that occur in the region, notably water depth, substrate type, turbidity, tidal regime and energetics, support a large variety of marine communities.

The proximity of Barrow Island to the western edge of the Rowley Shelf results in a wide range of oceanographic conditions around the island. The west coast is highly energetic, being subject to persistent southerly winds and deep ocean swell. The east coast is far less energetic, but has a series of small islets and shoals that increase the velocity of tidal streams.

This section addresses the following four main subtidal communities that dominate the Barrow Island region:

- coral reefs
- seagrass and macroalgal communities
- invertebrate filter feeding communities
- soft sediments

3.3.1 <u>Coral Reefs</u>

The broad, shallow Rowley Shelf contains a vast variety of coral habitats and an equally wide range of coral communities. The principal coral habitats include turbid inshore pavements and raised limestone shoals; fringing coral reefs around the sand cays; and offshore reefs in clear water. A number of major coral communities have been identified within the Barrow - Montebello Complex.

Biggada Reef is an extensive, largely intertidal coral reef on the west coast of Barrow Island at Turtle Bay (Section 3.2.5) that extends into the subtidal zone.

Large coral patch reefs have developed along the north facing edge of Barrow Shoals, on the south east side of Barrow Island. The largest of these, Dugong Reef, was severely degraded possibly due to an anoxic event associated with spawning in 1991. Surveys conducted on the reef in 1994 (Bowman Bishaw Gorham, 1994) identified at least 4.2 km^2 of dead coral. Another highly diverse live coral community on Barrow Shoals was less affected.

Narrow coral assemblages fringe parts of the north east coast and the east coast of Barrow Island. The extent and species composition of the north eastern coral community are unknown. It lies approximately 1.5km from the shore and extends north-eastern for at least 3km along the edge of the shallow subtidal platform between Square Bay and Ant Point. The eastern coral community, offshore from Shark Point, comprises isolated patches of coral that extend for up to 1.3km and run roughly parallel to the coast of Barrow Island.

Preliminary observations indicate a series of large *Porites* bomboras and mixed coral species bomboras, rising out of approximately 5-8m water depth at both locations.

The diversity of coral communities in the region was illustrated by a Museum of Western Australia survey in 1993, where 150 species of corals representing 54 genera were identified from the Montebello Islands (Marsh, 1993).

Other regionally significant coral communities in the Montebello/Lowendal groups of islands include:

- *Acropora, Porites* and hydrocoral (*Millipora*) dominated communities on the west coast of the Montebello Islands (Wonnich Reef).
- Patch reefs and bomboras stretching along the southeastern Montebello Islands.
- A series of bomboras on the eastern side of the Lowendal Islands.
- Scattered areas of coral in suitable habitats throughout the island groups.
- Coral patch reef and bombora fields on the southern end of the Lowendal Shelf.

3.3.2 Seagrass and Macroalgae Communities

Seagrasses and macroalgae are important components of shallow tropical marine environments. They are important primary producers, providing habitat for diverse biotic communities and food for protected animals such as dugong (*Dugong dugon*) and green turtles (*Chelonia mydas*). Dugongs occur at low densities throughout the area, and presumably feed on local *Halophila*, *Syringodium* and *Halodule* seagrass meadows. However, no feeding scars have been observed at Barrow Island, suggesting there may be other, possibly denser, meadows in unsurveyed areas.

Seagrasses occur throughout the Montebello/Lowendal region, the most common genera being *Halophila* and *Syringodium*, which often grow in association with macroalgae such as *Caulerpa*.

Seagrasses are widespread, but generally form sparse communities in the Barrow Island region. Preliminary investigations indicate that *Halophila* spp. are the most common seagrasses on shallow soft substrates and sand veneers throughout the area. They extend from the intertidal zone to approximately 15 m water depth.

Halodule uninervis, *Thalassia hemprichii* and *Syringodium isoetifollium* are less common species and are often found in association with *Halophila*. *Thalassodendron ciliatum* is less widespread, only known from small meadows on shallow reefs on the west side of the Montebello Islands and on the east side of Barrow Island.

Macroalgae are very common components of the marine environments in the shallow waters of the Pilbara. They are the dominant primary producers on the extensive areas of shallow pavement in the Barrow Island region. Macroalgae that are abundant in the region include the Phaeophytes (brown macroalgae) - *Dictyopterus*, *Dictyota, Cystoseira* and *Padina,* the Chlorophytes (green macroalgae) - *Halimeda*, *Codium* and *Caulerpa* and the Rhodophytes (red macroalgae) - *Hydrolithon* and *Laurencia.*

Sargassum and other brown macroalgae have the largest thalli and contribute most to the biomass on shallow pavement reefs. *Sargassum* spp. undergo large seasonal variations in biomass, having a summer growth and reproductive stage followed by winter senescence. During summer, the extremely foliose *Sargassum* thalli may exceed 1 m in height. In winter, when the reproductive thallus is shed, the senescent stipes are generally less than 20 cm high.

3.3.3 Filter Feeding Communities

Deeper limestone pavements on the southern Rowley Shelf sometimes support a diverse community dominated by attached filter feeding invertebrates. These communities typically contain diverse assemblages of tubular, digitate, laminar, branching, globose and encrusting sponge species in association with gorgonians, including sea fans (Subergorgiidae and Plexauridae) and sea whips (Leptogorgiidae), colonial and solitary ascidians, bryozoans, algae and scleractinian corals (eg. *Turbinaria*).

The distribution of these communities in the region is largely unknown due to the paucity of survey data for the deeper pavements. One community of undetermined extent occurs in water depths of about 15 – 20 m near the northeast corner of Barrow Island.

3.3.4 Sediment Habitats

Soft sediment habitats generally support a diverse assemblage of burrowing and crawling infauna, but are generally too unstable for larger attached organisms. Finer sediments generally accumulate in low energy areas and support richer infaunal assemblages. The extent of sediment habitat in the Barrow Islands region is unknown, but expected to be widespread. Large, apparently sandy, shoals to the east and south of Barrow Island have not been surveyed.

The large fauna of these habitats includes the burrowing gastropod *Amoria macandrewi*, which is endemic to the region, seapens (Pennatulacea), bivalves, crustaceans and benthic fish such as flathead and rays. The flora includes seagrasses, stoloniferous green macroalgae (*Caulerpa*) and other greens such as *Penicillium* and *Udotea*.

3.4 Conservation Reserves and Protected Fauna

A number of areas within the Barrow - Montebello Complex are either currently protected or proposed to be protected under State or Commonwealth legislation. Some of the faunal species in the area are also specifically protected.

3.4.1 Conservation Areas

Within the Barrow - Montebello Complex, there are two conservation parks and four nature reserves vested in the Nature Conservation Commission (Osborne *et al.* 2000):

- Montebello Islands Conservation Park (2 sections).
- Barrow Island Nature Reserve.
- Boodie and Double Islands Nature Reserve.
- Lowendal Islands Nature Reserve.
- Great Sandy Island Nature Reserve.

The Montebello Islands Conservation Park (Reserve Nos. 42196 and 42197) comprises more than 100 islands, islets and rocks. The islands are reserved as an 'A' class Conservation Park to the high water mark and as a 'C' class park down to low water.

The Lowendal Islands Nature Reserve comprises the land above the high water mark on 40 islands, islets and rocks including Varanus Island. It is a 'C' class nature reserve (Reserve No. 33502).

The most important conservation reserve within the region is Barrow Island itself, which is an 'A' class nature reserve down to the low water mark (Reserve No. 11648). Barrow Island was given reserve status in 1908. Middle, Boodie, Pascoe, Boomerang and Double Islands, immediately south and east of Barrow Island, make up a "C" class nature reserve (Reserve No. 38728) that extends down to the low water mark on these islands.

The Great Sandy Island Nature Reserve is a class 'B' nature reserve (No. 33831) extending down to low water. The reserve includes one of the sand cays known as the Barrow Island Shoals to the south of Barrow Island.

The important marine conservation resources of the region are being assessed by the Marine Parks and Reserves Scientific Advisory Committee. The advisory committee is following on from recommendations made in a report of the Marine Parks and Reserves Selection Working Group (Wilson *et al.,* 1994) who recommended three marine areas in the region for consideration in future marine reserves selection:

- the waters of the Montebello Islands.
- part of the west coast of Barrow Island including Biggada Reef.
- the shallow marine habitats in Bandicoot Bay at the south of Barrow Island.

The Wilson *et al.* (1994) report recommended the integration of these three possible marine reserves through a regional environmental management plan. A draft plan is currently being developed by a working group comprising government and industry stakeholders. At present, there is general agreement on a regional management plan with multiple use areas and high protection status for specific sanctuary zones.

3.4.2 Protected Marine Species

The protected marine fauna of the Barrow Island region includes mammals, reptiles and fish. All cetaceans are protected under the EPBC Act. Humpback whales (*Megaptera novaeangliae*), which are common in the area, are specially protected under Schedule 1 of the *Wildlife Conservation Act 1950* as animals that are rare or likely to become extinct

Fauna designated in the Schedules to the *Wildlife Conservation Act 1950* are wholly protected throughout the whole of Western Australia at all times. Fauna designated as threatened or migratory species under the EPBC Act are protected and a number of species are listed as marine protected species that are protected in Commonwealth waters and from activities in other areas that are likely to affect critical populations of these species in Commonwealth waters.

All sea turtles are protected under Schedule 1 of the *Wildlife Conservation Act 1950,* by the Bonn Convention for the protection of migratory animals and the EPBC Act.

Whale sharks (*Rhincodon typus*) and grey nurse sharks (*Eugomphodus taurus*) may be occasional visitors to the area and are protected as threatened and/or migratory species under the EPBC Act. Great white sharks (*Carcharodon carcharias*) may also visit the area very occasionally, but it is at the northern extreme of their distribution.

Dugong (*Dugong dugon*) are known to occur around most offshore islands in the region (Prince *et al*,. 2001) and are provided special protection under Schedule 4 of the *Wildlife Conservation Act*, *1950*. They are listed as threatened (vulnerable) under the EPBC Act.

The large fish of the family Serranidae, commonly termed grouper or cod, are considered vulnerable to exploitation. Potato cod (*Epinephelus tukula*) and Queensland grouper (*E. lanceolatus*) are protected under the *Fisheries Resource Management Act, 1994*.

Sea snakes, kraits and pipefish are listed as protected marine species under the EPBC Act and are widespread throughout the region in offshore and nearshore habitats. Little is known of the distribution of individual species within the region.

All of the islands in the region are either Nature Reserves or Conservation Parks. Reserve boundaries extend to the low water mark, therefore, all fauna and flora in the intertidal zones are protected.

4.0 LOCAL MARINE ENVIRONMENT

4.1 Marine Habitats at Flacourt Bay (West Coast)

4.1.1 Subtidal Benthic Habitats

Benthic marine habitats in Flacourt Bay were surveyed by towing an underwater video camera along two parallel transects following the proposed gas pipeline route, from 3.5 km offshore to the sandy beach. The seabed was characterised by bare sand habitats with areas of exposed limestone pavement near the beach and extending north from the Biggada Reef complex (Figure 2).

The sandy seabed supported a very sparse assemblage of epibiota. Many areas of sand were completely bare and the lack of obvious bioturbation indicated that large infauna were not abundant in the area. The absence of seagrass and stoloniferous macroalgae is consistent with the instability of the sandy sediments due to the high wave energy regime on this coast.

The pavement habitat in the high-energy zone near the beach supported a sparse cover of turfing brown and red macroalgae and small corals. The pavement reef in deeper water supported a low to medium density assemblage of sponges, sea whips, gorgonians, small corals such as *Turbinaria*, the green macroalga *Halimeda* and *Sargassum.*

The nearest significant coral reef community is at Biggada Reef, extending north for approximately 1.5 km from immediately north of Biggada Creek to the southern end of Flacourt Bay (Figure 2). This coral assemblage extends into the intertidal zone and is best developed at the southern end of the reef. The reef front has not been surveyed. The northern end of the reef is a rocky pavement reef with macroalgae and scattered corals.

4.1.2 Intertidal and Supratidal Habitats

Biggada Reef is the most significant intertidal habitat in the area of the proposed development. The coral reef appears to be based on structural limestone running seaward from the cliffs on the northern side of Biggada Creek. The reef is largely continuous, with a wide platform emergent at low spring tides and enclosing a shallow, sandy lagoon.

Brief surveys of the reef in 1995 revealed a very diverse coral assemblage, particularly along the margin of the coral platform at the northern end of the lagoon (Bowman Bishaw Gorham, 1996). The coral assemblage comprised at least 64 species with a further 13 species of zoanthids and soft corals.

The shoreline along Flacourt Bay is characterised by sandy beaches between rocky headlands (Plate 1). The beaches are subject to high wave energy and the biological assemblages on this coast are expected to be subject to dynamic seasonal and inter-annual changes in sand cover. The rocky headlands are almost vertical, with poorly developed notches and oyster zones. The narrow intertidal zones are subject to high wave energy and many of the intertidal organisms persist as stunted ecomorphs.

Plate 1: High-energy sandy beach at the southern end of Flacourt Bay. Biggada Reef is to the south of the point at the top right of the picture.

The narrow intertidal zone on the sandy beaches is home to a sparse infaunal assemblage, probably dominated by burrowing bivalve molluscs such as *Donax* sp. and polychaete worms. Large crustaceans such as ghost crabs (*Ocypode sp.*) are also likely to occur on these beaches.

The rocky intertidal zone in the development area was not examined in the current survey, due to surf conditions. Previous surveys of the intertidal platform at the southern end of Flacourt Bay indicated that the intertidal rock platform extends approximately 75 – 150 m from the top of the beach slope (Bowman Bishaw Gorham, 1996). The platform reef supported a dense and species rich macroalgal turf with mussel (*Brachidontes*) mats, small corals and better developed algae in shallow rock pools. Holothurians and molluscs were the dominant fauna.

The nearshore supratidal zone is the boundary between the sea and the land ecosystems and is used or inhabited by a range of marine and terrestrial animals. The sandy beach is a loafing area for oystercatchers and probably other wading birds that would feed on bivalves and other infauna at low tide. Green turtles nest in the soft sand in the supratidal zone and dunes above the high water mark. Female turtles rest on the beach during the breeding season. The large terrestrial reptile, *Varanus perentie*, forages amongst the wrack along the high tide line and predates on turtle eggs. Other terrestrial reptile and small mammal tracks were also common on the supratidal sand. Seabirds and waders also nest on the supratidal sand and rocks along this coast.

4.2 Marine Habitats from Latitude Point to Shark Point (East Coast)

4.2.1 Subtidal Habitats

The marine environment in the area of the proposed development on the east coast of Barrow Island comprises the southern end of the Lowendal shelf, the passage between Barrow Island and the shelf, submerged pavement along the coast of Barrow Island and the deeper area south of the shelf. The major benthic habitats in the area are shown in Figure 3.

The main marine benthic habitats in the area are:

- sandy sediments,
- shallow limestone pavement reef with *Sargassum* (macroalgae) and small corals,
- deeper limestone pavement reef with filter-feeding invertebrates,
- coral bomboras and coral reef.

The east coast of Barrow Island is a continuous limestone pavement running from the base of the low cliffs or sandy beaches through the intertidal zone into the shallow subtidal zone (Plate 2). The subtidal pavement reef along the edge of the island is dominated by the brown macroalgae *Sargassum*, with other macroalgae such as *Dictyopterus*, scattered small hard and soft corals and occasional bomboras of *Porites* and other coral genera up to 1 m high. The biomass of *Sargassum* varies seasonally, peaking in spring and summer. At the time of the survey, much of the *Sargassum* was senescent with short stipes and thalli.

Plate 2: Low cliffs and intertidal limestone platform reef that slopes into the subtidal zone, typical of the east coast development area.

To the east of the coastal platform reef, the channel between the Lowendal shelf and Barrow Island experiences tidal currents of up to several knots. The scoured seabed in the channel is characterised by pavement and rubble with patchy thin veneers of sand. The pavement reef supports macroalgae and a sparse assemblage of invertebrates such as gorgonians, sea whips, scleractinian corals and sponges. Towards the southern end of the channel, the tidal stream widens and the currents slacken. Deeper sand veneers overly the pavement reef in this area.

Humpback whales were observed in the channel on several days. The whales included a mother and calf pair that appeared to be milling about. The area is outside the main route for migrating humpbacks and may have been serving as a rest area for these individuals.

Seabirds were observed feeding in the channel near Double Island, to the north of the proposed development area. These birds are likely to feed in the southern parts of the channel also.

The large, shallow shelf at the southern end of the Lowendal Islands is mainly sand and rubble with areas of limestone pavement reef, rocky bomboras, coral reef and coral bomboras. Coral reef is restricted to the southwestern corner of the shelf, however, coral bomboras fringe the shelf and are scattered across the top of the shelf.

There is a patch of fragile *Acropora* staghorn coral and large tabular *Acropora* colonies on the southwestern edge of the shelf (Plates 3, 4). Staghorn corals are easily broken during storms and the persistence of this coral patch indicates it is in a sheltered area, protected from cyclonic swells. Within this patch, there are large areas of dead coral. The dead corals were still intact suggesting that they have died within the previous few years.

 

Plates 3 & 4: *Acropora* coral reef on the southwestern edge of the Lowendal shelf.

Large coral bomboras with diverse assemblages of hard corals, soft corals and associated fauna, interspersed with coral reef and rubble assemblages, occur along the edge of the Lowendal shelf. These bomboras are generally dominated by *Porites* colonies and are up to 3 – 4 m high (Plates 5, 6).

 

Plates 5 & 6: Coral bomboras along the southwestern edge of the Lowendal shelf.

An area of exposed pavement reef extends southwards from the southwestern end of the Lowendal shelf and a ridge of limestone runs parallel to the coast further south (Figure 3). The pavement reef adjacent to the shelf, and slightly deeper than the corals, supports a sparse to medium density assemblage of filter feeding invertebrates similar to other deep water hard substrates in the area (Plate 7). The ridge of limestone further south supports mainly macroalgae with scattered corals. There are also isolated patches of large coral bomboras, up to 1.3km long in this area (Figure 3).

Plate 7: Sparse filter feeding assemblage on hard substrate off the southern edge of the Lowendal shelf.

4.2.2 Intertidal and Supratidal Habitats

The shoreline of the study area comprises rocky headlands with limestone pavement, sand flats and sandy beaches between rocky headlands and cliffs.

The supratidal sandy beaches are important for sea turtle nesting and are also frequented by terrestrial mammals and reptiles foraging amongst the wrack. Sea turtles nest on the sandy beaches above the high tide line and some seabirds nest on the sandy and rocky beaches.

The rocky shores are typically double notched and essentially bare in the high upper intertidal apart from the littorinid snails (Plate 8). The upper intertidal zone is dominated by a band of rock oysters (*Saccostrea sp*.) approximately 1m high, with chitons (*Amphipleura spinosa*, *A. gemmata*), gastropods (littorines, turbinids, trochids, neritids), siphonate limpets, mytilids and barnacles. Immediately below the wave cut notch, the platform reef supports a low mat of green macroalgae (probably *Enteromorpha*), lithophagid bivalves and siphonate limpets. Grapsid crabs (*Leptograpsis*) are common in the intertidal notch habitats.

Plate 8: Double notched intertidal rock face at Latitude Point.

The mid-intertidal zone is much wider than on the west coast and less subject to physical disturbance from ocean swells. At low tide, several hundred metres of platform reef adjacent to the beach are exposed. The area exposed varies with tidal and weather conditions.

The desiccating effects of the sun, especially in summer, control the distribution of many taxa in the intertidal zone. The limestone pavement reef supports an assemblage of macroalgae and invertebrates that appears to increase in biomass, composition and diversity with increasing depth and hence decreasing exposure time.

The exposed platform reef supports a sparse assemblage of brown turfing macroalgae such as *Hydroclathrus clathratus* and filamentous species and calcareous red algae (Plates 2, 8). Earlier surveys of the east coast of Barrow Island indicated that red turfing algae such as *Laurencia*, *Chondria*, *Ceramium*, *Centroceras*, *Gelidiopsis* and *Hypnea* were dominant at many sites (Bowman Bishaw Gorham, 1997). There were occasional small hard corals (*Euphyllia*, *Trachyphyllia*, faviids) on the exposed pavement and scattered larger corals (*Acropora*, *Goniopora*, *Plesiastrea*, *Goniastrea*, *Porites*, *Turbinaria*, *Cyphastrea*, *Duncanopsammia*) on the lower intertidal platform. The soft coral assemblage in the lower intertidal zone included *Sarcophyton*, *Lobophyton* and *Dendronephthya*. Other filter-feeding invertebrates such as colonial ascidians, hydroids, zoanthids and sponges were scattered along the lower margin of the intertidal zone.

Rock pools on the limestone pavement reef retain water at low tide and support a more diverse assemblage of larger flora and fauna. Macroalgae such as *Acetabularia*, *Codium*, *Caulerpa*, *Padina*, *Halimeda*, *Sargassum* and *Dictyopterus* and seagrasses *Halodule*, *Halophila* and *Thallassia* were present in the rock pools. The fauna of the rock pools was dominated by bivalves (*Tridacna maxima*, *T. squamosa*, *Malleus* and *Pinna*) and other molluscs (*Octopus*, nudibranchs, *Conus*, *Astralium*, *Cypraea*, *Lambis*). Sea stars (*Protoreaster*, *Linckia*), crabs (Majidae, Paguridae, Xanthidae) and holothurians (*Holothuria* spp.) were scattered across the platform and in rock pools.

The small sand flats supported a dense assemblage of nemertean worms and burrowing infauna, probably polychaete worms. Wading birds such as grey tattlers, heron and pied oyster catchers were seen feeding on the sand flats. Terns were seen loafing on the sand flats.

There are small mangals approximately 5 km to the north of the marine development area.

5.0 SENSITIVITY AND CONSERVATION SIGNIFICANCE

5.1 Intertidal and Supratidal Habitats

There are habitats in the general area of the proposed development that have high intrinsic conservation significance. However, the intertidal habitats in the area to be directly impacted by the proposed development are widespread on Barrow Island and around other islands in the region and have low intrinsic conservation significance.

The major environmental sensitivity on the west coast is the large and regionally significant coral community at Biggada Reef. This area has regionally high species diversity. Corals are sensitive to hydrocarbon pollution and smothering, especially while physiologically stressed in summer and when reproducing. The intertidal corals at Biggada Reef would be particularly sensitive to buoyant chemical spills at low tide and to sedimentation in summer.

The fringe of corals, soft corals and other filter feeding invertebrates along the lower intertidal margin of the east coast development site are the most sensitive intertidal resource in this part of Barrow Island, but do not have particular conservation significance. The coral assemblages along the fringe of the development area do not appear to be as well developed as those further north. The Barrow Island endemic gastropod *Amoria macandrewi* was not found on the sand flat immediately north of the development area.

The mangals to the north of the development area are small, but in light of the rarity of mangals on Barrow Island, are of moderate conservation significance. Mangals and their associated fauna are sensitive to hydrocarbon and chemical spills, especially if the spill contacts the mangal on a falling tide.

Migratory seabirds and waders feed and roost in the area and turtles nest on the beaches. The significance of these areas for marine birds and turtles is discussed in separate reports.

5.2 Subtidal Habitats

The major environmental sensitivities in the subtidal zone of the proposed development area are coral reefs and protected mammals and reptiles.

The coral assemblages on the southwestern corner of the Lowendal Shelf and the large bombora fields to the east of Shark Point are of regional conservation significance. The extensive patch of *Acropora* on the southwestern edge of the Lowendal Shelf is one of the few extensive patches of fragile corals in the region. Some of the *Porites* coral bomboras in the area are 3 - 4 meters high and are estimated to be several hundred years old. These corals support diverse assemblages of fish and invertebrates.

The coral reef areas on the subtidal pavement adjacent Barrow Island are locally significant.

The seagrasses in the development area mainly comprise species such as *Halophila* and *Halodule*. The plants are small and the meadows are too sparse to provide habitat for the fauna that are usually associated with high-density seagrass meadows. These seagrasses are unlikely to be of high importance to local dugong or sea turtle populations.

Halophila and *Halodule* rapidly recover from disturbance and recolonise disturbed areas from sediment seed banks. These genera are widespread throughout the area and the low-density seagrass in the development area has low conservation significance.

Dugong (*Dugong dugon*) were not observed in the proposed development area during the field surveys, but have been previously observed off the east coast of Barrow Island, at the Lowendal Islands to the northeast and a number of other islands of the region (Prince *et al.* 2001). Dugong are listed as vulnerable under the EPBC Act.

Dugong are likely to pass through and possibly feed on sparse seagrass meadows in the area on occasion. Individual animals are likely to be disturbed by noise and shipping activity, however, population level effects are unlikely.

Sea snakes, sea turtles, pipe fish and sharks protected under the EPBC Act probably occur throughout the development area. These fauna, and their habitats, are likely to be widespread through the region and the local populations are not expected to be dependent on the habitats in the development area. Sea turtle populations breeding in the area and inhabiting the nearshore waters would be sensitive to disturbance during their breeding season.

Humpback whales were observed during the field surveys on both the east and west coasts of the island. These protected fauna, and other cetaceans that may pass through the area, are not dependent on benthic habitats, but may be disturbed by construction and operational activities. The development area is outside the main whale migration routes and is not expected to be regionally important for populations of cetaceans.

6.0 CONSTRUCTION IMPACTS

6.1 West Coast

Development on the west coast would involve laying gas import pipelines from the Gorgon field. These proposed pipelines are likely to be trenched into the seabed for stabilisation, although the shore crossing may involve directional drilling to facilitate laying the pipelines under the sandy beach and fore-dunes. Trenching may require blasting in some areas. Potential impacts associated with construction relate to blasting shock and noise, turbidity, suspended particle loads and shipping activities.

Work boats and barge movements would cause temporary disturbance to whales, turtles, seabirds or sharks in the immediate vicinity of their operations. This disturbance would be temporary, localised and have little impact on local populations if constrained to non-critical times. Blasting could cause physical injury to individual animals at close range, but there is little risk of injury in an appropriately managed operation. Noise from blasting is likely to temporarily affect cetacean behaviour over considerable distance.

Fine particles suspended during pipeline stabilisation could potentially affect the health of corals at Biggada Reef depending on the levels of suspended solids and time of year. Corals are often physiologically stressed at the end of summer, when water temperatures are greatest and metabolic resources are channelled into gamete production prior to spawning. Biggada Reef is located more than 3km from the proposed pipeline alignments and it is unlikely that a properly managed dredging operation would produce a dredge plume that would affect the corals or other fauna at Biggada Reef. Hydrological modelling could be applied during detailed planning to better assess and manage the risk of impact from suspended particles.

Vessel operations introduce the risk of hydrocarbon spills, introduction of feral pest species and accidental grounding of the vessels on Biggada Reef or the shore. However, the risk of hydrocarbon spills and vessel grounding is very low. Management of refuelling operations, anchoring and vessel movement will further reduce these risks. Ballast water management in accordance with AQIS protocols will minimise the risk of introducing marine pest species.

6.2 East Coast

Construction activities and facilities would comprise;

- a piled jetty from the shore to an offshore tanker loading facility,
- a MOF on the shore,
- dredging through the intertidal and shallow subtidal for barge access to the MOF,
- dredging for tanker access to the jetty offloading facility,
- disposal of dredge spoil,
- increased shipping traffic,
- installing the domestic gas export pipeline.

Dredging for the barge access channel to the jetty and the shipping channel for tanker access to the offloading facility will introduce the risk of sedimentation impacts on local corals. This risk will be low due to the distance between the significant coral reef resources and the dredging operations. Risks could be further minimised by developing a dredging management plan incorporating modelled predictions of the dispersion of the dredge plume.

Sedimentation may also increase due to erosion from earthworks at the plant site during heavy rain. The volumes of sediment are expected to be minor in comparison with natural loads due to erosion during cyclones. Appropriate management of stormwater on the development site would be expected to minimise the export of terrigenous sediments to the nearshore marine environment.

The MOF will bury a small proportion of the intertidal reef notch and upper intertidal platform habitats and modify beach cliffs over a section of the coast approximately 150m long. This will result in a negligible decrease in the total area of intertidal habitat of this type and the vertical face of the MOF will be rapidly colonised by the upper intertidal assemblage.

Disposal of 5-10 x 10^6 m^3 of spoil from dredging the barge access channel to the jetty and the tanker shipping channel will require a dedicated spoil ground. The spoil ground will be selected and assessed as part of an application for a dredging licence and will incur minimal risk of deleteriously affecting sensitive marine resources of the area. Possible locations will be assessed on the basis of hydrological modelling of the likelihood of resuspended sediments affecting sensitive habitats around the disposal site.

Increased shipping traffic will increase the risk of accidental spills of fuels and other chemicals during routine operations and increase the risk of collision with whales and other protected species. The risk of vessels grounding on the shelf and impacting the corals is also increased. An anchoring management plan will be required to ensure no anchoring occurs in sensitive coral areas during construction activities.

Vessels servicing the development would present a risk of introducing exotic species in ballast water, but this would be required to be managed in accordance with AQIS requirements. These currently include risk assessment to determine the likelihood of marine pest species being in ballast water from foreign ports and generally involve full exchange of ballast waters before entering Australian waters.

The potential construction of a 16 inch domestic gas (domgas) export pipeline, from Barrow Island to an undetermined site on the mainland, would directly impact a narrow swathe of benthic habitats along its length. The pipeline would be trenched or bolted to the seabed. An area several metres wide by the length of the pipeline would be impacted. The route has not been selected, but it is assumed that there will be sufficient flexibility in selecting the route to avoid deleterious impacts to sensitive habitats of high conservation significance. With appropriate siting and management of potential construction impacts, the domgas pipeline would be unlikely to result in significant impact on the regions marine environmental resources.

7.0 OPERATIONAL IMPACTS

7.1 Routine Operations

7.1.1 West Coast

Operational impacts would be limited to the presence of the pipeline and consequent restrictions on shipping and other marine activities.

7.1.2 East Coast

Resuspension of dredge spoil has the potential to cause minor physiological stress on the corals of the area if there is an effect on local water turbidity. Increased shipping traffic increases the risk of collision between ships and marine biota such as turtles and cetaceans. Shipping also introduces the risk of marine pest introductions, from ballast water discharge and growth on hulls, and pollution from anti-fouling compounds leaching into the seawater.

The presence of the MOF may affect nearshore sediment movement resulting in either accretion or erosion of sand around the MOF. This may affect the area of wading bird habitat near the proposed MOF location. The piling jetty and access channel will introduce new habitats to the area and tend to increase local biodiversity. The access channel may also affect the tidal regime and biotic assemblages on the intertidal platform by increasing the draining and flooding efficiency of the area. Detailed assessment of these impacts would require investigation of local coastal processes.

Contaminants from small volume spills or leakages would tend to accumulate in sediments at the bottom of the dredged areas over the life of the field. The accumulated contaminant load may have a minor, localised effect on sediment infauna.

Lights along the jetty may affect sensitive fauna such as turtles and seabirds. Fish aggregations around lights can affect local seabird populations by favouring species able to modify their behaviour to take advantage of extended feeding times. These impacts are discussed in separate reports on sea turtles and sea birds.

7.2 Non-routine Operations

Potential impacts from non-routine operations include accidental oil, chemical or sewage spills and the risk of ships running aground on shallow reefs or beaches. The coral reefs to the south of the project area on the west coast, and to the north of the area on the east coast, present the greatest susceptibility to significant environmental impact in the event of an oil spill or ship grounding. Accidental spillage of substantial volumes of hydrocarbons may be caused by rupture of a product export line or by rupture of fuel tanks or holding tanks onboard a vessel. Minor spills, for example during on-deck refuelling operations, are unlikely to have a significant impact on the receiving environment.

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FIGURES

PLATES

APPENDIX E

SURVEY OF AVIFAUNA ON THE EAST AND NORTH COASTS OF BARROW ISLAND, SEPTEMBER 2002

(ASTRON ENVIRONMENTAL)

REVISION STATUS

REVISIONS								
Rev	Date	Description	Prepared By		Reviewed By		Client Approval	
			Name	Sig	Name	Sig	Name	Sig
A	02/09/02	Issued for internal review	C. Surman		J. Kruger			
B	10/09/02	Issued for client review	C. Surman		S. Finn			
C	20/01/03	Final review	C. Surman					

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1 Introduction

Barrow Island has a diverse avifauna comprising at least 110 species, including 11 resident land birds, 22 species of migratory waders, 6 resident shorebirds, 8 resident seabirds, 17 visiting seabirds and 43 irregular visitors (Sedgwick 1978; WAPET 1989; Ninox 1997). Locally, this compares with 70 species recorded at the Montebello Islands and 89 species recorded at the Lowendal Group (Dinara Pty Ltd. 1991; Burbidge *et al*. 2000). Regionally, there have been 127 species recorded from the Burrup Peninsula and 238 recorded for the greater North West Shelf region (BBG 1995; Astron 2002). The avifauna of Barrow Island is thus poor in terms of land birds and waterfowl compared to mainland areas of the Pilbara.

Compared to nearby islands, Barrow Island has more migratory waders but fewer breeding seabirds. Both the Lowendal and Montebello Islands have 12 species of seabirds compared with only eight on Barrow Island. In contrast 20 species of migratory waders visit the Lowendal Group, and only 14 visit the Montebello's compared with Barrow Island's 22.

Maritime avifauna may be broken into two main groups of birds, shorebirds (including migratory waders) and seabirds. Typically, both groups are migratory, visiting Barrow Island and surrounding seas during the breeding period for seabirds and the non-breeding period for shorebirds. There are, however, exceptions. Some seabirds are resident throughout the area (Osprey *Pandion haliaetus*, White-bellied Sea Eagle *Haliaeetus leucogaster*, Silver Gull *Larus novaehollandiae*) as are some shorebirds (Eastern Reef Egret *Egreta sacra*, Pied Oystercatcher *Haematopus longirostris* and Sooty Oystercatcher *H. fuliginosus ophthalmicus*). Migratory waders (e.g. Ruddy Turnstone *Arenaria interpres*, Grey-tailed Tattler *Heteroscelus brevipes*) may also occasionally overwinter on Barrow Island rather than migrate to the northern hemisphere to breed.

Published observations on the presence of marine avifauna have been sparse (Serventy and Marshall 1964; Sedgwick 1978). This, however, has been augmented with consultant reports associated with specific projects and occasional updates from staff in the field that have been recorded in annual environmental reviews (e.g. Chevron 2000; Chevron 2002).

The aims of this survey were to assess the distribution and abundance of seabirds and shorebirds within the proposed Gorgon gas development area, and to identify nesting sites of any seabirds or shorebirds in these areas. It also aimed to assess the potential impacts of the Gorgon gas development on birds in this area. This work supplements that carried out by Dr M. Bamford on the terrestrial fauna of Barrow Island.

2 Methodology

An extensive literature search was carried out. Previous environmental reports and published records on avifauna on Barrow Island and the greater North West Shelf region were summarised.

Barrow Island was visited between 9-16 August 2002. Coastal areas, adjacent waters and reef flats were surveyed on foot with binoculars in a systematic manner. Sites covered during this survey included areas adjacent to the proposed gas processing facility site near Latitude Point, the proposed pipeline crossing at Flacourt Bay, as well as the potential CO_2 reinjection well area in the north of Barrow Island. To standardise beach surveys with the time of day and tide level a 200m semicircle of mud flats and beach at Latitude Point was monitored continuously for 12 hours from the shelter of a bird hide. To place north and east coast areas into an island perspective, spot checks were made of several sites along the west coast of Barrow Island. All birds observed were identified and counted for each beach area, taking care to avoid doubling up on birds already counted.

The study area was broken down into seven zones, to assess the distribution of shorebirds and seabirds throughout the study area. These zones are;

1. Eastern beaches and cliffs south of point centred on 339300, 7699400,

2. Eastern beach and cliff areas adjacent to, and south of Town Point,

3. Pipeline Beach, running between areas north of Town Point but south of the southern part of the Latitude Point headland,

4. Latitude Point and cliffs and Latitude Point Beach

5. Flacourt Bay and other west-coast beaches (The Chair, Eagles Nest, The Ledge, Turtle Bay, Biggada Creek and Boggs Beach)

6. Northern beaches and cliff areas from Surf Point to the mid-north coast, and

7. Northern beaches and cliffs from Cape Dupuy to the mid-north coast

3 Results

Twenty species of seabirds and shorebirds were recorded during the survey (Table 1). The majority of birds were observed whilst either foraging on reef flats or over deep water channels, or whilst roosting on beaches. Seabirds such as terns were confined to areas adjacent to foraging grounds, and so were represented only at a few sites in relatively large numbers. Of particular note were three large feeding flocks (500+, 1000+, 1000+ individuals) of Roseate Terns (*Sterna dougallii*) observed between 800-1200m offshore from the north coast. Osprey were found in few areas, but were usually associated with a nesting attempt. Many bird species had a cosmopolitan range, occurring across all areas surveyed. Typically, these were the Silver Gull, Grey-tailed Tattler, Large Sand Plover (*Charadrius leschenaultii*), Red-capped Plover (*Charadrius ruficapillus*), Sooty Oystercatcher, Pied Oystercatcher, and Eastern Reef Egret.

Table 1 lists the numbers observed and localities of birds observed during this survey. The highest densities of shore birds (including migratory waders) recorded were concentrated along the east coast of Barrow Island on reef flats between Dove Point in the north and Airport Creek in the south. Here, 67 % of all shorebirds were encountered. In contrast, the highest densities of seabirds were observed along the north coast, where 67 % of those recorded were observed.

In total, migratory waders represented 38.5 % of the total birds recorded during this survey. There were nine species of wader, representing 45 % of the total species that frequented the project area. All of these migratory waders fall under both the China Australia Migratory Bird Agreement (CAMBA) and the Japan Australia Migratory Bird Agreement (JAMBA).

Several active nests were located of the Osprey, Pied Oystercatcher and Sooty Oystercatcher. The numbers of nests, locations and breeding status are presented in Table 2. Figures 1-4 represent the locations of both active and inactive nests of birds observed within the proposed Gorgon gas development. Oystercatchers typically construct a basic nest consisting of a shallow scrape in sand between 2-13 m above the high water drift line. During this survey they either contained eggs or young. Only a single active Osprey nest was located within the Gorgon gas development area. This nest was situated on the edge of coastal rocky cliffs adjacent to the Terminal Tanks, just south of Latitude Point (Figure 1). Several disused nests were located (Figures 1, 2).

Results from the 12 hour watch at Latitude Point confirmed the importance of this bay as a foraging ground for migratory waders. The effect of tide on the abundance and distribution of birds was clear. During periods of low tide, all waders were found to be actively foraging across the reef flats, following the incoming tide. Birds then formed flocks and sheltered above the high water mark in the lee of *Spinifex longifolius*, during the high tide. During this period, waders are more difficult to observe, as they are less conspicuous against the background of beach sand and Spinifex compared to when they are observed against the reef flats. I found no evidence that birds in Latitude Bay moved from this area at any stage of the tide, although some areas surveyed may be less favourable as high-tide roosts. However, since the areas adjacent the proposed Gorgon gas processing facility site were surveyed either side of the high tide, and usually during low tide, it is believed that these results represent accurately the species diversity and abundances for these areas at this time of year.

4 Discussion and Recommendations

This study indicates that the areas that will be affected by the Gorgon gas development are unlikely to have any particular importance to marine avifauna within a local (Barrow Island) or regional context. However, several issues are considered important in terms of environmental management. The key issues are:

- The site footprint and proposed jetty sit adjacent to or across areas of intertidal habitat potentially important to resident shorebirds and migratory waders protected under CAMBA/JAMBA.

- A deepwater tidal channel, intended as use as a shipping channel and mooring area, is an important foraging area for Roseate Terns, Crested Terns and Lesser Crested Terns.

- Construction activity, such as blasting, may disturb foraging activity of migratory waders.

- Light cast from gas flares associated with the gas processing facility may disorientate and attract seabirds nesting on islands nearby. Tall flares tend to also attract Osprey, Brahminy Kites or White-bellied Sea Eagles, which see these as potential roosts.

- Plant and jetty lighting overspill may disorientate seabirds. Lighting overspill over water from the jetty will potentially increase availability of food to Silver Gulls, which may in turn impact on other nesting seabirds.

- Beaches adjacent to the plant site were found to be nesting areas for the "big-eyed" subspecies of the Sooty Oystercatcher *Haematopus fuliginosus ophthalmicus* as well as the Pied Oystercatcher *H. longirostris.*

The issues identified above may be addressed through simple changes to the potential design or the management of activities during construction.

The gas flare should include worlds best practice design, incorporating a shielded flare to reduce light overspill onto nearby beaches, reefs and water, as well as to reduce the likelihood of the combustion of Osprey, White-bellied Sea Eagles or other birds that may attempt to use the flare as a roost.

Lighting overspill from the plant area and jetty will need to be reduced to limit the impact on nesting turtles, and so this will also likely address similar issues for seabirds. However, experience in the region, has shown that any regular light source with overspill onto subtidal waters tends to increase marine productivity in the immediate area. This creates an increased foraging window of opportunity for the Silver Gull. At Harriet Alpha, near Varanus Island, light overspill from the gas flare resulted in a boom in the Silver Gull breeding populations on nearby islands, which had negative impacts of those seabirds that nest near gulls and which may face increased pressure from predation by gulls on their young and eggs, and competition for nesting space (L. Nicholson, J.N. Dunlop *pers.comm.*). If the plant incorporates worlds best practice light management, then the likely impact on shorebirds and seabirds in the area would be minimal.

The extensive reef flats of the east coast of Barrow Island are potentially an important foraging area for migratory waders during their annual southward (September-October) migration to their summer feeding grounds in the south of the state, as well as during their return northward migration during March. Australia is a partner in both the China Australia Migratory Bird Agreement and the Japan Australia Migratory Bird Agreement that falls under the Commonwealth government’s Environmental Protection and Biodiversity Conservation Act 1999. Construction activities likely to disturb waders, such as blasting, should be limited to those times outside of key migration periods for migratory waders. If, however, activities overlap with the migratory bird season, then there will be some affects on those birds using adjacent areas as foraging grounds. The scale of these affects on waders would be minimal in the senses of habitat loss. However, since blasting is an unpredictable activity from a bird’s point of view, this would disrupt feeding, and displace birds onto other reef flats. Although it is unlikely to have a significant negative impact on migratory waders, their displacement would have short-term effects on their foraging efficiency.

The presence of large foraging flocks of Roseate Terns and other seabirds in the tidal channel skirting Barrow Island signifies the importance of this area to those seabirds and their associated predatory fishes that help drive seabird prey to the surface. Although shipping activity may not directly impact on these foraging grounds, appropriate oil spill mitigation procedures should be in place to reduce the impact of any spills on this important foraging area.

All the Sooty Oystercatchers on Barrow Island are of the race *ophthalmicus*. This race has a limited distribution across northern Australia (Pizzey and Knight 1997; Marchant and Higgins 1990). Nesting takes place between late July and early October, and disturbance to potential nesting beaches should be limited during that time. Oystercatchers are very wary of intruders onto their beach areas, however activity offshore is not likely to disturb birds nesting above the high water mark. Activity around the high water mark and up to 15m above it should be limited to prevent destruction of nest sites.

Although this technical report has identified that parts of the east coast of Barrow Island have important foraging habitat for migratory waders, it is recommended that a further visit to Barrow Island to survey coastal areas for migratory waders be undertaken in early October to quantify the numbers of waders that use these areas at their peak migration time.

5 References

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Table 1: The number and location of birds recorded during the August 2002 survey of areas adjacent to the Gorgon gas development area.

Family	Scientific name	Common Name	Number	Locality	Conservation Status
Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	1	2	
Ardeidae	*Egretta sacra*	Eastern Reef Egret	18	1-7	CAMBA
Accipitridae	*Pandion haliaetus*	Osprey	2	4,5	CAMBA, JAMBA
Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	5	1,7	CAMBA, JAMBA
	Arenaria interpres	Ruddy Turnstone	49	2-7	CAMBA, JAMBA
	Calidris alba	Sanderling	4	2,7	CAMBA, JAMBA
	Calidris ruficollis	Red-necked Stint	14	1,4,5,7	CAMBA, JAMBA
	Heteroscelus brevipes	Grey-tailed Tattler	28	1-6	CAMBA, JAMBA
	Limosa lapponica	Bar-tailed Godwit	8	4,7	CAMBA, JAMBA
Haematopodidae	*Haematopus longirostris*	Pied Oystercatcher	36	1-7	
	Haematopus fuliginosus ophthalmicus	Sooty Oystercatcher	13	1,3-7	
Charadriidae	*Charadrius leschenaultii*	Large Sand Plover	31	1-7	CAMBA, JAMBA
	Charadrius ruficapillus	Red-capped Plover	25	1-7	
	Pluvialis squatarola	Grey Plover	1	4	CAMBA, JAMBA
	Pluvialis fulva	Pacific Golden Plover	1	2	CAMBA, JAMBA
Laridae	*Larus novaehollandiae*	Silver Gull	36	1-5	
	Sterna bengalensis	Lesser Crested Tern	2	6	CAMBA
	Sterna bergii	Crested Tern	12	3-7	
	Sterna caspia	Caspian Tern	4	2,4,5,7	CAMBA, JAMBA
	Sterna dougallii	Roseate Tern	76	6	

Table 2: The number and location of breeding sites for shorebirds and seabirds at the Terminal Tank area and Cape Dupuy area, August 2002.

Common Name	Scientific Name	Nest Observations	Locality
Terminal Tanks Area			
Pied Oystercatcher	*Haematopus longirostris*	Nest scrape in sand with 2 eggs	340018, 7700657
		Nest with 2 chicks	339389, 7699764
Sooty Oystercatcher	*Haematopus fuliginosus ophthalmicus*	Nest scrape in sand with 1 egg.	340378, 7701216
Osprey	*Pandion haliaetus*	Disused stick nest	339115, 7699126
		Active nest	340600, 7701298
White-bellied Sea Eagle	*Haliaeetus leucogaster*	Disused nest	340635, 7701320
Cape Dupuy Area			
Pied Oystercatcher	*Haematopus longirostris*	Nest scrape, runners nearby	339049, 7713049
		Nest scrape, runners nearby	337314, 7713885
Sooty Oystercatcher	*Haematopus fuliginosus ophthalmicus*	Nest scrape in sand with 2 eggs	339931, 7712583
Osprey	*Pandion haliaetus*	Disused stick nest	337259, 7713745

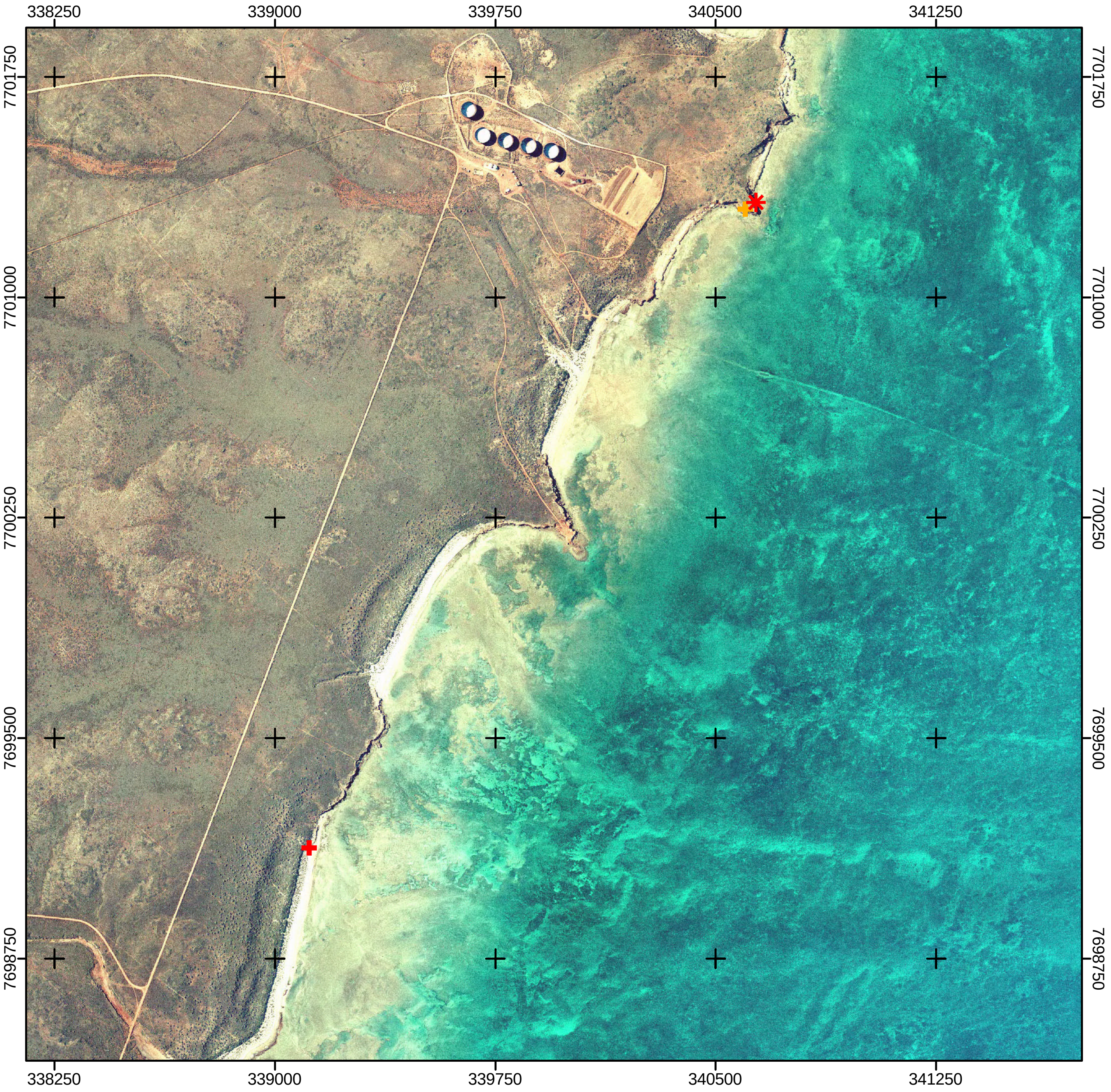
Key to Figures

Figure 1: Locations of active and inactive nest sites of Osprey and White Bellied Sea Eagles along the east coast of Barrow Island.

Figure 2: Locations of active and inactive nest sites of Osprey and White Bellied Sea Eagles along the north coast of Barrow Island.

Figure 3: Locations of current nest sites of the Eastern Reef Egret, Sooty Oystercatcher and Pied Oystercatcher along the east coast of Barrow Island.

Figure 4: Locations of current nest sites of the Eastern Reef Egret, Sooty Oystercatcher and Pied Oystercatcher along the north coast of Barrow Island.



LEGEND

- Osprey nest site - active
- Osprey nest site - inactive
- Sea Eagle nest site - inactive

N
W E
S

0 250 500 750 1000

Metres

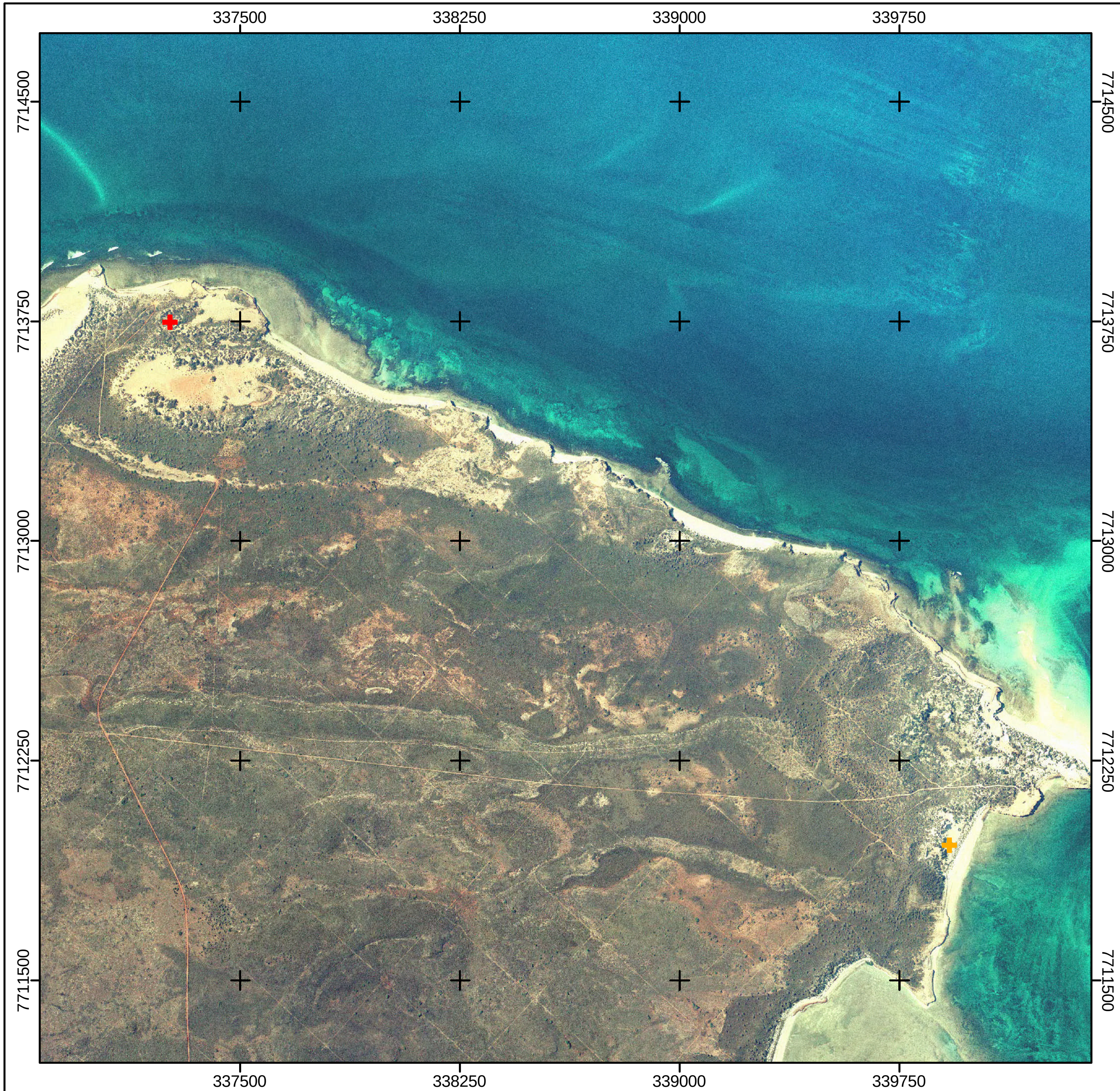
Scale 1:20,000

ChevronTexaco

Barrow Island

Sea Birds - East

Author: Chris Surman	Date : 30/8/2002	DRAWING No CHE014_21.apr [Sea Birds - East Barrow]
Drawn By: Craig Richards (NGIS)		



LEGEND

- Osprey nest site - active
- Osprey nest site - inactive
- Sea Eagle nest site - inactive

N
W E
S

0 250 500 750 1000

Metres

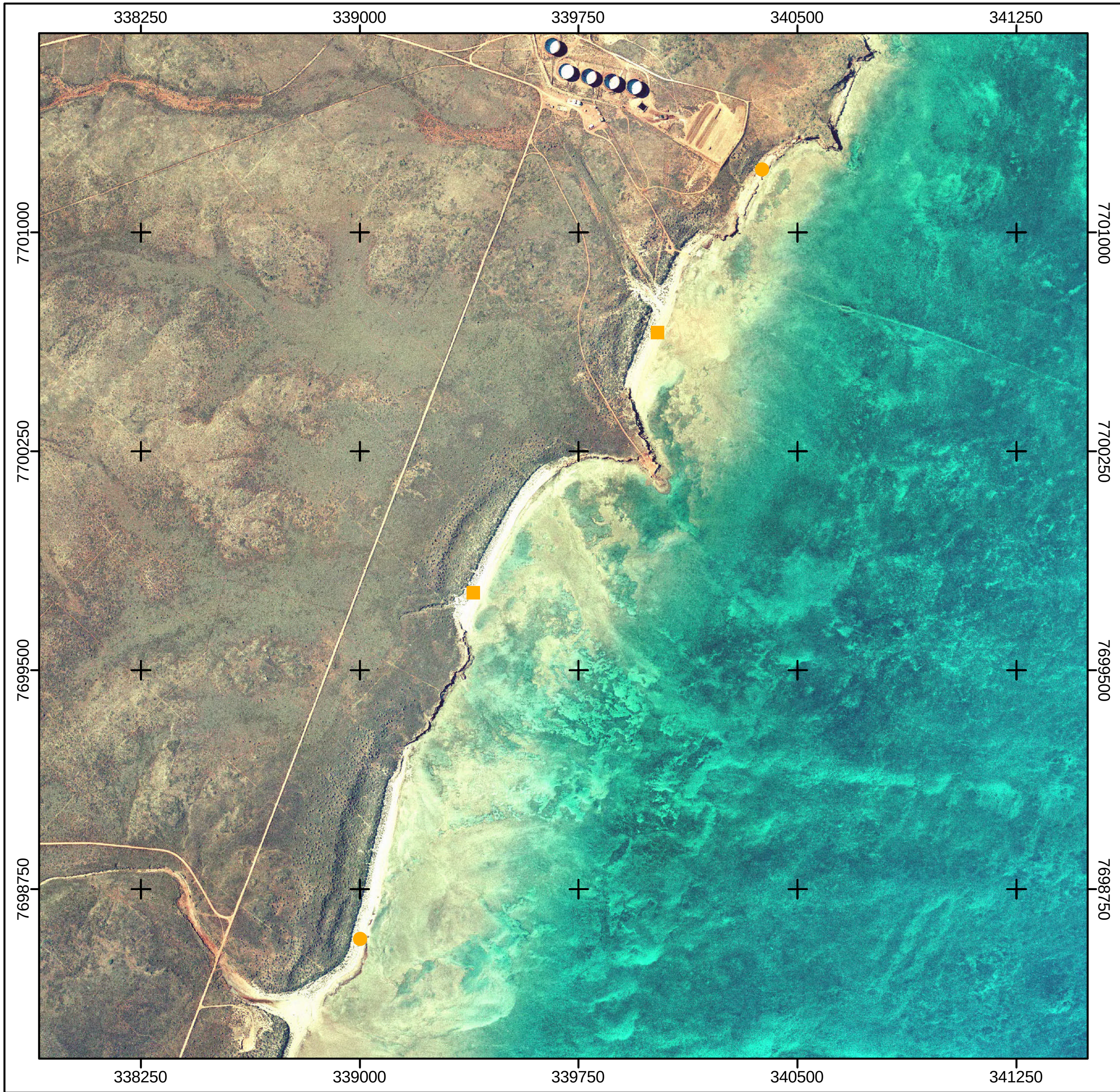
Scale 1:20,000

ChevronTexaco

Barrow Island

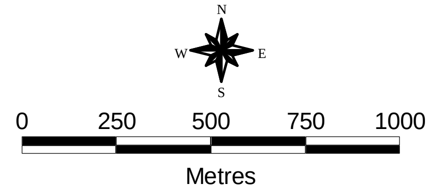
Sea Birds - North

Author: Chris Surman	Date : 30/8/2002	DRAWING No CHE014_21.apr [Sea Birds - North Barrow]
Drawn By: Craig Richards (NGIS)		



LEGEND

- ▲ Eastern Reef Egret nest
- ■ Pied Oystercatcher nest site
- ● Sooty Oystercatcher nest site



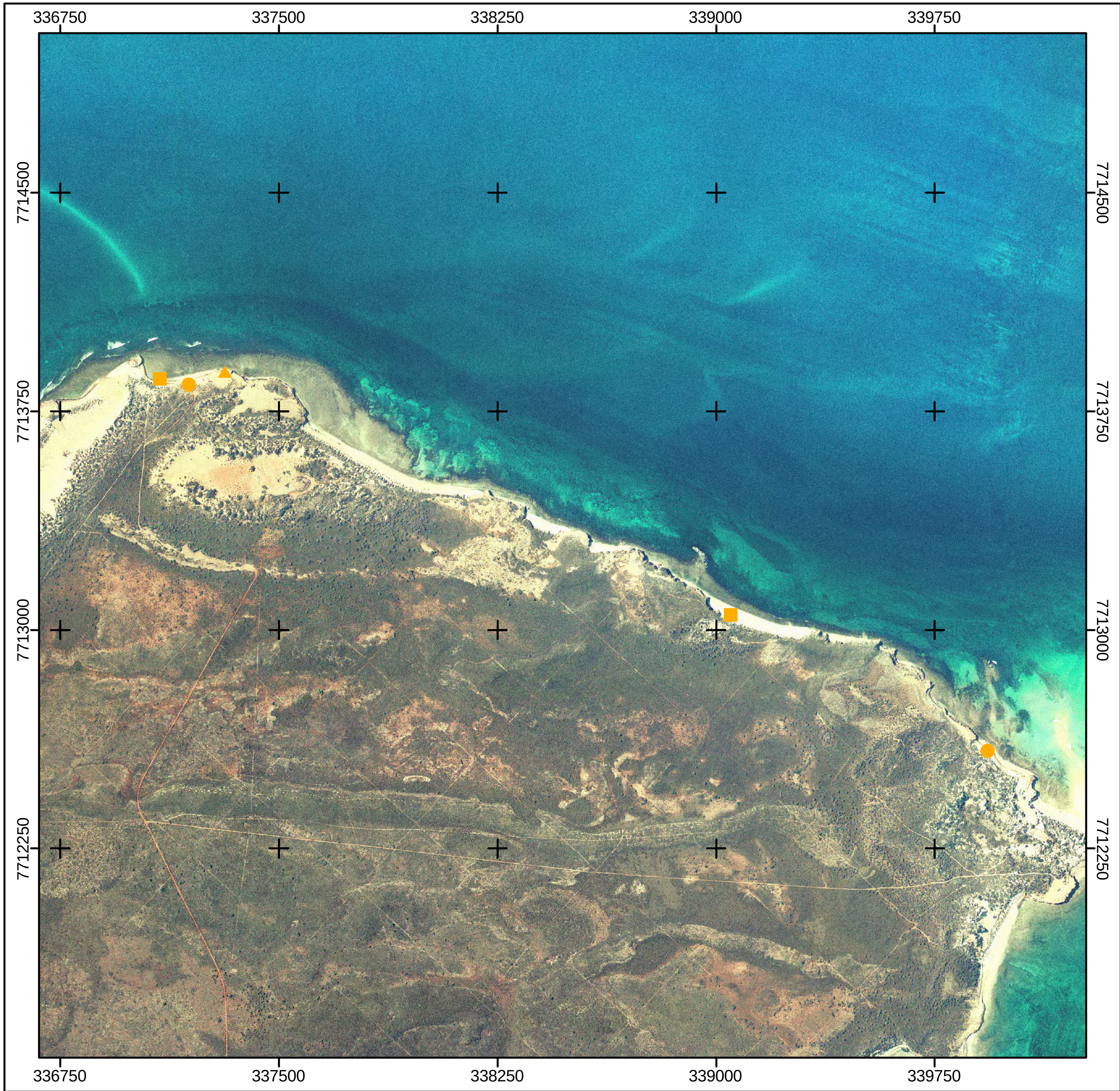
Scale 1:20,000

ChevronTexaco

Barrow Island

Shore Birds - East

Author: Chris Surman	Date : 30/8/2002	DRAWING No CHE014_21.apr [Shore Birds - East Barrow]
Drawn By: Craig Richards (NGIS)		



LEGEND

- ▲ Eastern Reef Egret nest
- ■ Pied Oystercatcher nest site
- ● Sooty Oystercatcher nest site

N
W E
S

0 250 500 750 1000

Metres

Scale 1:20,000

ChevronTexaco

Barrow Island

Shore Birds - North

Author: Chris Surman	Date : 30/8/2002	DRAWING No CHE014_21.apr [Shore Birds - North Barrow]
Drawn By: Craig Richards (NGIS)		

APPENDIX F

PRELIMINARY VEGETATION AND FLORA SURVEY OF PROPOSED GORGON DEVELOPMENT BARROW ISLAND, OCTOBER 2002

(ASTRON ENVIRONMENTAL)

REVISION STATUS

REVISIONS						
Rev	**Date**	**Description**	**Originated By**	**Checked By**	**Director's Approval**	**Client Rep.**
			Name	**Name**	**Signature**	
A	02/09/02	Draft Issued for Comment	V. Long	J. Kruger		Sean Finn
B	13/09/02	Draft Issued for Comment	V. Long	J. Kruger		Sean Finn
C	24/10/02	Draft Issued for Comment	V. Long			
0	11/11/02	Issued for Information	V. Long	P.Long		Sean Finn
1	24/01/03	Issued with Minor Edits	J. Kruger	J. Kruger		Sean Finn

Astron
ASTRON ENVIRONMENTAL
ASTRON ENGINEERING PTY LTD
A.C.N. 009 304 634

Report Reference: 2706-RV-01

Report Parameters	
Text	Word 2000
Referencing	Harvard
Text File	J:\Reimbursible\BBG 2700\2706 Gorgon Project Barrow Is\2706rv01FINAL VERSION - 2003.doc
Figures	Astron Pipeline GPS & Key fig BWI.F1 and Astron Plantsite GPS & Keyfig BWI.F2

Checking Status	
Text	IR
Figures	IR
Tabulations	IR
Calculations	NR
Statistics	NR

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Gorgon Gas Development
PRELIMINARY VEGETATION AND FLORA SURVEY OF PROPOSED GORGON GAS DEVELOPMENT, BARROW ISLAND

1 VEGETATION

1.1 EXISTING ENVIRONMENT

1.1.1 Historical Overview – Vegetation

Numerous studies of the vegetation of Barrow Island have been made, generally in relation to fauna and fauna habitat, and landform and soils, but also to flora and revegetation studies. All studies concur that the vegetation is dominated by *Triodia* hummock grassland (*including T. epactia, T. angusta and T. wiseana*) with scattered shrubs. Barrow Island is included in the Fortescue Botanical District, a subdivision of the Eremaean Botanical Province (Beard 1980). The pre-dominance of the families such as *Poaceae* (grasses), *Chenopodiaceae* (chenopods), *Papilionaceae* (peas), *Malvaceae* and *Asteraceae* (daisies) indicate the Eremaean nature of the Island. The dominant floristic components of the vegetation, namely *Triodia* and *Acacia* are typically Eremaean (Mattiske 1997).

Trudgen (1989) reported a correlation between certain floristic components of the Barrow Island vegetation with that of the Cape Range area. Surveys and studies conducted by the author over a period of more than 15 years on most islands off the North West Shelf, show little correlation between the vegetation types on those islands and Barrow Island. Those studies cover over 35 islands in the vicinity and, except for the vegetation found on coastal dune areas, it appears that Barrow Island, supports vegetation that is quite unique in terms of offshore islands. This is undoubtedly due to the fact that Barrow has been isolated from the mainland by rising sea levels and is similar in soils, geology and topography to the adjacent Cape Range area.

Eight major vegetation units are recognised for Barrow Island (Table 1). These were defined on the basis of dominant plant species and associated landform and soils (Butler 1970, Buckley 1983, WAPET 1988). These eight units were expanded into 34 “plant communities” based on the main landforms, soils, dominant and other indicator species (Mattiske 1993). These are presented in Appendix 1. Subsequent to this, Astron Environmental (Astron) mapped the northern portion of Barrow Island for Gorgon Australia LNG. Ground truthing the entire area allowed for a high level of detail resulting in an additional nine vegetation communities to those already described by Mattiske (Astron 1997).

Table 1: Summary of Habitat and Vegetation Units on Barrow Island (from Butler 1970; and Buckley 1983)

Habitat Units	Larger Scale Vegetation Unit	Smaller Scale Vegetation Unit
White sand foredune	*Spinifex longifolius* assemblage	*Ipomoea pes-caprae* and *Salsola kali* on strand line, with *Spinifex longifolius* on white foredunes.
Red sand dunes	*Triodia epactia* assemblage	*Triodia epactia* with *Acacia coriacea* and *Scaevola cunninghamii.*
Limestone ridges	*Triodia wiseana* assemblages	1. *Triodia wiseana* with *Ficus platypoda, Melaleuca cardiophylla* and mixed shrub species on ridges and caprock plateaus. 2. *Triodia wiseana* with mixed shrub species on

Habitat Units	**Larger Scale Vegetation Unit**	**Smaller Scale Vegetation Unit**
		lower ridges and slopes with limestone rubble. 3. *Triodia wiseana* with mixed shrubs on steep gullies and limestone solution hollows. 4. *Triodia wiseana* with emergent *Eucalyptus xerothermica* (ms). 5. Mixed *Triodia wiseana*, *T. angusta* and *T. epactia* on limestone ridges, white and red sands.
Clay pans	Mixed forb assemblages	1. *Sporobulus australasicus* and mixed herbs on red sands and clayey soils. 2. Mixed herbs with *Streptoglossa bubakii* and *Pterocaulon sphacelatum* on scalds and flood channels.
Red earth creekbeds	*Triodia angusta* assemblages	1. *Triodia angusta* on narrow dissecting water-courses in upland limestone. 2. *Triodia angusta* and *Gossypium robinsonii* on broader flat floors. 3. *Triodia angusta* with *Acacia bivenosa* on extensive lowland plains. 4. Mixed *Triodia angusta-T. pungens* with *Acacia coreacea* on near coastal sand plain. 5. *Triodia angusta* with *Erythrina vespertilio* in near coastal sands. 6. *Triodia angusta* with *Acacia victoriae* on red sands.
Tidal muds	Mangroves	*Avicennia marina* and chenopods in mud pockets and flats swamped by sand.
Coastal rock substrates	Mixed grass/herb/shrub assemblages	1. *Triodia epactia* and *Capparis spinosa* on coastal limestone. 2. *Triodia angusta* and *Frankenia pauciflora* on exposed cliffs. 3. *Frankenia pauciflora* on exposed headlands. 4. *Frankenia pauciflora*, *Spinifex longifolius* and *Acacia bivenosa* on strandline of pebble beaches. 5. *Frankenia pauciflora* and chenopods on low coastal limestone.
Salt flats	*Halosarcia* assemblage	*Halosarcia* spp. And chenopods on salt flats.

1.2 HISTORICAL OVERVIEW – FLORA

As a result of flora surveys by Buckley (1983), Trudgen (1989) and EM Mattiske and Associates (1993; 1997), a total of 350 vascular plants representing 64 families have been recorded on Barrow Island. Members of the Poaceae (grasses) family, with 52 species in 26 genera, are the most well represented, followed by Papillionaceae (peas) with 30 species, Asteraceae (daisies) with 25 species and both Malvaceae and Chenopodaceae (chenopods) with 24 species each. Buckley (1983) who conducted a brief review of the Island's flora in comparison with the mainland, found that species occurring on Barrow Island were generally considered to be either cosmopolitan species or well represented regionally. The number and diversity of genera and species recorded indicates the floristic richness of the Island. Many plants have not been determined at species level.

1.2.1 Priority Species

One species, *Corchorus interstans* is of conservation significance. *C. interstans* is listed on CALM's *Declared Rare and Priority Flora List* (January 2000) as a Priority 3 species (taxa which are known from several populations, at least some of which are not believed to be under immediate threat). *C. interstans* has also been collected from the Exmouth area. (Astron 2001).

1.2.2 Rare Flora

No Rare Flora as listed in the *Commonwealth Wildlife Conservation (Rare Flora) Notice, 1999*, (*Wildlife Conservation Act 1950*) or the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC) is known to occur on Barrow Island.

1.2.3 Species Needing Special Attention

Mattiske (1993b) has reported 27 species which are considered as geographically or habitat restricted and/or requiring further research to determine their status on Barrow Island. Details of each of these species are given in Table 2 below.

Table 2: Species Identified as Needing Special Attention on Barrow Island

FAMILY	GENUS SPECIES
POACEAE	*Dichanthium sericeum* subsp. *humilis*
	Sporobolus mitchelli
	Whiteochloa airoides
MORACEAE	*Ficus opposita* var. *micracantha*
	Ficus virens var. *virens*
PROTEACEAE	*Grevillea leucadendron*
	Hakea lorea (ex suberea)
SANTALACEAE	*Santalum murrayanum*
CHENOPODIACEAE	*Dysphania kalpari*
	Halosarcia indica subsp. *Leiostachya*
LAURACEAE	*Cassytha capillaries*
MIMOSACEAE	*Acacia cowleana*
	Acacia inaequilatera
	Acacia synchronicia
PAPILIONACEAE	*Erythrina vespertilio*
	Isotropis atropurpurea
	Cullen patens
EUPHORBIACEAE	*Euphorbia* sp.
	Mallotus disperses
MALVACEAE	*Abutilon otocarpum*
	Gossypium australe
	Hibiscus sturtii var. *platychlamys*
	Sida micracantha
VIOLACEAE	*Hybanthus aurantiacus*
MYRTACEAE	*Eucalyptus xerothermica* ms
	Melaleuca cardiophylla
SCROPHULARIACEAE	*Stemodia glabella*

1.2.4 Weed Species

Thirteen weed species have been recorded on the Island, as presented in Table 3.

Table 3: Weed Species Recorded on Barrow Island

FAMILY	GENUS SPECIES
POACEAE	*Cenchrus ciliaris* (Buffel grass)
	Cynodon dactylon (Couch grass)
POLYGONACEAE	*Emex australis* (Doublegee)
AMARANTHACEA	*Aerva javanica (2002)* (Kapok bush)
MALVACEAE	*Malvastrum americanum* (Spiked malvastrum)
PASSIFLORACEAE	*Passiflora foetida* var. *hispida* (Wild passionfruit)
MYRTACEAE	*Eucalyptus gomphocephala* (native to southwest Western Australia) planted around oval and offices.
GENTIANACEAE	*Centaurium erythraea* (Common centaury)
SOLANACEAE	*Solanum nigrum* (Blackberry nightshade)
ASTERACEAE	*Arctotheca calendula* (Cape weed)
	Conyza albida (2001) (Tall Fleabane)
	Pseudognaphalium luteoalbum (Jersey cudweed)
	Sonchus oleraceus (Milk Thistle)

2 VEGETATION AND FLORA – PROPROSED GORGON GAS DEVELOPMENT AREA

2.1 OVERVIEW OF GORGON SURVEY

A vegetation survey of the proposed Gorgon gas development area was conducted by Astron Environmental (Astron) between 12-16th August 2002. Assessment of the vegetation was made in relation to the previous mapping of vegetation on Barrow Island by Mattiske (1993), which is incorporated into the ChevronTexaco Geographic Information System

Mattiske (1993) described and mapped the broadscale descriptions of 34 prevailing vegetation types occurring on Barrow Island, to a level of detail commonly referred to as vegetation formations (vegetation groups with common structure). Ultimately, the conservation significance of vegetation within the proposed development area needs to be assessed at the level of vegetation associations (groups of plants with similar structure and dominance) and plant communities (groups of plants with similar structure, species dominance and floristic composition). Mattiske's mapping was based on aerial photographic analysis supported by limited field survey, which did not support descriptions to association or community level. Additionally, vegetation on Barrow Island is mostly dominated by *Triodia* hummock grassland with varying emergent shrubs, usually with low foliar cover compared to the *Triodia*. This means that while the stands of vegetation in the area mapped would belong to a range of formations, they would be very difficult to distinguish via aerial interpretation, even at the formation, let alone association, level.

Astron Environmental's survey for the Environmental, Social and Economic review of the proposed Gorgon gas development (ESE Review) described the vegetation associations (as per Specht as modified by Aplin, 1979) within the proposed plant site area and pipeline corridor. The survey was not comprehensive, due to time limitations, and not all areas were surveyed. Whilst the results this work supports a preliminary assessment of the conservation values of the vegetation in these areas, as provided hereunder, more detailed vegetation surveys are required to complete this assessment at the level of vegetation associations and plant communities. In particular, vegetation associations occurring within the proposed development area and having restricted distributions elsewhere on Barrow Island will need to be accurately mapped within an Island-wide perspective. It is anticipated that the Gorgon Venture would undertake detailed mapping and assessment as part of the formal environmental review of the proposed development, if the Government approves the proposed development to proceed to detailed evaluation.

2.2 RESULTS OF SURVEY

2.2.1 General Overview

Six broadscale vegetation types were identified for the Gorgon gas development study area. These include:

- Coastal dunes with beach spinifex grassland and scattered shrubs.
- Coastal limestone with open dwarf shrubs and scattered hummock grasses.
- Coastal plains with shrubland to heath of *Acacia* shrubs and mixed hummock grassland.
- Broad, shallow valleys and basins with shrubland and mixed hummock grassland.
- Undulating limestone hills with scattered low trees, shrubs and hummock grassland.
- Drainage lines and zones with shrubs over hummock grassland.

Although these six broadscale vegetation types extend throughout the majority of Barrow Island, a diverse range of key component species has been identified within each type.

2.2.2 Vegetation Present

The thirteen Mattiske vegetation formations mapped within the proposed Gorgon gas development area were ground-truthed by Astron during the vegetation survey. Of these, 6 (L9, F1, L7, L3, V1, D2) are found beneath the plant footprint, 12 within the adjacent southern area (L1, L3, L7, L9, F1, V1, D1, D2, C1, C2, C3, C5) and 10 along the pipeline corridor (V1, L1, L3, L4, L7, L9, D2, C1, C2, C5) . Within these broadscale units, 38 vegetation associations were described. These are presented in Appendix 2. These descriptions were based on a total of 40 samples made within 50 m x 50 m quadrats. Previous Astron descriptions (Astron 2002) were utilised in order to maintain consistency with past surveys.

A total of 153 GPS points were taken at which vegetation was described (using Specht as modified by Aplin, 1979), according to descriptions made at the sample sites, and existing descriptions. Each of these vegetation descriptions relates to the location at which it was recorded, but does not indicate the area occupied by each vegetation type. Considering that the time period available for survey was not sufficient to determine boundaries of the vegetation in each case, a series of closed polygons could not be drawn. The points are presented on Figure 1.

2.2.3 Discrepancies Between Mapping and Actual Vegetation Present

Discrepancies between the vegetation as it is currently mapped and what is actually present in the field were frequently found in all areas surveyed. Such discrepancies have been found previously during other island surveys conducted by Astron (2001, 2002). Generally, discrepancies are found in L7, V1 and L3 vegetation, although this varies as the results for the survey area indicate.

2.2.4 Significant Vegetation as per Mattiske (1993)

Two of the vegetation units described by Mattiske are considered as having conservation value, because their key component species have been identified as having conservation significance. These include:

L7 Hummock Grassland of *Triodia wiseana* with dense pockets of *Melaleuca cardiophylla* on limestone ridges, and

L5 Hummock Grassland of *Triodia wiseana* with emergent *Hakea lorea* (was *suberea*) on limestone ridges. This latter formation was not actually mapped but was identified during the survey as being present beneath the plant site footprint and in the adjacent area.

2.2.5 Significant Vegetation as per Astron (2002)

An additional association described during the current survey as occurring within the L7 formation is considered to have conservation significance. Details of this unit, L7d, are given below.

L7d Scattered (<2%) to Open (2-10%) Tall Shrubland of *Hakea lorea* over Low Shrubland (10-30%; 1 m) of *Melaleuca cardiophylla*/*Acacia bivenosa* over Mixed Hummock Grassland (30-70%), sometimes Dense (90%) of *Triodia wiseana/T. angusta*.

Vegetation association L7d is considered to have conservation significance as a result of the fact that its key components, *Hakea lorea* and *Melaleuca cardiophylla*, have been highlighted as some of the species needing special attention on Barrow Island (Mattiske 1993). It is worth noting that the occurrence of both of these species within this vegetation association is consistent throughout the 17 samples recorded. The association is also unusual in the fact that it is not only found on the limestone hillslopes (typical *Melaleuca cardiophylla* habitat) but also, uniquely, on the red earth flats. The frequency of this association is unknown in other parts of the Island and no accurate qualitative comment on its existence elsewhere can be made. It was recorded during this survey in both the nominated plant site footprint and in the area to the south of the plant site.

2.2.6 Areas of Previously Disturbed Vegetation within Development Area

It was apparent that a reasonably large area has been disturbed in the past beneath the proposed plant site footprint. This includes not only the more obvious drainage line that traverses the nominated plant site, but also a reasonably large area to the north west of the terminal tanks, mapped by Mattiske as L3 and V1. This observation was later confirmed by Mr Harry Butler (pers comm). The latter area is now generally well vegetated and previous disturbance would probably only be detectable by those knowledgeable of colonising species and their dominance over the original floristic components of the habitat. Astron described associations L3a, L11a, V1b within these two formation types. These descriptions reflect dominance of colonising *Petalostylis labichoides* and *Stylobasium spatulatum* with pockets of *Triodia angusta* typical of that found on disturbed areas.

2.3 RESULTS OF SURVEY – FLORA

Flora was recorded in each of the 40 sample quadrats, as well as opportunistically within each vegetation unit. Flora that could not be readily identified in the field was collected for later identification. Some flora, such as the *Corchorus* species were collected from a number of locations due to the fact that there remains some uncertainty as to the identification of species within this genus.

2.3.1 Priority Species

The sole known CALM Priority listed species on the Island, the Priority 3 species *Corchorus interstans*, was found relatively frequently throughout the study area. Collections of three *Corchorus* species were made, however, for further investigation. Two authorities on *Corchorus* species, Ms. Barbara Rye of the WA Herbarium and Mr David Halford, Herbarium of Queensland remain uncertain of the actual identifications of the Barrow Island *Corchorus* species. Currently it would appear that the following four *Corchorus* species are present within the surveyed area:

Corchorus interstans, Corchorus aff. *walcottii, Corchorus* sp. *hamersley, Corchorus parviflorus.*

2.3.2 Species "Needing Special Attention" (Mattiske 1993)

Nine of the species listed by Mattiske (1993b) as Needing Special Attention were found during the survey. These included:

Whiteochloa airoides
Ficus virens var. *virens*
Hakea lorea (was *suberea)*
Dysphania kalpari
Euphorbia sp A
Mallotus didmochryseus
Abutilon otocarpum
Hibiscus sturtii var. *platychlamys*
Melaleuca cardiophylla
Hybanthus aurantiacus

2.3.3 Weed Species

One weed species, *Malvastrum americanum* recorded from Terminal Creek, was observed during the current survey.

2.3.4 Species Recorded This Survey "Not Recently Recorded" – Mattiske 1993

Four species noted by Mattiske (1993) as "Not Recorded Recently" (i.e. not recorded by Mattiske but recorded at an earlier date by Butler or Buckley) were recorded during this survey. This may indicate that these species do not commonly occur on Barrow Island, although as noted previously, the 1993 Mattiske mapping did not involve extensive ground truthing. These include:

Chenopodium melanocarpum
Chrysopogon fallax
Euphorbia drummondii subsp *drummondii*
Jasminum didymum subsp *lineare*

3 DISCUSSION

3.1 VEGETATION PRESENT

The six broadscale vegetation types based on habitat and landform extend throughout the majority of Barrow Island. However, a wide range of vegetation formations and associations, including a diverse range of key component species, has been identified within each type. Mattiske identified 34 vegetation formations for Barrow Island, only 13 of these are represented within the Gorgon gas development area. Of these thirteen vegetation formations, six are found beneath the plant footprint, 10 along the pipeline corridor and 12 within the adjacent southern area.

3.1.1 Qualitative Assessment of Mattiske Vegetation Formations

A qualitative assessment of the Mattiske vegetation formations, indicating their conservation value on a local scale (i.e. on Barrow Island) is given below. These are based on the observations of Astron's botanists, Vicki Long and Julian Kruger, during previous surveys on Barrow Island.

L1 A small area of L1 occurs within the adjacent southern area and extensive areas occur along the pipeline corridor towards the west coast. L1 is well represented elsewhere, particularly along the western side of Barrow Island. A qualitative assessment would indicate that disturbance of L1 habitat for the pipeline will not cause significant impact providing knowledgeable management of installation is heeded. Older pipelines through L1 vegetation evidence the fact that regrowth can be successful if rootstock is not removed and providing pockets of low woodland (*Ficus platypoda/Pittosporum phylliraeoides*) are avoided (V. Long pers obs).

L3 L3 is represented beneath the proposed gas processing facility footprint, along the pipeline corridor and within the adjacent southern area. L3 is represented on a significantly smaller scale than is indicated by the Mattiske mapping in each of these areas. (Six of eight records taken within L3 as indicated beneath the gas processing facility footprint, were not L3). Although extensive areas of L3 are mapped for Barrow Island, ground-truthing has indicated that a significant proportion of the L3 mapped is incorrect (Astron 2000, 2001, 2002). A qualitative assessment indicates that L3 occurs randomly over the Island but its representation is significantly reduced from what is currently indicated and the L3 that actually occurs within the gas processing facility footprint is in proportion to this Island-wide reduction. The removal of this vegetation type, however, will not significantly impact the vegetation type.

L4 L4 occurs along the pipeline route. This vegetation type (with *Acacia pyrifolia* as its key species) is restricted to a relatively small area in the centre of the Island. Although the population is restricted in its distribution on Barrow Island, *Acacia pyrifolia* is known to regenerate well (V Long pers obs) and a qualitative assessment would indicate that the relatively narrow, linear, disturbance for pipeline installation will not be significant

L7 L7 occurs beneath the gas processing facility footprint, along the pipeline and within the adjacent southern area. This vegetation type is considered to be "significant" on Barrow Island because it's key component species, *Melaleuca cardiophylla* is one of those highlighted by Mattiske as "Needing Special Attention". *M. cardiophylla* populations occupy significant areas of limestone slope in the central and eastern sections of the Island. These are areas where ChevronTexaco oil operations occur. The species was highlighted as in need of special attention because it apparently does not regenerate well after disturbance (M.White). Although dwarfed, clustered foliage does emerge from rootstock, it does not appear to readily progress past this stage (V. Long, pers obs). Frequently, L7 is inaccurately mapped over the much of the Island (Astron, 2000, 2001) and this holds true in the Gorgon gas development area. However, a qualitative assessment is that the L7, *Melaleuca cardiophylla* vegetation type is frequently represented on the Island and its removal due to the proposed development will not significantly impact the Island population.

It is noteworthy however, that an association described within the L7 formation, L7d, see Section 3.1.3 below, should be given special consideration because it is considered to have conservation significance and the range of its occurrence is not known.

L9 L9 is represented beneath the gas processing facility footprint. The majority of the L9 vegetation mapped occurs relatively frequently along the eastern and southern coastlines. The area of L9 that occurs beneath the gas processing facility is actually much reduced from the area mapped. (5 of the 6 samples taken within L9 were not L9). It may be that L9 vegetation is not as widely occurring as mapped over the Island generally. According to the current mapping, however, the removal of this vegetation type will not significantly impact the vegetation type.

F1 F1 occurs beneath the plant site gas processing facility and within the adjacent southern area. The description for F1 "Hummock Grassland of *Triodia angusta* on red earth flats and drainage lines" did not apply to any, of the sites sampled in the areas mapped as F1, with the exception of one very small area within the adjacent southern area. Areas of F1 are mapped on the eastern side of the Island. The author has observed elsewhere on Barrow Island, broad drainage zones of F1 that can extend to 100 –150 m wide, but rarely larger areas of pure *T. angusta*. Most of the F1 area surveyed had shrub cover, in some areas this was dense. Broad areas of this vegetation type are considered to occur infrequently.

V1 V1 occurs beneath the gas processing facility footprint, along the pipeline corridor and within the adjacent southern area. A great deal of variation was found within this formation. Dominant shrub species varied and their cover ranged from "emergent" as described, to moderate shrubland (this was often the result of previous disturbance, barely detectable now, of valley slopes). V1 as mapped was found to include large areas of V2 and also L7, L1, L4, L11 etc. A relatively significant area of the Island is mapped as V1 but ground-truthing (Astron 2000, 2001, 2002) has indicated that the area of actual V1 as described more varied than the description reveals. A qualitative assessment would indicate that most of the vegetation associations described within V1 during this survey are found elsewhere except for L7d, which was recorded frequently within the mapped V1 both in the nominated plant site and the adjacent area to the south.

D1 Three small areas of D1 vegetation occur along drainlines within the adjacent southern area. One of these (Terminal Creek) has been heavily disturbed and for the majority of the area, no longer represents D1. A qualitative assessment indicates that D1 vegetation is more frequently represented on the Island than the current map would indicate. The type of shrub cover within D1 habitats needs to be carefully considered when assessing the conservation value of this vegetation type. Dense shrub cover of colonising species, (generally indicating borrowing from the drainline) have less conservation value than original shrub cover – although both have ecological value in terms of soil stability, flow dispersion etc).

D2 D2 drainlines, creeklines (gas processing facility and pipeline) and a broad drainage area (adjacent southern area) occur within the development area. A large proportion of D2 habitat, (drainage line) within the development area, and specifically within the gas processing facility footprint, has been previously borrowed (i.e. the alluvial topsoil found in drain lines has been frequently removed for other purposes, leaving the secondary layer of stony material). Regrowth generally indicates that the colonising species, *Triodia angusta* has regenerated reasonably well in disturbed drainage lines after initial disturbance. Regrowth of colonising shrub species in many instances more appropriately fits the D1 description. An extensive area of D2 indicated south of the gas processing facility footprint, within the adjacent southern area, actually supports a dense heath of shrubland which does not match the D2 description. It is considered that "pure" D2 type vegetation (i.e. undisturbed) is relatively rare on the Island and disturbance to it should be avoided.

C1 C1 is strandline/foredune vegetation that occurs on beach sands within the adjacent southern area and on the western-most portion of the pipeline corridor. Very narrow strips of C1 occur intermittently around the perimeter of the Island. Because dune vegetation is the stabilising factor on erodable beach sands, its disturbance or removal requires very careful management including minimising disturbance, active rehabilitation (temporary stabilising) and (seeding and planting).

C2 C2 occurs within the adjacent southern area and along the pipeline on the western coastline. C2 vegetation is not abundant on the Island. The key species, *Acacia coriacea* is known to not regenerate readily (Astron 2000) and once removed or impacted is quickly replaced by the more aggressive *Acacia bivenosa* (Astron 2001). Additionally, a large proportion of the C2 vegetation along the eastern coastline between the accommodation units and the terminal tanks has died within the past two years, reducing this vegetation type quite significantly. Based on this knowledge, impact to the vegetation type should be avoided.

C3 C3 is mapped within the adjacent southern area. It was not found during the survey, but time limited intensive searching.

C5 Very small areas of C5 occur on the coastline within the adjacent southern area and on the western coast within the pipeline. The coastal limestone is a harsh, exposed environment in which only highly adaptive species can survive. Once disturbed, regeneration of this vegetation type is poor (Astron 2001). It is considered that vegetation within this habitat is vulnerable and impact to it should be minimal.

3.1.2 Assessment of Vegetation Rarity

There are at least three basic variables, which affect the assessment of vegetation rarity (Trudgen 2002). These are:

1. Fineness of definition
2. Boundary of assessment area
3. Area of vegetation

Fineness of definition relates to the level at which the vegetation is to be assessed (i.e. whether at the very broad scale or formation level, at association level or at the very detailed community level). An area may be considered to be common at a very broad (formation) level, but the same area may be considered less common at a more detailed level (association or other). If assessment at the formation level is made it is likely that the real rarity of an area of vegetation may not be actually assessed. When broad areas only are considered, small, unusual vegetation types will be overlooked and consideration of this needs to be made. The real rarity of vegetation is a function of what actually occurs in the field rather than the rarity of abstract units defined at broad levels (Trudgen 2002).

Boundary of assessment area relates to the area in which the vegetation is to be assessed, that is an area of vegetation may appear to be common if a small area of assessment if used (locally common) but rare when a wider area is used (regionally rare). When assessing the rarity of vegetation, the boundary selected must have some meaning in relation to the distribution of the vegetation type. These boundaries may relate, at a broad level to a botanical district, or to geomorphological or geological boundaries. To obtain a realistic appraisal, a reasonably broad area must be assessed. If the vegetation covers many hundreds of thousands of hectares, it is much less likely to be rare than if it covers a few hundred hectares.

Further, the current state of disturbance, and likely future disturbance is an important consideration. In this regard, proportions, rather than absolute areas, are also relevant. For example, destruction of 90% of a vegetation unit comprising 200 ha, is more serious than destruction of 90% of a unit comprising 100,000 ha.

The question of what absolute area is appropriate appears to be qualitative rather than quantitative at this stage. Two works which consider the question are:

(a) The International Union for the Conservation of Nature (IUCN). Trudgen (1995) in his work for the Australian Heritage Commission utilises the IUCN minimum area for protection of an ecosystem.

(b) English and Blyth (1997) developed "categories for assigning conservation status to ecological communities".

Trudgen's definition of rare vegetation is that for which:

1. Original extent < 2000 ha
2. Original extent 2000 ha – 20,000 ha <u>and</u> less than 30% surviving
3. Original extent 20,000 ha – 100,000 ha and extent remaining is less than 30% - 10% respectively (ie. <6000 – 10,000 ha).
4. Original extent ≥ 100,000 ha and less than 10% surviving (based on the IUCN recommendation of 10% as the <u>minimum</u> area recommended for protection of an ecosystem or vegetation type).

English and Blyth also utilize the 90% destruction threshold when their definition of "Critically Endangered" vegetation is given:

1. Range / Area / Occurrence has been reduced by at least 90% <u>and</u>

(a) Complete destruction is imminent in five years <u>or</u>
(b) The community is so modified it is unlikely to be rehabilitated

2. Range / Area / Occurrence is limited <u>and</u>
   (a) Area is subject to threatening process, with total destruction likely in five years <u>or</u>
   (b) There are few occurrences, each of which is extremely vulnerable to threatening process <u>or</u>
   (c) There are many occurrences, but total area is small and extremely vulnerable to threatening process.

3. Range / Area / Occurrence is highly modified but may be rehabilitated if work begins in next five years.

Based on the IUCN definition, all but three (L1, L3, and V1) vegetation formations on Barrow Island are "rare", being less than 2000 ha in size. In consideration of this, and the difficulties with their true distribution and composition noted above, it is prudent to ensure a reasonable proportion of each such formation is conserved. The 90% destruction threshold of English and Blyth, in other words is probably inappropriate. However, even reducing this value to 30% results in none of the vegetation on Barrow Island being in danger of becoming "rare". Nevertheless, according to their criteria, on a regional scale, it may be considered that the vegetation on Barrow Island is rare because of its limited range/area/occurrence. This classification applies to those vegetation types where, "there are many occurrences but total area is small" (i.e. both locally on Barrow Island and in a regional context in relation the Pilbara region, where few comparisons have been made). This, coupled with the lack of detailed information for Barrow Island (i.e. lack of comprehensive knowledge of the **actual** distribution of vegetation associations), means that some vegetation can potentially be classified under English and Blyth component 2(c) : as "extremely vulnerable to threatening processes".

3.1.3 Significant Vegetation as per Mattiske and Astron

Previous surveys conducted on Barrow Island by Astron (2001, 2002) indicate that areas of vegetation dominated by *Melaleuca cardiophylla* (L7) are often incorrectly mapped. Despite that, it is considered by the author that this vegetation formation, as it is broadly described, occurs relatively frequently over the Island. Nevertheless, considering that the proposed development will impact on large areas of this species, trials should be conducted to establish the propagation and regeneration potential of *M. cardiophylla* after disturbance. Astron recorded the potentially 'Restricted' vegetation association, L7d (*Melaleuca cardiophylla* and *Hakea lorea* over hummock grassland), in both the nominated plant footprint area and the adjacent area to the south of the proposed gas processing facility site during this survey. However, the occurrence of this vegetation association on both limestone ridges **and** red earth flats areas in areas remote from the plant site boundary should be quantified.

The vegetation formation, L5, with key component species *Hakea lorea* was identified as being present on a small area beneath the gas processing facility footprint. This vegetation formation is only mapped in relatively small areas (as it is indeed found on the Island) and would be more accurately termed an association or even a community within a larger vegetation unit. A qualitative assessment would indicate that populations of *Hakea lorea* are generally restricted in size but occur with sufficient frequency over the Island so as not to be threatened by this proposed development.

3.1.4 Areas of Previously Disturbed Vegetation

The disturbed area identified to the north-west of the terminal tanks in addition to the significantly borrowed creek and drainlines, totals a significant area of previous, though revegetated, disturbance. If the Gorgon gas development is to be placed on Barrow Island, it would be favourable to remove previously disturbed vegetation/landform that is now at variance with the original, rather than impact pristine vegetation.

3.1.5 Priority Species

The removal of core Priority 3 species, *Corchorus interstans*, from the development area is not considered to be a significant impact due to its widespread representation on Barrow Island. The species has also been observed to regenerate successfully on rehabilitated sites (V. Long pers.obs, J. Fitzpatrick pers.com). However, its successful regeneration on any rehabilitated sites within the Gorgon gas development area should be monitored.

3.1.6 Species Needing Special Attention

The criteria on which the 27 species are identified by Mattiske (1993) as “needing special attention” were based on:

- The number of plant collections
- The number of known populations on the Island
- The number of restricted habitats
- The lack of information (poorly known species) on species
- Ability to regenerate following disturbance

These are sound criteria for conservation assessment of flora and the identification of 27 species nominated by Mattiske as “needing special attention”, based on these, is reasonable. However it should be remembered that 12 of these species are annuals or are weakly perennial (i.e. they become dormant during periods of dry) and are unlikely to be readily found unless conditions are favourable. It should also be noted that the total field survey time expended during the Mattiske work was 498 ha/person/day. This is too great an area for detailed mapping and flora record coverage. A more realistic figure is less than 100 ha/person/day as was expended in the recent Burrup vegetation mapping and flora survey. (Actual Burrup vegetation survey coverage was 74ha/person/day).

We believe it is unrealistic to expect that a comprehensive flora search can be conducted when each botanist must cover 498 ha per day, especially as other activities were being undertaken. While Mattiske also considered records from earlier surveys, conducted by Butler and Buckley, it is considered that the conservation status of the flora on Barrow Island needs further investigation.

Species “Needing Special Attention” recorded during the field survey for the Gorgon gas development included the following.

Table 4: Species Needing Special Attention (Mattiske 1993) Recorded within the Gorgon Gas Development Site.

FAMILY	COMMENT
POACEAE	
Whiteochloa airoides	**Mattiske comment:** On western coastal area and inland upland area. Appears that this species may be grazed in some areas and may, therefore, be more widespread. Needs more research. **Gorgon gas development:** A small population was recorded behind Flacourt Bay. Considered by Astron to be rarely occurring on Barrow Island. A coastal species, its occurrence "inland upland" would be unusual.
MORACEAE	
Ficus virens var. *virens*	**Mattiske comment:** Known from both the cliff faces near E and F blocks and limestone fault and near Biggada Creek on Y53. Appears to occur on edges of central limestone plateau. **Gorgon gas development:** scattered trees in the vicinity of Flacourt Bay; found as scattered individuals, generally but not always near coast, during previous Astron work
PROTEACEAE	
Hakea lorea (was *suberea)*	**Mattiske comment:** Scattered populations in the middle section of the Island. **Gorgon gas development:** Gorgon development is mid-Island, including the area where Mattiske indicates this species to be found. It is relatively frequent within the plant site and adjacent southern area. Small populations and scattered individuals have been found from development area south to M Station during Astron surveys.
CHENOPODIACEAE	
Dysphania kalpari	**Mattiske comment:** At northern end of island in sand dunes, Terminal Creek and in gully east of F24. Needs further research. **Gorgon gas development:** Found on coastal limestone beneath gas processing facility footprint. Found once only during previous Astron surveys on coastal limestone, south end of Island. A small inconspicuous, annual plant easily overlooked.
EUPHORBIACEAE	
Euphorbia sp *A.*	**Mattiske comment:** Found near entrance to Biggada Creek. Needs further research and in meantime entrance to Biggada Creek needs protection. **Gorgon gas development:** Found once only along Terminal Creek, an undescribed *Euphorbia* matched against the Mattiske specimen lodged in the Pilbara Regional Herbarium. An unusual annual, easily overlooked.

FAMILY	COMMENT
Mallotus didmochryseus	**Mattiske comment:** Localised in occurrence, near Y53 and patch of *Eucalyptus xerothermica* ms in Y block. Needs further searching to locate more populations. **Gorgon gas development:** This species was NOT found within the proposed Gorgon gas development area. The very similar *M. nesophilus* was found, but it occurs relatively frequently with *Ficus brachypoda* over the Island.
MALVACEAE	
Abutilon otocarpum	**Mattiske comment:** Only collected in Terminal Creek. Needs further research. **Gorgon gas development:** Found in Terminal Creek. Not found during any previous Astron surveys. A weakly perennial shrub that becomes dormant during periods of insufficient rainfall.
Hibiscus sturtii var. *platychlamys*	**Mattiske comment:** Located on edges of red sand areas and in gullies on western and northern edges of the Island. **Gorgon gas development:** One plant only found on red sand area beneath gas processing facility site. Not found previously during Astron survey but becomes dormant during periods of dry.
MYRTACEAE	
Melaleuca cardiophylla	**Mattiske comment:** Widespread in central part of Island on upland limestone areas. Apparently difficult to regenerate after disturbance (M White). **Gorgon gas development:** Populations occur within the Gorgon gas development area, although these often differ to mapped areas. Populations elsewhere are widespread. The species has been noted to produce dwarfed, clustered regrowth from rootstock but progress past this stage is rarely observed (V Long pers obs).
VIOLACEAE	
Hybanthus aurantiacus	**Mattiske comment:** Located on a disturbed site near BB52J on northern section of Island. Needs further research to locate more populations. Location on disturbed site may indicate that it is an opportunistic species. **Gorgon gas development:** Two plants found during survey. A relatively inconspicuous plant in *Triodia* on hillslopes, may be overlooked. Found rarely during previous Astron surveys.

3.1.7 Weed Species

Spiked malvastrum (*Malvastrum americanum*) was recorded present in Terminal Creek. It is rated by CALM (1999) as being "Moderate" in terms of its potential to invade and endure. The weed has become naturalised on the Pilbara mainland (S. van Leeuwin, pers com) where it poses less of a threat than in the Kimberley. Dense thickets of spiked malvastrum have been observed obstructing minor drainage lines in the Kimberley (V. Long pers obs) but it is unlikely that this situation would occur on

Barrow Island. Removal of the weed prior to disturbance of the area in which it occurs would help to ensure it will not be spread further.

The potential risk of spreading existing weeds (in particular buffel grass, *Cenchrus ciliaris*), from areas where they occur outside the development area (i.e. from around the airport, accommodation and office areas) into the development site is considered to be very high. Increased foot and vehicular movement from these areas to the development will increase the risk of spread of weeds into the favourable newly disturbed habitat. Buffel grass seed will persist in the soil for many years and ongoing monitoring will be necessary to ensure emergence is detected prior to flowering or seeding.

Quarantine on Barrow Island has always been given a very high priority. Considering the size of the operations on the Island, introduced species to the Island have been minimal, primarily due to the careful and strict quarantine management implemented by Mr Harry Butler. However, despite the strictest quarantine requirements, the introduction of new weeds to the development site remains a high risk and will need to be managed under strict guidelines.

3.1.8 Species Recorded this Survey “Not Recently Recorded” – Mattiske 1993

The four species recorded during the preliminary survey that were not recorded by Mattiske are habitat restricted.

- *Jasminum didymum* subsp *lineare* is a perennial climbing bush, generally found scrambling over low woodland in rock outcrops. It can be inconspicuous unless pockets of vegetation are carefully looked at. It has infrequently been found in pocket vegetation during Astron surveys elsewhere on the Island. It was found in L9 vegetation beneath the proposed gas processing facility footprint.
- *Chenopodium melanocarpum* is an annual, decumbent herb found on coastal areas of C2 (C2a and C2b) during the survey. It was abundant in the area of well drained sands in which it was found, but this may be the only location on the Island where it occurs. It has not been found previously during an Astron survey. It was found in coastal vegetation, mapped as C3, south of the proposed gas processing facility footprint.
- *Euphorbia drummondii* subsp *drummondii* is restricted to coastal limestone. It occurs on C5 areas within the development area. It has been recorded on Boodie Island on coastal limestone by Astron. It also occurs on Varanus Island. It was found in C5 vegetation, on the southern border of the gas processing facility footprint.
- *Chysopogon fallax* is a perennial grass that becomes dormant and dies off down to rootstock when conditions are not favourable. It is easily mistaken for *Sorghum plumosum*. The grass has not previously been recorded during Astron surveys, but these have all occurred during the dry. The grass occurs in small populations on the limestone slopes on Varanus Island. This was recorded in V1 vegetation south of the gas processing facility footprint.

4 IMPACTS

4.1 ACTUAL IMPACTS – PLANT SITE FOOTPRINT

- Six Mattiske vegetation types, containing 25 associations, will be cleared from beneath the plant site and associated infrastructure.
- A potentially restricted vegetation association, described as L7d during the current survey, occurs beneath the plant site and in adjacent areas. This association includes the "significant" (Species Needing Attention) species *Hakea lorea* and *Melaleuca cardiophylla*.
- A portion of vegetation type L7, which includes vegetation associations L7a, L7c, L7d, will be removed. This vegetation association includes the 'Significant' species *Melaleuca cardiophylla*.
- The removal of a number of individuals of the CALM Priority Species, *Corchorus interstans*, will occur.
- A number of 'Significant' (Needing Special Attention) species, as determined by Mattiske (1993), will be removed as a result of development within the gas processing facility footprint. These include *Hakea lorea, Dysphania kalpari, Abutilon otocarpum, Euphorbia sp A.*

4.2 ACTUAL IMPACTS – PROPOSED PIPELINE CORRIDOR

- Nine vegetation formations containing 12 vegetation associations will be removed or disturbed (depending on pipeline installation technique) by the pipeline corridor.
- A portion of vegetation type L7 (including associations L7a, L7c), the key component species of which is the "Significant" *Melaleuca cardiophylla*, will be removed.
- The removal of a number of individuals of the CALM Priority Species, *Corchorus interstans*, will occur.
- A number of 'Significant' species, as determined by Mattiske (1993), will be removed as a result of development within the pipeline corridor. These include *Hakea lorea* and should the alternative pipeline shore crossing be used (north of the current alignment), *Whiteochloa airoides* may be impacted.

4.3 POTENTIAL IMPACTS

Potential impacts associated with the Gorgon gas development (on Barrow Island) include:

- The spread of existing weeds that occur on other areas of Barrow Island (airport, accommodation, offices) to the development site through personnel and vehicle traffic.
- The introduction of new weeds through clothing of personnel, import of equipment, machinery and the like.
- Spread of existing known weed (*Malvastrum americanum)* from the development site into other areas.
- Damage to vegetation by trespass of vehicle or pedestrian traffic.
- Degradation of vegetation causing erosion, particularly of coastal dunes.
- Fire
- Further loss of habitat due to poor rehabilitation success.

5 MANAGEMENT

5.1 OVERVIEW

The existing information, including the results of this survey, does not provide for any definitive assessment of the vegetation types found within the development area. Adequate management strategies, based on more detailed information, should be developed in order to minimise the potential and actual impacts associated with development. These management strategies should be carefully implemented. Management strategies for all areas include the following.

5.2 MANAGEMENT OF ACTUAL IMPACTS

Impact: Loss of Vegetation

Management:

- Obtain quantitative values for the vegetation associations described to date within the study area.

This would involve:

  - Mapping the study area (i.e., defining vegetation associations within enclosed polygons).
  - Surveying and mapping at least two areas (or as many as needed) outside the study.

This would provide:

  - Some (not complete unless the entire Island was surveyed) quantitative information about the frequency of occurrence of these associations elsewhere.
  - Assurance that the 'Significant' vegetation associations found within the study area, for example vegetation association L7d, are represented in an area remote from the study area.

- Should any vegetation within the study area be found to occur infrequently in areas remote from the development, consideration should be given to avoiding it.
- Should avoidance of infrequent vegetation not be possible, consideration should be given to trying to re-establish it in the Island rehabilitation programme. This would include active re-seeding or transplanting of the species involved in the specific vegetation.

Impact – Loss of Restricted Vegetation

Management:

- Quantifying the vegetation present within the Gorgon gas development area. Vegetation within the study area must be quantitatively assessed (through adequate survey) in order to quantify adequate occurrence both within the study area and at remote sites. This is necessary as the results of the current survey indicate that there are inaccuracies in the current mapping.
- The establishment of industry and government guidelines as to what constitutes "restricted" vegetation on Barrow Island. This needs to be done following more detailed field assessment.
- Once a quantitative assessment is made, areas of 'Restricted' vegetation that are found to be of high conservation status should be avoided as far as practical. Should this not be possible, consideration should be given to trying to re-establish them in the Island rehabilitation programme.
- Active revegetation of disturbed areas that are no longer needed after construction should occur. This would involve actively seeding and planting cuttings.
- Seed collection and cutting propagation trials should commence 12 months, minimum, prior to construction.

- Previous surveys conducted on Barrow Island by Astron (2001, 2002) indicate that areas of vegetation dominated by *Melaleuca cardiophylla* (L7) are often incorrectly mapped. Despite that, it is considered that this vegetation type occurs relatively frequently over the Island. Nevertheless, considering that the proposed development will impact on large areas of this species, trials should be conducted to establish the propagation and regeneration potential of *M. cardiophylla* after disturbance.
- The distribution of the potentially 'Restricted' vegetation association, L7d, should be determined in areas remote from the development site footprint. The occurrence of this vegetation association on both limestone ridges **and** red earth flats areas outside of the gas processing facility site boundary should be quantified.
- The removal of core Priority 3 species, *Corchorus interstans*, from the development area is not considered to be a significant impact due to its widespread representation on Barrow Island. The species has also been observed to regenerate successfully on rehabilitated sites (V. Long, pers.obs). However, its successful regeneration on any rehabilitated sites within the Gorgon gas development area should be monitored.
- The remote occurrence of the "Significant" (Needing Special Attention) species, *Abutilon otocarpum*, found only in Terminal Creek at this stage. The presence of this species elsewhere on the Island would need to be determined, or strategies would need to be developed to avoid the population.
- The remote occurrence of 'Significant' (Needing Special Attention) species, as determined by Mattiske (1993), that have been located within the gas processing facility site footprint, and are infrequently located elsewhere (i.e. *Dysphania kalpari* found near the Terminal tanks and at only one other location, *Euphorbia* sp. *A*, found within the development area and by Mattiske near Biggada Creek) should be quantified. This would ensure that the proposed development does not result in the eradication of any species from the Island.
- The loss of fauna habitat with the clearing of vegetation is addressed in the fauna report (see Appendix H).

5.3 POTENTIAL IMPACTS

Potential Impact – Spread of existing weeds

The potential impact of spread of existing weeds on Barrow Island into the development area is a significant one. Although Barrow Island had a weed control programme in place, the risk associated with increased personnel and traffic movement on the Island is high.

- Heightened awareness and recognition of weeds found on the Island should be an important focus of the environmental induction.
- Education of personnel should stress the reasons why weed invasion is not desirable. Graphic examples (of weed invasion in other areas) are helpful tools in developing understanding of the potential problems.
- Constant surveillance should occur for seeds on clothing and,
- On-going monitoring for the emergence of weeds in any new areas should be undertaken.
- Weed recognition should be addressed with pamphlets/posters.

Potential impact: Introduction of new weeds

Management:

- ChevronTexaco and previously WAPET have always maintained strict quarantine procedures and a high level of surveillance for any introduced species. All procedures would continue to apply to all aspects of the Gorgon gas development to ensure the prevention of weed species.
- Education of personnel should include recognition of the fact that seeds and other plant material can be introduced in clothing, in particular socks, and boots. Constant reminders should be made. ChevronTexaco have already taken the initiative and signs in the Karratha airport request that personnel check the clothing they are wearing prior to flying.
- Education of personnel should stress the reasons why weed invasion is not desirable. Graphic examples (of weed invasion in other areas) are helpful tools in developing understanding of the potential problems.
- Weed recognition should be addressed with pamphlets/posters.

Potential impact: Spread of existing known weed on the development to other areas.

The weed species, *Malvastrum americanum* was recorded in Terminal Creek. The deep alluvial silty soils found here are ideal for rehabilitation purposes. Management should include strategies so that the soil can be used for rehabilitation, but in a way so that weed emergence can be controlled and hopefully eradicated. Management should include:

- Removal of all plants prior to any disturbance of that area.
- Topsoil from the area should be contained in an identifiable and well defined area to ensure it is not spread randomly into other areas.
- The topsoil could be used for rehabilitation purposes providing its spread is kept within a well defined area that should be monitored regularly for weed emergence.

Potential impact: Damage to vegetation by vehicle or pedestrian trespass.

Management:

- Vehicle/pedestrian impact can be managed by strict rules ensuring that there is no access beyond well defined lease area boundaries.
- Personnel education as to the value and vulnerability of the vegetation should be a key induction item.
- On-site environmental staff should be constantly vigilant with regard to this issue.
- A commitment to actively revegetate areas of damaged vegetation should be made.

Potential impact: Degradation of vegetation causing erosion

Management:

The risk associated with erosion, due to vegetation removal is highest on the coastal dunes and the sandy coastal flats.

- Disturbance through dunes should be minimised as much as possible.
- Removal of dune sands for trenching or construction should be done so that the deeper sands are stockpiled separately from the topsands. Backfilling should proceed with deeper sands then topsand.

- Seed collection of dune species and propagation of cuttings for revegetation should begin 12 months (minimum) prior to construction.
- Dunes should be stabilised initially with drift fences and erodable matting whilst active revegetation (seeding and planting of cuttings) establishes.
- Monitoring of revegetated dunes should be conducted regularly for a minimum of 10 years or until achievement of completion criteria can be demonstrated.

Potential impact: Fire

Management:
Fire is a potential impact on any construction site.

- Standard company construction procedures to minimise fire risk should be strictly adhered to.

Potential impact : Further loss of habitat due to poor rehabilitation success.

Management:
Rehabilitation success on Barrow Island is yet to be quantified (there is currently a rehabilitation programme being designed to achieve this). However it would appear in many instances, revegetation of disturbed areas with key species from the surrounding habitat is not occurring successfully. Colonising species native to Barrow Island quickly invade disturbed areas, and although they serve the purpose of stabilising soils, the ultimate result is loss of original habitat.

- The results of the ChevronTexaco rehabilitation investigation should be utilised to direct best rehabilitation and revegetation procedures for all disturbed sites.
- Active revegetation should include replacement of key species by seeding and /or establishment of cuttings. This would ensure colonising species would not invade and dominate.
- Collection of seed and propagation of cutting material should begin at least 12 months prior to construction.
- All rehabilitated areas should be monitored to demonstrate success for an adequate period (minimum 10 years) or until completion criteria is reached.

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APPENDICES

APPENDIX 1
Flora Species on Barrow Island

APPENDIX 1: VASCULAR PLANT SPECIES RECORDED ON BARROW ISLAND

	FAMILY	GENUS SPECIES
13	MARSILIACEAE	*Marsilea ?hirsuta*
23C	CYMODOCEACEAE	*Halodule uninervis*
23	POTAMOGETONACEAE	*Ruppia maritima*
31	POACEAE	*Aristida browniana* *Aristida contorta* *Aristida holathera* var. *holathera* *Bothriochloa bladhii* *Brachyachne* sp. **Cenchrus ciliaris* *Chrysopogon fallax* *Cymbopogon ambiguus* *Cymbopogon bombycinus* *Cymbopogon procerus* *Cymbopogon* sp. **Cynodon dactylon* *Dactyloctenium radulans* *Dichanthium sericeum* subsp. *Humilis* *Digitaria ctenantha* *Enneapogon caerulescens* var. *caerulescens* *Enneapogon caerulescens* var.*occidentalis* *Enneapogon oblongus* *Enneapogon polyphyllus* *Enneapogon sp.* *Eragrostis cumingii* *Eragrostis dielsii* *Eragrostis falcata* *Eragrostis sp.* *Eragrostis xerophila* *Eriachne benthamii* *Eriachne flaccida* *Eriachne mucronata* *Eulalia aurea* *Iseilema dolichotrichum* *Paspalidium clementii* *Paspalidium tabulatum* *Poaceae sp.* *Poaceae sp.1* *Poaceae sp.2* *Poaceae sp.3 (Tussock grass)* *Setaria dielsii* *Sorghum plumosum* *Spinifex longifolius* *Sporobolus australasicus*

	FAMILY	GENUS SPECIES
		Sporobolus mitchelli *Sporobolus virginicus* *Themeda australis* *Triodia angusta* *Triodia epactia* *Triodia pungens* *Triodia wiseana* *Triodia wiseana var. brevifolia* *Triodia wiseana var. wiseana* *Triraphis mollis* *Whiteochloa airoides* *Yakirra australiensis*
32	CYPERACEAE	*Bulbostylis barbata* *Cyperus bifax* *Cyperus cunninghamii* subsp. *cunninghamii* *Cyperus iria* *Cyperus squarrosus* *Fimbristylis dichotoma* *Fimbristylis schultzii* *Isolepis marginata* *Schoenoplectus dissachanthus*
47	COMMELINACEAE	*Commelina ensifolia* *Commelina lancelata*
54C	DASYPOGONACEAE	*Acanthocarpus verticillatus*
54F	ANTHERICACEAE	*Corynotheca flexuosissima*
87	MORACEAE	*Ficus opposita* var. *aculeata* (includes *Ficus opposita* var. *micracantha*) *Ficus platypoda* var. *cordata* (CALM 1997) *Ficus platypoda* var. *platypoda* (E.M. Mattiske & Associates 1993) *Ficus sp.* *Ficus virens* var. *virens*
90	PROTEACEAE	*Grevillea leucadendron* (not current – excluded taxon. This genus is currently under review, and the WA Herbarium is yet to allocate a more appropriate name to this taxon) *Grevillea pyramidalis* *Hakea lorea* (includes the non-current taxa *Hakea lorea* subsp. *cunninghamii* and *Hakea suberea*)
92	SAPINDACEAE	*Alectryon oleifolius* subsp. *oleifolius* *Diplopeltis eriocarpa* *Diplopeltis intermedia* ?var. *intermedia* *Dodonaea lanceolata* var. *lanceolata* (CALM 1997)
		Santalum murrayanum

	FAMILY	GENUS SPECIES
97	LORANTHACAEA	*Loranthacaea sp.*
105	CHENOPODIACEAE	*Atriplex isatidea* *Atriplex semilunaris* *Chenopodium melanocarpum* forma *leucocarpum* *Chenopodium pumilio* *Dysphania kalpari* *Dysphania plantaginella* *Dysphania rhadinostachya* subsp. *inflata* (CALM 1997) *Enchylaena tomentosa* var. *tomentosa* *Eremophea spinosa* *Halosarcia ?indica* *Halosarcia halocnemoides ssp. tenuis* *Halosarcia indica* subsp. *julacea* (E.M. Mattiske & Associates 1993) *Halosarcia indica* subsp. *leiostachya* (CALM 1997) *Halosarcia sp.* *Neobassia astrocarpa* *Rhagodia eremaea* *Rhagodia latifolia* var. *?recta* *Rhagodia latifolia* var. *latifolia* *Rhagodia preissii* subsp. *obovata* *Salsola tragus* (was *Salsola kali*) *Sclerolaena convexula* *Sclerolaena uniflora* *Threlkeldia diffusa*
106	AMARANTHACEAE	*Alternanthera nodiflora* *Amaranthus mitchelli* *Amaranthus pallidiflorus* *Amaranthus* sp. Barrow Island (R. Buckley 6884) (no record of this taxon in *Census of WA Plant Names*) *Gomphrena sordida* (was *Gomphrena conferta*) *Hemichroa diandra* *Ptilotus clementii* *Ptilotus exaltatus* var. *exaltatus* *Ptilotus fusiformis* *Ptilotus obovatus** (*abherent prostrate form on Island) *Ptilotus villosiflorus*
107	NYCTAGINACEAE	*Boerhavia ?repleta* *Boerhavia ?schomburgkiana* *Boerhavia burbidgeana* *Boerhavia coccinea* *Boerhavia gardneri* *Boerhavia sp* *Commicarpus australis*
108	GYROSTEMONACEAE	*Codonocarpus cotinifolius*

	FAMILY	GENUS SPECIES
110	AIZOACEAE	*Sesuvium portulacastrum*
111	PORTULACACEAE	*Calandrinia balonensis* *Calandrinia polyandra* *Calandrinia sp.* *Portulaca australis* *Portulaca intraterranea* *Portulaca oleracea* *Portulaca pilosa*
113	CARYOPHYLLACEAE	*Polycarpaea longiflora*
122	MENISPERMACEAE	*Tinospora smilacina*
131	LAURACEAE	*Cassytha capillaris*
137A	CAPPARACEAE	*Capparis lasiantha* *Capparis spinosa var. nummularia* *Capparis umbonata* *Cleome viscosa*
138	BRASSICACEAE	*Lepidium platypetalum*
152	PITTOSPORACEAE	*Pittosporum phylliraeoides* var. *phylliraeoides* (E.M. Mattiske & Associates 1993).
160	SURIANACEAE	*Stylobasium spathulatum*
163	MIMOSACEAE	*Acacia bivenosa* *Acacia coriacea ssp pendens* *Acacia coriacea* subsp. *coriacea* (CALM 1997) *Acacia cowleana* *Acacia grasbyi* *Acacia gregorii* *Acacia inaequilatera*
163	MIMOSACEAE	*Acacia pyrifolia* *Acacia synchronicia*
164	CAESALPINIACEAE	*Petalostylis labicheoides* *Senna artemisioides* subsp. *oligophylla* *Senna glutinosa* subsp. *glutinosa* *Senna glutinosa* subsp. *pruinosa* *Senna notabilis* *Senna planiticola* *Senna venusta*
165	PAPILIONACEAE	*Canavalia rosea* *Crotalaria cunninghamii* *Crotalaria medicaginea*

	FAMILY	GENUS SPECIES
		Crotalaria novae-hollandiae *Cullen* aff *pallidum* *Cullen lachnostachys* (was *Psoralea lachnostachys*) *Cullen leucanthum* (was *Psoralea leucantha*) *Cullen patens* (was *Psoralea patens*) *Cullen pustulata* (was *Psoralea pustulata*) *Erythrina vespertilio* *Indigofera boviperda* *Indigofera colutea* *Indigofera linifolia* *Indigofera linnaei* *Indigofera monophylla* *Indigofera sp* *Indigofera sp (RB6723)* *Indigofera trita* *Isotropis atropurpurea* *Lotus australis* *Lotus cruentus* *Rhynchosia minima* *Sesbania bispinosa* *Sesbania cannabina* *Swainsona formosa* *Swainsona kingii* *Swainsona pterostylis* *Tephrosia rosea* var. *clementii* (no record of this taxon in *Census of WA Plant Names*; probably confused with *Tephrosia clementii*) *Tephrosia rosea* var. *glabrior var. nov* *Tephrosia sp.*
173	ZYGOPHYLLACEAE	*Tribulus cistoides* *Tribulus occidentalis* *Tribulus terrestris*
183	POLYGALACEAE	*Polygala* aff. *Isingii*
185	EUPHORBIACEAE	*Adriana tomentosa* var. *tomentosa* (CALM 1997) *Euphorbia australis* *Euphorbia australis* subsp. *vaccaria* (no record of this taxon in *Census of WA Plant Names*; probably confused with *Euphorbia vaccaria*, which is now a synonym of *Euphorbia australis*) *Euphorbia coghlanii* *Euphorbia drummondii* subsp. *drummondii* *Euphorbia myrtoides* *Euphorbia* sp. (E.M. Mattiske & Associates 1993) *Euphorbia* sp.A *Euphorbia tannensis* subsp. *eremophila* *Flueggea virosa* subsp. *melanthesoides* *Mallotus dispersus* (was *Mallotus didmochryseus*) *Mallotus nesophilus* *Phyllanthus maderaspatensis*

	FAMILY	GENUS SPECIES
185	EUPHORBIACEAE	*Phyllanthus* sp.
202	STACKHOUSIACEAE	*Stackhousia muricata*
215	RHAMNACEAE	*Ventilago viminalis*
220	TILIACEAE	*Corchorus interstans* ms (was *Corchorus* sp. Barrow (B.Clay & M.Yardar s.n. 21 Nov.1965)) *Corchorus parviflorus* *Corchorus* sp Barrow *Corchorus* sp Barrow2 *Corchorus tridens* *Corchorus walcottii* (includes the non-current taxon *Corchorus* sp. Burrup (G.Craig 235) subsp. Barrow (R.Buckley 6870)) *Triumfetta clementii* *Triumfetta ramosa* *Triumfetta* sp. Rudall ssp. Woodstock
221	MALVACEAE	**Malvastrum americanum* *Abutilon cunninghamii* (was *Abutilon exonemum*) *Abutilon indicum* var. *australiense* *Abutilon leucopetalum* *Abutilon otocarpum* *Abutilon sp.* *Gossypium australe* *Gossypium robinsonii* *Herissantia crispa* *Hibiscus burtonii* *Hibiscus coatesii* *Hibiscus leptocladus* *Hibiscus sp. (EM12013)* *Hibiscus sturtii* var. *campylochamys* *Hibiscus sturtii* var. *platychlamys* *Lawrencia viridigrisea* *Sida calxhymenia* *Sida clementii* *Sida corrugata* *Sida echinocarpa* *Sida fibulifera* *Sida micracantha* (no record of this taxon in *Census of WA Plant Names*, possibly confused with *Triumfetta micracantha*) *Sida sp. EM12018* *Sida sp. EM20301B*
223	STERCULIACEAE	*Hannafordia quadrivalvis* *Keraudrenia sp.* *Melhania oblongifolia* *Waltheria indica*

	FAMILY	GENUS SPECIES
236	FRANKENIACEAE	*Frankenia ambita* *Frankenia pauciflora*
243	VIOLACEAE	*Hybanthus aurantiacus*
248	PASSIFLORACEAE	**Passiflora foetida* **Passiflora foetida* var. *hispida*
265	LYTHRACEAE	*Ammannia multiflora*
269	RHIZOPHORACEAE	*Rhizophora stylosa*
273	MYRTACEAE	**Eucalyptus gomphocephala* *Eucalyptus camaldulensis* *Eucalyptus gamophylla* *Eucalyptus torquata* *Eucalyptus xerothermica* ms *Melaleuca cardiophylla*
276	HALORAGACEAE	*Haloragis gossei*
293	PRIMULACEAE	*Samolus repens*
294	PLUMBAGINACEAE	*Muellerolimon salicorniaceum* *Plumbago zeylanica*
301	OLEACEAE	*Jasminum calcareum* *Jasminum didymuum*
303	GENTIANACEAE	**Centaurium erythraea* *Centaurium spicatum*
305	ASCLEPIADACEAE	*Cynanchum floribundum* *Marsdenia cinerascens* *Marsdenia* sp. *Sarcostemma viminale* subsp. *Australe* *Tylophora flexuosa*
307	CONVOLVULACEAE	*Convolvulus sp (RB7250)* *Evolvulus alsinoides* var. *decumbens* *Ipomoea pes-caprae* subsp. *brasiliensis* (E.M. Mattiske & Associates 1993) *Polymeria ?ambigua* *Polymeria ambigua*
		Polymeria sp.
307A	CUSCUTACEAE	*Cuscuta australis*
310	BORAGINACEAE	*Cordia subcordata* (Boodie Island) *Heliotropium conocarpum*

	FAMILY	GENUS SPECIES
		Heliotropium crispatum *Heliotropium cunninghamii* *Heliotropium glanduliferum* *Heliotropium inexplicitum* *Heliotropium ovalifolium* *Heliotropium sp. (perennial shrub0* *Heliotropium sp. (RB6866)* *Heliotropium sp. (RB737)* *Trichodesma zeylanicum*
311	VERBENACEAE	*Clerodendrum tomentosum* var. *lanceolatum* (E.M. Mattiske & Associates 1993)
312	AVICENNIACEAE	*Avicennia marina* subsp. *Marina*
315	SOLANACEAE	**Solanum nigrum* *Dubosia hopwoodii* *Nicotiana benthamiana* *Nicotiana occidentalis* subsp. *Occidentalis* *Solanum cleistogamum* *Solanum diversiflorum* *Solanum esuriale* *Solanum lasiophyllum* *Solanum sp.*
316	SCROPHULARIACEAE	*Mimulus gracilis* *Stemodia glabella* *Stemodia grossa*
317	BIGNONIACEAE	*Dolichandrone heterophylla*
318	PEDALIACEAE	*?Josephina eugeniae*
325	ACANTHACEAE	*Dicladanthera forrestii* *Dicladanthera* sp. (RB6863) *Dipteracanthus australasicus* *Dipteracanthus australasicus* subsp. cf. *corynothecus*
326	MYOPORACEAE	*Eremophila forrestii* subsp. *forrestii* ms (CALM 1997) *Eremophila leucophylla* *Myoporum acuminatum*
331	RUBIACEAE	*Hedyotis crouchiana* *Hedyotis galioides*
		Synaptantha tillaeacea var. *tillaeacea* (CALM 1997)
337	CUCURBITACEAE	*Mukia maderaspatana*

	FAMILY	GENUS SPECIES
339	CAMPANULACEAE	*Wahlenbergia* sp.
341	GOODENIACEAE	*Goodenia microptera* *Goodenia sp.* *Lechenaultia divaricata* (Florabase says this name is an excluded taxon (does not occur in W.A.) ie. there is no new name) *Scaevola amblyanthera* var. *amblyanthera* (CALM 1997) *Scaevola amblyanthera* var. *centralis* *Scaevola* cf. *Aemula* (The only confirmed record of *Scaevola aemula* in Western Australia is from the Recherche Archipelago, near Esperance) *Scaevola crassifolia* *Scaevola cunninghamii* *Scaevola sericophylla* *Scaevola* sp. *Scaevola spinescens*
345	ASTERACEAE	**Arctotheca calendula* *Asteraceae sp1* *Asteraceae sp2* *Centipeda minima* *Flaveria australasica* *Helichrysum oligochaetum* *Launaea sarmentosa* *Olearia dampieri* subsp. *dampieri* ms *Pentalepis trichodesmoides* *Pluchea dentex* (was *Pluchea squarrosa*) *Pluchea rubelliflora* *Pluchea* sp. *Pluchea tetranthera* **Pseudognaphalium luteoalbum* *Pterocaulon sphacelatum* *Pterocaulon sphaeranthoides* **Sonchus oleraceus* *Streptoglossa adscendens*
345	ASTERACEAE	*Streptoglossa bubakii* *Streptoglossa decurrens* *Streptoglossa macrocephala* *Vittadinia arida*
345	ASTERACEAE	*Vittadinia hispidula* *Vittadinia obovata* *Vittadinia sp.*

APPENDIX 2

Mattiske versus Astron Vegetation Descriptions

Habitat (Mattiske 1993)	**Mattiske Description and Code**	**C1**	**Coastal complex dominated by *Spinifex longifolius* on white fore-dunes; includi ng Coastal Complex of *Ipomoea pes-caprae* ssp *brasiliensis* and *Spinifex longifolius* on strand line fore-dunes**
Coastal Complex and Dune System	**Astron Code and Description**		
	C1a*		Open Grassland of *Spinifex longifolius* (10-30%) on the seaward facing foredunes. Note: No other species were present (at the time of the survey).
	C1b		Open Low Shrubland (2-10%; <0.5m) of *Myporoum montanum/Scaevola cunninghamii* over Mixed Grassland (30-40%) of *Triodia angusta/Spinifex longifolius* on erodable beach dunes.
	C1c		Open Shrubland (2-10%; 1-2m) of *Acacia coriacea* and occasionally *Acacia bivenosa* over Tall Grassland (30-40%) of *Spinifex longifolius* with patches of *Triodia angusta* on seaward side of dune.
	Mattiske Description and Code	C2	**Open Shrub of *Acacia coriacea –Rhagodia preissii* ssp. *obovata -Olearia dampieri* ssp. *dampieri* on elevated dunes on fringes of Island**
	Astron Code and Description		
	C2a*		Shrubland (30-40%; 1-2 m) of *Acacia coriacea* over Low Shrubland of *Rhagodia preissii obovata* over Grassland (30-50%) of mixed *Eulalia aurea/Spinifex longifolius* on landward side of foredunes. (Note this C2 includes grassland).
	C2b		Tall Shrubland (10-30%; >2m) of *Acacia coriacea* over Shrubland (10-30%; 1-1.5m) of *Acacia bivenosa* with *Olearia damperi* ssp *dampieri* over Low Shrubland (10-15%; <1m) of *Acanthocarpus verticillatus* over Hummock Grassland (30-70%) of *Triodia angusta* on hinddunes.
	C2c		Heath (30-60%; 1.5m) of *Acacia coriacea* over Very Open Hummock Grassland (2-10%) of *Triodia angusta* in swale in hinddunes.
	Mattiske Description and Code	C4	**Mixed Hummock Grassland of *Triodia angusta -Triodia pungens* with dense shrubs including *Acacia bivenosa* on back slopes of fore-dunes**
	Astron Code and Description		
	C4a*		Shrubland (10-30%) to Open Heath (30-50%; 1-2m) of *Acacia bivenosa/Stylobasium spathulatum* over Closed Hummock Grassland (70-100%) of *T. angusta* with occasional *T. epactia* on near coastal hillslopes.
	C4b		Shrubland to Heath *(30-40% 1m)* of *Acacia bivenosa* with less frequent *Acacia coriacea* over Low Shrubland (10-20%; <1m) of *Acanthocarpus verticillatus* over Mixed to Dense Hummock Grassland (50-90%) of *Triodia angusta/T. wiseana* on coastal flats.
	C4c		Shrubland to Heath (20-45%; 1m) of *Acacia bivenosa* with frequent *Petalostylis labicheoides* and mixed shrubs over dense Hummock Grassland (70-90%) of *Triodia angusta* with less frequent *T. wiseana* on very gently undulating coastal flats

* = Previously described (Astron 2001)

Habitat (Mattiske 1993)	**Mattiske Description and Code**	C5	**Low Mixed Shrubland of *Frankenia pauciflora* and *Hedyotis crouchiana* on exposed cliff faces around edge of Island**
	Astron Code and Description		
	C5a		Very Open Dwarf Shrubland (2-10%; <0.5m) of *Scaevola cunninghamii, Heliotropium ovalifolium, Corchorus ? parviflora (No 40)* with Very Open Hummock Grassland (2%) on coastal limestone platform.
	Mattiske Description and Code	**C14**	No Mattiske Formation for this Association
	Astron Code and Description		Hummock Grassland with scattered Low Shrubs on loosely consolidated pink sand dunes
	C14a		Hummock Grassland (30-70%) of *Triodia angusta* with scattered Low Shrubs (<2%) *Cynanchum floribundum, Myoporum montanum, Tephrosia rosea* var *clementii*.
Limestone Ridge	**Mattiske Description and Code**	L1	**Hummock Grassland of *Triodia wiseana* with *Ficus platypoda* on central limestone ridges**
	Astron Code and Description		
	L1a		Low Open Woodland (10-20% <5m) of *Ficus brachypoda* over Mixed Shrubland of *Acacia bivenosa/Stylobasium spathulatum* over Dwarf Shrubland (10-20%: 0.5m) of *Solanum lasiophyllum/Corchorus interstans* over mixed Hummock Grassland (30-70%) of *Triodia angusta/T. wiseana* on limestone ridges.
	L1b		Dwarf Shrubland (10-30%; 0.5m) of *Diplopeltis eriocarpa* over Hummock Grassland (30-70%) of *Triodia wiseana*. Very scattered *Ficus brachypoda* on limestone hillslopes.
	Mattiske Description and Code	L3	**Hummock Grassland of *Triodia wiseana* with low mixed shrubs including *Acacia gregorii* on limestone ridges**
	Astron Code and Description		
	L3a		Open Shrubland (2-10%; 1m) of *Petalostylis labicheoides /Stylobasium spathulatum* over Dwarf Shrubland (10-20% <0.5m) of *Acacia gregorii* over Hummock Grassland (30-70%) of mixed *Triodia wiseana/T. angusta*. There are scattered (<2%) *Hakea lorea* on limestone hillslopes.
	Mattiske Description and Code	L4	**Hummock Grassland of *Triodia wiseana* with dense emergent shrubs of *Acacia pyrifolia, Acacia gregorii* and *Petalostylis labicheoides* on limestone ridges**

	Astron Code and Description		
	L4a		Open Shrubland (2-10-20; 1m) of *Acacia pyrifolia* over Hummock Grassland (30-70) of *Triodia epactia* on limestone hillslopes.
	Mattiske Description and Code	L5	**Hummock Grassland of *Triodia wiseana* with emergent *Hakea suberea* on limestone ridges**
	Astron Code and Description		
	L5a		Low shrubland (10-30%; 1m) of *Acacia bivenosa* over Hummock Grassland (30-70%) of *Triodi wiseana*. There are scattered *Hakea lorea* on limestone hillslopes.
	Mattiske Description and Code	L7	**Hummock Grassland of *Triodia wiseana* with dense pockets of *Melaleuca cardiophylla* on limestone ridges**
	Astron Code and Description		
	L7a		Low Shrubland (10-30%; 0.5-1m) of *Melaleuca cardiophylla* with *Acacia gregorii* (occasional prostrate *Acacia bivenosa)* over Hummock Grassland (30-70%) of *Triodia wiseana* on limestone hillslopes.
	L7c		Shrubland (10-30%; 1-2m) of *Melaleuca cardiophylla/ Petalostylis labicheoides* over Dwarf Shrubland (10-30%, 0-0.5m) of *Acacia gregorii* with *Diplopeltis eriocarpa* over Hummock Grassland (30-70%) of *Triodia wiseana* on limestone hillslopes.
	L7d		Scattered (<2%) to Open (2-5%) Tall Shrubland of *Hakea lorea* over Low Shrubland (10-30% ; 1m) of *Melaleuca cardiophylla/Acacia bivenosa* over Mixed Hummock Grassland (30-70%) sometimes Dense (90%) of *Triodia wiseana/T. angusta* on limestone hillslopes but frequently also on red earth flats.
	Mattiske Description and Code	L9	**Hummock Grassland of *Triodia wiseana* – *Triodia angusta* with emergent *Sarcostemma viminali spp. australe* and *Ficus platypoda var. platypoda* on coastal limestone flats and low ridges with localized pockets of *Frankenia pauciflora***
	Astron Code and Description		
	L9a		Low Woodland (10-30% <5m) Ficus brachypoda over Very Open (2-10%; <1m) of Low Shrubland of *Sarcostemma viminale australe* over Hummock Grassland (30-40%) of *Triodia wiseana* on coastal limestone hillslopes and plateaus.
	L9b		Open Low Woodland (2-10%) of *Ficus brachypoda* over Open Low Shrubland (10-30% <1m) of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia wiseana* (30-70) on limestone coastal flats.
	Mattiske Description and Code	**L11**	No Mattiske Formation for this Association
	Astron Code and Description		Dwarf Shrubland to Heath over Closed Hummock Grassland on Limestone Hillslopes
	L11a*		Dwarf to Prostrate *Acacia bivenosa* Shrubland (10-30%) to Heath (30-40% 0-0.5m) over Closed Hummock Grassland (70-100%) of *Triodia wiseana* with scattered <2% *Petalostylis labicheoides /Stylobasium spathulatum.* Occurs on limestone slopes.

* = Previously described (Astron 2001)

	Mattiske Description and Code	**L12**	No Mattiske Formation for this Association
	Astron Code and Description		Mixed Shrubland over Hummock Grassland with Scattered Low Trees on Limestone Hillslopes
	L12a		Shrubland (10-30%, 1-2m) of *Acacia bivenosa*, with *Gossypium robinsonii, Capparis spinosa* over Hummock Grassland (30-70%) of *Triodia wiseana* with scattered (<2%) *Ficus platypoda* on small rock outcrops.
	Mattiske Description and Code	**L13**	No Mattiske Formation for this Association
	Astron Code and Description		**Open Shrubland over Dwarf Shrubland over Hummock Grassland on Limestone Hillslopes**
	L13a		Mixed Open Shrubland (2-10% 1m) of *Pentalepis labichoidies, Pentalepis trichodesmoides, Acacia bivenosa* over Open to Mid Dwarf Shrubland (2-20%; <0.5m) of *Acacia gregorii, Diplopeltis eriocarpa* over Hummock Grassland (30-50%) of *Triodia wiseana*.
	L13b		Shrubland (10-30% 1.m) of *Stylobasium spathulatum* over Open Low Shrubland (2-10% <0.5m) of *Acacia gregorii* over Hummock Grassland (30-70%) of *Triodia wiseana*.
	Mattiske Description and Code	L14	No Mattiske Formation for this Association
	Astron Code and Description		**Open Tall Shrubland over Open Low Shrubland over Dwarf Shrubland to Heath over Hummock Grassland on limestone hillslopes**
	L14a		Open Tall Shrubland (5-10%; 2m) of *Codonocarpus cotinifolius* over Open Low Shrubland (2-10% 1m) of *Petalostylis labicheoides /Acacia bivenosa* over Dwarf Shrubland to Dwarf Heath (20-40% <0.5m) of *Acacia gregorii/Diplopeltis eriocarpa* over Hummock Grassland (30-70%) of *Triodia wiseana*.
Valley Slopes and Escarpments	**Mattiske Description and Code**	V1	**Hummock Grassland of *Triodia wiseana* with mixed emergent shrub species on valley slopes**
	Astron Code and Description		
	V1a		Open Low Shrubland (2-10% <1m) of mixed *Petalostylis labicheoides/Acacia bivenosa* over Hummock Grassland (30-70%) of *Triodia wiseana* on valley slopes.
	V1b		Dwarf Shrubland (10-30% <0.5m) of *Diplopeltis eriocarpa* over Hummock Grassland (30-70%) of *Triodia wiseana*. There are scattered (<2%) *Pentalepis trichodesmoides* and *Petalostylis labicheoides* on valley slopes.
	Mattiske Description and Code	V2	**Hummock Grassland of *Triodia wiseana* with *Pentalepsis trichodemoides* on southern escarpment**

	Astron Code and Description		
	V2a		Open Low Shrubland (10-30%) of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia wiseana* (60%) and *T. angusta* (10%) on valley slopes.
	V2b		Open Low Shrubland (2-10%) of *Pentalepis trichodesmoides* with *Acacia bivenosa* over (Very Open Dwarf Shrubland (2-5%) of *Diplopeltis eriocarpa*) over Hummock Grassland (30-70%) of *Triodia wiseana* on valley slopes.
	V2c		Open to Mid Shrubland (2-20% 1m) of *Pentalepis trichodesmoides* with occassional *Acacia bivenos*a over Closed Hummock (70-100%) Grassland of *Triodia wiseana* and patches of *Triodia angusta*. There are scattered <2%) *Ficus brachypoda* and *Acacia coriacea* .
	Mattiske Description and Code	V3	No Mattiske Formation for this Association
	Astron Code and Description		**Open Shrubland over Dwarf Shrubland over Hummock Grassland on valley slopes**
	V3a*		Open Shrubland of *Petalostylis labicheoides* (2-10%; 1m) over Dwarf Shrubland (10-30%; 0.5m) of *Acacia gregorii* and *Diplopeltis eriocarpa* over Hummock Grassland (30-70%) of *Triodia wiseana*.
	Mattiske Description and Code	V4	No Mattiske Formation for this Association
	Astron Code and Description		Shrubland to Heath over Dwarf Shrubland over Hummock Grassland on valley slopes
	V4a*		Shrubland to Heath (20-40%; 1m) of *Acacia bivenosa* with less frequent *Stylobasium spathulatum/ Petalostylis labicheoides* over Dwarf Shrubland (10-20% <0.5m) of *Corchorus sp 22* over Dense Hummock (70-100%) of *Triodia wiseana*.
Creek or seasonal Drainage lines	**Mattiske Description and Code**	D1	**Mixed Hummock Grassland of *Triodia angusta* with pockets of dense shrubs along major creek-lines**
	Astron Code and Description		
	D1b		Low Woodland (10-30% <5m) of *Ficus brachypoda* with *Acacia coriacea/Pittosporum phylliraeoides* over Dense (70-100) Hummock Grassland of *Triodia angusta*.
	D1c		Shrubland to Heath (30-40%) of *Stylobasium spathulatum* with less frequent *Acacia bivenosa* and *Acacia pyrifolia* over Dense (70-100) Hummock Grassland of *Triodia angusta*.
	D1d		Very Open Tall Shrubland (2-10%; 2m) of *Acacia coriacea* over Shrubland (10-30%) of *Acacia bivenosa/Melaleuca cardiophylla* over Hummock Grassland (30-70%) of *Triodia angusta/T. wiseana*.
	D1e		Shrubland to Heath (20-40; 1.5m) of *Stylobasium spathulatum* with less frequent *Acacia pyrifolia, Petalostylis labicheoides* over Open Dwarf Shrubland (2% <0.5m) of *Acacia gregorii* over tall Dense Hummock Grassland (70-100%) of *Triodia angusta*. Narrow drainage line

* = Previously described (Astron 2001)

	D1f	High Shrubland (10-20% >2m) of *Acacia coriacea* over Shrubland (10-30%; 1m) of *Acacia bivenosa* over Dense Hummock Grassland (70-100%) of *Triodia angusta*.
	D1g	Scattered to Open (<2-2%)tall shrubs of *Hakea lorea* over tall Dense Hummock Grassland (70-100%) of *Triodia angusta* sometimes with scattered (<2%) *Pentalepis trichodesmoides*, *Acacia bivenosa*.
	D1h	Open Shrubland (2-10% 1m) of *Acacia bivenosa* over mixed Hummock and Tussock Grassland (30-50%) of *Triodia angusta/Cymbopogon ambiguus*.
	D1l	Shrubland to Heath (10-40%) of *Acacia bivenosa* with occasional *Melaleuca cardiophylla* over Dense Hummock Grassland (70-100%) of *Triodia angusta* with *T. wiseana*. There are scattered (<2%) *Hakea lorea*.

COLOUR PLATES

PLATE 1: Open Low Shrubland (2-10%) of *Pentalepis trichodesmoides* with *Acacia bivenosa* over (Very Open Dwarf Shrubland (2-5%) of *Diplopeltis eriocarpa*) over Hummock Grassland (30-70%) of *Triodia wiseana* on valley slopes. Recorded as association V2b in V2 vegetation type beneath development footprint.

PLATE 2: Low Woodland (10-30% <5m) *Ficus brachypoda* over Very Open (2-10%; <1m) of Low Shrubland of *Sarcostemma viminale australe* over Hummock Grassland (30-40%) of *Triodia wiseana* on coastal limestone hillslopes and plateaus. Recorded as association L9a in L9 vegetation type beneath development footprint

PLATE 3: Open Tall Shrubland (5-10%; 2m) of *Codonocarpus cotinifolius* over Open Low Shrubland (2-10% 1m) of *Petalostylis labicheoides /Acacia bivenosa* over Dwarf Shrubland to Dwarf Heath (20-40% <0.5m) of *Acacia gregorii/Diplopeltis eriocarpa* over Hummock Grassland (30-70%) of *Triodia wiseana*. Recorded as association L14a in L14 vegetation type, beneath development footprint.

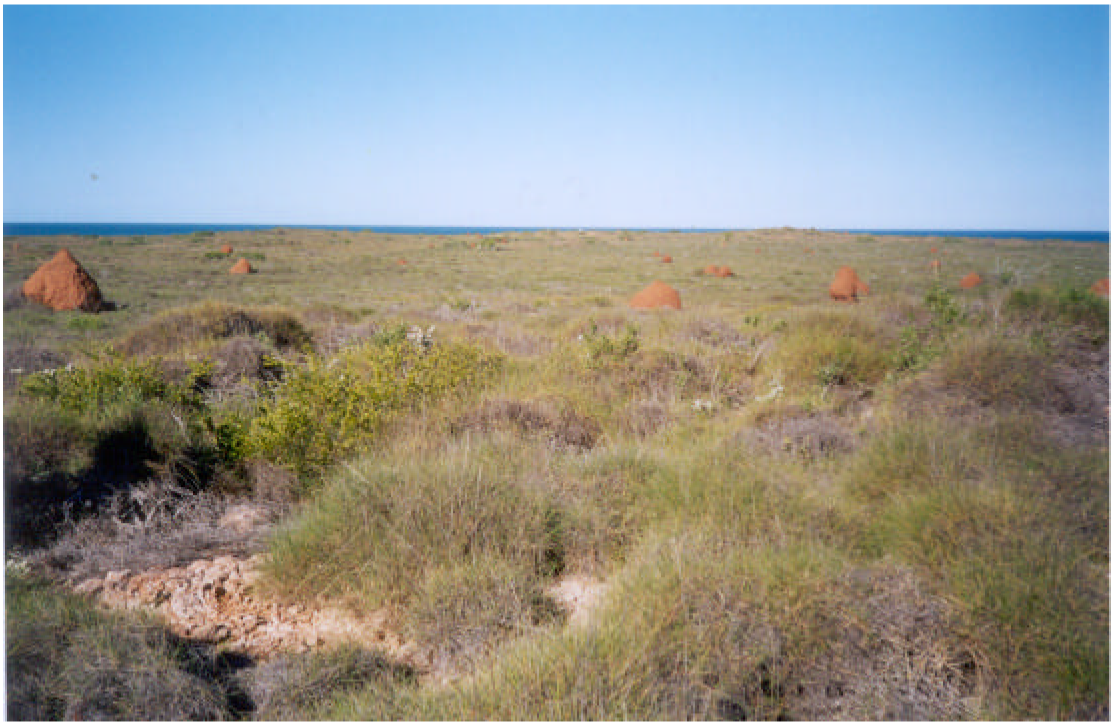

PLATE 4: Low Open Woodland (10-20% <5m) of *Ficus brachypoda* over Mixed Shrubland of *Acacia bivenosa/Stylobasium spathulatum* over Dwarf Shrubland (10-20%: 0.5m) of *Solanum lasiophyllum/Corchorus interstans* over mixed Hummock Grassland (30-70%) of *Triodia angusta/T. wiseana* on limestone ridges. Recorded as L9a in L9 vegetation type, beneath development footprint.

PLATE 5: Shrubland to Heath *(30-40% 1m)* of *Acacia bivenosa* with less frequent *Acacia coriacea* over Low Shrubland (10-20%; <1m) of *Acanthocarpus verticillatus* over Mixed to Dense Hummock Grassland (50-90%) of *Triodia angusta/T. wiseana* on coastal flats. Recorded as C4b – occurs in mapped F1, beneath development footprint.

PLATE 6: Open Shrubland (2-10-20; 1m) of *Acacia pyrifolia* over Hummock Grassland (30-70) of *Triodia epactia* on limestone hillslopes. Recorded as L4a in L4 vegetation type, in pipeline corridor.

FIGURES

Astron observations not in Mattiske mapping:

C14 Hummock Grassland with scattered Low Shrubs on loosely consolidated pink sand dunes

C14a Hummock Grassland (30-70%) of Triodia angusta with scattered Low Shrubs (<2%) Cynanchum floribundum, Myoporum montanum, Tephrosia rosea var clementii.

L11 Dwarf Shrubland to Heath over Closed Hummock Grassland on Limestone Hillslopes

L11a* Dwarf to Prostrate Acacia bivenosa Shrubland (10-30%) to Heath (30-40% 0-0.5m) over Closed Hummock Grassland (70-100%) of Triodia wiseana with scattered <2% Petalostylis labicheoides /Stylobasium spathulatum. Occurs on limestone slopes.

L12 Mixed Shrubland over Hummock Grassland with Scattered Low Trees on Limestone Hillslopes

L12a Shrubland (10-30%, 1-2m) of Acacia bivenosa, with Gossypium robinsonii, Capparis spinosa over Hummock Grassland (30-70%) of Triodia wiseana with scattered (<2%) Ficus platypoda on small rock outcrops.

L13 Open Shrubland over Dwarf Shrubland over Hummock Grassland on Limestone Hillslopes

L13a Mixed Open Shrubland (2-10% 1m) of Pentalepis labichoidies, Pentalepis trichodesmoides, Acacia bivenosa over Open to Mid Dwarf Shrubland (2-20%; <0.5m) of Acacia gregorii, Diplopeltis eriocarpa over Hummock Grassland (30-50%) of Triodia wiseana.
L13b Shrubland (10-30% 1.m) of Stylobasium spathulatum over Open Low Shrubland (2-10% <0.5m) of Acacia gregorii over Hummock Grassland (30-70%) of Triodia wiseana.

L14 Open Tall Shrubland over Open Low Shrubland over Dwarf Shrubland to Heath over Hummock Grassland on limestone hillslopes

L14a Open Tall Shrubland (5-10%; 2m) of Codonocarpus cotinifolius over Open Low Shrubland (2-10% 1m) of Petalostylis labicheoides /Acacia bivenosa over Dwarf Shrubland to Dwarf Heath (20-40% <0.5m) of Acacia gregorii/Diplopeltis eriocarpa over Hummock Gra

V3 Open Shrubland over Dwarf Shrubland over Hummock Grassland on valley slopes

V3a* Open Shrubland of Petalostylis labicheoides (2-10%; 1m) over Dwarf Shrubland (10-30%; 0.5m) of Acacia gregorii and Diplopeltis eriocarpa over Hummock Grassland (30-70%) of Triodia wiseana.

V4 Shrubland to Heath over Dwarf Shrubland over Hummock Grassland on valley slopes

V4a* Shrubland to Heath (20-40%; 1m) of Acacia bivenosa with less frequent Stylobasium spathulatum/ Petalostylis labicheoides over Dwarf Shrubland (10-20% <0.5m) of Corchorus sp 22 over Dense Hummock (70-100%) of Triodia wiseana.

Mattiske Mapping unit in bold, followed by Astron point observation

C1 Coastal complex dominated by Spinifex longifolius on white fore-dunes; including Coastalcomplex of Ipomoea pes-caprae ssp. brasiliensis and Spinifex longifolius on strand line fore-dunes

C1a* Open Grassland of Spinifex longifolius (10-30%) on the seaward facing foredunes. Note: No other species were present (at the time of the survey).
C1b Open Low Shrubland (2-10%; <0.5m) of Myporoum montanum/Scaevola cunninghamii over Mixed Grassland (30-40%) of Triodia angusta/Spinifex longifolius on erodable beach dunes.
C1c Open Shrubland (2-10%; 1-2m) of Acacia coriacea and occasionally Acacia bivenosa over Tall Grassland (30-40%) of Spinifex longifolius with patches of Triodia angusta on seaward side of dune.

C2 Open Shrub of Acacia coriacea - Rhagodia preissii ssp. obovata - Olearia dampieri ssp. dampieri on elevated dunes on fringes of Island

C2a* Shrubland (30-40%; 1-2 m) of Acacia coriacea over Low Shrubland of Rhagodia preissii obovata over Grassland (30-50%) of mixed Eulalia aurea/Spinifex longifolius on landward side of foredunes. (Note this C2 includes grassland).
C2b Tall Shrubland (10-30%; >2m) of Acacia coriacea over Shrubland (10-30%; 1-1.5m) of Acacia bivenosa with Olearia damperi ssp dampieri over Low Shrubland (10-15%; <1m) of Acanthocarpus verticillatus over Hummock Grassland (30-70%) of Triodia angusta on
C2c Heath (30-60%; 1.5m) of Acacia coriacea over Very Open Hummock Grassland (2-10%) of Triodia angusta in swale in hinddunes.

C5 Low Mixed Shrubland of Frankenia pauciflora and Hedyotis crouchiana on exposed cliff faces around edge of Island.

C5a Very Open Dwarf Shrubland (2-10%; <0.5m) of Scaevola cunninghamii, Heliotropium ovalifolium, Corchorus ? parviflora (No 40) with Very Open Hummock Grassland (2%) on coastal limestone platform.

D1 Mixed Hummock Grassland of Triodia angusta with pockets of dense shrubs along major creek-lines

D1b Low Woodland (10-30% <5m) of Ficus brachypoda with Acacia coriacea/Pittosporum phylliraeoides over Dense (70-100) Hummock Grassland of Triodia angusta.
D1c Shrubland to Heath (30-40%) of Stylobasium spathulatum with less frequent Acacia bivenosa and Acacia pyrifolia over Dense (70-100) Hummock Grassland of Triodia angusta.
D1d Very Open Tall Shrubland (2-10%; 2m) of Acacia coriacea over Shrubland (10-30%) of Acacia bivenosa/Melaleuca cardiophylla over Hummock Grassland (30-70%) of Triodia angusta/T. wiseana.
D1e Shrubland to Heath (20-40; 1.5m) of Stylobasium spathulatum with less frequent Acacia pyrifolia, Petalostylis labicheoides over Open Dwarf Shrubland (2% <0.5m) of Acacia gregorii over tall Dense Hummock Grassland (70-100%) of Triodia angusta. Narrow d
D1f High Shrubland (10-20% >2m) of Acacia coriacea over Shrubland (10-30%; 1m) of Acacia bivenosa over Dense Hummock Grassland (70-100%) of Triodia angusta.
D1g Scattered to Open (<2-2%)tall shrubs of Hakea lorea over tall Dense Hummock Grassland (70-100%) of Triodia angusta sometimes with scattered (<2%) Pentalepis trichodesmoides, Acacia bivenosa.
D1h Open Shrubland (2-10% 1m) of Acacia bivenosa over mixed Hummock and Tussock Grassland (30-50%) of Triodia angusta/Cymbopogon ambiguus.
D1l Shrubland to Heath (10-40%) of Acacia bivenosa with occasional Melaleuca cardiophylla over Dense Hummock Grassland (70-100%) of Triodia angusta with T. wiseana. There are scattered (<2%) Hakea lorea.

D2 Hummock Grassland of Triodia angusta along minor creek-lines and drainage lines

L1 Hummock Grassland of Triodia wiseana with Ficus platypoda var. platypoda on central limestone ridges.

L1a Low Open Woodland (10-20% <5m) of Ficus brachypoda over Mixed Shrubland of Acacia bivenosa/Stylobasium spathulatum over Dwarf Shrubland (10-20%: 0.5m) of Solanum lasiophyllum/Corchorus interstans over mixed Hummock Grassland (30-70%) of Triodia angust
L1b Dwarf Shrubland (10-30%; 0.5m) of Diplopeltis eriocarpa over Hummock Grassland (30-70%) of Triodia wiseana. Very scattered Ficus brachypoda on limestone hillslopes.

L3 Hummock Grassland of Triodia wiseana with low mixed shrubs including Acacia gregorii on limestone ridges

L3a Open Shrubland (2-10%; 1m) of Petalostylis labicheoides /Stylobasium spathulatum over Dwarf Shrubland (10-20% <0.5m) of Acacia gregorii over Hummock Grassland (30-70%) of mixed Triodia wiseana/T. angusta. There are scattered (<2%) Hakea lorea on lime

L4 Hummock Grassland of Triodia wiseana with dense emergent shrubs of Acacia pyrifolia, Acacia gregorii and Petalostylis labicheoides on limestone ridges

L4a Open Shrubland (2-10-20; 1m) of Acacia pyrifolia over Hummock Grassland (30-70) of Triodia epactia on limestone hillslopes.

L7 Hummock Grassland of Triodia wiseana with dense pockets of Melaleuca cardiophylla on limestone ridges

L7a Low Shrubland (10-30%; 0.5-1m) of Melaleuca cardiophylla with Acacia gregorii (occasional prostrate Acacia bivenosa) over Hummock Grassland (30-70%) of Triodia wiseana on limestone hillslopes.
L7c Shrubland (10-30%; 1-2m) of Melaleuca cardiophylla/ Petalostylis labicheoides over Dwarf Shrubland (10-30%, 0-0.5m) of Acacia gregorii with Diplopeltis eriocarpa over Hummock Grassland (30-70%) of Triodia wiseana on limestone hillslopes.
L7d Scattered (<2%) to Open (2-5%) Tall Shrubland of Hakea lorea over Low Shrubland (10-30% ; 1m) of Melaleuca cardiophylla/Acacia bivenosa over Mixed Hummock Grassland (30-70%) sometimes Dense (90%) of Triodia wiseana/T. angusta on limestone hillslopes but frequently also on red earth flats.

L8 Hummock Grassland of Triodia wiseana with pockets of Eucalyptus patellaris on limestone ridges

L9 Hummock Grassland of Triodia wiseana - Triodia angusta with emergent Sarcostemma viminali spp. australe and Ficus platypoda var. platypoda on coastal limestone flats and low ridges with localised pockets of Frankenia pauciflora

L9a Low Woodland (10-30% <5m) Ficus brachypoda over Very Open (2-10%; <1m) of Low Shrubland of Sarcostemma viminale australe over Hummock Grassland (30-40%) of Triodia wiseana on coastal limestone hillslopes and plateaus.
L9b Open Low Woodland (2-10%) of Ficus brachypoda over Open Low Shrubland (10-30% <1m) of Pentalepis trichodesmoides over Hummock Grassland of Triodia wiseana (30-70) on limestone coastal flats.

V1 Hummock Grassland of Triodia wiseana with mixed emergent shrub species on valley slopes

V1a Open Low Shrubland (2-10% <1m) of mixed Petalostylis labicheoides/Acacia bivenosa over Hummock Grassland (30-70%) of Triodia wiseana on valley slopes.
V1b Dwarf Shrubland (10-30% <0.5m) of Diplopeltis eriocarpa over Hummock Grassland (30-70%) of Triodia wiseana. There are scattered (<2%) Pentalepis trichodesmoides and Petalostylis labicheoides on valley slopes.

V2 Hummock Grassland of Triodia wiseana with Pentalepis trichodemoides on southern escarpment

V2a Open Low Shrubland (10-30%) of Pentalepis trichodesmoides over Hummock Grassland of Triodia wiseana (60%) and T. angusta (10%) on valley slopes.
V2b Open Low Shrubland (2-10%) of Pentalepis trichodesmoides with Acacia bivenosa over (Very Open Dwarf Shrubland (2-5%) of Diplopeltis eriocarpa) over Hummock Grassland (30-70%) of Triodia wiseana on valley slopes.
V2c Open to Mid Shrubland (2-20% 1m) of Pentalepis trichodesmoides with occassional Acacia bivenosa over Closed Hummock (70-100%) Grassland of Triodia wiseana and patches of Triodia angusta. There are scattered <2%) Ficus brachypoda and Acacia coriacea .

Astron Environmental Vegetation Survey August 2002 Map 1 of 2

Author: V. Long - Astron	Date : 12/9/2002	DRAWING No: CHE010/GORGON_SUREV_AUG02\ ASTRON_SEP02V2.APR
Drawn By: NGIS	Revision: 1.0	

Mattiske Mapping unit in bold, followed by Astron point observation

C1 Coastal complex dominated by Spinifex longifolius on white fore-dunes; including Coastalcomplex of Ipomoea pes-caprae ssp. brasiliensis and Spinifex longifolius on strand line fore-dunes

C1a* Open Grassland of Spinifex longifolius (10-30%) on the seaward facing foredunes. Note: No other species were present (at the time of the survey).
C1b Open Low Shrubland (2-10%; <0.5m) of Myoporum montanum/Scaevola cunninghamii over Mixed Grassland (30-40%) of Triodia angusta/Spinifex longifolius on erodable beach dunes.
C1c Open Shrubland (2-10%; 1-2m) of Acacia coriacea and occasionally Acacia bivenosa over Tall Grassland (30-40%) of Spinifex longifolius with patches of Triodia angusta on seaward side of dune.

C2 Open Shrub of Acacia coriacea - Rhagodia preissii ssp. obovata - Olearia dampieri ssp. dampieri on elevated dunes on fringes of Island

C2a* Shrubland (30-40%; 1-2 m) of Acacia coriacea over Low Shrubland of Rhagodia preissii obovata over Grassland (30-50%) of mixed Eulalia aurea/Spinifex longifolius on landward side of foredunes. (Note this C2 includes grassland).
C2b Tall Shrubland (10-30%; >2m) of Acacia coriacea over Shrubland (10-30%; 1-1.5m) of Acacia bivenosa with Olearia damperi ssp dampieri over Low Shrubland (10-15%; <1m) of Acanthocarpus verticillatus over Hummock Grassland (30-70%) of Triodia angusta on
C2c Heath (30-60%; 1.5m) of Acacia coriacea over Very Open Hummock Grassland (2-10%) of Triodia angusta in swale in hinddunes.

C3 Hummock Grassland of Triodia pungens with dense shrubs including Acacia bivenosa on back-slopes of fore-dunes

C4 Mixed Hummock Grassland of Triodia angusta - Triodia pungens with dense shrubs including Acacia bivenosa on back slopes of fore-dunes

C4a* Shrubland (10-30%) to Open Heath (30-50%; 1-2m) of Acacia bivenosa/Stylobasium spathulatum over Closed Hummock Grassland (70-100%) of T. angusta with occasional T. epactia on near coastal hillslopes.
C4b Shrubland to Heath (30-40% 1m) of Acacia bivenosa with less frequent Acacia coriacea over Low Shrubland (10-20%; <1m) of Acanthocarpus verticillatus over Mixed to Dense Hummock Grassland (50-90%) of Triodia angusta/T. wiseana on coastal flats.
C4c Shrubland to Heath (20-45%; 1m) of Acacia bivenosa with frequent Petalostylis labicheoides and mixed shrubs over dense Hummock Grassland (70-90%) of Triodia angusta with less frequent T. wiseana on very gently undulating coastal flats

D1 Mixed Hummock Grassland of Triodia angusta with pockets of dense shrubs along major creek-lines

D1b Low Woodland (10-30% <5m) of Ficus brachypoda with Acacia coriacea/Pittosporum phylliraeoides over Dense (70-100) Hummock Grassland of Triodia angusta.
D1c Shrubland to Heath (30-40%) of Stylobasium spathulatum with less frequent Acacia bivenosa and Acacia pyrifolia over Dense (70-100) Hummock Grassland of Triodia angusta.
D1d Very Open Tall Shrubland (2-10%; 2m) of Acacia coriacea over Shrubland (10-30%) of Acacia bivenosa/Melaleuca cardiophylla over Hummock Grassland (30-70%) of Triodia angusta/T. wiseana.
D1e Shrubland to Heath (20-40; 1.5m) of Stylobasium spathulatum with less frequent Acacia pyrifolia, Petalostylis labicheoides over Open Dwarf Shrubland (2% <0.5m) of Acacia gregorii over tall Dense Hummock Grassland (70-100%) of Triodia angusta. Narrow d
D1f High Shrubland (10-20% >2m) of Acacia coriacea over Shrubland (10-30%; 1m) of Acacia bivenosa over Dense Hummock Grassland (70-100%) of Triodia angusta.
D1g Scattered to Open (<2-2%)tall shrubs of Hakea lorea over tall Dense Hummock Grassland (70-100%) of Triodia angusta sometimes with scattered (<2%) Pentalepis trichodesmoides, Acacia bivenosa.
D1h Open Shrubland (2-10% 1m) of Acacia bivenosa over mixed Hummock and Tussock Grassland (30-50%) of Triodia angusta/Cymbopogon ambiguus.
D1l Shrubland to Heath (10-40%) of Acacia bivenosa with occasional Melaleuca cardiophylla over Dense Hummock Grassland (70-100%) of Triodia angusta with T. wiseana. There are scattered (<2%) Hakea lorea.

D2 Hummock Grassland of Triodia angusta along minor creek-lines and drainage lines

F1 Hummock Grassland of Triodia angusta on red earth flats and drainage lines

F7 Hummock Grassland of Triodia pungens - Triodia angusta - Triodia wiseana on slopes of escarpments on fringes of red earth flats

L1 Hummock Grassland of Triodia wiseana with Ficus platypoda var. platypoda on central limestone ridges.

L1a Low Open Woodland (10-20% <5m) of Ficus brachypoda over Mixed Shrubland of Acacia bivenosa/Stylobasium spathulatum over Dwarf Shrubland (10-20%: 0.5m) of Solanum lasiophyllum/Corchorus interstans over mixed Hummock Grassland (30-70%) of Triodia angust
L1b Dwarf Shrubland (10-30%; 0.5m) of Diplopeltis eriocarpa over Hummock Grassland (30-70%) of Triodia wiseana. Very scattered Ficus brachypoda on limestone hillslopes.

L3 Hummock Grassland of Triodia wiseana with low mixed shrubs including Acacia gregorii on limestone ridges

L3a Open Shrubland (2-10%; 1m) of Petalostylis labicheoides /Stylobasium spathulatum over Dwarf Shrubland (10-20% <0.5m) of Acacia gregorii over Hummock Grassland (30-70%) of mixed Triodia wiseana/T. angusta. There are scattered (<2%) Hakea lorea on limestone hillslopes.

L4 Hummock Grassland of Triodia wiseana with dense emergent shrubs of Acacia pyrifolia, Acacia gregorii and Petalostylis labicheoides on limestone ridges

L4a Open Shrubland (2-10-20; 1m) of Acacia pyrifolia over Hummock Grassland (30-70) of Triodia epactia on limestone hillslopes.

L5 Hummock Grassland of Triodia wiseana with emergent Hakea suberea on limestone ridges

L5a Low shrubland (10-30%; 1m) of Acacia bivenosa over Hummock Grassland (30-70%) of Triodi wiseana. There are scattered Hakea lorea on limestone hillslopes.

L7 Hummock Grassland of Triodia wiseana with dense pockets of Melaleuca cardiophylla on limestone ridges

L7a Low Shrubland (10-30%; 0.5-1m) of Melaleuca cardiophylla with Acacia gregorii (occasional prostrate Acacia bivenosa) over Hummock Grassland (30-70%) of Triodia wiseana on limestone hillslopes.
L7c Shrubland (10-30%; 1-2m) of Melaleuca cardiophylla/ Petalostylis labicheoides over Dwarf Shrubland (10-30%, 0-0.5m) of Acacia gregorii with Diplopeltis eriocarpa over Hummock Grassland (30-70%) of Triodia wiseana on limestone hillslopes.
L7d Scattered (<2%) to Open (2-5%) Tall Shrubland of Hakea lorea over Low Shrubland (10-30% ; 1m) of Melaleuca cardiophylla/Acacia bivenosa over Mixed Hummock Grassland (30-70%) sometimes Dense (90%) of Triodia wiseana/T. angusta on limestone hillslopes but frequently also on red earth flats.

L9 Hummock Grassland of Triodia wiseana - Triodia angusta with emergent Sarcostemma viminali spp. australe and Ficus platypoda var. platypoda on coastal limestone flats and low ridges with localised pockets of Frankenia pauciflora

L9a Low Woodland (10-30% <5m) Ficus brachypoda over Very Open (2-10%; <1m) of Low Shrubland of Sarcostemma viminale australe over Hummock Grassland (30-40%) of Triodia wiseana on coastal limestone hillslopes and plateaus.
L9b Open Low Woodland (2-10%) of Ficus brachypoda over Open Low Shrubland (10-30% <1m) of Pentalepis trichodesmoides over Hummock Grassland of Triodia wiseana (30-70) on limestone coastal flats.

V1 Hummock Grassland of Triodia wiseana with mixed emergent shrub species on valley slopes

V1a Open Low Shrubland (2-10% <1m) of mixed Petalostylis labicheoides/Acacia bivenosa over Hummock Grassland (30-70%) of Triodia wiseana on valley slopes.
V1b Dwarf Shrubland (10-30% <0.5m) of Diplopeltis eriocarpa over Hummock Grassland (30-70%) of Triodia wiseana. There are scattered (<2%) Pentalepis trichodesmoides and Petalostylis labicheoides on valley slopes.

V2 Hummock Grassland of Triodia wiseana with Pentalepis trichodemoides on southern escarpment

V2a Open Low Shrubland (10-30%) of Pentalepis trichodesmoides over Hummock Grassland of Triodia wiseana (60%) and T. angusta (10%) on valley slopes.
V2b Open Low Shrubland (2-10%) of Pentalepis trichodesmoides with Acacia bivenosa over (Very Open Dwarf Shrubland (2-5%) of Diplopeltis eriocarpa) over Hummock Grassland (30-70%) of Triodia wiseana on valley slopes.
V2c Open to Mid Shrubland (2-20% 1m) of Pentalepis trichodesmoides with occassional Acacia bivenosa over Closed Hummock (70-100%) Grassland of Triodia wiseana and patches of Triodia angusta. There are scattered <2%) Ficus brachypoda and Acacia coriacea .

Astron Environmental Vegetation Survey August 2002 Map 2 of 2

Author: V. Long - Astron	Date : 21/8/2002	DRAWING No: CHE010/GORGON_SUREV_AUG02\ ASTRON_SEP02.APR
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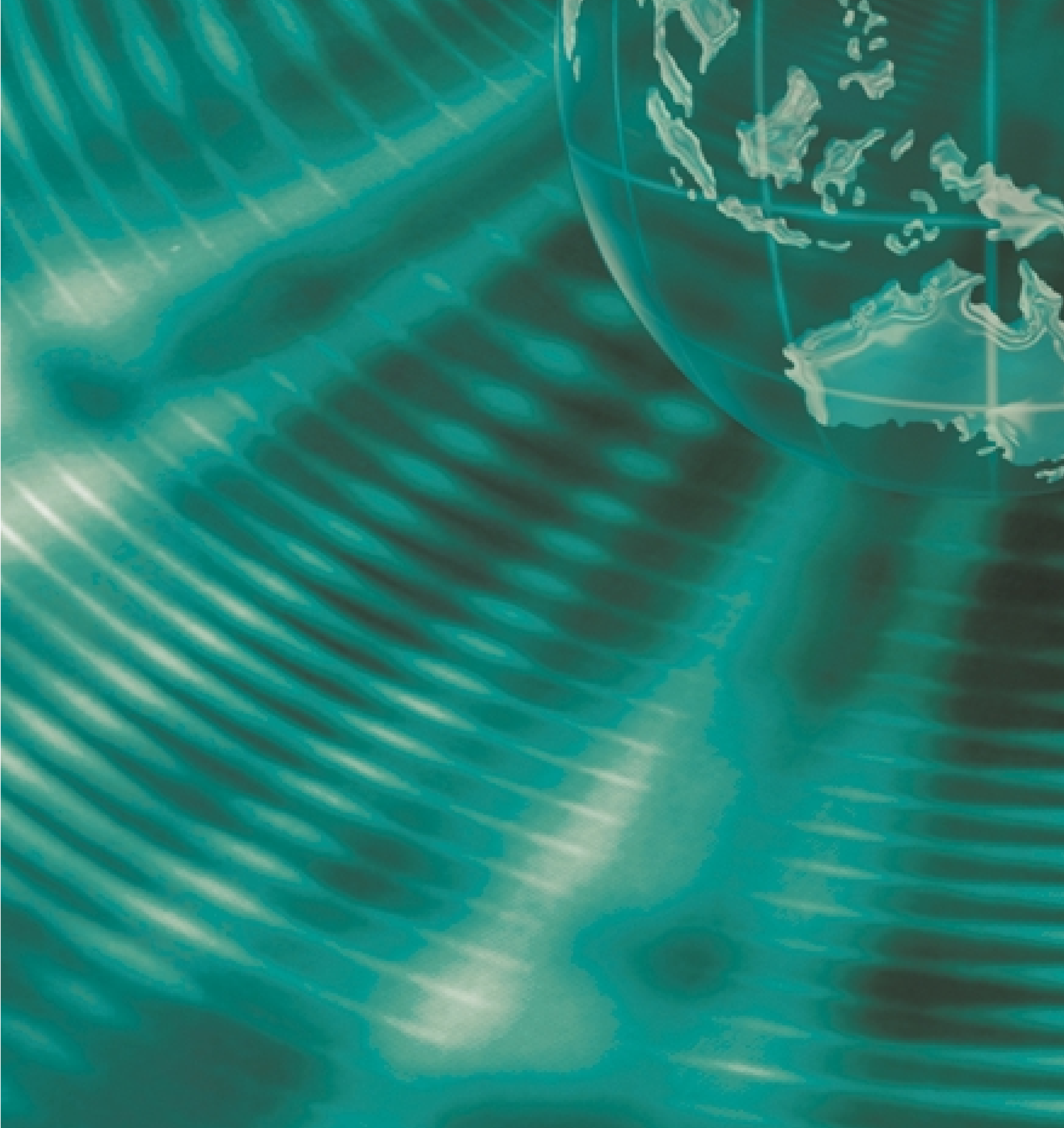

APPENDIX G

THE TERRESTRIAL VERTEBRATE FAUNA OF BARROW ISLAND IN RELATION TO THE GORGON GAS DEVELOPMENT AUGUST 2002

(BAMFORD CONSULTING ECOLOGISTS)

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1.0 INTRODUCTION

The terrestrial vertebrate fauna of Barrow Island has been well-documented over a number of decades due to the conservation value of the island and the support of ChevronTexaco and its predecessors, and is of particular significance because of species that have declined or become extinct on the mainland and because of endemic races. In addition to this documentation, a number of studies have investigated aspects of the ecology of the vertebrate fauna (eg. Pruett-Jones and Tarvin 2001), while populations of some of the mammal species are being monitored by the Department of Conservation and Land Management (2001). The fauna likely to occur within the area of the proposed Gorgon gas development can therefore be predicted with a high degree of confidence. As a result, this fauna assessment was based upon a review of available information and a thorough site inspection to put this information into the context of the site.

2.0 METHODS

2.1 Field surveys

The site inspection was carried out by Dr Mike Bamford of Bamford Consulting Ecologists over the period 9th-13th August 2002. During this inspection, the area of investigation consisted of the proposed gas processing facility site at Latitude Point, particularly the notional 300 ha site indicated on provided aerial photographs, but also the area south of this, and the preferred pipeline route from Flacourt Bay to the gas processing facility site. In addition, the route to the proposed CO_2 re-injection well in the north of the island was traversed. This area had previously been visited by the consultant in 1997.

The landform and vegetation of the area of investigation were typical of much of Barrow Island but included a number of habitats to be noted with respect to the fauna investigation. Within the gas plant footprint from the coast to inland, habitats included:

- Sparse, low heathland on skeletal soil over limestone on Latitude Point;
- Acacia shrubland over spinifex on sandy-loam soils near the coast;
- Melaleuca open shrubland over spinifex on shallow sandy loam with some exposed limestone, primarily in the north of the Latitude Point development area, and in the area south of this site;
- Low hills of spinifex hummock grassland on very shallow soil, often with a layer of coarse gravel on the surface, with a lot of exposed limestone and occasional clumps of figs associated with limestone outcroppings and overhangs; and
- Spinifex tall hummock grassland in valleys, often associated with dry watercourses.

Much of the proposed pipeline route passes through spinifex hummock grassland and tall hummock grassland, including areas where there were clumps of figs near Flacourt Bay and north of well T74 (about 336 500 to 336 800 E). Immediately west of the Barge

Landing road, the proposed pipeline route passes though spinifex hummock grassland with scattered acacias, forming an open shrubland. Near Flacourt Bay, the proposed pipeline route passes through a small gorge system with limestone breakaways supporting many clumps of fig and containing small caves and overhangs. The limestone gorges near Flacourt Bay represent the most restricted terrestrial fauna habitat on the Island.

Field work carried out during the site inspection consisted of a habitat survey and a targeted survey for some significant species to determine their distribution and to obtain measures of abundance. Because of existing information on the fauna of Barrow Island, surveying the habitats within the area of investigation makes it possible to predict what species are present and even how important the development areas are likely to be for those species. The targeted survey focussed on species that could be readily observed and included species of conservation significance, such as the Boodie and White-winged Fairy-wren.

The general approach taken during the site inspection was to walk slowly, recording observations and deliberately seeking out Boodie warrens by inspecting clumps of figs and other outstanding patches of vegetation that might be indicative of a warren. Observations were recorded in half-hourly intervals, with the observer's location recorded with a hand-held GPS at the start and end of each interval. Boodie warrens, Spectacled Hare-Wallabies and the locations of parties of White-winged Fairy-wrens were also recorded with the GPS, with other wildlife being noted within each interval. Birds other than White-winged Fairy-wrens were also counted. The area covered during each half-hour interval varied with the terrain and particularly the density of features that needed to be inspected for Boodie warrens, but was approximately 4 ha. It is therefore possible to express the abundance of the more conspicuous species, such as birds, as a density per ha.

This approach of half-hour surveys was applied at Latitude Point, in the area south of this site and along the proposed pipeline route. Within the development area at Latitude Point, 31 half-hourly surveys were carried out, therefore covering an area of approximately 124 ha, representing 42% of the notional 300 ha development area. In the area south of the proposed gas processing facility site, only 10 half-hourly surveys were carried out, covering an estimated 40 ha and therefore about 10% of the total southern area. There were also 10 half-hour surveys carried out along the proposed pipeline route. With a length of *ca.* 7 km and a width of 500 m, the corridor within which the pipeline may be located has an area of *ca.* 350 ha so in excess of 10% of this area was visited. Note that coverage was greater than indicated for Boodie warrens, since favourable locations were deliberately inspected, but coverage was more variable for birds, with some species being conspicuous and others less so. In addition, species such as the Spinifexbird and White-winged Fairy-wren were probably undersampled through the middle of the day when they call less frequently than in the mornings and evenings.

2.2 Assessment of conservation significance

For the determination of conservation significance, the conservation status of fauna species is assessed under Federal and State Acts such as the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and the WA Wildlife Conservation Act 1950. These use levels of significance recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994), although the WA Act also has a category of "Other Specially Protected Fauna" that has no equivalent IUCN level. These categories are described in Appendix One. The EPBC Act also lists migratory species that are present in the Japan-Australia and China Australia Migratory Bird Agreements, and the Bonn Convention on the Protection of Migratory Animals. The migratory list includes some whole families, such as the ducks, but the list has been updated to include only truly migratory species, and the updated list has been used in this report.

In addition, Environment Australia has supported the publication of reports on the conservation status of reptiles (Cogger *et al.* 1993) and birds (Garnett and Crowley 2000). These publications also use the IUCN categories, although those used by Cogger e*t al.* (1993) differ in some respects as this report pre-dates Mace and Stuart's review.

In Western Australia, the Department of Conservation and Land Management has produced a supplementary list of Priority fauna, being species that are not considered Threatened under the IUCN categories but for which the Department feels there is cause for concern. Levels of Priority are described in Appendix One.

With respect to Barrow Island, it should be noted that most of the species occur as isolated populations but only some have been recognised as sub-species, and that the recognition of conservation significance can be influenced by this recognition. The recognition of sub-species is common among the terrestrial mammal fauna, where 4 of the 13 common native terrestrial species are considered to be endemic races, but rare among birds and reptiles (only one endemic race of about 8 resident bird species, and one endemic race and one endemic species of 44 resident reptile species). The isolation of most of the resident species on the Island, however, means that there are likely to be some genetic differences from mainland populations, and this lends the island populations an unrecognised conservation significance.

Taxonomic orders and names used in this report generally follow Aplin and Smith (2001) for amphibians and reptiles, Johnstone (2001) for birds and How *et al.* (2001) for mammals. For some species, however, there are alternative and widely recognised scientific and common names (e.g. Menkhorst and Knight (2001) for mammals and Christidis and Boles (1994) for birds), and where such alternatives exist they are given in parenthesis.

3.0 THE TERRESTRIAL VERTEBRATE FAUNA OF BARROW ISLAND AND THE PROPOSED DEVELOPMENT AREAS

3.1 Frogs

The only frog species resident on Barrow Island is *Cyclorana maini* (Table 1). The WA Museum database suggests the presence of two additional species, the Water-holding Frog *Cyclorana platycephala* and the Inland Tree-Frog *Litoria rubella*. These were checked with the WA Museum as they are not listed in publications or reports on the Island's fauna. The specimen of the Water-holding Frog could not be located, while the record of the Inland Tree-Frog was from 1965 and was probably a specimen introduced from the mainland, as the species is usually very conspicuous when present. None of these species is of conservation significance.

There appear to have been no studies on *C. maini* on the island, but in the adjacent Pilbara, where it is widespread, it breeds in seasonal watercourses and is associated with habitats close to such sites. It can be assumed to occur in similar areas on Barrow Island. It is almost certainly present and breeding in ephemeral water bodies in the Latitude Point area and along the proposed pipeline route. In the latter area, seasonal watercourses at about 335 295 E, 7 702 837 N and in the gorges adjacent to Flacourt Bay may be particularly important. The route to the proposed CO_2 re-injection well passes through a claypan area that may also be important for frogs.

The proposed Gorgon gas development has the potential to impact *C. maini* (and other frog species if present) if it results in changes to surface water flow and/or the persistence of pools used for breeding. Such alterations should be minimised, particularly along the proposed pipeline route.

3.2 Reptiles

The terrestrial reptile fauna of Barrow Island consists of 43 species (see Table 1). Of these, seven species were observed during the site inspection but most species were not active because of seasonal conditions. The reptile assemblage on Barrow Island is a subset of the fauna of the adjacent Pilbara, but includes two species (the skinks *Lerista elegans* and *Morethia lineoocellata*) that have mainland distributions along the west coast as far north as Cape Range. Such biogeographic affinities between Barrow Island and the Cape Range area are also seen in the cave fauna. The skink *Ctenotus pantherinus acripes* is an endemic race, while the blind snake *Ramphotyphlops longissimus* is the only vertebrate species endemic to the island. This blind snake is suspected of being troglobytic (cave-dwelling) and a related but undescribed species occurs on the Cape Range (Storr *et al.* 2002). It is the only terrestrial reptile species of recognised conservation significance on the island, being classed as Priority 2 by CALM. Note, however, that it was unknown at the time of publication of the review carried out by Cogger *et al.* (1993).

Some research has been done on the reptiles of Barrow Island (Heatwole and Cogger 1981), while additional information on habitat preferences, although based on Pilbara populations, is available from WA Museum publications such as Storr *et al.* (1999). The local patterns of distribution of reptile species tend to be very closely related to the substrate (eg soil type, presence/absence of rock), accumulation of leaf litter and to distinctive vegetation types, such as spinifex and low trees. The presence of termite mounds may also be important.

Within areas associated with the Gorgon gas development, there are likely to be distinctive assemblages of reptile species in the sandy loam soils close to the coast (probably dominated by fossorial skinks such as *Lerista* bipes), compared with the habitats of shallow soils with exposed limestone that dominate the island, although some species will probably be present throughout. Of more interest with respect to the proposed Gorgon gas development are species associated with restricted habitats. For example, *Lerista elegans* and *Glaphyromorphus isolepis* may be associated with clumps of figs, which have distinctive soil and leaf litter and are also usually associated with sheets of limestone. The tall, dense spinifex along seasonal watercourses may be important for species that favour spinifex, including the endemic race *C. pantherinus acripes*, although it should be stressed that the sort of detailed habitat sampling required has not been carried out. The distribution of the Priority 2 *R. longissimus* is virtually impossible to determine, as it may occur in subterranean cavities within the limestone (Storr *et al.* 2002).

There are no reptile habitats unique to the areas of the proposed Gorgon gas development and impacts upon reptiles will be roughly correlated with the proportional loss of habitat. Therefore, disturbance or loss of rare habitats should be minimised. For example, coastal and near coastal sandy to sandy-loam soils occupy a smaller proportion of the Island than the extensive shallow soils over limestone that occur over much of the Island. The most restricted reptile habitats are clumps of figs, the limestone slopes and breakaways near Flacourt Bay and tall, dense spinifex along seasonal watercourses. The open acacia shrubland over spinifex that occurs along the pipeline route, in the vicinity of a seasonal watercourse and limestone breakaway at 335 295 E, 7 702 837 N, is also an area where impacts should be minimised.

3.3 Birds

Because of the mobility of landbirds, the 53 species recorded on Barrow Island (see Table 2) consist mostly of vagrants. Sedgwick (1978) recognised only 23 species as residents or regular migrants, although the status of some of these has been questioned (Pruett-Jones and O'Donnel (unpub.)). Fourteen of the residents or regular migrants were observed during the site inspection. These included the five most common species identified by Pruett-Jones and O'Donnel (Unpub.): Spinifexbird, White-winged Fairy-wren, Singing Honeyeater, White-breasted Woodswallow and Welcome Swallow. They also included the Osprey and White-bellied Sea-Eagle which, although seabirds, nest on the land and take some prey from terrestrial environments (Sedgwick 1978). The Barrow

Island White-winged Fairy-wren is a distinctive endemic race that is classed as Vulnerable but none of the other resident or regular landbird species is of conservation significance. Some island populations of the Singing Honeyeater are known to differ from those of the adjacent mainland, often being larger and darker (Higgins *et al.* 2001), but it is not known if investigations into this have been carried out on the Barrow Island population.

Some of the landbirds of Barrow Island have been subject to studies of their diet (Wooller and Calver 1981) and breeding biology (Ambrose and Murphy 1994), while there have been physiological studies carried out in conjunction with the University of Western Australia, but studies that have looked at habitat usage and patterns of distribution are limited to the work of Sedgwick (1978), Pruett-Jones and Tarvin (2001) and Pruett-Jones and O'Donnel (unpub.). There may be other unpublished studies in these areas, but the available studies provide the sort of information needed to assess likely impacts of the proposed Gorgon gas development.

Table 3 presents the Island population estimates of Pruett-Jones and O'Donnel (unpub.) and Sedgwick (1978), as well as the total counts of each species made during the August 2002 site inspection. These total counts are divided between the development area at Latitude Point (*ca.* 300 ha), the area south of this site and the proposed pipeline route, with the numbers seen in each half-hour survey presented in Appendix 2. Most of the birds were seen in very small numbers, but the White-winged Fairy-wren, Singing Honeyeater and Spinifexbird were very abundant. Furthermore, it is possible to estimate their populations on the basis of survey coverage as described above and the densities in different habitats presented by Pruett-Jones and O'Donnnel (unpub.).

On the basis of the number observed (74) and survey coverage (42%), there were 176 White-winged Fairy-wrens in the proposed gas processing facility area at Latitude Point. This equates to a density of 0.6 birds/ha, which is well within the range of 0.08 to 1.75 birds/ha found by Pruett-Jones and O'Donnnel (unpub.). The value of 176 White-winged Fairy-wrens represents 2.3% of the lower population estimate for the Island (see Table 3), and suggests that the development area has a higher overall density of fairy-wrens than the total Island, since the area represents only 1.3% of the Island. This is consistent with the vegetation types present and the observations of Pruett-Jones and O'Donnel (unpub.), who found White-winged Fairy-wren density to be highest where spinifex was tall, close to roads, and in areas of melaleuca open shrubland over spinifex. During the site inspection, the highest densities of fairy-wrens were in melaleuca open shrubland over spinifex both in the development area and in the southern area.

The density of White-winged Fairy-wrens was greater in the area to the immediate south of the proposed plant footprint where the preference of the species for melaleuca open shrubland over spinifex was very apparent, with a density of 2.25 birds/ha in two of the survey areas. Surveys in the area south of the proposed gas processing facility site were biased towards the melaleuca open shrubland but did include less favoured habitat, so even conservatively the area supported 200-300 fairy-wrens if an overall density of <1 bird/ha is assumed. In contrast, the pipeline corridor supported only small numbers of the species and they were absent from the entire western half of the route where the vegetation consisted of low spinifex with no shrubs. With only 12 fairy-wrens observed and a survey coverage of *ca.* 10%, it is estimated that there were 120 birds between Flacourt Bay and the western edge of the proposed gas processing facility site at Latitude Point. Most of these were probably in an area immediately west of the Barge Landing road, where the vegetation consisted of acacia open shrubland over spinifex.

Singing Honeyeaters also displayed complex patterns of distribution and these were consistent with the observation by Pruett-Jones and O'Donnel (unpub.) that this species favours vegetation where shrubs and bushes form an open stratum above the spinifex. Of the 12 records of Singing Honeyeaters in the proposed gas processing facility site at Latitude Point, all were in acacia shrubland or melaleuca open shrubland and therefore there was a strong coastal bias to their distribution. The area of this habitat in the development area can be estimated as 50 ha, which suggests a local population (assuming a 42% coverage) of 29 birds at a density of 0.58 birds/ha. This is within the range found by Pruett-Jones and O'Donnel (unpub.) for the species, but is much lower than their value of 2.5 birds/ha in acacia shrubland close to the coast. A total of 29 birds represents just under 1% of the lower population estimate for the island (Table 3), but this may be an underestimate.

In the southern area, nine Singing Honeyeaters were recorded in acacia shrubland over spinifex close to the coast, with the highest record being of three birds in a 4 ha survey area. In this area, virtually all habitat suitable for Singing Honeyeaters is between the road that leads to the tanks and the coast.

Along the pipeline route, three of the five records of Singing Honeyeaters were amongst figs growing in the limestone gorges and breakaways near Flacourt Bay.

The Spinifexbird was the most widespread of the three abundant bird species, being present in 32 of the 51 survey areas, compared with 29 for the White-winged Fairy-wren and only 19 for the Singing Honeyeater. On the basis of the number observed (50) and survey coverage (42%), there were 119 Spinifexbirds in the development area at Latitude Point. This equates to a density of 0.4 birds/ha, which is below all the density estimates for the species presented by Pruett-Jones and O'Donnnel (unpub.). The low value is probably a result of the Spinifexbirds calling only infrequently in August, whereas the surveys conducted by Pruett-Jones and O'Donnel (unpub.) took place in October when calling frequencies are high. Spinifexbirds are inconspicuous when not calling. A density of 1 to 1.5 birds/ha can probably be assumed, suggesting a population in the Latitude Point development area of 300-450 birds. Even the lower estimate represents 1.7% of the Island population estimate proposed by Sedgwick (1978), or 1.2% of the higher estimate of Pruett-Jones and O'Donnel (unpub.), with the higher estimate for the development area representing as much as 2.5% of the Island's population. Densities of Spinifexbirds in the southern area and along the proposed pipeline route are probably similar to those found around Latitude Point, as the species does not have the coastal habitat bias seen in Singing Honeyeaters and to some degree White-winged Fairy-wrens.

The remaining bird species observed during the site inspection were the Bar-shouldered Dove, Horsfield's Bronze-Cuckoo, White-breasted Woodswallow, Welcome Swallow, Spotted Harrier, Nankeen Kestrel and Osprey. A Sacred Kingfisher was reported from the coast near Latitude Point (C. Surman pers. comm.). Only a single Bar-shouldered Dove was seen and the Island population is estimated as 180 (see Table 3), with the species apparently showing a slight preference for coastal habitats (Sedgwick 1978). There were also single records of the Horsfield's Bronze-Cuckoo, Spotted Harrier and Nankeen Kestrel, with the latter species reported to breed on the tanks at Latitude Point. An Osprey nest with three eggs was located on a cliff at Latitude Point. Both the White-breasted Woodswallow and Welcome Swallow were restricted to coastal habitats, especially over acacia and melaleuca open shrublands.

With respect to the proposed development area, there is a clear bias in the distribution of most common bird species towards vegetation with an open stratum of either acacia or melaleuca, with the exception of the Spinifexbird. As a result, most species are largely restricted to coastal areas, although the White-winged Fairy-wren also occurred in suitable vegetation west of the Barge Landing road. Reducing impacts on taller and especially coastal vegetation should make it possible to reduce impacts of the development upon bird species.

3.4 Mammals

The terrestrial mammal fauna of Barrow Island is depauperate with only 14 resident native species, but is highly significant because six of the taxa are listed as Vulnerable and one is classed as Priority 4 by CALM (See Table 4). Four of the Vulnerable taxa (Barrow Island Golden Bandicoot, Boodie, Spectacled-Hare-Wallaby and Black-flanked Rock-Wallaby) fall into the critical weight range (*sensu* Burbidge and McKenzie 1989), and have declined across much of their former range due to changes in fire regimes and predation by Foxes. In contrast, the Barrow Island Euro (Vulnerable) and Chestnut Mouse or Moolboo (Vulnerable) are endemic races with secure mainland races. The Rakali or Water-rat (Priority 4) has declined in parts of its mainland range, with the Barrow Island population being the only occurrence of this species in the Pilbara. The mammal fauna is also significant because of the absence of introduced species. The House Mouse *Mus musculus* and Black Rat *Rattus rattus* have been actively excluded and at times eradicated from Barrow Island and small islands offshore.

The mammal fauna is subject to a monitoring programme and existing Island population estimates are under review because of extreme differences in estimates for some species (Morris *et al.* 2001). Species for which population estimates are available (WAPET 1991 and Strahan 1995) are: Brush-tailed Possum (10 000), Golden Bandicoot (8 900 – 80 000), Spectacled Hare-Wallaby (10 000), Boodie (3 400 – 5 000), Black-flanked Rock Wallaby (150) and Euro (1 800). The extreme variation, particularly with the Golden Bandicoot, is a result of the estimates being based on spotlighting surveys during which the visibility of species is highly variable.

During the site inspection, all resident species were recorded (Table 4) with the exception of the Rakali or Water-rat, which is almost certainly present along the coast at Latitude Point and Flacourt Bay, and the Planigale. Most species were detected only during spotlighting, with spotlighting results summarised on Table 5 (raw data presented in Appendix 4). This spotlighting really only served to confirm the presence of species known to occur in the area and was inadequate to provide quantitative information.

More detailed observations on mammals were limited to searching for Boodie warrens and some opportunistic observations on Spectacled Hare-Wallabies and Euros. These were carried out during the half hour surveys conducted throughout the Latitude Point development area, southern area and along the pipeline route. Details on mammal observations made during these surveys appear in Appendix 3, including the locations and sizes of all Boodie warrens. Six warrens (and one possible warren) were located in the Latitude point area, with a minimum of 55 entrances, and these included the only warren previously known in the area. Four of the warrens were clustered on a limestone ridge at the base of Latitude Point. Two warrens were located in the southern area, with a total of 6 entrances. Attempts to locate other warrens known from this area were unsuccessful, presumably because GPS readings were approximations only, but exact locations of warrens in this region are not important with respect to development. Only one warren with 10 entrances was located along the pipeline route. This was in the area just west of the Barge Landing road.

Within the proposed gas processing facility site at Latitude Point, coverage for warrens cannot be considered to have been complete, but searching was intensive and the majority of warrens were probably located. Coverage was also good along the proposed pipeline route, but was incomplete in the southern area.

Only four Spectacled Hare-Wallabies were located during the half hour surveys, despite the amount of ground covered. Three of these were in the proposed Latitude Point processing facility site and one along the proposed pipeline route, and all were in tall, dense spinifex of valleys.

It is possible to take the information collected during the field inspection, and other available data, and consider the pattern of distribution of each species with respect to the proposed development. These patterns are as follow:

- Planigale. On the mainland, associated with clay soils. Apparently few records from Barrow Island, but a specimen caught under brush on clay soil near Surf Point in 1997 (pers. obs.). This species may be uncommon in the development area.
- *P. roryi*. On the mainland, often associated with rocky environments so probably widespread in the development area except on the near-coastal sandy loams and sands.
- Brush-tailed Possum. Widespread but reported to shelter in limestone crevices and solution pipes, so possibly most abundant along coast and in centre of the

Island where the greatest exposure of limestone occurs. Therefore may be most abundant along the pipeline route.

- Golden Bandicoot. Widespread but considered to be most abundant in coastal habitats (Strahan 1995).
- Boodie. Widespread but with warrens often constructed under slabs of limestone amongst figs. However, no warrens located in apparently suitable areas along much of the proposed pipeline route, while the density of tracks in the southern area appeared to be greatest close to the coast. Concentration of warrens in the north-east of the Latitude Point processing facility site needs to be considered during detailed planning. There are at least half as many Boodies in a warren as there are entrances (Strahan 1995), so there are at least 30 Boodies within the proposed Latitude Point processing facility site, representing about 1% of the Island population.
- Spectacled Hare-Wallaby. Favours dense, tall spinifex of valleys for shelter and observations during the site inspection were consistent with this. Widespread when foraging at night. Some areas of suitable shelter habitat in proposed development areas. The average density on Barrow Island is given as 42/km^2 (Strahan 1995), so the proposed Latitude Point processing facility site may support about 13 Hare-Wallabies.
- Euro. Widespread but needs shelter under limestone overhangs, especially during the hotter months. Makes wide use of artificial structures for shelter.
- Black-flanked Rock-Wallaby. Confined to limestone gorges and breakaways in the west of the island, particularly John Wayne Country. Several sightings of this species in the gorges above Flacourt Bay by other observers (S. Finn and G. Humphries). With an estimated population of only 150, any slight impact will be significant.
- Common Sheathtail Bat and *V. finlaysoni*. Probably widespread with roosting caves reported in south of island. Both may also make use of other roosting sites. For example, *V. finlaysoni* was observed in a dry drainage channel approximately 2 km south of the development area and possibly roosts in its eroded banks,
- Rakali or Water-rat. Coastal environments, foraging on beaches and sheltering in limestone crevices. Therefore present at both Latitude Point and Flacourt Bay.
- Chestnut Mouse of Moolboo. Probably most abundant on coastal sandy loams and sands in the vicinity of Latitude Point.
- Djoorri or Rock-rat. Areas of exposed limestone, particularly in centre and west of island and therefore mainly along pipeline route.

The above observations suggest that impacts on mammals will result from loss or disturbance of habitat, particularly in near-coastal locations at Latitude Point, areas of tall, dense spinifex and in the limestone gorges near Flacourt Bay. Also of concern is the effect of the pipeline as a barrier to the movement of mammals, requiring that the pipe be either raised or buried.

4.0 CONCLUSIONS; IMPACTS AND KEY ISSUES

Key impacts and issues associated with the Gorgon gas development can be summarised as follows:

- Barrow Island supports a terrestrial vertebrate fauna that is of great conservation significance.
- Fauna habitats in areas likely to be affected by the development are typical of those found right across Barrow Island. Therefore, at the simplest level, impacts upon fauna can be assumed to be proportional to the area of habitat loss. For example, the total area of impact for the development site at Latitude Point is *ca.* 1.3 % of the Island, so the impact upon the populations of most species will be *ca.* 1.3 %. Population estimates calculated for the site suggest that impacts might be slightly greater than this on some species (eg White-winged Fairy-wren) if the more important coastal habitats are affected
- Most habitats run in roughly concentric rings around the Island, with the coastal habitats being smaller in area than the broad expanses of spinifex over limestone that occupies much of the island. Therefore, development along and parallel to the coast will tend to impact rarer habitats than development that runs in from the coast. Tall spinifex of valleys is an exception to the general pattern of habitat distribution.
- The potential exists to reduce impacts on some species (Boodie, Golden Bandicoot, White-winged Fairy-wren, Singing Honeyeater) by avoiding coastal and near-coastal areas at the proposed Latitude Point processing facility site. Impacts on the Spectacled Hare-Wallaby can be minimised by avoiding tall spinifex of valleys if possible. These principles also apply to the proposed CO_2 reinjection site near Cape Dupuy.
- Further potential to reduce impact on Boodies exists by avoiding all warrens. The cluster of warrens in the north-west of the footprint is particularly important and these animals probably require access to areas immediately north for foraging. Integrating the development across the landscape and retaining habitat wherever possible, rather than developing the site as a block and losing all habitats within that block, should enable species to persist within the proposed development areas.
- The mammal species with the smallest population and most restricted distribution is the Black-flanked Rock-Wallaby. It could be sensitive to even minor disturbance in the gorges near Flacourt Bay. With minimal disturbance, a raised pipeline could ultimately be used for shelter by the Rock-Wallabies.
- The proposed pipeline has the potential to act as a barrier to the free movement of fauna across the island and therefore needs to be buried or raised. Clearing associated with the proposed pipeline should be minimised.

Table 1. Frog and reptile species recorded from Barrow Island, excluding marine species, based upon WA Museum records and WAPET (1991). Species observed within the project area in August 2002 are indicated (+). The conservation status of species under the WA Wildlife Conservation Act, Federal EPBC Act and CALM priority list is indicated. Sub-specific names are given only where the species present on the island is endemic or the sub-species has a conservation status different from other races of that species.

Species		August 2002	Conservation status
Hylidae (tree-frogs)			
	Cyclorana maini		
Gekkonidae (geckoes)			
	Diplodactylus jeanae		
	Diplodactylus stenodactylus		
Tree Dtella	*Gehyra variegata*		
Pilbara Dtella	*Gehyra pilbara*		
Bynoe's Gecko	*Heteronotia binoei*	+	
Pygopodidae (legless-lizards)			
	Delma borea		
	Delma nasuta		
	Delma tincta		
Burton's Legless-Lizard	*Lialis burtonis*		
Hooded Scalyfoot	*Pygopus nigriceps*		
Agamidae (dragon lizards)			
Ring-tailed Dragon	*Ctenophorus caudicinctus*		
Long-nosed Water-Dragon	*Gemmatophora longirostris*		
Bearded Dragon	*Pogona minor*	+	
Varanidae (goannas or monitor lizards)			
Spiny-tailed Goanna	*Varanus acanthurus*	+	
Short-tailed Goanna	*Varanus brevicauda*		
Perentie	*Varanus giganteus*	+	
Scincidae (skink lizards)			
	Carlia triacantha		
	Cryptoblepharus carnabyi		
	Ctenotus grandis	+	
	Ctenotus pantherinus acripes		endemic
	Ctenotus duricola		
	Ctenotus hanloni		
	Ctenotus saxatilis		
	Ctenotus serventyi	+	
	Cyclodomorphus melanops		+
	Eremiascincus richardsonii		
	Glaphyromorphus isolepis		

Table 1 (cont.)

Species		August 2002	Conservation status
	Lerista bipes		
	Lerista elegans		
	Lerista muelleri		
Dwarf Skink	*Menetia greyii*		
	Morethia lineoocellata		
	Morethia ruficauda	+	
	Notoscincus ornatus		
	Proablepharus reginae		
Typhlopidae (blind snakes)			
	Ramphotyphlops ammodytes		
	Ramphotyphlops longissimus		P2
Boidae (pythons)			
Stimson's Python	*Antaresia stimsoni*		
Elapidae (front-fanged snakes)			
Rufous Whip-Snake	*Demansia rufescens*		
Moon Snake	*Furina ornata*		
Mulga Snake	*Pseudechis australis*		
Monk Snake	*Suta (Rhinoplocephalus) monachus*		
	Brachyurophis (Vermicella) approximans		

Table 2. Bird species recorded from Barrow Island, based upon WA Museum records and WAPET (1991), excluding marine species but including some that forage in both marine and terrestrial environments. Species observed within the project area in August 2002 are indicated (+), while under Island Status, species that are residents or regular visitors (based largely on Sedgwick 1978) are shown as R. The conservation status of species under the WA Wildlife Conservation Act, Federal EPBC Act and CALM priority list is indicated.

Species		Aug 2002	Island status	Conservation status
Phasianidae (pheasants and quails)				
Brown Quail	*Coturnix ypsilophora*	+	?R	
Accipitridae (kites, hawks and eagles)				
Osprey	*Pandion haliaetus*	+	R	
Black-shouldered Kite	*Elanus notatus*	+	R	
Square-tailed Kite	*Lophoictinia isura*			P4
Black-breasted Buzzard	*Hamirostra melanosternon*			
Whistling Kite	*Haliastur sphenurus*			
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	+	R	
Spotted Harrier	*Circus assimilis*	+	R	
Wedge-tailed Eagle	*Aquila audax*			
Falconidae (falcons)				
Brown Falcon	*Falco berigora*			
Australian Hobby	*Falco longipennis*			
Nankeen Kestrel	*Falco cenchroides*	+	R	
Otidae (bustards)				
Australian Bustard	*Ardeotis australis*			near threatened
Glareolidae (pratincoles)				
Australian Pratincole	*Stiltia isabella*			migratory
Columbidae (pigeons and doves)				
Crested Pigeon	*Ocyphaps lophotes*			
Peaceful Dove	*Geopelia placida*			
Bar-shouldered Dove	*Geopelia humeralis*	+	R	
Cacatuidae (cockatoos)				
Galah	*Cacatua roseicapilla*			
Little Corella	*Cacatua sanguinea*			
Cockatiel	*Nymphicus hollandicus*			
Psittacidae (lorikeets and parrots)				
Budgerigar	*Melopsittacus undulatus*			
Cuculidae (cuckoos)				
Pallid Cuckoo	*Cuculus pallidus*		R	
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*	+	R	
Black-eared Cuckoo	*Chrysococcyx osculans*		R	

Table 2 (cont.)

Species		Aug 2002	Island status	Conservation status
Strigidae (hawk-owls)				
Southern Boobook Owl	*Ninox novaeseelandiae*		R	
Tytonidae (barn owls)				
Barn Owl	*Tyto alba*			
Apodidae (swifts)				
swiftlet species	*Collocalia* sp.			
Fork-tailed Swift	*Apus pacificus*		R	
White-throated Needletail	*Hirundapus caudacutus*		R	
Halcyonidae (forest kingfishers)				
Red-backed Kingfisher	*Todiramphus pyrrhopygia*			
Sacred Kingfisher	*Todiramphus sanctus*	+	R	
Maluridae (fairy-wrens)				
Barrow Island White-winged Fairy-wren	*Malurus leucopterus edouardi*	+	R	Sched. 1, Vulnerable
Meliphagidae (honeyeaters)				
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*			
Singing Honeyeater	*Lichenostomus virescens*	+	R	
Brown Honeyeater	*Lichmera indistincta*			
Crimson Chat	*Epthianura tricolor*			
Dicruridae (flycatchers)				
Magpie-lark	*Grallina cyanoleuca*			
Willie Wagtail	*Rhipidura leucophrys*			
Campephagidae (cuckoo-shrikes)				
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*			
White-winged Triller	*Lalage sueurii*		R	
Artamidae (woodswallows)				
White-breasted Woodswallow	*Artamus leucorhynchus*	+	R	
Masked Woodswallow	*Artamus personatus*			
Black-faced Woodswallow	*Artamus cinereus*			
Corvidae (ravens and crows)				
Little Crow	*Corvus bennetti*			
Motacillidae (pipits and true wagtails)				
Richard's Pipit	*Anthus novaeseelandiae*			
Passeridae (finches and allies)				
Painted Firetail	*Emblema picta*			
Zebra Finch	*Taeniopygia guttata*		R	
Hirundinidae (swallows)				
Welcome Swallow	*Hirundo neoxena*	+	R	
Tree Martin	*Hirundo nigricans*		R	
Fairy Martin	*Hirundo ariel*			
Sylviidae (Old World warblers)				
Spinifexbird	*Eremiornis carteri*	+	R	

Brown Songlark	*Cincloramphus cruralis*				
Zosteropidae (silvereyes) Yellow White-eye	 *Zosterops luteus*		?R		

Table 3. Island populations of the landbird species recorded during the August site inspection as estimated by Pruett-Jones and O'Donnel (unpub.) and Sedgwick (1978), compared with counts of these species in the Latitude Point area (primarily the notional 300 ha development area), the area south of the proposed gas processing facility site and along the proposed pipeline route. See text for details on these areas. A question mark indicates what is certainly an over-estimate due to a bias introduced by the survey technique (Sedgwick 1978).

	Pruett-Jones & O'Donnel	Sedgwick	Latitude Point	Southern area	Pipeline route
Osprey		39	2		2
White-bellied Sea-Eagle		12	0		0
Spotted Harrier		? 180	1		0
Nankeen Kestrel		? 1 650	1		0
Bar-shouldered Dove		180	1		0
Horsfield's Bronze-Cuckoo		? 910	1		0
Sacred Kingfisher		12	1		0
White-winged Fairy-wren	7 519	8 150	81	27	12
Singing Honeyeater	3 920	3 050	20	1	5
Welcome Swallow	1 077	8 500	9	2	0
White-breasted Woodswallow	1 945	3 450	2		0
Spinifexbird	24 623	17 800	57	2	5

Table 4. Mammal species recorded from Barrow Island, based upon WA Museum records and WAPET (1991), excluding marine species. Species observed within the project area in August 2002 are indicated (+). The conservation status of species under the WA Wildlife Conservation Act, Federal EPBC Act and CALM priority list is indicated. Introduced species considered to be absent from the main island have been excluded.

Species		Aug 2002	Conservation status
Dasyuridae			
	Planigale sp.		
	Pseudantechinus roryi	+	
Phalangeridae (possums)			
Northern Brush-tailed Possum		+	
	Trichosurus vulpecula arnhemensis		
Peramelidae (bandicoots)			
Barrow Island Golden Bandicoot		+	Vulnerable
	Isoodon auratus barrowensis		
Potoroidae (potoroos and bettongs)			
Barrow Island Boodie		+	Vulnerable
	Bettongia lesueur (Barrow Island race)		
Macropodidae (kangaroos and wallabies)			
Barrow Island Spectacled Hare-Wallaby		+	Vulnerable
	Lagorchestes conspicillatus conspicillatus		
Barrow Island Euro	*Macropus robustus isabellinus*	+	Vulnerable
Black-flanked Rock-Wallaby	*Petrogale lateralis*	+	Vulnerable
Pteropodidae (fruit bats or flying-foxes)			
Black Flying-fox	*Pteropus alecto*		(vagrant)
Emballonuridae (sheathtail bats)			
Common Sheathtail Bat	*Taphozous georgianus*	+	
Mollosidae (mastiff bats)			
White-striped Bat	*Tadarida (Nyctinomus) australis*		(vagrant)
Vespertilionidae (vesper bats)			
	Vespadelus (Eptesicus) finlaysoni	+	
Muridae (rats and mice)			
Rakali or Water-rat	*Hydromys chrysogaster*		Priority 4
Barrow Island Chestnut Mouse or Moolboo		+	Other Specially
	Pseudomys nanus ferculinus		Protected Fauna
Djoorri or Common Rock-Rat	*Zyzomys argurus*	+	

Table 5. Summary of observations during spotlighting. Each spotlighting survey was carried out from near the ChevronTexaco Camp to Flacourt Bay, a distance of 16 km, except where noted. Spotlighting began within half an hour after sunset and had a duration of 1.5 hours. Details of spotlighting results are presented in Appendix 5.

Species	ChevronTexaco Camp-Flacourt Bay (16 km)			John Wayne Country 11/08 (4.6 km)
	10/08	11/08	12/08	
P. roryi	1			
Bandicoot	2	6	5	1
Possum	4	1	2	2
Boodie	6		2	
Hare-Wallaby	1	5	5	2
Rock-Wallaby				1
Euro	1			
Rock-Rat	1			1
Chestnut Mouse			1	
V. finlaysoni	1			
T. georgianus		1		

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APPENDIX 1. Categories used in the assessment of conservation status.

Environmental Protection and Biodiversity Conservation Act and the WA Wildlife Conservation Act (categories from IUCN, based on review by Mace and Stuart (1994)).

Extinct. Taxa not definitely located in the wild during the past 50 years.

Extinct in the Wild. Taxa known to survive only in captivity.

Critically Endangered. Taxa facing an extremely high risk of extinction in the wild in the immediate future.

Endangered. Taxa facing a very high risk of extinction in the wild in the near future.

Vulnerable. Taxa facing a high risk of extinction in the wild in the medium-term future.

Near Threatened. Taxa that risk becoming Vulnerable in the wild.

Conservation Dependent. Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.

Data Deficient (Insufficiently Known). Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.

Least Concern. Taxa that are not Threatened.

WA Department of Conservation and Land Management Priority species (species not listed under the Conservation Act, but for which there is some concern).

Priority 1. Taxa with few, poorly known populations on threatened lands.

Priority 2. Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.

Priority 3. Taxa with several, poorly known populations, some on conservation lands.

Priority 4. Taxa in need of monitoring.

APPENDIX 2. Observations on birds in each half-hour survey of the Latitude Point development area, southern area and proposed pipeline route. Locations, habitats, dates and times of each survey are given in Appendix 4.

Proposed Latitude Point processing facility site

Survey No.	NKes	Osp	HBC	BshD	WwFw	SingH	WelSw	WbWs	Spinbd
1	1				5	1	1		
2						2			4
3									
4		2				1	1		
5						2	2		1
6						1	1	1	3
7					3				1
8					3	2			3
9					3		1		3
10					3	1			6
11				1	3	1		1	3
12					3				4
13			1		6	1			
14									1
15									2
16					6				2
17					3				
18					3				2
19					3				1
20					3				1
21									
22									2
23					6				
24					3				
25									
26					3				1
27					6				4
28					3				3
29					3				1
30									1
31					3				1

Area south of the proposed Latitude Point processing facility site

Survey No.	NKes	Osp	HBC	BshD	WwFw	SingH	WelSw	WbWs	Spinbd
32						1			
33						2	1		
34					3	1	1		1
35					3		1		2
36						1			1
37						3		3	3
38					3				
39					3				1
40					9				
41					9	1	2		1

Proposed pipeline route

Survey No.	NKes	Osp	HBC	BshD	WwFw	SingH	WelSw	WbWs	Spinbd
42						1			1
43						2			
44									
45									1
46						1			
47					3				
48									2
49					6				
50					3	1			
51									1

APPENDIX 3. Observations on mammals in half-hour survey of the proposed Latitude Point gas processing facility site, southern area and proposed pipeline route. Locations of Boodie warrens and Spectacled Hare-Wallabies are indicated. Only surveys in which mammals were recorded are indicated. Locations, habitats, dates and times of each survey are given in Appendix 4.

Proposed Latitude Point processing facility site

Survey No.	Boodie Warrens	Euro	Hare-Wallaby
3	340 089 E, 701 563 N (5 entrances) 340 111 E, 701 644 N (20+ entrances) 340 107 E, 701 721 N (5 entrances)		
4	340 195 E, 701 732 N (5 entrances)	2	
5			2 at 340 269 E 701 816 N
12	339 145 E, 702 400 N (10 entrances)		
14	possible warren, enlarged by Euros? 338 318 E, 702 245 N		
20	339 147 E, 701 242 N (10 entrances)		
25			1 at 337 790 E, 701 534 N

Area south of the proposed Latitude Point processing facility site

Survey No.	Boodie Warrens	Euro	Hare-Wallaby
32		2	
33	339 592 E, 700 711 N (1 entrance)		
36	339 282 E, 700 128 N (5 entrances)		

Proposed pipeline route

Survey No.	Boodie Warrens	Euro	Hare-Wallaby
42		2	
43		2	
47			1 at 334 090 E, 702 856 N
49	335 297 E, 702 589 N (10 entrances)		

Locations of Boodie warrens south of the airport:
330 832 E, 7 693 858 N
330 792 E, 7 693 199 N
327 347 E, 7 692 716 N
329 233 E, 7 693 772 N

APPENDIX 4. Survey numbers, start and finish locations, dates, times and habitats of each survey.

Proposed Latitude Point gas processing facility site

Survey No.	start	finish	date	time	Vegetation/habitat
1	701 500 E 336 600 N	702 000 E 339 600 N	09/08	1300- 1330	Spinifex with some acacia and melaleuca, including dense, tall spinifex in valley and ridge of limestone with fig clumps. Soils from shallow over limestone to red sandy loams. Small area of skeletal soils and sparse shrubs near coast.
2	702 000 E 339 600 N	701 750E 339 900 N	09/08	1330- 1400	
3	701 750E 339 900 N	701 760 E 340 240 N	09/08	1400- 1430	
4	701 760 E 340 240 N	701 780 E 340 370 N	09/08	1430- 1500	
5	701 780 E 340 370 N	702 020 E 340 080 N	09/08	1500- 1530	
6	702 020 E 340 080 N	702 400 E 339 900 N	09/08	1530- 1600	
7	702 400 E 339 900 N	702 580 E 339 780 N	09/08	1600- 1630	Spinifex on low limestone ridges, with tall spinifex in broad valleys.
8	702 580 E 339 780 N	702 300 E 339 700 N	09/08	1639- 1700	
9	702 300 E 339 700 N	702 000 E 339 650 N	09/08	1700- 1730	
10	701 650 E 339 450 N	339 345 E 702 340 N	10/08	0645- 0715	Low spinifex on shallow soil over limestone hills, with some valleys of tall, dense spinifex in red sandy loam.
11	339 345 E 702 340 N	339 327 E 702 807 N	10/08	0715- 0745	
12	339 327 E 702 807 N	339 251 E 702 275 N	10/08	0745- 0815	
13	339 251 E 702 275 N	338 713 E 702 168 N	10/08	0815- 0845	
14	338 713 E 702 168 N	338 318 E 702 245 N	10/08	0845- 0915	
15	338 318 E 702 245 N	337 659 E 701 943 N	10/08	0915- 0945	
16	337 659 E 701 943 N	338 273 E 701 852 N	10/08	0945- 1015	Low spinifex on shallow soil of low hills, with a lot of exposed limestone. Some dense, tall spinifex in gullies. Generally very few shrubs.
17	338 273 E 701 852 N	338 989 E 701 963 N	10/08	1015- 1045	
18	338 989 E 701 963 N	339 200 E 701 620 N	10/08	1045- 1115	
19	339 200 E 701 620 N	339 340 E 700 993 N	10/08	1345- 1415	

Appendix 4 (cont.)

Survey No.	start	finish	date	time	Vegetation/habitat
20	339 340 E 700 993 N	339 147 E 701 242 N	10/08	1415- 1445	Low spinifex on shallow soil of low hills, with a lot of exposed limestone. Some dense, tall spinifex in gullies. Generally very few shrubs.
21	339 147 E 701 242 N	339 037 E 700 830 N	10/08	1445- 1515	
22	339 037 E 700 830 N	338 545 E 701 033 N	10/08	1515- 1545	
23	338 545 E 701 033 N	338 216 E 701 097 N	10/08	1545- 1615	
24	338 216 E 701 097 N	338 123 E 701 222 N	10/08	1615- 1645	
25	338 123 E 701 222 N	337 790 E 701 534 N	10/08	1645- 1715	
26	337 790 E 701 534 N	338 070 E 701 690 N	10/08	1715- 1745	
27	337 604 E 701 555 N	337 228 E 700 919 N	11/08	0700- 0730	Undulating limestone hills with low spinifex and few shrubs, but including dense spinifex along a seasonal watercourse and a few fig clumps.
28	337 228 E 700 919 N	337 237 E 701 527 N	11/08	0730- 0800	
29	337 237 E 701 527 N	338 037 E 701 708 N	11/08	0800- 0830	
30	338 037 E 701 708 N	338 658 E 701 521 N	11/08	0830- 0900	
31	338 658 E 701 521 N	339 176 E 701 355 N	11/08	0900- 0930	

Appendix 4 (cont.)

Area south of the proposed Latitude Point gas processing facility site

Survey No.	start	finish	date	time	Vegetation/habitat
32	339 176 E 701 355 N	339 740 E 701 042 N	11/08	0930- 1000	Spinifex with an overstorey of acacia. Soils a sandy loam with patches of exposed limestone and some dolines.
33	339 740 E 701 042 N	339 593 E 700 711 N	11/08	1000- 1030	
34	339 593 E 700 711 N	339 515 E 700 677 N	11/08	1030- 1100	
35	339 515 E 700 677 N	339 226 E 700 248 N	11/08	1100- 1130	
36	339 226 E 700 248 N	339 282 E 700 128 N	11/08	1130- 1200	
37	339 282 E 700 128 N	338 797 E 699 513 N	11/08	1645- 1715	
38	336 861 E 701 558 N	337 006 E 700 900 N	12/08	1530- 1600	Low spinifex on limestone ridges with few fig clumps
39	337 006 E 700 900 N	337 818 E 700 382 N	12/08	1600- 1630	
40	337 818 E 700 382 N	338 540 E 700 282 N	12/08	1630- 1700	Low spinifex with an open, shrubby overstorey of acacia and melaleuca
41	338 540 E 700 282 N	339 150 E 700 210 N	12/08	1700- 1730	

Appendix 4 (cont.)

Proposed pipeline route

Survey No.	start	finish	date	time	Vegetation/habitat
42	331 357 E 705 442 N	331 691 E 705 003 N	12/08	0715-0745	Sandy beach of Flacourt Bay into limestone gorge with breakaways and figs
43	331 691 E 705 003 N	332 186 E 704 449 N	12/08	0745-0815	
44	332 186 E 704 449 N	332 270 E 703 757 N	12/08	0815-0845	Low spinifex with scattered figs in shallow soil over limestone, but with slight valleys supporting dense spinifex
45	332 270 E 703 757 N	333 275 E 703 321 N	12/08	0845-0915	
46	333 275 E 703 321 N	333 696 E 703 114 N	12/08	0915-0945	
47	333 696 E 703 114 N	334 371 E 702694 N	12/08	0945-1015	
48	334 371 E 702694 N	334 988 E 702 522 N	12/08	1015-1045	Low spinifex with a shrub overstorey of acacia and melaleuca, few figs. Seasonal watercourse with dense spinifex and a limestone breakaway nearby
49	334 988 E 702 522 N	335 297 E 702 589 N	12/08	1045-1115	
50	335 297 E 702 589 N	336 536 E 701 959 N	12/08	1430-1500	
51	336 536 E 701 959 N	336 861 E 701 558 N	12/08	1500-1530	Low spinifex on limestone hills with scattered figs

APPENDIX 5. Results of spotlighting surveys. Note: sunset about 18.30 hrs, new moon setting about 20.00 hrs on 10/08/. Each survey within period 19.00 to 21.00 hrs.

10/08
Road south of tanks: 4 Boodies, 2 Bandicoots, 2 Hare-Wallabies and a small bat (*Vespedalus*).
From tanks to 5 km west: 2 Possums, 1 Hare-Wallaby.
From 5 m west to Flacourt Bay: 2 Possums, 2 Boodies, 1 Hare-Wallaby, 1 Zyzomys (male, scrotal testes) and 1 Euro.
Head-torching over same period along road south of tanks. *Pseudantechinus* scats, 1 *Heteronotia binoei*.

11/08/'02. 1900-2030 hrs. Same route as on 10/08, but also did sector down into John Wayne Country.
0 km. Start at intersection of roads near camp.
1.2 km. 1 bandicoot
2.2 km. 1 bandicoot and 1 Spectacled Hare-Wallaby
2.9 km. 1 Brush-tailed Possum
3.1 km. 1 bandicoot
3.7 km. 1 bandicoot, 1 hare-wallaby
3.9 km. 1 hare-wallaby
5.2 km. 1 hare-wallaby
5.8 km. tanks
8.0 km. 1 bandicoot
9.6 km. crossroads
11.2 km. 1 bandicoot
12.3 km. hare-wallaby
15.9 km. Flacourt Bay

0 km. start of diversion into John Wayne Country
0.6 km. Zyzomys
2.8 km. Hare-wallaby
3.0 km. Bandicoot
3.2 km. possum
4.0 km. rock wallaby and hare wallaby
4.1 km. possum
4.6 km. beach

Appendix 5 (cont.)

12/08. 1920- Same route as previously (excluding John Wayne Country).
0.0 km. Start at intersection of roads near camp.
0.3 km. 1 Spectacled Hare-Wallaby
1.4 km. 1 Bandicoot
5.8 km. tanks
6.9 km. 1 Boodie
8.6 km. 1 Spectacled Hare-Wallaby
9.8 km. 1 Bandicoot
11.0 km. 1 Possum
11.3 km. 1 Spectacled Hare-Wallaby
11.5 km. 1 Bandicoot
11.6 km. 1 Bandicoot
11.8 km. 1 Possum and 2 Spectacled Hare-Wallaby
12.5 km. 1 Boodie
12.8 km. small rodent, presumably *P. nanus*
14.3 km. 1 Bandicoot
15.9 km. Flacourt Bay

APPENDIX H

A PRELIMINARY SURVEY OF THE TERRESTRIAL MOLLUSCAN FAUNA OF AREAS WITHIN AND ADJACENT TO THE LAND-BASED COMPONENT OF THE PROPOSED GORGON DEVELOPMENT, BARROW ISLAND, WESTERN AUSTRALIA. SEPTEMBER 2002

(S.M SLACK- SMITH, WESTERN AUSTRALIAN MUSEUM)

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1 Introduction

The fieldwork component of a preliminary survey of the terrestrial molluscan fauna of Barrow Island, Western Australia was carried out from the 9th to 13th of August 2002. The stations sampled included areas which may be impacted by the land-based components of the proposed Gorgon gas development, and those immediately adjacent to them (see Figures 1 and 2).

This is the first survey of the non-marine molluscan fauna of any part of Barrow Island. Specimens and data collected during this survey have significantly augmented those previously available in the collections of the Western Australian Museum, which had comprised few and generally poorly-localised snail specimens.

Figure 1. Survey Area and Sampling Stations

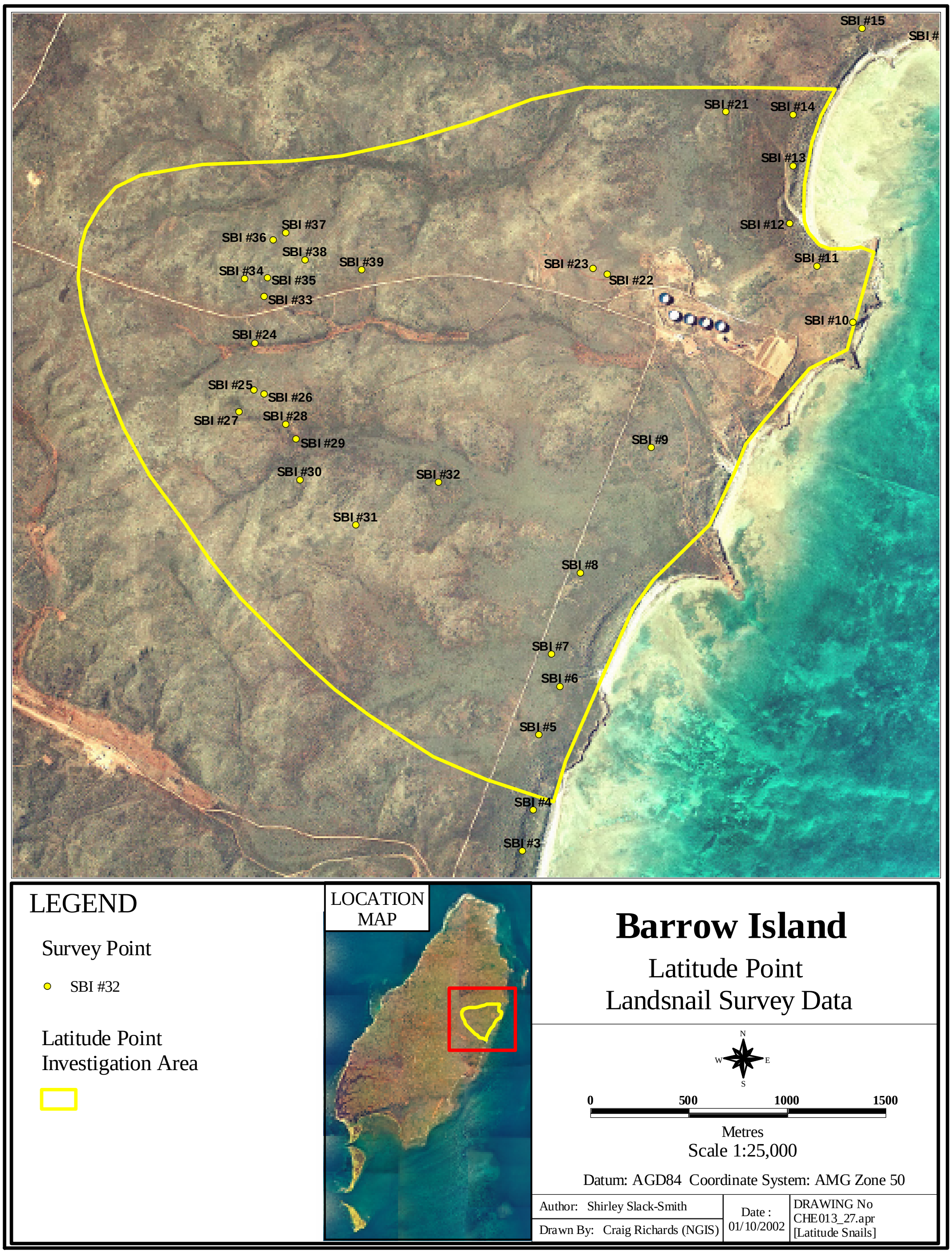


Figure 2. Latitude Point and Sampling Stations

2 Procedures

2.1 Introduction

During the four days of fieldwork, 51 survey stations were established in accordance with the current plans for the project. These stations were located within an "area under investigation" on the east coast of Barrow Island that included the proposed gas processing facility "footprint" area near Latitude Point and immediately surrounding areas (Figure 1), as well as along much of the route of the currently-proposed pipeline between Latitude Point and Flacourt Bay on the west coast. In addition, stations were established outside but adjacent to these areas. As well as giving a consistent coverage of these areas, survey stations were sited to sample available variation in habitat.

2.2 Procedures

At each Survey Station:

- A description of the habitat and a GPS reading were recorded.
- Snail shells on the soil surface were collected over an area of approximately 30 square metres.
- Litter and soil was excavated over an area of approximately 30 cm^2 to a depth of about 10 cm in search of live snails. These were taken at the base of trees, shrubs or spinifex clumps.
- Soil and litter samples (approximately 1 litre in volume) were then sieved in the field and any visible shells were collected. These samples were retained for later examination and sorting under a stereomicroscope in the laboratory, when small to minute snails, both juvenile and adult and not initially obvious, were collected.

Both dead-taken and live-taken specimens were retained for identification. All are to be registered and placed into the research collections of the Western Australian Museum as voucher specimens.

2.3 Survey Stations

Table 1 presents the locations, habitats and brief vegetation descriptions for the stations sampled during the land snail survey of Barrow Island.

Table 1. Location, Habitat and Brief Vegetation Descriptions for the Stations Sampled During the Land Snail Survey of Barrow Island.

Station Number	Date Collected	Time	Latitude	Longitude	Location	Habitat and Vegetation Description
SBI # 1	09/08/2002	13:00	20°48'18.8"S	115°27'02"E	Near east coast; about 4 km SSW of Latitude Point; east of road; to the north of tidal creek bed.	Red soil; spinifex with *Grevillea* and *Acacia* to 2 m.
SBI # 2	09/08/2002	13:26	20°48'15.3"S	115°27'10.4"E	Near east coast; about 4 km SSW of Latitude Point; east of road; to north of SBI# 1	Red soil with limestone outcrop downhill; spinifex with *Acacia* spp. and *Grevillea* to 3 m.
SBI # 3	09/08/2002	13:53	20°48'07.2"S	115°27'13.7"E	Near east coast; SSW of Latitude Point; in slight gully between low east-west dunes.	Red sand with some marine sediment; many bushes of *Acacia* spp. to 2 m.
SBI # 4	09/08/2002		20°48'00.5"S	115°27'15.7"E	Near east coast; SSW of Latitude Point; in shallow north-south gully between first and second dunes from beach.	Brown soil; spinifex with *Acacia* spp.
SBI # 5	09/08/2002	14:53	20°47'48.1"S	115°27'16.8"E	Near east coast; SSW of Latitude Point; north facing slope from north end of second dune from beach; first dune had merged with second further south.	Red soil with calcrete; spinifex with *Solanum* & low *Acacia* bushes.
SBI # 6	09/08/2002		20°47'40.1"S	115°27'20.6"E	Near east coast; SSW of Latitude Point; at west end of narrow shallow but vertical-sided gully.	Limestone outcrop with little soil; spinifex with herbaceous plants with *Acacia* to 1 m.
SBI # 7	09/08/2002	15:45	20°47'34.8"S	115°27'19.1"E	Near east coast; SSW of Latitude Point; to the north and west of SBI # 6 and nearer to road.	Red-brown soil with calcrete; spinifex with *Acacia* spp. to 1 m, *Solanum* and *Grevillea* to 1.5 m.
SBI # 8	09/08/2002	16:20	20°47'21.4"S	115°27'24.3"E	Near east coast; SSW of Latitude Point; flat plain.	Red soil; spinifex with low shrubs and *Grevillea* and *Acacia* to 2 m.
SBI # 9	09/08/2002	16:57	20°47'00.9"S	115°27'36.9"E	Near east coast; SSW of Latitude Point; approx. 500 m south of eastern most tank; low rise on plain.	Red soil; spinifex with *Grevillea* and clump of *Ficus* trees.
SBI # 10	10/08/2002	06:55	20°46'40.6"S	115°28'12.6"E	Near east coast; SSW of Latitude Point; east of tanks; above limestone cliff.	Much litter with little red-brown soil on limestone; spinifex with *Euphorbia* to 1m.
SBI # 11	10/08/2002	07:20	20°46'31.3"S	115°28'06.3"E	Near east coast; SW of Latitude Point; inland from south end of beach.	Red soil with limestone rubble and calcrete; low spinifex with clump of *Ficus* trees to 2 m.
SBI # 12	10/08/2002	08:00	20°46'24.2"S	115°28'01.5"E	Near east coast; west of Latitude Point; shallow gully; between first and second dunes from beach.	Brown soil with marine sediments; spinifex with Solanum and *Acacia*.

Table 1. Location, Habitat and Brief Vegetation Descriptions for the Stations Sampled During the Land Snail Survey of Barrow Island. (Continued)

SBI # 13	10/08/2002		20°46'14.7"S	115°28'02.2"E	Near east coast; WNW of Latitude Point; to ENE of tanks on dune; immediately north of aerial to west of creek bed on top of dune; dry north-south creek bed between SBI #12 & #13; running into southern part of beach.	Brown soil with marine sediments; spinifex with *Acacia* spp. to 2 m.
SBI # 14	10/08/2002	08:52	20°46'06.3"S	115°28'02.3"E	Near east coast; NW of Latitude Point; ENE of tanks; on plain below dune;	Red soil; spinifex 0.5 m with *Acacia* and *Solanum*.
SBI # 15	10/08/2002	09:21	20°45'52.2"S	115°28'14.7"E	Near east coast; west of Dove Point; ENE of tanks; immediately to west of track to point at north end of beach; on plain west of dunes.	Brown-red soil with marine sediments; spinifex with *Acacia* and *Ficus*.
SBI # 16	10/08/2002	10:20	20°45'54.9"S	115°28'30.7"E	Near east coast; west of Dove Point and ENE of tanks; on track to point.	Red-brown soil with calcrete sheets nearby; spinifex with *Ficus* clump.
SBI # 17	10/08/2002	12:15	20°45'31.2"S	115°27'59.9"E	Just inland from east coast; NW of Dove Point; on top of hill near south end of beach; south of deep gully leading to beach.	Limestone outcrop with little soil; clump of low *Ficus* trees.
SBI # 18	10/08/2002	14:30	20°45'26.8"S	115°28'11.8"E	Just inland from east coast; NW of Dove Point; dry tidal creek bed in east-west gully leading to beach;	Limestone outcrop forming north bank of dry creek bed; *Ficus* trees and soft grasses.
SBI # 19	10/08/2002	15:10	20°45'38.6"S	115°27'59.4"E	Just inland from east coast; NW of Dove Point; south of SBI #17; west of track.	Red soil; low abundant spinifex with low shrubs.
SBI # 20	10/08/2002		20°45'23.1"S	115°27'50.9"E	Just inland from east coast; NW of Dove Point; south of SBI #19 and north of western-most tanks; west of track.	Hard surfaced red soil with areas of calcrete and limestone rubble; spinifex with *Acacia* and other low shrubs.
SBI # 21	10/08/2002		20°46'05.7"S	115°27'50.7"E	Just inland from east coast; WSW of Dove Point and north of west tank; west of track and "tower".	Spinifex with *Solanum* and *Acacia* spp. to 2 m.
SBI # 22	10/08/2002	16:50	20°46'32.3"S	115°27'29.5"E	Inland from east coast; west of Dove Point and west of tanks; uphill from road.	Hard baked red soil with calcrete areas and limestone rubble; spinifex with shrubs to 0.5 m.
SBI # 23	10/08/2002	17:15	20°46'31.4"S	115°27'27.1"E	Inland from east coast; west of Dove Point and west of tanks and SBI #22; uphill from road.	Hard baked red soil with calcrete areas and limestone rubble; spinifex with *Ficus* clumps.
SBI # 24	11/08/2002	07:00	20°46'43.0"S	115°26'27.7"E	Inland from east coast; WSW of Latitude Point; west of tanks and south of road to Flacourt Bay.	Red-brown soil with much limestone rubble; spinifex with *Acacia* to 0.5 m.

Table 1. Location, Habitat and Brief Vegetation Descriptions for the Stations Sampled During the Land Snail Survey of Barrow Island. (Continued)

SBI # 25	11/08/2002		20°46'50.8"S	115°26'27.5"E	Inland from east coast; WSW of Latitude Point and south of SBI #24; near top of ridge;	Mainly limestone with much rubble and very little red-brown soil or litter; spinifex with *Acacia* spp. to 2 m.
SBI # 26	11/08/2002	07:50	20°46'51.5"S	115°26'29.2"E	Inland from east coast; WSW of Latitude Point; ESE along ridge from SBI #25.	Mainly limestone with stones, little red-brown soil or litter; small low spinifex and shrubs to 1.5 m.
SBI # 27	11/08/2002	08:15	20°46'54.3"S	115°26'24.8"E	Inland from east coast; WSW of Latitude Point and west of SBI #26; on SE-facing slope.	Some limestone patches, much limestone rocks and rubble; spinifex to 0.5 m and *Ficus* clump.
SBI # 28	11/08/2002	08:50	20°46'56.5"S	115°26'32.9"E	Inland from east coast; WSW of Latitude Point at oil pipeline running east-west to tanks; beside track at base of shallow valley;	Red soil with little rubble; spinifex to 0.75 m with *Acacia* spp. and other low shrubs.
SBI # 29	11/08/2002	09:23	20°46'59.0"S	115°26'34.7"E	Inland from east coast; WSW of Latitude Point and just south of SBI # 28; at base of gully.	Red soil with little limestone rubble; spinifex to 0.8 m with *Acacia* to 1.5 m.
SBI # 30	11/08/2002	09:57	20°47'05.7"S	115°26'35.3"E	Inland from east coast; WSW of Latitude Point and south of SBI #24; near top of ridge on slope to north.	Red brown soil with much limestone sheets, stones and rubble; spinifex to 0.5 m with *Acacia* to 2.5 m and other low shrubs.
SBI # 31	11/08/2002		20°47'13.2"S	115°26'45.1"E	Inland from east coast; WSW of Latitude Point and NW of tanks; near top of east-west ridge on south-east facing slope.	Almost no soil with limestone stones and rubble; spinifex to 0.3 m with low *Cassia* bushes, *Grevillea* to 1.75 m.
SBI # 32	11/08/2002	11:15	20°47'06.3"S	115°26'59.6"E	Inland from east coast; WSW of Latitude Point and west of tanks.	Spinifex with *Acacia* trees to 2.5 m.
SBI # 33	11/08/2002	13:30	20°46'35.4"S	115°26'29.4"E	Inland from east coast; west of Latitude Point and NW road to north end of island; at western limit of examination area; on a south-facing slope.	Red soil with much limestone rocks and gravel; low spinifex with *Cassia* and *Acacia* spp. to 1.25 m.
SBI # 34	11/08/2002	14:00	20°46'32.4"S	115°26'26.0"E	Uphill to west of SBI #33 and slightly south of western tanks; near crest of hill	Limestone outcrop with rocks and rubble, no soil; low spinifex with *Ficus* trees to 1.25 m.
SBI # 35	11/08/2002	14:35	20°46'32.3"S	115°26'30.0"E	Inland from east coast; west of Latitude Point, downhill and slightly to south of SBI #34; on SE-facing slope.	Limestone outcrop with rocks and rubble, almost no soil; spinifex to 0.45 m with few low *Acacia* and *Ficus* to 1.5 m.

Table 1. Location, Habitat and Brief Vegetation Descriptions for the Stations Sampled During the Land Snail Survey of Barrow Island. (Continued)

SBI # 36	11/08/2002	15:15	20°46'26.1"S	115°26'31.0"E	Inland from east coast; west of Latitude Point and north of SBI # 35; on low N-facing slope of small rise;	Dark brown soil, limestone outcrop with rocks and rubble; scattered spinifex to 0.45 m with various small shrubs to 1 m.
SBI # 37	11/08/2002		20°46'24.9"S	115°26'33.3"E	Inland from east coast; west of Latitude Point and north of SBI # 36; very shallow gully with limestone outcrop 30 cm high	Limestone outcrop forming 0.3 m "cliff" across slope, small boulders rocks and rubble; few spinifex clumps to 0.5 m with low *Cassia* bushes.
SBI # 38	11/08/2002		20°46'29.5"S	115°26'36.6"E	Inland from east coast; west of Latitude Point and SE of SBI # 37; on NW-facing slope just below summit of ridge	Large limestone outcrop with rocks and rubble; spinifex to 0.5 m with *Ficus* to 1.5 m.
SBI # 39	11/08/2002		20°46'31.2"S	115°26'46.5"E	Inland from east coast; west of Latitude Point and SE of SBI # 38; on south-east facing slope on road to north of island.	Limestone outcrop with rocks and rubble; spinifex nearly 1 m high with small shrubs to 0.45 m, *Ficus* to 1.5 m.
SBI # 40	12/08/2002	07:30	20°44'36.6"S	115°23'00.1"E	Flacourt Bay area; north-south valley south of beach parking area; on west side of gully leading to beach (proposed pipeline entry) and three-quarter way up slope;	Light red-brown sand below small limestone outcrop; spinifex to 0.5 m.
SBI # 41	12/08/2002		20°44'38.1"S	115°23'02.2"E	Flacourt Bay area; north-south valley south of beach parking area; just above dry creek bed at base of W-facing slope	Limestone outcrop with rocks, some rubble and brown soil; spinifex to 0.5 m with *Ficus* trees to 2 m.
SBI # 42	12/08/2002		20°44'45.3"S	115°22'57.5"E	Flacourt Bay area; north-south valley south of beach parking area; at head of deep E/W gully which opens into N/S gully; on top of ridge, 50 m east of road;	Limestone outcrop with boulders, stones and red soil; spinifex to 0.5 m with *Ficus* trees to 0.75 m.
SBI # 43	12/08/2002	09:04	20°44'50.5"S	115°23'05.8"E	Flacourt Bay area; north-south valley south of beach parking area; at head of north-south gully; on north facing slope; dry creek bed.	Limestone outcrop with boulders, stones and some rubble, little red soil but deeper with much litter under trees; *Ficus* and *Mallotus* trees to 2.5 m.
SBI # 44	12/08/2002	09:40	20°45'02.5"S	115°23'02.1"E	South of Flacourt Bay and west of vehicle track to beach; inland from proposed marine park; just below summit of ridge on north facing gentle slope.	Limestone with boulders and stones, red soil, spinifex to 0.5 m with *Ficus* to 1.5 m.

Table 1. Location, Habitat and Brief Vegetation Descriptions for the Stations Sampled During the Land Snail Survey of Barrow Island. (Continued)

SBI # 45	12/08/2002	10:10	20°45’06.4”S	115°23’07.8”E	Flacourt Bay area; at head of SE-NW branch of valley leading to beach and east of SBI #44; at head of north-south gully to north of road; on north facing slope	Limestone outcrop with boulders, stones and little red soil; spinifex to 0.5 m with *Ficus* to 2 m.
SBI # 46	12/08/2002	10:50	20°45’16.2”S	115°23’20.4”E	Along Flacourt Bay track; on plateau	Limestone sheets with much rubble and little hard-surfaced red-brown soil; low spinifex.
SBI # 47	12/08/2002		20°45’20.4”S	115°23’24.0”E	Along Flacourt Bay track; on summit of low rise on plateau.	Limestone outcrop with stones, rubble and almost no (red) soil; spinifex to 0.4 m with *Ficus* to 2 m and other small trees.
SBI # 48	12/08/2002	14:45	20°45’25.3”S	115°23’32.0”E	SW of Flacourt Bay E of junction of Point Malouet Road with Flacourt Bay track; on south-east facing gentle slope; approximately 2km from Flacourt Bay.	Limestone outcrop with boulders and stones but virtually no surface soil; leaf litter but little soil under *Ficus* clump.
SBI # 49	12/08/2002		20°45’27.6”S	115°23’37.1”E	SW of Flacourt Bay near junction of Point Malouet Road with Flacourt Bay track and east of SBI #48; adjacent to north side of road.	Little calcrete, hard surfaced red soil; spinifex only.
SBI # 50	12/08/2002		20°45’40.5”S	115°23’47.0”E	SW of Flacourt Bay near junction of Point Malouet Road with Flacourt Bay track and east of SBI #49; on north side of road.	Limestone outcrops, stones and granular hard-baked red soil; spinifex to 0.3 m, almost no litter.
SBI # 51	12/08/2002	16:20	20°46’04.1”S	115°24’01.9”E	SW of Flacourt Bay near junction of Point Malouet Road with Flacourt Bay track; on top of rise; just east of oil well;. on south side of road;	Low limestone outcrops with stones and little rubble, red soil; spinifex to 0.45 m with *Ficus* and other trees to 3 m.
# Lat-Pt	09/08/2002				Latitude Point at cliff to east of tanks; collector Roy Teale	
# W-Tank	10/08/2002				Near Latitude Point; just west of western-most tank; at side of road in spinifex clump; collector Peter Doig	On spinifex
# SP-CS	12/08/2002		20°41’1.273”S	115°27’52.253”E	Surf Point; 8 m north of rocky cliff edge; 4 m above high water level, below small rock ledge; collector Chris Surman.	
# SP-SSS	13/08/2002				Surf Point, near cliff edge; collector S. Slack-Smith.	among and under spinifex

3 Results

The majority of the molluscs recorded during this survey belong to the families Camaenidae and Pupillidae. Table 2 presents the locations sampled and non-camaenid snail species collected during the survey. Table 3 presents the locations sampled and the camenid snail species collected during the survey. Figure 2 presents the distribution maps of key species collected.

3.1 Family Camaenidae

This very diverse family is widespread in Asia and the Indo-Pacific area. In Australia it is best represented in the molluscan faunas of northern Australia but does extend into more temperate regions of southern Australia, except in Tasmania and the south-western region of Western Australia.

Most of the camaenid species found in the Pilbara area of Western Australia were researched by the late Dr A. Solem and the results of that work were included in his posthumous publication of 1997.

Those Australian camaenid snail species inhabiting areas that have prolonged periods of dry weather are well adapted to resisting the effects of desiccation. They aestivate either in rock piles or crevices or buried in the soil. Only when the relative humidity is high do they become active and are able to mate, feed and lay eggs.

The camaenid snails of Barrow Island encountered during this survey belong to the genera *Rhagada* and *Quistrachia*, both of which are well represented in the faunas of northern-Australia. Most specimens were dead-taken but a number of aestivating snails of all species were collected.

3.1.1 Genus Rhagada

The genus *Rhagada* is considered to be an Australian endemic (Solem 1997: 1672), with a distributional range extending from the northern-Kimberley to the Carnarvon area. With 29 named species it was, in 1990, the second most diverse camaenid genus in Western Australia (Solem 1997). In addition, a few other currently undescribed species within this genus are now recognised.

A number of *Rhagada* species inhabit the coastal area of the Pilbara region and the islands offshore. Solem (ibid.) recorded 8 species in the Dampier area including the islands of the Dampier Archipelago. One of these is also on the Muiron Islands and it, plus a further species, inhabits the Cape Range Peninsula. An endemic species is recorded for the Montebello Islands. A number of other species are recorded north and south of these areas and in the hinterland.

However, no species of *Rhagada* has been recorded for Barrow Island except for a brief mention of an unnamed species from the northern coast of the Island, then represented by a few specimens in the collections of the Western Australian Museum (Solem ibid.: 1672).

Of the two species of *Rhagada* recorded during the August 2002 survey at Barrow Island, one is, apparently, the north coastal species to which Solem had referred (see above).

However the other, a much larger and more widespread species, had been represented by a number of dead-taken specimens in the Museum's collections at the time Dr Solem was carrying out his research. He had at one time tentatively identified those specimens as *R. tescorum* (Benson, 1853), type locality Shark Bay. However later (Solem 1997: 1672) he decided that he could not confidently assign that species name to any set of populations.

Table 2. Non-camaenid Species Collected During the Land Snail Survey of Barrow Island (* indicates live specimens).

Station Number	Taxa				
	Pupoides beltianus	Pupoides contrarius	Gastrocopta deserti	Eremopeas interioris	Truncatellidae
SBI # 1	2	10	5	1	2
SBI # 2		2			
SBI # 3	3	6			
SBI # 4	2	14			
SBI # 5		6			
SBI # 6	1	1			
SBI # 7	1	14	3		
SBI # 8	1	8			
SBI # 9	2	10			
SBI # 10					
SBI # 11	6	6 & 1*			
SBI # 12	3	5	2		
SBI # 13	1	12			
SBI # 14	1*	5	2		
SBI # 15	1				
SBI # 16	15	2			
SBI # 17					
SBI # 18	8	5		1	1
SBI # 19	5	2			
SBI # 20		1			
SBI # 21	2	8 & 1*	3		
SBI # 22	2				

Table 2. Non-camaenid Species Collected During the Land Snail Survey of Barrow Island (* indicates live specimens) (Continued)

Station Number	Taxa				
	Pupoides beltianus	Pupoides contrarius	Gastrocopta deserti	Eremopeas interioris	Truncatellidae
SBI # 23	1	7			
SBI # 24	3		4		
SBI # 25					
SBI # 26					
SBI # 27	6				
SBI # 28	3				
SBI # 29		1*			
SBI # 30	7		3		
SBI # 31					
SBI # 32	1	4	1		
SBI # 33					
SBI # 34					
SBI # 35					
SBI # 36					
SBI # 37					
SBI # 38					
SBI # 39					
SBI # 40		3			
SBI # 41		2			
SBI # 42					
SBI # 43					
SBI # 44					
SBI # 45					
SBI # 46	2				

Table 2. Non-camaenid Species Collected During the Land Snail Survey of Barrow Island (* indicates live specimens) (Continued)

Station Number	Taxa				
	Pupoides beltianus	Pupoides contrarius	Gastrocopta deserti	Eremopeas interioris	Truncatellidae
SBI # 47					
SBI # 48					
SBI # 49		1			
SBI # 50	1				
SBI # 51		9			
#W-Tank					
#Lat-Pt					
#SP-SSS					
#SP-CS					

Table 3. Camaenid Species Collected During the Land Snail Survey of Barrow Island

Station Number	**Taxa**									
	Rhagada sp. # 1		**Rhagada sp. # 2**				**Quistrachia barrowensis**			
	Dead	**Live**	**Dead**		**Live**		**Dead**		**Live**	
			A	**J**	**A**	**J**	**A**	**J**	**A**	**J**
SBI # 1			14	12			13	6		
SBI # 2			13	2			2	1		
SBI # 3			7	11			3	3		
SBI # 4			6	7			10	5		
SBI # 5			10	9			6	3		
SBI # 6			4	2			4	35		
SBI # 7			9	20			9	3		
SBI # 8			19	35			14	8		
SBI # 9			1				10	12		
SBI # 10							21	13		
SBI # 11			2	3	2		11	12	1	1
SBI # 12			5	11			4	1		
SBI # 13			1	2			7	2		
SBI # 14			4	3			7	4		1
SBI # 15			1	5			9	11	4	5
SBI # 16			1	2			8	38	1	
SBI # 17			2				22	21		
SBI # 18			1				8	4		2
SBI # 19			5	4			7	8		
SBI # 20			3	2			4	1		
SBI # 21			3	6			5	2		
SBI # 22			8	4			4	2		
SBI # 23			9		1		2	5		
SBI # 24			4	7			6	3		

Table 3. Camaenid Species Collected During the Land Snail Survey of Barrow Island (Continued)

Station Number	Taxa									
	Rhagada sp. # 1		Rhagada sp. # 2				Quistrachia barrowensis			
	Dead	Live	Dead		Live		Dead		Live	
			A	J	A	J	A	J	A	J
SBI # 25			1	2				2		
SBI # 26			1				3			
SBI # 27			20	10			45	35		
SBI # 28			5	2			5	7		
SBI # 29			7	2			2			
SBI # 30			2	11				5		
SBI # 30-31					1					
SBI # 31										
SBI # 32			16	12			8	3		
SBI # 33			2	6			10	12		
SBI # 34			5				23	17	1	1
SBI # 35			11	2			38	11	1	
SBI # 36			18	6			10	4		
SBI # 37			11	1	1		3			
SBI # 38			9	5			15	10		2
SBI # 39			3				5	2		
SBI # 40			1	4			4	2		
SBI # 41			6	1			23	13		
SBI # 42			1				24	16	3	
SBI # 43			1				12	6	1	
SBI # 44			1				40	11	2	
SBI # 45							3	21		
SBI # 46			4	15			2			
SBI # 47			3	5			12	11	1	

Table 3. Camaenid Species Collected During the Land Snail Survey of Barrow Island (Continued)

Station Number	Taxa									
	Rhagada sp. # 1		Rhagada sp. # 2				Quistrachia barrowensis			
	Dead	Live	Dead		Live		Dead		Live	
			A	J	A	J	A	J	A	J
SBI # 48			3	7			13	9	1	1
SBI # 48-49			2							
SBI # 49			20	11		1				
SBI # 50			5	4			2	1		
SBI # 51			22	6			45	19		1
# W-Tank					1					
# Lat-Pt					1					
# SP-SSS	70	6								
# SP-CS	7									

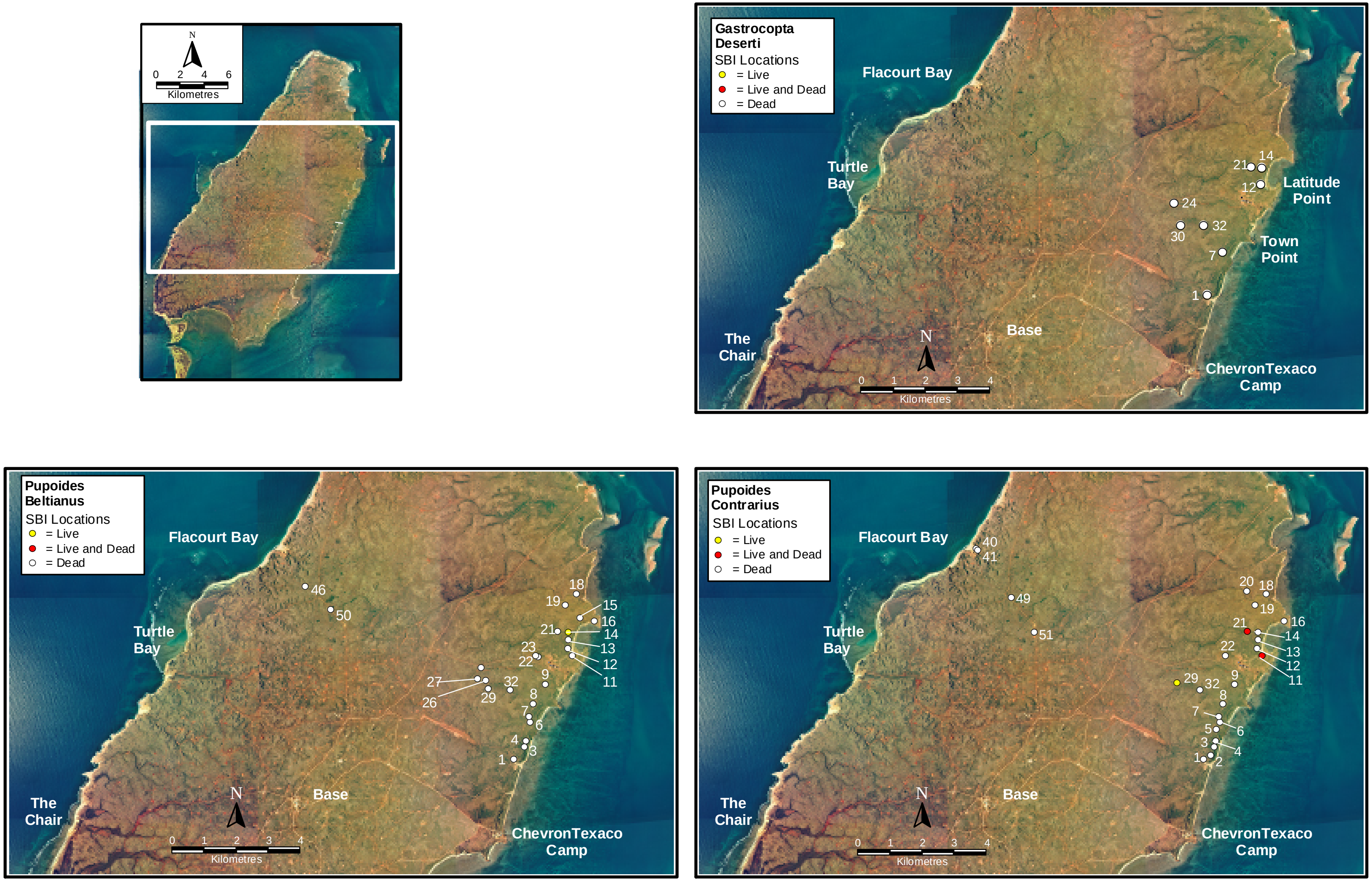
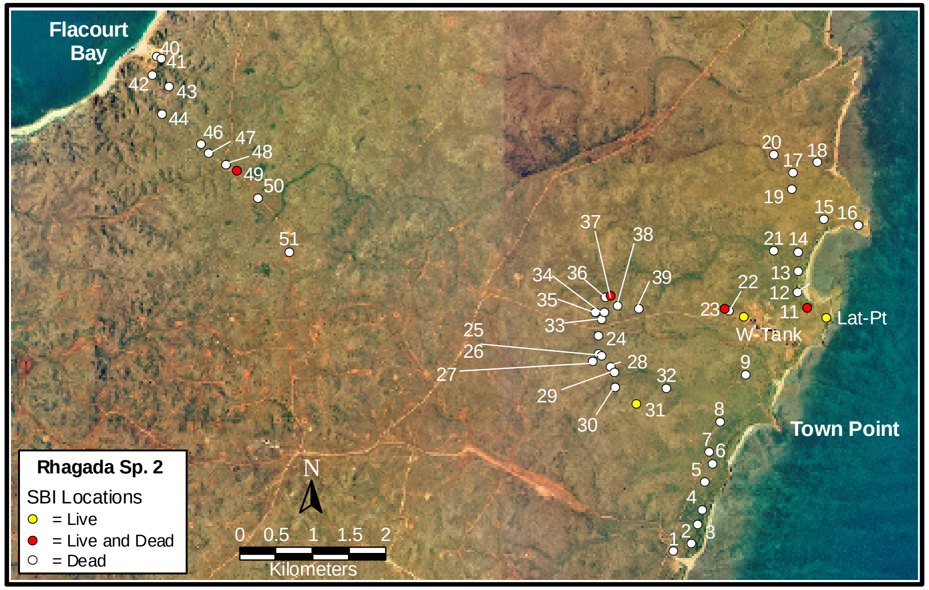


Figure 3. Distribution Maps of Key Species Collected on Barrow Island



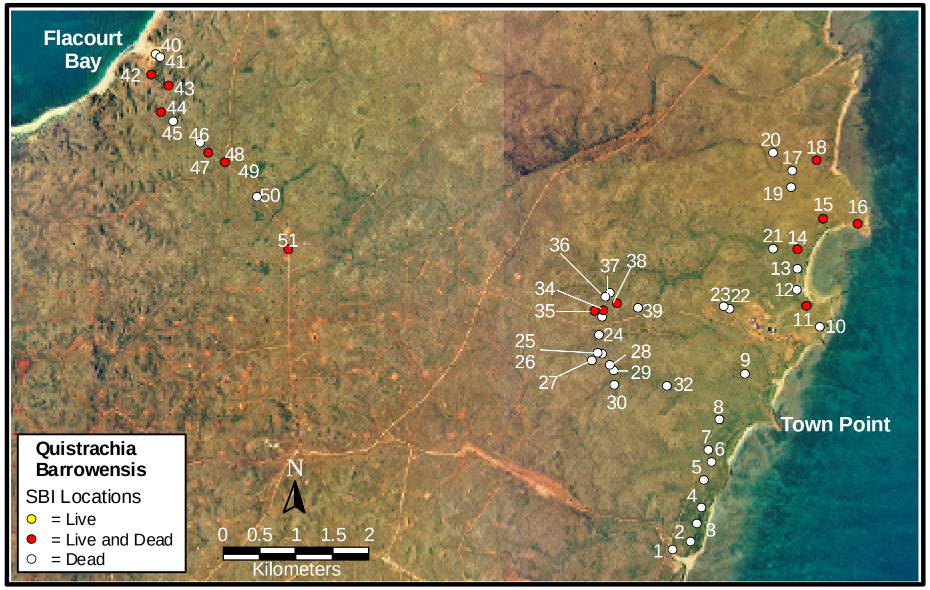


Figure 3. Distribution Maps of Key Species Collected on Barrow Island (Continued)

3.1.2 Rhagada species #1 (see Solem 1997: 1672)

Both live and dead-taken specimens of this species were collected during this survey. However, the collecting locality at the north end of the island was not within the "area under investigation", and so the records do not need further consideration at this time.

3.1.3 Rhagada species # 2

This large undescribed species is abundant and widespread both within and adjacent to the "area under investigation" (see Table 3 and Figure 2). Its patterns of distribution and abundance did not appear to change greatly across the width of the Island, passing from the limestone of Miocene age in the west to the Pleistocene sediments in the east (see McNamara & Kendrick 1994).

On the basis of shell characters alone, *Rhagada* species #2 appears to most closely resemble some of the larger species of this genus inhabiting the nearby mainland and islands in the vicinity. *R. perprima* is recorded from three of the islands of the Dampier Archipelago and *R. capensis* inhabits the Cape Range Peninsula. The geographic range of *R. convicta,* the most widespread of these large species, extends from north of Dampier south along the coastal plains to the Minilya River and also to the Muiron Islands.

Using only shell characters, I consider that the specimens taken on Barrow Island during this survey are perhaps more like those of the species *R. capensis* than of *R. convicta* and *R. perprima.*

However, in view of the slight differences in shell characters which are used to differentiate these species, along with the variation existing within each of these species, the degree and duration of isolation of Barrow Island from the mainland and other islands, and the difficulty which Dr Solem had in deciding on the status of the Barrow Island specimens then available, I consider it wise to regard the Barrow Island population as distinct from these taxa at the subspecific if not at the specific level.

In comparison with the number of dead-taken shells of this species, living specimens were scarce. The distribution of the shells indicated that this species favours the more open areas of spinifex and/or rock. A few adult live animals were taken in and under spinifex clumps at a number of stations west and north of Latitude Point. At only one station (SBI#11) were live juveniles of this species taken (along with adults and juveniles of *Quistrachia barrowensis*) under a fig tree (*Ficus platypoda*).

At least some individuals of *Rhagada* species #2 seem to be able to take advantage of cool humid nights to become active and to climb up through spinifex clumps. When stranded there by the onset of day they can seal the shell aperture with a thin film of mucus. This presumably gives the snail some protection against water loss and, together with being elevated from the hot soil, enables the snail to survive a hot dry day. Buried aestivating snails, on the other hand, have their shells sealed with a dense calcareous epiphragm.

3.2 Genus Quistrachia

The geographic range of the genus *Quistrachia* extends from the central Kimberley region southwards to the Warroora area, south of the Cape Range Peninsula. The only record of this genus outside Western Australia is of a single species in western Queensland.

Within the area between the Cape Range Peninsula and Dampier, including the islands offshore, five species are recognised. None are sympatric and the species recorded for Barrow Island is distinctive in its morphology.

3.2.1 Qistrachia barrowensis Solem, 1997

This species, endemic to Barrow Island and some of the islands nearby, can be distinguished from other species in the area by its shell size, shape and/or sculpture. It is obviously distinct from its congeners on the Montebello Islands, the Dampier Archipelago and the Cape Range.

Solem (ibid) recorded a size difference in this species – animals taken from areas towards the northern end of Barrow Island and from the islands being larger than those from the rest of Barrow Island. He raised the question of whether a complex of taxonomic units might be united under this name (: 1827). With the limitation of this preliminary survey to the "area of investigation" and closely adjacent areas, no comment can be made on this point.

During this survey *Q. barrowensis* was found to be widespread across the areas surveyed, being more abundant under fig (*Ficus platypoda*) and other trees and shrubs, where many live specimens were taken aestivating beneath the soil surface. The small size of some of the dead-taken specimens sieved from the soil indicated that this habitat had also been used for egg laying. However, the absence of live-taken individuals in this size range indicated that breeding had not occurred recently. This species is not abundant in spinifex-dominated areas lacking in trees.

3.3 Family Pupillidae

This diverse family of small land snails has a worldwide distribution except in polar regions. Little is known about the biology of the Australian species but Solem (1986, 1989, 1991) published on the Australian taxa of this family and also discussed the patterns of their distribution within Australia and countries nearby (Solem 1997).

Many of the pupillid species represented in the Western Australian fauna occur elsewhere. Particularly widespread are species of the drier regions of the State, some of which are found from the eastern States, through the Red Centre to the Kimberley and Pilbara areas.

3.4 Genus Gastrocopta

Species within the genus *Gastrocopta* are known to occur in most tropical and temperate regions except Europe. The genus is widespread in Australia except for the wettest parts of Victoria and Tasmania. In Western Australia the greatest diversity within this genus is exhibited by the Kimberley fauna. Only 2 species, both with shell lengths of less than 3 mm, are recorded from the coastal regions of the Pilbara.

3.4.1 Gastrocopta deserti Pilsbry, 1917

This species has been recorded from the western areas of Queensland, through the Northern Territory and northern South Australia to Western Australia, having been found from the Kimberley south to the Carnarvon area.

Its shell characters are sufficiently distinctive to allow separation of this species from *G. pilbarana* Solem, 1986, a Western Australian endemic ranging from the Chichester Range south to the Shark Bay area.

G. deserti was first recorded from Barrow Island by Solem 1986, this record being based on specimens in the collections of the Western Australian Museum collected by H. Butler near Flacourt Bay in 1977.

Specimens taken from soil and plant litter samples collected during this study indicate that this species is present over the extent of the Pleistocene sediments of the eastern part of the island that were surveyed. It occurred both within and outside of the "area under investigation', although, in contrast to the earlier records, was not found in samples from the western coast. None of the specimens were, apparently, live-taken specimens, although it is difficult to tell with snails of this size.

3.5 Genus Pupoides

This genus has an unusual pattern of distribution. Species occur in the Americas, in southern Asia east from India, the Middle East through to northern Africa, southern Africa and semi-arid Australia.

Within the Australian fauna series of both dextrally and sinistrally-coiling species of these small snails occur. Two species of this genus were taken during this survey, one species belonging to each of these coiling groups.

3.5.1 Pupoides contrarius (E.A. Smith, 1894)

This sinistrally coiling species, which reaches a shell length of just over 5 mm, is distributed along the north-west coastal areas of Western Australia south to the shark Bay area and the Houtman Abrolhos. It was recorded from Barrow Island by Solem (1986).

During this survey it was found to occur at most of the stations on the Pleistocene sediments along the eastern coastal areas and at a scattering of the stations on the Miocene area to the west. Live specimens were collected near Latitude Point and to the north-west of that area.

3.5.2 Pupoides beltianus (Tate, 1894)

The species *P. beltianus* is a dextrally-coiling species, first described from and apparently widespread in Central Australia. At the time of Solem's 1986 revision of the pupillids of the south and mid-west coasts of Australia, the specimens in the collections of the Western Australian Museum from the west coast did not include any from Barrow Island. The paucity of specimens then available did not allow him to determine the degree of relationship between them and the Central Australian populations.

Without making direct comment upon this point, Solem (1989) included the WA coastal specimens, together with some from more inland parts of the Pilbara, in his understanding of the species *P. beltianus.* He recorded its distribution as far south as Shark Bay.

During this survey the species *P. beltianus* was found to occur mainly at the stations near the east coast, both within and outside the "area under investigation". However the pattern of its distribution at stations to the west of that area could, perhaps, indicate a looser tie to the area of Pleistocene sediments than is shown by *P. contrarius*. Live specimens were collected west of Dove Point.

3.6 Family Subulinidae

This family of small elongate snails is widespread in many tropical and warm temperate areas. Many of its species have been spread from their area of origin by the activities of humans and, it is thought, by rafting on drifting debris. Most of the species which inhabit northern Australia are of wide occurrence in the coastal areas of many other countries.

The 2 dead-taken shells taken during this survey are in poor condition and cannot, with any certainty, be identified with the species *Eremopeas interioris* which is endemic to Australia. That species has been collected at a few coastal localities in the north of Western Australia but is more typically found in inland areas of Western Australia, the Northern Territory and other States.

These specimens are not considered meaningful in the context of this report.

3.7 Family Truncatellidae

The members of this family are typical of supratidal marine habitats, particularly among boulders where decaying plant material (marine and terrestrial) collects.

The single juvenile dead-taken specimen collected during this survey was found on the bank of a dry tidal creek bed and could have been a remnant from a population living there during a period of high water levels or simply a shell which had been washed inland, perhaps during cyclonic weather.

This specimen is not considered meaningful in the context of this report.

4 Discussion

This survey provides a good indication of the broad scale habitats and species of land snails that occur within the proposed gas processing facility sites and immediately adjacent areas. The range of habitats encountered both in the footprint area and other areas surveyed seem to be well represented in other parts of the Island traversed during the period of this survey.

Neither the results of this survey nor the data contained in the collections of the Western Australian Museum give any but the most meagre indications of the broader distribution of these species on Barrow Island outside the area of this study. However, within that area, land snail populations were found to be dominated by the camaenids *Rhagada* sp. #2 and *Quistrachia barrowensis* and the pupillids *Pupoides beltianus* and *P. contrarius*. These species appear to be well represented over the areas surveyed.

In addition, these survey results indicate that none of the species found within the "area under investigation", including the gas processing facility "footprint", have a distributional range that is restricted to that area. *Gastrocopta pilbarana* appears to favour the more calcareous soils of the eastern coastal area, and the two species of *Pupoides* are certainly much more abundant and widespread there. However, this type of habitat appears to be relatively widespread over eastern coastal areas and these species were found to be widely distributed across the survey sites in this area.

Nothing is known about the genetics of these species in the "area under investigation" or elsewhere (within or beyond Barrow Island). This means that no information is available concerning the degree to which reproductive isolation may occur (or have occurred) between populations of any of the species living on the Island, whether the species are limited to Barrow Island or not.

All species of snails encountered during this survey showed evidence of predation. The camaenid species, particularly, are obviously heavily predated, evidenced by the many excavations and the abundance of broken shells. The variation in breakage patterns of these shells seems to indicate a diversity of predators. One concludes, therefore, that these herbivores are important in the nutrition of their vertebrate predators. They may be similarly important in the nutrition of some invertebrates which feed upon dead snails, such as victims of desiccation.

It should be noted that no evidence of the introduction of "foreign" snail or slug species was found – a heartening result of the quarantine regime in force at present and in the past.

5 Recommendations

5.1 Conservation

It seems advisable that a more comprehensive survey of the nature and distribution of the snail fauna of Barrow Island be carried out. This could well be supplemented with a genetic study of the island fauna and that of adjacent and mainland faunas, where this would have bearing on the evaluation of the "conservation value" of the Barrow Island snails. This would be of particular importance in evaluating the "value" of snails and their habitats to be directly affected by proposed developments.

A study of the place which the snail fauna of Barrow Island plays in the nutrition of other groups would be of great value in the conservation of the Island's mammals, reptiles and, perhaps, some of the birds.

5.2 Management

Of great importance in the planning of any large-scale development is the question of quarantine. Many snails from the Pilbara mainland, as well as snails and slugs from foreign areas with similar climates, would be capable of out-competing (and, in some cases, devouring) native species.

In addition, many species of non-Australian snails and slugs and a few Australian species are known to be capable of acting as hosts for a wide variety of parasitic worms which are of importance to the health of humans and domestic and native animals. In general, the capacity of our native molluscan species in this regard has not been assessed.

Local and foreign aestivating snails have been shown to be capable of remaining hidden in containers, within vehicles and machinery for months if not years. The chance of such items being invaded by snails can be lessened if they can be loaded onto transport vehicles or barges without delay and, preferably, during the dryer months when terrestrial snails are less active. Containers, machinery etc. should be fumigated before disembarkation on the Island.

Many if not most snails can burrow into soil and rubble to aestivate or to lay eggs. They, or their eggs, can remain there dormant for long periods. Soil or similar filling for roads etc., if it needs to be brought onto the Island, should be fumigated before landing.

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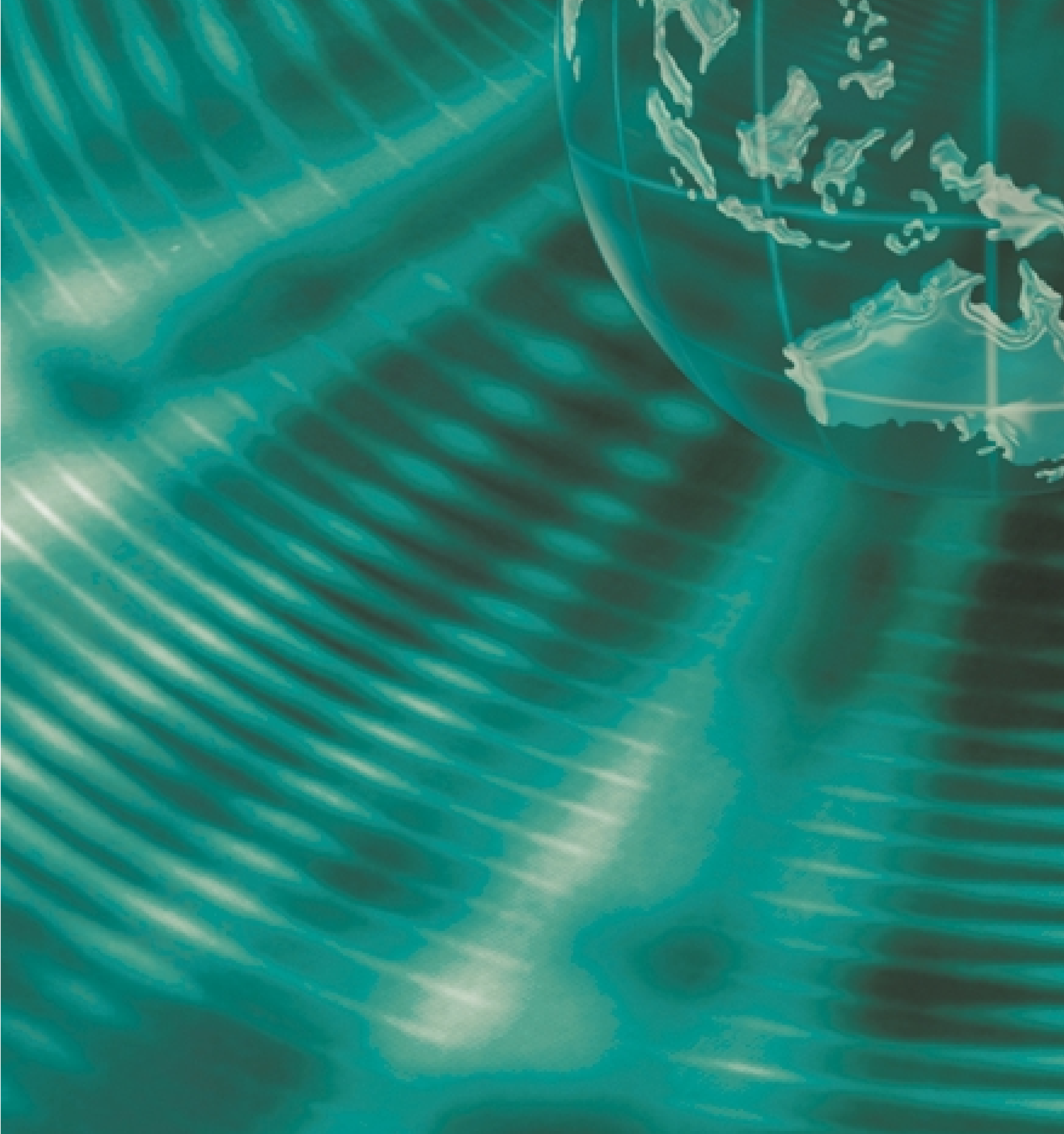

APPENDIX I

BARROW ISLAND GORGON DEVELOPMENT SUBTERRANEAN FAUNA SURVEY. AUGUST 2002

(BIOTA ENVIRONMENTAL SERVICES).

ABN 49 092 687 119
2 / 186 Scarborough Beach Rd
Mt Hawthorn WA 6016
Ph: (08) 9201 9955 Fax: (08) 9201 9599

Project No.: 144

Prepared by: G. Humphreys

Checked by: K. Armstrong

Barrow Island Gorgon Gas Development Subterranean Fauna

Contents

Plates

1.0 Introduction

1.1 Project Background

ChevronTexaco is the operator of the Gorgon gas fields located some 130 km off the north-west coast of Western Australia. The Gorgon field is the largest gas field ever discovered in Australia and together with the other fields in the area represents an estimated 40 trillion cubic feet of resource. ChevronTexaco and its joint-venture partners, Shell and ExxonMobil (the Gorgon Venture) are investigating a range of initial development options for Gorgon area gas, including liquefied natural gas (LNG) and gas-to-liquids (GTL) opportunities.

The Gorgon gas field requires LNG or a large-scale industrial gas user to underpin its initial development. Central to the commercial viability of the development of the Gorgon gas fields is the siting of gas processing facilities on Barrow Island off the north-west coast of Western Australia. The Island has been an active onshore oilfield since 1967 and was also gazetted as a Class A Nature Reserve in 1910. The Gorgon Venture have approached the Western Australian Government with a request for an in-principle decision as to whether Barrow Island could be used as a site for gas processing facilities. The Minister for State Development has indicated that the government is prepared to consider the restricted use of Barrow Island for the initial development of the Gorgon gas fields, after considering the environmental, social, economic and strategic ramifications, and provided there are net conservation benefits. Such in-principle approval, if granted, would enable the Gorgon Venture to proceed with detailed development, planning and market representations ahead of detailed evaluation pursuant to the provisions of Part IV of the *Environmental Protection Act* 1986 and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (the *EPBC Act*).

The Environmental, Social and Economic Review (the ESE Review) will address the Gorgon gas development's ability to mitigate potential on-site impacts and generate social and economic benefits for the region, state and the nation. The ESE Review will also aim to demonstrate that the development could meet a range of broad strategic criteria and achieve net conservation benefits. This report on subterranean ecosystems represents a supporting technical document, providing input to the ESE Review on this ecological factor.

1.2 Overview of Subterranean Fauna

Subterranean fauna has been known from Western Australia since the 1940s, with the Blind Gudgeon *Milyeringa veritas*, amongst other fauna, being documented from groundwater beneath the coastal plain at Cape Range (Humphreys, 2001). However, little work was carried out in relation to subterranean communities until the early 1990s. The increase in knowledge and general profile of subterranean communities in Western Australia has largely been due to work conducted by the WA Museum, which focussed initially on Cape Range (Humphreys, 1993), and has also included substantial work on Barrow Island (see Section 1.3).

Two broad categories of fauna are generally considered to comprise true subterranean fauna:

- Stygofauna – obligate groundwater-dwelling, aquatic fauna.
- Troglobites – obligate cave or karst-dwelling, terrestrial subterranean fauna occurring above the watertable.

A broad overview of typical ecological characteristics of subterranean fauna and their environment is provided in Table 1.1.

Table 1.1: Characteristics of subterranean ecosystems and their components (adapted from Gibert *et al.* 1994).

Environment	Constant darkness
	Physical inertia which increases with depth
	Predictability: hydrologic and chemical variation usually not very evident in interstitial environments
	Restricted variety of habitats: lack of vegetation, reduction of space
	Habitat heterogeneity results from arrangement of grains, void size, physical and chemical characteristics of aquifers within the pore space
Organisms	Obligate groundwater dwellers
	Morphological, physiological and behavioural specialisations to subterranean environment: • general lack of pigmentation • ocular regression • appendages long and numerous • highly developed chemical and mechanical receptors • convergence of vermiform body shape for different taxa
Biocenosis	Dominance of one species
	Richness, diversity and density low and variable
	A-type strategy of Greenslade (1983): • slower metabolic rates and growth, reduced motor output • lengthening of each stage of the lifecycle, late maturity, increase in longevity • less frequent reproduction, lower fecundity • unique behaviours such as stereotropism, thigmotropism and thigmotactism
Functional Characteristics	Heterotrophy and allotrophy
	Short, simple food webs with few trophic links
	Detritus feeders dominant
	System with low productivity
	Invertebrate diets not specialised, polyphagous

Groundwater food webs are typically almost entirely heterotrophic, with bioproduction primarily dependent on the transport of resources (biomass, detritus) from the surface (allotrophy; Gibert *et al*. 1994). There are few primary producers (chemolithotrophic bacteria; Danielopol *et al.* 1994). Groundwater microbes (ie. bacteria, fungi and protozoans) are the primary consumers, with general short direct trophic links to most meiofauna in the system. It is worth noting that Barrow Island appears to potentially represent an exception to this rule (see Section 1.3; Humphreys, in press).

The distribution of subterranean fauna species appears to generally be more restricted than that of surface fauna analogues. High levels of endemicity are also typically characteristic of subterranean taxa, often at high taxonomic levels. Endemic species tend to be concentrated in regions that support relatively diverse communities, rather than being distributed randomly (see review in Strayer 1994; also Humphreys, 2000).

Stygofauna in Western Australia, and in particular Barrow Island and Cape Range, are regarded as geological relicts, descendants from ancient pre-Gondwanan lineages, with species characterised by restricted distributions and a low tolerance to disturbance. The stygofauna of Barrow Island represent relict lineages that are closely related to fauna of Gondwana, the Tethys Sea and epigean ancestors that occurred prior to the breakup of Pangaea (see review in Humphreys 2001).

1.3 Previous work on Barrow Island

Work on subterranean ecosystems of Barrow Island has been carried out for a number of years by the WA Museum. This has included seven sampling visits to the Island over the past decade and Humphreys (in press) has recently assembled a summary account of the findings of this work, both on stygofauna and troglofauna. This included documentation of the known subterranean fauna, its distribution and conservation status. Stable isotope analysis data were also presented indicating that some of the groundwater ecosystems on the Island may be chemoautotrophic – that is that their energy production is derived via bacterial systems from petroleum rather than surface inputs as with most subterranean systems (Humphreys, in press).

Other key studies that have been completed on the subterranean fauna of Barrow Island include:

- *Haptolana pholeta* sp. nov., the first subterranean flabelliferan isopoda crustacean (Cirolanidae) from Australia (Bruce and Humphreys, 1993);
- *Speleostrophus nesiotes*, the first known troglobitic spiroboloid millipede, from Barrow Island, Western Australia (Hoffman, 1994);
- Freshwater amphipods from Barrow Island, Western Australia (Bradbury and Williams, 1996);
- Two new species of anchialine amphipods from Barrow Island, Western Australia (Bradbury and Williams, 1996a); and
- The hypogean fauna of Cape Range Peninsula and Barrow Island, north-western Australia (Humphreys, 2000).

1.4 Legislative Framework

In addition to the more general requirements of the *Environmental Protection Act* 1986, there are two acts which are relevant to subterranean fauna:

1. *Wildlife Conservation Act* 1950-1979

In Western Australia, all native fauna species are protected under the *Wildlife Conservation Act* 1950-1979. The Act is administered by the Department of Conservation and Land Management (CALM). Fauna species that are considered rare, threatened with extinction or have high conservation value are specially protected under the Act. Classification of rare and endangered fauna under the *Wildlife Conservation (Specially Protected Fauna) Notice* recognises four distinct schedules of taxa, with Schedule 1 taxa being those ‘which are rare or likely to become extinct’. In addition to this statutory classification, CALM also classifies other fauna under four different Priority codes, recognising other species which are of poorly known conservation status or which could become threatened if conditions change.

2. *Environment Protection and Biodiversity Conservation Act* 1999

Under the *Environment Protection and Biodiversity Conservation (EPBC) Act* 1999, an ‘action’ consists of ‘a project, development, undertaking, activity or series of activities’. Actions are required to be referred under the *EPBC Act* 1999 if they take place on Commonwealth land or are an action by the Commonwealth, or are likely to significantly impact a matter of National Environmental Significance (NES). There are currently six NES factors identified in the Act. One of these, relating to threatened flora and fauna species and threatened ecological communities, is relevant to the conservation of subterranean biota. Certain threatened species, including some subterranean fauna, are formally listed under the *EPBC Act* 1999 and actions which impact on these require referral to the Federal Minister for the Environment to determine if the action will be a ‘controlled action’ for the purposes of the Act and be subject to Federal formal environmental assessment.

Whilst the requirements of these acts will be addressed in more detail at later stages of the environmental assessment process, they still provide context for evaluation of conservation significance as part of the ESE Review.

2.0 Approach and Methodology

2.1 General Approach

The approach to this study has consisted of:

- Liaison and consultation with the WA Museum (Drs. Bill Humphreys and Mark Harvey), CALM Woodvale (Dr. Stuart Halse, Adrian Pinder and Jane McRae), and the University of WA Zoology Department (Dr. Terrie Finston);
- A search of the specimen records database of the WA Museum for stygofauna and troglobite records from Barrow Island;
- Background literature searches (via on-line databases, biological abstracts and other sources), sourcing and review; and
- Field survey and subterranean fauna sampling within the main area of investigation and the associated pipeline corridor, with additional reference sampling across the rest of the Island to provide context to the results from the development area.

More detail on the methodology for specific components of the study is provided in the following sections.

2.2 Field Sampling Methodology

2.2.1 Stygofauna Sampling

Stygofauna were sampled from bores, drillholes and wells by means of modified plankton haul nets between 9/8/02 - 13/8/02. The nets were constructed from 200 µm mesh, with apertures of various sizes attached to a weighted catch jar. Each hole was dragged at least three times. If fauna were observed in the sample, further samples were taken. Once the net reached the bottom, it was agitated gently to bring the benthos and any fauna above the net before dragging the column. On the surface, the net was flushed thoroughly with water bailed from the same hole and the resultant sample placed in a labelled plastic bag within a shaded esky. A hygiene protocol was followed at the completion of each hole whereby nets and catch bottles were washed clean to avoid any sample contamination between boreholes.

Samples were not fixed prior to sorting as live stygofauna are more easily observed and recovered. Samples were sorted under a dissecting microscope (magnification up to 40x.). Stygofauna specimens were tracked on Biota's standard tracking forms and preserved in 100% ethanol (suitable for both morphological and DNA analyses). A subsample of live amphipods collected was frozen in liquid nitrogen for use in ongoing genetic (allozyme) analysis work being conducted at the University of Western Australia (see Section 2.3).

Sampling for stygofauna was conducted according to this protocol at 18 boreholes within the proposed gas processing facility site, most of which were located in the immediate vicinity of the terminal tank farm (see Table 2.1). Of these, four were substantially affected by hydrocarbons and could not be adequately sampled. A further 20 boreholes were sampled on other parts of Barrow Island to provide additional reference data and material for genetic and morphological analysis (see Section 2.3; Table 2.1).

Table 2.1: Boreholes sampled on Barrow Island during the survey ('Development' Area = area of investigation for plant site, 'Reference' Area = contextual sampling elsewhere on the Island, coordinates in UTMs AGD84 datum).

Borehole	Area	Easting	Northing	Comments
MW3	Development	-	-	
MW4	Development	-	-	Oil affected – not sampled
MW7	Development	340159.00	7701530.00	
MW7nr1	Development	340158.00	7701532.00	Trog fauna trap installed
MW8	Development	-	-	
MW9	Development	-	-	
MW13	Development	340228.00	7701084.00	
MW14	Development	-	-	
MW15	Development	-	-	Oil affected –sampled
MW16	Development	340001.00	7701183.00	
MW16nr1	Development	340068.00	7701219.00	Trog fauna trap installed
MW16nr2	Development	340246.00	7701370.00	Oily – trog trap installed
MW17	Development	340343.00	7701456.00	
MW18	Development	340421.00	7701304.00	
MW21	Development	-	-	Oil affected –sampled
MW22	Development	-	-	Oil affected – not sampled
Terminal tanks water bore	Development	-	-	
Abandoned seismic hole	Development	-	-	Dry – trog trap installed
AMW10	Reference	334192.00	7691344.00	Airport monitoring well
AMW11	Reference	334188.00	7691340.00	Airport monitoring well
AMW15	Reference	334191.00	7691330.00	Airport monitoring well
AMW18	Reference	334206.00	7691339.00	Airport monitoring well
AMW19	Reference	334196.00	7691301.00	Airport monitoring well
AMW20	Reference	334206.00	7691327.00	Airport monitoring well
B14 South	Reference	328637.00	7692399.00	
C62	Reference	332790.00	7690453.00	
C62NR1	Reference	332797.00	7690466.00	
C65	Reference	331896.00	7689829.00	
F41A North	Reference	330400.00	7694380.00	
L18A	Reference	333183.00	7699032.00	
L32j	Reference	331038.00	7697999.00	
L4N1	Reference	332213.00	7698310.00	
J16j	Reference	331488.18	7697437.23	
L8	Reference	332663.63	7697030.81	> 30 m water column
Tip MW 1	Reference	328195.00	7699302.00	Very turbid
Tip MW 2	Reference	328195.00	7699302.00	Very turbid – not sampled
Washdown pond MW1	Reference	-	-	Very turbid
Washdown pond MW2	Reference	-	-	Very turbid

2.2.2 Troglobitic Fauna Sampling

There are no known caves located within the proposed gas processing facility site or any other obvious surface expressions of substantial karst development. Foot traverses of the area were carried out by other members of the Gorgon gas development terrestrial study team and no significant formations were noted. As a result, troglobitic fauna sampling in the area of investigation was limited to installation of litter traps in four abandoned drill holes within the project area.

Traps were constructed from 60 mm internal diameter PVC stormwater pipe cut to a length of 120 mm. Both ends were blocked with aviary mesh after the tubing was filled with wet leaf litter. Leaf litter material was gathered from the ground surface on the Island, particularly from the bases of *Melaleuca* and *Ficus* shrubs. The litter was soaked in water and irradiated in a microwave oven on the maximum power setting. Litter was added to the traps wet, and kept in sealed containers until immediately prior to insertion into the boreholes. After the installation of each trap, the opening of each borehole was sealed to maintain humidity and to minimise the input of surface fauna into the traps.

These traps are currently installed on site and need to be in place for a minimum of two months to enable sufficient time for fauna to colonise the traps.

2.3 Identifications and Genetic Analyses

Specimens were sorted live and identified as far as possible in an on-site laboratory prior to curation. In some cases it was possible to identify material to species level at this stage, but for most of the recovered fauna this represented order or family level taxonomic resolution.

More detailed identification work was carried out by Jane McRae at CALM Science Woodvale, utilising existing taxonomic descriptions and keys published by various taxonomic authorities. Adrian Pinder of CALM Woodvale carried out further identification of worm taxa collected. Material is currently being forwarded to various taxonomic specialists as appropriate for confirmation of identification, or description in the case of newly recorded taxa, and will ultimately be lodged with the WA Museum.

Frozen material, primarily amphipods, is currently undergoing electrophoretic analysis by Dr. Terrie Finston at the University of WA Zoology Department. This work is also ongoing and may also be extended to include DNA analyses.

2.4 Limitations of this Report

Several limitations should be recognised in the interpretation of this report:

- There was relatively poor spatial coverage of the area of investigation in terms of access to subterranean habitats. Bores were essentially limited to the immediate area of the terminal tanks only and a proportion of these were significantly affected by hydrocarbons in the groundwater. Those bores that could be sampled in this area also had poor penetration into the aquifer, with only a few metres of saturated thickness present to sample.
- The required timing for this study has meant that assessment of troglobitic fauna in the area of investigation has been limited to a desktop assessment only.
- As outlined in Section 2.3, this report is based on provisional species identifications that require further confirmation via relevant taxonomic specialists in light of supporting genetic data. It should be recognised that the results of this ongoing work may alter the findings of the current report and have bearing on any further assessment of the proposed development.
- It is assumed that more detailed investigation of subterranean ecosystems would be undertaken as part of any future EIS process and that the evaluation and data presented in this report recognises this.

3.0 Results

3.1 Stygofauna

3.1.1 Summary

Stygofauna were recovered from 13 of the 38 bores visited during the field survey (34% of sites). Five of these locations were within the terminal tanks area associated with the proposed development site (see Figure 3.1).

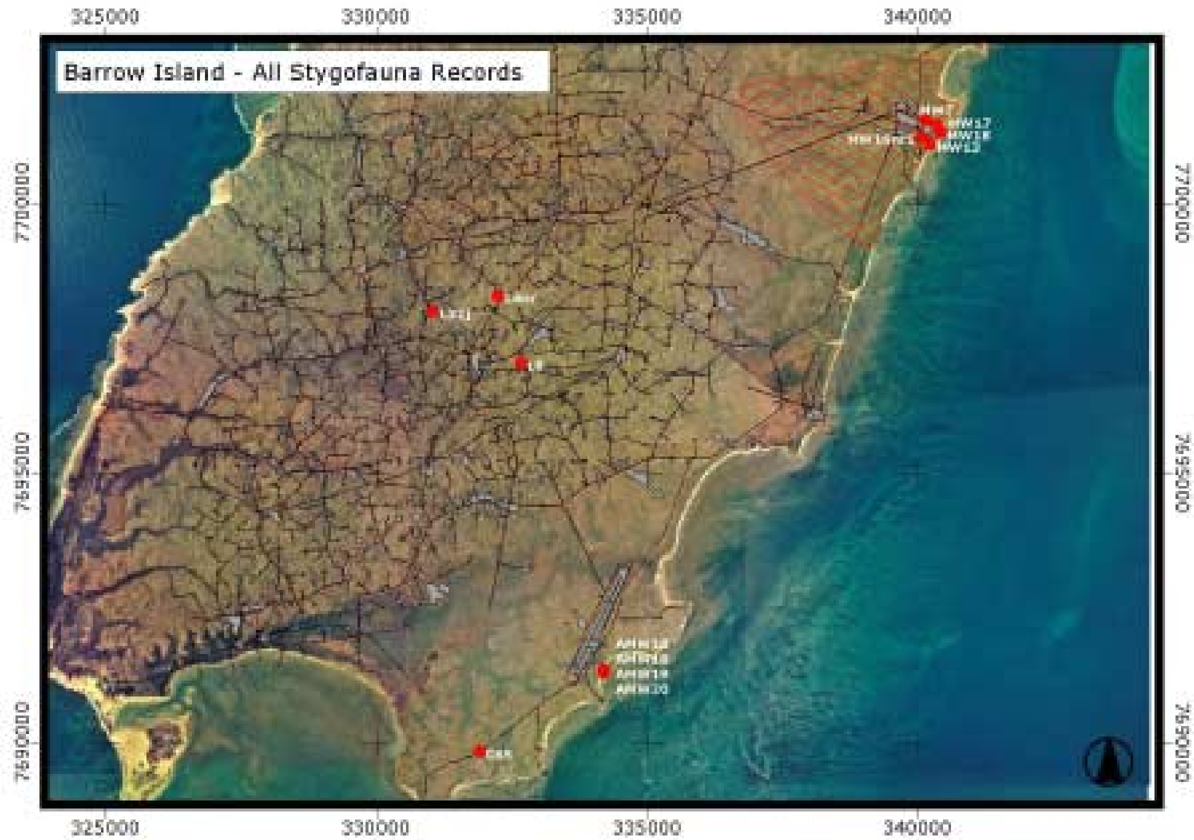

Figure 3.1: Borehole sampling locations on Barrow Island which yielded stygofauna (hatched red area = area of investigation).

A summary of the relative abundances of the various stygal taxa recovered is presented in Table 3.1. The collected specimens represented four classes, nine orders and 12 families, with a total of 21 taxa (including 10 described species). Twelve of these taxa were recorded from the proposed development area and seventeen from elsewhere on the Island. Eight of the 21 taxa were recorded from both the development area and other parts of the Island (see Table 3.1; Appendix 1).

Copepods were the most abundant and diverse component of the recorded fauna, accounting for 40% of the specimens and nine of the 21 taxa currently documented (43% of the species richness) (see Table 3.1). The amphipods were the next most common and species rich group, with 102 individuals (30%) representing at least four species. The numerical and species level dominance of these two orders is a common feature of stygal communities (Biota, unpublished data). Note that the identification of amphipods belonging to the genus *Nedsia* was limited by the lack of mature and intact animals amongst the collected specimens. An annotated list providing more detail on each order represented within the fauna is provided in Section 3.1.2.

Table 3.1: Stygofauna abundance recorded from the development area and other reference sites sampled across the Island

Taxon	Development	Reference	Total
Isopoda: Cirolanidae: *Haptolana pholeta*	-	13	13
Isopoda: Oniscoideae: sp. nov. 1	1	-	1
Amphipoda: Melitidae: *Nedsia sculptilis/macrosculptilis*	-	2	2
Amphipoda: Melitidae: *Nedsia* nr. *hulberti*	-	1	1
Amphipoda: Melitidae: *Nedsia* spp.	5	90	95
Amphipoda: Bogidiellidae: *Bogidella* sp.	-	3	3
Copepoda: Cyclopoida: *Diacyclops* aff. *humphreysi*	4	4	8
Copepoda: Cyclopoida: *Diacyclops* sp.	2	-	2
Copepoda: Cyclopoida: *Halicyclops rochai*	-	15	15
Copepoda: Cyclopoida: *Halicyclops* sp.	1	2	3
Copepoda: Harpacticoida: *Sarsameira* sp.	16	3	19
Copepoda: Harpacticoida: *Phyllopodopsyllus wellsi*	1	-	1
Copepoda: Harpacticoida: *Phyllopodopsyllus* aff. *thiebaudi*	1	3	4
Copepoda: Harpacticoida: *Phyllopodopsyllus* sp. 1	1	-	1
Copepoda: Calinoida: sp. nov. 1	1	81	82
Decapoda: Atyidae: *Stygiocaris stylifera*	-	43	43
Thermosbenacea: *Halosbaena tulki*	13	26	39
Vertebrata: Perciformes: *Milyeringa veritas*	-	1	1
Ostracoda: sp.	-	4	4
Nematoda: sp. 1	-	4	4
Oligochaeta: Phreadrilidae: sp. 1	-	4	4
	47	**298**	**345**

3.1.2 Annotated List

PHYLUM NEMATODA

Three nematodes were collected during the survey, but the specimens were extremely small and appear to have curated poorly. They could not be located for more detailed examination. The animals were not recorded from the gas processing facility site and, given the state of stygal nematode taxonomy, it is unlikely that they could have been identified beyond the family level (A. Pinder, pers. comm., 2002).

CLASS OLIGOCHAETA

Four oligochaete specimens were collected from well L8 (outside of the development area) during the current study. These specimens belonged to the family Phreadrilidae and represent the first record of this family from Barrow Island (A. Pinder, pers. comm., 2002; Appendix 2). The specimens are therefore likely to represent an undescribed species, but the material collected was not mature enough to allow for a formal description.

CLASS OSTRACODA

Three ostracods were collected during the survey, all from areas outside of the proposed development site (Table 3.1). These await examination by an ostracod specialist, but it is probable that they represent a previously unknown species, given that the recent review of the Island's fauna by Humphreys (in press) lists no ostracods for Barrow Island and the Museum's records contain only two other ostracod records (see Appendix 2).

ORDER COPEPODA

The copepods were the most diverse group amongst the stygofauna, with nine taxa representing three families (see Table 3.1). The presence of the Calinoid copepods was significant in that there are no calinoid copepod species currently described for Barrow Island (J. McRae, pers. comm., 2002), although material has previously been collected by the WA Museum (Appendix 2).

Most other species were either confirmed or tentatively identified as previously described species (Table 3.1). Three of the copepod taxa, *Diacyclops* sp., *Phyllopodopsyllus wellsi* and *Phyllopodopsyllus* sp. 1, were only recorded from the terminal tanks area (Figure 3.2). *P. wellsi* has been previously described and is known to occur on Cape Range (J. McRae pers. comm.). The other two taxa appear to represent currently undescribed species.

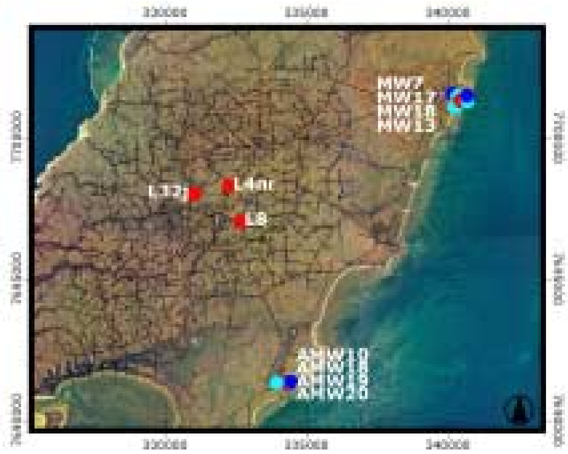

Figure 3.2: Copepod records (red = Calinoida, light blue = Harpacticoida, dark blue = Cyclopoida).

ORDER THERMOSBAENACEA

A single species of thermosbaenacean was collected during the survey, *Halosbaena tulki*, which has previously been documented as relatively widespread and common across the Island (Humphreys, in press). The species was present in reasonable abundance both within the development area (n=13) and elsewhere on the Island (n=26) (Table 3.1).

ORDER ISOPODA

Two families were represented amongst the isopods, the Cirolanidae and the Oniscoideae (Table 3.1). The most commonly recorded species was the cirolanid *Haptolana pholeta* (13 records from three locations, all outside of the area of investigation) (Plate 3.1; Figure 3.3). This species was described from Barrow Island in 1993 (Bruce and Humphreys, 1993) and occurs at at least four other sites on the Island (Humphreys, in press; Appendix 2).

Plate 3.1: Isopoda: *Haptolana pholeta.*

Figure 3.3: Isopod records (red = Cirolanidae, blue = Oniscoideae).

The other family of isopods represented was the Oniscoidea, with a single animal recorded from an old bore adjacent to terminal tanks monitoring well MW16 (MW16nr1) (Figure 3.3). This is a significant specimen as it is the first record of an aquatic oniscoid isopod from Barrow Island and probably represents a previously undescribed species (see Section 4.0).

ORDER AMPHIPODA

Two families were represented amongst the collected material (Figure 3.4). The majority of the amphipods collected (99 of 102 individuals) were melitid amphipods of the genus *Nedsia* (Table 3.1). This is a difficult group to identify with confidence and this material needs to be dissected and slide-mounted to be examined. Two animals recorded from outside of the area of investigation have been identified as *Nedsia sculptilis/macrosculptilis* (bores AMW18 and L4nr) and one as *Nedsia* nr. *hulberti* (bore L32j) (Bradbury and Williams, 1993; Humphrey, in press). Many of the remaining amphipod specimens were juvenile, damaged or incomplete, lacking many of the diagnostic characters required by Bradbury and Williams (1993) and Bradbury (2001). It will probably not be possible to take this material to species level identification based on morphology but allozyme and DNA analyses currently underway may provide further information on species distributions. Preliminary allozyme results indicate at least three genetic types, with genetic distances at the species level of separation, with one of these genetic types occurring both within the development area and elsewhere in the Island (at bore L32j).

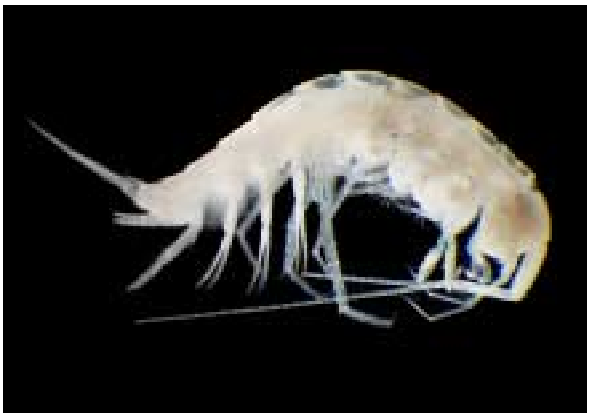

Plate 3.2: Amphipoda: *Nedsia sculptilis* (photo: J. McRae, CALM).

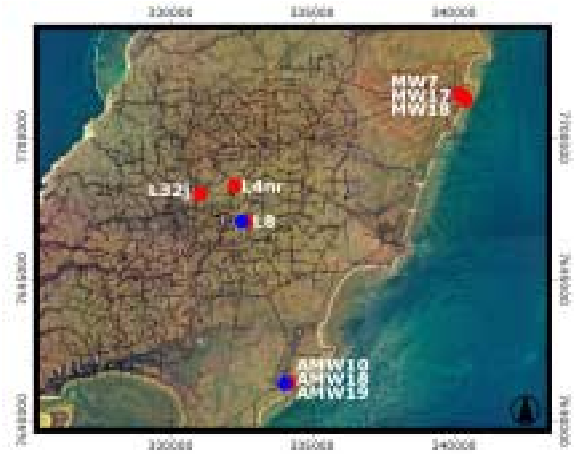

Figure 3.4: Amphipod records (red = Melitidae, blue = Bogidiellidae).

The remaining amphipods were all collected from outside of the area of investigation (AMW18 at the airport and L8 near the Base), and belong to the family Bogidiellidae. These specimens are again of considerable significance as the only previously described member of this family from Barrow Island is *Bogidomma australis*. This monospecific genus was erected specifically as *Bogidomma* was the only stygal amphipod with eyes – a feature absent from the bogidiellids collected during the current study. It is most likely that these new specimens belong to the genus *Bogidiella* (J. McRae, pers. comm., 2002) and probably represent an undescribed species.

ORDER DECAPODA

One decapod crustacean was collected during the current study, the atyid *Stygiocaris stylifera* (Plate 3.3). It was relatively abundant where present (n=43 from two locations, both outside the proposed development area). This species is known to be fairly widespread on the Island, having been recorded from 16 locations during previous surveys by the WA Museum (Humphreys, in press).

Plate 3.3: Decapoda: *Stygiocaris stylifera*

Plate 3.4: Vertebrata: *Milyeringa veritas*

CLASS VERTEBRATA

One stygal vertebrate was recorded during the study, the Blind Gudgeon *Milyeringa veritas* (Plate 3.4). This species is listed as Schedule 1 under the *Wildlife Conservation Act* 1979 and as 'vulnerable' under the *EPBC Act* 1999. It is one of only two known stygal vertebrate species in Australia, with Cape Range the only known locality outside of Barrow Island (Humphreys, 2001). The single animal collected during the current study was recovered from bore L8 outside of the proposed development area, at a sample site from which it had previously been documented (Humphreys, in press). The recovered specimen was preserved in liquid nitrogen to provide for any future electrophoretic work that may be undertaken.

3.2 Troglobitic Fauna

As no field sampling results are available for the development area (see Section 2.0), this discussion is limited to an appraisal of the habitat of the area and known records from previous work on the Island.

The WA Museum's database includes 324 records of terrestrial invertebrate taxa collected from caves or other subterranean environments on Barrow Island. The distribution of these records on the Island is shown in Figure 3.4. A detailed listing of these records is provided in Appendix 2.

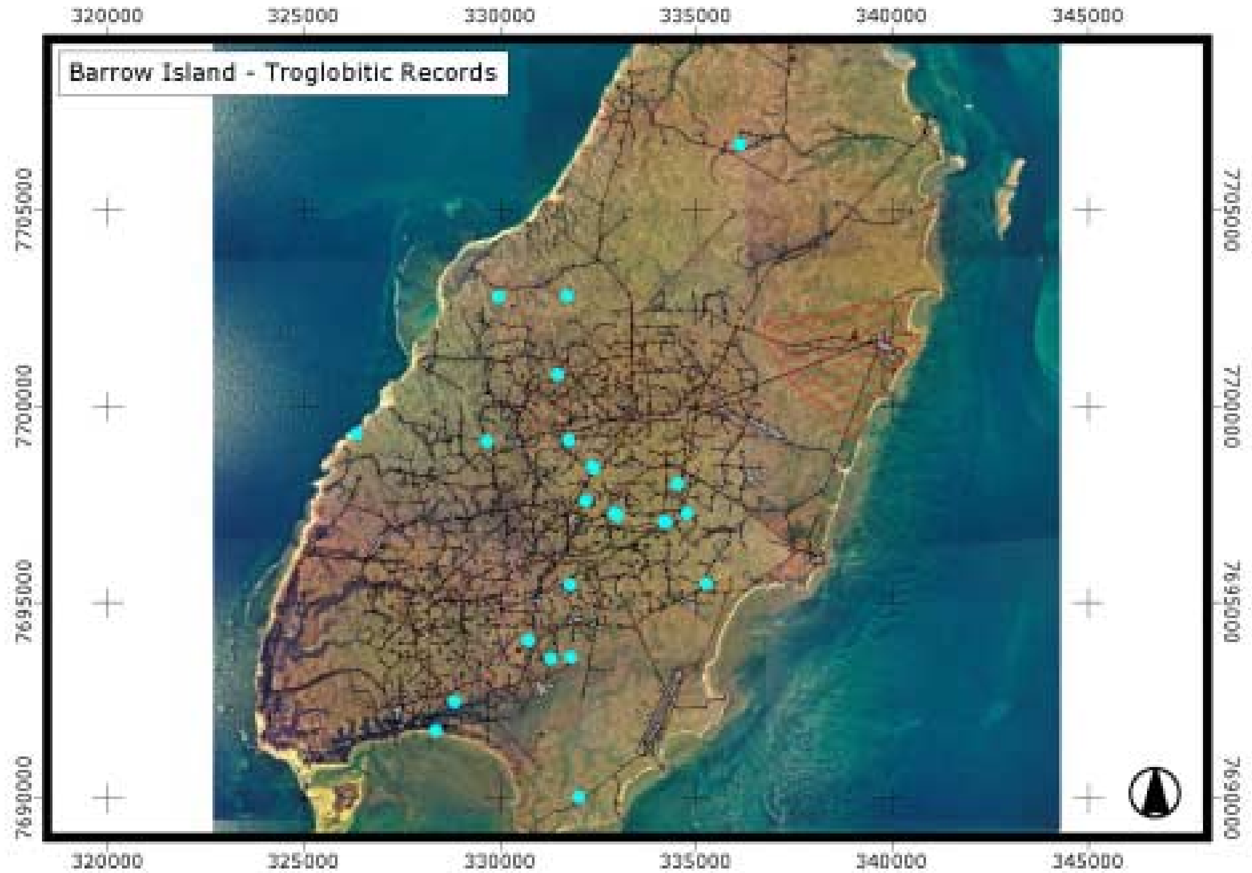

Figure 3.5: Troglobitic fauna records from Barrow Island (data source: WA Museum).

A proportion of this fauna contains terrestrial invertebrate taxa which are not strongly troglobitic and are probably accidentals or troglophiles rather than a true component of the troglofauna. This includes ants (Hymenoptera: Formicidae), several beetle taxa (Coleoptera), springtails (Collembola), and ticks (Acarina: Ixodidae) (see Appendix 2). Humphreys (in press), provides an account of the true troglobitic species currently described from Barrow Island and this is summarised in Table 3.2 below.

Table 3.2: Troglobitic fauna species known from Barrow Island.

Species	Records	Conservation Status
Draculoides bramstokeri (Schizomida: Hubbardiidae)	7	Schedule 1 (Wildlife Conservation Act)
Speleostrophus nesiotes (Diplopoda: Trigoniulinae)	1	Schedule 1; (Wildlife Conservation Act)
Nocticola sp. nov. (Blattodea: Nocticolidae)	1	Undescribed species
Isopoda: Oniscidea: sp. indet.	5	Undescribed species
Arachnida: Scorpiones: sp. nov. (family uncertain)	1	Undescribed genus

The majority of these troglofauna records have come from cave 6B1 (Ledge Cave) which is clearly a highly significant site for this fauna. It is situated in the south-west of the Island, well removed from the proposed gas processing facility site. Of the troglobitic species documented from the Island, the schizomid *Draculoides bramstokeri* is known to be widespread having been recorded from several sites on Barrow Island and also occurring across Cape Range (Biota, 2002; Humphreys, in press). It is considered likely that this species occurs in karstic formations across most of the Island, including the proposed development area and the pipeline route.

Other potentially troglobitic species have also been collected from Barrow Island (see Appendix 2) but in many cases the taxonomy of these groups has not been advanced. One potentially troglobitic species stands out in particular: the blind snake *Ramphotyphlops longissimus*. This species is known from only a single specimen that was recovered during removal of a well casing on the Island (Aplin, 1988; Humphreys, in press). The species is depigmented, has very reduced eyes and an extremely vermiform morphology. It is possibly troglobitic, which would make *R. longissimus* the only known reptile troglobite in the world (Humphreys, in press).

The majority of the known troglofauna records are associated with caves, although some are from fauna recorded during borehole sampling (see Appendix 2). There are no records of troglobitic fauna from the area of investigation. This is probably a function of sampling access availability to the karst underlying the site as well as the apparent lack of caves with suitable microclimates. There is considerable evidence of subsurface cavities on the Island that do not open to the surface (Humphreys, in press), but seismic and geotechnical data do not indicate any significant voids at the proposed gas processing facility site. It is likely that the limestone strata below the proposed development area provide some level of suitable habitat for troglobitic fauna, but this is likely to be limited by the extent of caverns and fracturing. Most of the area traversed by the planned pipeline route is similar in nature in this respect, with the exception of the area on the western side of the Island approaching Flacourt Bay. In this locality the karstic development becomes more massive and developed with the formation of gorges and incised drainages reminiscent of the geomorphological features of Cape Range (see Plate 3.5 and 3.6).

No caves or major sinkholes were located during ground-truthing of this area, but there were numerous solution tubes and fractures in the better developed formations. A considerable array of troglobitic fauna has been recovered from habitats very similar to this on the Cape Range peninsula (Biota, 2002). Given the biogeographical linkage of Barrow Island with the Cape (Humphreys, 2000), it is likely that this western portion of the pipeline route also supports troglobitic fauna.

Plate 3.5 & 3.6: Well developed karst features in the western-most portion of the proposed pipeline route approaching Flacourt Bay.

4.0 Conclusions and Recommendations

4.1 Conservation Significance

Barrow Island is well recognised as being of high conservation significance for subterranean fauna communities at the State, National and International levels of consideration. The subterranean fauna of the Island demonstrates a high level of endemicity and species diversity, with over twenty species known only from Barrow Island. The fauna of the Island includes one of only two stygal vertebrate species occurring in Australia and potentially the only troglobitic reptile known globally. There is also evidence to suggest that the subterranean ecosystems of Barrow Island may be at least locally driven by chemautotrophic energy sources, rather than traditional allotrophic (surface energy) inputs.

Twelve of the species known from the Island are listed as Schedule fauna under the State *Wildlife Conservation Act* 1979 and also one listed as 'vulnerable' under the Federal *EPBC Act* 1999. This tally includes three Schedule 1 species recorded during the current study, *Milyeringa veritas, Nedsia hulbertii* and *N. macrosculptilis,* none of which were recorded from within the proposed development area (see Section 3.1). Five other *Nedsia* species are also Schedule listed and it is possible that some of these are represented amongst the specimens collected from the terminal tanks area. This includes *Nedsia hulbertii* which has previously been recorded from the area by the WA Museum (MW17; Humphreys, in press).

In addition to the currently described and Schedule listed fauna, a significant component of the Island's troglofauna and stygofauna comprises poorly sampled or undescribed taxa. This is illustrated by the results of the current survey which yielded several specimens that are either currently undescribed or are entirely new records for the Island (see Section 3.1). Four of these taxa were recorded outside of the proposed development area and four within. Of the undescribed taxa only within the area of investigation, two are copepods and they may correspond to material contained within the 'Copepoda: indet.' group listed in Humphreys (in press). The oniscoid Isopod specimen appears to be the first representative of this family known from the Island and was recovered from MW16nr1. Further work is being undertaken on this material. The status and conservation significance of these undescribed taxa is unknown, but it is likely that they are endemic to Barrow Island, given the biogeographic patterns generally evident amongst the described fauna (Humphreys, 2000). It is worth noting that these specimens are not just new species, but representatives of new genera and family level records for the Island in some instances, highlighting the levels of biodiversity involved.

At a regional scale of consideration, all of Barrow Island has a high conservation value. The specific conservation values of the development area include that it:

- supports subterranean fauna endemic to Barrow Island;
- has records of Schedule 1 fauna (*Nedsia hulbertii*) and the potential to support other Schedule species (particularly *Draculoides bramstokeri*);
- is the only known location for *Nedsia chevronia* (well MW15; Bradbury, 2002)*;* and
- has records of undescribed stygofauna taxa not known from elsewhere on the Island;

and would therefore be ascribed high conservation value in a regional context.

Compared to other parts of the Island, particularly 6B1 (Ledge Cave) and well L8, the species richness and abundance is relatively low within the development area. On the scale of Barrow Island then, and on the basis of available data, the proposed development area appears to have only moderate conservation significance for subterranean fauna. This is likely to be a reflection of both the limited sampling adequacy that has been possible in this area, and the apparent lack of caves with appropriate microclimates.

4.2 Potential Impacts

Assessing the significance of the potential impact on subterranean fauna involves consideration of both the conservation significance of the biota involved and the nature and extent of the predicted impacts. The conservation significance at the Barrow Island and regional scales is outlined in Section 4.1.

4.2.1 Sources of Potential Impact

Sources of potential impact arising from the Gorgon gas development proposal include:

- construction of the LNG plant and associated infrastructure;
- construction of any onshore marine infrastructure, which may require excavation or levelling of coastal limestone formations;
- delivery of water supply for construction and accommodation purposes; and
- construction of the gas delivery pipeline, particularly in the western-most sections of the proposed route.

Four potential impacts to subterranean systems arise from these sources.

- **Changes to surface hydrology**

Construction of the plant and associated infrastructure will result in the effective closure of surface drainage inputs over an area of approximately 300 ha. This will block any areas of current groundwater recharge and remove water and nutrient inputs to underlying subterranean systems. The extent to which this impacts locally occurring subterranean communities will depend on the extent of impermeable hardstand footprint and the drainage strategy adopted for disposal and dispersal of stormwater. It is recommended therefore that surface drainage is not significantly impeded in the development area and that drainage management aims to avoid changes to existing hydrology and maximise local recharge. The extent to which the geology underlying the site is fed by groundwater flow from other undisturbed recharge areas would also proportionally reduce the extent of this potential impact. In addition, there is some evidence that subterranean systems on the Island are not driven by surface energy (see Section 1.3) and this could also serve to buffer local ecosystems.

Sediment transport, resulting in the accumulation of silt in the karst and elevated turbidity in the aquifer, could also result from altered surface drainage regimes on the site. A suitable stormwater drainage plan for the site could address this issue, as well as the efficient dispersal of stormwater (see Section 4.3).

- **Groundwater abstraction**

Pumping of groundwater for construction and water supply purposes has some potential for localised impacts on stygofauna, but not to the extent of that associated with mine-scale dewatering activities. Several bores on the Island have been historically utilised for water abstraction purposes and still contain styogfauna populations (notably well L8). Groundwater abstraction is therefore considered a low risk provided it is not carried out on a large scale (e.g. the construction of a water supply borefield). For large water requirements, the project will make use of a reverse osmosis desalination plant, removing the risk of impacting local stygofauna communities.

- **Groundwater contamination**

Given the nature of the proposed LNG gas processing facility, the risk of significant groundwater contamination occurring is probably low. In any event, the existing terminal tank farm has resulted in localised hydrocarbon contamination in the groundwater and stygofauna still persist in the area (up to within 50 m of the tanks). Provided adequate management of potential contaminants is carried out during construction and operation of the facility, the risk of groundwater contamination significantly affecting local subterranean fauna systems appears low.

- **Direct physical impact on karst formations**

Excavation and earthworks associated with the gas processing facility and onshore marine works has the potential to directly impact karst areas that constitute habitat for troglobitic fauna. This will probably result in the removal of some areas of troglobitic fauna habitat in the development area.

Given the:

- lack of any known troglobitic species from this area;
- relatively shallow nature of the excavations which will probably be required;
- apparent lack of caves in this area; and
- the relatively low risk of troglobitic fauna being restricted to the works area,

it appears unlikely that the conservation significance of any troglobitic fauna species present would be significantly affected by this potential impact. It should be reiterated that the area has been poorly sampled for this fauna and the findings of future work could alter this assessment.

The western-most portion of the gas pipeline route will pass through an area of more developed karst and troglobitic fauna habitat (see Section 3.2). In this area the final alignment of the pipeline should be located such that direct construction impacts, including the need for any blasting, on significant karst formations are minimised.

4.2.2 Assessment

In terms of relative conservation significance, the proposed development area is not one of the more significant sites within Barrow Island. It does, however, have records of *Nedsia hulbertii* (Schedule 1), the holotype location for *Nedsia chevronia* and records of three undescribed stygofauna taxa not known from elsewhere on the Island (see Section 4.1).

An assessment of the aspects of the proposal that could affect this stygofauna generally indicates a relatively low risk of significant impacts. The greatest broad scale risk would appear to relate to changes in localised recharge and reduction in surface energy inputs to subterranean systems. A better understanding of how these systems function, including hydrology, hydrogeology and energy sources could assist in better assessing this potential impact (see Section 4.3.2). Project design and management will also serve to mitigate some of the risks associated with the factors identified in Section 4.2.1 (see Section 4.3).

Four taxa are currently only known from the area proposed for gas processing facility and this should warrant a precautionary view of this impact assessment. Work is underway to better clarify the distribution and taxonomic status of this fauna, along with its phylogeny and population genetics.

5.0 Acknowledgments

The assistance of the following individuals is acknowledged:

- Dr. Bill Humphreys of the WA Museum who provided general background on the fauna of Barrow Island and kindly supplied a manuscript of his in press review paper;
- Jane McRae and Adrian Pinder of the Department of Conservation and Land Management, Woodvale who provided species identifications and more detailed accounts of the taxonomic context of the specimens (in addition to the photomicrograph of *Nedsia sculptilis*;
- Dr. Terrie Finston of the University of Western Australia's Zoology Department who is currently conducting molecular genetic investigations on the material collected from Barrow Island; and
- Mr. Peter Doig and Mr. Keith Hallet who provided logistical support and identified sampling bore locations during the survey.

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Stygofauna Survey

Records from Barrow Island

Appendix 1

BIOta

Site: Barrow Island **Collectors:** Garth Humphreys and Roy Teale

					Isopoda		Thermosbaenacea	Amphipoda		Copepoda	Decapoda	Vertebrata	Ostracoda	Nematoda	Oligochaeta	
Borehole	**Easting**	**Northing**	**Area**	**Id No.**	***H. pholeta***	**Oniscoid**	***H. tulki***	***Nedsia* spp.**	**Bogidiellid sp.**		***S. stylifera***	***M. veritas***	**Sp. 1**	**Sp. 1**	**Sp. 1**	**Curation**
MW16nr1	340068.00	7701219.00	Impact	MW16nr1.1	1											100%
MW18	340421.00	7701304.00	Impact	MW18.1			1									100%
MW18	340421.00	7701304.00	Impact	MW18.2			1									100%
MW18	340421.00	7701304.00	Impact	MW18.3			2									100%
MW18	340421.00	7701304.00	Impact	MW18.4			1									100%
MW18	340421.00	7701304.00	Impact	MW18.5			1									100%
MW18	340421.00	7701304.00	Impact	MW18.6			1									100%
MW18	340421.00	7701304.00	Impact	MW18.7				2								100%
MW18	340421.00	7701304.00	Impact	MW18.8						1						100%
MW18	340421.00	7701304.00	Impact	MW18.9			5									100%
MW7	340159.00	7701530.00	Impact	MW7.1						4						100%
MW7	340159.00	7701530.00	Impact	MW7.2				1								LN
MW17	340343.00	7701456.00	Impact	MW17.1				1								100%
MW17	340343.00	7701456.00	Impact	MW17.2												100%
MW17	340343.00	7701456.00	Impact	MW17.3						2						100%
MW13	340228.00	7701084.00	Impact	MW13.1						4						100%
AMW20	334206.00	7691327.00	Control	AMW20.1						20						100%
AMW20	334206.00	7691327.00	Control	AMW20.2			1									100%
AMW18	334206.00	7691339.00	Control	AMW18.1		1										100%
AMW18	334206.00	7691339.00	Control	AMW18.2			1									100%
AMW18	334206.00	7691339.00	Control	AMW18.3				2								LN
AMW18	334206.00	7691339.00	Control	AMW18.4				2								100%
AMW18	334206.00	7691339.00	Control	AMW18.5									1			100%
AMW18	334206.00	7691339.00	Control	AMW18.6						15						100%
AMW10	334192.00	7691344.00	Control	AMW10.1				1								100%
AMW10	334192.00	7691344.00	Control	AMW10.2			2									100%
AMW19	334196.00	7691301.00	Control	AMW19.1										4		100%
AMW19	334196.00	7691301.00	Control	AMW19.2						10						100%
MW18	340421.00	7701304.00	Impact	MW18.7						1						100%
MW18	340421.00	7701304.00	Impact	MW18.8						7						100%
MW7	340159.00	7701530.00	Impact	MW7.3						3						100%

Site: Barrow Island **Collectors:** Garth Humphreys and Roy Teale

					Isopoda		Thermosbaenacea	Amphipoda		Copepoda	Decapoda	Vertebrata	Ostracoda	Nematoda	Oligochaeta	
Borehole	**Easting**	**Northing**	**Area**	**Id No.**	***H. pholeta***	**Oniscoid**	***H. tulki***	***Nedsia* spp.**	**Bogidiellid sp.**		***S. stylifera***	***M. veritas***	**Sp. 1**	**Sp. 1**	**Sp. 1**	**Curation**
MW17	340343.00	7701456.00	Impact	MW17.3				1								100%
MW17	340343.00	7701456.00	Impact	MW17.4				1								LN
L8	332663.63	7697030.81	Control	L8.1							6					100%
L8	332663.63	7697030.81	Control	L8.2							6					100%
L8	332663.63	7697030.81	Control	L8.3							7					100%
L8	332663.63	7697030.81	Control	L8.4							3					LN
L8	332663.63	7697030.81	Control	L8.5							2					LN
L8	332663.63	7697030.81	Control	L8.6				1								LN
L8	332663.63	7697030.81	Control	L8.7					1							100%
L8	332663.63	7697030.81	Control	L8.8				1								100%
L8	332663.63	7697030.81	Control	L8.9		7										100%
L8	332663.63	7697030.81	Control	L8.10			10									100%
L8	332663.63	7697030.81	Control	L8.11							5					LN
L8	332663.63	7697030.81	Control	L8.12							5					LN
L8	332663.63	7697030.81	Control	L8.13								1				LN
L8	332663.63	7697030.81	Control	L8.14						20						100%
L8	332663.63	7697030.81	Control	L8.15											4	100%
L8	332663.63	7697030.81	Control	L8.16				1								100%
L8	332663.63	7697030.81	Control	L8.17				1								LN
L8	332663.63	7697030.81	Control	L8.18			15									100%
L8	332663.63	7697030.81	Control	L8.19							7					100%
L8	332663.63	7697030.81	Control	L8.20				3								100%
C65	331896.00	7689829.00	Control	C65.1									3			100%
L32j	331038.00	7697999.00	Control	L32j.1				5								LN
L32j	331038.00	7697999.00	Control	L32j.2				5								LN
L32j	331038.00	7697999.00	Control	L32j.3				1								LN
L32j	331038.00	7697999.00	Control	L32j.4				4								LN
L32j	331038.00	7697999.00	Control	L32j.5				50								100%
L32j	331038.00	7697999.00	Control	L32j.6				1								100%
L32j	331038.00	7697999.00	Control	L32j.7												100%
L32j	331038.00	7697999.00	Control	L32j.8						30						100%
L4nr	332241.30	7698285.52	Control	L4nr.1				1								LN

Site: Barrow Island **Collectors:** Garth Humphreys and Roy Teale

					Isopoda		Thermosbaenacea	Amphipoda		Copepoda	Decapoda	Vertebrata	Ostracoda	Nematoda	Oligochaeta	
Borehole	**Easting**	**Northing**	**Area**	**Id No.**	***H. pholeta***	**Oniscoid**	***H. tulki***	***Nedsia* spp.**	**Bogidiellid sp.**		***S. stylifera***	***M. veritas***	**Sp. 1**	**Sp. 1**	**Sp. 1**	**Curation**
L4nr	332241.30	7698285.52	Control	L4nr.2							2					100%
L4nr	332241.30	7698285.52	Control	L4nr.3		4										100%
L4nr	332241.30	7698285.52	Control	L4nr.4				1								100%
L4nr	332241.30	7698285.52	Control	L4nr.5						1						100%
AMW18	334206.00	7691339.00	Control	AMW18.1				1								LN
AMW18	334206.00	7691339.00	Control	AMW18.2				1								LN
AMW20	334206.00	7691327.00	Control	AMW20.1		1										100%
AMW20	334206.00	7691327.00	Control	AMW20.2						6						100%
AMW18	334206.00	7691339.00	Control	AMW18.3				1								LN
AMW18	334206.00	7691339.00	Control	AMW18.4				1								LN
AMW18	334206.00	7691339.00	Control	AMW18.5				2								100%
AMW19	334196.00	7691301.00	Control	AMW19.1				1								LN
AMW18	334206.00	7691339.00	Control	AMW18.6						10						100%
AMW18	334206.00	7691339.00	Control	AMW18.7				5								100%
AMW10	334192.00	7691344.00	Control	AMW10.1						1						100%
AMW10	334192.00	7691344.00	Control	AMW10.2			1									100%

WA Museum
Stygofauna and Troglofauna
Records from Barrow Island

Appendix 2

BIOTA

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
B-1	-20.79806	115.33139	Arachnida	Araneae	Ctenidae (JW)		
B-1	-20.79806	115.33139	Arachnida	Acarina	Ixodidae	Amblyomma	triguttatum
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Malacostraca	Amphipoda	Melitidae	Nedsia	hurlberti Bradbury & Williams, HOLOTYPE
B-1	-20.79806	115.33139	Malacostraca	Amphipoda	Hadziidae	Liagoceradocus	subthalassicus Bradbury & Williams
B-1	-20.79806	115.33139	Arachnida	Araneae	Oecobiidae	Oecobius	sp.
B-1	-20.79806	115.33139	Arachnida	Araneae	Gnaphosidae		
B-1	-20.79806	115.33139	Arachnida	Araneae	Ctenidae		
B-1	-20.79806	115.33139	Arachnida	Araneae	Gnaphosidae		
B-1	-20.79806	115.33139	Arachnida	Araneae	Stiphidiidae	Janusia	
B-1	-20.79806	115.33139	Arachnida	Araneae	Gnaphosidae		
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria			
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139		Blattaria	Nocticolidae	Nocticola sp.	
B-1	-20.79806	115.33139	Maxillopoda: Copepoda		Calanoida		
B-1	-20.79806	115.33139	Maxillopoda: Copepoda		Calanoida		
B-1	-20.79806	115.33139	Insecta	Coleoptera	Trogidae	Omorgus dilaticollis (Macleay)	
B-1	-20.79806	115.33139	Insecta	Coleoptera	Carabidae		
B-1	-20.79806	115.33139	Insecta	Collembola			
B-1	-20.79806	115.33139	Insecta	Collembola			
B-1	-20.79806	115.33139		Decapoda: Natantia		Atyidae	Stygiocaris sp.
B-1	-20.79806	115.33139		Decapoda: Natantia		Atyidae	Stygiocaris sp.
B-1	-20.79806	115.33139		Decapoda: Natantia		Atyidae	Stygiocaris sp.
B-1	-20.79806	115.33139	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris stylifera Holthuis
B-1	-20.79806	115.33139	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris stylifera Holthuis
B-1	-20.79806	115.33139	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris stylifera Holthuis
B-1	-20.79806	115.33139	Insecta	Diptera			
B-1	-20.79806	115.33139	Insecta	Diptera			
B-1	-20.79806	115.33139	Insecta	Diptera			
B-1	-20.79806	115.33139	Insecta	Diptera			

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
B-1	-20.79806	115.33139	Insecta	Hemiptera	Reduviidae: Emesinae	Ploiaria	sp.1
B-1	-20.79806	115.33139	Insecta	Hemiptera	Reduviidae: Emesinae	Ploiaria	sp.1
B-1	-20.79806	115.33139	Insecta	Hemiptera	Reduviidae: Emesinae	Ploiaria	sp.1
B-1	-20.79806	115.33139	Insecta	Hemiptera	Reduviidae: Emesinae	Ploiaria	sp.1
B-1	-20.79806	115.33139	Insecta	Hemiptera			
B-1	-20.79806	115.33139	Insecta	Hemiptera	Cixiidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139		Hymenoptera	Formicidae		
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	Laevophiloscia	yalgoonensis Wahrberg 1922
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	Laevophiloscia	yalgoonensis Wahrberg 1922
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	Laevophiloscia	yalgoonensis Wahrberg 1922
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	Laevophiloscia	yalgoonensis Wahrberg 1922
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	Laevophiloscia	yalgoonensis Wahrberg 1922
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	Laevophiloscia	yalgoonensis Wahrberg 1922
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	Laevophiloscia	yalgoonensis Wahrberg 1922
B-1	-20.79806	115.33139	Malacostraca	Isopoda			
B-1	-20.79806	115.33139		Isopoda: Oniscidea		Philosciidae	?Laevophiloscia Wahrberg, 1922 sp. nov.
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Insecta	Psocoptera			
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-1	-20.79806	115.33139	Arachnida	Scorpionida	Ischnuridae	Liocheles	sp.
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	Speleostrophus	nesiotes Hoffman 1994
B-1	-20.79806	115.33139	Thermosbaenacea		Thermosbaenacea	Halosbaena	tulki Poore & Humphreys, 1992
B-1	-20.79806	115.33139			Japygidae		
B-2	-20.71667	115.38333	Insecta	Lepidoptera			
B-2	-20.71667	115.38333	Insecta	Lepidoptera			
B-2	-20.71667	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-2	-20.71667	115.38333	Arachnida	Araneae	Theridiidae	Icona	sp.
B-2	-20.71667	115.38333	Arachnida	Acarina			
B-2	-20.71667	115.38333	Arachnida	Araneae	Theridiidae		
B-2	-20.71667	115.38333	Arachnida	Araneae			
B-2	-20.71667	115.38333	Arachnida	Araneae	Pholcidae		
B-2	-20.71667	115.38333	Arachnida	Araneae	Theridiidae		
B-2	-20.71667	115.38333	Insecta	Coleoptera			
B-2	-20.71667	115.38333	Insecta	Collembola			
B-2	-20.71667	115.38333	Insecta	Hemiptera	Cixiidae?		
B-2	-20.71667	115.38333	Insecta	Hymenoptera	Formicidae		
B-2	-20.71667	115.38333	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	Barrowdillo	pseudopyrgoniscus Dalens
B-2	-20.71667	115.38333	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	Barrowdillo	pseudopyrgoniscus Dalens
B-2	-20.71667	115.38333	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	Barrowdillo	pseudopyrgoniscus Dalens
B-2	-20.71667	115.38333	Malacostraca	Isopoda: Oniscidea			
B-2	-20.71667	115.38333	Malacostraca	Isopoda: Oniscidea			
B-2	-20.71667	115.38333	Insecta	Lepidoptera			
B-2	-20.71667	115.38333	Insecta	Psocoptera			
B-2	-20.71667	115.38333	Insecta	Psocoptera			
B-3	-20.80000	115.36331	Arachnida	Acarina	Ixodidae	Amblyomma	limbatum Neumann
B-3	-20.80000	115.36331	Arachnida	Acarina	Ixodidae	Amblyomma	limbatum Neumann
B-3	-20.80000	115.36331	Arachnida	Acarina			
B-3	-20.80000	115.36331	Insecta	Coleoptera	Trogidae	Omorgus	dilaticollis (Macleay)

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
B-3	-20.80000	115.36331	Insecta	Coleoptera	Trogidae	Omorgus	dilaticollis (Macleay)
B-3	-20.80000	115.36331	Insecta	Coleoptera	Dermestidae	Dermestes	frischi Kugelann
B-3	-20.80000	115.36331	Insecta	Collembola			
B-3	-20.80000	115.36331	Insecta	Collembola			
B-3	-20.80000	115.36331	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-3	-20.80000	115.36331	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-3	-20.80000	115.36331	Insecta	Hymenoptera	Formicidae		
B-3	-20.80000	115.36331	Arachnida	Acarina	Ixodidae	Amblyomma	sp.
B-3	-20.80000	115.36331	Arachnida	Araneae	Heteropodidae	Heteropoda	sp
B-3	-20.80000	115.36331	Arachnida	Araneae	Pholcidae		
B-3	-20.80000	115.36331	Arachnida	Araneae	Ctenidae		
B-3	-20.80000	115.36331	Arachnida	Araneae	Pholcidae	Trichocyclus	
B-3	-20.80000	115.36331	Insecta	Coleoptera	Trogidae		
B-3	-20.80000	115.36331	Insecta	Collembola			
B-3	-20.80000	115.36331	Insecta	Diptera			
B-3	-20.80000	115.36331	Insecta	Hemiptera			
B-3	-20.80000	115.36331	Insecta	Hymenoptera	Formicidae		
B-3	-20.80000	115.36331	Insecta	Hymenoptera	Formicidae		
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	Barrowdillo	pseudopyrgoniscus Dalens
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	Barrowdillo	pseudopyrgoniscus Dalens
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	Barrowdillo	pseudopyrgoniscus Dalens
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	Barrowdillo	pseudopyrgoniscus Dalens
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	Barrowdillo	pseudopyrgoniscus Dalens
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Philosciidae		Laevophiloscia yalgoonensis Wahrberg 1922
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea			
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea			
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea		Philosciidae	
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea			Barrowdillo
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea		"Porcellenid"	
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea			
B-3	-20.80000	115.36331		Pscocidae			
B-3	-20.80000	115.36331	Insecta	Thysanura	Lepismatidae	Heterolepisma	sp.
B-3	-20.80000	115.36331	Diplopoda				epigean species
B-3	-20.80000	115.36331		Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Heteropodidae	Heteropoda	sp
B-4	-20.76667	115.38333	Arachnida	Araneae	Heteropodidae	Heteropoda	sp.
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Insecta	Coleoptera	Tenebrionidae	Brises	sp.
B-4	-20.76667	115.38333	Insecta	Hemiptera	Reduviidae: Emesinae	Stenolemus	giraffa Wygodzinsky
B-4	-20.76667	115.38333	Arachnida	Araneae	? Gnaphosidae (JW)		
B-4	-20.76667	115.38333	Arachnida	Araneae	? Cyclotenidae (JW)		
B-4	-20.76667	115.38333	Arachnida	Araneae	Heteropodidae	Heteropoda (JW)	
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Cyclotenidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Gnaphosidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Heteropodidae	Heteropoda	
B-4	-20.76667	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-4	-20.76667	115.38333	Malacostraca	Isopoda: Oniscidea			
B-4	-20.76667	115.38333	Malacostraca	Isopoda: Oniscidea			Barrowdillo
B-4	-20.76667	115.38333	Insecta	Psocoptera			
B-4	-20.76667	115.38333	Diplopoda				epigean species
B-5	-20.76667	115.36667	Arachnida	Acarina	Ixodidae	Amblyomma	limbatum Neumann
B-5	-20.76667	115.36667	Arachnida	Araneae	Pholcidae		
B-5	-20.71667	115.38333	Arachnida	Araneae	Pholcidae		
B-5	-20.76667	115.36667	Insecta	Hemiptera	Reduviidae: Emesinae	Stenolemus	giraffa Wygodzinsky
B-5	-20.76667	115.36667	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-5	-20.76667	115.36667	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-5	-20.76667	115.36667	Arachnida	Pseudoscorpionida		Atemnidae	Oratemnus sp. nov.
B-5	-20.76667	115.36667	Arachnida	Araneae	Heteropodidae (JW)	Heteropoda	
B-5	-20.76667	115.36667	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-5	-20.76667	115.36667	Malacostraca	Isopoda: Oniscidea			Buddelundia
B-5	-20.76667	115.36667	Malacostraca	Isopoda: Oniscidea		Pholoscidae	
B-5	-20.76667	115.36667	Arachnida	Pseudoscorpionida		Atemnidae	Oratemnus sp. nov.
B-5	-20.76667	115.36667	Insecta	Psocoptera			
B-6	-20.83333	115.38333	Arachnida	Acarina			
B-6	-20.83333	115.38333	Arachnida	Acarina			
B-6	-20.85000	115.38333	Arachnida	Araneae	Araneidae	Argiope	protensa
B-6	-20.83333	115.38333	Arachnida	Araneae	Oonopidae	?Opopaea	sp.
B-6	-20.83333	115.38333	Arachnida	Araneae	Theridiidae	Euryopis sp.	
B-6	-20.85000	115.38333	Arachnida	Araneae			
B-6	-20.85000	115.38333	Arachnida	Araneae	Desidae	Badumna	
B-6	-20.83333	115.38333	Arachnida	Araneae	Oonopidae		
B-6	-20.83333	115.38333	Arachnida	Araneae	Gnaphosidae		
B-6	-20.83333	115.38333	Arachnida	Araneae	Zoridae		
B-6	-20.83333	115.38333	Arachnida	Araneae	Amaurobidae		
B-6	-20.85000	115.38333	Arachnida	Araneae	Pholcidae		
B-6	-20.83333	115.38333	Insecta	Blattodea			
B-6	-20.83333	115.38333	Insecta	Blattodea			
B-6	-20.83333	115.38333	Insecta	Coleoptera	Carabidae: Pterostichini	Prosopogmus	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Curculionidae: Entiminae		
B-6	-20.83333	115.38333	Insecta	Coleoptera	Curculionidae: Cryptorhynchinae		
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Ectychini	Ectyche	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Crypticini	Microcrypticus	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Opatrini	Mesomorphus	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Carabidae: Pterostichini	Prosopogmus	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Curculionidae: Entiminae		
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Ectychini	Ectyche	

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Opatrini	Mesomorphus	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Curculionidae: Crytptorhynchinae		
B-6	-20.83333	115.38333	Insecta	Coleoptera	Lathridiidae: Lathridiinae	genus?	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Ptiliidae		
B-6	-20.83333	115.38333	Insecta	Collembola			
B-6	-20.83333	115.38333	Insecta	Collembola			
B-6	-20.83333	115.38333	Insecta	Collembola			
B-6	-20.83333	115.38333	Insecta	Collembola			
B-6	-20.85000	115.38333	Insecta	Diptera			
B-6	-20.83333	115.38333	Insecta	Diptera			
B-6	-20.83333	115.38333	Insecta	Diptera			
B-6	-20.83333	115.38333	Mollusca	Gastropoda			
B-6	-20.83333	115.38333	Mollusca	Gastropoda			
B-6	-20.85000	115.38333	Insecta	Hemiptera	Reduviidae	Centrogonus	sp. 1
B-6	-20.85000	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-6	-20.85000	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-6	-20.85000	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	Centrogonus	sp.1
B-6	-20.85000	115.38333	Insecta	Hemiptera			
B-6	-20.85000	115.38333	Insecta	Hemiptera			
B-6	-20.83333	115.38333	Insecta	Hemiptera			
B-6	-20.83333	115.38333	Insecta	Hemiptera			
B-6	-20.85000	115.38333	Insecta	Hymenoptera	Formicidae		
B-6	-20.83333	115.38333	Insecta	Hymenoptera	Formicidae		
B-6	-20.83333	115.38333	Insecta	Hymenoptera	Formicidae		
B-6	-20.85000	115.38333	Insecta	Hymenoptera	Formicidae		
B-6	-20.85000	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.85000	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.83333	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.83333	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.83333	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.85000	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.85000	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.85000	115.38333	Insecta	Isoptera			
B-6	-20.83333	115.38333	Insecta	Orthoptera			
B-6	-20.85000	115.38333	Insecta	Orthoptera			
B-6	-20.83333	115.38333	Diplopoda	Polyxenida	Polyxenidae		
B-6	-20.83333	115.38333	Arachnida	Pseudoscorpionida		Olpiidae	Xenolpium sp.
B-6	-20.83333	115.38333	Arachnida	Pseudoscorpionida		Cheirididae	
B-6	-20.83333	115.38333	Arachnida	Pseudoscorpionida		Olpiidae	
B-6	-20.83333	115.38333	Arachnida	Pseudoscorpionida		Cheirididae	
B-6	-20.83333	115.38333	Insecta	Psocoptera			
B-6	-20.83333	115.38333	Insecta	Psocoptera			
B-6	-20.83333	115.38333	Insecta	Psocoptera			
B-6	-20.85000	115.38333	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae	Acrotelsella	sp.

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae	Heterolepisma	sp.
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae	Acrotelsella	sp.
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae	Heterolepisma	sp.
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae		
B-6	-20.83333	115.38333	Insecta				
B-6	-20.85000	115.38333	Gastropoda				
B-8	-20.83333	115.41667	Insecta	Hemiptera	Reduviidae: Emesinae	Stenolemus	giraffa Wygodzinsky
B-10	-20.80000	115.38333	Insecta	Coleoptera	Pselaphidae		
B-10	-20.80000	115.38333	Insecta	Diptera			
B-10	-20.80000	115.38333	Insecta	Hemiptera			
B-10	-20.80000	115.38333	Malacostraca	Isopoda: Oniscidea			Barrowdillo
B-10	-20.80000	115.38333	Insecta	Psocoptera			
B-10	-20.80000	115.38333	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-10	-20.80000	115.38333	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B-18	-20.85000	115.31667	Ostracoda	Ostracoda	Candonidae: Paracypridinae	Phlyctenophora	mesembria Wouters
B-18	-20.85000	115.31667	Copepoda				
B -1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B -1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
Q5	-20.78472	115.38083		Decapoda: Natantia		Atyidae	Stygiocaris sp.
"F Cave"			Arachnida	Araneae	Pholcidae	Trichocyclus	sp. nov.
B2	-20.86667	115.35000	Malacostraca	Amphipoda	Melitidae	Nedsia	fragilis Bradbury & Williams, HOLOTYPE
B2	-20.86000	115.35472	Maxillopoda: Copepoda		Calanoida		
B2	-20.86000	115.35472	Maxillopoda: Copepoda		Calanoida		
B2	-20.86667	115.35000	Maxillopoda: Copepoda		Calanoida		
B2	-20.86667	115.35000	Maxillopoda: Copepoda		Calanoida		
B2	-20.86667	115.35000	Maxillopoda: Copepoda		Calanoida		
B2	-20.86667	115.35000	Insecta	Coleoptera	Curculionidae: Cryptorhynchinae		
B2	-20.86667	115.35000	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2	-20.86667	115.35000	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2	-20.86667	115.35000	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2			Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2			Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2	-20.86000	115.35472		Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2	-20.86000	115.35472		Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2	-20.86000	115.35472		Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2	-20.86667	115.35000	Insecta	Hymenoptera	Formicidae		
B2	-20.86667	115.35000	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B2	-20.86667	115.35000	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B2	-20.86667	115.35000	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B2			Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
B2	-20.86667	115.35000	Malacostraca	Isopoda: Oniscidea		Armadillidae	
B2	-20.86667	115.35000	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri
B2	-20.86000	115.35472	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri
B2	-20.86667	115.35000	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.
B2	-20.86667	115.35000	Malacostraca	Syncarida Bathynellacea		Parabathynellidae,	Atopobathynella sp. nov.

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
B2	-20.86667	115.35000	Malacostraca	Syncarida	Bathynellacea	Parabathynellidae,	Atopobathynella sp. nov.
B2	-20.86667	115.35000	Malacostraca	Syncarida	Bathynellacea	Parabathynellidae,	Atopobathynella sp. nov.
B2	-20.86667	115.35000	Thermosbaenacea		Thermosbaenacea		Halosbaena tulki Poore & Humphreys, 1992
B2	-20.86000	115.35472		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
B2	-20.86000	115.35472	Maxillopoda:	Copepoda	Calanoida		
B2	-20.86000	115.35472		Decapoda: Natantia		Atyidae	Stygiocaris sp.
B2	-20.86000	115.35472	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri
B7			Malacostraca:	Pancarida	Thermosbaenacea		Halosbaena tulki Poore & Humphreys, 1992
C38	-20.86917	115.40111		Araneae	Pholcidae		
C38	-20.86917	115.40111		Collembola			
C65	-20.88222	115.38500	Arachnida	Acarina			
C65	-20.88222	115.38500	Arachnida	Araneae			
C65	-20.88222	115.38500	Maxillopoda:	Copepoda	Calanoida		
C65	-20.88222	115.38500		Cyclopoida		Halicyclops	rochai Delaurentiis et al 1999
C65	-20.88222	115.38500	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
C65	-20.88222	115.38500	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
C65	-20.88222	115.38500		Decapoda: Natantia		Atyidae	Stygiocaris sp.
C65	-20.88222	115.38500		Isopoda: Oniscidea			
C65	-20.88222	115.38500		Collembola			
C65	-20.88222	115.38500		Araneae			
C65N	-20.87833	115.39250	Ostracoda				
C66	-20.87917	115.39167	Malacostraca	Amphipoda	Melitidae	Nedsia	macrosculptilis Bradbury & Williams, HOLOTYPE
C66	-20.87917	115.39167	Maxillopoda:	Copepoda	Calanoida		
C66	-20.87917	115.39167	Maxillopoda:	Copepoda	Calanoida		
C66	-20.87917	115.39167	Maxillopoda:	Copepoda	Calanoida		
C66	-20.87917	115.39167	Maxillopoda:	Copepoda	Calanoida		
C66	-20.87917	115.39167	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
C66	-20.87917	115.39167	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
C66	-20.87917	115.39167	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
C66	-20.87917	115.39167	Thermosbaenacea		Thermosbaenacea		Halosbaena tulki Poore & Humphreys, 1992
C77J	-20.88278	115.39556	Maxillopoda:	Copepoda	Calanoida		
C77J	-20.88278	115.39556	Maxillopoda:	Copepoda	Cyclopoida		Halicyclops rochai Delaurentiis et al 1999
E1	-20.83472	115.40250	Maxillopoda:	Copepoda	Calanoida		
E1	-20.83472	115.40250		Decapoda: Natantia		Atyidae	Stygiocaris sp.
F11	-20.84606	115.37309	Arachnida	Araneae			
F11	-20.84606	115.37309	Arachnida	Araneae	Trochanteriidae		
F11	-20.84611	115.37306	Maxillopoda:	Copepoda	Calanoida		
F11	-20.84606	115.37309	Maxillopoda:	Copepoda	Calanoida		
F11	-20.84611	115.37306	Insecta	Coleoptera			
F11	-20.84611	115.37306	Maxillopoda:	Copepoda	Cyclopoida		Diacyclops "humphreysi unispinosa n. ssp."
F11	-20.84611	115.37306		Cyclopoida		Halicyclops	rochai Delaurentiis et al 1999
F11	-20.84611	115.37306		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
F41A			Maxillopoda:	Copepoda	Calanoida		
F41A			Maxillopoda:	Copepoda	Calanoida		
F41A				Hemiptera	Meenoplidae		

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
F53S	-20.84361	115.38083		Collembola			
F7	-20.85028	115.37861	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri
G19			Maxillopoda: Copepoda		Calanoida		
G19			Maxillopoda: Copepoda		Calinoida		
G19			Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
G19			Arachnida	Scorpionida	Buthidae	Lychas	marmoreus?
G19			Thermosbaenacea		Thermosbaenacea	Halosbaena	tulki Poore & Humphreys, 1992
K11	-20.81778	115.37250	Malacostraca	Amphipoda	Melitidae	Nedsia	?urifimbriata Bradbury & Williams ALLOTYPE?
K11	-20.81778	115.37250	Malacostraca	Amphipoda	Melitidae	Nedsia	urifimbriata Bradbury & Williams, HOLOTYPE
K11			Arachnida	Araneae			
K11			Insecta	Hymenoptera			
K3N	-20.80944	115.36389	Copepoda	Cyclopoida	Cyclopidae	Halicyclops	longifurcatus
K3N	-20.80944	115.36389	Maxillipoda: Copepoda		Cyclopoida	Cyclopidae	Halicyclops longifurcatus
K3N	-20.80944	115.36389	Maxillipoda: Copepoda		Harpacticoida	Ameiridae	Inermipes humphreysi Lee & Huys; HOLOTYPE &
PARATYPES							
K3N	-20.80944	115.36389	Maxillipoda: Copepoda		Harpacticoida	Ameiridae	Inermipes humphreysi Lee & Huys; HOLOTYPE &
PARATYPES							
K3N	-20.80944	115.36389	Copepoda	Harpacticoida	Ameiridae	Inermipes	humphreysi Lee & Huys; PARATYPES
L 16			Malacostraca	Amphipoda	Melitidae	Nedsia	straskaba Bradbury & Williams, HOLOTYPE
L 16			Malacostraca	Amphipoda	Melitidae	Nedsia	straskraba Bradbury & Williams, 1996
L 16			Maxillopoda: Copepoda		Calanoida		
L 16			Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
L 16			Thermosbaenacea		Thermosbaenacea	Halosbaena	tulki Poore & Humphreys, 1992
L17			Maxillopoda: Copepoda		Calanoida		
L17			Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
L17			Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
L2	-20.80917	115.36417		Collembola			
L32J	-20.80944	115.37833		Amphipoda			
L32J	-20.80944	115.37833	Maxillopoda: Copepoda		Calanoida		
L32J	-20.80944	115.37833	Maxillopoda: Copepoda		Calanoida		
L32J	-20.80944	115.37833		Collembola			
L32J	-20.80944	115.37833	Maxillopoda: Copepoda		Cyclopoida		Diacyclops "humphreysi unispinosa n. ssp."
L32J	-20.80944	115.37833	Amphipoda				
L32J	-20.80944	115.37833		Araneae	Pholcidae		
L4	-20.80667	115.38944	Malacostraca	Amphipoda	Melitidae	Nedsia	humphreysi Bradbury & Williams, HOLOTYPE
L4	-20.80667	115.38944	Malacostraca	Amphipoda		Nedsia	sp. nov.? (cf sculptilis)
L4	-20.80667	115.38944	Malacostraca	Amphipoda			
L4	-20.80611	115.38917	Maxillopoda: Copepoda		Calanoida		
L4	-20.80667	115.38944	Maxillopoda: Copepoda		Calanoida		
L4	-20.80667	115.38944	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
L4	-20.80611	115.38917		Decapoda: Natantia		Atyidae	Stygiocaris sp.
L4	-20.80611	115.38917		Decapoda: Natantia		Atyidae	Stygiocaris sp.
L4	-20.80608	115.38922	Copepoda	Harpacticoida			
L4	-20.80611	115.38917	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri
L4	-20.80667	115.38944	Arachnida	Schizomida	Hubbardiidae	Draculoides	bramstokeri Harvey and Humphreys sp. nov.

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
L4	-20.80667	115.38944	Thermosbaenacea		Thermosbaenacea		Halosbaena tulki Poore & Humphreys, 1992
L4	-20.80611	115.38917		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
L4	-20.80667	115.38944		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
L4	-20.80667	115.38944	Amphipoda				
L4N	-20.80608	115.38922	Malacostraca	Amphipoda			
L4N	-20.81728	115.39506	Malacostraca	Amphipoda			
L4N	-20.81728	115.39506	Maxillopoda: Copepoda		Calanoida		
L4N	-20.81728	115.39506	Insecta	Coleoptera			
L5	-20.81409	115.38747	Maxillopoda: Copepoda		Calanoida		
L5	-20.81409	115.38747	Maxillopoda: Copepoda		Calanoida		
L5	-20.81409	115.38747	Insecta	Hymenoptera	Formicidae		
L8	-20.81739	115.39497	Arachnida	Acarina			
L8	-20.81728	115.39506	Arachnida	Acarina			
L8	-20.81694	115.39444	Malacostraca	Amphipoda	Bogidielliedae	Bogadomma	australis Bradbury & Williams
L8	-20.81694	115.39444	Malacostraca	Amphipoda	Bogidiellidae	Bogidomma	australis Bradbury & Williams, HOLOTYPE
L8	-20.81694	115.39444	Malacostraca	Amphipoda		Nedsia	sculptilis
L8	-20.81694	115.39444	Malacostraca	Amphipoda	Melitidae	Nedsia	sculptilis Bradbury & Williams, HOLOTYPE
L8	-20.81728	115.39506	Malacostraca	Amphipoda			
L8	-20.81694	115.39444	Arachnida	Araneae			
L8	-20.81694	115.39444	Maxillopoda: Copepoda		Calanoida		
L8	-20.81694	115.39444	Maxillopoda: Copepoda		Calanoida		
L8	-20.81694	115.39444	Maxillopoda: Copepoda		Calanoida		
L8	-20.81694	115.39444	Maxillopoda: Copepoda		Calanoida		
L8	-20.81739	115.39497	Maxillopoda: Copepoda		Calanoida		
L8	-20.81739	115.39497	Maxillopoda: Copepoda		Calanoida		
L8	-20.81728	115.39506	Maxillopoda: Copepoda		Calanoida		
L8	-20.81728	115.39506	Maxillopoda: Copepoda		Calanoida		
L8	-20.81728	115.39506	Maxillopoda: Copepoda		Calanoida		
L8	-20.81694	115.39444	Maxillopoda: Copepoda		Calanoida		
L8	-20.81694	115.39444	Maxillopoda: Copepoda		Calanoida		
L8	-20.81694	115.39444	Insecta	Coleoptera			
L8	-20.81728	115.39506	Insecta	Collembola			
L8	-20.81728	115.39506	Insecta	Collembola			
L8	-20.81694	115.39444	Maxillopoda: Copepoda		Cyclopoida		Diacyclops "humphreysi unispinosa n. ssp."
L8	-20.81694	115.39444	Maxillopoda: Copepoda		Cyclopoida		Halicyclops rochai Delaurentiis et al 1999
L8	-20.81728	115.39506	Maxillopoda: Copepoda		Cyclopoida		Halicyclops rochai Delaurentiis et al 1999
L8	-20.81694	115.39444		Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81694	115.39444		Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81694	115.39444		Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81739	115.39497		Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81739	115.39497		Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81728	115.39506		Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris stylifera Holthuis, 1960
L8	-20.81694	115.39444	Copepoda	Harpacticoida	Ameiridae	Inermipes	humphreysi Lee & Huys; PARATYPE
L8	-20.81728	115.39506	Insecta	Hymenoptera	Formicidae		
L8	-20.81694	115.39444	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
L8	-20.81694	115.39444		Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
L8	-20.81694	115.39444		Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
L8	-20.81694	115.39444		Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
L8	-20.81728	115.39506	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
L8	-20.81694	115.39444	Insecta	Psocoptera			
L8	-20.81694	115.39444	Thermosbaenacea		Thermosbaenacea		Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444	Malacostraca	Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81728	115.39506		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444	Thermosbaenacea		Thermosbaenacea		Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444	Thermosbaenacea		Thermosbaenacea		Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444	Thermosbaenacea		Thermosbaenacea		Halosbaena tulki Poore & Humphreys, 1992
L8	-20.81694	115.39444	Amphipoda				
L8	-20.81694	115.39444	Amphipoda				
L8	-20.81694	115.39444	Amphipoda				
L8	-20.81889	115.40667	Amphipoda				
L8	-20.81739	115.39497	Amphipoda				
L8	-20.81739	115.39497		Collembola			
L8	-20.81739	115.39497	Amphipoda				
L8	-20.81728	115.39506	Pisces		Eleotridae	Milyeringa	veritas
L8	-20.81728	115.39506	Amphipoda			Nedsia	
M13	-20.81719	115.41233	Malacostraca	Amphipoda			
M13	-20.81719	115.41233	Arachnida	Araneae	Desidae		
M13	-20.81719	115.41233	Insecta	Diptera			
M13	-20.81719	115.41233	Insecta				
M5	-20.81222	115.40972		Decapoda: Natantia		Atyidae	Stygiocaris sp.
M5	-20.81222	115.40972	Malacostraca	Isopoda	Cirolanidae	Haptolana	pholeta Bruce & Humphreys
M52	-20.81586	115.40814	Maxillopoda: Copepoda		Calanoida		
M52	-20.81586	115.40814	Maxillopoda: Copepoda		Calanoida		
M52	-20.81586	115.40814		Thermosbaenacea			Halosbaena tulki Poore & Humphreys, 1992
M5N	-20.81017	115.41006	Arachnida	Araneae	Pholcidae		
M5N	-20.81017	115.41006	Arachnida	Araneae	Pholcidae		
M5N	-20.81017	115.41006	Maxillopoda: Copepoda		Calanoida		
M5N	-20.81017	115.41006	Maxillopoda: Copepoda		Calanoida		
M5N	-20.81017	115.41006	Maxillopoda: Copepoda		Cyclopoida		Halicyclops rochai De Laurentiis et al 1999
M5N	-20.81017	115.41006	Maxillopoda: Copepoda		Cyclopoida		Halicyclops rochai Delaurentiis et al 1999
M5N	-20.81017	115.41006	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species	
M5N	-20.81017	115.41006	Insecta	Hemiptera: Fulgoroidea?				
M5N	-20.81017	115.41006		Thermosbaenacea			Halosbaena	tulki Poore & Humphreys, 1992
M62	-20.81889	115.40667	Arachnida	Acarina				
M62	-20.81919	115.40706	Arachnida	Acarina				
M62	-20.81919	115.40706	Malacostraca	Amphipoda				
M62	-20.81919	115.40706	Malacostraca	Amphipoda				
M62	-20.81889	115.40667	Maxillopoda: Copepoda		Calanoida			
M62	-20.81919	115.40706	Maxillopoda: Copepoda		Calanoida			
M62	-20.81919	115.40706	Maxillopoda: Copepoda		Calanoida			
M62	-20.81889	115.40667	Maxillopoda: Copepoda		Cyclopoida		Diacyclops	"humphreysi unispinosa n. ssp."
M62	-20.81889	115.40667		Thermosbaenacea			Halosbaena	tulki Poore & Humphreys, 1992
M62	-20.81889	115.40667	Amphipoda					
M62	-20.81919	115.40706	Foramenifera					
M62			Maxillopoda: Copepoda		Calanoida			
M62			Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.	
Malouet Cave			Arachnida	Araneae	Ctenidae	Janusia	sp.3	
Malouet Cave			Arachnida	Araneae	Pholcidae			
MW13	-20.78083	115.46694		Harpacticioda		Inermipes	humphreysi Lee & Huys	
MW13 / SB31	-20.78083	115.46694		Harpacticioda		Inermipes	humphreysi Lee & Huys	
MW15	-20.78278	115.46472	Amphipoda					
MW15	-20.78278	115.46472	Amphipoda					
MW15	-20.78278	115.46472	Amphipoda					
MW17	-20.77861	115.46778	Amphipoda					
MW3 /SB8	-20.77972	115.46333	Malacostraca	Syncarida Bathynellacea				
MW3 /SB8	-20.77972	115.46333	Syncaridae	Bathynellacea				
MW7	-20.77775	115.46561		Cyclopoida		Diacyclops		"humphreysi unispinosa n. ssp."
N62			Arachnida	Acarina				
N62			Arachnida	Araneae	Pholcidae	Trichocyclus		
N62			Arachnida	Araneae				
N62			Insecta	Collembola				
N62			Insecta	Diptera				
N62			Insecta	Hemiptera	Reduviidae: Emesinae			
N62			Malacostraca	Isopoda: Oniscidea				
N62			Malacostraca	Isopoda: Oniscidea			Barrowdillo	
N62			Insecta	Orthoptera				
Old batch plant bore		-20.82417	115.43861		Cyclopoida		Allocyclops	"barrowi n.sp. Karanovic"
Old batch plant bore		-20.82417	115.43861		Collembola			
Old batch plant bore		-20.82417	115.43861		Acarina			
Q5	-20.78472	115.38083	Maxillopoda: Copepoda		Calanoida			
Q5	-20.78472	115.38083	Maxillopoda: Copepoda		Calanoida			
Q5	-20.78472	115.38083	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.	
Q5	-20.78472	115.38083	Insecta	Hymenoptera				
Q5	-20.78472	115.38083	Thermosbaenacea		Thermosbaenacea		Halosbaena	tulki Poore & Humphreys, 1992
S87	-20.76667	115.38333	Arachnida	Araneae	Salticidae	Zenodorus		?orbiculatus
S87	-20.76667	115.38333	Arachnida	Araneae	Zodariidae	Habronestes		sp

Cave or well	Dec Lat	Dec Long	Class	Order	Family	Genus	Species
W62JW	-20.73222	115.42611	Malacostraca	Amphipoda		Nedsia	hurlberti
W62JW	-20.73222	115.42611	Maxillopoda: Copepoda		Calanoida		
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia		Atyidae	Stygiocaris sp.
X62JW	-20.73222	115.42611	Malacostraca	Amphipoda			
X62JW	-20.73222	115.42611	Arachnida	Araneae	Theridiidae	Latrodectus	hasseltii
X62JW	-20.73222	115.42611	Maxillopoda: Copepoda		Calanoida		
X62JW	-20.73222	115.42611	Maxillopoda: Copepoda		Calanoida		
X62JW	-20.73222	115.42611		Decapoda: Natantia		Atyidae	Stygiocaris sp.

APPENDIX J

BARROW ISLAND ENVIRONMENTAL QUARANTINE PROCEDURES

CONTENTS

TABLES

FIGURES

SECTION 14: ENVIRONMENTAL QUARANTINE
SECTION OWNER: ENVIRONMENAL COORDINATOR

14.1 PURPOSE

Quarantine is an integral part of EH&S management at a field operations level and is driven by environmental legislation for Barrow and Thevenard Islands operations.

The purpose of this section is to detail the minimum standards that shall be applied to prevent the introduction of foreign species to Barrow and Thevenard Islands, or neighbouring island-based facilities, through ChevronTexaco operations.

Deviation from these procedures requires documented approval of the Materials Coordinator who will in turn advise the Environmental Coordinator of each such occurrence detailing steps taken to meet the objective of this procedure.

14.2 SCOPE

These minimum standards shall apply to the transport of all goods, both ChevronTexaco and Contractor, by road, air, or sea to or from Welshpool Transit Depot, Dampier Supply Base, Onslow Supply Base, Barrow Island, and Thevenard Island. Goods going to or arriving from Airlie, Varanus or other island, require documented approval of the Materials Coordinator who will in turn advise the Environmental Coordinator of each such occurrence detailing steps taken to meet the objective of this procedure.

Foreign species that these minimum standards aim to keep out include:

- Vermin, such as house mouse, black rat and cats
- Insects, such as European Bees, Ticks and Wood borers
- Flora, such as Double-gee, Kapok bush, Buffel grass, Noogoora burr, Mesquite, Caribbean Stylo and Mexican poppy.

These minimum standards shall also apply to the eggs, seeds and other life cycle stages and any juveniles, living matter or **soil**, that may be associated with such pests.

14.3 DEFINITIONS

Vermin – mammals and birds injurious to natural species, noxious plants and insects, any introduced species of flora or fauna.

14.4 RESPONSIBILITIES

Management is responsible for:

- providing the resources necessary for effective implementation of the quarantine program;
- monitoring the compliance with relevant legislation, company policies and "best practice" for quarantine management.

Line Managers and Supervisors are responsible for:

- implementation of quarantine work practices;
- supervision and instruction to Suppliers, Contractors and Personnel involved in work requirement application of quarantine procedures;
- reporting every occasion of non-compliance with quarantine procedures.

Employees and Contractors are responsible for:

- working in accordance with quarantine procedures;
- reporting every occasion of non-compliance with quarantine procedures.

Project Managers shall ensure compliance with these procedures and shall take them into account at an early stage in project planning. Importantly, project managers shall avoid consignment of palletised, caged, boxed, loose or bundled goods and, where possible use sealable containers as a preferred option. Where pipe or tubing is to be consigned, project managers shall arrange supply with sealed end caps.

A summary is provided in Table 14.1 of the responsibilities of ChevronTexaco and contractor-personnel for the various handling, inspection, detection and treatment actions required by these procedures.

Table 14.1: Responsibilities for Various Quarantine Activities

Activity	Reference Section	Project Managers	Project Contractors	Toll Wlshpl Staff	Toll Dampier Staff	Toll Onslow Staff	Barge Master	BWI* Arrival	BWI Outward to TVI	BWI Storage Areas	TVI Arrival	TVI Outward to BWI*
Project Management	14.1 – 14.7	x										
Unlocked Containers	14.3		x									
External Inspections	14.2 - 14.5, 14.10		x	x	x	x		x	x		x	x
Washdown	14.2		x	x	x	x			x			x
Internal Inspections	14.2 – 14.6		x	x	x	x			x			x
Flour Tray Test	14.3, 14.11, 14.12			x	x	x				x		x
Fumigation	14.5	x	x			x						x
Place Labels & Tape	14.2 - 14.5, 14.13			x	x	x			x			x
Verify Labels/Manifest	14.8, 14.10				x	x	x	x			x	
Remove Labels & Tape	14.10							x			x	
Poison Baiting	14.3, 14.4, 14.8, 14.9			x	x	x	x				x	
Dispose Poison Baits	14.3, 14.8, 14.10						x	x			x	
Witness Door Lowering	14.8						x					
Maintain Laydown Site	14.6			x	x	x			x			x
Minimise Holding Time	14.4, 14.6	x		x	x	x			x			x
Authorise Barge Moves	14.8				x							
Incident Reporting	14.11	x	x	x	x	x	x	x	x	x	x	x

* Note: No freight from TVI to BWI without fumigation or unloaded at BWI during darkness

14.5 WASHDOWN

All goods including vehicles, mobile plant and equipment, transportable units, containers, pipes, etc shall be closely inspected for signs of earth, seeds, webs, eggs or vegetation at:

- Welshpool Transit Depot;
- Dampier Supply Base or Onslow Supply Base prior to transport to Barrow or Thevenard Islands;
- Barrow Island prior to transport to Thevenard Island; and
- Thevenard Island prior to transport to Barrow Island (note: no goods shall be transported TVI to BWI without fumigation or unloaded at BWI during darkness)

Any equipment that has visible contamination is to be thoroughly washed down immediately prior to loading on a vessel for shipment.

Water shall be used as the primary method of removing any contamination. The water shall be delivered at a pressure sufficient to ensure penetration to base metal or paintwork through any encrusting earth.

Particular attention will be given to the following locations when washing down goods:

- chassis and underside of machinery;
- radiator cores and their immediate surrounds;
- the underside and rear surfaces of mudguards and fenders fitted to vehicles;
- the top and underneath of tracks on tracked vehicles;
- skids and fork carriages;
- inside uncapped pipes.

After washdown, mobile equipment shall not be driven, unless loading onto the transport vessel. Where it is necessary to drive vehicles or equipment off the road after the washdown is complete, equipment shall be completely re-inspected and treated as necessary.

When the goods are clean and all other necessary quarantine has been completed, a Green Clearance Label and/or Quarantine Tape (as appropriate - see following sections), shall be placed in a prominent position prior to loading.

14.6 QUARANTINE OF CONTAINER GOODS

Only containers that are sealable, structurally sound, free from holes and have close-sealing doors shall be used. Containers shall include toolbox's, Sea-Tainers, CB4, CB8, 6x6 Containers, 20' Containers and 40' Containers.

14.6.1 From Welshpool Transit Depot

The Flour Tray Test shall be applied to containers at Welshpool Transit Depot, prior to transport to Dampier or Onslow Supply Bases, in the following circumstances:

- where a container has not been packed by Toll Energy staff; or
- where a container has been packed by Toll Energy staff but the container has remained open overnight.

Containers arriving at Welshpool Transit Depot for transport to Barrow or Thevenard Islands already locked or strapped shall be opened and subjected to the Flour Tray Test.
After the Flour Tray Test has been successfully completed the containers shall be marked with Quarantine Tape and transported directly to the Dampier or Onslow Supply Base.

Where there is a demonstrated urgent need to transport a container that has not received suitable quarantine treatment, a baited Talon Bait Station shall be placed into the container in question and a label placed on the container to indicate that a poison bait is inside. In such cases it is the responsibility of the Person In Charge (or his trained nominee) at BWI or TVI, as appropriate, to remove the Bait Station and bait immediately after unloading and immediately arrange to dispose them into the High Temperature Incinerator on Barrow Island.

All treatment of containers is to be noted in the Freight Management System.

14.6.2 From Dampier and Onslow Supply Bases

All containers arriving with Quarantine Tape shall be externally inspected, to ensure their integrity, and washed down, where required, prior to loading onto the barge. Any container that is "holed" or not completely sealed will **not** be loaded.

All containers arriving without Quarantine Tape shall be opened and inspected and subjected to a Flour Tray Test; where there are no signs of vermin or other pests, Quarantine Tape shall be placed in a suitable location and containers may be transported to Barrow or Thevenard Islands.

Where there is a demonstrated urgent need to transport a container that has not received suitable quarantine treatment, a baited Talon Bait Station shall be placed into the container in question and a label placed on the container to indicate that a poison bait is inside. In such cases it is the responsibility of the Person In Charge (or his trained nominee) at BWI or TVI, as appropriate, to remove the Bait Station and bait immediately after unloading and immediately arrange to dispose them into the High Temperature Incinerator on Barrow Island.

The treatment applied to each container shall be recorded in the Cargo Manifest.

14.6.3 From Thevenard Island

No goods shall be transported from Thevenard to Barrow Island without fumigation. A licensed contractor shall conduct the fumigation using methyl bromide. Fumigation will be conducted so those fumigated goods can be loaded onto the barge as soon as possible after the fumigation process is complete. Under no circumstances shall such goods be loaded after they have been standing unprotected during darkness. No such goods shall be unloaded at BWI during darkness.

All freight and its treatment will be recorded in the Cargo Manifest.

14.6.4 From Barrow Island

Containers bound for Thevenard Island shall be visually inspected and washed down prior to transport. Containers shall be free of earth, insects, seeds, vegetation and native animals.

Where signs indicate that vermin are present, personnel inspecting containers shall immediately report the potential presence of vermin to Person In Charge, who shall consult the BWI Emergency Procedures Manual and discuss appropriate further action with the Environmental Coordinator; the minimum response shall be overnight Flour Tray Test and trapping .

14.7 QUARANTINE OF PALLETISED, BOXED, BUNDLED AND LOOSE GOODS

14.7.1 From All Mainland Locations

Palletised, boxed, bundled and loose goods shall be inspected and treated **immediately** before loading for transport. Inspection and treatment shall be recorded on the Freight Management System. Green Label and Quarantine Tape will be applied to all inspected and cleared goods in such a way that it will endure barge transportation.

A single Green Clearance Label can cover multiple pallets of the same goods. The number of pallets to which a label applies shall be recorded on the label.

Where vermin are observed or suspected in consignments of multiple pallets or boxes, the consignment shall be **isolated** (such as in a sealed 20’ Container) then baited overnight and subjected to the Flour Tray Test. No baits shall remain within the freight.

Boxed goods that are holed or otherwise not sealed (so that vermin or insects can enter) shall be **isolated** (eg in a sealed 20’ Container) then baited overnight and subjected to the Flour Tray Test. No baits shall remain within the freight.

Other goods that might provide refuge to vermin, such as drill tubing without end-caps, shall be subjected to high-pressure washdown prior to transportation. Where such goods remain in place overnight, prior to loading, washdown shall be repeated to ensure the goods are free of vermin.

14.7.2 From Thevenard Island

No goods shall be transported from Thevenard to Barrow Island without fumigation. A licensed contractor shall conduct the fumigation with methyl bromide. Fumigation will be conducted so those fumigated goods can be loaded onto the barge as soon as possible after the fumigation process is complete. Under no circumstances shall such goods be loaded after they have been standing unprotected during darkness. Such goods shall not be unloaded at BWI in darkness.

14.7.3 From Barrow Island

Palletised, boxed, bundled and loose goods shall be inspected and be free of pests, earth and native animals prior to dispatch to Thevenard Island. A Small Green Clearance Label or Quarantine Tape shall be affixed to indicate clearance.

Wooden pallets and wooden packaging shall not be stored on Barrow Island and shall either be removed from the island or burned at an approved location as soon as possible after unloading.

14.8 QUARANTINE OF LARGE TRANSPORTABLE UNITS

All transportable offices, accommodation units, tool sheds, food storage units, mobile messes and kitchens, logging cabins, dog houses, koomey shacks, caravans, work boats, etc will be fumigated with methyl bromide by a licensed pest controller at an appropriate location before dispatch to Barrow or Thevenard Islands.

All goods that have been successfully fumigated shall have a Green Clearance Label and Quarantine tape affixed to them. The word “FUMIGATED” shall be written onto the label in thick red pen.

Prior to transportation of large transportable units between offshore islands (with the exception of units coming from Barrow), units shall be fumigated and each unit will have a Green Clearance Label and Quarantine Tape affixed.

14.9 VERMIN AND WEEDS AT DAMPIER AND ONSLOW

All materials shall be transhipped as quickly as possible through Dampier and Onslow Supply Bases to prevent contamination by local vermin. Lay-down areas at Dampier and Onslow Supply Bases shall be maintained clean, weed free and preferably be hardstand.

Materials or goods that have been stored for a prolonged period at Dampier and Onslow Supply Bases shall receive close inspection and treatment prior to forwarding to Barrow or Thevenard islands.

14.10 DISPATCH THROUGH "NON-TOLL" SUPPLY FACILITIES

Freight dispatched to Barrow or Thevenard Islands other than through Welshpool Transit Depot or Dampier and Onslow Supply Bases must receive equally strict quarantine treatment applied to meet the minimum standards set out in this procedure. Individual cases will be referred to the ChevronTexaco Materials Coordinator and Environmental Coordinator.

14.11 VERMIN CONTROL

14.11.1 Vessels

Barge crews shall maintain baiting and trapping programs to prevent the spread of the introduced house mouse (Mus musculus) and black rat (Rattus rattus) from Dampier and Onslow Supply Bases and from Thevenard Island to all island landing sites.

If vermin are sighted on the barge the Barge Master shall, by arrangement with the Dampier Supply Base Manager, return the loaded barge to Dampier or another mainland port at the earliest practicable time for further quarantine treatment.

The Master shall ensure that all cargo has a Green Clearance Label or Quarantine Tape attached and that the Cargo Manifest is properly completed to indicate that it has undergone Quarantine proper quarantine. The Master shall **reject** shipment of cargo without label/tape coverage or that where the Cargo Manifest indicates incomplete quarantine.

Companies operating landing vessels and providing supply services to ChevronTexaco facilities shall ensure that the vessels are free of pests and baited. Landing vessel operators shall ensure that their vessels carry sufficient supplies of bait stations and baits and hold a copy of the MSDS for the type of bait used.

Bait stations shall be constructed from plastic containers accessible by mice. Stations shall be positioned around the deck and in the accommodation in such a manner that in the opinion of the Master, they will be secure and effective in eradicating any vermin that may board the vessel and will not present an unacceptable risk to human health.

Where the Master of the vessel has doubts about the positioning or number of baits required, they shall seek the advice of the ChevronTexaco Environmental Coordinator.

Each bait station shall be baited with one 20gm of approved bait. The bait stations shall be checked and filled on a weekly basis and a record of bait use, mouse deaths and any other comments shall be entered in the deck log.

Upon arrival at Barrow and Thevenard Islands, a nominated crewmember shall observe the lowering of the bow or stern door to determine if vermin leave the vessel. If vermin are observed, then:

- the bow or stern door shall be raised
- ChevronTexaco shall be advised immediately
- Arrangements shall be made through the Dampier Supply Base Manager to return to a mainland port for quarantine treatment on the first available tide

All poison baits shall be disposed of appropriately on the mainland.

14.11.2 Thevenard Island

Thevenard Island accommodation units may be baited in the following manner:

Bait stations shall be constructed from plastic containers accessible by mice. In addition, the use of bucket traps which use peanut butter and a turning "can bridge" is also acceptable.

Bait stations shall be placed inside accommodation units, dining, kitchen, storage, laundry, control room and recreation areas. Single baits shall be used in the accommodation units while not less than 3 baits shall be used in each of the larger areas.

The Person In Charge or their nominee shall be responsible for the placement and maintenance of bait stations.

Each station shall be baited with one 20gm square of approved bait and bait stations shall be checked on a weekly basis and re-filled as necessary.

14.12 BAIT TYPES AND SAFE HANDLING

Bromkokil shall be used as the bait in bait stations. The following safe practices shall be applied when handling, using or disposing of Bromkokil:

- Obtain the MSDS for Bromkokil prior to handling
- Avoid contact with skin and eyes. Wear elbow length gloves when handling.
- Wash exposed skin with soap and water. Antidote is Vitamin K. Contact the Poisons Information Centre on Telephone No. 131 126 for further information.
- Do not place where other animals can access eg. birds, lizards, native rodents etc.
- Do not use or dispose of near water-ways.
- Any used baits can be suitably packaged and marked and sent to Barrow Island for disposal in the high temperature incinerator or appropriately disposed on the mainland.

14.13 CLEARANCE and UNLOADING AT BARROW AND THEVENARD

The ChevronTexaco Person In Charge shall be responsible for nominating a suitably trained person to manage quarantine aspects of incoming goods. The nominated person shall ensure that they:

- Are present at the Landing Site to complete the appropriate checks before any goods are unloaded;
- Discuss with the Master the placement of baits and, with the Master or Mate, inspect baits in place;
- Check all goods externally for signs of soil, vegetation, seeds, insects and vermin. Goods that show signs of these shall not be landed. If signs of vermin are present then **no goods shall be unloaded**, the bow or stern door shall be raised and the barge must, by arrangement with the Dampier Supply Base Manager, depart on the first available tide;
- Check that the seal is intact on all containers and large transportable closed items and that they have not been holed so that vermin may have entered. If an item is not intact then it shall not be landed;
- Check that all goods are accounted for on the Cargo Manifest, that they have received the required quarantine, and that they display a Green Clearance Label or Quarantine Tape, as appropriate;

- Where the quarantine treatment for any item cannot be established then no goods shall be unloaded, the bow or stern door shall be raised and the barge must, by arrangement with the Dampier Supply Base Manager, depart on the first available tide;
- Identify any containers that contain Bait Stations and after unloading immediately open the container(s) and dispose of the baits and Bait Station to the High Temperature Incinerator on Barrow Island.

The Warehouse person-in-charge shall ensure that all Green Clearance Labels and Quarantine Tape are removed from recyclable containers and disposed in accordance with the Island Waste Disposal Directions before they are shipped back to the mainland.

14.14 MONITORING AND REPORTING

14.14.1 On Barrow and Thevenard Island

Detection of any foreign species shall be immediately reported to the ChevronTexaco Person In Charge who, together with the Environmental Coordinator, shall immediately advise CALM (0891 43 1488 – Regional Manager or 08 9405 5100/0418 907371 – Manager WATSCU) to plan contingency action (see local Emergency Procedure manuals).

Personnel responsible shall regularly inspect all landing areas, storage areas, warehouses and food preparation areas.

On Barrow Island, the Flour Tray Test (excluding the use of accompanying poisonous baits) shall be undertaken daily within the Warehouse and Kitchen areas. In the event of detection, Elliott Trap(s) with non-poisonous baits shall be set for several nights so as to verify the identity of the animals.

In the event that vermin are detected (other than house mouse on TVI) or the identity of a trapped animal is unknown, this must be reported immediately to the ChevronTexaco Person In Charge. The ChevronTexaco Person In Charge shall notify the Environmental Coordinator and they will initiate the appropriate action.

Environmental Staff and external parties shall conduct inspections on an opportunistic basis. Manifests shall be subject to inspection by PIC-nominated person at each island unloading and periodic inspection by the Materials Coordinator and the Environmental Coordinator.

Any breach of quarantine shall be reported through the ChevronTexaco Incident Reporting System to determine if a foreign species was introduced.

14.14.2 All Locations

Laydown areas at Dampier and Onslow Supply Bases shall be regularly inspected and maintained in a clean and weed-free state.

Incidents that shall be reported include:

- Contractor or Supplier does not comply with quarantine requirements;
- Observation of Vermin on barge or on Barrow or Thevenard Island (other than house mouse on TVI);
- Observation of new weed growing on Barrow or Thevenard islands or mainland Supply Bases;
- Insect nest, eggs or pupae within freight on barge or Barrow or Thevenard islands;
- Vermin, vegetation, eggs, webs or earth within freight on barge or Barrow or Thevenard islands;
- Non-quarantined soil or aggregate arrives on island;
- Landing of Non-ChevronTexaco operated or controlled vessel at Barrow or Thevenard islands (excluding Mackerel Islands Resort);
- Holed or unsealed containers on barge or arrives at Barrow or Thevenard islands; and
- Omitted clearance labels/tape or ambiguous clearance labels on barge or arrival Barrow or Thevenard islands.

14.15 FLOUR TRAY TEST – VERMIN DETECTION

When checking goods for vermin infestation using the Flour Tray Test, the required resources are:

- one tray approximately 30cm x 30cm x 1cm;
- 2 kg of flour; and
- Spatula or ruler.

The following steps shall apply to the Flour Tray Test:

1. The flour shall be placed into a tray and spread evenly across the tray using a spatula or ruler so that the base of the tray is completely and smoothly covered. Several trays may be required depending on the size and design of the unit.
2. Open the unit that is to be inspected and place the tray(s) of flour inside. The unit shall then be sealed and left undisturbed overnight.
3. Open the container the following morning and check for signs of vermin tracks in the flour.

Where the flour tray is not disturbed, the unit shall be labelled using Quarantine Tape and can be transported to Barrow or Thevenard Islands.

Where vermin disturb the tray of flour:

- Food and dry-goods containers shall be treated with baits or traps. After treatment the food and dry goods containers are to be checked again for vermin using the Flour Tray Test and the process repeated until no disturbance is observed. Once cleared, the unit is sealed and Quarantine Tape is placed over the door or lid seals.
- Other containers and units shall be unpacked and re-tested/baited until no evidence of vermin is found. The containers shall then be labelled using Quarantine Tape and can be transported to Barrow or Thevenard Islands.

14.16 CLEARANCE LABELS

The Green Clearance Label is shown in Figure 14.1. In addition, Quarantine Tape is available for use in combination with the Label in case labels are "washed off" during barge transportation.

All labels shall be placed on the access points of units so that the seal is broken when the unit is opened or on the inside windscreen of vehicle cabs.

14.16.1 GREEN CLEARANCE LABEL

This label shall be placed on all:

- machinery, mobile plant and equipment when the washdown procedure is completed – an additional label should be affixed to the inside windscreen of mobile plant/vehicles;
- Palletised, boxed, bundled and loose goods when cleared for transhipment; and
- large transportable units after fumigation.

Fumigated units shall be clearly marked "FUMIGATED" using a thick red pen on the Green Clearance Labels to alert personnel that these units must be aerated for safety reasons before release from quarantine.

Where there are large numbers of identical items in a consignment, for example pallets, a single label may be used to apply to the entire consignment. In this case the total number of items shall be written on the label.

Quarantine Tape should be used where there is any likelihood that labels will "wash-off" during barge transportation and on all items not "covered" by a Green Clearance Label.

Figure 14.1: Clearance Label

GREEN CLEARANCE LABEL

CLEARED FOR TRANSPORT

TO ____ ISLAND

INSPECTED BY ____________________________________
(SIGNATURE)

AT ____________________ ON ________________________
(LOCATION) (DATE)

APPENDIX K

NATIONAL AND WESTERN AUSTRALIAN ECONOMIC IMPACTS OF THE GORGON GAS SUPPLY AND LNG PROJECTS

(ACCESS ECONOMICS).

CONTENTS

1. EXECUTIVE SUMMARY

ChevronTexaco has commissioned Access Economics to assess the national and Western Australian economic and budgetary impacts of development of the Gorgon gas fields, situated near Barrow Island off the Western Australian coast.

In undertaking this analysis, we have relied heavily on input data provided by the client. In the scenario evaluated here, most of the Gorgon field gas is converted into LNG at a plant on Barrow Island and then exported. The project also generates condensate for export, and natural gas piped onshore for the Western Australian domestic market.

ACIL Consulting supplied projections of the prospective demand for and supply of natural gas in Western Australia incorporating the Gorgon development. These indicate that there would be sufficient gas supplied to the domestic market to allow development of an additional gas-based export project. We include a hypothetical representation of this project in the analysis.

Projects' direct economic contribution

The Gorgon gas supply and LNG joint venture is projected to:

- contribute some $11 billion of investment expenditure (in today's prices) between now and the mid 2020s. The data imply direct employment of around 3,000 in the peak investment year (2006), with further employment in subsequent investment phases;
- generate exports from 2007 onwards. At full operation, net exports would average $2.4 billion annually (in today's prices) over the period from 2012 to 2030. Operational employment would average some 400 persons, with an additional annual average of 200 persons associated with an ongoing investment program.;
- contribute company tax and PRRT payments totalling $17 billion (in today's prices) over the life of the project. In net present value terms this comes to $7 billion at a 5 percent real discount rate.

National economic impacts

We have analysed the national economic impacts of the project using Access Economics AE-MACRO macroeconomic model of the Australian economy. The analysis involves comparing two long-term simulations of the AE-MACRO model – representing worlds with and without the project.

According to our modelling, the project would generate substantial positive economic impacts.

During the initial investment phase, from 2003 to 2009:

- as investment reaches its peak in 2006, GDP increases by about $1.5 billion (at today's prices), and total employment by up to 15 ½ thousand. Private consumption is about $750 million higher at this point, reflecting higher wage incomes.
- Higher aggregate demand leads to a $1.7 billion increase in imports in 2006, and a $1.6 billion deterioration in the trade balance (at today's prices). This is financed by capital inflows from the project's investors.

During full operation (from 2012 to 2030):

- there is a substantial increase in gross domestic product and net exports. There is an offsetting outflow in the invisibles' account of the balance of payments to pay dividends to the project's owners. However, the project's overall impact on the balance of payments is strongly positive;
- the real exchange rate increases, leading to an improvement in the competitiveness of imports relative to domestic production. Imports stay high, bringing the current account back towards balance. The imports flow mainly into higher private consumption;
- the project raises government revenues, allowing a cut in personal income taxes. Higher consumer demand reflects in higher imports, but also an increase in Australian production and employment;
- between 2012 and 2030, annual GDP is on average ¼ percent - some $3.6 billion (at today's prices) - above the level in a world without the project. Private consumption is nearly $1.8 billion higher – a 0.2 percent increase. Employment is up, on average, by over 6,000 between 2012 and 2030.

Impacts on national public sector finances and Australian economic welfare

The Gorgon joint venture project and the associated developments have substantial impacts on overall public sector finances, the Commonwealth budget and on national economic welfare

We measure the overall impact on public sector finances as the sum of the model's estimates of additional public sector revenues, plus the revenue foregone through income tax cuts:

- on this definition, the net present value of the impact on overall public sector finances is an estimated $11.3 billion in 2002 at a real discount rate of 5 percent;
- using a similar definition of net impact, the net present value of the impact on Commonwealth budget finances is an estimated $9.2 billion in 2002 at a real discount rate of 5 percent.

In AE-MACRO the best measures of the project's overall impact on economic welfare are:

- the increase in annual flows of private consumption and public sector final expenditures that it allows, and
- the increase in public and private sector wealth at the end of the simulation period. [This is the best available indicator of the possible impact beyond that date.]

As modelled, in net present value terms, the welfare impact is mainly on the private sector.

- At a real discount rate of 5 percent the project improves Australian economic welfare by an estimated $24 billion (net present value in 2002).

Western Australian economic impacts

The Western Australian macroeconomic impacts broadly mirror the national results, with some differences. The project's output and expenditures occur mainly in Western Australia. However, the tax revenues flow mainly to the Commonwealth.

The project provides a substantial boost to Western Australian business investment over the period till 2009, with further investment continuing until the mid 2020s. The projected response of WA business investment tracks closely that of the project, but is slightly higher over the entire period.

- As expenditure on the first production phase reaches its peak in 2006, Gross State Product increases by about $650 million (at today's prices), and total employment by almost 8 thousand. Private consumption is $200 million higher at this point, reflecting higher wage incomes.

Once the project begins operation the direct impacts include a substantial contribution to gross state product and merchandise exports.

The impacts of these are mainly felt at the national level – through the real exchange rate and Commonwealth taxation revenues. They flow back to Western Australia – as to other states/territories – through a rise in real incomes and wealth, a reduction in the average rate of personal income tax and an increase in Commonwealth transfers of GST revenues to the state government.

The project also has direct impacts on Western Australia through the employment of production workers, payment of payroll tax and expenditure on intermediate inputs. However, unlike the situation during the investment phase, these are not the main source of benefit to the state.

Between 2012 and 2030, annual gross state product is on average some $2.9 billion (at today's prices) - above the level in a world without the project. The percentage increase is over 2 percent in 2012. Private consumption is on average some $240 million higher over the period from 2012 to 2030. On average it is ¼ percent higher than in the world without the project.

Western Australian employment is up, on average, by about 1,700 over the period 2012 to 2030. The increase in the state's employment is partly met by increased labour supply from the existing population - and partly by a small increase in interstate migration.

In percentage terms, the project has a much larger impact on the Western Australian economy than on the national economy. The peak impact on the gross state product (at about 2.2 percent) is well above the corresponding impact on gross domestic product (1/4 percent).

Impacts on Western Australian budget and economic welfare

The project has only modest direct impacts on WA public sector finances. Indirect effects are more substantial, but modest compared to the impacts on the Commonwealth budget.

In the absence of large specific impacts, the net effect on the state budget is finely balanced and dependent on the precise assumptions employed. The budget bottom line (and the consequent impact on state debt) is the difference between revenue and expenditure – two much larger quantities that are both subject to independent assumptions.

In the scenario presented here, there are increases in both revenues and expenditures. Initially expenditures run ahead of revenues as the state economy expands. However, as production plateaus and the project's national economic impacts flow through in the form of higher consumption expenditure and GST revenues, the position is reversed and the state budget benefits.

The net present value of the projected revenue gain to Western Australia over the period to 2030 is approximately $1.1 billion in today's prices at a 5 percent real discount rate. The net present value of projected additional outlays is slightly larger, resulting in a small fall in the net present value of the state's net lending.

We estimate, also, that at a real discount rate of 5 percent the project improves Western Australian economic welfare by about $4 billion. This estimate is about one sixth of the increase in total Australian economic welfare derived in the national modelling of the project[1].

Access Economics
December 2002

[1] The definition of economic welfare is slightly broader in the national model, in that it includes estimates of the changes in private and public wealth, rather than just the change in net public debt.

2. INTRODUCTION

ChevronTexaco has commissioned Access Economics to assess the national and Western Australian economic and budgetary impacts of development of the Gorgon gas fields, situated near Barrow Island off the Western Australian coast. ChevronTexaco is the major partner (with a $4/7^{th}$ share) in a consortium that also comprises Shell ($2/7^{ths}$) and ExxonMobil ($1/7^{th}$).

In undertaking this analysis, we have relied heavily on input data provided by the client. The results obtained are predicated on project information provided by ChevronTexaco. In the scenario evaluated here, most of the Gorgon field gas is converted into LNG at a plant on Barrow Island and then exported. The project also generates condensate for export, and natural gas piped onshore for the Western Australian domestic market.

ACIL Consulting supplied projections of the prospective demand for and supply of natural gas in Western Australia incorporating the Gorgon development. These indicate that there would be sufficient gas supplied to the domestic market to allow development of an additional gas-based export project. We include a hypothetical representation of this project in the analysis.

The modelling horizon extends to 2030, by which point the existing explored Gorgon field will probably be depleted. There are significant additional gas resources nearby that might allow the project to continue operating. However, we do not consider this in the current study.

2.1 THE PROJECT

The key elements of the project are the LNG plant and the upstream development of the Gorgon gas field. There is also the DOMGAS development, including the hypothetical gas-based resource project.

Upstream gas field development

Extraction of natural gas requires substantial ongoing investment. The feed gas will be collected from development wells and infield flow-lines, using sub-sea equipment and hardware. Export flow-lines will transmit the gas onshore into a slug-catcher, that separates the condensate. Next carbon dioxide and inert gases are removed, for pumping underground. The remaining water and higher hydrocarbons are then removed before the gas passes to further processing.

Raw gas production begins at 150 PJ in 2007. It rises to plateau of around 740 PJ annually from 2019 until 2030.

Condensate is derived from both upstream and downstream production phases, with a greater share produced from the slug-catcher (upstream) than from LNG liquefaction (downstream). The total output of this valuable by-product will reach a peak from 2019 to 2030, at around 5.6 million standard barrels per annum (MMSTB/year). The price of condensate is closely related to world oil prices.

The LNG plant

The LNG plant uses feed gas which has been subject to pre-treatment processes and then piped ashore. Liquefaction involves the removal of condensate, water and inert gases, and compression of the raw feed gas. The LNG produced is stored until exported.

The project is expected to begin producing LNG from 2007, achieving full LNG throughput from 2012. From this point until 2030, LNG output will average 9.85 million tonnes per annum (energy content 538 PJ).

DOMGAS supply

The project will also yield natural gas for sale into the domestic market for commercial and industrial uses. The gas will be piped to the mainland, compressed and then injected into the Dampier-to-Bunbury gas pipeline. Natural gas will be available for sale from 2012. Volumes will then increase progressively. Full production of 110 PJ per annum is reached in 2015.

ACIL Consulting have modelled the WA gas market. This suggests that up to 60 PJ of the gas would be available to allocate to an export oriented gas-based resource project. We assumed that this project would not have gone ahead in the absence of the Gorgon project. Hence the income generated by this project adds to Australian economic welfare.

The remaining gas supplements the overall domestic supply, improving supply security and maintaining downward pressure on prices to users. We do not count the gas sales revenue itself as a source of net benefit, since we assume it displaces other potential gas production. We do however treat as a net benefit the cost reduction to gas users, resulting from greater competition in domestic gas supply.

ACIL have estimated this overall price reduction at nominal A$0.10/GJ of gas in 2012. The discount then fluctuates between 2012 and 2020. From 2021 onwards the discount is held at A$0.10 per GJ in nominal terms.

Direct impacts

Overall capital expenditure on the upstream gas supply development and the downstream LNG facility is projected at around A$11 billion in 2002 prices. Approximately half will be spent overseas (in US$) and the remainder in Australia.

According to the information supplied, there is a reasonable level of local content in almost all the expenditure categories. The highest levels of local content are in front-end costs, receival and condensate treatment, CO_2 re-injection, LNG storage and LNG utilities.

The data indicate that direct employment would be around 3,000 persons during the year of peak expenditure of the initial construction phase in 2006. There will be additional investment (implying additional employment) in later years as successive Gorgon gas fields are exploited. Operational employment would average some

400 persons, with an additional annual average of 200 persons associated with an ongoing investment program.

The joint venture partners for the Gorgon upstream and downstream developments are wholly foreign-owned. It is understood that they would finance the entire scheme by direct equity investment. Profits after tax are assumed to be fully distributed and repatriated.

The gas development and LNG projects would make projected payments of company tax to the Commonwealth, totalling $A15 billion in nominal terms (about $10 billion at today's prices, or $4.5 billion expressed at a net present value at a 5 percent real discount rate). The Gorgon development would also generate Petroleum Resource Rent Tax (PRRT) payments of approximately A$11 billion in nominal terms (about $6.8 billion at today's prices, or $2.5 billion expressed at a net present value at a 5 percent real discount rate).

The gas-based resource project

Based on ACIL's projections we have assumed that the gas available to a new gas-based project is around 29 PJ annually from 2016 to 2019, and 61 PJ from 2020 to 2030. This would be sufficient to sustain a petrochemicals facility, constructed in two stages as the available gas increased.

We have constructed this hypothetical export-oriented petrochemicals plant using information gleaned from a mix of other resource projects which use gas as a feedstock. To avoid biasing the overall results of the modelling, we assumed that the project generated only a modest return to the overall investment.

The hypothetical project is constructed in two phases, with capital expenditure concentrated in two periods, from 2014 to 2015, and from 2018 to 2019. It would export its product, and would rely mainly on gas as a raw material. Total investment is projected at US$200 million, with approximately 40 percent local content. Employment during the main operational phase would be 70 persons from 2020 to 2030.

As projected, the hypothetical project makes company tax payments totalling $0.1 billion in today's prices over its relatively limited period of operation.

2.2 Modelling approach

We have analysed the national and WA economic impacts of the project using Access Economics' AE-MACRO macroeconomic model of the Australian economy.

AE-MACRO is a relatively small dynamic model of the Australian economy. It was developed in 1992 by Access Economics, and is based on standard modelling practice. It has a stable long-term growth path that accords with neoclassical economic theory, together with short-term dynamics derived from Australian economic experience over the past 25 years.

The analysis involves comparing two long-term simulations of the AE-MACRO model. The first ("No change" scenario) is a standard long-run projection, based on Access Economics assumptions about trends in major economic variables. In the second, we take the model used in the standard projection and add the gas supply and LNG projects. The difference between the two simulations provides an indication of the likely macroeconomic impact of the project.

Representation of the project relies heavily on data and modelling assumptions supplied by the client. Access Economics has adjusted the data to fit its own long-term projections of inflation and exchange rates, but has not sought otherwise to verify the data provided.

The results reported in this paper are a projection, on the assumption that past economic trends and current policies continue. The results are conditional on the numerous assumptions required in the modelling. They represent a potential outcome, rather than an exact forecast of the long-term behaviour of the economy. Further details are of the modelling approach are given in Appendix A.

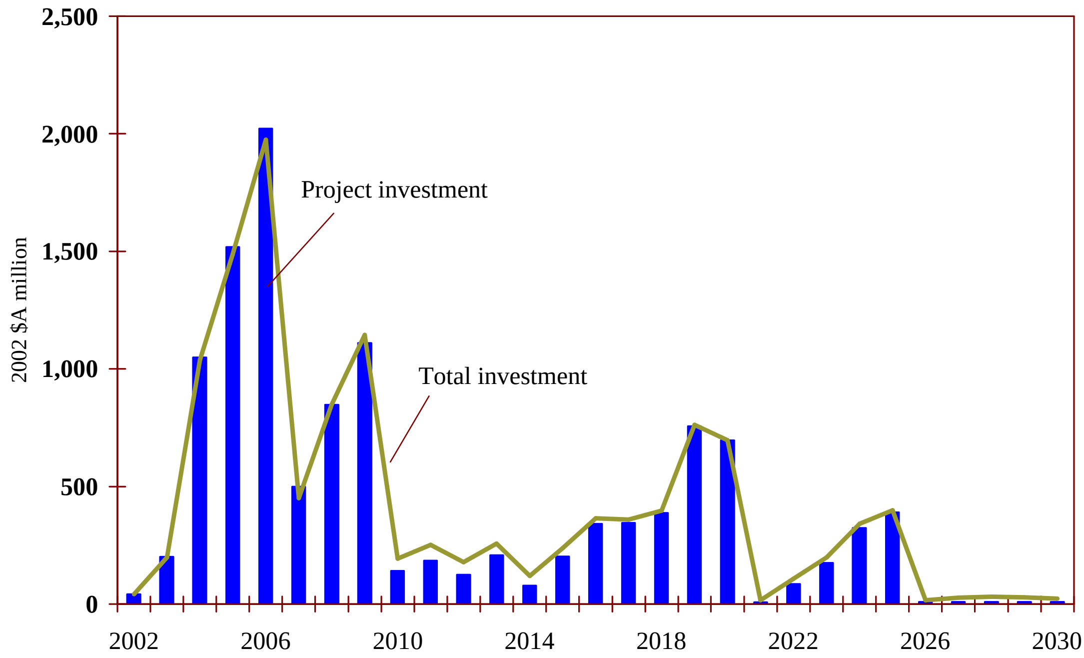
Modelling the Western Australian economic impacts

To estimate the economic impacts on Western Australia, we used the state and industry modules of AE-MACRO. These allocate a national simulation of the model to states and industries, in line with projected long run trends in demand structure and industry and state relativities. We are able to modify the modules so that they incorporate the state-specific impacts of an investment project within an individual state. Further details are in Appendix A.

3. NATIONAL ECONOMIC IMPACTS

Key results of the national economic modelling are summarised in the following charts.

CHART 1. GORGON JOINT VENTURE PROJECT: IMPACT ON INVESTMENT



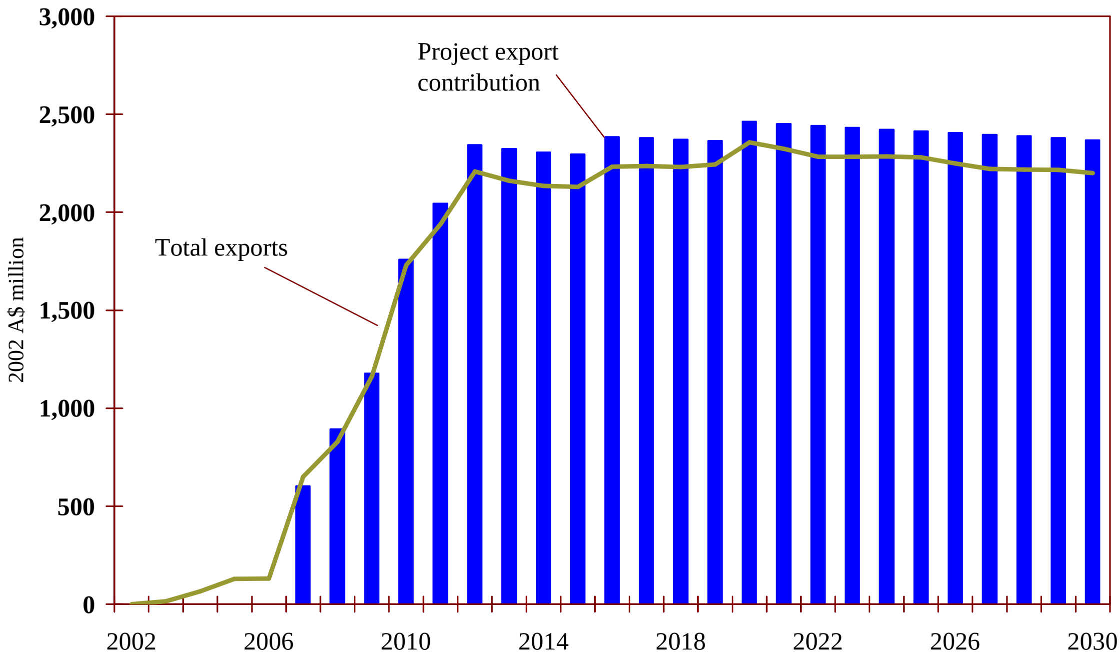
3.1 DIRECT IMPACTS

The project's main direct impacts on the macroeconomy are on business investment, exports and Commonwealth tax revenues. As shown in Chart 1, the project provides a substantial boost to overall business investment until the 2020s. Following the main burst of investment in the period 2003 to 2009, there is further investment in later years to maintain the gas supply. Over the entire period project investment totals over $11 billion at today's prices. Project investment dominates the overall investment response in the economy.

Once production begins, there are substantial export revenues, principally from LNG and condensate sales. This is reflected in overall Australian exports as shown in Chart 2.

Over the period from 2007 to 2030 project exports average over $2 billion annually at today's prices. Total exports shown in the chart are less than the project exports because the impact of the project on the real exchange rate results in some crowding out of other exports.

CHART 2. GORGON JOINT VENTURE PROJECT: IMPACT ON EXPORTS



3.2 FLOW-ON IMPACTS

Investment and initial production: 2003 to 2009

The project investment raises aggregate demand economy-wide. A considerable proportion of the investment is imported. But there is still a substantial increase in national output and employment.

As investment reaches its peak in 2006, GDP increases by about $1.5 billion (at today's prices) (Chart 3), and total employment by up to 15 ½ thousand at its maximum point. Private consumption is about $750 million higher at this point, reflecting higher wage incomes (Chart 5).

Higher aggregate demand leads to a $1.7 billion increase in imports in 2006, and a $1.6 billion deterioration in the trade balance (at today's prices). This is financed by capital inflows from the project's investors.

The sharp rise in total demand leads to a temporary increase in inflation, peaking in 2007. This raises the price of domestic output relative to imports, raising the real exchange rate (Chart 7). The government also responds by raising short-term interest rates (Chart 6). Imports rise and interest-sensitive components of demand such as dwelling investment fall.

GDP increases further from 2009 onwards, as the first investment phase increases production while investment in the second phase is at a peak. Domestic final demand and imports reach a second peak in 2009. In that year GDP is some $2 billion at today's prices (0.2 percent) above the level in a world without the project. Employment impact is some 7,000 higher in 2009. There is a further slight rise in inflation (Chart 6).

CHART 3. GORGON JOINT VENTURE PROJECT: IMPACT ON GDP AND EMPLOYMENT

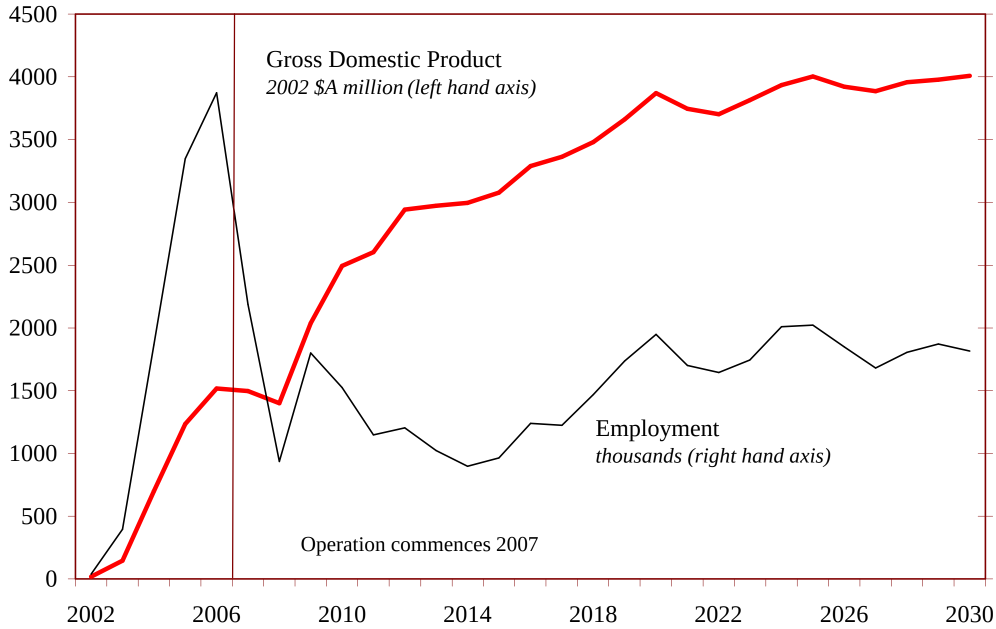


CHART 4. GORGON JOINT VENTURE PROJECT: IMPACT ON THE BALANCE OF PAYMENTS

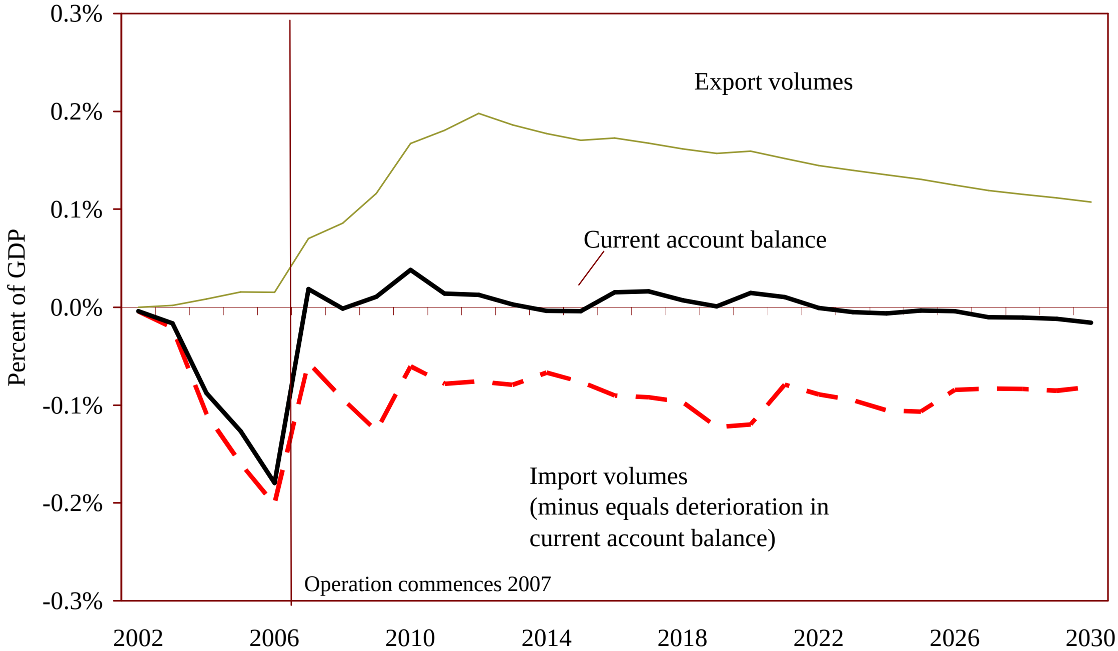


CHART 5. GORGON JOINT VENTURE PROJECT: PRIVATE CONSUMPTION AND IMPORTS

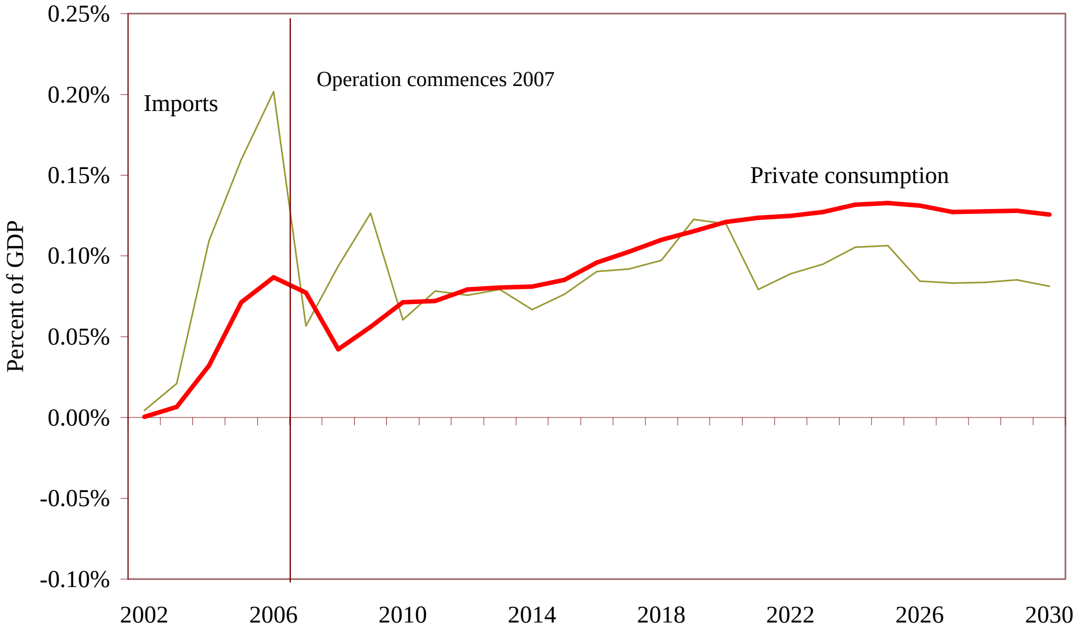


CHART 6. GORGON JOINT VENTURE PROJECT: INFLATION AND INTEREST RATES

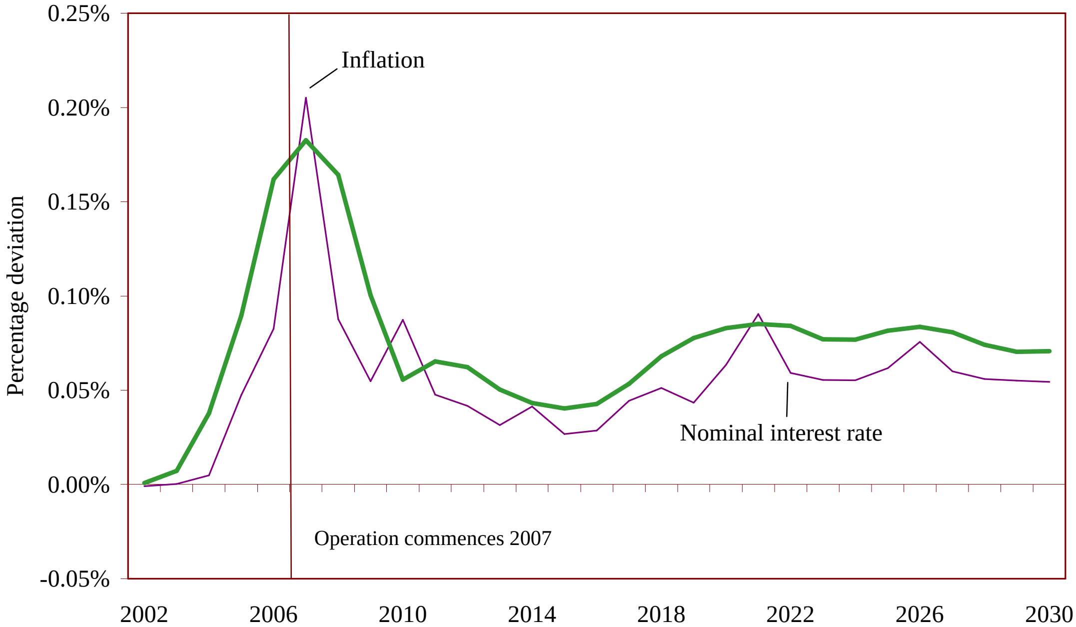
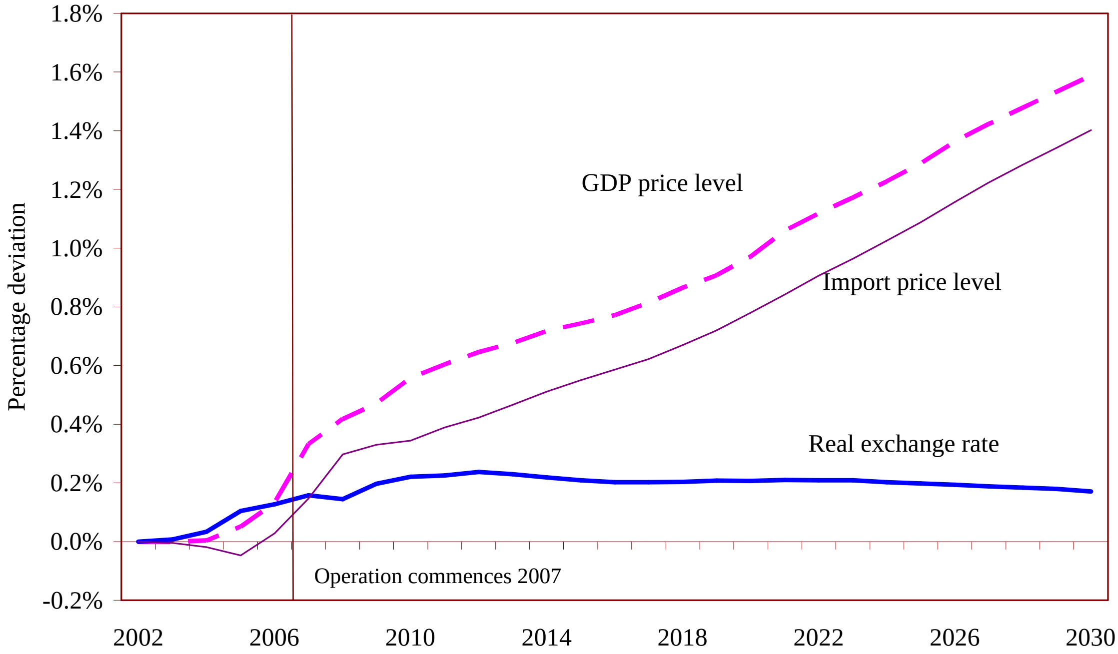


CHART 7. GORGON JOINT VENTURE PROJECT: EXCHANGE RATE AND PRICE LEVELS



Full operation: 2012 to 2030

The LNG plant reaches full operation in 2012 and produces at a constant level. DOMGAS production increases further until 2019. The project's direct impacts include a substantial increase in gross domestic product and net exports. It generates an offsetting outflow in the invisibles' account of the balance of payments to pay dividends. However, the project's overall direct impact on the balance of payments is strongly positive.

The real exchange rate increases (Chart 7), leading to an improvement in the competitiveness of imports relative to domestic production. Imports increase and stay high, bringing the current account rapidly back to balance (Chart 5). The imports flow mainly into higher private consumption (Chart 4).

The project raises government revenues, allowing a cut in personal income taxes. Higher consumer demand reflects in higher imports, but also an increase in Australian production and employment.

Between 2012 and 2030, annual GDP is on average ¼ percent - some $3.6 billion (at today's prices) - above the level in a world without the project. Private consumption is nearly $1.8 billion higher – a 0.2 percent increase. Employment is up, on average, by over 6,000.

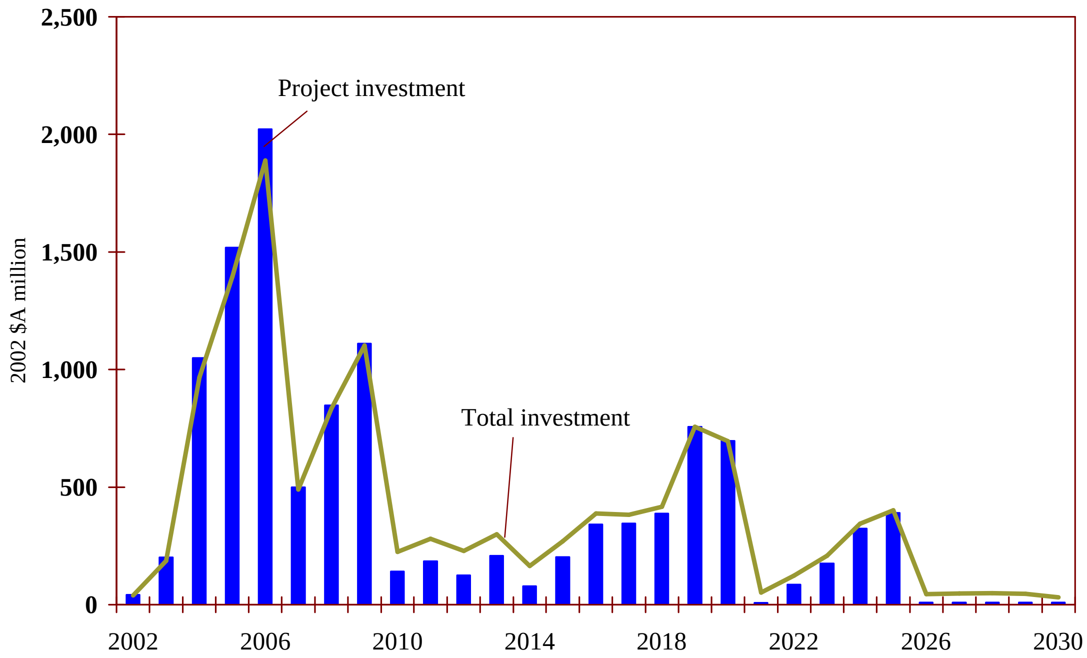
Higher demand and activity leads to some increase in inflation that is not fully offset by higher interest rates and a higher exchange rate. Inflation on average is some 0.05 percentage points higher over the period from 2012 to 2030. The short term interest rate is on average 0.07 percentage points above the level in the world without the project, while the real exchange rate is up by 0.2 percent on average.

4. WESTERN AUSTRALIAN ECONOMIC IMPACTS

The Western Australian macroeconomic impacts broadly mirror the national results, with some differences. These reflect:

1. the differing nature of the national and state impacts during the investment and operational phases of the project and
2. differing statistical treatment of some macroeconomic aggregates by the Australian Bureau of Statistics. For example, the ABS does not measure interstate trade.

CHART 8. GORGON JOINT VENTURE PROJECT: IMPACT ON WESTERN AUSTRALIAN INVESTMENT



4.1 DIRECT IMPACTS

The project's main direct impacts on the macroeconomy are on business investment, exports and Commonwealth tax revenues. The project's output and expenditures occur mainly in Western Australia. However, the tax revenues flow mainly to the Commonwealth.

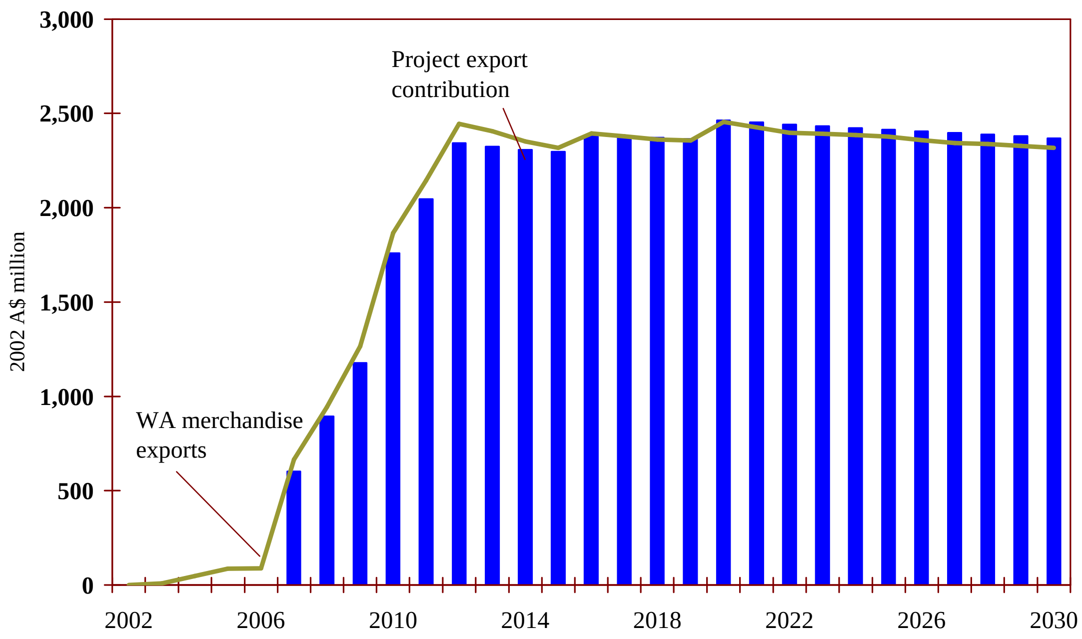
The project's investment adds directly to state final demand, so that almost the entire boost to national investment is reflected in the state outcome.

As shown in Chart 8 the project provides a substantial boost to Western Australian business investment over the period till 2009, with further investment continuing until the mid 2020s. The projected response of WA business investment tracks closely that of the project, but is slightly higher over the entire period.

Once the project begins production, it generates substantial export revenues that reflect in the state's merchandise exports.

Over the period from 2012 to 2030 project exports are projected to average nearly $2.5 billion annually at today's prices. As Chart 9 shows, the net increase in the state's merchandise exports closely mirrors project exports.

CHART 9. GORGON JOINT VENTURE PROJECT: IMPACT ON EXPORTS



4.2 FLOW-ON IMPACTS

Project investment and initial production

The project's investment raises aggregate state demand to successive peaks, the largest in 2006. (Chart 10) A considerable proportion of the investment is imported. But there is still a substantial increase in output and employment. (Chart 11)

Chart 10. Gorgon joint venture project: impact on final demand and consumption

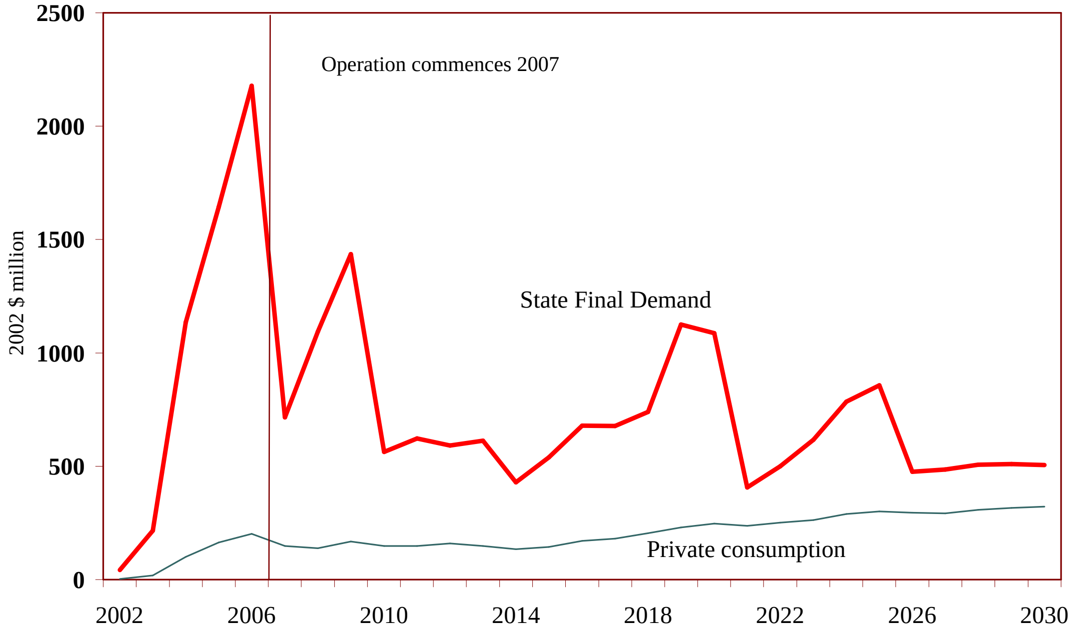
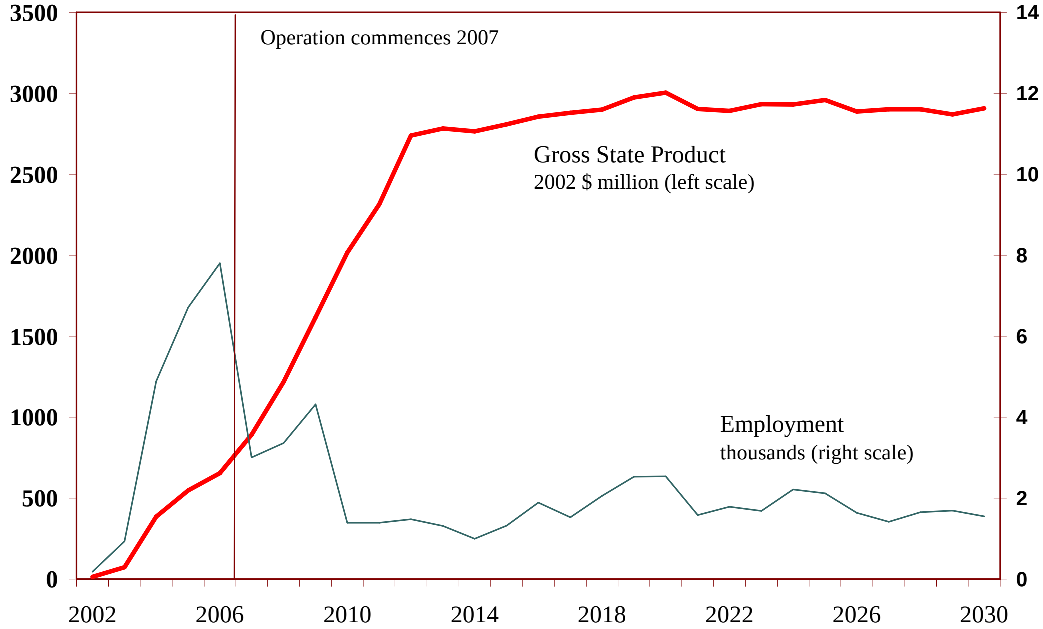


Chart 11. Gorgon joint venture project: impact on production and employment



As expenditure on the first production phase reaches its peak in 2006, Gross State Product increases by about $650 million (at today's prices), and total employment by almost 8 thousand. Private consumption is $200 million higher at this point, reflecting higher wage incomes.

Full operation: 2012 to 2030

The Gorgon joint venture plant reaches full operation in 2012 and produces at a constant level. The project's direct impacts include a substantial contribution to gross state product and merchandise exports.

The impacts of these are mainly felt at the national level – through the real exchange rate and Commonwealth taxation revenues. They flow back to Western Australia – as to other states/territories – through a rise in real incomes and wealth, a reduction in the average rate of personal income tax and an increase in Commonwealth transfers of GST revenues to the state government.

The project also has direct impacts on Western Australia through the employment of production workers, payment of payroll tax and expenditure on intermediate inputs. However, unlike the situation during the investment phase, these are not the main source of benefit to the state.

Operational expenditures and project employment rise as the project is implemented. Direct employment by the Gorgon joint venture is over 600 in 2012. Non-wage operating costs average some $230 million annually at today's prices. Some of this, however, is imported.

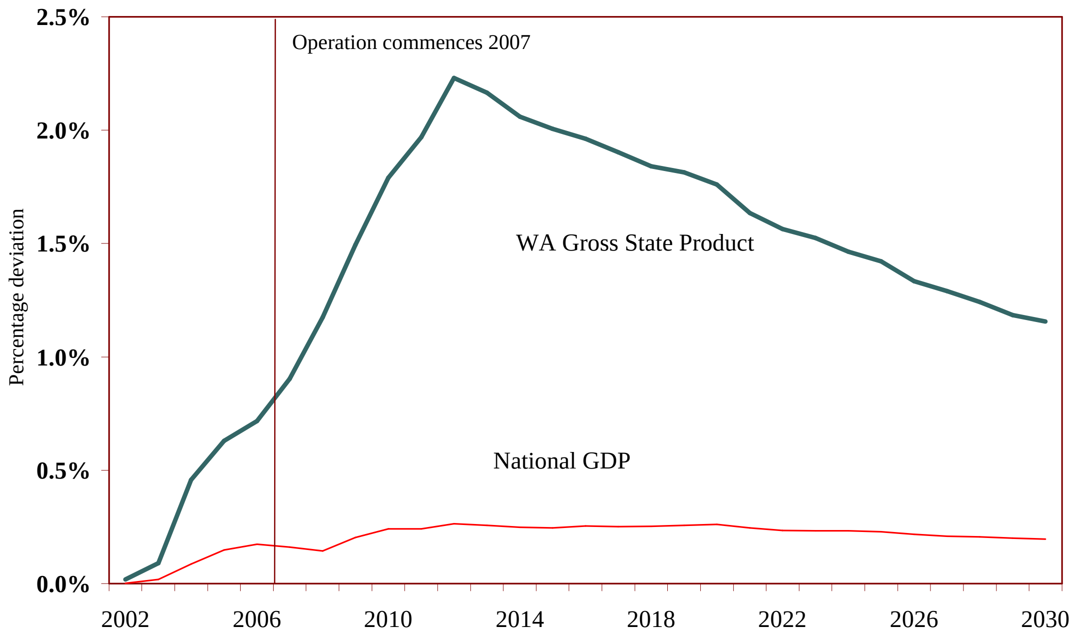
Between 2012 and 2030, annual gross state product is on average some $2.9 billion (at today's prices) - above the level in a world without the project. The percentage increase is over 2 percent in 2012. It then declines mainly because the project's output remains constant while the state overall experiences strong growth.

Private consumption is on average some $240 million higher over the period from 2012 to 2030. Reflecting the national pattern it shows a gradual increase throughout this period. On average it is ¼ percent higher than in the world without the project.

Western Australian employment is up, on average, by about 1,700 over this period. The project is creating demand for labour through its ongoing investment expenditure, as well as its operational employment. The wider increase in demand and activity The increase in the state's employment is partly met by increased labour supply from the existing population - and partly by a small increase in interstate migration.

In percentage terms, the project has a much larger impact on the Western Australian economy than on the national economy. The peak impact on the gross state product, at about 2.2 percent, is well above the corresponding impact on gross domestic product, 1/4 percent (Chart 12).

CHART 12. GORGON JOINT VENTURE PROJECT: RELATIVE NATIONAL AND WESTERN AUSTRALIAN IMPACTS



5. IMPACTS ON NATIONAL PUBLIC SECTOR FINANCES AND ECONOMIC WELFARE

The Gorgon joint venture project has substantial projected impacts on overall public sector finances, the Commonwealth budget and on national economic welfare. We consider these in the following sections.

5.1 IMPACT ON OVERALL PUBLIC SECTOR FINANCES

The project and the additional economic growth it stimulates generate substantial additional revenue for governments. The Australian public sector includes:

- the Commonwealth budget sector
- the combined state/territory budget sectors
- Commonwealth and state/territory off-budget authorities
- local government

This section considers the impact on the public sector as a whole.

Gorgon joint venture project's direct contribution

The Gorgon joint venture project and the associated upstream development are projected to make additional company tax and PRRT payments to governments projected at around $17 billion (in today's prices) over the life of the project, under current tax arrangements[2]. In net present value terms this comes to $7 billion at a 5 percent real discount rate.

Gorgon joint venture project's overall impact

Governments are assumed to respond to increased revenues from the project and the additional growth stimulated by it. They do this by increasing expenditures in line with the growth in the economy, and reducing the average personal income tax rate to keep the ratio of public debt to GDP from falling too rapidly. Income tax reductions in turn stimulate further growth.

The impact on government revenues, with and without the tax reduction is illustrated in Chart 13. The shaded portion of the chart shows the dollar value of the income tax reduction which the public sector is able to provide (rather than accumulating higher Budget surpluses).

CHART 13. GORGON JOINT VENTURE PROJECT: IMPACT ON GOVERNMENT REVENUES AND NET LENDING

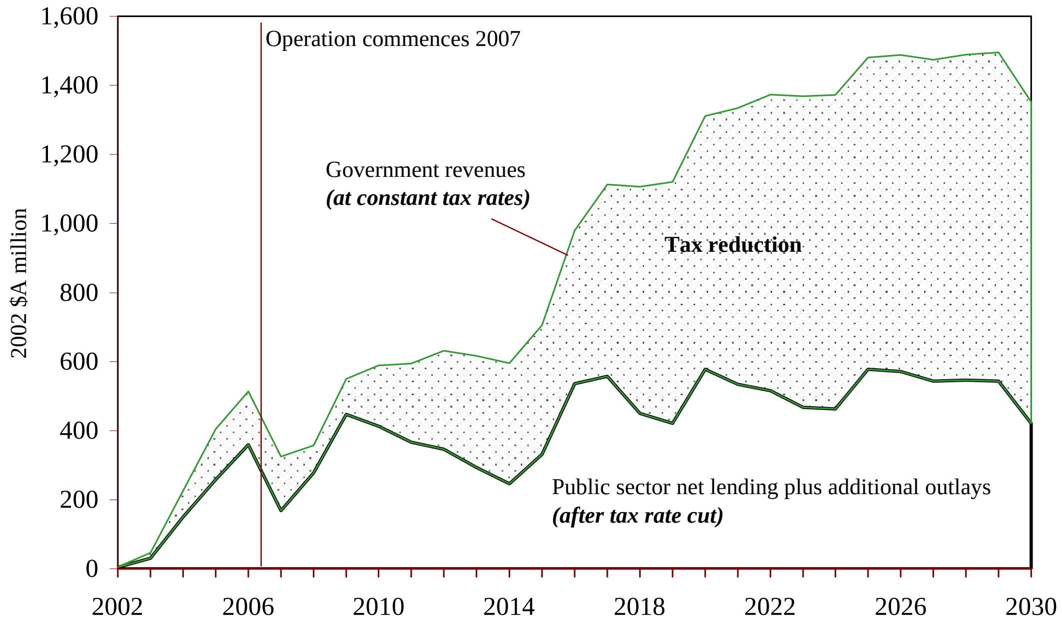


Table 1 summarises the impacts as net present values in $ million in 2002, for a variety of real discount rates.

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[2] In deriving these projections, the PRRT estimates are as supplied by the Gorgon joint venture. Company tax is estimated within the model, consistent with the input and other assumptions of the modelling.

TABLE 1. GORGON JOINT VENTURE PROJECT: IMPACT ON PUBLIC SECTOR FINANCES

Net present values over the period 2002 to 2030

Public sector	Real discount rate 3%	5%	7%
	2002 $ million		
Project's company tax and PRRT	9,840	7,020	5,110
Other revenue (net)	5,630	4,280	3,350
Total public sector impact	15,470	11,300	8,460
Of which:			
Revenue foregone through tax cut	8,330	5,900	4,280
Additional outlays + net lending	7,140	5,400	4,180

The overall public sector gain can be seen as the direct company tax and PRRT payments generated by the Gorgon joint venture project, along with other revenue stimulated by the additional economic activity. In turn, that equals the sum of additional outlays by governments and their additional net lending to other sectors of the economy, together with revenue the public sector forgoes because it provides a tax cut.

At a discount rate of 5 percent in real terms, the project generates an overall net impact of $11.3 billion in today's prices – of which $5.9 billion takes the form of an assumed cut in income taxes.

5.2 IMPACT ON THE COMMONWEALTH BUDGET

The impacts of the project on the Commonwealth budget can also be isolated. The Commonwealth receives company tax and PRRT payments from the project's investors. Commonwealth tax receipts also benefit from the overall increase in economic activity. Commonwealth expenditures also rise in an expended economy.

Recorded budget revenues increase, despite the substantial income tax cut assumed to offset the effect of higher revenues. Adding back the tax revenue foregone via the income tax cut shows the solid Budget gains projected to accrue to the Commonwealth.

Table 2 summarises these impacts as net present values in 2002, for a variety of real discount rates. The total Commonwealth budget gains are defined in the same way as the total public sector impact in Table 1. At a real discount rate of 5 percent the net present value of overall Commonwealth budget gains is projected at over $9 billion.

Further details on the impacts on Commonwealth revenue and expenditure items are provided in the Appendix.

TABLE 2. GORGON JOINT VENTURE PROJECT: IMPACT ON COMMONWEALTH BUDGET

Net present values over the period 2002 to 2030

Commonwealth Budget	**Real discount rate** 3%	5%	7%
		2002 $ million	
Project's company tax and PRRT	9,840	7,020	5,110
Other revenue (net)	2,870	2,160	1,670
Total Commonwealth Budget gains	12,710	9,180	6,780
Of which:			
Revenue foregone through tax cut	8,330	5,900	4,280
Additional outlays	6,510	4,800	3,620
Net lending (Budget balance)	-2,130	-1,520	-1,120

5.3 IMPACT ON AUSTRALIAN ECONOMIC WELFARE

In AE-MACRO the best measures of the project's overall impact on economic welfare are:

1. the increase in annual flows of private consumption and public sector final expenditures that it allows, and
2. the increase in public and private sector wealth at the end of the simulation period. [This is the best available indicator of the possible impact beyond that date.]

To compare these welfare impacts, that occur at different points in time, we convert them into net present values by summing and discounting back to the present. Table 3 shows the result.

TABLE 3. GORGON JOINT VENTURE PROJECT, IMPACTS ON AUSTRALIAN ECONOMIC WELFARE

Net present values over the period 2002 to 2030

	Real discount rate		
	3%	**5%**	**7%**
	2002 $ million		
Private sector			
consumption + increase in wealth in 2030	24,710	17,610	12,910
Public sector			
expenditure + increase in wealth in 2030	9,160	6,420	4,660
Total economic benefit			
private + public	33,870	24,030	17,570

According to AE-MACRO the welfare impact is mainly on the private sector. At a real discount rate of 5 percent the project improves Australian economic welfare by an estimated $24 billion in net present value terms. The estimates vary as the discount rate is raised or lowered.

6. IMPACTS ON THE WESTERN AUSTRALIAN BUDGET AND ECONOMIC WELFARE

The Gorgon joint venture project would have significant impacts on Western Australian public sector finances, and on the state's economic welfare.

6.1 WESTERN AUSTRALIAN BUDGET IMPACTS

Methodology

The project's impacts on the Western Australian Budget were calculated using the methodology underlying Access Economics' *State Budget Monitor* publication. *State Budget Monitor* operates over a six to seven year horizon, with comparisons against the current State Government outlooks (two to three years). It has recently been updated to use the accrual accounting framework being progressively implemented by State Treasuries.

Longer term projections have been obtained with most policy consistently maintained. This is particularly important for revenues from the Commonwealth (in the form of GST and other payments), that are assumed to be distributed on the same basis as at present.

It also implies no change in State tax rates. The projection of expenditures is consistent with relevant national and state macroeconomic determinants. This avoids policy changes that would result in substantial deficits, as well as reductions in tax rates to take advantage of a strong Budgetary position.

Impacts on revenues, expenditure and the bottom line

The project has only modest direct impacts on WA public sector finances. On the revenue side, the main impact is the additional payroll tax on the project's employment. On the expenditure side, it is assumed that there are no state government subsidies. Nor is there a requirement for project-specific investment in infrastructure by state authorities.

Indirect effects are more substantial, but modest compared to the impacts on the Commonwealth budget.

In the absence of large specific impacts, the net effect on the state budget is finely balanced and dependent on the precise assumptions employed. The budget bottom line (and the consequent impact on state debt) is the difference between revenue and expenditure – two much larger quantities that are both subject to independent assumptions.

In the scenario presented here, the project causes increases in both revenues and expenditures. Initially expenditures run ahead of revenues as the state economy expands. However, as production plateaus and the project's national economic impacts flow through in the form of higher consumption expenditure and GST revenues, the position is reversed and the state budget benefits. The overall increase in state employment boosts payroll tax receipts and the slight increase in state population raises the state's share of the GST pool.

Deviations in key Budgetary items as a result of the project are shown in Appendix Table 13 and Chart 14. In the scenario shown, revenues reach a peak (in real terms) around 2010 at the end of the initial investment phase. They next surpass this level in the 2020s, as the project's wider benefits flow through. Current expenses also show substantial real growth over the period to 2012, but are lower thereafter.

The impact on the headline budget balance is negative till 2013; positive thereafter. Allowing for public capital expenditure, the net negative impact on the underlying fiscal position is somewhat greater than that on the headline budget. As shown in Chart 15, the underlying impact is positive by 2017 and continues to strengthen thereafter. The resultant impact on the ratio of state debt to GSP is also shown. The ratio is projected to reach its lowest point (a deterioration of 0.2 percent of GSP) in 2014 to 2016. By the end of the simulation horizon, however, there is a projected net improvement in the overall debt position resulting from the project.

CHART 14. GORGON JOINT VENTURE PROJECT: IMPACT ON THE WA BUDGET

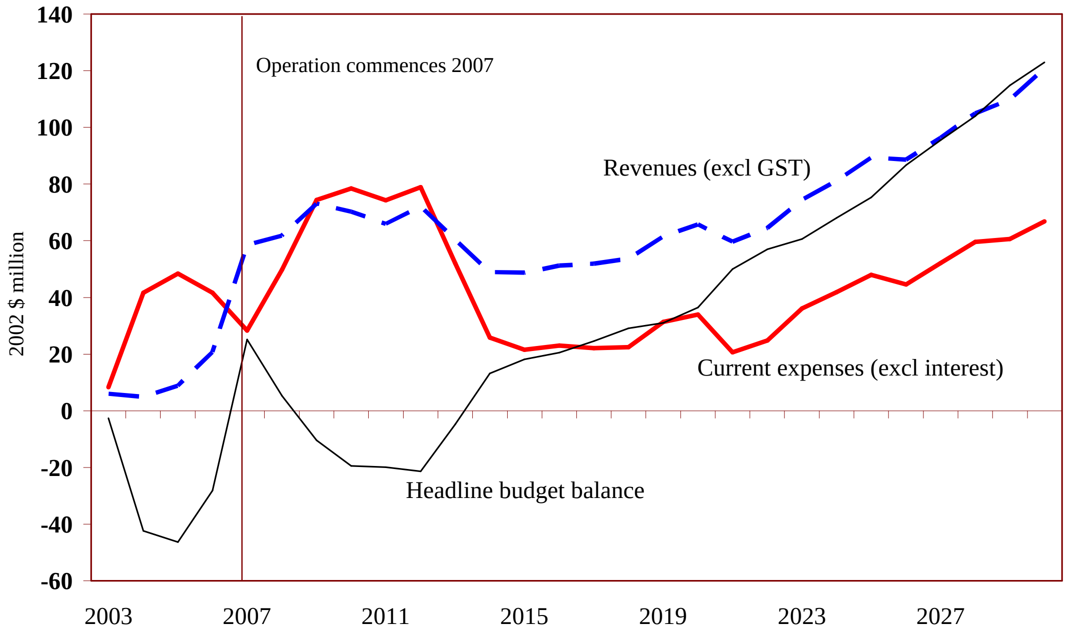
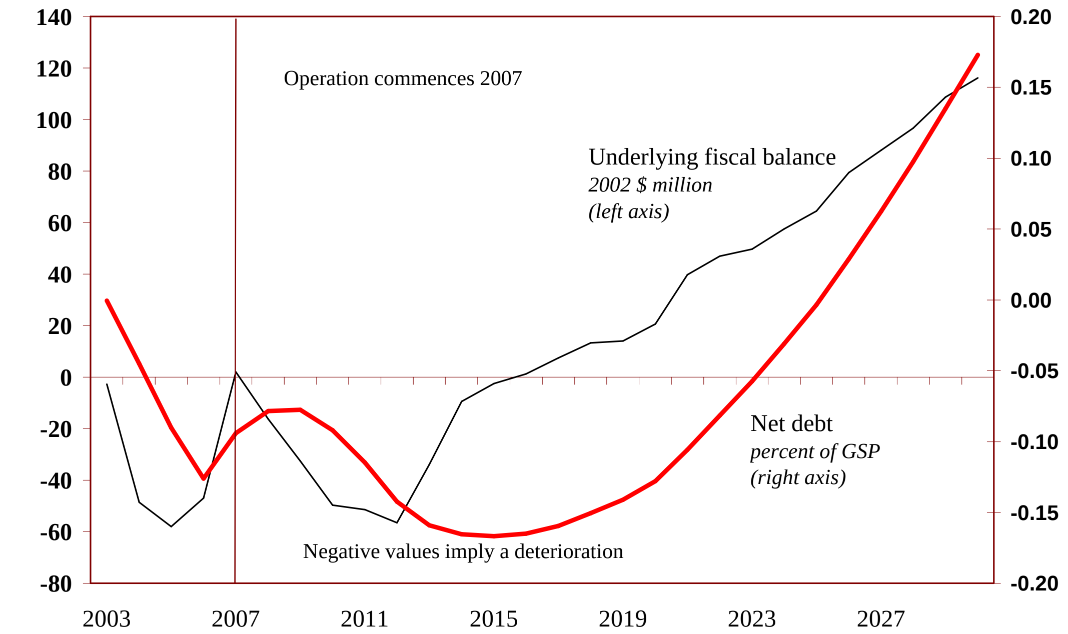


CHART 15. GORGON JOINT VENTURE PROJECT: IMPACT ON STATE DEBT



The net present values of the projected state budget impacts, at various real discount rates, are shown in Table 4. The net present value of the projected revenue gain is approximately $1.1 billion in today's prices at a 5 percent real discount rate. The net present value of projected additional current expenses is slightly smaller (at

$0.8 billion), resulting in an improvement in the net present value of the General Government balance. However, taking account of projected capital expenditures and other items, turns this into a slight fall in the net present value of the state's underlying fiscal position (and net lending). Reflecting the projected initial deterioration and later improvement in the state's fiscal position, the net present values of the reduction in net lending are larger at higher rates of discount.

TABLE 4. GORGON JOINT VENTURE: NET PRESENT VALUE OF WA BUDGET IMPACTS

Net present values over the period 2002 to 2030

Western Australian Budget	Real discount rate 3%	5%	7%
	2002 $ million		
Total revenues	1,520	1,120	840
Current expenses	1,030	820	670
General Government balance	490	300	180
Of which:			
Headline budget balance	370	210	100
Underlying fiscal position	60	-40	-100

6.2 IMPACT ON WESTERN AUSTRALIAN ECONOMIC WELFARE

In AE-MACRO the best measures of the project's overall impact on economic welfare are:

- the increase in annual flows of private consumption and public sector final expenditures that it allows, and
- the increase in public and private sector wealth at the end of the simulation period. [This is the best available indicator of the possible impact beyond that date.]

At the state level, we do yet not have comprehensive measures of wealth. However, we can take account of the net change in state debt at the end of the simulation period.

To compare welfare impacts, that occur at different points in time, we convert them into net present values by summing and discounting back to the present. Table 3 shows the result.

TABLE 5. GORGON JOINT VENTURE PROJECT, IMPACTS ON WESTERN AUSTRALIAN ECONOMIC WELFARE

Net present values over the period 2002 to 2030

WA economic welfare	Real discount rate 3%	5%	7%
	2002 $ million		
Private sector			
Consumption expenditure	3,550	2,680	2,070
Public sector			
Final demand + reduction in debt in 2030	1,820	1,430	1,170
Total economic benefit			
Public + private	5,370	4,110	3,240

The welfare improvement affects both private and public sectors. At a real discount rate of 5 percent the project improves Western Australian economic welfare by an estimated $4 billion in net present value terms. The estimates vary as the discount rate is raised or lowered.

This estimate is about one sixth of the increase in total Australian economic welfare derived in the national modelling of the project[3].

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[3] The definition of economic welfare is slightly broader in the national model, since it includes estimates of the changes in private and public wealth, rather than just the change in net public debt.

7. APPENDIX A. APPLICATION OF THE AE-MACRO MODEL

7.1 INTRODUCTION

AE-MACRO is a relatively small dynamic model of the Australian economy (with 16 stochastic equations – 84 behavioural and accounting identities). It was developed in 1992 by Access Economics, and is based on standard modelling practice. It has a theoretically-consistent long-term open-economy growth path, together with short-term dynamics derived from Australian economic experience over the past 25 years.

AE-MACRO is a 'new Keynesian' model with neoclassical long run properties. It features:

- a deregulated financial sector, with a floating exchange rate and market-determined bond rate;
- an integrated treatment of the investment, jobs, production, importing, exporting and pricing decisions of firms;
- it is data consistent - most of the model's parameters are estimated using quarterly data extending from 1976 to the present. Special attention is paid to dynamics and diagnostic testing.

A complete description of AE-MACRO and its properties is contained in *The AEM in Detail: A Manual*, Access Economics, Canberra, 1998.

The predominant use of the model is as an aid to forecasting and policy analysis. Its record in this is excellent – though in our experience, substantial elements of judgement are required in any short-term practical application, given the extensive structural changes in Australia in recent years, and the degree of "noise" in the short-term statistical data.

The model has also been used to assess the long-term macroeconomic impact of major investment projects. We would in no way claim that a model such as AE-MACRO could reliably predict the future course of the Australian economy over a 30-year horizon. Rather, the purpose of such applications is to explore the possible medium-term macroeconomic impact of the exogenous shocks to investment, exports and tax receipts provided by the project, measured as deviations from a control simulation about the model's long-run growth path. The focus of the analysis is the aggregate economic response over periods from one to ten years, rather than on the long-run growth path of the overall economy.

Simulations using AE-MACRO help throw light on the possible economic impacts of the project.

7.2 Modelling the Gorgon gas development

The AE-MACRO model needs modifying to cover the longer time horizon, and to incorporate the Gorgon joint venture and associated developments. The changes include:

- extending the time horizon of the model and of the exogenous variables (growth of population, productivity and some expenditure aggregates and policy parameters, as well as foreign interest rates, inflation rates etc.);
- aggregating the results from quarterly to calendar years, the basis upon which Gorgon project and financial information was provided to us;
- modifying the equations for business investment, exports and imports, together with the identities for employment, private wealth, public debt, net foreign assets and the net income balance of the current account, to accommodate the project. We also derived some supplementary equations to generate project aggregates, such as tax payments.

For the purposes of the modelling, we have defined the overall project to include:

- upstream development of the Gorgon gas fields, pipelines and offshore platforms;
- downstream establishment of the LNG preparation facility and all associated infrastructure;
- construction of a hypothetical gas-based resource project in two phases, and its ongoing operation; and
- increased competition in the Western Australian domestic gas market.

In modelling the project we have made the following amendments (reflecting the input data supplied):

1. Detailed capital expenditure data was provided to us by ChevronTexaco, divided into an Australian and an imported component (fixed in real $US terms). The imported component was larger than the average implied by the model's equations. We allowed for this by boosting the induced imports beyond the level normally generated by the model. Capital spending for the gas-based resource project was combined with that for the broader Gorgon development.
2. Labour costs and other operating expenditures were constant in real A$ terms.
3. The non-labour operating expenditure supplied by Gorgon was already disaggregated into domestic and overseas components. For the petrochemicals venture, however, the local and overseas split was estimated using 'initial' input-output multipliers, weighted by the industry sectors from which it was presumed that the plant would purchase its inputs. The weights were held constant over time, but the multipliers, drawn from the industry module of the AE-MACRO model, evolved over time in line with assumed trends in economic structure.

4. The resource demands implied by the project's operating expenditures are captured by deriving the implied demands on labour, capital and imports using input output methods. A further allowance was made for the relatively high import content of operating expenditures reported in the project's input data.
5. For natural gas sold domestically, ChevronTexaco provided an estimate, in A$/MMBTU of the price which they would receive in 2002 for delivery of gas into the Epic Energy, Dampier to Bunbury gas pipeline at the point of injection. We then assumed that this price would increase by a small margin below consumer price inflation, over the forecast horizon.
6. For prices of products sold internationally, we relied on advice provided by ChevronTexaco which represented the aggregate view of the joint venture partners. The assumed price trajectory was then matched up with an appropriate commodity price series in AE-MACRO. Over the long term, prices of condensate were assumed to remain constant in inflation adjusted terms, whilst prices of LNG experienced real price declines. The nominal rate of increase for US dollar denominated condensate prices was approximately 2% per annum, whilst for LNG it was 1%. These prices are indicative and do not represent the state of current or impending contractual negotiations.
7. The export price of the product of the hypothetical gas-based resource project was also assumed to grow by 2% annually in US dollar terms. The price of natural gas sold to this project was assumed to be in line with other sales to DOMGAS by Gorgon.
8. ChevronTexaco provided a schedule of asset lives for approximately thirty asset classes, together with an estimate of depreciation values for those assets in the years in which depreciation was expected to commence. For most asset classes, depreciation commences when the asset has come into productive use, not when capital expenditure is first undertaken. The depreciation values were denominated in constant 2002 prices, and so adjustments were made to allow for domestic inflation (in the case of domestic capital spending) and overseas inflation and exchange rate effects (in the case of overseas capital spending). Straight-line depreciation was then computed. Front-end engineering and design costs, incurred during both the upstream and downstream investment phases were listed by ChevronTexaco as being immediately deductible for tax purposes.
9. Negative tax was permitted, and the project economics were run on an incremental tax basis. These assumptions conformed to the current tax status of the joint venture partners.
10. There is a full representation in the model of the overall project's financing and use of funds. The Gorgon upstream and downstream developments are wholly foreign owned, and financed entirely by equity. The hypothetical gas-based resource project was assumed to have domestic and foreign ownership in equal proportions, and to be equity financed. All cash surpluses were assumed to be distributed as dividends.
11. No assistance or tax concessions by either Commonwealth, State, or local governments were assumed in the projections. Carbon taxes and carbon credits were also excluded from the scenario under consideration.

7.3 Macro-economic assumptions

Beyond Access Economics' normal five-year forecasting horizon[4], we assume that the Australian and international economies develop along steady long-run paths. Key long-run economic assumptions underlying our analyses are shown in Table 6. below.

Table 6. Long run economic assumptions

	Average annual growth rates (% per annum)
Australia	
Employment	0.7%
Labour productivity	2.6%
Real GDP	3.4%
Consumer price index (CPI)	2.8%
10-year bond yield (rate)	6.7%
United States	
Inflation	2.3%
10-year bond yield (rate)	5.8%

Source: AE Macro model.

These assumptions are stylised. They do not make allowances for specific disturbances that will affect the Australian and world economies in coming decades. There is an implicit assumption that governments will follow sound fiscal and monetary policies, and that current views on policy objectives (e.g. for inflation) will continue. The future will no doubt deviate from the stylised assumptions in ways that are difficult to predict.

7.4 National economic impacts of the Gorgon joint venture development

Further national results from introducing the Gorgon project as an exogenous shock to the AE-MACRO model are summarised in the following tables.

[4] Access Economics, *Business Outlook*, Canberra, published quarterly

TABLE 7. GORGON JOINT VENTURE PROJECT: MACROECONOMIC IMPACTS

	Deviations from baseline simulation levels				
	2002-06	**2007-15**	**2016-20**	**2021-25**	**2026-30**
Aggregate expenditures:	(Real terms; percentage deviation)				
Household disposable income	0.10%	0.12%	0.19%	0.22%	0.20%
Private consumption	0.07%	0.12%	0.18%	0.22%	0.22%
Business investment	0.85%	0.30%	0.28%	0.10%	0.01%
Public final demand	0.09%	0.14%	0.17%	0.16%	0.14%
Domestic final demand	0.17%	0.15%	0.20%	0.19%	0.18%
Exports	0.04%	0.57%	0.60%	0.50%	0.40%
Imports	0.41%	0.30%	0.38%	0.34%	0.30%
GDP	0.09%	0.22%	0.26%	0.24%	0.21%
	(Number; thousands)				
Employment	7.6	5.2	6.1	7.3	7.2
	(Percentage deviation)				
Employment	0.08%	0.05%	0.05%	0.06%	0.06%
Prices & wages:					
Price level	0.04%	0.57%	0.87%	1.17%	1.48%
Nominal wage rate	0.09%	0.61%	0.92%	1.22%	1.51%
Inflation rate	0.03%	0.07%	0.05%	0.06%	0.06%
Interest rate, tax rate & exchange rate:					
Interest rate (Bill rate)	0.06%	0.08%	0.06%	0.08%	0.08%
Income tax rate	-0.02%	-0.04%	-0.09%	-0.11%	-0.10%
Exchange rate (TWI)	0.01%	-0.39%	-0.68%	-0.96%	-1.27%
	(Ratio to nominal GDP; percentage points)				
Public sector borrowing	0.01%	0.01%	0.00%	0.01%	0.01%
Balance of payments:					
Trade balance	-0.09%	0.06%	0.05%	0.03%	0.02%
Current account balance	-0.08%	0.01%	0.01%	0.00%	-0.01%

Note: Interest rate, inflation rate and tax rate deviations expressed in percentage points

TABLE 8. GORGON JOINT VENTURE PROJECT: MACROECONOMIC IMPACTS

	2002-06	2007-15	2016-20	2021-25	2026-30
	Annual averages (2002 $ million)				
Household disposable income	575	901	1,810	2,412	2,559
Private consumption	333	784	1,512	2,097	2,458
Business Investment	948	408	516	212	25
Public final demand	171	332	514	572	607
Domestic final demand	1,448	1,644	2,717	3,110	3,338
Exports	68	1,660	2,260	2,291	2,221
Imports	-833	-854	-1,451	-1,562	-1,606
GDP	723	2,447	3,533	3,840	3,950
Public sector borrowing	96	127	239	378	441
Current account balance	-754	-249	-461	-842	-1,264

7.5 COMMONWEALTH BUDGET IMPACTS

The impacts of the project on the Commonwealth Budget were analysed within the framework used for Access Economics' *Commonwealth Budget Monitor* publication. *Commonwealth Budget Monitor* operates over a four year forecasting horizon and has a well known track record for accurately assessing the Commonwealth budgetary position and outlook.

For the purposes of analysing the project Access' standard short term Budget forecasting horizon to 2004-05 has been maintained. Longer term projections have been established using relevant relationships to macroeconomic variables for major revenue and expenditure items. The forecasts assume indexation of tax brackets on average beyond 2004-05 i.e. the revenue benefits of fiscal drag for the Budget are not included.

Deviations in key Budgetary items as a result of the project are shown in Table 9. It shows that the project produces significant gains for the Commonwealth Budget over time.

TABLE 9. GORGON JOINT VENTURE PROJECT: COMMONWEALTH BUDGET IMPACTS

	Deviations from baseline simulation levels				
	2002-06	2007-15	2016-20	2021-25	2026-30
	Annual averages (2002 $ million)				
Individuals income tax	31	-101	-459	-727	-773
Company taxes	9	223	704	883	953
Excises and sales tax	15	41	68	79	83
Customs duty	10	5	10	12	13
Other taxes and revenue	6	30	43	49	50
Total revenue	71	199	367	296	326
Total expenditure	89	272	442	545	602
Recorded Budget balance	-17	-74	-75	-249	-276
Revenue foregone through tax cut	79	231	618	874	934
Total Commonwealth Budget gains	151	429	984	1170	1260

Access Economics' modelling of the project assumes a stability function whereby the public sector budget (not just the Commonwealth) is restored to balance over the long term. The mechanism to achieve this is via movements in the rate of income tax – that is: public sector surpluses are given back in the form of income tax cuts with all other taxes assumed unaffected. Over the full time horizon the project allows for a substantial reduction in income tax. Adding this revenue foregone back to the recorded Budget balance produces strong gains to the Commonwealth Budget.

Other revenue items benefit from the economic stimulus the project provides. Company tax and PRRT collections benefit from the profit the project makes, as well as tax revenue from increased business activity elsewhere. An increase in private consumption sees higher receipts from the GST (though this accrues to States and Territories), as well as other sales taxes and excises.

The joint venture partners in the Gorgon field are ChevronTexaco (4/7), Shell (2/7) and ExxonMobil (1/7). The joint venture partners are likely to have a similar position for Australian company tax purposes with all three having significant Australian income: ChevronTexaco with its sixth of the NWS Project, Shell with the same plus Laminaria oil and ExxonMobil with Bass Strait oil. For PRRT purposes, the extent of PRRT deductions preserved from exploration and development expenditure differs across the companies. The modelling represents an amalgam of the companies' positions. The ultimate PRRT revenue to the government will depend on the positions of the companies at the time which will be influenced by other project revenues, further Gorgon expenditure and the time of application for the Petroleum Licence.

On the expenditure side, many of the government's functions and payments are assumed to move in line with GDP, and thus are boosted by the stimulus the project creates. However, the project also creates some short term reductions in unemployment, reducing benefit payments required to be paid by the Commonwealth. The boost to revenues helps to reduce Commonwealth debt in the short term, and consequently expenditure on debt repayments. These reduced spending requirements help lock in the gains to the Commonwealth Budget.

7.6 Measurement of economic welfare

To measure the impact of the Gorgon joint venture project on Australian economic welfare, we need to consider the impacts over time on the Australian private and public sectors.

The benefit to Australians is the flow of additional household consumption and additional public services that the project makes possible. These we can measure as the annual increase in real private consumption expenditure and the annual increase in real government current expenditure. By summing and discounting at an appropriate social discount rate, we can construct a single net present value estimate of the increase in Australian economic welfare made possible by the project.

Reflecting the scope of the model, this welfare estimate has limitations:

- there is a presumption that markets for public and private goods and services are efficient and free from distortion, so that an increase in expenditures in base period (1999/00) prices represents an improvement in welfare;
- no account is taken of changes in the distribution of income or wealth, as a result of the project; nor of any environmental impacts; and
- the measure is limited to the time horizon of the model – in this case 30 years.

We can make some allowance for impacts beyond the model's time horizon by adding to the welfare estimate the net present value in 2002 of the change in public and private sector wealth in the final year (2030) as a result of the project. If in the final year, Australians have increased the stock of assets they own, they will be able to generate a higher level of consumption expenditure beyond that date. If, on the other hand, they have financed previous increases in consumption through a deterioration in the balance of payments, then net liabilities to foreigners will have increased (resulting in a reduction in Australian wealth).

Private sector wealth includes:

- currency holdings
- Australian public sector debt held by residents

- the replacement value of the business capital stock owned by Australians
- the replacement value of the dwelling stock
- the replacement value of private business farm and non-farm inventories
- less net private sector debt liabilities to foreigners.

Public sector wealth includes:

- the replacement value of general government and public enterprise capital stocks
- the replacement value of public enterprise inventories
- less public sector net financial liabilities

7.7 Limitations of the modelling results

The results reported in the paper reflect the assumptions and parameter estimates built into AE-MACRO. In turn, these assumptions and estimates reflect the actual experience of the Australian economy in the past 25 years.

The model exhibits a traditional Keynesian response to domestic demand stimuli. It also incorporates a strong expectations link from monetary policy to wage behaviour. The latter reduces the extent to which demand stimuli dissipate in higher inflation. This tends to increase the initial impact on employment, but to have the opposite (and offsetting, as far as consumption spending is concerned) effect on real wages.

The moderate inflationary response keeps the pressures on interest rates and the exchange rate within manageable bounds. The assumed fiscal policy reaction function also ensures that government uses the additional revenue flowing from higher economic activity to reduce taxes rather than to increase spending.

The results are an indicative guide to the likely impact of the project. Macroeconomic simulations of a project such as the Gorgon joint venture project can only provide a broad indication of its likely impact. While the model is internally consistent, and in accordance with economic theory, it is highly aggregate and may therefore miss some important detail. The Gorgon joint venture project itself is still at the feasibility stage. The economy itself will change, and the overall economic environment will certainly not be as smooth as that implied by the baseline scenario. The effectiveness and emphasis of Australian economic policy may fluctuate.

If different assumptions had been built into the model, the macroeconomic impacts would still have been significant and positive. For example, if we had assumed a stronger response of wages to increased demand for labour, then the employment impact would have been smaller, but the average real wage would have been higher. There would still have been a substantial increase in private consumption.

Similarly, if we had assumed that governments increased spending more and reduced taxes less, there would still have been a significant impact on aggregate demand and activity.

7.8 Modelling the Western Australian economic and budgetary impacts

The AE-MACRO model allows us to illustrate the implications of a shock to the national economy at the level of an individual state.

These projections are calculated by taking the components of national GDP (E) forecasts from AE-MACRO and then splitting them into State and GDP (P) industry forecasts using the methods outlined below. The AE-MACRO forecasts used are:

1. components of final demand (public and private consumption and investment, exports and imports etc);
2. national forecasts of output, employment, unemployment and population; and
3. export, import and GDP price deflators.

Underlying the projection is a dynamic representation of national and state final demand and industry structure, based around a dynamic input output structure. This can be extended to incorporate the state-specific impacts of an investment project on the state's demand and production.

The model takes the changes in various components of national final demand, and distributes them among industries based on the dynamic input-output framework

The mathematical model for linking aggregate demand and national industry outputs was developed by the Japanese statistical agency. It was adapted for Australian data in a paper *"Input-Output: Derived tables for Australia based on a Japanese Input-Output model"* by Barbetti, Bobbin, De Zilva and Ho.

Access Economics has adapted the methodology to a dynamic input output framework. The method gives estimates of industry output, value added components, imports and employment.

Industry outputs are allocated across states in proportion to base period shares, with an allowance for any projected trends. These in turn determine employment demand, which in turn flows on to interstate migration.

The whole of the output of an investment project is allocated to the state in which it is located. A dynamic state input output framework, consistent with the national framework ensures that project-specific demands flow through to the relevant industry outputs.

The components of state final demands are determined endogenously, with reference to the corresponding national aggregates and the available state variables. State deflators are generated from relevant national aggregates, according to the input output framework, and modified for relative demand pressures across states.

TABLE 10. GORGON JOINT VENTURE PROJECT: WESTERN AUSTRALIAN MACROECONOMIC IMPACTS

	Deviations from baseline simulation levels				
	2002-06	2007-15	2016-20	2021-25	2026-30
Aggregate expenditures:	(Real terms; percentage deviation)				
Household disposable income	0.40%	0.37%	0.51%	0.55%	0.51%
Private consumption	0.22%	0.24%	0.25%	0.27%	0.26%
Dwelling investment	-0.04%	0.43%	0.53%	0.58%	0.58%
Business investment	6.45%	2.03%	1.86%	0.66%	0.11%
Public final demand	0.32%	0.56%	0.29%	0.22%	0.20%
State final demand	1.31%	0.65%	0.58%	0.35%	0.23%
Merchandise exports	0.14%	3.68%	3.76%	3.21%	2.71%
Merchandise imports	-4.26%	-1.94%	-2.25%	-1.04%	-0.41%
GSP	0.40%	1.80%	1.85%	1.52%	1.24%
	(Number; thousands)				
Employment	4.1	2.1	2.1	1.9	1.6
	(Percentage deviation)				
Employment	0.39%	0.17%	0.16%	0.13%	0.11%
Prices & wages:					
State output deflator	0.03%	0.53%	0.81%	1.11%	1.41%
Nominal wage rate	0.24%	1.31%	1.71%	2.00%	2.30%
State CPI inflation	0.05%	0.06%	0.05%	0.06%	0.06%
Merchandise trade balance					
Share to GSP	-0.59%	0.65%	0.93%	0.67%	0.61%

Note: Inflation rate deviations expressed in percentage points

TABLE 11. GORGON JOINT VENTURE PROJECT: WESTERN AUSTRALIAN MACROECONOMIC IMPACTS

	2002-06	2007-15	2016-20	2021-25	2026-30
	Annual averages (2002 $ million)				
Household disposable income	175	200	313	362	362
Private consumption	98	149	207	268	307
Dwelling investment	-2	28	42	60	62
Business Investment	895	432	527	225	43
Public final demand	52	122	84	78	84
State final demand	1,043	734	862	633	497
Merchandise exports	46	1,823	2,389	2,395	2,337
Merchandise imports	-531	-391	-595	-322	-145
GSP	335	2,127	2,923	2,924	2,893

TABLE 12. GORGON JOINT VENTURE PROJECT: SHARE OF OUTPUT DEVIATION IN WESTERN AUSTRALIA BY INDUSTRY

	2002-06	2007-15	2016-20	2021-25	2026-30
	Average % share of WA output deviation				
Agrifood	2.9%	1.8%	2.2%	2.9%	3.5%
Resources & energy	6.4%	4.8%	5.9%	8.9%	11.7%
Gorgon JV project	0.0%	65.8%	61.7%	50.6%	40.5%
Other manufacturing	9.4%	1.8%	1.7%	2.0%	2.4%
Construction	25.2%	4.5%	4.4%	5.2%	6.1%
Logistics	25.2%	7.0%	7.5%	9.2%	10.8%
Business services	21.8%	5.8%	6.2%	7.6%	8.7%
Ownership of dwellings	0.8%	2.1%	2.7%	3.6%	4.4%
Government & Consumer services	8.3%	6.4%	7.7%	10.1%	12.1%
Total	100%	100%	100%	100%	100%

Description of state budget methodology

The main analytical focus of the modelling is the State non-financial public sector as a whole (the “State sector”). Access Economics analyses the fiscal performance and position of the State sector for each State by distinguishing the contributions made by the two component sectors, namely:

- the **general government** sector ("GG sector") – comprising the units of government mainly engaged in the provision of goods and services free of charge or at nominal charge well below the cost of production and mainly funded from taxation revenues ; and
- the public non-financial corporation sector ("**PNFC** sector", previously public trading enterprises (PTEs)) – comprising the government-owned businesses mainly engaged in the production of goods and services of a non-financial nature for sale in the market place at economically significant prices.

The GG sector is the sector over which individual State Governments exercise direct control. Control over the PNFC sector is indirect, exercised mainly in a manner akin to a controlling shareholder.

In compiling the State sector statistics, transactions and debtor-creditor relationships between the two component sectors are eliminated to avoid double counting.

The State sector excludes all public financial corporations (PFCs). Central borrowing authorities are classified as being in the public financial sector and so are outside the State sector.

The State Budget modelling undertaken by Access Economics now also focuses on the ***accruals-based*** government finance statistics (GFS) series being published by State governments and the Australian Bureau of Statistics (ABS). This replaced the ***cash-based*** methodology used previously. The accruals methodology changes the timing of a number of transactions, and limits the ability of States to move these transactions from year to year without reasonable justification. The main aggregates determined under the accruals methodology do not differ significantly from earlier cash based calculations – it is usually in the detail that differences appear.

In the statistical series provided under the new GFS guidelines, four indicators of a government "fiscal balance" are provided, namely:

- the **net operating balance**: an accruals-based measure of the *operating* (or current) balance;
- the **net cash flow from operations**: a cash-based measure of the *operating* balance;
- the **net lending(+)/borrowing(-)**: an accruals-based measure of the *overall* fiscal balance; and
- the **cash surplus(+)/deficit(-)**: a cash-based measure of the *overall* fiscal balance.

Access Economics adds two indicators to this list:

- the **underlying cash deficit(+)/surplus(-)**: the cash-based measure of the *overall* fiscal balance but using the previous sign convention; and

- the **net borrowing requirement(+)/repayment(-)** : which measures the change in *net debt* as a consequence of annual financial transactions.

While the sign conventions in State Budget Monitor are as shown above, for the current analysis the reverse has been used to maintain the convention that a positive outcome means an improvement in the Budget conditions in Western Australia.

The use of all indicators will invariably lead to confusion. Moreover, discretion as to the use of indicator will lead to a temptation for some to choose the indicator(s) which put a State government in the best (or worst) light. We prefer to make a transparent choice up front, and have opted to use the 'net operating balance' largely on pragmatic grounds: the States provide a more detailed breakdown of their income and expenses items than they do of their cash operating revenues and cash operating payments items, which therefore provides a stronger basis for forecasting. The 'net operating balance' is described as the 'headline Budget balance' in the tables.

The overall fiscal balance is generally calculated by one of two means. One is an accruals-based measure (the 'net lending/borrowing' indicator) while the others are cash-based measures (the 'overall surplus/deficit', its obverse the 'underlying cash deficit' and the 'net borrowing requirement').

The Commonwealth Treasury has stated that:

> *"The two measures will differ due to differences between accrual transactions and cash flows. In the medium-term both should indicate a similar fiscal stance and hence government contribution to the external current account deficit. …*
>
> *Nevertheless, the two fiscal indicators will diverge in the short-term. The [net lending/borrowing indicator of the] fiscal balance will detect non-monetary effects, such as increases in accruing superannuation entitlements which would be ignored by the underlying cash balance. Conversely, the underlying cash balance will detect cash transactions such as superannuation payouts (outlays), that do not effect the fiscal balance. Neither indicator will perfectly detect demand effects. …Both indicators … will need to be observed in reaching conclusions about the demand effect of the fiscal stance." ("Fiscal Policy Under Accrual Accounting", April 1999) (p.12)*

For the purposes of this analysis the difference to the baseline under the two measures is identical. Both are labelled as 'underlying fiscal position' in the tables.

The final aggregate value (Net debt) changes with the underlying Budget balance in each year. Overall changes to net debt, therefore, are the aggregate changes to the underlying fiscal position. A change in net debt in one year will also affect later underlying deficits or surpluses, mainly through changes to interest payments on debts.

The assumptions in the baseline simulation, on growth in expenditures and revenues and unaltered tax rates, mean that the state heads further into surplus over time as a result of GST receipts from the Commonwealth. We have not allowed in this projection for any long term transfers of spending responsibility from the Commonwealth to the state, nor for any increases long term in the trends of expenditure, resulting (for example) from the ageing of the population. These assumptions do not affect the comparison between the two scenarios reported here, since we are interested only in the difference in the budget position resulting from the project.

TABLE 13. GORGON JOINT VENTURE PROJECT: STATE BUDGET IMPACTS

	Deviations from baseline simulation levels				
	2002-6	**2007-15**	**2016-20**	**2021-25**	**2026-30**
A) Receipts and outlays	*Annual averages (2002 $ million)*				
State taxes	8	62	57	74	104
Commonwealth grants	2	16	27	41	57
Total revenue	10	78	84	115	161
less					
Interest payments	4	18	23	12	-7
Other current expenses	28	54	27	34	57
Total current expenses	32	71	49	46	49
equals					
General government operating balance (1)	-22	6	35	68	112
less					
Public capital expenditure	6	18	12	11	12
Other items (net) (2)	4	16	11	6	2
equals					
Underlying fiscal position (1)	-31	-28	11	52	98
Headline Budget balance (3)	*-24*	*-2*	*28*	*62*	*105*
B) State debt					
level (1)	-65	-296	-383	-208	182
	percentage points				
ratio to Gross State Product	-0.1	-0.2	-0.2	-0.1	0.1

Notes: (1) A negative value implies a deterioration in the budget position

(2) Comprises: Public non-financial corporations' net operating balance and dividends, less increase in provisions and sale of non-financial assets

(2) Equals the General Government balance plus Public non-financial corporations' net operating balance

Access Economics
December 2002

APPENDIX L

THE SOCIAL IMPACT OF THE PROPOSED GORGON GAS DEVELOPMENT

(ACIL TASMAN)

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Tables

Figures

1 Introduction

This Technical Appendix provides background to the economic, social, environmental and strategic assessment of the proposed Gorgon Gas development on Barrow Island. The objective of this analysis is to assess the social impact on local communities, the Pilbara region, and Perth and the rest of Western Australia of the construction and operation of the proposed development.

For the purposes of this study, the local communities are the towns of Karratha, Dampier, Onslow and Roebourne in the Shires of Ashburton and Roebourne.

In addition to the background information set out in this document, the assessment of the social effects of the development draws heavily on records of interview with some 30 representatives of stakeholder groups from State and Local Government, business and Indigenous organisations, a social welfare agency, and education institutions.

2 Demographics

2.1 Pilbara demographics

In 2001, there were 42,747[1] people living in the Pilbara region. The population is distributed amongst four local government areas - the Shires of Ashburton, East Pilbara, Roebourne and the Town of Port Hedland.

The population of the Pilbara tends to fluctuate with development of resources projects. This is reflected in the Table 1 which shows the population declining in the mid to late 1990's due to changing work practices such as fly in – fly out, reductions in workforce numbers engaged in mining, and a winding-down of construction activities due to a lack of new large scale developments.

The effect of construction projects on population can be seen in 1998 and 1999 in the Town of Port Hedland when the BHP hot briquetted iron plant (now Boodarie Iron) was being built – although the increase was not great. The larger population increase in the Shire of Roebourne in 2001 can be attributed to the construction of Phase IV of the North West Shelf LNG project.

Table 1: Population of the Pilbara (1990 - 2001)

Shire	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Roebourne	15,540	16,001	15,919	14,909	14,529	14,038	13,829	13,983	14,417	14,507	14,320	15,974
Ashburton	7,967	7,922	7,762	7,201	7,210	7,329	7,379	7,369	6,917	6,503	6,386	6,888
East Pilbara	8,673	10,111	9,673	8,959	8,057	7,372	6,937	7,046	7,117	6,819	6,552	6,786
Port Hedland	13,901	12,516	12,626	12,542	12,405	12,134	12,281	12,821	13,270	13,248	13,171	13,099
Total Pilbara	**46,081**	**46,550**	**45,980**	**43,611**	**42,201**	**40,873**	**40,426**	**41,219**	**41,721**	**41,077**	**40,429**	**42,747**

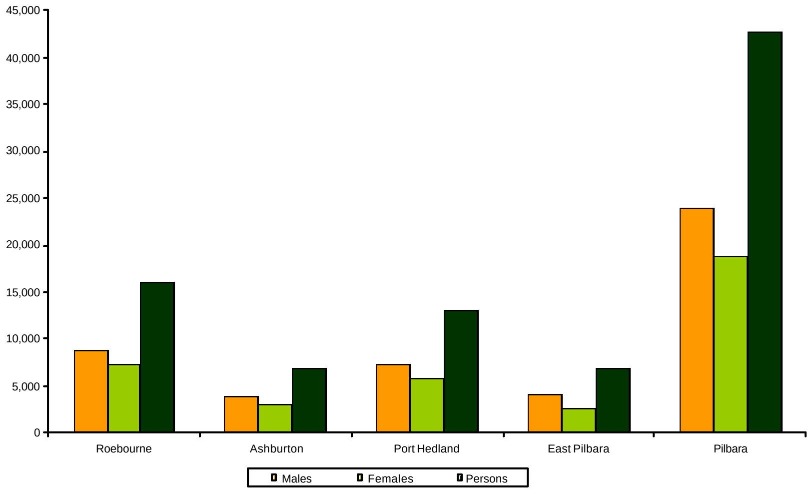
Source: Pilbara Development Commission, Australian Bureau of Statistics

[1] Australian Bureau of Statistics, 2001 Census

A male-dominated population

The number of males in the Pilbara is10 to 12 percent greater than the number of females except for the Town of Port Hedland where there are 20 per cent more males than females. In Western Australia as a whole, the number of males and females is equal. The disparity in gender in the Pilbara is due to the nature of resources projects, which tend to attract a male dominated workforce.

Figure 1: Number of persons by gender and local government authority: Pilbara (2001)



Source:: Australian Bureau of Statistics

A young population

The Pilbara population is also tends to be younger than that of the rest of the State. This is due to resource development projects attracting young workforces, some of whom bring young families with them to the nearby towns. They contribute to a lower median age for the Pilbara region – 28.7 compared with 33.3 for the whole of Western Australia in 2001. Table 2 shows the median age for each of the regions in Western Australia in 1997. The regions of the Pilbara, Kimberley and the Goldfields – Esperance all have a resources industry economic base and lower median ages (under 30) than the State average.

There is a large proportion of young people living in the Pilbara, especially in the 25 to 44 year age group. 38 per cent of the population of the Pilbara is aged 25 to 44 compared to 31 per cent for the whole of Western Australia.

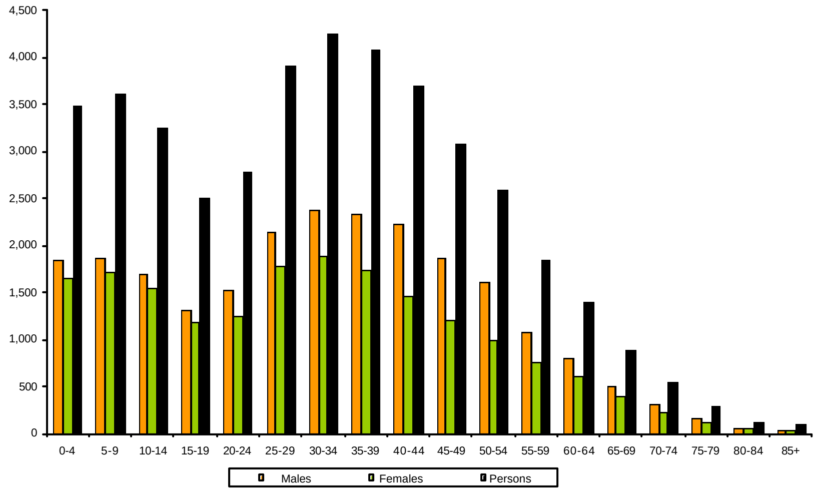
Whilst there is a larger number of children in the under 14 age group, but there is a noticeable fall in the number of children in the 15 to 24 year age group – reflecting a tendency for such young people to move to Perth for their education. There are fewer numbers of people in the 45+ age groups than the State average.

Table 2: Median age by region: years (1997)

Region	Median Age	Region	Median Age
Gascoyne	32.4	Pilbara	28.7*
Goldfields	28.9	Southwest	34
Great Southern	35.3	Wheatbelt	34.6
Kimberley	27.5	Regional Western Australia	32.5
Midwest	31.9	Perth	33.7*
Peel	36.6	**Western Australia**	**33.3***

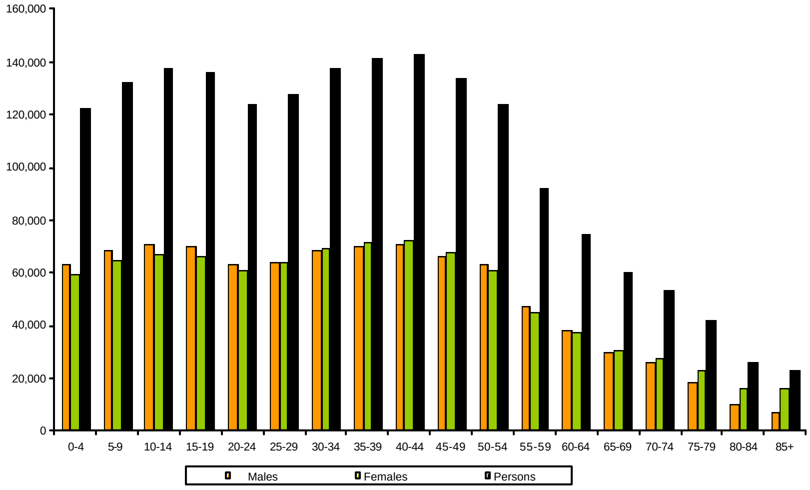
*Source:: Regional Development Council WA; * 2001 Census data*

Figure 2: Population age distribution: Pilbara region (2001)



Source:: Australian Bureau of Statistics

Figure 3: Population age distribution: Western Australia (2001)



Source:: Australian Bureau of Statistics

Population estimates for the key towns in the study over the past decade are presented in Table 3, as are projected future population numbers. The populations of most towns are expected to remain static or experience only modest growth except for Karratha, which is expected to grow by around 15 per cent.

Table 3: Population by town (1991 - 2006)

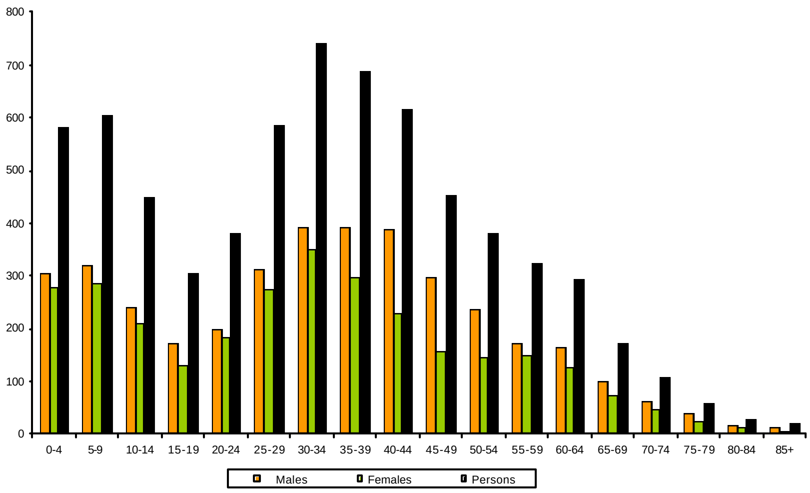
LOCATION	Census 1991	Census 1996	Census 2001	Projected 2006[1]
Karratha	11,325	10,057	10,776	12,576
Dampier	180	1,424	1,490	1,580
Roebourne	1,213	954	946	970
Wickham	1,973	1,649	1,731	1,775
Point Samson	180	256	312	360
Onslow	-	588	-	-

Sources:: Australian Bureau of Statistics, 1. Shire of Roebourne estimate

2.1.1 Shire of Ashburton demographics

The demographics of the Shire of Ashburton differ to that of the Pilbara region. During the past decade, it has experienced a constant decline in population and does not seem to have been as affected by the resources development cycle as the Shire of Roebourne. The Shire of Ashburton has a higher proportion of its population over the age of 35 than the Pilbara average. The relatively older population in the Shire could be explained by a smaller Indigenous population (which tends to be younger) than other areas and a more stable population that is less influenced by major developments.

Figure 4: Population age distribution: Shire of Ashburton (2001)

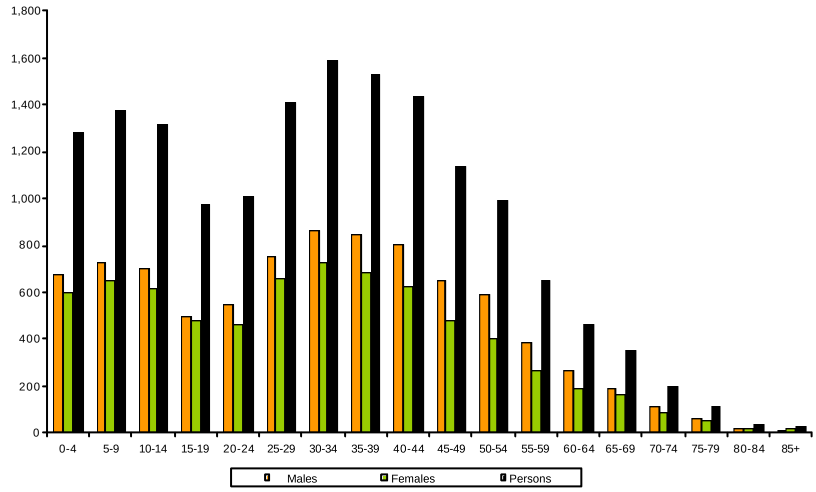


Source:: Australian Bureau of Statistics

2.1.2 Shire of Roebourne demographics

The Shire of Roebourne has a population age and gender distribution that mirrors that of the Pilbara region. These trends are driven by the strong resources sector in the Shire, which is catered to almost entirely by the town of Karratha, home to two thirds of the Shire's population.

Figure 5: Population age distribution: Shire of Roebourne (2001)



Source:: Australian Bureau of Statistics

2.2 Perth region demographics

The 2001 Census found that there were 1,339,993 people living in the Perth region, of which 656,798 were males and were 683,195 females. Only 20,015 people or 1.5% of the Perth population are Indigenous.

The median age of the population of Perth is 34 years. There is a reasonably flat age profile except for the 20 – 30 age group, which shows a decline in relative population. This is most probably caused by the high mobility of this age group who are more likely to travel away from the Perth area to seek employment and a different lifestyle. Some of these people could be a ccounted for in the Pilbara, Kimberley and Goldfields population profile whilst others choose to live in the rest of Australia and overseas.

2.3 Population projections

Section 2.1 discussed the link between the population of the Pilbara and construction and operation of resources projects. It is likely that population growth will also be dependent on future resources development in the region. Development of other sectors such as the tourism industry could also encourage population growth in the region, although this is expected to be a minor influence relative to resources development.

The Ministry of Planning[2] (now the WA Planning Commission) predicts that the population of the Pilbara will grow by an average of 0.8 per cent per annum from 2001 to 2016 and then 0.4 per cent from 2016 to 2031. This equates to a population of 48,000 in 2016 and 51,100 by 2031.

This compares with an estimated annual population growth for Western Australia of 1.4 per cent for the period 1996 – 2031. This means that by 2031 the population of Western Australia is expected to be 2,907,669 compared to a current population of 1,851,252[3] people.

2.4 Indigenous population

2.4.1 Pilbara overview

The 2001 Census recorded that there were 5,736 Indigenous[4] people living the towns and communities of the Pilbara. This represents 13.4 per cent of the total Pilbara population, the third highest proportion of Indigenous people in the State. Indigenous people make up less than 2 per cent of the population of Western Australia as a whole.

Table 4: Indigenous population as a percentage of total population by Shire / Town (2001)

SHIRE / TOWN	POPULATION			
	Indigenous	Total	Indigenous (% total)	Indigenous (% total Indigenous)
Roebourne	1,673	15,974	10.5	29.2
Ashburton	645	6,888	9.4	11.2
Port Hedland	1,991	13,099	15.2	34.7
East Pilbara	1,427	6,786	21.0	24.9
Total Pilbara	**5,736**	**42,747**	**13.4**	

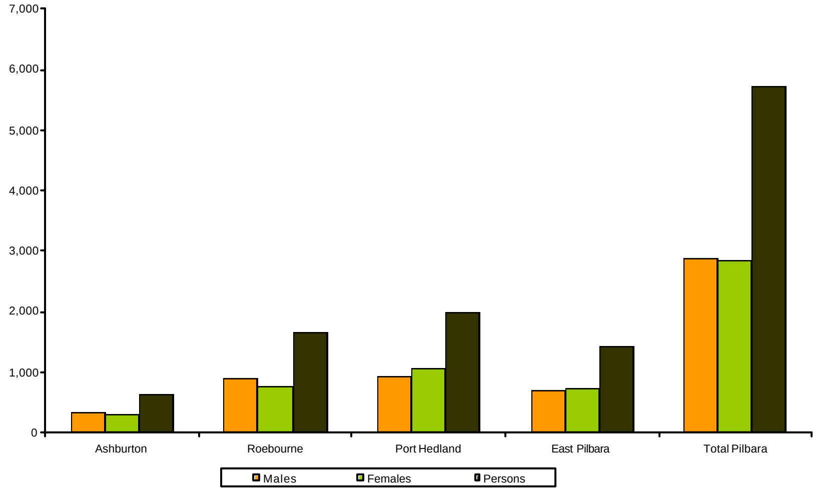
Source: Australian Bureau of Statistics

[2] Department of Local Government and Regional Development and the Pilbara Development Commission, *Pilbara Economic Perspective*: July 2001, p 4

[3] Australian Bureau of Statistics, 2001 Census

[4] Indigenous people include Aboriginal people, Torres Strait Islanders and those that are both Aboriginal and Torres Straight Islanders

Figure 6: Indigenous population: Pilbara region (2001)



Source:: Australian Bureau of Statistics

Table 5: Indigenous population by gender: Shires of Ashburton and Roebourne (2001)

	Ashburton			Roebourne			Pilbara		
	Males	Females	Persons	Males	Females	Persons	Males	Females	Persons
Aboriginal	313	289	602	815	717	1,532	2,713	2,712	5,425
Torres Strait Islander	13	18	31	56	30	86	100	67	167
Both Aboriginal and Torres Strait Islander	8	4	12	24	31	55	70	74	144
Total Indigenous Persons	**334**	**311**	**645**	**895**	**778**	**1,673**	**2,883**	**2,853**	**5,736**

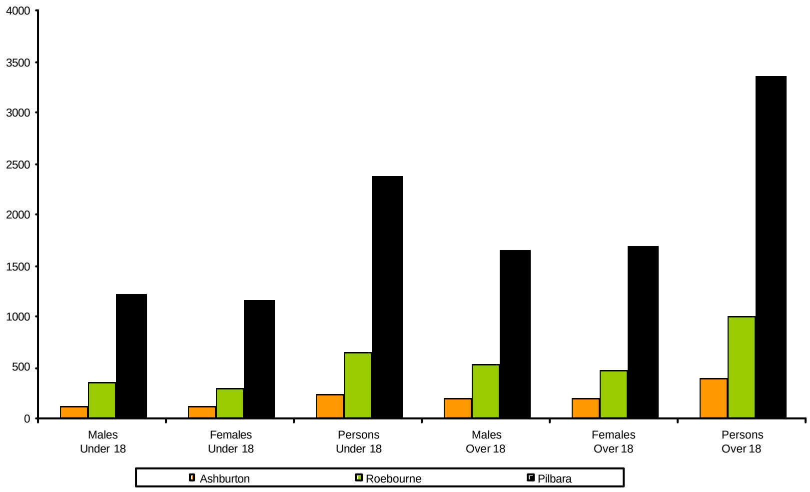
Source:: Australian Bureau of Statistics

Table 6: Indigenous population aged under 18, and 18 and over (2001)

	Under 18			18 and over		
	Males	**Females**	**Persons**	**Males**	**Females**	**Persons**
Ashburton	127	116	243	207	195	402
Roebourne	356	304	660	539	474	1,013
Pilbara	1,223	1,156	2,379	1,660	1,697	3,357

Source:: Australian Bureau of Statistics

Figure 7: Indigenous population aged under 18, and 18 and over (2001)



Source:: Australian Bureau of Statistics

2.5 Ethnic profile

2.5.1 Ethnic profile of the Pilbara

About 27 per cent of the population of the Pilbara was born outside of Australia. This is the same proportion of the population as the rest of Western Australia. The Pilbara shares the ethnic diversity of Western Australia. The people of the Pilbara originate from a wide number of countries with the biggest numbers being from New Zealand and the United Kingdom, which is also the pattern for the whole of Western Australia.

As noted in the previous section, the Pilbara has a relatively high proportion of Indigenous people.

Table 7: Population born outside of Australia by country of birth (2001)

Birthplace	Ashburton	Roebourne	Pilbara
Australia	5,137 (75%)	12,309 (77%)	31,378 (73%)
Canada	8	11	41
China (excludes SARs and Taiwan Province)(a)	3	3	16
Croatia	3	17	66
Egypt	0	3	15
Fiji	4	12	26
France	3	11	21

Germany	25	59	180
Greece	0	6	18
Hong Kong (SAR of China)(a)	0	3	9
India	13	37	131
Indonesia	3	9	56
Ireland	19	51	152
Italy	14	23	68
Korea, Republic of (South)	0	0	6
Lebanon	0	3	17
Macedonia, FYROM(b)	19	68	161
Malaysia	12	33	111
Malta	0	3	8
Netherlands	31	59	144
New Zealand	277	528	1,764
Philippines	37	83	247
Poland	3	7	27
Singapore	4	17	87
South Africa	33	66	173
Sri Lanka	0	10	57
Turkey	0	3	6
United Kingdom(c)	428	1,042	2,645
United States of America	10	29	64
Vietnam	3	9	37
Yugoslavia, Federal Republic of	3	24	85
Total population	**6,878**	**15,979**	**42,750**

Source:: Australian Bureau of Statistics

Almost 10 per cent of the Pilbara speaks a language other than English at home. However, in the Shires of Ashburton and Roebourne only 6 per cent of the population speak a language other than English at home. In both Shires, the largest language group comprises Indigenous languages.

Table 8: Language spoken at home: 2001 (%)

	English	Language other than English (total)	Indigenous language	Not stated
Shire of Ashburton	84.6 %	6.1 %	2.6 %	7.7 %
Shire of Roebourne	85.9%	6.1 %	2.2 %	7.3 %
Pilbara region	80.8%	9.4 %	3.9 %	8.9 %

Source:: Australian Bureau of Statistics

2.5.2 Ethnic profile of the Perth region

Of the Perth population, 64 per cent was born in Australia whilst 82 per cent of the population speak English at home. The main countries of birth outside of Australia are the United Kingdom, New Zealand and Italy whilst the major non-English languages spoken at home are Italian, Chinese and Vietnamese.

3 Social infrastructure and services

3.1 Pilbara social infrastructure and services

There are a number of private and government agencies that provide a comprehensive range of social infrastructure and services to the Pilbara towns of Karratha, Dampier, Onslow, Roebourne and Wickham. Most services in the areas of education, social welfare, community groups, religion, sports and recreation are available in the Pilbara. However, being relatively small communities in a remote region of Australia, these towns do not have the full range of services enjoyed by capital cities and large regional centres.

The size of Karratha means that the town has the most comprehensive social infrastructure and services.

Table 9 to Table 12 contain a summary of infrastructure and services in the areas of education, social welfare, community groups, sports and recreation and so on.

Table 9: Summary of services for the town of Karratha

Service	Description
Education Facilities	
Pre primary	Karratha Pre-primary Centre, Millars Well Pre-primary Centre, Pegs Creek Pre-primary Centre, Tambrey Pre-primary (2 centres)
Primary	Karratha Primary School, Millars Well Primary School, Pegs Creek Primary School, Tambrey Primary, St. Pauls Catholic Primary School
Secondary	Karratha Senior High School, St. Luke's Catholic College
Tertiary	West Pilbara College of TAFE
Support Centres	Karratha Education Support Centre
	Pilbara Education District Office
Children & Family services	
Day care centres	Karratha Family Centre Playgroup

Support services	Family Development and Information Service, Local Information Network Karratha (LINK)
Youth services	Karratha Youth Housing Project
Migrant	Migrant Comminty Worker (Frontier Services Centre)
Aged Services	
Services	Pilbara Homecare, Samson Beach Stay
Clubs	Karratha Autumn Club
Disability Services	
Services	CRC Australia Rehabilitation Services Disability Services Commission Pilbara Homecare Pilbara Individual and Family Support Centre Resource Unit for Children with Special Needs Samson Beach Stay
Education, training and employment	Career Network Karratha Education Support Centre
Groups	Support Group for People with Disabilities
Health Services	
General	Nickol Bay District Hospital
	Medical centres
	Doctors
	Visiting specialists
	Patient Assisted Travel Scheme
Community health centres	Karratha Community Health Centre, Karratha Physiotherapy Centre, Karratha Speech Pathology Centre, North West Mental Health Service, Pilbara Radiology, West Pilbara Health Service, West Pilbara Palliative Care Service
Child health	Hedland Place Child Health Clinic, Millars Well Child Health Centre
Groups	Multiple Birth Group, Alcoholics Anonymous, Breastfeeding Association, Cancer Foundation,

Support Accommodation	
	Women's refuge
	Youth housing centre
Emergency Services	
	Police station Crime Prevention Resource Centre Volunteer fire and rescue service State Emergency Service Fire and rescue service St John Ambulance
Sporting Facilities	
Ovals	Bulgarra Oval, Karratha Entertainment Centre Oval, Millars Well Oval, Pegs Creek Oval, Tambrey Oval
Facilities	Karratha Country Club Karratha Aquatic Centre Karratha Entertainment Centre – Squash Courts,
Clubs	Numerous sporting clubs for a variety of sports
Recreation and Community Groups	
Recreation	Karratha cinemas, restaurants (Chinese, Australian etc…), Karratha Entertainment Centre, Karratha Out of School Vocational Care
Community Groups	Apex, Business and Professional Women Pilbara, Karratha and Districts Chamber of Commerce, Country Womens Association, Karratha and Districts Returned Services League, Lions Club, Rotary Club
Religious groups	Anglican, Apostolic, Baptist, Church of Jesus Christ of Latter Day Saints, Congregation of Jehovah's Witnesses, Karratha Inter Church Council, St Peter's Roman Catholic Church, Salvation Army Family Church, Seventh Day Adventist Church, Uniting Church

Table 10: Summary of services for the town of Onslow

Service	Description
Education Facilities	
	Onslow Pre Primary Onslow Primary State School Onslow Secondary School
Children/Family Services	
Play Groups	Onslow Occasional Child Care Centre
Services	Family and Children’s Services Onslow Home and Community Care Waylun Mia – Onslow Safehouse
Youth Services	
	Onslow Youth Centre
Health Services	
	Onslow Hospital Onslow Community Health Centre
Emergency Services	
	Police St Johns Ambulance Fire and Rescue Service State Emergency Service
Sporting Facilities	
Ovals	Cameron Avenue Oval
Facilities	Basketball courts, bowling club
Clubs	Onslow Bowling Club, Onslow Golf Club, Ashburton Race Club
Recreation and Community Groups	

Religious groups	Anglican

Table 11: Summary of services for the town of Roebourne

Service	Description
Education Facilities	
	Roebourne primary school
Children/Family Services	
Play groups	Roebourne child care centre
Services	Family support service Safe House for short term accommodation and counseling services for women at risk of domestic violence
Aged Services	
	Pilbara Homecare Roebourne Home and Community Care WIROS Senior Citizens Yaandina Aged Care Hostel
Disability Service	
	Pilbara Homecare Roebourne Home and Community Care
Health Services	
	Roebourne Hospital Roebourne Child Health Service Roebourne Community Health Centre Mawarnkarra Health Service & Aboriginal Medical Centre
Emergency Services	

	Police station Volunteer fire brigade State Emergency Services St John's Ambulance
Aboriginal Services	
	Ngarliyarndu Bindirri Aboriginal Corporation (employment and business service)
	Mawarnkarra Aboriginal Medical Centre
Sporting Facilities	
Ovals	Gus Jager Oval
Facilities	Roebourne Aquatic Centre
Clubs	Roebourne Recreational Council
Recreation and Community Groups	
Recreation	Town Centre (library, art and craft facility)
Community Groups	Community Centre, Mawarnikarra Centrelink Agent, Pilbara Community Legal Service
Religious groups	Apostolic, Pilbara Aboriginal Church,

Table 12: Summary of services for the town of Wickham

Service	Description
Education Facilities	
Schools	Wickham Pre Primary Wickham Primary West Pilbara College of Tafe
Children/Family Services	
	Wickham Day care centre
Health Services	
	Wickham Hospital
Emergency Services	

	Police station Volunteer fire brigade State Emergency Service station St John's Ambulance sub-centre
Sporting Facilities	
Ovals	Wickham Sports ground
Facilities	Yatch Club, Gymnasium, Squash Courts, Swimming Pool
Clubs	Wickham Cricket Clubs, Wickham Darts Association, Wickham Football Clubs, Wickham Gym Club, Wickham Netball Association, Wickham Rugby League Club, Wickham Soccer Club, Wickham Softball Club, Teeball Association
Recreation and Community Groups	
Recreation	Town centre (library etc
Community Groups	OB's Wickham, Wickham Tidy Towns
Religious groups	Church of our lady of the Pilbara (Roman Catholic)

Source:s: Various Local Government Authority publications

3.2 Perth region social infrastructure and services

Perth is a modern, cosmopolitan city with an excellent standard of services and infrastructure that cater to the social well being of its residents and those in the rest of the State. All State government administration and substantial offices of companies with operations in Western Australia are located in Perth.

4 Livelihood and lifestyle

4.1 Livelihood and lifestyle in the Pilbara region

4.1.1 Pilbara employment profile

Employment in the Pilbara is dominated by the resources sector, which tends to attract a young male-dominated workforce. In 2001, 83 per cent of the mining workforce in Western Australia was male, compared with 55 per cent of the general workforce.

The resources sector not only provides jobs in mining but also in the industries that help support the sector and the downstream industries that process the minerals and petroleum products that are mined. The impact of these other industries is evident in the Pilbara where other major employers include the retail, health and education, manufacturing and construction industries. The manufacturing and construction industries are both directly related to the resources sector and the importance of both these sectors is expected to grow as the region encourages a greater amount of value adding activities in the minerals and petroleum sectors.

The hospitality and service industry is another that is experiencing a growth in employment opportunities. As the importance of the tourism industry as a contributor to the economy grows, then so will the employment opportunities in this sector.

The major employment prospects in the Pilbara are for semi-skilled and skilled workers. There are fewer opportunities for professional or management workers. However as the number of downstream minerals and petroleum processing increases and the development of industries that manufacture equipment for the construction and operation of large scale resource developments grows, there will be greater opportunities for more skilled personnel.

4.1.2 Indigenous employment

Employment of Indigenous people in the Pilbara region has traditionally been in the pastoral industry. While employment plunged in the 1960s and 1970s, opportunities for employment of Indigenous people on pastoral properties has increased as the number of pastoral leases held by Indigenous interests has increased. The trend towards Indigenous people establishing and running their own businesses has also resulted in new businesses in other areas such as tourism, fishing and contracting.

Nature-based and cultural tourism in particular is an area that offers business and employment opportunities for Indigenous people.

4.1.3 Indigenous employment in the resources industry

The sector offering the greatest opportunities for Indigenous business development and employment is resources.

All minerals and oil and gas operations in the Pilbara have increased employment of Indigenous people in recent years. They have programs in place that aim to further increase the proportion of Indigenous employees in their workforces. These programs include basic skills training, trade and operator training, contractor requirements, and business support and mentoring. While some Indigenous people are employed in management, supervisory, technical and high skill occupations, most are employed in contract work that services the mining industry such as earthmoving, road works, gardening and catering services. Resources companies aim to increase the number of Indigenous people at all levels and in all occupations within their operations. Some have set employment targets.

Several Indigenous businesses have been established in recent years specifically to service the resources sector and related activities. Examples are Ngarda Civil and Mining (see Box), and Gumula Corporation.

There are opportunities for other businesses to be established and develop to cater to the resources sector. However, lack of capital, administrative capacity, and business and quality systems has hampered more rapid development. To help overcome these shortcomings, several initiatives have been implemented. Joint venturing between established companies and start-up Indigenous businesses have provided access to systems and management expertise, and Indigenous Business Australia has provided start-up equity capital. The recently formed Pilbara Aboriginal Chamber of Commerce was established to provide accounting services to the five Community Development

Employment Projects (CDEP) in the Pilbara area. The Chamber will employ specialised people to provide accounts, budget, financial statement, wage payment and tax record keeping services. The Chamber will employ a Certified Practicing Accountant as well as a number of bookkeepers. It aims to provide similar services to other businesses in the Pilbara.

Box 1: Ngarda Civil and Mining

Ngarda Civil and Mining (Ngarda) is a contracting company that was established to service the mining and associated industries in the Pilbara region. The business is a joint venture that is 50 per cent owned and operated by local Indigenous people. The aim is to provide training and employment opportunities to Indigenous people in a variety of areas such as maintenance and service, earthworks, concrete works, building maintenance, landscaping, plant operating and general labouring.

The business has been successful in competing for substantial civil and mining contracts including:

- Harmony Minesite
- West Angelas Work Camps
- Woodside
- BHP Billiton Property Maintenance Services
- Mining Are C Road Maintenance

The joint venture is made up of mining, engineering and environmental services contractor Henry Walker Eltin (50% interest), Ngarda Ngarli Yarndu Foundation (25% interest) and Indigenous Business Australia (25% interest).

4.1.4 Pilbara lifestyle

Despite the Pilbara being fairly isolated, towns such as Karratha, Dampier, Port Hedland and Newman offer good recreational facilities for both sports and leisure activities. They also offer a high standard of services and infrastructure. The average level of weekly household income in the Shires of Ashburton and Roebourne is in the range $500 -

$599[5], which is higher than the Perth and State average, which are both in the range $300 - $399 a week.

The young population of the Pilbara region means that sport is one of the most popular forms of recreation. Family-based activities are also popular.

Close proximity to Karijini National Park and Dampier Archipelago ensures that camping, boating, diving and fishing are frequent leisure pursuits of Pilbara residents. There are high levels of ownership of boats and four wheel drive vehicles.

The weather is monsoonal, with part of the year having a pleasant warm and dry climate, whilst the remainder is hot and humid and can be uncomfortable.

There are good transport services linking the Pilbara with Perth, although the distance and cost mitigates the frequency of travel by Pilbara people to the south.

The outdoor lifestyle and the good employment opportunities attract young people who are seeking well-paid employment and an easygoing lifestyle.

The town of Roebourne has a different ambience to other Pilbara communities. The majority of its population is Aboriginal together with long-term residents. Its average household income level is lower.

The town of Onslow has a very small population (less than 600) and a small economic base. Household incomes are low in comparison with most other Pilbara towns. However, its proximity to the cost mean that outdoor and water pursuits are popular.

4.2 Livelihood and lifestyle in the Perth region

4.2.1 Perth employment profile

Perth is a large city with a diverse economy. Occupations of Perth residents are generally comparable to those of other Australian State capitals. The location of Perth as the nearest major city to the State's resources regions has, however, resulted in comparatively higher levels of employment in resources-related jobs. Many minerals and petroleum companies have major offices in Perth. Numerous engineering and service providers to

[5] Australian Bureau of Statistics, *2001 Census*, average weekly income for persons aged 15+

the resources sector also have large operations in Perth. As a result many people in Perth are employed in the minerals and energy sector or those industries that support it such as construction, banking and finance, government services, education and training, manufacturing and so on.

The resources sector has been credited with underpinning Western Australia and Perth's low unemployment rate relative to the rest of Australia[6].

Compared with some other States and capital cities of Australia, Perth and Western Australia have small economies and as such are not able to support a large complex manufacturing base – some notable exceptions such as shipbuilding, the food sector and specialised electronics. This further reinforces the role of the resources sector.

Table 13 shows the numbers of people employed statewide by Western Australia's major industries. Primary oil and gas processing is included in "Mining", which, while the largest (private) industry sector, is a relatively small direct employer.

Table 13: Employment by Industry 2001: Western Australia

	Males	Females	Persons
Agriculture, Forestry and Fishing	25,404	11,270	36,674
Mining	23,850	4,921	28,771
Manufacturing	64,933	19,348	84,281
Electricity, Gas and Water Supply	5,499	1,379	6,878
Construction	53,087	8,874	61,961
Wholesale Trade	29,021	13,284	42,305
Retail Trade	56,898	66,151	123,049
Accommodation, Cafes and Restaurants	15,461	22,860	38,321
Transport and Storage	24,239	8,391	32,630
Communication Services	7,910	4,205	12,115

[6] Minerals and Regional Employment in Western Australia by KW Clements and PL Johnson, Economic Research Centre, Department of Economics, The University of Western Australia 1999

Finance and Insurance	9,718	14,403	24,121
Property and Business Services	49,255	40,886	90,141
Government Administration and Defence	19,111	16,977	36,088
Education	18,698	41,620	60,318
Health and Community Services	16,570	62,706	79,276
Cultural and Recreational Services	9,221	8,999	18,220
Personal and Other Services	17,939	15,165	33,104
Non-classifiable economic units	4,268	2,825	7,093
Not Stated	6,910	6,525	13,435
Total	**457,992**	**370,789**	**828,781**

Source:: Australian Bureau of Statistics

4.2.2 Perth lifestyle

Perth offers all the services, infrastructure, shopping and entertainment expected of a major city. It is a multicultural city with 30 per cent of its population born overseas.

Education and health care services are comprehensive and of a high standard. Transport infrastructure, combined with low population density enables easy access to both recreation and employment.

Perth's Mediterranean climate allows its people to lead an outdoor lifestyle for a large proportion of the year.

Perth’s location on the coast ensures high participation in water-based recreation. Perth’s climate and sporting facilities also lead to high participation in sport.

The cost of living is one of the lowest in Australia, and there is a high level of home ownership.