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Review of Gorgon Gas Development Environmental Impact Statement and Environmental Review and Management Programme

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EXECUTIVE SUMMARY

Chapters 9, 11 and 12 of the Gorgon EIS/ERMP contain some commendable analyses. Unfortunately these rare, and as yet incomplete, examples of good quality work are overwhelmed by too many examples of poor quality analysis. The scoping and definition of terms used to describe impacts in the marine environment needs further work, particularly the meaning of the term ‘local’. The joint venturers do not appear to have used a systematic hazard analysis tool to identify and prioritise impacts in the marine environment, and there is no evidence that the beliefs and values of stakeholders and community groups have been formally acknowledged or incorporated into the assessment. Regional risk arguments used in Chapter 11 are not supported by an equivalent regional assessment and are not therefore risk averse.

The level of detail and quality of analysis varies dramatically between marine taxa. Disproportionately large sections of Chapter 11 and the technical appendices are dedicated to potential impacts on coral and some (but not all) species of turtles. The level of detail and quality of work directed to other primary producer communities and protected marine species is cursory and poor. Chapter 11 identifies 45 marine ecosystem components/processes that are directly related to the assessment endpoints and potentially threatened by the construction and operation activities of the Gorgon Gas development. The chapter, however, only specifies performance indicators for 5 of these. The chapter goes on to specify some performance targets but the approach is neither consistent in coverage (targets are only specified for 26 of the ecosystem component and processes) or approach (only 4 of the targets are measurable quantitative values whereas the remainder are qualitative aspirations). The end result is a confusing mix of specific performance indicators, measurable targets, and vague statements of intent and aspiration. Consistency and clarity of approach across all components and processes that are potentially threatened by the development is notably absent.

The joint venturers have clearly put a great deal of effort into developing and implementing a quarantine management system that will protect the endemic and native species on Barrow Island. This is appropriate given that Barrow Island’s iconic conservation status largely stems from the absence of introduced terrestrial pests that have exterminated, or continue to threaten, species of plants, birds and mammals on mainland Australia. Unfortunately the quarantine risk management strategies described in Chapter 12, and the additional information package, are fatally undermined by demonstrably flawed logic.

The flaw in the joint venturers logic is best exemplified by considering the effect of 10 totally ineffective quarantine barriers – i.e. ten barriers that each score 10 (infections occur continuously throughout the year) in terms of the likelihood of pathway infection. Under the approach described in the EIS/ERMP the residual risk of introduction for that pathway would be 10-(10-1) = 1 - i.e. the infection is extremely remote, highly unlikely. This is obviously nonsense. The joint venturers describe the resultant QMS as ‘world class’ but in reality it provides an arbitrary and unquantified level of protection to the endemic, threatened and protected species of Barrow Island. It is also apparent from the detailed pathway analysis that the residual introduction risk of some pathways/biological group combinations exceeds the community expectations (notwithstanding the flawed logic of the risk estimates). The joint venturers’ approach to this is unclear.

We recommend that the joint venturers should:

1. in collaboration with stakeholders, augment the current risk assessment with a formalised, systematic and transparent hazard analysis that addresses and prioritises all potential threats to the marine (and terrestrial) environment;

2. conduct quantitative surveys of all relevant (impact and control) subtidal and intertidal habitats;

3. conduct a much more thorough investigation of the distribution, abundance and behaviour of protected marine species in each of the proposed development areas. This is particularly pertinent to the endangered species of loggerhead turtles and olive ridley sea turtle;

4. extend quantitative turtle surveys to fully include the nesting season of green, flatback and hawksbill turtles;

5. develop a management and monitoring strategy for all ecosystem components/process identified in the EIS/ERMP as threatened by the proposed development. Each of these strategies, including the current strategy, should be formally evaluated;

6. incorporate all new and existing bio-physical models into the formal management strategy evaluation recommended above, for all measurement endpoints, as soon as possible;

7. undertake a much more thorough uncertainty analysis, ideally within the risk management framework recommended above;

8. discard the current qualitative decision rules for quarantine barrier selection and replace them with quantitative estimates of efficacy;

9. use the IMEA to prioritise potential quarantine hazards and then use relevant statistical models, in a quantitative risk management analysis, to demonstrate compliance with community expectations; and,

10. augment the proposed marine environmental-match assessment with a species-specific assessment.

We also suggest that the joint venturers consider adopting a quantitative population viability analysis for protected marine species instead of the current qualitative approach. In addition we suggest they consider simplifying the quarantine risk assessment by asking the community to re-specify its acceptance criteria at earlier points in the infection pathway, and establish statistically sound testing and inspection routines at these points to ensure that the community's expectations are met.

In conclusion we believe that in order to reach a good scientific standard the EIS/ERMP needs to develop a comprehensive management strategy for key threatened marine and ecosystem components/processes, supported by considerably better data and analysis, together with a new quantitative approach to quarantine risk management.

CONTENTS

1. INTRODUCTION

1.1 Background

1.1.1 Barrow Island

Barrow Island is situated on Australia's North West shelf approximately 70 kms off the Pilbara coast of Western Australia. The island has a total area of 234 kms^2 and is the largest of a series of islands in this region. Barrow Island supports a diversity of species, some of which have evolved in isolation from the mainland for 8000 years. Its land mass and surrounding waters provide habitat and refuge for 4 endangered species (loggerhead sea turtle, olive ridley sea turtle, southern giant petrel and blue whale), 6 vulnerable species of terrestrial mammal, one vulnerable species of land bird, 3 vulnerable species of sea turtles, 2 vulnerable species of subterranean fish, together with 27 migratory species, all of which are protected under state and commonwealth legislation, including the Environmental Protection and Biodiversity Conservation (EPBC) Act (Chevron Australia 2005).

Barrow Island is internationally recognised for its conservation status. It was declared a Nature Reserve in 1908, and proclaimed a 'Class A' Nature Reserve two years later (Chevron Australia 2005). It has been described as the 'jewel in the crown' of the conservation estate of Western Australia (EPA 2003). The island's iconic conservation status stems largely from the absence of introduced mice, rats, cats, goats, sheep, rabbits and foxes. This is unique for a tropical island of this size. The island provides a haven for native species threatened or exterminated by introduced species elsewhere in Australia and the world. It is home for 24 terrestrial taxa found nowhere else in the world and 5 terrestrial taxa that are restricted elsewhere (EPA 2003).

1.1.2 The proposed Gorgon Development

The Gorgon Joint Venturers (Chevron Australia, Texaco Australia, Shell Development Australia and Mobil Australia) are proposing to build and operate a Liquefied Natural Gas (LNG) and domestic gas processing facility on Barrow Island. The facility will produce approximately 10 million tonnes of LNG per annum, together with 300 terajoules of domestic gas and 2000 m^3 of hydrocarbon condensate per day. Construction of the plant is currently scheduled for late-2006 and is anticipated to operate for approximately 60 years (Chevron Australia 2005).

The key construction elements of the proposed Gorgon Development are:

- sub-sea production centres (18 to 25 well heads) in the Gorgon Gas Field, approximately 70 kms to the North-West of Barrow Island;
- feed gas (approximately 84 kms) and domestic gas (approximately 100 kms) pipelines, together with associated easements and land fall facilities, from the Gorgon Gas Field to the Barrow Island processing facility;

- construction of a gas processing and production facility at Town Point, Barrow Island;
- construction of a materials offloading facility (MOF) with an 800 m causeway and an LNG load-out facility with 3.1 km jetty;
- dredging an MOF access channel and turning basin (approximately 0.8 million m^3) together with a shipping channel and turning basin (between 7 and 8 million m^3) and associated dredge spoil ground (approximately 1500 ha); and
- approximately 2800 barge movements , 94,000 to 170,000 personnel landings between the mainland and Barrow Island, and 1.2 million imported freight tonnes over a 40 month construction period (Chevron Texaco Australia 2003, Chevron Australia 2005).

The key operational elements of the proposed Gorgon Development are:

- An approximate 300 ha footprint that accommodates the gas processing facility, associated infrastructure and pipeline easements;
- power supply and water supply, treatment and disposal facilities;
- greenhouse gas emissions (approximately 4 million tonnes of CO_2 equivalents), NO_x (approximately 4430 tonnes) and SO_x (approximately 0.15 tonnes) emissions, together with approximately 241 tonnes of total emitted particulates (PM10), per annum;
- periodic maintenance dredging of the shipping channel and turning basin;
- 3 LNG ship visits per week and one condensate ship visit per month; and,
- an initial estimate of 200 barge movements per annum and 75 personnel landings per week between the mainland and Barrow island during the operational period of the facility (Chevron Texaco Australia 2003).

1.2 Aim and objectives

The overall aim of this project is to conduct a desk-top review of the Gorgon Gas Project Environmental Impact Statement and Environmental Review and Management Programme (hereafter referred to as the Gorgon EIS/ERMP). The project will review Chapter 9 (Risk Assessment Approach), Chapter 11 (Marine Environment – Risks and Management) and Chapter 12 (Quarantine Risks and Management), associated technical appendices, relevant additional material and other sections of the Gorgon EIS/ERMP document directly relevant to these chapters.

The specific project objectives are:

1. Assess the theoretical underpinnings and practical efficacy of the Gorgon EIS/ERMP with respect to the marine environmental values of Barrow Island;

2. Where appropriate, outline any modifications to the quarantine management system necessary to adequately protect the terrestrial and marine environmental values of Barrow Island;

3. Review the detailed assessments of the three quarantine pathways completed to date;

4. Subject to cost and time constraints, provide specific comments on:

    a. the impact and risks to benthic primary producers and marine fauna, particularly with respect to proposed dredging activities;

    b. the impact and risks to protected marine fauna;

    c. the impact and risks to intertidal habitats;

    d. the dredge plume model validation;

5. Submit a report to the Western Australia Environmental Protection Authority (EPA) covering the above points.

This report represents the project deliverable under the fifth objective. During this review we noted a number of editorial errors in the EIS/ERMP such as incorrect references to figure headings, table legends or entire sections of the document, and various inconsistencies between text, tables and Appendices. This report does not document these errors.

2. CHAPTER REVIEW

2.1 Chapter 9: Risk assessment approach

2.1.1 Methodology

The joint venturers adopt a qualitative risk assessment approach that complies with current Australian standards (AS/NZS 4360:2004). This approach uses a standardised ‘risk matrix’ to combine qualitative estimates of the likelihood and consequence of undesired events into a single risk estimate. It is important to note, however, that the current Australian and New Zealand standard does not provide comprehensive guidance on the potential pitfalls associated with qualitative risk assessment or ways to try and avoid these pitfalls (Burgman 1999). As a result compliance with the current standard does not guarantee a high scientific standard.

2.1.2 Scientific credibility

The scientific credibility of a qualitative risk assessment is largely determined by the expertise of the group performing the assessment and the manner in which the group’s opinions and predictions are elicited, combined, and prioritised. All humans exhibit a range of psychological behaviours that have a profound influence on qualitative risk estimates. Our judgement is adversely affected by personal experience, level of understanding and control over the outcome, its apparent dreadfulness and who ultimately bears the burden of risk. Furthermore when individuals assess risks subjectively they are often influenced by cognitive bias (overconfidence in one’s ability to predict), framing effects (judgements of risk are sensitive to the prospect of personal gain or loss), anchoring (the tendency to be influenced by initial estimates) and insensitivity to sample size (Burgman 2001, 2005).

These “psychological frailties” can lead to unfounded certainty– both naïve and sophisticated subjects tend to be more confident about their predictions than they should be. Qualitative assessments may not therefore err on the side of conservatism even when they purport to do so (Ferson and Long 1995). Conversely, the risk matrix approach espoused by current Australian standards can, under certain circumstances, lead to overconservative bias (Cox et al 2005). Furthermore, the same qualitative assessment, conducted by different interest groups, can reach opposite conclusions, when presented with the same data, for no apparent reason (Hayes 2003). These effects undermine the repeatability, transparency and scientific credibility of qualitative risk assessments.

There are a number of hazard analysis and risk assessment techniques designed to maintain the scientific credibility of qualitative risk assessments (Table 2.1). These techniques encourage consistent, systematic evaluation, clear communication and help expose assumptions and value judgements. The joint venturers have adopted some of these techniques. Chapter 9 scopes the assessment. Some measurable effects are predicted in Chapter 11, and Chapter 12 uses formal hazard assessment techniques. Nonetheless serious problems remain in each of these areas (see sections 2.1.3, section 2.2.1 and section 2.3.3 respectively).

Table 2.1 Hazard analysis and risk assessment methods and techniques that help maintain the scientific credibility of qualitative risk assessment

Issue	Methods and techniques
Be representative	Identify all relevant experts and stakeholders and seek to include them in the assessment team from the very start of the assessment.
Scope and define	Ensure the spatial and temporal scope of the assessment is understood by all. Clearly define all predictive terms (such as high, medium or low likelihood and consequence) in terms relevant to the scope of the assessment.
Avoid predictive bias	Use structured elicitation and aggregation techniques to help avoid "psychological frailties" such as insensitivity to sample size, overconfidence, judgemental bias and anchoring (Burgman 2001, 2005).
Identify all possible hazards	Use structured hazard identification techniques such as influence diagrams (Hart et al 2005), fault tree analysis (Haimes 1998, Hayes 2002a), Failure Modes and Effects Analysis (Palady 1995, Hayes 2002b), Hazard and Operability Analysis (Kletz 1999) or Hierarchical Holographic Modelling (Haimes 1998, Hayes et al 2004) to rigorously and systematically identify all possible hazards.
Formally prioritise hazards	Consider using formal prioritisation procedures such as the Analytical Hierarchy Process (Saaty 1988), or Failure Modes and Effects Analysis, when prioritising hazards or combining the predictions of different stakeholders. Keep a careful record of the process, methods and predictions of the assessment.
Monitor and test predictions	Predict measurable effects and monitor these with sufficient sensitivity to test the risk assessment predictions and thereby close the regulatory loop and generate additional data.
Peer review	Seek an independent peer review of the risk assessment and its results.

2.1.3 Scope, definitions and consequence characterisation

The first step in a risk assessment is to carefully define the boundaries and scope of the assessment, and the risk assessment terms used. The Gorgon EIS/ERMP defines all the terms that it uses but in many instances the definitions are circular, unbounded and vague. For example the term ‘widespread’ is defined as ‘impacts extending to areas well-outside the direct impact zone from the development’. This definition lacks boundaries and is too vague (what does well-outside mean in a marine context?). The definition of ‘local’ is circular – it refers to ‘the immediate vicinity of the development’ but the term ‘immediate vicinity’ is not defined and the marine boundary of the ‘immediate region’ is unclear. Note that these types of problems are repeated for a variety of other terms used to characterise impacts in the marine environment (see below). Finally, the definition of impact as a ‘direct interaction of a stressor with the environment’ appears to preclude the possibility of indirect effects of stressors, which presumably is not the intent.

Chapter 9 of the EIS/ERMP distinguishes impacts at the level of individual organisms and at a population level. At the individual level the joint venturers use ‘sharp’ spatial and temporal boundaries to distinguish moderate, serious, major and critical consequences. Sharp boundaries are commonly used in qualitative risk assessment to avoid a phenomena known as ‘Sorites Paradox’ (Regan et al 2002, Burgman 2005) by giving definition borders to categories (of likelihood and consequence for example) that lie along a continuum. They are an attempt to avoid vagueness (a type of linguistic uncertainty) associated with terms such as low, medium and high. Sharp boundaries, however, are not a good way to avoid vagueness because small changes close to the boundary give rise to (potentially misleading) category changes.

Consider for example the difference between the following impacts on the behaviour of protected marine species: ‘local, short term’, ‘local, long term or widespread short term’ and ‘widespread long term’. These are defined in the Gorgon EIS/ERMP as minor, moderate and serious consequences respectively. As noted above, the terms ‘local’ and ‘widespread’ are problematic in this context. Notwithstanding these difficulties note that a local impact that lasts 5.1 years and a widespread impact that lasts 4.9 years would be assigned the same ‘moderate’ consequence. Alternatively consider the statement, ‘the consequences of deterred nesting and selection of less suitable beaches is considered to be moderate with a loss of a proportion of 3 to 4 seasons of hatchlings’. Note that if hatchling loss lasted 5 seasons the consequences would be deemed ‘serious’.

At the population level, the joint venturers place less emphasis on the spatial and temporal boundaries discussed above in favour of population viability criteria. At this level the moderate, serious and major consequences categories for protected species have the same spatial and temporal boundary (local long term or widespread short term) and are defined as ‘loss of small number of individuals without reduction in local population viability’, ‘loss of individuals leads to reduction in viability of local population’ and ‘loss of local population(s)’ respectively. There are two problems here. The first is linguistic uncertainty. The term ‘local population’ is vague because the definition of local (as noted above) is circular and the term ‘small’ is undefined in this context. There is considerable scope for different interpretation of these consequence categories leading to very different risk estimates.

The second problem with these definitions is that they do not adequately address the possibility of cumulative impact - i.e. localised, long term, recurrent loss of ‘small’ numbers of individuals that eventually reduces the viability of local populations resulting ultimately in their loss. Consider for example the impacts associated with maintenance dredging and resuspension caused by the propeller wash of arriving/departing ships and tugs (if any – none are mentioned in the EIS/ERMP) that usually assist large vessels in port. The impacts associated with these activities are recognised to be long term but the consequences are rated low in the EIS/ERMP which by definition implies ‘no expected decrease in local population viability’. Coral settlement, however, can be significantly affected by changes in sedimentation as low as 3-10 mg cm^{-2} day^{-1} particularly where it increases from a low base (~1 mg cm^{-2} day^{-1}) (Babcock and Davies 1991, Babcock and Smith 2003). We suspect that the cumulative impact of weekly sediment resuspension for 60 years will have a moderate to serious impact on local populations of coral, depending on the subsequent dispersal of the sediment plumes and how one defines ‘local’. Moreover in the absence of a formal population viability analysis (Boyce 1992, Burgman et al. 1993, Possingham et al 1993, McCarthy et al 2001), it is difficult to see how the joint venturers are able to distinguish between the moderate/serious and serious/major consequence categories of any protected species over a 60 year duration. We suggest that the joint venturers consider adopting a quantitative population viability analysis in favour of the current qualitative approach.

2.1.4 Hazard and uncertainty analysis

The hazards and threats associated with the proposed Gorgon development were systematically identified through a number of hazard identification workshops (Chevron Australia 2005). The EIS/ERMP does not, however, describe the formal process, if any, that was adopted in these workshops. It appears as if hazards were simply identified by brainstorming. The resulting list of stressors and associated development activities appears to be comprehensive but in the absence of a formal procedure this is difficult to confirm. There is no record of potentially threatening processes that were deemed irrelevant. For example, are there any electrical or electro-magnetic threats associated with the development? As a result it is possible that potential threats have been overlooked (see also section 2.2.5).

The stressors identified in the EIS/ERMP represent direct threats to the environmental values of Barrow Island. There is no evidence that the joint venturers have systematically evaluated planned and unplanned events, interactions between natural (e.g. cyclones) and Gorgon-induced threats, or antagonistic effects of multiple stressors operating in concert. As a result it is possible that potential threat scenarios have been overlooked or not adequately addressed.

There are various types of uncertainty in environmental risk assessment (Regan et al. 2002, Regan et al. 2003, Burgman 2005, Hayes et al. in review). The EIS/ERMP does not formally recognise different types of uncertainty, or provide any systematic evaluation of uncertainty in its predictions. The joint venturers claim that there is little uncertainty in the exposure mechanisms of planned events and that the exposure mechanisms of unplanned events are well understood. It is very difficult to believe that there is no uncertainty in planned exposure mechanisms in a development of this magnitude at this (relatively early) stage of development. The revised estimates of personnel landings from 170,000 (Chevron Texaco Australia 2003) to 94,000 (Chevron Australia 2005), for example, are indicative of the uncertainty that arises as major developments are planned and progress. Furthermore, in the absence of a hazard analysis procedure that asks, ‘What can go wrong?’ it is also difficult to accept that the joint venturers have fully explored all potential exposure mechanisms of unplanned events, outside of hydrocarbon leaks and spills.

Overall, the joint venturers’ approach to uncertainty is unclear. The EIS/ERMP claims to adopt a ‘worst-case’ approach, combining the most serious of a range of potential consequences, with the most frequent of a range of potential likelihoods, in its final risk estimates. This approach is not consistently applied (see section 2.2.6), and cannot be verified given the information presented in the EIS/ERMP.

2.2 Chapter 11: Marine environmental risks and management

2.2.1 Methodology

The joint venturers have clearly consulted a large number of stakeholders (Chevron Australia 2005) but there is no evidence in the Gorgon EIS/ERMP that their opinions or beliefs have been formally included within the marine impact/risk assessment. For example, there is no evidence of any formal elicitation techniques, Delphi process, analytical hierarchy process or equivalent techniques to help elicit and aggregate opinions of stakeholders and experts. Chapter 11 of the EIS/ERMP appears to simply portray the beliefs and values of the proponents.

The EIS/ERMP identifies a number of assessment endpoints for five marine ecosystem categories (Table 2.2). In risk assessment parlance, assessment endpoints represent the values that the analyst is trying to protect by conducting the risk assessment. In this example some of the assessment endpoints are very broad and/or poorly specified. Maintenance of ‘environmental value’ for example is extremely vague and open to several alternative interpretations depending on one’s point of view.

Table 2.2 Assessment endpoints for ecosystem components identified in the Gorgon EIS/ERMP

Ecosystem description	Assessment endpoint(s)
Foreshore	Maintain integrity and stability of beaches
Marine benthic habitat, subtidal and intertidal zone	Maintain ecological function and environmental value
Marine benthic primary producers	Maintain ecological function, abundance, species diversity and geographic distribution
Marine fauna	Maintain abundance, species diversity, geographic distribution and ecological function. Avoid, minimise and/or mitigate impacts on locally significant marine communities. Protect EPBC Act listed threatened and migratory species. Protect specially protected (threatened) fauna consistent with provisions of Wildlife Conservation Act 1950
Marine water column	Maintain existing and potential values and ecosystem function

Risk analysts avoid these types of problems by distinguishing what they are trying to protect (assessment endpoints) from what they can actually measure (measurement endpoints). Measurement endpoints are quantitative, measurable characteristics or processes that are related to the assessment endpoints, and are measured to test the predictions of the risk assessment and thereby ensure that the assessment endpoints are met. Measurement endpoints are in effect performance indicators and are often referred to as such.

The EIS/ERMP identifies 45 marine ecosystem components/processes that are directly related to the assessment endpoints and potentially threatened by the construction and operation activities of the Gorgon Gas development. The document, however, only specifies performance indicators (measurement endpoints) for 5 of these (Table 2.3). The document goes on to specify some performance targets but the approach is neither consistent in coverage (targets are only specified for 26 of the ecosystem component and processes) or approach (only 4 of the targets are measurable quantitative values whereas the remainder are qualitative aspirations). The end result is a confusing mix of specific performance indicators, measurable targets, and vague statements of intent and aspiration. Consistency and clarity of approach across all components and processes that are potentially threatened by the development is notably absent.

2.2.2 Impacts on intertidal habitats and benthic primary producers

Chapter 11 of the EIS/ERMP concludes that all residual risks[1] to marine primary producers will be low to medium. Here we interpret marine primary producers to mean inter-and subtidal benthic primary producers. The data, analysis and monitoring program described in the EIS/ERMP, however, do not inspire confidence in these conclusions. Notable omissions in this context include:

- performance indicators and management strategies for all at risk components;
- an adequate description of intertidal and subtidal (benthic) habitats; and,
- a detailed description of the proposed measurement strategies.

A substantial proportion of Chapter 11 is dedicated to impacts on coral species, culminating in a monitoring and management strategy for water quality, sedimentation rates and coral health in a zone of moderate impact and in the zone of the visible plume. The EIS/ERMP uses corals as sentinel species for all other benthic primary producers. The joint venturers' attempt to develop a transparent monitoring and management strategy in this context is commendable. Equivalent management strategies, however, are not specified for the other 41 ecosystem components and process that are threatened by the development, many of which are not benthic primary producers and not therefore represented or protected by the sentinel species approach (Table 2.3). We recommend that a management and monitoring program is developed for all other ecosystem components/process as a matter of high priority. Furthermore we recommend that each of these strategies, including the current strategy, be formally evaluated (see section 2.2.4).

[1] Residual risks are defined in the EIS/ERMP as 'the remaining level of risk after management/treatment measures have been taken into account'.

Table 2.3 Ecosystem components/processes, performance indicators and targets identified in the Gorgon EIS/ERMP (gaps in the table indicate gaps in the EIS/ERMP)

Specific component/process at risk	Performance indicator(s)	Target(s)	Management strategy	Strategy evaluated
Seabed profile		Compliance with EPA guidance statement	No	No
Seabed type			No	No
High profile reef structures			No	No
Long shore coastal sediment dynamics		Transport minimised, no detectable long-term change	No	No
Subtidal sediment size			No	No
Subtidal sediment oxygen profile			No	No
Subtidal sediment chemical composition		No long-term contamination outside of development area	No	No
Intertidal sediment size			No	No
Intertidal sediment oxygen profile			No	No
Intertidal sediment chemical composition		No long-term contamination outside of development area	No	No
Seawater nutrients			No	No
Seawater clarity	Total suspended solids	2d, < 3x TSS (Zone 2); 2d, < 80^{th} percentile median TSS (Zone 3) cf reference sites	Yes	No
Seawater oxygen concentration			No	No
Seawater chemical concentration		Heavy metal limits not exceeded, no long-term contamination outside develop. area	No	No
Seawater pH			No	No
Soil porosity (compaction)			No	No
Soil depth and extent (erosion)			No	No
Foreshore profile			No	No
Soil pH	Soil pH		No	No
Sea-level			No	No
Long shore coastal sediment dynamics		No detectable long-term change	No	No
Mangrove: *Avicennia marina*			No	No
Mangrove: *Rhizophora stylosa*			No	No
Seagrass: *Halophila ovalis*			No	No
macroalgae: *Sargassum* spp.			No	No
macroalgae: *Caulerpa* spp.			No	No
Coral: *Porites lobata*	Bleaching & mortality	< 10% increase in bleaching, < 30% decrease in live cover, cf reference site	Yes	No
Coral: *Acropora* spp	Bleaching & mortality	< 50% increase in bleaching cf reference site	Yes	No
Coral: *Turbinaria bifrons*	Bleaching & mortality	< 10% increase in bleaching, < 30% decrease in live cover, cf reference site	Yes	No

Table 2.3 Ecosystem components/processes, performance indicators and targets identified in the Gorgon EIS/ERMP (gaps in the table indicate gaps in the EIS/ERMP)

Specific component/process at risk	Performance indicator(s)	Target(s)	Management strategy	Strategy Evaluation
Whale shark		Long term viability maintained	No	No
Rock pipefish		Long term viability maintained	No	No
Potato cod		Long term viability maintained	No	No
Humpback whale		Long term viability maintained	No	No
Sperm whale		Long term viability maintained	No	No
Common dolphin		Long term viability maintained	No	No
Bottlenose dolphin		Long term viability maintained	No	No
Dugong		Long term viability maintained	No	No
Green turtle		Long term viability maintained	No	No
Flatback turtle		Long term viability maintained	No	No
Olive sea snake		Long term viability maintained	No	No
Osprey		Long term viability maintained	No	No
Greater sand plover		Long term viability maintained	No	No
Wedge-tailed shearwater		Long term viability maintained	No	No
Infauna communities		No long-term impact to significant communities	No	No
Filter feeding communities		No long-term impact to significant communities	No	No

The EIS/ERMP repeatedly emphasises the low conservation value of the sub- and inter-tidal habitats in the proposed development areas. The document does not, however, scientifically substantiate these statements. The sub- and inter-tidal surveys commissioned by the joint venturers lack quantitative rigour and scientific quality (see sections 3.3 and 3.4 respectively). The data that were gathered during these surveys do not represent an adequate baseline description of the biodiversity and ecological functions in the proposed development areas. There is a notable absence of species lists and quantitative descriptions of diversity, abundance and extent. These information gaps undermine the scientific credibility and approach of the EIS/ERMP. For example, it is impossible to test the assumption that corals, as sentinel species, will provide a conservative indicator of the response of all benthic primary producers to development induced stress. In summary, the sub- and intertidal information presented in the EIS/ERMP does not provide adequate support for the conclusions that it draws and, importantly, does not provide an adequate basis for before/after or control/impact comparisons.

Chapter 9 of the EIS/ERMP highlights the importance of environmental monitoring to confirm the actual impacts of the development and adequacy of its management strategies, but Chapter 11 does not provide an adequate description of how impacts on intertidal habitats and benthic primary producers will be actually measured. In particular, practical and statistical issues are not adequately addressed. There is, for example, no detailed description of how coral cover will be measured (particularly in low or nil visibility conditions) and how appropriate reference sites are determined.

Other issues of concern include the poor characterisation of coral communities in Management Units 3, 5, 6, and 8, anticipated habitat losses in excess of the cumulative loss thresholds in unit 8, and the simplistic interpretation of the literature cited in Section 11.3. The discussion in this section implies that the impacts associated with sediment loads are linear. This is not true. Increasing sedimentation from 1 to 25 mg cm^{-2} day^{-1}, for example, is a much more significant effect than increasing it from 250 to 275 mg cm^{-2} day^{-1}. Furthermore the choice of 5 mg cm^{-2} day^{-1} as a chronic stress load is not justified and data on ‘natural’ sedimentation rates is not presented.

2.2.3 Impacts on protected marine fauna and turtles

Chapter 11 of the EIS/ERMP concludes that residual risks to protected marine fauna ranges from low to high. The data, analysis and monitoring program described in the EIS/ERMP do not inspire confidence in the predictions of low risk, nor that the high risks can be effectively managed.

The document lists 102 protected vertebrate species that ‘may’ be present in the waters around Barrow Island, but the quality and scientific credibility of the data presented in the document varies dramatically between taxonomic groups. The ecology, distribution and habitat preferences of cetaceans, turtles and dugongs is reasonably well described but statements such as ‘development areas do not support aggregations of marine mammals…’ are not supported by quantitative survey results. The quantitative baseline survey that has been commissioned for flatback turtles is not yet complete. Furthermore there is virtually no reliable survey data for sharks, sea snakes and pipefish (see also section 3.1). We recommend that the joint venturers conduct a much more thorough investigation of the distribution, abundance and behaviour of protected marine species in each of the proposed development areas. This is particularly pertinent to the endangered species of loggerhead turtles and olive ridley sea turtle for which no information is provided (see section 3.2.2). We also recommend that quantitative turtle surveys are extended to fully include the nesting season of green, flatback and hawksbill turtles. These surveys should focus their effort in all relevant development areas.

2.2.4 Management strategy evaluation

Chapter 11 describes a monitoring and management plan for Horizontal Directional Drilling (HDD), dredging and dredge spoil disposal in two impact zones – a zone of moderate impact and a visible plume and sedimentation zone. The successful development and implementation of this type of management tool, for all measurement endpoints, is critical to the successful protection of the marine (and terrestrial) environmental values of Barrow Island.

Uncertainty associated with the dynamics of ecological systems has important financial and environmental implications. In this context, failure to adhere to the performance targets specified for water quality, sedimentation rate or coral health, for whatever reason, exposes the joint venturers to significant financial loss (through project delays) and the community to significant environmental loss (through loss of corals and associated assemblages). Alternatively, failure to recognise actual environmental harm, or inaccurate reports of supposed environmental harm, will cause false negative and false positive results with concomitant environmental and financial implications respectively.

Management strategy evaluation helps minimise the financial and environmental risks associated with measurement and management plans by:

- identifying a range of proposed management options (the strategies);
- turning environmental aspirations into specific and quantifiable performance indicators;
- identifying and incorporating key uncertainties into an evaluation of the consequences, for the chosen performance indicators, of the proposed activity and management strategy; and
- communicating the results effectively to stakeholders and decision-makers.

The monitoring and management strategies specified in the EIS/ERMP do not appear to have been formally evaluated. In particular there is no quantitative evaluation of the likelihood of strategy success or failure and no formal uncertainty analysis. It does not therefore provide confidence that the environment will be protected or that false negative and false positive results will be identified and avoided. Important, but as yet unquantified parameters, identified in the EIS/ERMP include:

- expected recovery rates of impacted coral;
- baseline coral bleaching in the reference sites, dimensions and total coral cover in the reference site and current bleaching levels in the two management zones;
- coral health detection probability in low visibility conditions and the overall statistical power of the measurement and sampling strategy;

- how the zone of the visible plume will be determined and the extent to which this zone will overlap with the zone of sedimentation;
- turnaround time for tier 1 and tier 2 management activities; and,
- the dredge entrainment rate of turtles, effectiveness of controlled trawling methods and turtle deflection devices.

Note that this does not represent an exhaustive list of important parameters. These are simply parameters which we readily recognised as important to the successful implementation of the proposed management and monitoring strategy.

Management strategy evaluation relies on a bio-physical model that captures the dynamic and uncertain behaviour of the natural system in question, the impacts of human activity on this system and the response of the system to the proposed management actions. Importantly some of these components, for example a sediment dispersal model, are already in place for the Gorgon Gas Development (but see comments in section 2.2.8). Furthermore the joint venturers are currently in the process of ‘examining the likelihood that corals outside the high and moderate impact zones will be subject to short term pulses of turbidity or sedimentation that may lead to mortality over a protracted period’. The results of this modelling have important implications for the monitoring and management strategy outside of the moderate impact zone but within the visible plume zone. We recommend that all new and existing models are incorporated into a formal management strategy evaluation, for all measurement endpoints, as soon as possible.

2.2.5 Hazard identification and prioritisation

As noted in section 2.1.4 the joint venturers do not appear to have followed a formal hazard analysis procedure to identify and prioritise the potential impacts of the Gorgon development on the marine environment. As a result potential impacts or threat scenarios may have been overlooked or inappropriately prioritised. Chapter 6 for example states that the offshore feed gas pipeline may be stabilised using a top and intermediate rock mattress. Similar rock armouring techniques are proposed for the HDD shore crossing at North White’s Beach. Chapter 11, however, fails to identify the source of the rock used to armour and stabilise the pipeline, and does not discuss the potential impacts associated with the extraction and transport of the rock. Weekly resuspension of sediment by arriving/departing vessels and periodic dredging to maintain the shipping channel may also impede the recovery of corals in management units 3, 4 and 8 (and perhaps 5 and 6 depending on plume dispersion) impacted during construction activities.

A relatively high proportion of Chapter 11, and its associated technical appendices, is dedicated to the hazards associated with light, and its potential impacts on turtles. The hazards and impacts associated with underwater blasting and seismic tests, for example, are not afforded anywhere near the same level of detail. The level of detail within the EIS/ERMP is an implicit measure of hazard prioritisation but this is not supported by an explicit prioritisation procedure.

We suspect that a formal hazard analysis procedure would identify additional hazards and threat scenarios and provide a more defensible prioritisation. We therefore recommend that the joint venturers augment the current assessment with a formalised, systematic and transparent hazard analysis that addresses and prioritises all potential threats to the marine and terrestrial environment.

2.2.6 Uncertainty analysis

In Chapter 9 of the EIS/ERMP the joint venturers state that they have adopted a worst case approach to uncertainty. Worst case deterministic risk assessments are typically 'worst-case' for only one source of uncertainty (variability). They can be useful in risk averse circumstances but they provide an unknown level of protection that may not be 'conservative' because of the other sources of uncertainty that are unwittingly ignored (*pers comm.* Mark Burgman, University of Melbourne). Furthermore this approach is not consistently applied throughout the EIS/ERMP.

In Chapter 11 the joint venturers adopt a best – anticipated – worst case approach for sedimentation impacts on coral that explicitly recognises that coral's resistance to turbidity is variable. Other inherently variable parameters, such as nesting turtle population estimates, turtle recruitment rate and hatchling mortality rate, however, are treated in a deterministic fashion. We therefore recommend that the joint venturers undertake a much more thorough uncertainty analysis, ideally within the framework of a formal management strategy evaluation.

2.2.7 Regional risks

Many of the 'low' risk assignations in Chapter 11 are justified by the joint venturers on the basis that the species/habitats impacted at Barrow Island are well represented through-out the region. This is not a risk averse strategy, particularly in the absence of any formal assessment of existing or potential threats to species/habitats in the entire Pilbara region. This approach exposes the species and habitats in the area to the 'Tragedy of the Commons" (Hardin 1968) wherein industries and developments throughout the region individually claim that their activities are low risk because species/habitats that they impact are well represented. This approach can only be defended from a risk assessment perspective if the joint venturers increase the boundaries of the assessment to include the entire Pilbara, and thereby assess the cumulative impacts of all activities in this region. There is, however, no evidence of this in Chapter 11 of the EIS/ERMP and we are unaware of any equivalent assessment.

2.2.8 Sediment dispersal model

The additional information package does not provide a detailed description of the sediment dispersal model (GCOMD) used in the EIS/ERMP. These types of models are now freely available as downloadable software and we would not therefore expect to see such a description. The implementation of the model, however, is critical to its efficacy. We would therefore expect to see a detailed description of how the model was set, how the resolution was chosen, how it resolves the bathymetry, what the boundary conditions are and how they work, how the density structure is specified and maintained, what kind of mixing scheme is used, and so on. It is difficult to comment on the efficacy of the model in the absence of this information.

The model clearly simulates tidal currents well. Suspended sediment plumes, however, will remain in suspension over many tidal cycles. Tidal movement largely represents a background back-and-forth motion. The dredge plume will also be subject to lower frequency events such as extreme wave or current conditions – i.e. the plume may propagate by settling during calm weather, and being resuspended under higher wave or current conditions. Importantly we do not know if and how the model simulates these events and are therefore unable to gauge the potential accuracy of the model under the range of actual environmental conditions that will be experienced during the dredging operation.

2.3 Chapter 12: Quarantine risks and management

2.3.1 Methodology

The introduction and establishment of non-indigenous species (NIS) is considered to be the primary potential threat to the conservation values of Barrow Island (EPA 2003). The joint venturers assert that they collaborated closely with community groups and stakeholder, to develop a 'world class' Quarantine Management System (QMS) that responds to this threat in a manner which meets the communities expectations. The Quarantine Management System is based on three assessment techniques:

- an Infection Modes and Effects Analysis (IMEA) that identifies and prioritises quarantine hazards;
- a Preliminary Barrier Assessment (PBA) that identifies potential quarantine barriers that are subsequently carried through to a detailed design phase; and,
- a Quarantine Hazard (QHAZ) workshop that evaluates the quarantine risks associated with the detailed design and design improvements and controls.

The PBA is only needed in the absence of a detailed development design which prevents execution of the full-scale QHAZ workshop. Hence, at the conceptual design stage all three techniques are employed resulting in a 7 step QMS process that systematically identifies all potential quarantine risks and management options to reduce these risks to a level that is consistent with community expectations. At a detailed design stage the PBA is unnecessary, the QHAZ and its planning step follow immediately from the IMEA, reducing the QMS to a 5 step process (Chevron Australia 2005).

The joint venturers have identified 13 terrestrial exposure pathways and 9 marine exposure pathways and three biological groups: vertebrates, invertebrates and plants. Note that this results in 66 group/pathway combinations across the marine and terrestrial environment, in a 7 step (conceptual design) or 5 step (detailed design) QMS process. The total number of evaluation steps in the QMS process therefore ranges from 330 to 462. To date the joint venturers have only completed approximately 100 of these steps (Chevron Australia 2005).

2.3.2 IMEA and QHAZ

Infection Modes and Effects Analysis (IMEA) (Hayes 2002b) is a variant of a well trusted hazard identification tool, Failure Modes and Effects Analysis that has a long history of successful industrial application (Palady 1995). IMEA is designed to systematically identify and prioritise potential biological hazards. It is important to note that IMEA provides robust hazard rank scores. It is not designed to provide robust measures of absolute risk and its results should not be interpreted in this manner. The QHAZ procedure adopted by the joint venturers is based on HAZOP analysis (Kletz 1999). Again this is a well tried, proven methodology that allows the proponents to systematically explore deviations from the intent of each quarantine barrier.

Technical Appendix D2 demonstrates that the joint venturers have a good understanding of IMEA and HAZOP. The biological groups and invertebrate sub-groups identified in the Appendix and additional information package are sensible. The application of IMEA and QHAZ in this quarantine context is highly commendable. Note, however, that similar approaches do not appear to have been applied to other hazards associated with the proposed development. The IMEA may be improved slightly by reducing the number of scoring categories from ten to five. This may facilitate the workshops. In our experience participants at IMEA workshops often have difficulty distinguishing between scores of (for example) 3 and 4, or 7 and 8.

The IMEA methodology appears to have been implemented appropriately but we cannot verify this because the EIS/ERMP does not contain records of any of the IMEA workshops, or more importantly, the results of these workshops. The variance associated with the IMEA scores, for example, provides interesting insight into the group's deliberation process. These data, together with the final hazard rank scores, are not presented in the EIS/ERMP or the additional information package. It is also unclear how the joint venturers have used the results of the IMEA. Priority pathways addressed in the additional information package, for example, were 'nominated by the Quarantine Expert Panel' and not apparently prioritised via the IMEA. The results of the QHAZ are also not presented here, presumably because none had been completed when the EIS/ERMP was released.

2.3.3 Quarantine barriers and community expectations

The quarantine barrier selection method, or more specifically the decision rules which they are based on, is seriously flawed. This is undoubtedly the most important error in the proposed QMS. This error arises because the joint venturers have incorrectly interpreted the IMEA infection scores to represent absolute measures of risk. They do not - they are only robust in a relative, not an absolute, sense (see above). This error is most damaging in the decision rules that qualitatively combine infection scores at each pathway step into an overall introduction score. Here the joint venturers propose that if the effectiveness score of m barriers - scored in terms of the likelihood of pathway infection with the barrier in place – is n or less, then the overall residual risk of introduction for that pathway is n-(m-1).

The rationale behind the joint venturers' approach is that multiple barriers along a pathway, each of which individually reduce the risk of infection, must reduce the overall risk of infection. This proposition is true but the overall risk reduction, and ultimate level of protection provided by multiple barriers, cannot be accurately measured using semi-quantitative scoring systems such as the infection scores of the IMEA. This approach is analogous to the flawed logic of qualitative risk calculations that assert that the product of two 'low' probabilities is 'very low' (Hayes 2002c). The product of two 'low' probabilities does not equal 'very low' - it's just lower than 'low'– you cannot say any more than this without resorting to quantitative risk estimates. Similarly the joint effect of two quarantine barriers that each reduce the likelihood of infection to a slight chance is something lower than a slight chance. Nothing else, however, can be defensively deduced from this logic.

The flaw in the joint venturers' logic is best exemplified by considering the effect of 10 totally ineffective quarantine barriers – i.e. ten barriers that each score 10 (infections occur continuously throughout the year) in terms of the likelihood of pathway infection. Under the approach described in the EIS/ERMP the overall residual risk of introduction for that pathway would be 10-(10-1) = 1 - i.e. the infection is extremely remote, highly unlikely. This is obviously nonsense and clearly not a sound basis for a 'world class' QMS.

The reality of the joint venturers' approach to quarantine barriers is an arbitrary, unquantified level of quarantine protection that can not demonstrably meet community expectations. It is unfortunate that this logic features early on in the QMS process because everything from this point forward is fundamentally flawed and scientifically indefensible. We strongly recommend that the barrier selection analysis be completely re-done.

We suggest that the only defensible way forward from this point is for the joint venturers to use the work completed to date to:

- in close collaboration with the community re-specify the qualitative expression of their expectation into a quantitative measure of quarantine risk;
- use existing information sources to quantify a range of possible infection metrics for each pathway/group, together with the expected range of import units (tonnes of aggregate, number of personnel visits, etc) for each pathway;
- quantify the likelihood of detection and sterilisation for promising quarantine barrier methods; and,
- quantify the residual risk of infection and compare this to the community expectation.

The statistical sensitivity of a range of potential quarantine procedures is well described in the international literature (see for example Hayes et al. 2005a, Redmund et al. 2001, Yamamura and Katsumata 1999). We recommend that the joint venturers use the IMEA to prioritise potential quarantine hazards and then use relevant statistical models such as these in a quantitative risk management approach.

We also note that many of the infection pathways described in the EIS/ERMP are long and complicated. In some cases this may preclude confident quantitative risk estimate predictions. If this proves to be the case the joint venturers should consider simplifying the assessment by asking the community to re-specify its acceptance criteria at earlier points in the pathway, and establish statistically sound testing and inspection routines at this point to ensure that their expectations are met. Note this approach does not preclude quarantine management activities at later points in the event chain.

2.3.4 Marine quarantine threats

The joint venturers' assessment of marine quarantine threats is poor. The EIS/ERMP notes that the marine environment is exposed to NIS from a number of sources, many of which are independent of the proposed development activities. This is true but it is not sufficient rationale to ignore the sources of marine NIS that are directly associated with the proposed development. The potential for new trading routes linking Barrow Island to new sources of potential NIS is particularly important in this context (see Carlton 1996). The proposed development will entail weekly visits by LNG ships to Barrow Island. The EIS/ERMP, however, does not identify the international ports of departure and trading routes of these vessels relative to existing international routes in the Pilbara region. It is not possible therefore to assess the extent to which Barrow Island will be exposed to potential new marine pests.

The EIS/ERMP notes that ‘prior to accepting marine vessels from international ports, an environmental matching risk assessment will be undertaken to determine if environmental conditions are compatible for the translocation of species’. The waters around Barrow Island are warm and fully saline. We therefore suspect that an environmental matching risk assessment will provide little if any risk resolution for the vast majority of ports in low latitude areas of the world (see Barry et al. submitted). We therefore recommend that the joint venturers augment the environmental match assessment with a species-specific assessment based on, for example, the potential next pest list (Hayes and Sliwa 2003, Hayes et al. 2005b).

The baseline survey conducted in the waters around Barrow Island (Technical Appendix D7) is cursory, poorly described and apparently incomplete. The sampling methods are described in very general terms such as ‘diving’, ‘snorkelling’ and ‘samples were collected’. It is not clear from this which areas were surveyed and how, for example, dinoflagellate species were collected and identified. The sensitivity of the survey methods relative to target species is completely ignored. Furthermore the reference to the target marine species (declared pest species) is out of date and ignores the potential next pests identified in the new National System for the Prevention and Management of Marine Pest Incursions (Hayes et al 2005).

Finally, the efficacy and practicality of the suggested management measures for hull fouling threats is dubious. The EIS/ERMP does not appear to recognise the threat posed by niche areas on vessels (Coutts and Taylor 2001) and does not describe how wetted hull surfaces of vessels will be inspected and cleaned/disinfected, particularly for large (> 25m) vessels.

2.3.5 Detailed pathway assessments

The detailed pathway assessments described in the additional information package provide a comprehensive description of the infection pathways and potential quarantine barriers. The arguments provided here, however, are largely mute because of the flawed logic that pervades the residual risk estimates (section 2.3.3). The substantial data contained within these assessments, however, could support a quantitative risk management approach. For example, the joint venturers note that an outline of the quantity and frequency of personnel and cargo movements are presented at the start of each quarantine risk assessment workshop. This type of data could help inform a statistically valid inspection and testing routine.

The infection pathways described for each of the priority pathways represent planned events. This analysis could be improved by also considering the effect that unplanned events along the infection pathway may have on the residual risk estimates. These types of events can be postulated using the formal hazard techniques discussed in section 2.1.4 and section 2.2.5.

It is apparent from the detailed pathway analysis that the residual introduction risk of some pathways/biological group combinations exceed the community expectations (notwithstanding the flawed logic of the risk estimates). The joint venturers' approach to this is unclear. Technical Appendix D3 notes that the joint venturers' inability to meet the community's expectations became apparent in the early quarantine workshops. As a result the Appendix recommends an establishment quarantine endpoint as opposed to an introduction endpoint. The additional information package, however, does not appear to acknowledge this, discuss it or recommend quarantine barriers between the introduction and establishment steps.

Extending the quarantine assessment from introduction to establishment lengthens the assessment event chain and thereby increases the complexity of the infection pathway. This increases the difficulty of the risk assessment. We suggest that the joint venturers consider shortening these event chains by seeking (in close collaboration with stakeholders) assessment and measurement endpoints earlier in the infection pathway.

3. TECHNICAL APPENDIX REVIEW

3.1 Protected Marine Species

3.1.1 Methodology

Appendix C6 – Protected Marine Species (PMS) – was prepared by RPS Bowman Bishaw Gorham Environmental Management Consultants. The consultants were engaged to conduct a literature review of protected marine species occurring within the proposed development area. In addition, the Appendix includes “opportunistic field observations” collected during intertidal, and marine benthic habitat surveys conducted by the consultants.

The Appendix states that the literature review was conducted with the assistance of independent researchers, Universities, the Western Australian Museum (WAM) and other State and Federal government organisations. Literature and data sources cited in the Appendix, however, are based primarily on the web-based information and restricted government department surveys on several taxonomic groups or un-referenced information. The habitat and food preferences of turtles, for example, are based on web-based information sheets Environment Australian (2000/1) rather than the scientific papers used to produce them. While the distribution of two whale species “occurring in the Barrow Island region” are referenced as “listed on the DEH website”. Many sections of the Appendix are based on a single general text such as Storr et al. (1986). Unpublished WAM fish data is included for nearby areas but there is no obvious information from university studies. Notable references that do not appear to have been sourced include: Allen (2000), Fry et al. (2001), Pogonoski et al. (2002), Hutchins (2003), and Guinea and Whiting (2005).

3.1.2 Results

The Appendix lists 102 protected vertebrate species that ‘may be’ resident, occasional visitors or migrants in the waters around Barrow Island. It contains a useful description of which aspects of the development potentially threaten the PMS, a concise explanation of West Australia’s marine conservation park and nature reserve system and a good summary of relevant national and international legislation.

The quality of information and scientific credibility of the Appendix varies between taxonomic groups. The distribution and habitat preferences of cetaceans, turtles and dugongs are reasonably well described. More quantitative information on the areas used by dugongs and resident populations of several dolphin species is needed, however, to determine whether or not they will be impacted by the proposed development. Reliable data is also absent for a number of (non-migratory) whale species that are listed as likely to be present in waters around Barrow Island. This data could be obtained from the DEH *Species Profile and Threats web-based Database*(http://www.deh.gov.au/cgi-bin/sprat/public/sprat.pl).

There is a pervasive lack of reliable survey data for the listed sea snakes and fish (sharks, pipefish, seahorses and seadragons and serranids). The Appendix is replete with statements such as ‘appears to be...abundant around Barrow Island’ (sea snakes), ‘may occur near Barrow Island’ (sharks) and ‘unconfirmed sightings have been made’ (seadragons). Anecdotal information of this type is insufficient support for the purposes of, and the current conclusions drawn by, the EIS/ERMP. Seadragons, for example, are a temperate, southern Australian species that (to our knowledge) have never been recorded in sub-tropical or tropical waters. The presence, abundance and distribution of all PMS, both inside and outside the development’s impact zones, should be properly addressed via a quantitative sampling strategy.

This problem is compounded by the absence of information on the reproductive behaviour, preferred habitat and diet requirements of PMS. This data could identify locations around Barrow Island where PMS, if they were present, may aggregate to reproduce and feed, and hence the likelihood that they would be affected by the proposed development. There are 32 EPBC listed species of Sygnathids (sea dragons, seahorses and pipefish) and 14 EPBC listed species of sea snakes. The Appendix does not address the presence, abundance, habitat or dietary preferences of any of these species.

Relevant information sources that do not appear to have been used include:

- the diet and reproductive behaviour of sea snakes in northern Australia (Fry et al. 2001, Guinea and Whiting 2003, Philips and Hale 2005);
- distribution, habitat and diet information for seahorses listed in Fishbase http://www.fishbase.org; and,
- habitat, distribution and ecology of seahorses, pipefish and Serranid fish (Hutchins 2003, Pogonoski et al. 2002, Allen 2000)

This does not represent an exhaustive list of relevant literature. These are simply examples that are readily apparent to us. As a literature review, the Appendix fails to examine all relevant and readily available literature on all PMS listed in the EIS/ERMP. It also fails to determine whether the PMS are definitely present in the proposed development areas, with the exception of some species of sea turtles and migratory whales. Furthermore, it fails to address the presence of PMS on the approach to, and shore crossing of, the mainland end of the proposed domestic gas pipeline. This may be due to the presence of an existing pipeline in the preferred location (East of Passage Island), but nonetheless the alternative shore crossing (East of Cowle Island) should be addressed.

3.2 Sea Turtles

3.2.1 Methodology

Appendix C7 – Sea Turtles – was prepared by RPS Bowman Bishaw Gorham Environmental Management Consultants. It provides an overview of the literature for species known from the Barrow Island region. It also summarises the results of two summer monitoring programs of turtle nesting sites and three light influence experiments conducted by Pendoley Environmental Pty Ltd for Sinclair Knight Merz. We are not qualified to comment on the efficacy and quality of the light experiments. The Appendix also notes that surveys were carried out between 1998 and 2004 and that selected beaches were routinely monitored but does not provide details of the methodology, timing and location of these surveys.

The Appendix describes two quantitative turtle nesting site surveys conducted in the summer of 2003/04 and 2004/05. The first survey included areas around a proposed pipeline crossing at Cape Dupuy. The pipeline landfall locations, however, were subsequently altered so the 2003/04 surveys targeted the wrong area. Sampling locations for the second survey were reduced and altered to include proposed development sites and adjacent beaches, and sampling was extended into February to cover the peak period of green turtle nesting. The survey methodology, based largely on turtle tracks in the sand, is clearly explained. It is not clear from the discussion, however, whether different species can be easily distinguished on this basis, or whether sampling once a month on spring low tide is sufficient, given the variability in numbers. The data is presented as number of animals per kilometre of beach per night to allow a comparison of the relative nesting effort for each species between beaches.

3.2.2 Results

The Appendix introduction states there are 6 species of sea turtles in northern WA waters, but of the 4 species typically found nesting on the north-west shelf, only three are commonly found in the Barrow Island region: the green, flatback and hawksbill turtles. The Appendix contains no information on the presence, distribution or nesting behaviour of loggerhead turtles and the olive ridley sea turtle. This is an important omission.

The literature review could be improved by more specific reference to the species found on Barrow Island, and species-specific summaries of their breeding and feeding activities (supported by appropriate citations), and a more thorough definition of the habitat terms that are subsequently used.

The surveys confirm that Barrow Island is an important nesting and feeding site for green, flatback and hawksbill turtles on a regional scale. It shows that turtle nesting numbers can exhibit high variability on a short term and annual basis. The 2003/2004 survey provides a baseline of turtle nesting activity around the island. Important information in Pendoley (2005), however, was not included in the environmental consultant’s summary, including the fact that successful turtle nesting events only resulted from 50% of counted turtle tracks and that the Barrow Island populations of flatback, green and hawksbill turtles represent a significant proportion of the total estimated populations in the entire North West region.

Flatback turtles appear to nest predominately on the mid-east coast beaches adjacent to the proposed development site. Hawksbill nest sites have been found all around the island and appear to favour small rocky beaches and rubbly beach corners on the north east coast where the shallow sand depth precludes successful green or flatback nesting. These nesting preferences suggest that the survey methodology (which is based largely on sand tracks) may not be adequate for this species. Green turtles feed all year round on algae-covered rocky inter- and sub-tidal platforms of the west coast of Barrow Island. These turtles aggregate in spring and summer to mate. The location of these aggregations relative to the proposed development area, however, is not clearly stated.

Survey data is presented for various beaches on Barrow Island but their importance/proximity to the proposed development areas is not consistently described. Furthermore monitoring was not conducted during the entire nesting period of all three species that are discussed. Surveys were conducted during November, December, January and February. Data presented in the introduction, however, suggests that hawksbill nesting activity starts in August, peaks in October and diminishes in November. Furthermore the emergence of young flatback turtles in April after a 6 to 8 week incubation period suggests that flatback females may still be laying eggs in March. These results suggest that the survey period should have been extended to cover the months from August to March.

Monitoring data is only provided on nesting females. Some information on the presence, abundance and habitats of (adult and juvenile) turtles around Barrow Island at other times of the year is provided but needs to be quantified. The satellite telemetry study lacks information on the methodology and number of turtles sampled. This data shows green turtles are using the beach, rocky intertidal/subtidal platforms, rock pools and shallow inshore zones for such activities as feeding, nesting, resting and mating, throughout the proposed west coast development zone. All future survey activity should also clearly identify turtle nesting, inter-nesting, feeding and resting grounds relative to the proposed development locations. This information is not currently presented in a clear and concise format. Total number of turtle nests, together with number of animals per kilometre of beach, would also assist in identifying significant turtle aggregations.

3.3 Marine Benthic Habitats

3.3.1 Methodology

Appendix C8 – Marine Benthic Habitats – was prepared by RPS Bowman Bishaw Gorham Environmental Management Consultants. The consultants were engaged to survey marine benthic habitats in the proposed development areas. The consultants highlight the importance of benthic habitats stating that ‘the twin goals of maintaining biodiversity and maintaining ecosystem function can be achieved through protection of the benthic habitats on which the ecosystems depend.’ (Chevron Australia 2005).

The survey of marine benthic habitats was achieved via a ‘review of available information’ and a combination of snorkel and video transects conducted in August 2002, January 2003 and January 2004. Video footage was examined by marine biologists in order to characterise benthic habitats and assemblages. This information was supplemented by examination and photographs taken during the snorkel dives.

The Appendix does not describe how different habitats are identified, distinguished or assigned a conservation status. It does not describe the measurements (if any) that were taken or how many divers/biologists were used in the survey or the field conditions (e.g. visibility) at the time of the survey.

3.3.2 Results

Appendix C8 is of a low scientific quality. It lacks detail, quantitative rigour and does not adequately describe the benthic ecosystem function or biodiversity. The cited literature is potentially useful but does not appear to have been used to assist in the design and implementation of the surveys. The Appendix identifies a few organisms to species level but (in contrast to the terrestrial survey results) there is a notable absence of any species lists.

The coral communities surrounding Barrow Island are poorly described. Species that are present or characteristic of the various reefs, defining criteria for ‘high-profile’ reefs, and the proportional cover are not adequately or consistently described, particularly for Turtle Bay, the southern end of the Lowendal Shelf and the Barrow Island Shoals. The Appendix notes that Dugong Reef is degraded but does not describe which species are missing, the extent of coral cover relative to other areas, how much coral is still alive and whether or not there is any evidence of recovery. The Appendix also notes that the extent and composition of the fringing coral communities of the northeast and east of Barrow Island are unknown.

The Appendix highlights the importance of seagrass and macroalgae to marine food webs and as habitat for other marine organisms. The Appendix does not, however, recognise that they are ecologically and geomorphologically different and are likely to react differently to stressors (e.g. sedimentation) associated with the proposed development. Some species of seagrass are listed but it is not clear whether these species were actually observed during the survey, and there is no information on their distribution and abundance.

The situation is similar for the macroalgae habitats which make up 40% of benthic habitats in the Montebello/Barrow islands marine conservation area. Absent information that would allow some assessment of the relative risk to these areas, includes whether algal communities are uniform across the entire conservation area, or whether different types of algal communities are present and if so what the actual algae composition is. The Appendix alludes to differences between communities on the west and east coasts of Barrow Island, but the extent, species composition, diversity etc. of the two coasts are not developed further.

The description of infaunal soft-sediment and filter feeding communities is particularly poor. Filter feeding communities are likely to be the most diverse assemblages of invertebrates in the region. The Appendix recognises that the habitat value of these areas depends on how well developed these assemblages are, but provides no estimate of diversity or abundance, does not characterise different assemblages and does not assess their relative extent in the proposed development areas. The Appendix notes that areas covered periodically by transient sand sheets will have invertebrate assemblage that are more sparse than other areas, but it does not identify these areas or document how extensive they are.

3.4 Intertidal Habitats

3.4.1 Methodology

Appendix C9 - Intertidal habitats - was prepared by RPS Bowman Bishaw Gorham Environmental Management Consultants. The appendix provides information on six intertidal habitats (e.g. limestone reef, sand and mudflats, mangrove forests) found in the Barrow Island/Pilbara region (including the adjacent mainland) describing the geomorphology, flora and faunal assemblages. The subsequent description of proposed development areas, however, is brief and it is not readily apparent which of the intertidal habitats is relevant to each of the proposed developments.

The consultants appear to have conducted a single intertidal survey at spring low tide on the 26th to 28th January 2004. The area between the very low intertidal to supra-tidal zones was examined but survey methods are not described. Furthermore, there is no evidence of a comprehensive literature survey, collection of physical samples, lodgement of samples with appropriate museums or the involvement of any taxonomic experts. Potentially important data sources such as Wells et al. (2000) and MarLIN (http://www.marine.csiro.au/marlin/) do not appear to have been consulted.

The authors acknowledge that the alternate mainland crossing site (East of Cowle Island) was not adequately sampled, stating "the intertidal comprises of a flat limestone pavement extending approximately 400m seaward of the mangrove zone. The uppermost extent was not examined but the exposed limestone pavement extends at least 80m into the mangrove forest". (Chevron Australia 2005). No reasons are provided for this omission

3.4.2 Results

Appendix C9 is of a low scientific quality. It lacks detail, the survey methods are not described and there is no quantification of the presence of intertidal flora and fauna. Terms used are descriptive (eg. appears to be, moderately to densely vegetated…) and generalise over the entire region rather than the specific proposed development sites. Very few organisms are identified to species level and (in contrast to the terrestrial survey results) there is a notable absence of any species lists. The appendix provides a limited description of large obvious flora and fauna such as macroalgae, corals, crabs, gastropods, barnacles and fish. All these species can be observed by eye and we therefore suspect that few (if any) specimens were physically collected. Smaller macrofauna such as polychaete worms and small crustaceans, taxa groups that can be important indicators of environmental damage, are not mentioned. There is no evidence that the infauna (sediment fauna) was sampled at all.

Large species such as turtles, dugongs, dolphins, sharks, crustaceans and gastropods utilise intertidal habitats at high tide. The appendix does not assess presence/absence, distribution, seasonality, foraging behaviour, etc of these species beyond a photo of sharks foraging over intertidal flats. There is no discussion of the importance of the seagrass/macroalgae beds, either as a food source for grazing dugongs and turtles, or as a refuge for juvenile fish species during high tide.

There is very little information on the supratidal (dry sand and rocky areas at the top of the beach). This area is used by nesting turtles (addressed in Appendix C7) and as a foraging area for terrestrial vertebrates (e.g. lizards, water rats, possums and bandicoots) and invertebrates (isopods etc.). We assume that these species are addressed in the terrestrial appendices. The intertidal zone is also an important seabird roosting and foraging area. The Appendix notes that a juvenile sea eagle was found roosting in the mangroves near the proposed mainland pipeline crossing. We assume the presence/absence, distribution, seasonality, foraging behaviour, etc of other seabirds (including migratory waders protected by international treaties) are addressed in Appendix C3.

Appendix C9 concludes that the intertidal habitats of the east and west coast of Barrow Island, including the potential pipeline landfalls at North White's Beach and Flaucourt Bay, and the Town Point Causeway and landing, are of low conservation value. It is difficult to concur with this conclusion given the lack of detail provided in the Appendix. The description of the intertidal zone in the Town Point area is particularly insufficient given the development proposed for this area.

The scientific quality of the Appendix would be markedly improved by the inclusion of:

- a map of the surveys area showing their proximity to the proposed development areas;
- details of the survey and sampling methods used;
- some measure of the level of certainty of the identifications,
- quantified estimate of the intertidal fauna and flora to enable comparisons between areas; and,
- a list of species/taxa found in each surveyed area.

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4. CONCLUSIONS AND RECOMMENDATIONS

Chapters 9, 11 and 12 of the Gorgon EIS/ERMP contain some commendable analysis. The joint venturers attempted to carefully scope the assessment and define the terms they used. They recommend a measurement and monitoring strategy for impacts on water quality and benthic primary producers, and have used systematic hazard analysis tools to identify quarantine hazards associated with the construction and operation of the Gorgon gas project. Unfortunately these rare, and as yet incomplete, examples of good quality work are overwhelmed by too many examples of poor quality analysis.

The scoping and definition of terms used to describe impacts in the marine environment needs further work, particularly the meaning of the term ‘local’. The definition is currently circular, vague and open to different interpretations. The joint venturers do not appear to have used a systematic hazard analysis tool to identify and prioritise impacts in the marine environment. There is no evidence that the beliefs and values of stakeholders and community groups have been formally acknowledged or incorporated in the qualitative risk assessment. Many of the low risk predictions in Chapter 11 are justified on grounds of regional integrity, but are not supported by an equivalent regional assessment. This is not a risk averse management strategy. Furthermore this approach fails to recognise that the conservation status of Barrow Island is greater than the sum of its parts – i.e. the conservation value of Barrow Islands is greatly enhanced by the combination of its largely uninterrupted ecosystem components and processes.

The level of detail and quality of analysis varies dramatically between marine taxa. Disproportionately large sections of Chapter 11 and the technical appendices are dedicated to potential impacts on coral and some (but not all) species of turtles. The level of detail and quality of work directed to other primary producer communities and protected marine species is cursory and poor. Technical appendices C6, C8 and C9 are particularly poor. The literature review, surveys and data collation described here lack rigour and do not adequately support the risk assessment predictions made in Chapter 11. The chapter does not specify performance indicators, measurement or management strategies for the vast majority of assessment endpoints (valued ecosystem components and processes) that it identifies. Instead it is characterised by a few measurable performance indicators scattered amongst a sea of vague statements of intent. Consistent approach, supported by high quality analysis, is notably absent. All of these problems, coupled to the lack of a formal analysis of uncertainty analysis and sharp boundaries between different consequence categories, seriously undermine the scientific credibility of Chapter 11.

Burgman et al. (1999) note that population viability analysis is frequently ignored in favour of qualitative risk protocols, and highlight the weaknesses of these approaches for threatened species. All of these weaknesses, and more, are apparent in Chapter 11 of the Gorgon EIS/ERMP. Put simply the qualitative risk assessment and data presented by the joint venturers are not good enough to provide a high level of confidence that the threatened and endangered marine species in and around the waters of Barrow Island will continue to exist when the development is eventually decommissioned.

The joint venturers have clearly put a great deal of effort into developing and implementing a quarantine management system that will protect the endemic and native species on Barrow Island. This is appropriate given that Barrow Island’s iconic conservation status largely stems from the absence of introduced terrestrial pests that have exterminated, or continue to threaten, species of plants, birds and mammals on mainland Australia. Unfortunately the quarantine risk management strategies described in Chapter 12, and the additional information package, are fatally undermined by demonstrably flawed logic. The joint venturers describe the resultant QMS as ‘world class’ but in reality it provides an arbitrary and unquantified level of protection to the endemic, threatened and protected species of Barrow Island.

In completing this review we have made a number of recommendations. These are summarised as follows. We recommend that the joint venturers should:

1. in collaboration with stakeholders, augment the current risk assessment with a formalised, systematic and transparent hazard analysis that addresses and prioritises all potential threats to the marine (and terrestrial) environment;

2. conduct quantitative surveys of all relevant (impact and control) subtidal and intertidal habitats;

3. conduct a much more thorough investigation of the distribution, abundance and behaviour of protected marine species in each of the proposed development areas. This is particularly pertinent to the endangered species of loggerhead turtles and olive ridley sea turtle;

4. extend quantitative turtle surveys to fully include the nesting season of green, flatback and hawksbill turtles;

5. develop a management and monitoring strategy for all ecosystem components/process identified in the EIS/ERMP as threatened by the proposed development. Each of these strategies, including the current strategy, should be formally evaluated;

6. incorporate all new and existing bio-physical models into the formal management strategy evaluation recommended above, for all measurement endpoints, as soon as possible;

7. undertake a much more thorough uncertainty analysis, ideally within the risk management framework recommended above;

8. discard the current qualitative decision rules for quarantine barrier selection and replace them with quantitative estimates of efficacy;

9. use the IMEA to prioritise potential quarantine hazards and then use relevant statistical models, in a quantitative risk management analysis, to demonstrate compliance with community expectations; and,

10. augment the proposed marine environmental-match assessment with a species-specific assessment.

We also suggest that the joint venturers consider adopting a quantitative population viability analysis for protected marine species instead of the current qualitative approach. In addition we suggest they consider simplifying the quarantine risk assessment by asking the community to re-specify its acceptance criteria at earlier points in the infection pathway, and establish statistically sound testing and inspection routines at these points to ensure that the community's expectations are met.

In conclusion we believe that the EIS/ERMP needs to develop a comprehensive management strategy for key threatened marine and ecosystem components/processes, supported by considerably better data and analysis, together with a new quantitative approach to quarantine risk management, in order to reach a good scientific standard.

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