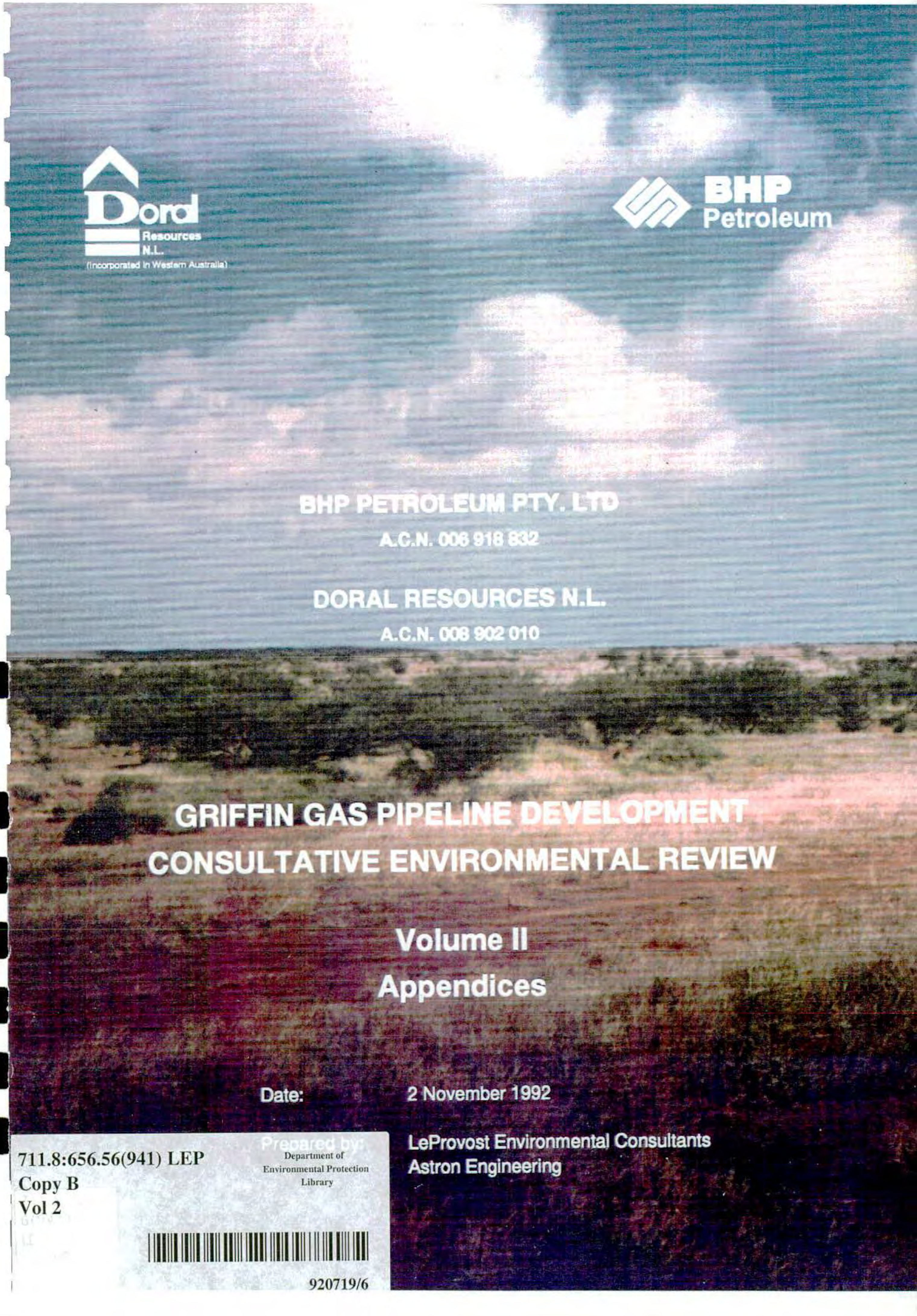

Doral Resources N.L.
(Incorporated in Western Australia)

BHP Petroleum

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GRIFFIN GAS PIPELINE DEVELOPMENT
CONSULTATIVE ENVIRONMENTAL REVIEW

Volume II
Appendices

Date: 2 November 1992

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Astron Engineering

APPENDIX 1

GRIFFIN GAS PIPELINE DEVELOPMENT

CONSULTATIVE ENVIRONMENTAL REVIEW GUIDELINES

ENVIRONMENT PROTECTION AUTHORITY

WESTERN AUSTRALIA

21st August, 1992

GAS PIPELINE FROM GRIFFIN OILFIELD TO MAINLAND FACILITY NEAR ONSLOW

CONSULTATIVE ENVIRONMENTAL REVIEW GUIDELINES

Overview

In Western Australia all environmental reviews are about protecting the environment. The fundamental requirement is for the proponent to describe what they propose to do, to discuss the potential environmental impacts of the proposal, and then to describe how those environmental impacts are going to be managed.

If the proponent can demonstrate that the environment would be protected from unacceptable environmental impacts, then the proposal would be found environmentally acceptable; if the proponent cannot demonstrate this, then the Environmental Protection Authority (EPA) would recommend against the proposal.

Throughout the environmental review process it is the aim of the EPA to advise and assist the proponent to improve or modify the proposal in such a way that the environment is protected. Nonetheless, the environmental review in Western Australia is proponent driven, and it is up to the proponent to identify the potential environmental impacts and design and implement its proposal so as to protect the environment.

The proposal currently has not been designated under the Commonwealth's Environment Protection (Impact of Proposals) Act, 1974. The Commonwealth Environment Protection Agency and the Department of Primary Industries and Energy are reviewing the decision and may yet decide to designate the proposal. If this occurs the guidelines may be amended and conditions could be set by the Commonwealth Minister for Resources for that part of the proposal in Commonwealth waters.

State environmental legislation only applies to the portion of the proposal in State waters, in terms of setting legally binding environmental conditions on the proponent. Although legally binding environmental conditions cannot be set for the portion of the proposal outside State waters, the Western Australian Environmental Protection Authority expects the proponent, BHP Petroleum Pty Ltd, to make appropriate commitments to address the environmental issues associated with that portion of the proposal.

For this proposal, protecting the environment means that the natural and social values associated with the inner continental shelf off Onslow and the terrestrial section of the pipeline route near Onslow are protected to the greatest extent possible. Where the values cannot be totally protected actions to mitigate or ameliorate the impacts are required.

Purpose of a CER

The primary purpose of a CER is to communicate clearly with the public and government agencies so that the EPA can obtain informed comments on the proposal. This provides the basis for the EPA to assess the proposal and to provide advice to Government on protecting the environment. As such, environmental impact assessment is quite deliberately a public process.

Objectives of the review

The Consultative Environmental Review should have the following objectives:

- to place this proposal in the context of the local and regional environment and to identify the environmental impacts of the progressive development of the oil and gas resources in the region, including the cumulative impact of this development;

- to explain the issues, decisions and feasible alternatives which led to the choice of this proposal at this place and at this time;

- to set out the specific environmental impacts that the proposal would or may have, including impacts from pipeline construction, possible petroleum spillage, possible shipping accidents and impacts of onshore facilities; and

- for each impact, to describe any environmental management steps, including monitoring, that the proponent believes would avoid, mitigate or ameliorate that impact.

The CER should focus on the key issues for the proposal and anticipate the questions that members of the public will raise. Data describing the environment should be directly related to the discussion of the potential impacts of the proposal. The discussion should then relate directly to the actions proposed to manage those impacts.

Key issues

The critical issue for the proposal is the need to show that there would be no significant impacts upon any sensitive marine or terrestrial biological communities from the construction of the pipeline and associated facilities and to evaluate the risk to any such communities from the operation of or accidents to the pipeline. The CER should therefore show a clear understanding of the conservation values of the biological communities potentially affected by the pipeline proposal.

In this case the key issues should include:

- the description and evaluation of the conservation and national estate values of the areas and biological communities potentially affected;

- an assessment of the impacts of the proposal upon any other industries affected by the proposal, for example, the prawning industry;

- the development of contingency plans and oil sensitivity maps in case of accidental events;

- the impacts of the development of the onshore support base, including the social impacts;

- the rehabilitation strategy for the terrestrial sections which are particuarly sensitive to erosion, for example, the coastal section.

- evaluate the relative environmental benefits of the alternative production facility options, for example, the floating production/storage and offloading facility (FPSO) and fixed platform facility; and

- evaluate the impacts of the tanker ballasting operations.

Any other key issues raised during the preparation of the report should also be discussed in detail along with the minor issues associated with the proposal.

Public participation and consultation

A description should be provided of whatever public participation and consultation activities are undertaken by the proponent in preparing and exhibiting (for four weeks) the CER. It should describe the activities undertaken, the dates, the groups and individuals involved and the objectives of the activities. Cross reference should be made with the description of environmental management for the proposal which should clearly indicate how any community concerns have been addressed. For this proposal, the social impacts of the development of the onshore support base and inerts treatment plant require assessment.

Detailed list of environmental commitments

The commitments being made by the proponent to protect the environment should be clearly defined and separately listed. Where an environmental problem has the potential to occur, there should be a commitment to rectify it. They should be numbered and take the form of :

what the work is;
who would do the work;
when the work would be carried out; and
to whose requirement (regulatory agency) the work would be carried out.

•All actionable and auditable commitments made in the body of the document should be summarised in this list, which may be included as a condition of approval.

APPENDIX 2

GRIFFIN GAS PIPELINE DEVELOPMENT

SUMMARY OF ENVIRONMENTAL EFFECTS OF GRIFFIN FIELD DEVELOPMENT

BHP PETROLEUM

October, 1992

APPENDIX 2 - SUMMARY OF ENVIRONMENTAL EFFECTS OF GRIFFIN FIELD DEVELOPMENT

TABLES

1.0 ENVIRONMENTAL EFFECTS OF FPSO

The Griffin oil field development is located in the North West Shelf area of Western Australia. The field is located in 130 metres of water, 70 km offshore and 30 km from the nearest shallow water or island shoreline. It is proposed that the field development will involve a series of subsea completed wells linked to a Floating Production, Storage and Offloading (FPSO) facility held on location by a disconnectible mooring system. Stabilised crude will be offloaded by means of a floating hose to an export tanker moored in tandem to the FPSO. Gas produced from the field will be compressed and transferred to shore via a submarine pipeline. Figure 1 provides details of the FPSO facility and subsurface development philosophy.

The FSPO is basically a large modified tanker constructed to enable:

- disconnectable mooring to the riser;
- monitoring of oil/gas production rates from the field;
- separation and stabilisation of the reservoir fluid into oil and gas sales products and produced water for discharge overboard after treatment;
- storage of oil product and offloading to export tanker;
- mooring of export tanker;
- accommodation of crew and crew changes;
- self-propelled movement and navigation; and
- assurance of crew safety.

The FSPO will be a purpose built, self propelled vessel. The vessel will be classed with one of the major Classification Societies and will have an unrestricted worldwide service notation.

The vessel will be designed to incorporate all necessary equipment and systems to comply with the requirements of regulations under the Petroleum Submerged Lands Act P(SL)A and the requirements of the Navigation Act (Marine Orders) as administered by the Department of Transport and Communications. These include safety equipment and fire control systems, navigation aids and pollution control equipment.

The size of the vessel will be in the vicinity of 110,000 deadweight tonnes (DWT).

This appendix details the environmental effects associated with an FPSO production facility and the environmental management strategies to be employed at the facility.

1.1 Facility Operations- Environmental Effects

These effects arise as a consequence of ongoing operations.

1.1.1 Drilling Operations

Drilling emissions and associated environmental effects related to this phase of development of the Griffin Field are contained in Table 1.

The most significant environmental effect associated with this phase is increased water turbidity surrounding the drilling vessel during mud discharge to the ocean environment. The turbidity will be localised to within 500 metres of the development and will dissipate within hours of discharge.

All other emissions indicated in Table 1 will have minimal environmental impact.

1.1.2 Production Operations

Production emissions and associated environmental effects related to this phase of development of the Griffin Field are contained in Table 2.

The most significant environmental effect associated with the producing phase of the development is the elevation in water temperatures associated with produced and cooling water streams from hydrocarbon processing carried out on the FPSO. The wastewater discharge is anticipated to have a detrimental effect on plankton either entrained in the cooling water streams or located at the outlet of the outfall during the summer period. The area effected will be localised to the vicinity of the outfall. The environmental effect likely to be observed as a result of the discharge is that fish will avoid the area in summer and will be attracted to the area in winter.

All other emissions indicated in Table 2 will have minimal environmental impact.

1.1.3 General

General environmental effects of the facility, not associated with a particular phase of development includes:

- The provision of artificial reef habitats at the development in the form of subsea structures (wellheads, flowlines, production riser, etc).

- Fishing exclusion zones surrounding the development which will provide refuge for marine species within the area and a haven for species recruitment. This will assist in the maintenance of fishery resources within the region.

- The provision of socio-economic benefits to the Australian Community, specifically to the :

  - Federal Treasury (Taxation benefits from project and employees);
  - Australian Balance of Payments (reduction in oil imports & opportunity to export domestic crude)
  - Australian Construction Industry (Project Development)
  - Australian Workforce (Increased employment opportunities);
  - local (WA) community (Benefit directly and indirectly from jobs created).

1.2 Potential Environmental Effects of FSPO Facility - Oil Spill

Further environmental effects may arise as a result of an oil spill.

1.2.1 Sources of Oil Spill on FPSO

Potential sources of oil spill have been identified for the FPSO Facility and are given in more detailed in Table 3. These sources include:

- minor incidents (tank overflows, pipe coupling failures, etc);
- floating hose failure;
- flowline rupture;
- major structural damage to FPSO or shuttle;
- total loss of offshore facility;
- exploration well blowout; and
- failure of automatic shutdown systems.

The risk associated with these sources contributing to an oil spill from the facility has been minimised through the:

(i) design and installation of reliable automatic safety equipment at the Griffin facility;
(ii) a thorough knowledge of the reservoir stratigraphy and formation pressure conditions to prevent blowout; and
(iii) adoption of operational procedures which will minimise the chance of tanker accident or loss of the FPSO.

1.2.2 Environmental Effects of an Oil Spill

Spilt oil having entered the environment will undergo weathering. This process consists of physical and chemical changes such as spreading, evaporation, dissolution, photooxidation, emulsification, biodegradation, sinking and beaching. The process of weathering reduces the volume, concentration and toxicity of the spilt oil with time.

In the unlikely event of an oil spill from the Griffin field, the field's distance from sensitive habitats (30 km to south and [illegible]0-70 km to the east and NE), coupled with the extremely light and volatile nature of the oil, means substantial evaporation and weathering will have occurred to the slick before sensitive shallow waters are threatened. Ample time will also be available to initiate approved oil spill contingency plans.

More specifically:-

- Griffin Oil is a very light crude oil (API Gravity 53o). Such a crude undergoes rapid weathering, with a well dispersed residue consisting of only 10% of the original volume after 24 hours.

- Deep water oil spills from the Griffin field which do not threaten the natural resources of the inner shelf will be left to degrade naturally where possible.

- Oil spills from the Griffin Development during conditions that move the spill toward the inner shelf would be treated by dispersant application. The distance between the Griffin development and sensitive natural resources ensures that only minor volumes of weathered oil **may** reach the shallow inner shelf.

- Modelling of a Griffin oil spill utilising largest wind excursions for summer and winter, indicate the coastlines of North Muiron Island & Flat Island at the mouth of the Exmouth Gulf are the only areas likely to experience oil spill residue encroachment, 48 hours after the initial spill. As a consequence the volatile nature of the oil the probability of encroachment after this period of time is less than 1 % of the spill volume.

2.0 ENVIRONMENTAL BENEFITS OF A FPSO VERSUS FIXED PLATFORM

This section details the relative environmental benefits associated with the Griffin field development as a Floating Production Storage & Offloading (FPSO) Facility versus a Fixed Platform development.

2.1 Environmentally Neutral Effects

The areas where the FPSO and fixed Platform developments are perceived as being 'environmentally neutral' are:

- Onshore Support Base Development.

  Both developments will require a shore based support facility of similar sizes, to provide:
  (a) Material Receipt, Storage & Handling;
  (b) Helicopter & Supply Vessel Logistics;
  (c) Operations and Technical Support;
  (d) Maintenance Support;
  (e) Communications;
  (f) Safety & Environmental Supervision of Projects;
  (g) Management, Finance and Personnel Administration.

- The development of artificial reefs around facilities.

  Both facilities will create an artificial reef habitat which will be colonised by a diverse range of encrusting organisms. This in turn will attract a wide range of fish species for shelter and food resources. This will be beneficial to the marine environment.

- Emissions associated with Drilling and Production Phases of the Development.

  Both developments will have the same method of oil and gas production, and drilling and development programs, hence the effects of the quality and quantity of environmental emissions and methods of waste disposal are neutral between the two developments.

- Fishing Exclusion Zones surrounding the developments.

  Both developments will require the declaration of a Fishing Exclusion Zone surrounding the facility. This zone will provide a refuge for fish and prawns and a haven for species recruitment which will assist in the maintenance of fishery resources within the region.

- Efficiency and Recoverability of the Oil/Gas Resource.

  Both methods of oil and gas production at the field can achieve optimum recoveries of oil and gas reserved within the area. The FPSO development will yield the hydrocarbon recovery at the lowest cost.

2.2 Environmentally Beneficial Effects of FPSO

The areas where the FPSO development is perceived to have beneficial environmental benefits over the fixed platform options are:

- The FSPO development does not require an onshore oil processing, storage and loading facility.

  The FSPO facility provides processing facilities on the vessel to stabilise crude oil for transportation in export tankers. A fixed platform development would require an onshore stabilisation, storage and loading facility. The alternative method of development would probably involve significant pipeline and pier development to allow for crude stabilisation within environmentally sensitive areas (inner shelf region).

- Significant advantages in decommissioning and reuse options for FPSO.

  The FPSO development, having extreme mobility (i.e. the capability to connect and disconnect to the mooring riser), will have significant advantages associated in the decommissioning phase of the development. Accordingly, reuse options associated the facility will be more attractive than those with the fixed platform option.

- Flexibility of process modifications and capacity upgrades with FPSO option.

  The availability of substantial deck area on the FPSO will allow for greater flexibility associated with process modifications and capacity upgrades. Increases in capacity associated with additional field developments can be achieved without consideration of additional fixed platform facilities and their associated environmental effects.

3.0 ENVIRONMENTAL EFFECTS OF BALLASTING OPERATIONS

Environmental concern associated with ballasting operations relates to the possibility of introducing marine organisms into Australian waters. This has occurred in many Australian ports in recent years. In general, introduced organisms tend to be a potential problem when either:

- exotic organisms which have a deleterious effect on natural systems or endemic species are discharged and subsequently establish and thrive in local ports; or when

- deballasting occurs close to a sensitive receptor, such as an aquaculture farm, where concentrated populations of fish are more susceptible to disease or parasite attack.

Neither of these circumstances apply at Griffin which is located 70 km offshore and in 140 meters of water. However, important human and marine resources occur in the coastal region adjacent to the oilfield. These are:

- the Rowley Shelf islands (35 km approximately to the south);
- Ningaloo Marine Park (90 km approximately to the south-west);
- Exmouth Gulf prawn fishery (100 km approximately to the south);

hence the need for reliable assessment of potential effects.

Ballasting and deballasting by the FPSO should not be a problem because it will be moored at the Griffin site and will only discharge seawater taken on at the site.

Export tankers' ballast water however, may contain marine organisms from the port of origin, hence raising the question of potential for introducing nuisance organisms.

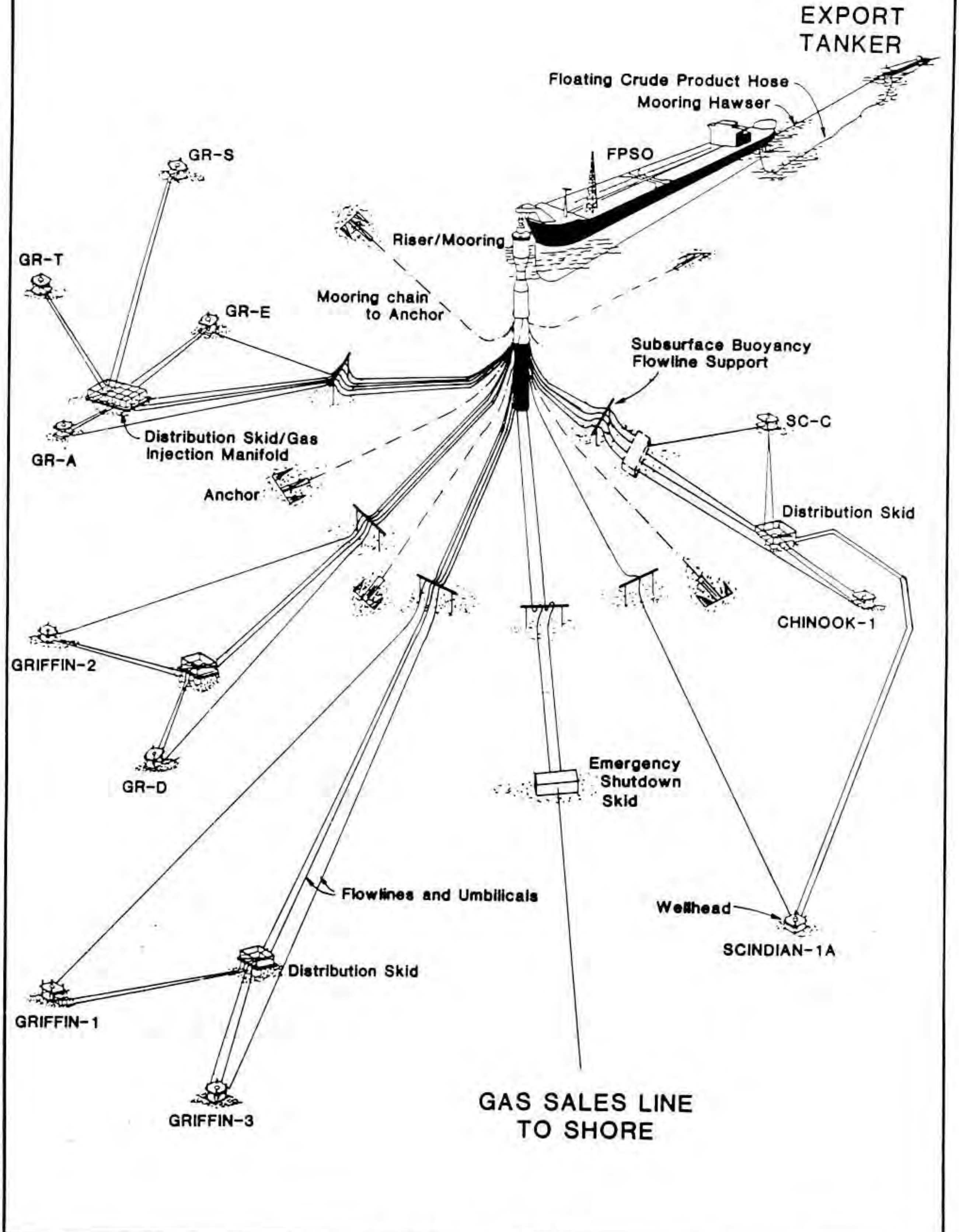
This issue is a function of world trade of bulk commodities. It has been reviewed by the Bureau of Rural Resources (Jones 1991) who indicates that control measures are presently not available, but are under investigation. This review indicates that no introductions of deleterious organisms have been recorded in tropical Australian waters. The probable reasons for this are as follows:

- if the port of origin is temperate, then introduced organisms are unlikely to survive; or
- if the port of origin is tropical, then most organisms will probably be in general tropical circulation and therefore in Australian waters already.

The potential for adverse impact arriving from export tanker activities associated with the Griffin development, seems low given that:

- most recorded deleterious introductions are of nearshore and intertidal organisms;
- the Griffin site is located well offshore and major oceanic currents in the region tend to flow parallel to the coast (i.e. Leeuwin Current);
- there have been no recorded introductions for North West Australian tropical waters (Jones 1991) despite the fact that some of Australia's largest ports, in terms of tonnage occur in the region (i.e. Dampier and Port Headland); and
- most of the export tankers visiting the Griffin site will originate from the South-East Asian region which is mainly tropical in nature.

The international shipping industry has recognised the potential problems that can arise from the discharge of ballast waters and the International Maritime Organisation (IMO) is currently preparing a set of operational guidelines to manage ballast waters. In accord with the BHP Environmental Policy, the Griffin development will adopt relevant international measures which might be adopted by the IMO to manage ballast water.



Environmental Drafting

BHP Petroleum Pty Ltd
GRIFFIN GAS PIPELINE DEVELOPMENT

SCHEMATIC DIAGRAM OF GRIFFIN OIL FIELD FPSO

Figure **1**

J249 R393 RWH 9/92

TABLE 1 - ENVIRONMENTAL EFFECTS - DRILLING

Emission	Quantity	Quality of Discharge to Environment	Duration	Environmental Management and Effect
. Drilling Cuttings . Water Based Drilling Mud	400m3/well 2000m3/well	Sand sized particles of calcarenite and claystone Non-toxic water based drilling fluid	Continuous (slow release) Intermittent	. Cuttings and mud to be released in accordance with P(SL)A requirements which set appropriate performance criteria for environment protection in the ocean environment. . Increase in water turbidity surrounding the drilling vessel during mud discharge. Turbidity localised within 500 metres of the development and will dissipate within hours of discharge. No detrimental environmental effects due to the: - selection of non-toxic water based drilling muds for routine drilling. Oil based muds are not anticipated at this stage; - the depth of water and associated oceanographic conditions (high dispersion and dilution) at site to prevent sediment accumulation beneath the rig; - the isolation of the development with respect to sensitive ecological resources (closest proximity areas are Serrurier and Bessiere Islands 30km SSE of development).
. Deck Drainage a. Uncontaminated Rainfall b. Contaminated Rainfall	 As developed As developed	 Stormwater quality <u>Oil in water content:</u> 30mg/l (24 hr average) 50 mg/l (instantaneous)	 Intermittent Intermittent	. Contaminated stormwater given primary treatment in separator to reduce oil content to P(SL)A requirements. All other discharge parameters are in accordance with P(SL)A requirements. . No detrimental environmental effects due to (as per drilling residues): - high water dilution and dispersion effects at site; - isolation of the development with respect to sensitive environmental resources.
. Domestic Wastes	30m3/day	Treated sanitary effluent and kitchen scraps, comminuted to particle size less than 25mm.	Continuous	. Emission is disposed in accordance with P(SL)A requirements for domestic wastes in offshore ocean environments. . No detrimental environmental effects anticipated due to: - high water dilution and dispersion characteristics at site; - isolation of the development with respect to sensitive environmental resources; - small volume of discharge stream.
. Oil Wastes	As developed	No discharge to the ocean/environment	Intermittent	. Wastes to be contained and transported onshore for appropriate disposal as per P(SL)A requirements.
. Solids/Packaged Wastes	As developed	No discharge to the ocean environment	Intermittent	. Wastes to be contained and transported onshore for appropriate disposal as per P(SL)A requirements.

TABLE 2 - ENVIRONMENTAL EFFECTS - PRODUCTION

Emission	Quantity	Quality of Discharge to Environment	Duration	Environmental Management and Effect
. Produced Water	Increasing to 12.72Mm3/d	Oil in water content: 30mg/l (24 hr average) 50mg/l (instantaneous) Discharge temperature approximately 70°C	Continuous	. Water will be continuously monitored for oil in water and discharged overboard in accordance with P(SL)A requirements which sets appropriate performance criteria for environmental protection in the ocean environment; . Recent marine monitoring programmes in vicinity of produced water outfalls confirm that there is no chronic hydrocarbon contamination in sediments and molluscs. . Temperature of formation water discharge will have detrimental effects on plankton in the vicinity of produced water outfall; Environmental effects include: - fish will avoid outfall area in summer, but be attracted to the area in winter; - effect will be localised to the area of outfall; . This will have no major effects upon the local ecosystems due to: - the high water dilution and dispersion characteristics at site; - isolation of development to sensitive environmental resources; - reliability of water handling equipment and operating processes/procedures associated with this type of offshore development.
. Cooling Water (Seawater Sources)				. Temperature increase in cooling water systems will have detrimental effects to plankton entrained in cooling water or receiving water from outfall in summer; Effects will include: - fish will avoid area in summer and be attracted to area in winter; - effect localised to area of outfall; . No significant environmental effect anticipated in local ecosystems due to: - water dilution and dispersion characteristics at site; - isolation of development with respect to sensitive environmental resources.
a. Process Cooling	1200m3/h	+10°c above ambient Copper content - 2mg/l Aluminium content - 1mg/l	Continuous	
b. Engine Cooling	100m3/h	+6°C above ambient Copper content - 2mg/l Aluminium content - 1mg/l	Continuous	
c. Gas Scrubbing	140m3/h	+5°C above ambient water emission will contain particulates	Intermittent	
. Deck Drainage				. Contaminated drainage from process skids given primary treatment to reduce oil content to P(SL)A requirements. All other discharge parameters used in accordance with P(SL)A requirements; . No detrimental environmental effects due to: - high water dilution and dispersion characteristics at site; - isolation of the development; - small magnitude of waste stream.
a. Uncontaminated Rainfall	As developed	As developed	Intermittent	
b. Contaminated Drainage from Process Area	As developed	Oil in Water Content: 30mg/l (24 h/range) 50mg/l (instantaneous)	Intermittent	

TABLE 2 - ENVIRONMENTAL EFFECTS - PRODUCTION (cont.)

Emission	Quantity	Quality of Discharge to Environment	Duration	Environmental Management and Effect
. Domestic Waste	100m3/d	Treated sanitary effluent and kitchen scraps comminuted to particle size less than 25mm.	Continuous	. Domestic wastes are disposed in accordance with P(SL)A requirements for domestic wastes in offshore ocean environments; . No detrimental environmental effects anticipated due to: - high water dilution and dispersion characteristics at site; - isolation of development with respect to environment sensitive resources; - small magnitude of discharge stream.
. Flue Gas from FPSO Engines (Fuel-Diesel/Natural Gas)	-	Standard combustion emissions - H_2O, CO_2, NO_x, SO_x.	Continuous	. No detrimental effects are anticipated due to atmospheric dispersion at site and distance from environmentally sensitive areas.
. Inert gas from FPSO Inert gas from Export Tanker	600m3/h 5000m3/h	N_2, CO_2 N_2, CO_2	Continuous Intermittent	. No detrimental effects are anticipated due to atmospheric dispersion at site distance offshore from environmentally sensitive areas.
. Flare Gas	0-113 km3/d	Standard combustion products H_2O, CO_2, NO_x	Continuous	. Development will recover available gas from reservoir, compress and transport the resource to shore via a gas pipeline. . Flare will be operational during commissioning, production upsets and emergency situations only. . No detrimental effects are anticipated due to atmospheric dispersion at site distance from environmentally sensitive areas.
. Ballast Water	-	Seawater quality	Intermittent	. No detrimental effects are anticipated due to: - quality of ballast water discharged; - segregation of ballast water tanks from oil tanks aboard export tankers and FPSO facility; - highwater dilution and dispersion characteristics at site; - distance offshore from environmentally sensitive areas.
. Solid Waste Residues a. Process Generated b. Waste Chemicals	 As developed As developed	 No discharge to ocean environment No discharge to ocean environment	 Intermittent Intermittent	. Solid waste residues to be contained and disposed in accordance with P(SL)A requirements. . Solid waste residues to be transported for onshore disposal. . No environmental impact from this source.

TABLE 3 - SOURCES OF OIL SPILL FROM FSPO

Source	Oil Spill Volume/Rate	Duration
. Minor Incidents - Failure of Flare Boom Burners during production testing from drilling rig; - Tank overflows; - Faulty operation of sea valves - Failure of pipe couplings on FPSO/tanker	2m3	Isolated incident
. Floating Hose Failure	40m3	Isolated Incident
. Flowline Rupture	80m3	Isolated Incident
. Structural Damage to FPSO/Shuttle Total loss of Offshore Facility	20 - 120m3	Isolated Incident
. Exploration Blowout	100m3/hr	Continuous Discharge until well controlled
. Failure of Automatic Shutdown Systems Combined with incident such as flowline rupture/floating hose failure	100m3/hr	Continuous Discharge until shutdown system is manually reinstated

APPENDIX 3

GRIFFIN GAS PIPELINE DEVELOPMENT

SUBMARINE GAS PIPELINE

SEAFLOOR SURVEY OF POTENTIAL ROUTES

Report	to	:	BHP Petroleum Pty. Ltd., BHP Petroleum Plaza, 120 Collins Street, MELBOURNE VIC. 3000
	by	:	LeProvost Environmental Consultants, Suite 2, Preston Centre, 175 Labouchere Road, COMO WA 6152

5 October 1992.

LEC Ref: J244

Report No. R387

GRIFFIN GAS PIPELINE DEVELOPMENT

SUBMARINE GAS PIPELINE

SEAFLOOR SURVEY OF POTENTIAL ROUTES

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SUBMARINE GAS PIPELINE

SEAFLOOR SURVEY OF POTENTIAL ROUTES

1 INTRODUCTION

1.1 BACKGROUND

The Griffin Area Oilfields are located approximately 60 km offshore to the north-west of Onslow, Western Australia in about 130 m depth of water (Fig. 1).

BHP Petroleum Pty Ltd (BHPP) proposes to install a submarine gas pipeline between a floating production, storage and offloading (FPSO) facility located at the oilfield and the mainland coast near the Tubridgi gas field west of Onslow. Where the pipeline crosses coastal waters (water depths <20 m), four potential routes have been proposed.

Routes 1 and 2 enter coastal waters approximately 4 km to the west of Bessieres Island, with Route 1 coming ashore close to the Tubridgi gas field at Urala whilst Route 2 reaches the mainland some 6 km to the south-west (Fig. 2). Routes 3 and 4 enter coastal waters 5 km to the north-east of Bessieres Island, with Route 3 also terminating at Urala (Fig. 2). Route 4 heads south-east towards the Roller oil field (near Ashburton Island), then parallels the mainland coastline before coming ashore 3 km west of the Ashburton River (Fig. 2).

As part of a feasibility study of the gas pipeline proposal, BHPP commissioned LeProvost Environmental Consultants (LEC) to undertake a seafloor survey along the four potential routes. The objective was to provide information on seabed character for route selection and environmental impact assessment purposes. The methods and results of this survey are presented in this report.

1.2 ACKNOWLEDGMENTS

Approval from West Australian Petroleum Pty Ltd (WAPET) to access information from other studies undertaken in the survey area is gratefully acknowledged, as is the assistance of Mr Jim Cullen, owner of Urala Station.

2 OBJECTIVE AND SCOPE

The objective of the survey was to obtain sufficient information on the seafloor and habitat characteristics along and in the vicinity of the four potential pipeline routes so that ecologically sensitive areas could be identified, thereby enabling more informed decisions to be made with respect to route selection.

The scope of work undertaken during this survey comprised:

- recording the bathymetric profile of each potential pipeline route;
- describing the seafloor and habitat type at appropriate locations along each route (selected on the basis of bathymetric information, including features indicating a marked change to substrate and/or habitat type);
- inspecting shallow subtidal habitats of potential ecological significance in the vicinity of the potential routes; and
- reviewing previous reports containing descriptions of shallow marine habitats in the survey area.

3 METHODS

3.1 SURVEY DETAILS

The survey was conducted during the neap tide period of 8-12 May 1992, using the Exmouth-based charter vessel *The Gun*. Winds were light for the duration of the survey period, and sea conditions were mostly calm with little swell. Precision of the bathymetric profiles is therefore high. Water clarity was good (>8 m) in all offshore areas, but decreased in nearshore areas (particularly where the silt component of the substrate was high). An almost continuous outflow from the Ashburton River between February 1992 and the survey period had contributed to high levels of water turbidity in nearshore areas. Underwater visibility in locations near the Ashburton River delta was frequently less than 20 cm.

3.2 BATHYMETRIC PROFILES

Bathymetric profiles were recorded on paper using a Furuno FE-400 depth sounder, with interpretation of seafloor characteristics assisted by inspecting the colour images produced by a JRC GFV-120 depth sounder. Position fixes along each pipeline route were obtained from the global satellite positioning system using a JRC JLU-122 and GPS plotter.

3.3 SEAFLOOR INSPECTIONS

A series of brief (five to ten minute) seafloor inspections were made by divers along each pipeline route. Inspection points were selected by interpreting the bathymetric profile in conjunction with the colour depth sounder images. Inspections were made at locations considered representative of apparently uniform tracts of the seafloor, and also at bathymetric features indicating a marked change to substrate or habitat type.

The seafloor inspections were made by two divers using Surface Supplied Breathing Apparatus (SSBA). At locations where water depth did not exceed 20 m, the following information was obtained:

- a photographic record (video and still) where water clarity permitted;
- a description of the surficial seafloor sediments and an estimate of their thickness;
- a sediment sample for in-field grain size estimation; and
- a description of the habitat type and visually dominant epibenthic biota, including visual estimations of the amount of seafloor coverage by these organisms.

Video records were obtained using a hand-held video camera and flood light, linked by umbilical to a TV monitor and VHS cassette recorder installed on deck. A Nikonos-V camera with a 20 mm lens was used for the still photographs.

Sediment thickness was estimated using a stainless-steel probe approximately 12 mm in diameter and sharpened to a point. The shaft was 1 m in length and graduated at 10 cm intervals. The probe was driven into the seafloor with a mallet either to its full length or to the point where an impenetrable substrate was encountered.

In-field estimation of the dominant grain-size of surficial sediments used conventional units, i.e. gravels (>2 mm), coarse sands (0.6-2.0 mm), medium sands (200-600 µm), fine sands (63-200 µm), silts and clays (<63 µm).

At locations where water depths were greater than 20 m, divers descended to 20 m to describe substrate features and any dominant epibenthic biota that could be identified beneath them [dive profiles exceeding 20 m could not be undertaken; these require a recompression chamber in accordance with Schedule 1990 of the *Petroleum (Submerged Lands) Act 1981* (Western Australia)].

4 RESULTS AND DISCUSSION

4.1 SEAFLOOR CHARACTERISTICS ALONG THE POTENTIAL PIPELINE ROUTES

Information on the substrate, sediment thickness, and benthic macroflora and epifauna obtained by the diver inspections are listed in Tables 1A-D, together with the geographical co-ordinates and water depth for each site.

The seafloor character between the inspection points was extrapolated by matching the diver descriptions with the bathymetric profile and colour sounder images, and is depicted in Figures 2 and 3. Because of alterations to vessel speed, the horizontal scale of the depth profiles shown in Figure 3 varies both along and between each of the four routes. However, the position of the inspection sites in Figure 3 can be used to match the depth profiles with the plan view of the pipeline routes shown in Figure 2.

The pertinent biophysical features which were found along each of the four routes are described below, and should be read in conjunction with Figures 2 and 3 and Tables 1A-D.

4.1.1 Route 1

The survey of Route 1 commenced at the base of the relatively steep slope forming the edge of the inner Rowley Shelf, and where water depth was 30 m (Fig. 2). At the first inspection site, the colour depth sounder (plus the divers description from 10 m above the seafloor) indicated that the substrate comprised a relatively featureless seafloor covered by a deep layer of silty sands.

Between 30 m and 22 m, an unbroken and mainly exposed limestone pavement occurred. Macrofaunal cover was estimated at less than 50%, with sponges and gorgonian sea whips the visually dominant components.

Between 22 m and 20 m, there was a terraced area covered by a thick (>1 m) sheet of fine sands colonised by a sparse epibiota (Figs 2, 3). This substrate type extended to the next portion of the incline, which comprised an exposed limestone pavement that was inspected at a depth of 17.5 m (site 1/4; Figs 2, 3). Benthic biota remained sparse (~10% cover; Table 1A), but there were areas of raised and broken limestone forming low ledges and shelter for fish and crustaceans (Plate 1).

The exposed limestone pavement formed a distinct ridge at right-angles to Route 1, and which peaked at a depth of 13 m (Fig. 3). Beyond this ridge the seafloor fell to a depth of 17 m, where there was a relatively flat area covered by unrippled medium-sized sands (65 cm thick) and colonised by a sparse epibiota (site 1/6; Table 1A). This sandy substrate extended to the base of a second slope, which comprised a further tract of unbroken limestone pavement rising from approximately 15 m to 11 m deep (Figs 2, 3).

Much of this pavement was covered by thin veneers of coarse to medium-sized sands (0-2 cm thick), and sponges and gorgonian fans were the most visually dominant component of a varied epibiota (which included macroalgae, bryozoans, ascidians, crinoids, sea stars, oysters and occasional favid and *Turbinaria* corals; Plate 2; site 1/7 in Table 1A).

At the top of the second slope, which also marks the divergence of Route 2 from Route 1 (Fig. 2), an area of raised and broken limestone pavement supported a dense coverage (80%) of the brown macroalga *Sargassum* (site 2/1; Table 1B). Where this pavement was overlaid by thin veneers of sand, *Turbinaria* corals were prevalent.

Beyond the second limestone ridge, the seafloor along Route 1 undulated between depths of 13.5 m and 12 m, and comprised a relatively uniform tract of limestone pavement which was veneered with medium to coarse-sized sands (0-38 cm thick). Patches containing shell gravel and limestone rubble were also present (sites 1/8-1/10; Table 1A). Coverage by benthic epibiota along this section of Route 1 was variable, with total cover of sponges, gorgonians, hydroids and hard corals ranging from <1% to 10%. Coverage by calcareous green macroalgae (*Halimeda*) and coralline and filamentous red and green algae ranged from 1% to 25% (Table 1A).

Between sites 1/10 and 1/14, Route 1 traversed two 5 m high ridges which were covered by a thick (65 cm to >1 m) sheet of medium-sized sands. This area was colonised by patches of seagrass (mainly *Halophila ovalis* and *Halophila spinulosa*) with seagrass cover ranging up to 25% at site 1/11 (Table 1A). Sparser patches of seagrass (<1 to 10% cover of *Halophila* spp.) colonised sand sheets to the south-east of the two ridges, and where depths remained close to 11 m (sites 1/13 and 1/14; Figs 2, 3).

The sandy seafloor extended to the edge of an area of unbroken limestone pavement which was veneered by thin sand sheets (0-55 cm) and colonised by a well-developed epibenthic community including the green alga *Halimeda* as well as sponges, gorgonians and hydroids (site 1/14 in Table 1A). Further south-east, the limestone pavement was covered by a bank whose surficial sediments comprised gravels and coarse to medium sands (Figs 2, 3). These were >1 m thick at site 1/15, and supported a 15% coverage of *Halimeda* and patches of *Halophila* spp. seagrass meadow.

Beyond the bank, limestone pavement and platform areas at sites 1/16 and 1/17 were veneered by sediment sheets of varying thickness (0-1 m) and composition (including shell gravels, sands and silts; Table 1A). Sponges and gorgonian whips were the most visually dominant biota, with isolated coral colonies (*Turbinaria* and *Porites*) common in areas where the sand veneer was very thin or absent.

The seafloor along the remainder of Route 1 (i.e. after site 1/17) gradually sloped upwards from a depth of 11 m to the mainland shoreline, and was dominated by soft sediments which contained an increasing silt component. This broad and relatively featureless tract of silts and sands (with occasional gravel patches) had a sparse epibenthic biota and appeared to have been regularly trawled (Table 1A).

At site 1/22, the route traversed a limestone outcrop which came within 2 m of the surface (Fig. 3). The outcrop was colonised by gorgonians, whips and fans producing a 10% cover, and by hard corals (mainly *Turbinaria* and *Montipora*) producing an estimated 25% coverage of living coral (Table 1A). Shoreward the seafloor comprised thick (>1 m) sheets of very soft silty sediments which were dominated by red/brown terrigenous silts and clays. Burrow holes were common (2-5 per m^2), indicating the presence of a substantial benthic infauna.

The Route 1 bathymetric survey was terminated approximately 1 km from the mainland beach at site 1/25, and where a 2 m high shallow limestone platform protruded from the 3 m deep seafloor. This platform was colonised by a high coverage (50-80%) of sponges, gorgonians and hard corals (including *Acropora*, *Montipora*, *Turbinaria* and favid species; Table 1A; Figs 2, 3). Very high water turbidity prevented the full extent of this nearshore platform area being determined, but it appeared to be at least 100 m in width. On the shoreward side of the platform the surficial sediments were less silty, with wave-stirred shallow subtidal sands merging with the coarser intertidal sediments that formed the sandy beach.

4.1.2 Route 2

Route 2 shares the same offshore section as Route 1 until water depths of 13.5 m are attained near site 1/8 (Figs 2, 3). The Route 2 survey commenced at site 2/1, which was located between sites 1/7 and 1/8 (i.e. near the top of the second limestone ridge where exposed portions of the pavement had a high cover of the brown alga *Sargassum*; Table 1B).

Southward along Route 2, the limestone pavement was veneered by patchy sand sheets up to 30 m in width and variable in thickness (2-60 cm; sites 2/1-2/2; Table 1B). The pavement area supported sponges, ascidians, crinoids and gorgonian whips, and at site 2/2 isolated coral colonies (*Turbinaria* and *Porites*) were present in low numbers (<1 per 5 m^2). The largest *Porites* colony observed was 1 m high and 2 m in diameter (Table 1B).

The area of exposed and veneered limestone pavement ended between sites 2/2 and 2/3, and where the bathymetric profile indicated the start of a large and relatively steep sand-covered ridge (Figs 2, 3). Water depth at the top of this 5 m high ridge was 8 m (site 2/3), and the substrate comprised a series of 1 m high sand waves which were 5 m apart and oriented in an east-west direction across the route. The medium-sized sandy sediments were 70 cm thick (in the troughs of the sand waves), and were colonised by patchy meadows of *Halophila* spp. seagrasses. These patches were up to 50 m wide and occupied some 50% of the seafloor.

Smaller patches of *Halophila* spp. producing coverages up to 20% were encountered along the relatively flat sand area between sites 2/3 and 2/8, and where depths ranged between 10.5 and 12.1 m (Table 1B). To the south of this sand and seagrass area, silt became an increasingly significant component of the surficial sediments.

West of Santo Rock, Route 2 traversed an area of broken limestone pavement thinly veneered by silty sands (<1 cm thick at site 2/8) and colonised by sponges, gorgonians, hard corals and crinoids (Table 1B). Between sites 2/8 and 2/14, the seafloor was relatively uniform, comprising a thick (>1 m) sheet of sediments dominated by silty sands and supporting a sparse community of epibenthic organisms typical of that found in trawl grounds (Figs 2, 3; Table 1B). The exception was an area immediately east of Locker Reef (site 2/12), where the seafloor comprised a silt veneered limestone pavement which supported a high coverage of sponges, gorgonians and a variety of hard corals (Table 1B).

South of Locker Island, Route 2 traversed relatively uniform areas dominated by thick sheets of silty sands (>1 m deep at sites 2/13 and 2/14), and then by gravelly sands and silts (65 cm to >1 m thick at sites 2/15-2/17). Epibenthic biota was sparse, with the most diverse area occurring at the low, gravelly ridge inspected at site 2/15 (Table 1B; Fig. 3).

Closer inshore, the gravelly substrate was replaced by sandy sediments with few burrow marks (sites 2/18 and 2/19). The Route 2 survey ended at the mainland coastline at site 2/19, which was located immediately seaward of a long sand beach and where water depth was 2 m.

4.1.3 Route 3

Routes 3 and 4 follows the same track from the Griffin Oilfields area until they reach the edge of the inner Rowley Shelf north-east of Bessieres Island (Fig. 2). Route 3 diverges from Route 4 where water depth is approximately 24 m and where the survey was commenced at site 3/1 (Figs 2, 3). At this site, the sloping, sand-veneered limestone pavement was colonised by a sparse cover (1%) of sponges, ascidians and *Halimeda* algae (Table 1C).

This pavement led to the base of a 4 m high sand-covered ridge where the thickness of the sand sheet exceeded 1 m (site 3/2; Fig. 3). Scattered pebble-sized rubble on the crest of this ridge provided a substrate for an estimated 5% coverage of sponges, ascidians, hydroids and crinoids (Table 1C). On the south side of this ridge a sand-covered slope led to the base of a well-defined 3 m high limestone ridge which was inspected at site 3/4 (Figs 2, 3). At this point thin veneers (<10 cm thick) of coarse sands covered a limestone pavement colonised predominantly by sponges, gorgonians and hard corals. This biota produced a 20% coverage, while seafloor coverage by *Halimeda* and coralline red algae was estimated at 50% (Table 1C).

To the south of this ridge, depths ranged from 16.5 m to 14.0 m over a relatively flat tract of limestone pavement covered with patchy sand veneers (Figs 2, 3). The macrobiota colonising the exposed or thinly-veneered pavement areas were dominated by sponges, gorgonian fans and sea whips (producing an estimated cover of 10% at site 3/6), while the sandy areas were most extensive at site 3/5 (where they were 70 cm thick and sparsely covered [<1%] by *H. spinulosa* and *H. ovalis* seagrasses; Table 1C).

Beyond this area of limestone pavement, a relatively uniform tract of sand-covered seafloor extended 6 km to the south between sites 3/7 and 3/10 and at a depth of 12-13 m (Figs 2, 3). The sheet of coarse to medium-sized sands along this section of Route 3 was over 1 m deep except at site 3/10 (where it was 25 cm thick over limestone). The sandy seafloor was colonised by patchy meadows of *Halophila* spp. seagrasses producing a cover ranging from 5-15%, and by the occasional sponge and ascidian (Table 1C).

West of Tortoise Island, the plateau of sandy sediments terminated at the base of a sloping exposed limestone pavement which rose from 13 m to a peak at 10 m (Figs 2, 3). This pavement was colonised by a 50% cover of *Halimeda* algae and a 25% coverage of sponges, gorgonians and crinoids at site 3/11 (Plate 3). The top of this slope and the southern downslope of the limestone pavement was veneered by sandy sediments up to 10 cm thick, and supported a relatively diverse benthos of sponges, gorgonians, soft corals, ascidians and crinoids, with both *Halimeda* and sparsely-distributed *Halophila* seagrasses also present (sites 3/11-3/14; Table 1C).

A sparse coverage (<1%) of *Halophila* seagrasses continued over a sand-covered, 2.5 m high ridge which was inspected at site 3/15, and where coverage by other soft bottom organisms (ascidians, hydroids, crinoids and sand dollars) was similarly low (<1%; Table 1C). Between sites 3/15 and 3/19, the seafloor comprised a relatively homogenous tract of gently undulating soft-bottom areas whose surficial sediments comprised varying proportions of gravels, fine sands and silts. The lack of significant epifauna and numerous burrow marks (typical densities 5-15 per m^2) are consistent with use of this area by local prawn trawlers.

A broad, 5 m high ridge to the south-west of Tongue Shoals was inspected at site 3/19 (Figs 2, 3). This ridge was covered by a thick (>1 m) sheet of silty fine to medium-sized sands, and the dominant epibenthos produced a very low coverage (<1% of *Halophila*, hydroids and crinoids; Table 1C).

Shoreward of this ridge, Route 3 traversed a 10 km long tract of seafloor which sloped gradually from 10 m to the mainland shoreline (Figs 2, 3). Seafloor sediments comprised very soft surficial sediments dominated by red, clayey silts containing little benthic epifauna but many burrow marks (densities 5-10 per m^2; sites 3/21-3/23).

This nearshore section of Route 3 traversed one area of raised limestone platform to the south-west of Manicom Bank at site 3/24 (Figs 2, 3). This small platform reef was colonised by sponges, hydroids, hard corals and filamentous algae producing a 50% coverage. The dominant corals were *Turbinaria* and favid species. Further to the south, Route 3 terminates on the same limestone platform surveyed at the southern end of Route 1 (site 1/25).

4.1.4 Route 4

The Route 4 survey commenced at site 4/1 where water depth was 30 m. The seafloor comprised silty sands and was apparently bare of benthic biota (Table 1D). Beyond site 3/1 (where Route 3 diverged to the south; Table 1C; Figs 2, 3) the sand-veneered limestone pavement continued upslope to the base of a 5 m high limestone ridge. This ridge peaked at a water depth of 17 m, where it supported a 10% coverage of sponges, ascidians, gorgonian fans and various hard corals visually dominated by *Turbinaria* (Table 1D). Most corals were small, isolated favids (typical diameter 20 cm), with densities of one colony per m^2 (Table 1D).

Beyond the crest, Route 4 followed an undulating tract of seafloor which comprised a thinly-veneered limestone pavement that extended 12 km to the south-east (sites 4/3-4/7; Figs 2, 3)). Where sand veneers were 25 cm thick, biota cover was approximately 5% (mainly clumps of sponges, ascidians and gorgonians). On ridges and where veneers were less than 10 cm thick, coverage reached up to 50% (mainly by the presence of *Turbinaria* corals and *Sargassum* algae).

South-east of the thinly-veneered limestone area, a tract dominated by thick (>50 cm) sheets of coarse and medium sands supported little epifauna and a low cover of *Halophila* seagrass (<5%; Plate 4; Table 1D). The gravelly area inspected at site 4/9 (north-west of Ashburton Island) supported a 5% cover of biota comprising mainly sponges, ascidians and gorgonians.

Immediately south-east of the gravelly area there was a steep, 5 m high sand-covered ridge which was inspected at site 4/10 (Figs 2, 3). There was little biota on the slope and a 25% cover of *Halophila* spp. seagrasses at the crest (Table 1D). South-east of this ridge the amount of biota covering the thick sheets of coarse to medium sands was low, except at site 4/12 (west of Ashburton Island), where coverage by *Halophila* spp. seagrasses was again estimated at 25% (Table 1D; Figs 2, 3).

South of Ashburton Island, gravel and silt became significant components of the surficial sediments. This substrate supported a relatively depauperate epibenthos typical of trawling grounds (mainly ascidians, fragmented sponges and damaged gorgonians; Plate 5; sites 4/13-4/16; Table 1D). Where Route 4 passed to the north and west of Roller Shoal (sites 4/15-4/16), numerous burrows (densities of 10-20 per m^2) indicated the presence of a diverse and abundant benthic infauna.

East of Manicom Bank, the final leg of Route 4 traversed the nearshore area where surficial sediments were dominated by red clayey silts and very little epifauna was found (virtually zero light and visibility prevented assessment of burrow marks).

4.2 SURVEY OF THE SHALLOW SUBTIDAL HABITATS IN THE VICINITY OF THE POTENTIAL PIPELINE ROUTES

4.2.1 Introduction

The expansive shallow subtidal areas surrounding many of the islands in the vicinity of the four potential pipeline routes have been inspected and mapped during previous surveys undertaken by LEC on behalf of WAPET (Figs 4-6). These areas are discussed in Section 5.

However, several shallow subtidal features in the vicinity of the routes have not been inspected, and these were visited immediately after the pipeline route survey. Diver inspections were undertaken at Table Island, Santo Rock, Tongue Shoals, Manicom Bank, East Locker Patch, Locker Reef and the Baylis Patches. The location of these sites is shown in Figure 2.

4.2.2 Table Island

Drift dives were conducted across the nearshore fringing reef along the eastern and northern sides of Table Island.

At the edge of the outer reef slope (water depth 6 m), the fringing reef was dominated by *Porites* bommies approximately 3 m high and 1.5 m in diameter and tabular *Acropora* colonies 1 m in diameter. Live hard coral cover was estimated at 50%, and the diversity of coral species was high (>40). The *Porites* bommies occupied an area 200 m in width and extended into 8 m deep water, with individual bommies up to 4 m high and 3 m in diameter. Most of the bommies were deeply undercut, providing shelter for a diverse community of mostly small reef fish species.

On the north-east side of the island, hard coral cover in the shallower water (4 m) was estimated at 70%, and was dominated by tabular and branching forms of *Acropora*, encrusting *Montipora*, and *Pocillopora* and *Pavona* spp. Further north was an area of dead staghorn and plate *Acropora* colonies. Many plates were overturned (indicating recent storm damage) and coral-eating gastropod snails (*Drupella*) were common.

Where depths attained 10 m on the north side, coverage by living hard coral was estimated at 75% and species diversity was high (>40 species). *Drupella* were found on some of the *Acropora* plates and recent predation by these snails was evident from the characteristic bands of white, dead tissue on these plates.

During the drift dives, the only large (>30 cm) predatory reef fish observed was a 2 m long groper (*Epinephelus lanceolatus*). The apparent lack of territorial reef fish such as coral trout suggests that Table Island is a favoured fishing and diving location.

4.2.3 Santo Rock

Inspection of Santo Rock (at 21° 38.120'S 114° 46.586'E) revealed this feature to be a limestone reef which rises almost 5 m from the surrounding seafloor (Plate 6). Much of this reef was covered by silt and turfing algae, and coverage by macrofauna (including corals) was estimated at less than 10%. However, the sparse hard coral community was reasonably diverse (mostly favid and encrusting species), and sponges, soft corals, gorgonians and crinoids were also present.

The fish fauna included planktivores (red-bellied fusilier, *Caesio cuning*), pelagic carnivores such as stripey (*Lutjanus carponatatus*), baldchin groper (*Choerodon rubescens*), red emperor (*Lutjanus sebae*) and spangled emperor (*Lethrinus nebulosus*), benthic-feeders (dasyatid stingrays) and a variety of herbivorous reef-dwellers including the ubiquitous damselfishes (*Pomacentridae*).

4.2.4 Tongue Shoals

The inspection dive at Tongue Shoals was centred at 21° 38.953'S 114° 50.420'E, and covered an area of gravel and sand with a heavy silt veneer. The area appeared to be regularly trawled, and the only biota observed were scattered seagrass plants (*Halophila spinulosa*). No bathymetric features indicating the presence of exposed limestone were found.

4.2.5 Manicom Bank

The inspection site at Manicom Bank was at 21° 41.753'S 114° 51.063'E, and covered an area of rippled sandy sediments with gravels and a heavy silt veneer. The area appeared to be regularly trawled and the only biota observed were a large sand-dwelling anemone and two groups of colonial anemones. Bathymetric features indicating the presence of exposed limestone were not found.

4.2.6 East Locker Patch

This shallow subtidal area lies 3.5 km east of Locker Island (Fig. 2), and at 21° 43.020'S 114° 47.754'E it comprised an area of high-relief (3-4 m) limestone veneered by silts. The hard coral community (Plate 7) was diverse though sparse (about 10% cover) with the exception of two *Porites* bommies approximately 1 m high and 2 m in diameter (Plate 8). A variety of gorgonians, sponges and hydroids was also present, along with coral trout (*Plectropomus leopardus*), stripey (*Lutjanus carponotatus*) and a diverse population of damselfish (*Pomacentridae*).

4.2.7 Locker Reef

Locker Reef comprises an area of exposed limestone of moderate relief, rising 2-3 m from the surrounding seafloor. One area on the reef top had a 60% coverage of *Montipora* coral plates (Plate 9), with favid corals and gorgonian fans also present. Towards the edge of the reef top several species of tabular *Acropora* were found, and these colonies provided an 80% coverage of living hard coral.

On the crest of the reef, hard coral cover was 70% (Plate 10), with 60% of this occupied by *Pocillopora* corals and a further 10% comprising the hydrocoral *Millepora*. The biota on the reef slope formed about 40% cover, and this community was dominated by soft corals, small *Turbinaria* and *Porites* colonies, and sponges. At the base of the slope *Porites* bommies about 1 m high and 2 m in diameter were common, and within 20 m of the reef base were coral gardens comprising 80% coverage by mostly *Acropora* and *Pocillopora* species.

4.2.8 Baylis Patches

The inspection site at Baylis Patches (21° 46.136'S 114° 42.536'E) was selected after a brief bathymetric survey to identify the highest feature above the surrounding seafloor. This comprised a raised, silt-veneered limestone platform rising about 3 m above the adjacent seafloor. The top of the platform was colonised by an estimated 50% coverage of soft coral and 30% coverage of hard coral. There were at least six species of soft corals, while the hard coral community was dominated by encrusting and foliaceous forms (mainly *Montipora*, *Echinopora* and *Turbinaria* spp.) with typical colony diameters of 0.5-1.0 m. Towards the edge of the platform small *Porites* heads up to 1 m high and 1.5 m in diameter were common. Coral colony sizes rapidly decreased and coral cover reduced to 5% near the edge of the reef, where water depths were 7-8 m.

5 REGIONAL PERSPECTIVE

5.1 INTRODUCTION

Most of the intertidal and shallow subtidal marine habitats in the region of the proposed pipeline have been mapped and described during previous surveys undertaken on behalf of WAPET (Figs 4-6; from LEC, 1991a,b). These studies concentrated on key mainland and island shoreline habitats, and their results are incorporated into this section courtesy of WAPET.

The principal coastal and marine habitats in the vicinity of the four potential pipeline routes are as follows:

- **intertidal flats**: supporting mangals, halophytic shrubs and/or blue-green algal films, the intertidal flats are associated with tidal creeks and the Ashburton River delta, and occur extensively behind the mainland beaches;

- **sand beaches**: occurring along almost all of the mainland coastline and encircling all islands;

- **intertidal limestone platform**: occurring in the low intertidal zone, and abutting most island sand beaches and limited sections of mainland beaches (e.g. at Rocky Point);

- **subtidal terrigenous silts and clays**: forming an apron in front of the Ashburton River delta.

- **subtidal limestone pavement and limestone platform**: bare or thinly veneered by silts or sands, and comprising extensions of the intertidal platform or forming discrete platform reefs and 'pinnacle' outcrops;

- **coral reef**: occurs on the above habitat, typically best developed around islands where it forms fringing reefs (e.g. at Serrurier, Table, Bessieres, Locker, Ashburton, Tortoise and Thevenard Islands);

- **subtidal sheets and shoals**: comprising gravelly, sandy or silty veneers of varying thickness throughout the region, with silts and gravelly shoals predominant in nearshore waters within 10 km of the mainland shore.

The distribution of these habitats which have been inspected and mapped near the four potential pipeline routes during the present and recent surveys is shown in Figure 7. Their distribution at known points has been extrapolated to provide an idea of the apparent regional distribution of the major habitat areas across the study region (Fig. 8). The inferred distribution pattern shown in Figure 8 is not actualistic, and merely presents a 'broad-brush' regional picture.

The following sections provide a summary description of the intertidal and shallow subtidal marine habitats and their associated species assemblages. Most species and assemblages within these habitats are characteristic of the tropical Indo-Pacific Biogeographic Region (Wilson et al., 1979).

5.2 INTERTIDAL FLATS

Occurring behind the mainland sand beaches, they support mangrove forests, heaths of low halophytic shrubs, or leathery films of blue-green algae (cyanobacterial mats).

The mangals are typical in both floristic and vegetation structure to those found along the Pilbara coastline. However, in contrast to other sections of this coast (where mangroves have developed along shoreline mudflats), mangals between Tubridgi Point and Onslow are confined to the Ashburton River delta and to six tidal creek systems (from Urala Creek in the west to Beadon Creek in the east; Figs 7, 8). The most developed and diverse mangrove forests are located in the Ashburton River delta, where six mangrove species were recorded during a recent survey (LEC, 1991b).

The extensive high tidal salt flats that lie behind the mangal zones and mainland beaches between Tubridgi Point and Onslow support halophytic heath communities and cyanobacterial mats which are typical of the region (LEC, 1991a,b).

5.3 SAND BEACHES

Sand beaches occur along most of the mainland coastline between Tubridgi Point and Beadon Creek and encircle the islands.

The beaches contain a limited range of burrowing macrofauna including polychaetes (e.g. lumbrinerid, phyllodocid and glycerid worms), crustaceans (e.g. isopods and *Ocypode* ghost crabs) and bivalve molluscs (e.g. mesodonaciids and donaciids). The beaches are used by seabirds for loafing, foraging or nesting (at the back of the beach), and many of the island beaches are also used by turtles for nesting.

5.4 INTERTIDAL LIMESTONE PLATFORM

Intertidal limestone platforms occupying the low intertidal zone surround most of the island sand beaches, but form a relatively minor component of the mainland coastline (Figs 7, 8). The platforms are typically peneplanar, thinly veneered by sands or silts consolidated by cyanobacterial films and filamentous algae, and occasionally are strewn with limestone and coral rubble.

A range of organisms is distributed over the platform according to tidal height and variations in topography, shading and presence of rock pools. Floral elements typically comprise algal films and filamentous green algae at or just above mean sea level, and algal turfs at the lower end of the tidal range. Larger green and brown algae, including *Digenea simplex, Dictyota, Amphiroa, Codium, Padina, Caulerpa* and *Gracilaria* spp., as well as red algae, are usually found within or beside rocky pools or splash zones. Very wide, shallow pools comprising sand-filled depressions with patches of *Halophila* seagrass are occasionally present (e.g. at Locker Island).

Fauna colonising the mid-tidal zone often include bioherms of rock oysters (*Saccostrea cucullata*) which support littorinids, mytilids, limpets, chitons and barnacles. Below the mid-tide level, sea anemones, crabs (e.g. *Metapograpsus* sp.), and larger gastropod molluscs (e.g. *Morula granulata*) are common. Faunal diversity increases most sharply at the lowest intertidal level of the platform, and where a wide range of species including sponges, cowries, soft corals, hard corals, clams, hermit crabs, spider crabs, sea urchins and sea cucumbers can be found at both offshore and nearshore locations.

5.5 SUBTIDAL TERRIGENOUS SILTS AND CLAYS

The seafloor in the nearshore region surrounding the Ashburton River delta is presently characterised by an extensive soft sheet of red/brown terrigenous silts and clays (Figs 7, 8). These sediments reflect the fact that the Ashburton River has been flowing almost continuously since February 1992, and long red plumes of fine fluviatile sediments extending from the mouth of this river have been occurring virtually on a daily basis.

Although nearshore turbidity was very high and extremely poor underwater visibility restricted the diver inspections during the survey in May 1992, it is reasonable to assume that biota colonising these sediments is presently restricted to mainly a burrowing infauna.

5.6 SUBTIDAL LIMESTONE PAVEMENT AND LIMESTONE PLATFORMS

Along the mainland coast, limited areas of shallow subtidal limestone pavement comprise extensions of the intertidal platforms abutting the sand beaches, or form isolated nearshore platform areas such as those at Tubridgi Point and near Urala Station. The latter are surrounded by nearshore silt and sand sheets (Figs 7, 8), and all are colonised by corals to varying extents (see Section 5.7).

Further away from the mainland coastline, isolated outcrops of limestone (in the form of raised platforms or 'pinnacle' reef rising up to 5 m above the surrounding seafloor) occur at the Baylis Patches, Locker Reef, East Locker Patch, Santo Rock and Roller Shoal. These isolated subtidal structures are colonised by widely varying amounts of hard and soft coral (from 10% observed at Santo Rock and East Locker Patch) to over 50% at Locker Reef and Roller Shoal; see Section 5.7).

Many of the larger islands in the region are surrounded by wide and occasionally extensive areas of shallow (<5 m deep) subtidal limestone pavement (Figs 7, 8). These frequently comprise large offshore extensions to the intertidal platforms, and are typically bare or only thinly veneered with sediment.

The offshore shallow subtidal pavement areas (< 5 m deep) are colonised by calcareous green and foliose brown macroalgae including *Sargassum, Halimeda, Laurencia, Hydroclathrus*, and *Udotea*, as well as by patchy seagrass meadows. The most extensive shallow meadows of macroalgae and seagrass occur near Thevenard and Serrurier Islands. Sponges and ascidians (sea squirts) are also common, but hard coral numbers are low, with coral cover typically less than 5% and rarely exceeding 10%.

In depths beyond 5 m, the subtidal limestone pavement is either covered by thick sheets of sediment or remains bare or thinly veneered by sands and silts. The latter habitat is typically colonised by sponges, gorgonian sea fans and sea whips, macroalgae and isolated hard coral colonies (predominantly *Turbinaria*, *Porites* and favid species).

5.7 CORAL REEFS

Coral reefs comprise diverse and productive shallow water ecosystems that provide food and shelter for a wide range of marine organisms, including numerous representatives of the sponges, cnidarians, crustaceans, molluscs, echinoderms and fishes. For the purposes of mapping, the coral reef areas shown in Figures 7 and 8 are those where the cover of living hard coral exceeds 25%.

No major coral reefs occur along the mainland coastline between Tubridgi Point and Onslow, a feature probably related to the turbidity of the waters and the amount of silty sediments originating from the Ashburton River delta. However, limestone reef and platform areas where hard coral coverage exceeds 25% are present close to the mainland shore near Urala Station and west of Locker Point, as well as at the Baylis Patches (Figs 7, 8). Much higher coverages of hard coral (>60%) occur at Locker Reef, Roller Shoal and Ward Reef (Figs 7, 8; LEC, 1992).

An interesting finding has been the occurrence of *Acropora* corals amongst the more typical sediment-resisting species (e.g. *Montipora*, *Turbinaria* and Faviidae spp.) found at Roller Shoal, Ward Reef and an inshore reef near Urala Station. That *Acropora* species are capable of colonising silty areas where waters are also very turbid may be related to their location (on topmost surfaces of the reefs) where depths are shallow (within 0-2 m of the low water mark). Thus wave action during low tides is probably sufficient to remove any temporary accumulations or build-up of silt that could be detrimental to *Acropora* growth and survival.

Most of the islands in the region, as well as some of the offshore reefs such as Trap Reef, are at least partially, if not almost completely, encircled by coral reefs. These occupy a depth zone ranging from 1 m to as much as 8 m. These zones of fringing reef often commence at the outer edges of the intertidal platform (where live hard coral cover suddenly increases from <10% to values between 30% and 80%). The largest area of coral reef in the region is located on the south side of Thevenard Island, but extensive areas of coral also occur on both sides of Serrurier Island (Figs 7, 8). Although insufficient time prevented an underwater inspection of the reef at Black Ledge, it is assumed that coral reef is present (Fig. 8) as it is a popular destination for recreational divers and fishermen. One charter boat was observed anchored at Black Ledge at the time of the survey.

5.8 SUBTIDAL SHEETS AND SHOALS

Beyond the present apron of red silts and clays surrounding the Ashburton River delta, much of the seafloor near the mainland coastline comprises thick sheets of dark to light brown silty sands and gravelly shoals which cover underlying limestone (Figs 7, 8). Distinct shoaling areas, including those at Manicom Bank, Tongue Shoals, South West Patch and the Glennie Patches, are probably formed from reworking of terrigenous sediments which are expelled from the Ashburton River during times of peak flow.

The sheets of silty sands are extensive in the area south of a line which curves between Round Island, Tortoise Island and Ashburton Island (Figs 7, 8). In current and wave-stirred shallow nearshore areas along the mainland coastline, they are intermixed with coarser sands which form the cheniers, spits and bars at the mouths of tidal creeks and Ashburton delta.

The nearshore subtidal sand and silt habitats have been regularly trawled for prawns and are colonised by a relatively sparse epibenthic fauna. The most common components of this surface-dwelling fauna are sponges, cnidarians (hydroids, sea anemones and free-living fungiid corals), bryozoans ('lace' coral), echinoderms (sea stars, sand dollars and crinoids). The burrowing infauna includes polychaete worms, molluscs, crustaceans (including tiger prawns) and gobiid fishes. The lack of widespread algae or seagrass beds (and attendant fauna) can be related to high water turbidities and frequent sediment reworking by tidal currents, storms, and trawling.

Further away from the mainland, and where depths approach 10 m, the sediment sheets and veneers are dominated by white medium and coarse sands. These also occur over much of the shallower (<10 m) area between Serrurier and Bessieres Islands, and in the shallower areas to the north-west and west of Ashburton Island (Figs 7, 8). At the time of the present survey (May 1992), these sand sheets supported patchy meadows of minor seagrass species (mainly *Halophila ovalis* and *H. spinulosa*), with substrate coverages ranging from <1% to 50%.

6 ASSESSMENT OF PIPELINE ROUTES

Each of the four potential pipeline routes which run between the 30 m isobath and the mainland beach west of the Ashburton River was found to traverse a set of similar habitats, albeit distributed in varying proportions. The broad distribution of these habitats is shown in Figure 8 and can be summarised as follows:

- sand dunes and a sand beach at the shoreline crossing;
- localised inshore occurrences of silt-veneered limestone platform, colonised by varying proportions of turfing algae, sponges and corals;
- very soft muddy sediments in shallow (<5 m deep) and highly turbid inshore waters (dominated by red silts and clays from the Ashburton River);
- brown gravelly, sandy and silty sediments in nearshore waters 5 m to 10 m deep, and which extend to roughly 10 km offshore. Much of this habitat appears to be regularly trawled;
- white sandy sediment sheets (typically >50 cm thick) supporting seagrass beds, prevalent on the outer region of the inner Rowley Shelf where waters are clearer and typically less than 12 m deep;
- bare or sand-veneered limestone pavement colonised by sponges, algae, gorgonians and isolated corals, most prevalent at the edge of the inner shelf where water depths increase from 12 m to 30 m.

Of the above benthic habitats, the most important from an ecological perspective is the bare or thinly-veneered limestone pavement, since this supports the greatest abundance and variety of macroflora, and is therefore considered the most productive.

The other habitat of interest, and an unexpected finding of the survey, is the occurrence of apparently extensive (though generally sparse) meadows of minor seagrass species along the offshore portion of the inner shelf. *Halophila* and *Halodule* species are much smaller than *Posidonia* and *Amphibolis* seagrasses and, unlike the latter forms, are capable of rapidly colonising bare or disturbed sandy sediments. For this reason they are often collectively termed 'pioneering' seagrasses. The meadows found in the deeper offshore areas may function as important feeding grounds for dugongs, but their significance as food sources for turtles is less certain.

In terms of productivity, however, both the limestone pavement and *Halophila* seagrass beds are probably less productive than two other habitat types in the region. These are the areas of shallow subtidal limestone pavement (<5 m deep) and the fringing coral reefs, both of which experience higher illumination, particularly in areas away from the mainland coast.

All the pipeline routes traverse extensive areas of predominantly bare silty sands and gravels, since this is a common habitat in the nearshore half of the inner shelf. This habitat is relatively depauperate of epibenthic organisms, and much of it is trawled by local professional fishermen.

The principal environmental effects of submarine pipeline installation are:

- direct loss and/or major disturbance of habitat within the pipelay corridor (a width of approximately 5 m and usually always less than 20 m);
- temporary and localised increases in water turbidity in the vicinity of the pipelay spread, particularly in areas where silty sediments prevail and/or where the pipeline is buried; and
- the loss of fishing grounds if the pipeline is left on the seafloor surface.

None of the habitats traversed by potential pipeline routes are sufficiently rare or unusual to warrant their being considered a constraint on pipeline construction, and all of the habitats encountered are well distributed throughout the region, with the possible exception of isolated nearshore subtidal platform areas which are colonised by coral. However, there appears to be no reason why the pipeline cannot be deviated around them, to avoid both a direct habitat loss as well as the cost of achieving an evenly-contoured pipelay corridor. Therefore the isolated inshore platforms are not considered to be a major constraint affecting final route selection.

The main indirect effect of pipeline installation will be the temporary and localised increases in water turbidity in the down-current areas of the pipelaying spread. This disturbance is likely to be most noticeable in shallow nearshore waters where silty sediments predominate. On the other hand, when viewed in the historical and regional perspective of seasonal trawling activity, occasional cyclones and episodic major discharges from the Ashburton River, sedimentation effects caused by the temporary and localised increases in turbidity from pipelaying are limited and highly unlikely to cause an unacceptable impact.

From an environmental management perspective (i.e. minimisation of potential impacts), the four routes can be ranked in order of preference as follows:

- Route 1 and Route 3 - both involve the shortest distance, and hence reduced time and area of disturbance during construction. They have similar localised amounts of exposed and sand-veneered limestone pavement and seagrass beds. In addition they do not pass close to major coral reef areas, although they will both terminate on (or near) an inshore reef which supports coral. Of the two routes, Route 3 could be described as the most environmentally benign since, unlike Route 1, it does not pass near limestone and coral reefs such as East Locker Patch, Santo Rock and Black Ledge.

- Route 2 - is the route containing most sandy substrate but it is longer than Route 1 and Route 3, and passes close to moderate sized coral reefs at Locker Island, Table Island and Black Ledge.

- Route 4 - is by far the longest route and the route supporting the greatest amount of sand-veneered limestone pavement. It also passes close to coral reefs at Ashburton Island and Roller Shoal.

From a social perspective, all routes except Route 2 (west of Locker Island) traverse prawn trawling grounds considered important by local commercial fishermen, and the pipeline may need to be buried to avoid both accidental damage and loss of fishing grounds to the fishery.

From an energy resource perspective, Route 4 provides an option for utilising gas from the Saladin and Roller oilfields, as it passes close to these developments.

In conclusion, no major environmental constraints have been identified along any of the four potential routes which would preclude these from being utilised on an ecological basis. There will also be no social constraints if the pipeline can be buried in nearshore sections where it traverses prawn trawling grounds.

Routes 1 and 3 are preferable from an environmental management perspective, Route 2 would be preferable to local prawn fishermen, and Route 4 is preferable from a resource utilisation viewpoint.

7 REFERENCES

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TABLE 1A

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 1

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
1/1	21° 31.330'S 114° 42.758'E	29.9 m	Silty sands	NR	No epibiota seen.
1/2	21° 31.702'S 114° 43.004'E	22.9 m	Undulating, unbroken limestone pavement with silt and sand veneers.	NR	50% cover - sponges, gorgonian whips and fans, sea pens, hard coral (mainly *Montipora*), molluscs, crinoids [fish: rock cod, butterflyfish, angelfish, wrasse, damselfish, lionfish].
1/3	21° 32.020'S 114° 43.123'E	20.7 m	Unrippled thick sheet of fine to medium-sized sands (forming low hummocks).	>100 cm	<1% cover - colonial ascidians, sea whips, hydroids, crinoids, sea stars.
1/4	21° 32.230'S 114° 43.321'E	17.4 m	Limestone pavement - mainly flat with occasional broken areas.	0 cm	10% cover - sponges, ascidians, sea whips, hard corals (*Porites*, *Turbinaria*), crinoids, oysters, crayfish; encrusting coralline algae [fish: coral trout, damselfish, fusilier, surgeonfish, squirrelfish, bullseye].
1/5	21° 32.397'S 114° 43.325'E	14.0 m	Limestone pavement.	0 cm	50% cover - coralline algae and *Halimeda*; 10% cover - sponges, ascidians, sea whips, hard corals (faviids, *Montastrea*, *Porites*); 10% cover - *Sargassum* brown algae [fish: damselfish].
1/6	21° 32.648'S 114° 43.566'E	17.0 m	Sheet of medium-sized sands.	65 cm	1% cover - sponges, ascidians, sea whips, sea pen, crinoids; <1% cover - *Halimeda* calcaerous green alga. Burrows: <1 m^2.
1/7	21° 33.064'S 114° 43.818'E	11.6 m	Limestone pavement with thin sand veneers.	<2 cm	50% cover - coralline algae, *Halimeda* calcareous green alga; 10% cover - sponges, bryozoans, ascidians, gorgonian fans and whips, hydroids, hard corals (*Turbinaria*, faviids), crinoids, sea stars, holothurians, oysters; 1% cover - *Sargassum* [fish: butterflyfish, wrasse].
1/8	21° 33.528'S 114° 44.073'E	13.5 m	Limestone pavement with sand veneers.	38 cm	1% cover - *Halimeda* green alga, *Sargassum* brown alga, filamentous red and green algae; <1% cover - sponges, ascidians, sea whips, hydroids and crinoids
1/9	21° 34.045'S 114° 44.309'E	12.1 m	Broken limestone pavement, patches veneered by medium and coarse-sized sands.	<5 cm	10% cover - sponges, ascidians, hydroids, hard corals (*Acropora*, *Turbinaria*, faviids), nudibranchs; 10% cover - *Sargassum* brown alga, *Halimeda* green alga, coralline green and red algae.

NR = Not recorded due to water depth >20 m.

TABLE 1A (cont'd)

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 1

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
1/10	21° 34.514'S 114° 44.551'E	12.8 m	Limestone pavement with rubble, veneered by medium to coarse sands, plus patches of shell gravel.	32 cm	25% cover - *Halimeda*, coralline and filamentous green and red algae; 1% cover - sponges, ascidians, hydroids, gorgonian fans and whips, hard corals (*Turbinaria*, *Porites*), crinoids, holothurians.
1/11	21° 34.863'S 114° 44.677'E	8.6 m	Undulating thick sheet of medium-sized sands.	>100 cm	25% cover - *Halophila ovalis*, *H. spinulosa* and *Halodule uninervis* seagrasses; <1% cover - solitary ascidians, crinoids.
1/12	21° 35.184'S 114° 44.840'E	7.8 m	Thick sheet of medium-sized sands.	>100 cm	<1% cover - crinoids, holothurians.
1/13	21° 35.892'S 114° 45.127'E	11.0 m	Unrippled sheet of medium-sized sands and shell fragments.	65 cm	<1% cover - crinoids. <1% cover - *Halophila spinulosa* seagrass.
1/14	21° 36.659'S 114° 45.580'E	10.9 m	Limestone pavement with thin sand veneer; then sheet of medium-sized sands.	<10 cm 55 cm	Limestone pavement: 50% cover - *Halimeda*, coralline green and red algae; 25% cover - sponges, hydroids, gorgonian fans and whips, crinoids. Sand: 10% cover - *Halophila* spp. seagrasses; 1% cover - sponges, gorgonians.
1/15	21° 37.578'S 114° 45.715'E	10.2 m	Medium/coarse sands with gravel and shell fragments.	>100 cm	15% cover - *Halimeda* alga and meadows of *Halophila* spp. and *Halodule uninervis* seagrasses; 1% cover - sponges, anemones, free-living corals (fungiids), crinoids.
1/16	21° 38.123'S 114° 45.904'E	12.1 m	Coarse sands with gravel over limestone; then limestone pavement veneered by sands and silts.	96 cm <20 cm	Coarse sand: 10% cover - *Halophila* spp. seagrasses; 1% cover - sponges and gorgonians. Limestone pavement: 10% cover - sponges, ascidians, sea whips, hydroids, crinoids, sea stars, nudibranchs [fish: goby holes, damselfish].
1/17	21° 39.218'S 114° 46.702'E	10.1 m	Limestone pavement with holes, patchy gravel and silt veneers.	0 cm	10% cover - sponges, solitary ascidians, gorgonian fans and whips, colonial hydroids, hard corals (*Porites*, *Turbinaria*), crinoids, holothurians [fish: goby holes].
1/18	21° 39.917'S 114° 47.247'E	11.5 m	Gravels with shell fragments and silt (probable trawl ground).	40 cm	10% cover - hydroids; 5% cover - *Halimeda*, brown algae; <1% cover - small sponges, gorgonians, sea stars [fish: goby holes].
1/19	21° 40.734'S 114° 47.764'E	9.5 m	Fine/medium sands and silt (probable trawl ground).	>100 cm	<1% cover - crinoids.

NR = Not recorded due to water depth >20 m.

TABLE 1B

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 2

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
2/1	21° 33.321'S 114° 44.066'E	13.2 m	Limestone platform (~1 m high). Patches (30 m diameter) of medium to coarse sands.	60 cm	Scattered sponges and ascidians. 80% *Sargassum* cover.
2/2	21° 34.106'S 114° 44.004'E	13.5 m	Limestone pavement veneered by medium to coarse sands with shell fragments.	25 cm	Many sponges, ascidians, gorgonians (whips), sea pens, hard coral (*Turbinaria*), crinoids. One small coral bommy - *Porites*, 1m high, 2m diameter. Scattered *Sargassum*.
2/3	21° 35.094'S 114° 43.998'E	8.0 m	Thick sheet of medium/coarse sands (sand waves 1 m high, and 5 m apart; oriented east-west).	70 cm	50m long seagrass meadow - *Halophila ovalis*, *ovata* and *spinulosa*, 50% cover.
2/4	21° 35.583'S 114° 44.013'E	11.5 m	Undulating thick sheet of medium/coarse sands.	100 cm	Patchy distribution (1 clump per 2 meters) - Sponges, ascidians (colonial and solitary), gorgonians, soft corals, sea pens, occasional faviid, egg cowrie. Small *Halophila* patches.
2/5	21° 36.617'S 114° 44.027'E	10.5 m	Undulating thick sheet of medium/coarse sands.	>100 cm	Scattered sponges, bryozoans and crinoids. Scattered small (5m diameter) seagrass patches - *Halophila ovalis* and *ovata*.
2/6	21° 37.170'S 114° 44.118'E	12.1 m	Undulating thick sheet of fine/medium sands.	>100 cm	Sand dollars, crinoid, scattered burrows. Uniform 20% cover - *Halophila ovalis* and *spinulosa*.
2/7	21° 37.891'S 114° 44.123'E	12.2 m	Thick sheet of medium-sized sands with overlying veneer of fine sand, silt and shell fragments.	100 cm	Scattered sponges and crinoids, anemones, solitary hard corals (fungiids), polychaete tube worms, goby burrows. One patch (5m diameter) of *Halophila spinulosa*.
2/8	21° 38.729'S 114° 44.192'E	13.6 m	Broken limestone pavement veneered by medium-sized sands and silt.	<1 cm	Sponges, occasional ascidian, bryozoans, gorgonians (fans and whips), soft corals, hard corals (*Goniastrea*, *Stylophora*, *Turbinaria*), many crinoids.
2/9	21° 39.230'S 114° 44.204'E	12.8 m	Thick sheet of fine to medium-sized sands and silts (probable trawl ground)	>100 cm	Very little epifauna - scattered ascidians, stalked crinoids, swimmer crab, gobies, burrows.
2/10	21° 39.721'S 114° 44.216'E	11.9 m	Thick sheet of coarse to medium-sized sands and silt (probable trawl ground).	>100 cm	Scattered sponges, colonial ascidians and fungiid corals, sand dollar, cidarid sea urchin. *Halimeda*.

TABLE 1B (cont'd)

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 2

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
2/11	21° 40.958'S 114° 44.303'E	11.9 m	Silts and fine sands (probable trawl ground).	>100 cm	Colonial ascidians on sponge, many burrows.
2/12	21° 41.632'S 114° 44.302'E	10.4 m	Limestone pavement with thin silty sand veneers.	0 cm	'Garden country', comprising many sponges, gorgonian fans and whips, hard corals (including *Astreopora, Cyphastrea, Euphyllia, Goniastrea, Goniopora, Porites*), sea stars, sand dollars, etc.
2/13	21° 42.733'S 114° 44.357'E	9.2 m	Fine to medium-sized sands with silt (probable trawl ground).	>100 cm	Sparse - bryozoans, crinoids, sand dollars, cidarid sea urchin, few burrows. Sparse *Halimeda*.
2/14	21° 43.841'S 114° 44.447'E	7.2 m	Fine to medium-sized sands with silt (probable trawl ground).	>100 cm	Sparse - occasional colonial ascidians, colonial anemones with bryozoans, burrows.
2/15	21° 44.024'S 114° 44.577'E	6.4 m	Gravel, rubble and shell fragments, intermixed with fine sands and silt (probable trawl ground).	>100 cm	Sponges, ascidians, gorgonians, occasional anemone, hard corals (*Cyphastrea*, many *Euphyllia*, fungiids, *Porites, Turbinaria*), crinoids, holothurians, murex shell. *Halimeda*.
2/16	21° 44.816'S 114° 45.233'E	6.5 m	Gravel intermixed with silts and sands.	>100 cm	Soft corals, scattered hard corals (*Cyphastrea*, fungiid, *Turbinaria*), many holothurians. *Halimeda, Dictyopterus*.
2/17	21° 45.613'S 114° 45.902'E	5.4 m	Gravel bank, with fine sands and silt.	65 cm	Colonial ascidians, small faviid corals (3 species). *Halimeda*.
2/18	21° 46.143'S 114° 46.253'E	4.8 m	Fine sands with silt and shell fragments.	50 cm	Few burrows. *Halimeda*.
2/19	21° 47.153'S 114° 47.205'E	2.0 m	Coarse sands with shell fragments.	>100 cm	Nil.

TABLE 1C

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 3

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
3/1	21° 28.813'S 114° 47.945'E	24.2 m	Broken limestone pavement with sand veneer.	NR	1% cover - sponges, ascidians; <1% cover - *Halimeda*.
3/2	21° 29.301'S 114° 48.047'E	20.0 m	Undulating thick sheet of medium-sized sands with pebble-sized rubble.	>100 cm	<1% cover - small sponges, solitary ascidians, hydroids, crinoids; <1% cover - foliose red algae.
3/3	21° 29.858'S 114° 48.239'E	17.8 m	Undulating thick sheet of medium-sized sands.	>100 cm	1% cover - small sponges, solitary and colonial ascidians, hydroids, crinoids; 1% cover - *Sargassum*, foliose red algae.
3/4	21° 30.178'S 114° 48.313'E	14.3 m	Limestone ridge with thin veneers of coarse sands.	<10 cm	50% cover - *Halimeda*, coralline red algae; 20% cover - sponges, ascidians, gorgonian whips and fans, hard corals (faviids, *Montipora*, *Turbinaria*), sea stars [fish: damselfish, angelfish].
3/5	21° 30.694'S 114° 48.473'E	16.4 m	Sheet of medium-sized sands.	70 cm	<1% cover - *Halophila spinulosa* seagrass. Burrows: 10 m^{-2}
3/6	21° 31.194'S 114° 48.599'E	15.5 m	Limestone pavement with patchy sand veneers.	35 cm	Pavement: 10% cover - sponges, ascidians, gorgonian whips and fans, sea stars, crinoids. Sand: 1% cover *Halophila ovalis* and *H. spinulosa* seagrasses.
3/7	21° 31.660'S 114° 48.778'E	12.3 m	Thick sheet of coarse to medium-sized sands.	>100 cm	5% cover - *Halophila spinulosa* seagrass; <1% cover - ascidians, gorgonians, scallops.
3/8	21° 32.097'S 114° 48.877'E	13.0 m	Thick sheet of coarse to medium-sized sands.	>100 cm	5% cover - *Halophila spinulosa* seagrass; <1% cover - sponges, ascidians, gorgonians.
3/9	21° 33.097'S 114° 49.198'E	12.8 m	Thick sheet of coarse to medium-sized sands.	>100 cm	10% cover - *Halophila ovalis* and *H. spinulosa* seagrass, *Halimeda* green alga; <1% cover - ascidians and crinoids [fish: goby].
3/10	21° 33.913'S 114° 49.437'E	13.4 m	Thin sheet of coarse to medium-sized sands.	25 cm	10% cover - *Halophila ovalis* and *H. spinulosa* seagrass; <1% cover - sponges, ascidians, hydroids, sea whips [fish: oriental sea robin].

NR = Not recorded

TABLE 1C (cont'd)

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 3

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
3/11	21° 34.700'S 114° 49.715'E	10.1 m	Bare limestone pavement.	0 cm	50% cover - *Halimeda* green alga; 25% cover - sponges, gorgonian whips and fans, crinoids [fish: angelfish, butterflyfish, damselfish, goatfish, wrasse].
3/12	21° 35.206'S 114° 49.693'E	10.0 m	Limestone pavement with thin veneers of sands.	<1 cm	10% cover - sponges, gorgonian whips and fans, small *Turbinaria* corals, sea stars, crinoids. 10% cover - *Halimeda* and other green algae, *Halophila spinulosa* seagrass.
3/13	21° 35.452'S 114° 49.858'E	9.7	Limestone pavement veneered by coarse to medium-sized sands.	<15 cm	1% cover - sponges, sea whips, sea stars. 1% cover - *Halimeda* green algae, *Halophila ovalis* seagrass.
3/14	21° 35.762'S 114° 49.885'E	12.0 m	Limestone pavement veneered by fine to medium-sized sands and silts.	<10 cm	10% cover - sponges, ascidians, gorgonians, hydroids, soft corals, crinoids. 1% cover - *Halimeda*, *Halophila ovalis* seagrass, occasional brown algae.
3/15	21° 36.509'S 114° 49.990'E	9.9 m	Undulating thick sheet of coarse to medium-sized sands and silts.	>100 cm	<1% cover - ascidians, hydroids, crinoids, sand dollars, mantid shrimps. <1% cover - *Halophila spinulosa* seagrass. Burrows: 5 m^{-2}.
3/16	21° 37.293'S 114° 50.124'E	12.3 m	Gravel intermixed with coarse sands, shell fragments and silts (probable trawl ground).	>100 cm	<1% cover - ascidians, hydroids, crinoids [fish: goby burrows]. <1% cover - *Halimeda*, *Halophila spinulosa*.
3/17	21° 37.981'S 114° 50.130'E	11.2 m	Sheet of fine sands and silt.	>45 cm	1% cover - *Halimeda* green alga and *Halophila ovalis* seagrass; <1% cover - crinoids, sea stars. Burrows: 5 m^{-2}.
3/18	21° 38.294'S 114° 50.184'E	11.3 m	Sheet of fine sands and silt.	>45 cm	<1% cover - sponges (v. small), ascidians, hydroids, anemones, crinoids, sea stars [fish: silver biddy]. Burrows: 15 m^{-2}.
3/19	21° 39.348'S 114° 50.210'E	6.4 m	Thick sheet of medium to fine sands with silt.	>100 cm	<1% cover - hydroids, crinoids. <1% cover - *Halophila spinulosa* seagrass.
3/20	21° 39.750'S 114° 50.221'E	10.0 m	Gravel intermixed with coarse to medium sized sands and silt (probable trawl ground).	>100 cm	<1% cover - hydroids, gorgonians. <1% cover - *Halimeda* green alga, foliose red algae.

NR = Not recorded

TABLE 1C (cont'd)

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 3

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
3/21	21° 40.321'S 114° 50.205'E	10.2 m	Red/brown silts and clays.	25 cm	<1% cover - hydroids, gorgonians. Burrows: 5 m^{-2}.
3/22	21° 40.772'S 114° 50.240'E	10.4 m	Red/brown silts and clays.	NR	Burrows: 10 m^{-2}.
3/23	21° 41.803'S 114° 50.273'E	8.0 m	Red brown silts and clays.	>50 cm	Burrows: 10 m^{-2}.
3/24	21° 42.768'S 114° 50.258'E	4.0 m	Limestone platform with silt veneer.	0 cm	25% cover - sponges, hydroids, hard corals (faviids, encrusting *Turbinaria* dominant). 25% cover - filamentous algae.
3/25	21° 43.553'S 114° 50.307'E	4.6 m	Red/brown silts and clays.	>15 cm	Nil visibility.

NR = Not recorded

TABLE 1D

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 4

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
4/1	21° 28.375'S 114° 47.361'E	30.3 m	Bare silty sands.	NR	No epibiota visible.
4/2	21° 29.575'S 114° 48.802'E	17.1 m	Ridge formed by broken limestone pavement on shallow incline. Steep drop behind ridge crest to sand area.	0 cm	10% cover - sponges, ascidians, gorgonians, hard coral (15 species, av. size 20cm diameter, one colony m^{-2}: *Turbinaria* dominant, also *Acropora, Cyphastrea, Echinopora, Goniopora, Leptoria, Montipora, Platygyra, Porites*), sea stars. Fish: Damselfish, cardinalfish. 75% cover - turfing algae (*Padina*, <1% cover).
4/3	21° 29.771'S 114° 48.997'E	14.6 m	Limestone pavement with veneers of coarse sands and gravel.	25 cm	1% cover - sponges, ascidians, gorgonians. 10% cover - brown algae and *Halimeda*.
4/4	21° 30.224'S 114° 49.518'E	16.6 m	Coarse shell sands and scattered rubble. Sand waves 30 cm high, 2 m apart.	25 cm	5% cover - sponges, ascidians, gorgonians. 5% cover - brown algae (including *Sargassum*).
4/5	21° 30.595'S 114° 49.874'E	12.2 m	Limestone ridge with coarse sand veneer; then sand area.	10 cm	Ridge: 10% cover of sponges, bryozoans, gorgonians (fans and whips), hard coral (*Turbinaria*), crinoids, holothurians. 50% cover by algae: foliose reds, *Halimeda* and *Sargassum*. On sand area: 5% cover of ascidians and gorgonians.
4/6	21° 31.313'S 114° 50.633'E	15.2 m	Limestone pavement with coarse to medium-sized sand veneers.	<30 cm	5% cover - sponges, ascidians, gorgonians (fans and whips), crinoids. <1% cover - *Halophila ovalis* on sand.
4/7	21° 32.730'S 114° 52.076'E	13.5 m	Limestone pavement with sand veneers of various thickness.	1-25 cm	On thick sandy veneers: 5% cover - *Halophila spinulosa, Halophila ovalis*. Pavement: 25% cover - sponges, ascidians, gorgonians (fans and whips), hard corals (*Goniopora, Turbinaria*, faviids), crinoids, sea stars. Scribbled angelfish. 50% cover - *Halimeda*, foliose red algae.
4/8	21° 33.725'S 114° 53.182'E	12.2 m	Undulating thick sheet of medium-sized sands.	>50 cm	<1% cover - crinoids, sea stars. Burrows: <1 m^{-2}. 1% cover - *Halophila ovalis* and *spinulosa*.
4/9	21° 34.473'S 114° 53.901'E	12.4 m	Gravel bank strewn with pebble-sized rubble, shell fragments and forams, with thin veneer of silts.	>50 cm	1% cover - sponges, ascidians (colonial and solitary), bryozoan fans, gorgonians. 10% cover - *Padina, Halimeda*.

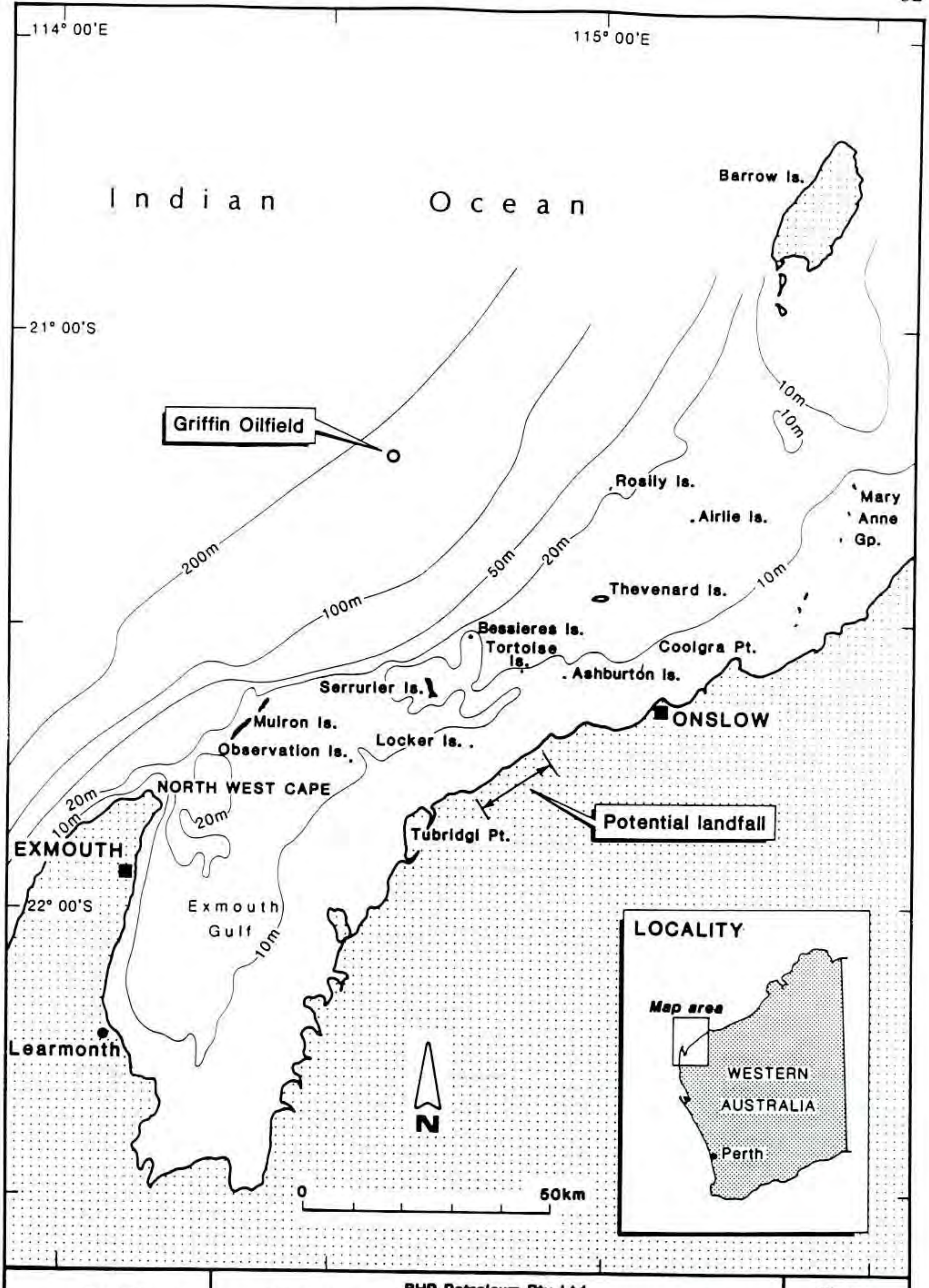
NR = Not recorded

TABLE 1D (cont'd)

SEAFLOOR CHARACTERISTICS ALONG POTENTIAL PIPELINE ROUTE 4

SITE	LOCATION	WATER DEPTH	SUBSTRATE		BIOTA
			PREDOMINANT COMPONENT	Sediment Depth	
4/10	21° 34.582'S 114° 53.994'E	10.5 m	Ridge covered in thick sheet of medium sands. Sand ripples 10 cm high and 25 cm apart.	>50 cm	<1% cover - sponges, solitary ascidians, hydroids. 25% cover - *Halophila ovalis*, *ovata* and *spinulosa*.
4/11	21° 35.414'S 114° 54.722'E	10.6 m	Mainly coarse sands with shell fragments.	>50 cm	<1% cover - sponges, ascidians, hammer oysters. <1% cover - *Halophila spinulosa*.
4/12	21° 35.908'S 114° 55.229'E	8.7 m	Thick sheet of medium-sized sands.	>50 cm	<1% cover - sponges, solitary ascidians, sea pen, colonial anemones, sand dollars. 25% cover - *Halophila ovalis* and *spinulosa*.
4/13	21° 36.878'S 114° 56.180'E	11.0 m	Coarse sands intermixed with shell fragments, gravel and silt (probable trawl ground).	>25 cm	1% cover - remnant sponges and gorgonians, stalked colonial ascidians, large hydroids, small solitary corals. 5% cover - *Halimeda*.
4/14	21° 37.451'S 114° 56.707'E	8.8 m	Gravel, with shell fragments and silt (probable trawl ground).	>50 cm	1% cover - sponges, solitary ascidians, hydroids, damaged and undamaged gorgonians, sea urchin. 1% cover - *Halimeda*, articulated coralline red algae.
4/15	21° 38.327'S 114° 56.045'E	10.2 m	Gravel and shell fragments intermixed with medium-sized sands and silt (probable trawl ground).	>50 cm	1% cover - sponge fragments, solitary ascidians, remnant gorgonians, sea stars. Burrows: 10 m^{-2}. <1% cover - *Padina*.
4/16	21° 39.430'S 114° 54.267'E	9.4 m	Fine sands and silt (probable trawl ground).	>50 cm	<1% cover - remnant gorgonians, colonial ascidians. Burrows: 20 m^{-2}.
4/17	21° 39.688'S 114° 53.817'E	8.4 m	Gravel bank with shell fragments and silt; then thick sheet of red/brown silts and clays (probable trawl ground).	>25 cm	Gravel bank: <1% cover - hydroids. Red silts: <1% cover - ascidians, remnant gorgonians.
4/18	21° 40.910'S 114° 52.517'E	7.8 m	Red/brown silts and clays with shell fragments (probable trawl ground).	>50 cm	No biota seen (nil visibility).
4/19	21° 42.349'S 114° 53.092'E	4.9 m	Red/brown silts and clays (probable trawl ground).	>100 cm	One hydroid found (very poor visibility).

NR = Not recorded



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Griffin Areas Oilfield Development – Submarine Gas Pipeline
SEAFLOOR SURVEY OF POTENTIAL ROUTES

LOCALITY DIAGRAM

Figure 1

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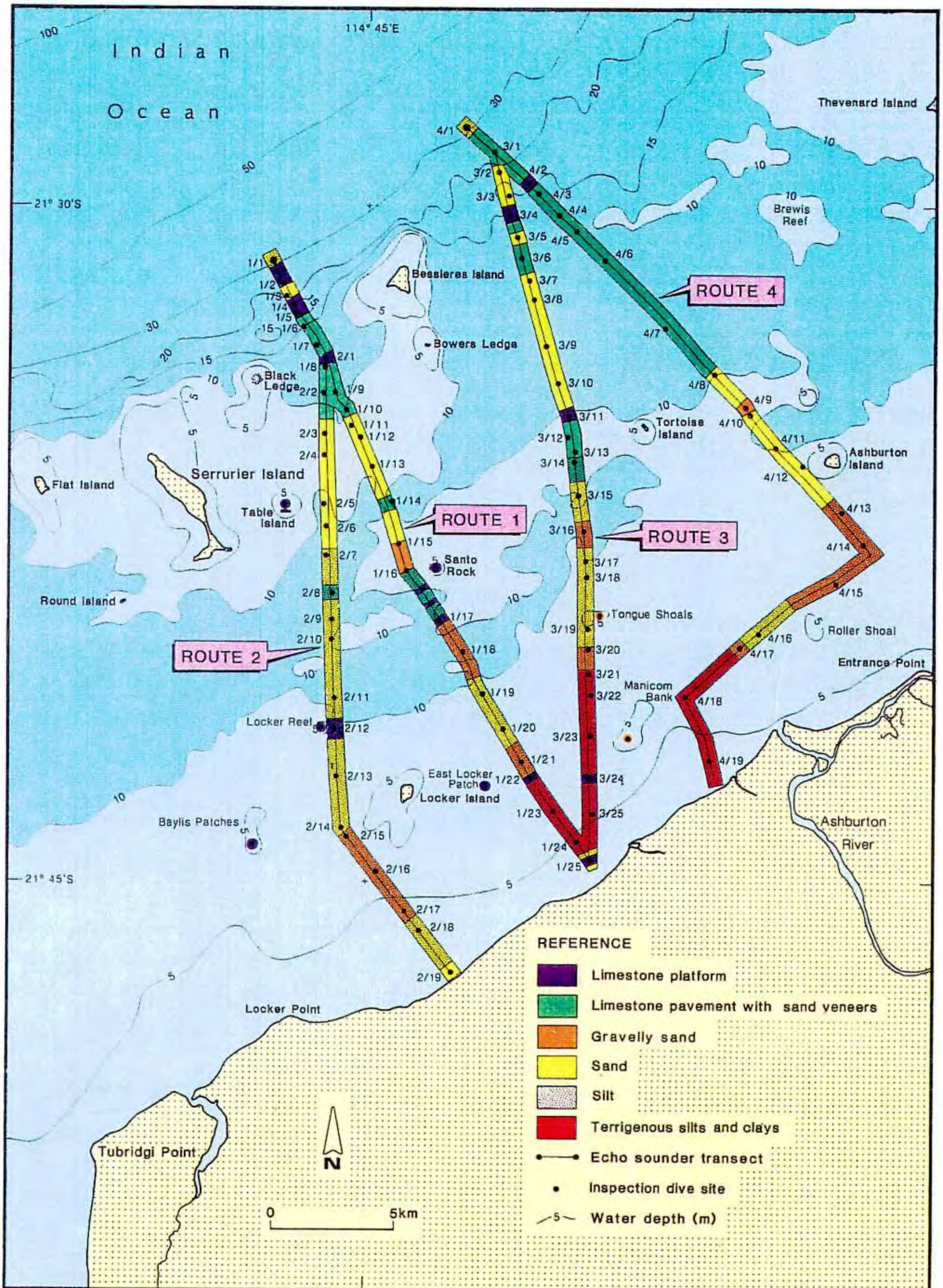
Environmental Drafting

J244 R387



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SEAFLOOR SURVEY OF POTENTIAL ROUTES

HABITAT DISTRIBUTION ALONG POTENTIAL PIPELINE ROUTES

Figure 2

Environmental Drafting

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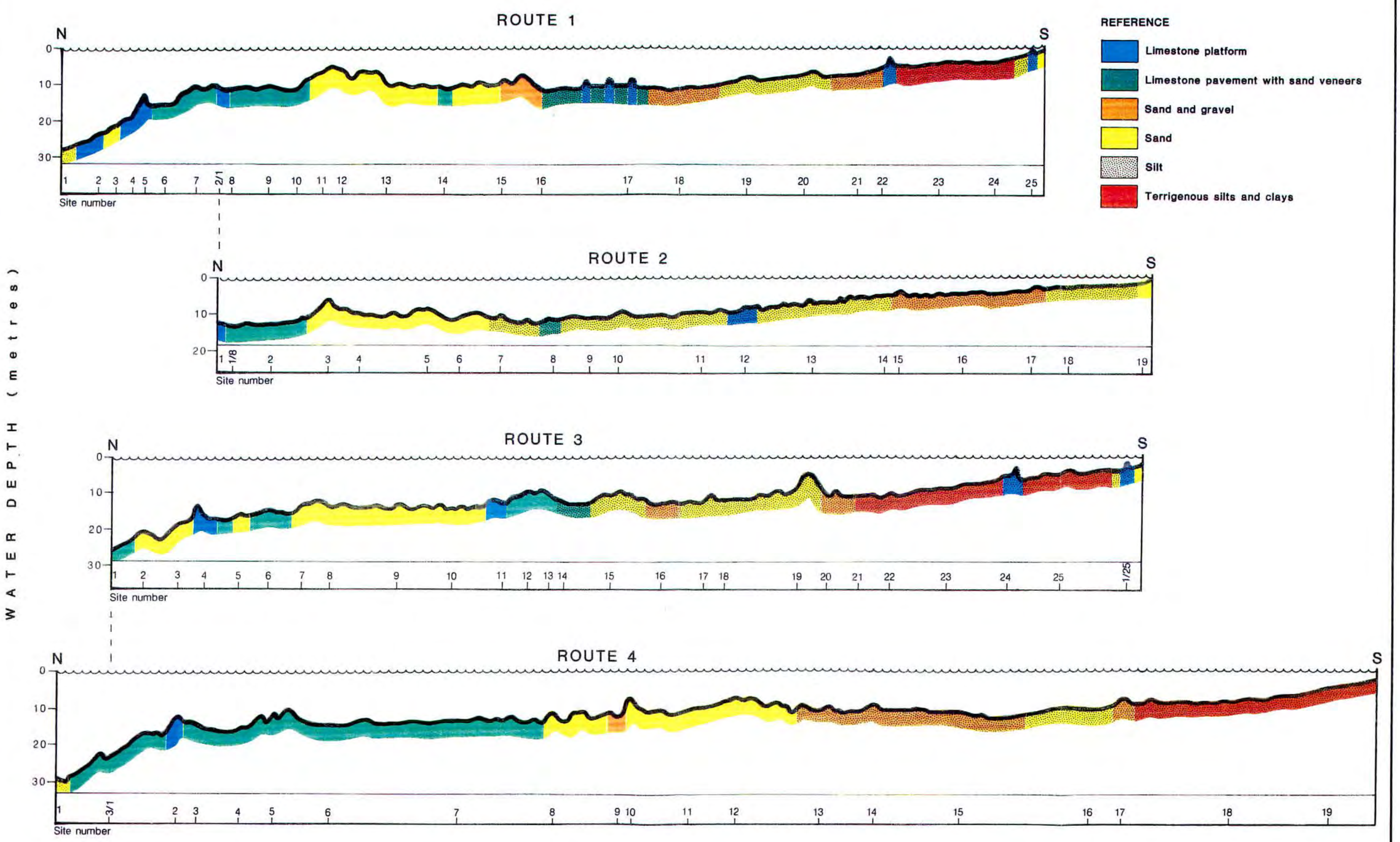

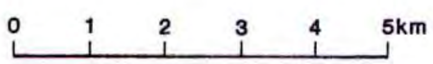

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SEAFLOOR SURVEY OF POTENTIAL ROUTES

BATHYMETRIC PROFILES AND HABITAT DISTRIBUTION ALONG POTENTIAL PIPELINE ROUTES

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Figure 3

Environmental Drafting

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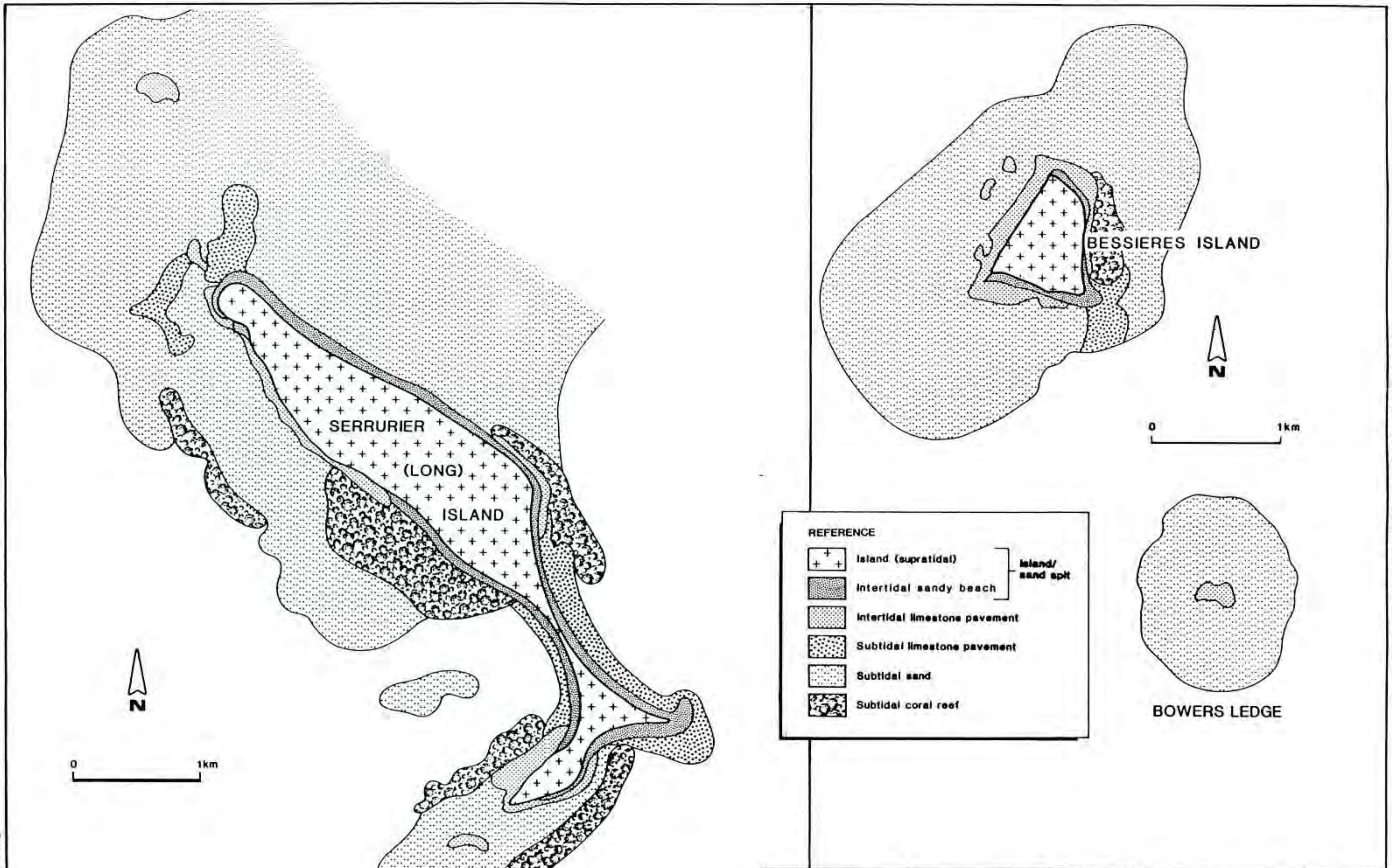

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SEAFLOOR SURVEY OF POTENTIAL ROUTES

HABITAT DISTRIBUTION AT SERRURIER AND BESSIERES ISLANDS

Figure 4

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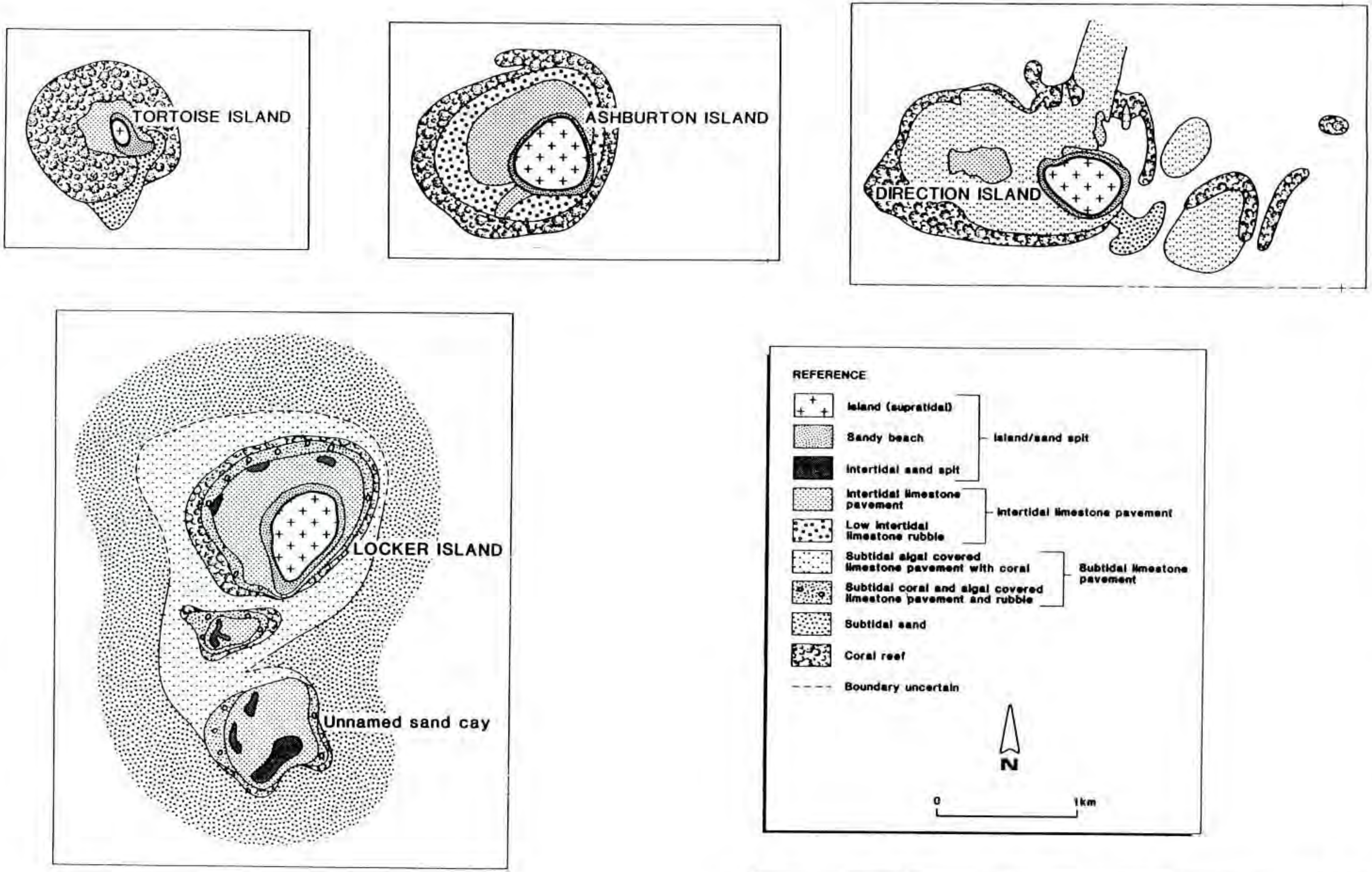

Source : WAPET Roller Oilfield Development CER

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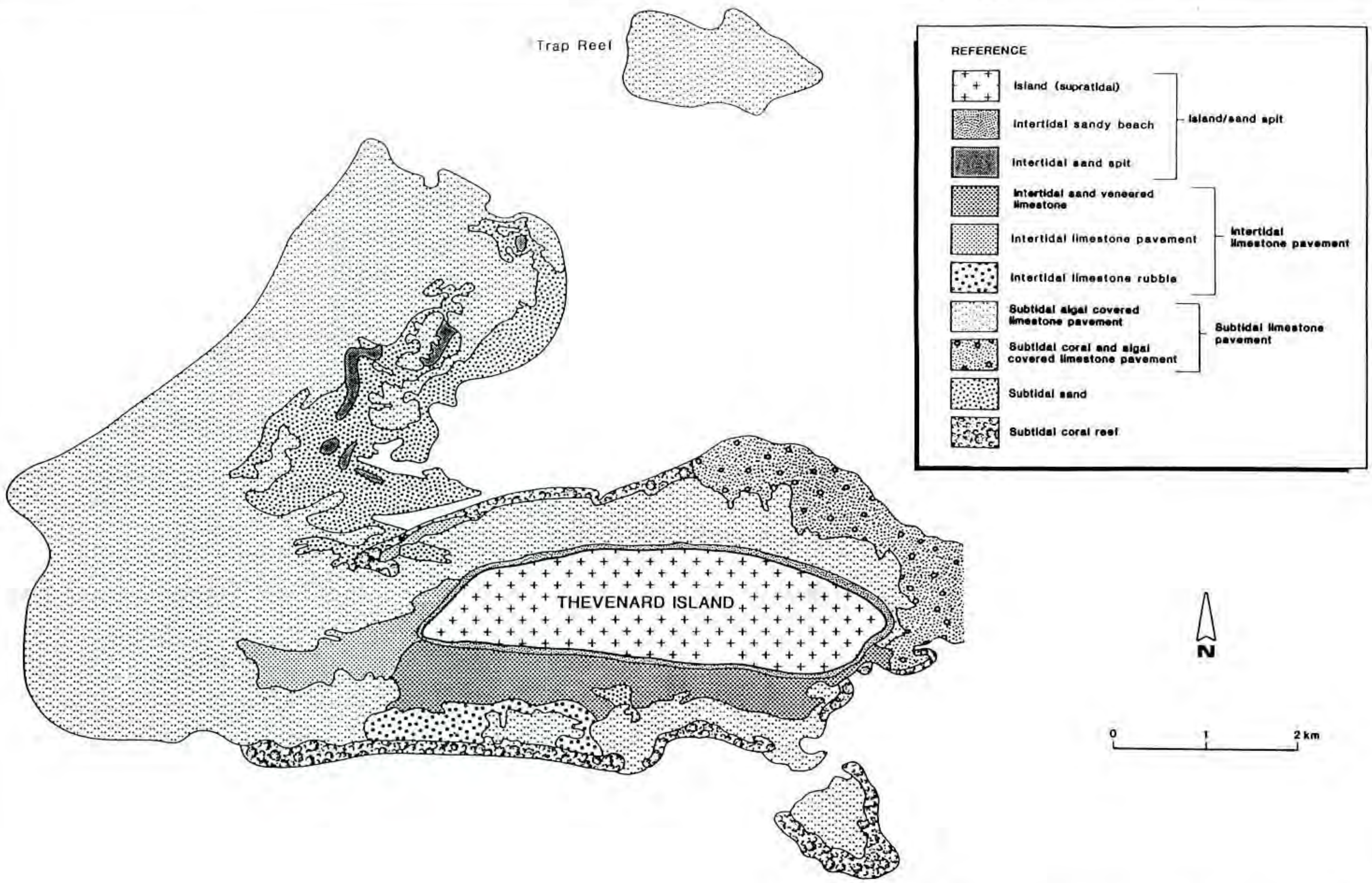
SEAFLOOR SURVEY OF POTENTIAL ROUTES

HABITAT DISTRIBUTION AT ASHBURTON, TORTOISE, LOCKER AND DIRECTION ISLANDS

Figure **5**



Source : WAPET Roller Oilfield Development CER

	BHP Australia Pty Ltd Griffin Areas Oilfield Development - Submarine Gas Pipeline SEAFLOOR SURVEY OF POTENTIAL ROUTES **HABITAT DISTRIBUTION AT THEVENARD ISLAND**	Figure **6**
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Environmental Drafting

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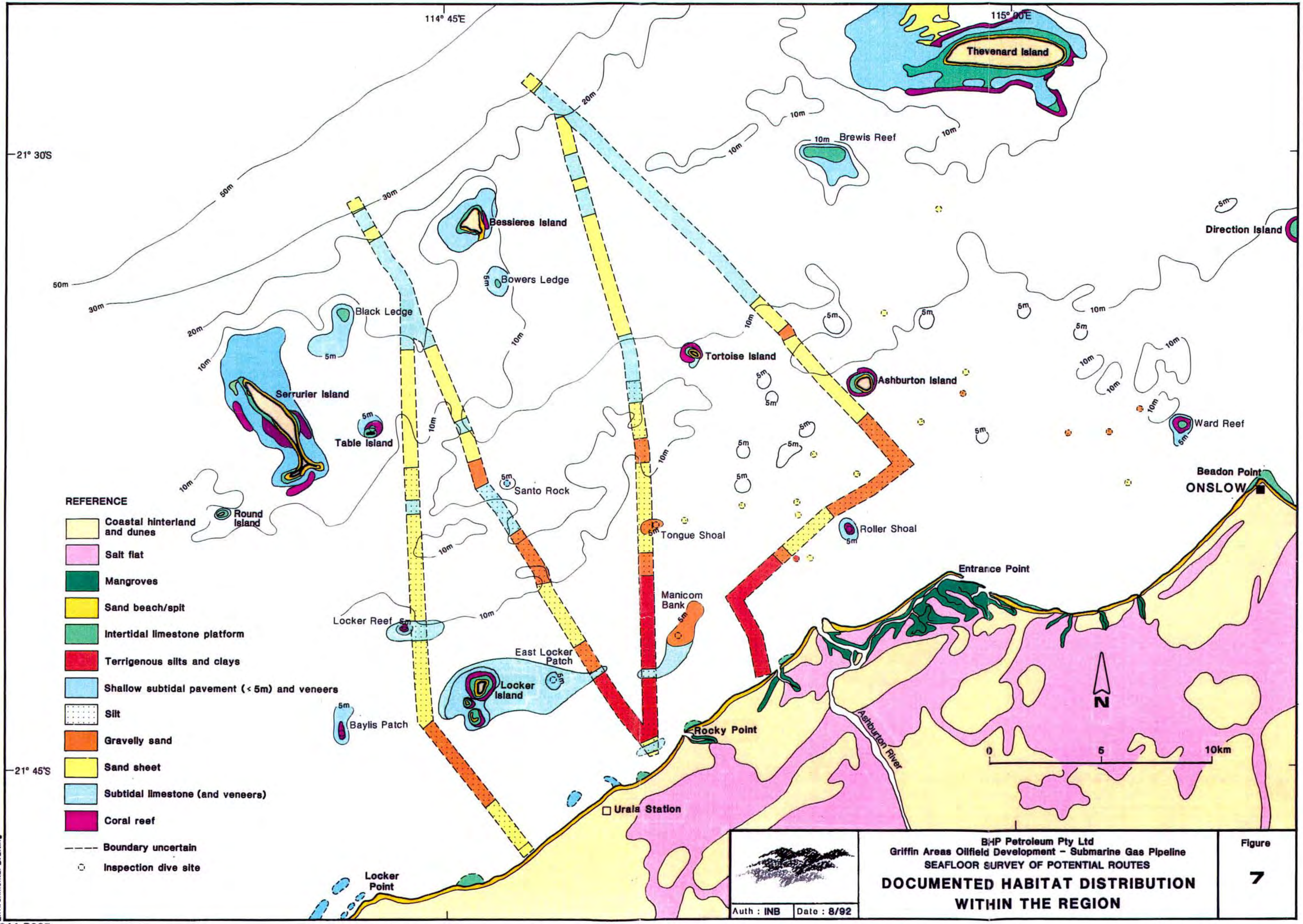

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SEAFLOOR SURVEY OF POTENTIAL ROUTES

DOCUMENTED HABITAT DISTRIBUTION WITHIN THE REGION

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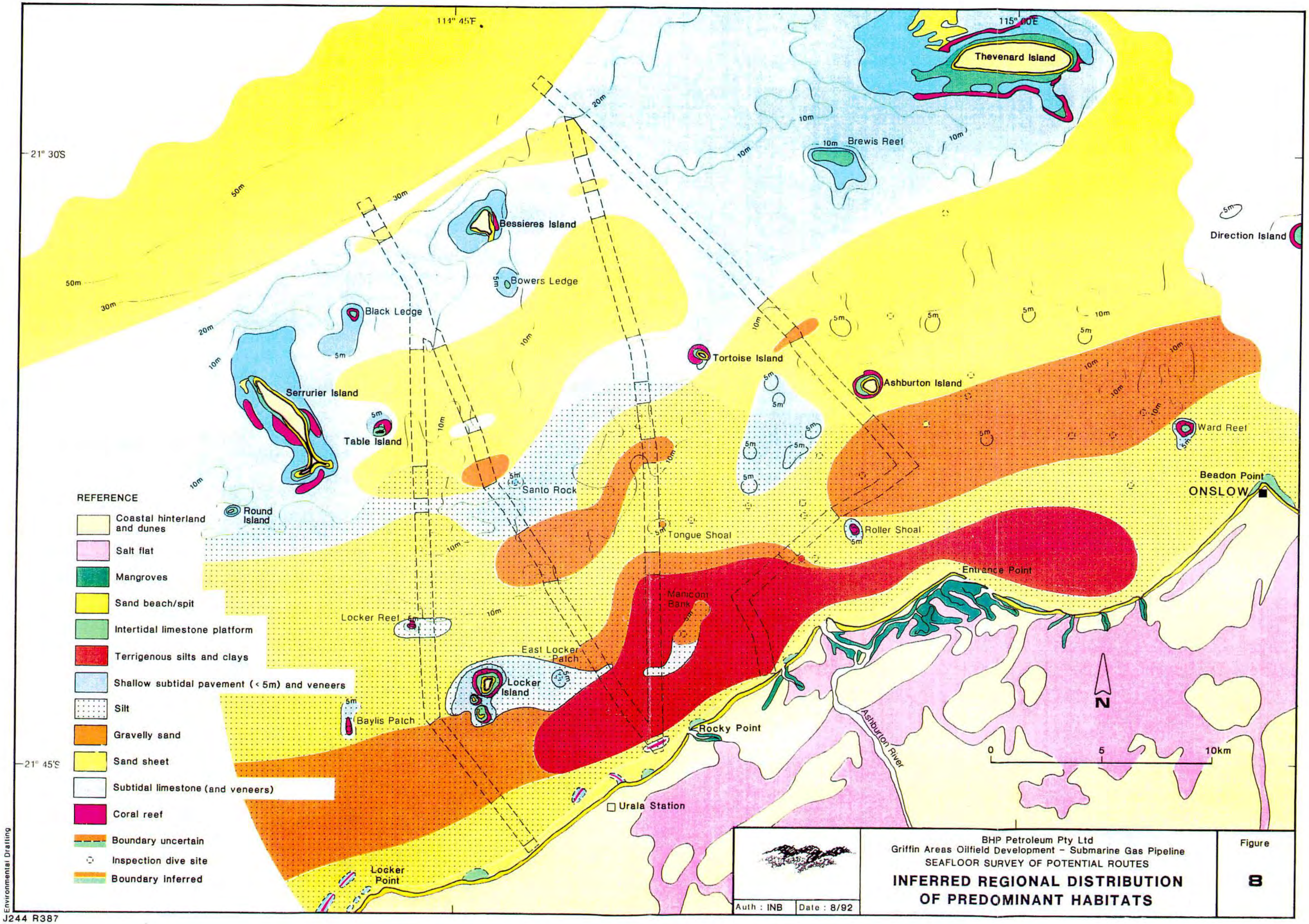
Figure 7



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SEAFLOOR SURVEY OF POTENTIAL ROUTES

INFERRED REGIONAL DISTRIBUTION OF PREDOMINANT HABITATS

Figure 8

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Environmental Drafting

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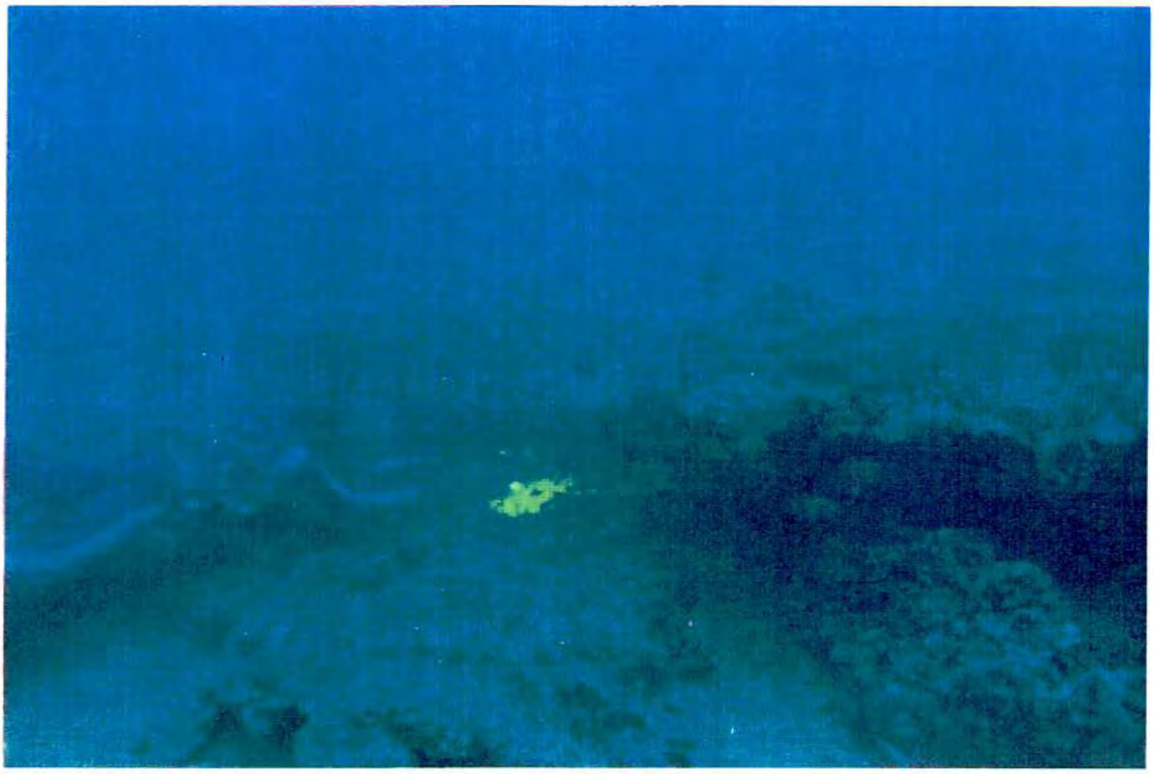

Plate 1: Broken limestone pavement at 16 m depth - Site 4, Route 1. Diver with video camera is inspecting undercut ledge where a crayfish and a school of Bullseye (*Pempherididae*) were recorded. Sponges, sea whips and hard corals occur in low abundance on the limestone substrate.

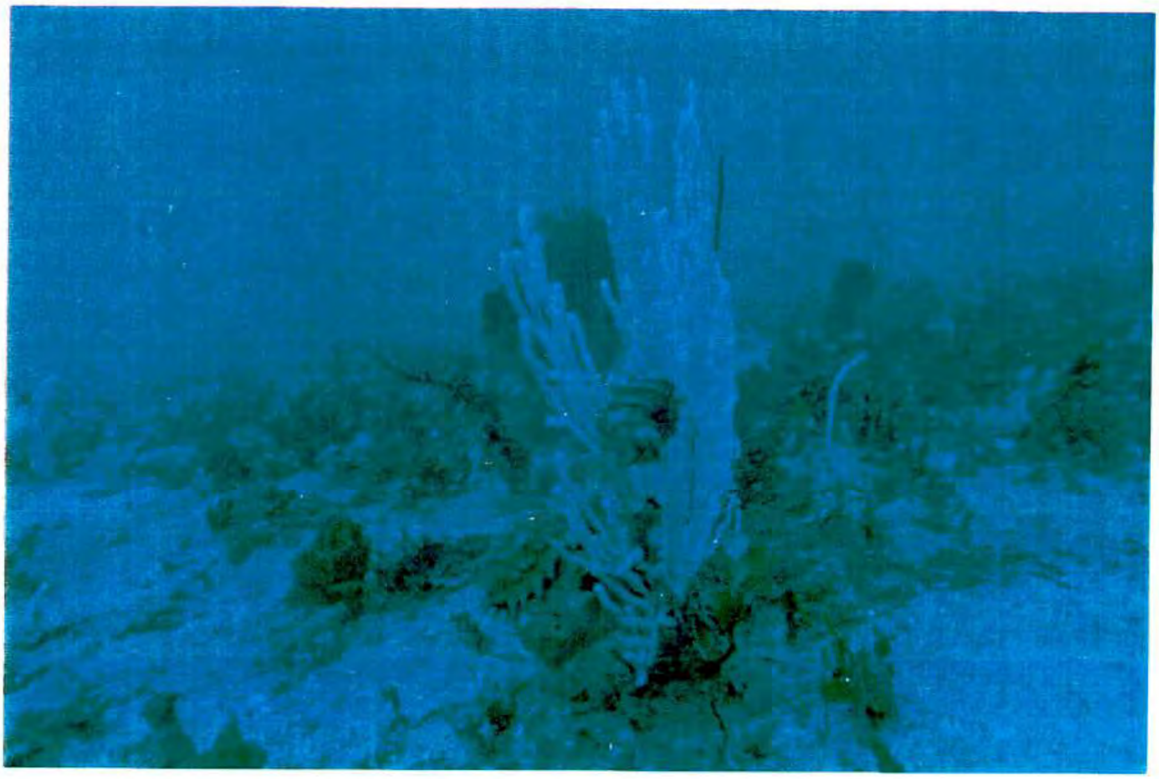

Plate 2: Limestone pavement with a thin (<2 cm) veneer of sand at 12 m depth - Site 7, Route 1. Sea fan (*Gorgonacea*), feather star (*Crinoidea*), sea cucumber (*Holothurioidea*) and calcareous green algae (*Halimeda* sp) in foreground are associated with protruding limestone. In the background are sponges (*Porifera*), solitary ascidians (*Ascidiacea*), a sea whip (*Gorgonacea*) and brown algae (*Sargassum* sp).

Plate 3: Exposed limestone pavement at 10 m depth - Site 11, Route 3. Gorgonians (*Gorgonacea*) are the visually dominant biota.

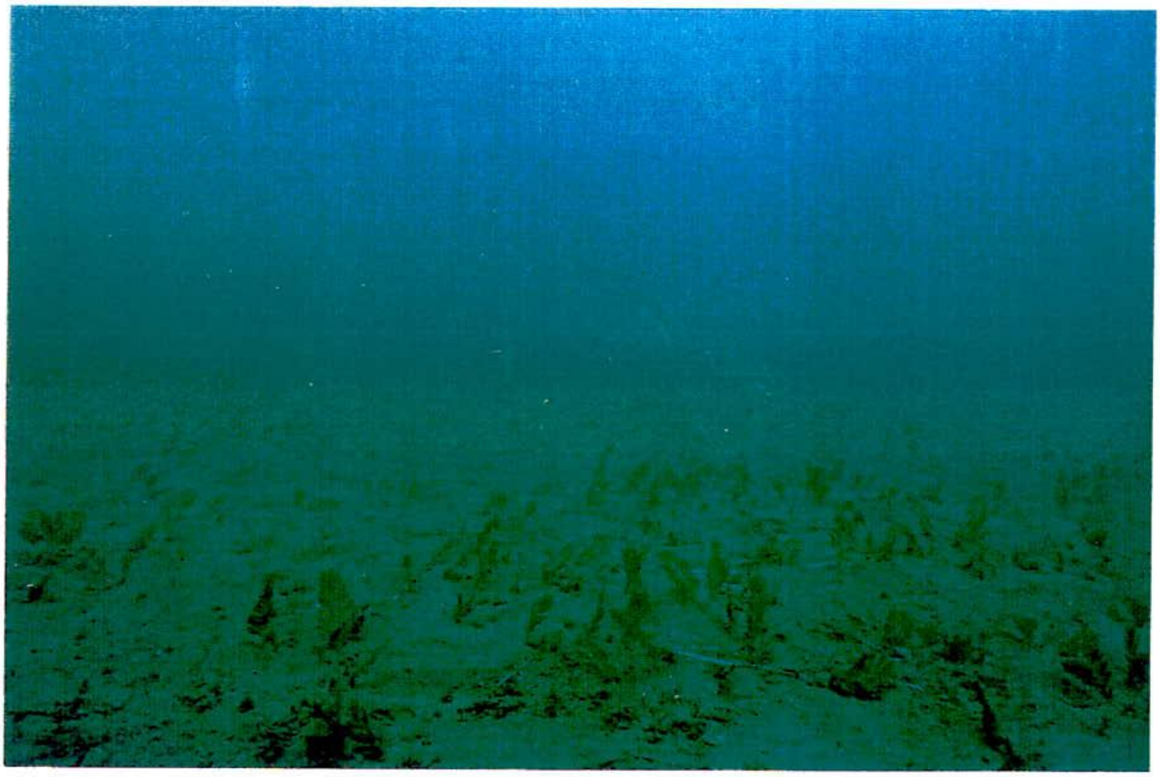

Plate 4: Sand bank at 10 m depth - Site 10, Route 4. Sand is medium texture with seagrass (*Halophila spinulosa*) and a colonial hydroid (*Hydrozoa*). Seagrass cover on the bank reached 25% by area.

Plate 5: Trawl ground, showing typical substrate of coarse sand and gravel with shell fragments and silt, at 9 m depth - Site 14, Route 4. Small gorgonians (*Gorgonacea*) and sea stars (*Asteroidea*) as shown, as well as small sponges (*Porifera*), hydroids (*Hydrozoa*) and ascidians (*Ascidiacea*) are the main components of the very sparse epifauna in these areas.

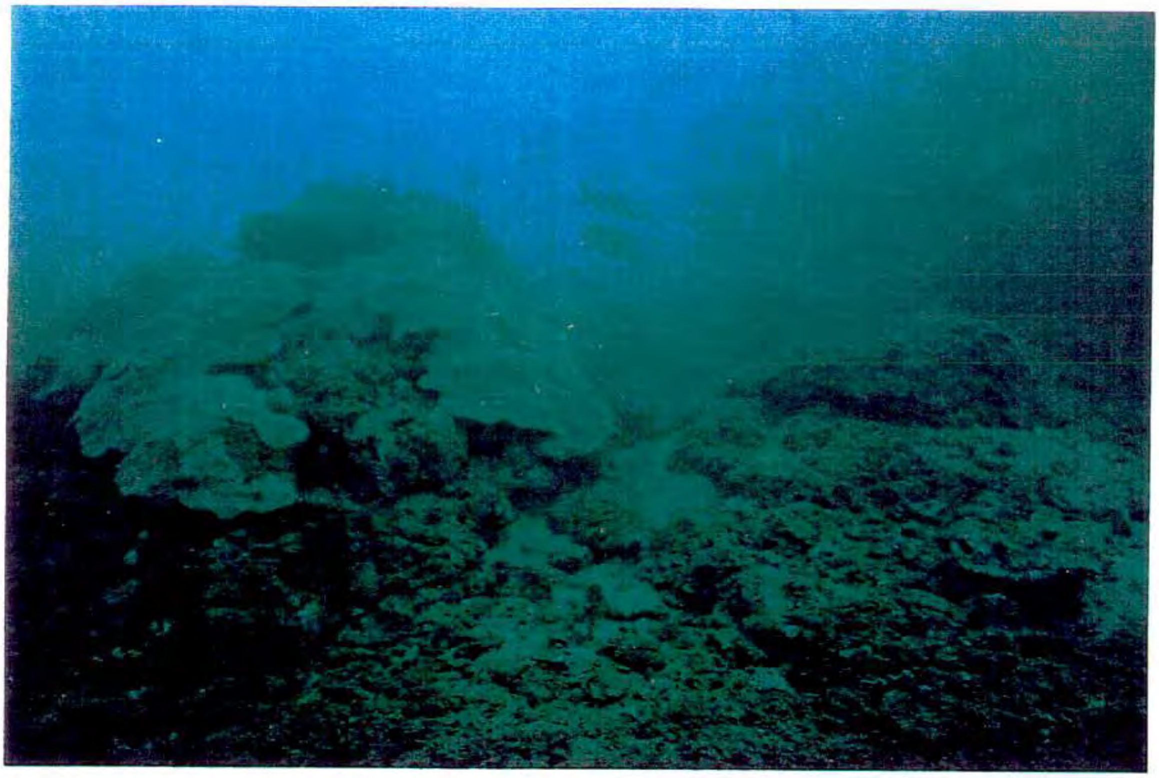

Plate 6: High-relief limestone at 8 m depth - Santo Rock. *Porites* coral colony at left and silt veneer/algal turf over substrate were typical for the area.

Plate 7: High-relief limestone at 4 m depth - East Locker patch. Sparse (10%) hard coral cover was dominated by *Turbinaria* (foreground) *Montipora, Acropora* (centre) and *Porites*. A silt veneer was present over most of the substrate.

Plate 8: High-relief limestone at 5 m depth - East Locker patch. *Porites* coral bommies, approximately 1 m high and 2 m in diameter.

Plate 9: Reef top at 5 m - Locker Reef. Cover of encrusting *Montipora* hard coral (at left) was about 60% in this area. Also shown are the hydrocoral *Millepora* in the foreground and a sea fan (*Gorgonacea*) at right.

Plate 10: Reef top at 5 m - Locker Reef. Cover of the hard coral *Pocillopora* (left foreground) was 60% and cover of the hydrocoral *Millepora* (right foreground) was 10% in this area. Other hard coral species contributed a further 10% cover of the substrate.

APPENDIX 4

GRIFFIN GAS PIPELINE DEVELOPMENT

A DESCRIPTION OF EXISTING FLORA AND FAUNA ALONG THE PROPOSED GRIFFIN GAS PIPELINE ROUTE

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ASTRON ENGINEERING PTY LTD

August 1992

Job No. 805 *cfr: 927/dr/drrev802* *Report No. 802*

A DESCRIPTION OF EXISTING FLORA AND FAUNA ALONG THE PROPOSED ONSHORE GRIFFIN GAS PIPELINE ROUTE

1.0 INTRODUCTION

This report describes flora and fauna along a corridor immediately west of the Ashburton River, in an area known as the Northern Ashburton region. It is through this region that the proposed Griffin Gas Pipeline will be layed. Much of the base line data presented here was originally collected for inclusion in a Consultative Environmental Review produced for Doral Resources' development of the Tubridgi Gasfield. This documentation covered the installation of a gas pipeline from the Tubridgi Gasfield to the Dampier to Perth (SECWA) Pipeline plus plant facilities and flowlines at the field itself. Since the original data was collected, continued environmental monitoring work along the pipeline and in the general vicinity, has resulted in further data being collected. The report is included not only as an indication of the flora and fauna which is present in the vicinity of the pipeline route, but also as a document to be referred to when considering rehabilitation and revegetation methods.

2.0 VEGETATION

2.1 Introduction

The pipeline route traverses the biogeographical region referred to by botanists as the Eremaean Botanical Province (Beard 1975). This vast Province has been subdivided into naturally occurring districts; the Carnarvon Botanical District being the district relevant to this study. According to the descriptions given by Beard (1975) and Beard and Webb (1974) there are four major vegetation units to be found along the pipeline route, these being, Samphire Mud Flats, Shrub Steppe, Tree Steppe, and Shrub Steppe and Wattle Scrub. For this report, however, 10 vegetation units have been described, as below. The area is semi-arid and vegetation is sparse to moderately dense with low ground cover. There are areas totally denuded of vegetation. The northern end of the pipeline route lies in coastal dunes dominated by acacia scrub, which is dense in swales. The hind dunes slope down into samphire covered tidal mudflats behind which are claypans with tussock grasses amid sandy ridges covered with low scrub. At about 25km inland the claypans and sand ridges are replaced by a flat sand plain dotted with Coolabah, Wattle scrub and hummock grassland. The southern end of the pipe route displays outcrops of rock, and alluvial river deposits. Fringing the Ashburton River are moderately dense stands of Coolabah, River Red Gum and Cajeput.

One confirmed species classified as "Rare and Poorly Known" and a second species classified as "Priority 3" under thr Wildlife Conservation Act, occur in the vicinity of the pipeline route. There is also one declared noxious weed.

2.2 Methodology

Vegetation of the area was initially surveyed by helicopter as a part of the pipe route determination exercise performed for the Tubridgi Gas Pipeline. Ten significant physiographic vegetation units were identified along the route. Helicopter landings were made in representative vegetation units in order that identifications and collections could be made. A later survey was undertaken using a four-wheel drive vehicle which enabled more data to be collected. Since these initial surveys, the pipeline route has been travelled many times and the opportunity has been taken for further species identification. The rehabilitated right-of-way has provided information on the success of colonising species and revegetation generally. Records of this have been made and used to make recommendations in the Environmental Management and Rehabilitation Plan.

2.3 Vegetation Units

The major units of vegetation along the pipeline route are as listed below.

1. Coastal Dunes

Pinkish coastal sand dunes lie linear and parallel to the sea. Secondary dunes are as high as 16 metres, with narrow swales between. The dunes support scattered *Acacia coriacea* and hummock grasses *Spinifex longifolius* and *Triodia pungens*. The herbs *Sida rohlenae* and *Solanum lasiophyllum* are abundant. In the swales, acacia cover becomes extremely dense. *Acacia coriacea* is the dominant species, with occasional *A. translucens*. The declared noxious weed, Mesquite (*Prospis* sp.) is also to be found in these areas. In the shallow swale which occurs on the berm between the fore and secondary dunes shallow pools of fresh water are found for some time after rain. It is around these pools that the Stemodia species, *Stemodia* sp. *"Onslow"*, classified as "Rare and Poorly Known" (W H Barker pers comm) is to be found. The hindmost dune and backslope are dominated by *Cenchrus ciliaris*.

2. Saline Flats.

Saline mud flats develop inland of the dune backslope. Their occurrence is common in the vicinity of the proposed Plant Site area. The reddish brown clay soil is dominated by the Halosarcia species, namely *Halosarcia halocnemoides*, *H. auriculata*, *H. indica*, and Sea Couch, *Sporobolus virginicus*. The recently discovered "rare" species, *Stemodia* sp. *"Onslow"* is commonly found on the fringes of these flats. Pale pink sand dunes bordering the Saline Flats support hummock grassland of *Triodia pungens*, (Soft Spinifex), along with the perennial introduced species, Buffel Grass, *Cenchrus ciliaris*. *Solanum lasiophyllum* is frequent with *Pityrodia paniculata* and an overstorey of the low shrub, *Acacia translucens*.

3. Sand Plains

Red sands support hummock grassland of Soft Spinifex *Triodia pungens*, with an overstorey of *Acacia tetragonaphylla*, *Acacia synchronicia*, *Acacia farnesiana*, *Acacia schlerosperma* and *Eucalyptus coolabah*, with lower shrubs *Rhagodia eremaea* and *Senna artemisioides* subsp. *oligophylla*.

4. Circular Depressions

Reddish brown soil with tussock grassland, predominantly *Eriachne Benthamii*, *Eragrostis setifolia* and *Sporobolus mitchellii* The margins of these depressions are fringed with *Eucalyptus coolabah,*, which are usually extremely stunted.

5. Low Lying Plains and Depressions

Found in the area of permanent/semi-permanent water courses, dark red soils support tall shrubland of *Acacia tetragonaphylla*, *Acacia synchronicia*, *Acacia farnesiana*, *Eucalyptus coolabah* with *Scaevola spinescens* and an understorey of tussock grasses *Chrysopogon fallax* and *Eragrostis xerophila*.

6. Alluvial Plains

Red soil supports *Acacia xiphophylla*, *Acacia synchronicia*, *A. tetragonaphylla*, *Acacia sclerosperma*, with scattered *Eucalyptus coolabah* and occasional low shrubs *Rhagodia eremaea* and *Enchylaena tomentosa*. Ground storey includes dense *Cenchrus ciliaris*, Triodia species and *Eragrostis xerophila* along with other ephemeral grasses.

7. Stony Drainage Area

Red soil with pebble overlay supports groves of Snakewood, *Acacia xiphophylla* with occasional *Acacia sclerosperma* and *Acacia synchronicia*.

8. River

The edges of the Ashburton River are fringed with dense tall trees, *Eucalyptus camaldulensis*, *Eucalyptus coolabah*, *Melaluca leucodendra* and *Melaluca glomerata*. The poorly developed levees also support *Acacia coriacea*, *Acacia trachycarpa*, *Acacia synchronicia* and the grasses *Cenchrus ciliaris* and *Paspalidium jubiflorum*. The annual creeper *Operculina brownii* along with the exotic species, *Malvastrum americanum* form the dominant ground cover.

9. Grassland Parallel to the River

Sandy areas of hummock grassland of Soft Spinifex, *Triodia pungens*, Hard Spinifex, *T. wiseana* and *T. lanigera*, tussock grass *Eriachne Gardneri* with an overstorey of occasional *Acacia trachycarpa*, *Acacia synchronicia*, *Acacia farnesiana*, and *Acacia sclerosperma*.

10. Inland Dunes

These dunes run parallel to the Ashburton River and are often curved. Their red sandy soils support *Triodia pungens*, *T. angusta*, *Cenchrus ciliaris* with occasional *Plectrachne schinzii* and *Pityrodia paniculata* and an overstorey of sparse *Acacia sclerosperma*, *A. translucens* and *Grevillea stenobotrya*.

Only dominant and frequent species in each of the above units have been named.

2.4 "Rare" Species in the Vicinity of the Pipeline Route

There is definitely one species, classified under the Wildlife Conservation Act as "Rare and Poorly Known" in the immediate vicinity of the pipeline route, and the possibility of a second, classified as "Rare". The former is currently being referred to as *Stemodia* sp. *"Onslow"* until its description and nomenclature is formerly published. It is found in the shallow swale behind the coastal fore dune, around the edges of fresh water pools. It is also found on the fringes of the saline flats, including the area of backslope between the saline flats and hind dunes. Although it is found relatively frequently in the immediate area of the pipeline route, the extent of its occurrence beyond this area is presently unknown. For example, it has not to date been found at the nearby location of Onslow.

The second plant which is noteworthy is _Acacia glaucocaesia_. This species has been recently described subsequent to the subdivision of the original _Acacia victoriae_ (referred to in the Tubridgi Report). This newly described species has been classified by CALM as "Priority 3" under the Wildlife Conservation Act. Attempts were made to resurvey the proposed pipeline route prior to this report in order to confirm whether or not the previously identified _A. victoriae_ might in fact be _A. glaucocaesia_. This survey was not successful however, due to extensive water covering the pipeline route approximately 5 km from the plant site. Samples of the plant were taken from the dunes and the first 5 km along the route. These have all been identified as _A. synchronicia_.

2.5 Noxious Weeds

On the foredune and primary swale, the declared noxious tree species, Mesquite, (_Prospis_ sp.) is to be found. One large specimen is located within 10m of the proposed pipeline route on the foredune. This tree appears to have been treated as foliage is dying off. Other trees were found in the vicinity which had not been treated. Quarantine of machinery working in the area of these trees will be necessary before it proceeds along the pipeline route in order to prevent the spread of the weed.

2.6 Species List

In total, 160 plant species were identified, representing 40 families. (Confirmation is still pending on some of these). A full list is included in Table 1.

2.7 Recommendations

It is recommended that the new pipeline route lies as closely as possible to the existing Tubridgi pipeline in order to avoid further disturbance to vegetation. Where areas of dense vegetation, including stands of larger trees, wattle scrub and areas of the samphire species have previously been avoided, the same policy should apply. Saline flats are equally vulnerable to erosion and degradation; the low *Halosarcia* bushes both stabilise the soil and, importantly, add nutrients essential for keeping the area fertile. The *Halosarcia* species are an important fodder for stock, and also, presumably, for native species.

During construction of the Tubridgi pipeline, many well established shrubs and trees which occur along the right-of-way, were left insitu. Machinery and vehicles went around them. It is recommended that this policy is again adhered to, thus minimising destruction where it is not necessary.

Tall trees, such as those found along the banks of the Ashburton River, are relatively scarce in the region and therefore it is imperative that destruction of these be minimised. The river crossing selected for the Tubridgi gas pipeline was located where these trees were sparse so this particular vegetation unit and fauna habitat would not be greatly affected. It is recommended that the Griffin pipeline be laid as closely as possible to the existing pipeline, thus minimising vegetation damage and the possibility of further erosion on the river banks. To encourage revegetation on the banks, it is recommended that they be stabilised with sandbags seeded with local grass, Eucalypt and Melaluca species.

Of significant concern are the sandhills as they are extremely fragile. Vehicle tracks, removal of vegetation and altering of contours will inevitably cause erosion, and loss of soil to the elements. Because the sand on these dunes is prone to shift, vegetation takes many years to establish. Experience on the Tubridgi pipeline indicates that even opportunistic ephemerals do not readily revegetate the sand dunes.

Considerable attention needs to be given to the coastal dunes. They are subject to movement and sand loss which is caused by strong winds. Vegetation, which is dense in places, serves to stabilise sand and its disturbance will need to rectified as quickly as possible. Temporary sand stabilising methods should be investigated as a stop-gap measure whilst vegetation reinstates itself. The area should be the subject of a careful revegetation program, which should involve pre-construction tests to determine soil/sand composition and chemistry. In addition seed germination and propagation success rates on major and significant species need to be determined. This is especially so for A. coriacea, the dominant species, which is known to be difficult to germinate, and also for the "rare" species Stemodia sp. "Onslow".

3.0 FAUNA

3.1 Introduction

A relatively small range of ecosystems occur within the biogeographical region known to zoologists as the Eyrean Zoogeographic Zone (Serventy & Whittell 1976). It is through this zoogeographic zone that the proposed Griffin gas pipeline will be layed, running beside the existing Tubridgi pipeline.

The natural ecosystems along the proposed pipeline route have been somewhat degraded by introduced grazing animals both domestic and feral. Fauna in the area of the pipeline route is poorly documented and research data is scarce. The Pebble Mound Mouse, Pseudomys chapmani, classified as "Vulnerable" under Schedule 1 of the Wildlife Conservation Act, has been recorded in the vicinity of the southern portion of the pipeline route.

Fauna in the region tend to be hardy and well adapted to the arid conditions. The larger species are generally nomadic, following food and water sources as necessary, therefore population numbers at any one time vary. Other species, especially frogs, reptiles and snails have the ability to aestivate. Pastoral areas along the proposed route provide windmills and bores to support more water reliant species, as does the close proximity of the Ashburton River. Despite baiting and various other eradication programmes, feral cats, donkeys and foxes all compete with native fauna populations in the area.

3.2 Collection of Data

Extensive rains occurred shortly before the planned survey and prevented access to the study area due to boggy conditions. Consequently no further sightings or collection of vertebrate fauna was possible for this report. The vertebrate fauna was studied in a previous survey for the Doral pipeline route, however. The information from this survey was collected by visual observation, pit traps, Elliot traps and anecdotal evidence. A list of species is presented in Table 3.

To supplement the information of the vertebrate fauna in the study region, a list of the reptilian fauna, was supplied from the Western Australian Museum's vertebrate computer database. This list was not extensive, nor was it confined solely to the study area but it indicates the type of reptiles that may be encountered. This data is also presented in Table 3.

3.3 Mammals

There are approximately 20 species of mammals thought to inhabit the northern Ashburton area (Strahan, 1983). These are thought to include three species of mouse, several rats, two antechinus, two dunnarts and three wallabies. The Spinifex Hopping Mouse, *Notomys alexis*, has occasionally been seen in the area. The Vulnerable Pebble Mound Mouse, *Pseudomys chapmanii*, has been previously recorded in the vicinity of the southern portion of the route, however, no local sightings have been confirmed.

The pit and Elliot traps, which were set in the initial study, covered three types of habitats along the proposed route but did not trap any mammals. Extensive rain just before this survey made natural food and water sources abundant and made the trapping of animals difficult.

The rains brought into the area the Red Kangaroo, *Macropus rufus*. Water and food in an area guarantees a large population of this species, but during the dry months it migrates south following the rains. Its population thus fluctuates during the year according to precipitation. Small populations of the Common Wallaroo or Euro, *Macropus robustus*, are to be found within an 8 km radius of Minderoo homestead, where they are protected from any shooting.

Despite eradication programs, numerous feral cats and goats have been seen throughout the area. A small number of feral donkeys have also been observed at the southern end of the pipeline route . The population of feral foxes has decreased significantly due to the eradication programme and a noticeable increase in the Emu, reptile and other native bird species has been observed. The Dingo, *Canis familiaris dingo*, is not resident in the area but migrates towards the river from the hills during the summer months.

3.4 Reptiles

Due to the large number or micro-habitats encountered along the proposed route it is estimated that approximately 60 species of reptiles could potentially inhabit the area. Fifteen definite recordings are presented in Table 3.

3.5 Birds

A total of 51 bird species have been identified to date and these are listed in Table 2.

Like the Red Kangaroo, large flocks of Emu, *Dromaius novaehollandiae*, are brought into the area with the rains and their population number will fluctuate during the year as they follow the rains.

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TABLE 1

TUBRIDGI PIPELINE - VEGETATION LIST

FAMILY & No.		GENUS SPECIES	AUTHOR	COMMON NAME
Poaceae	31	Aristida Browniana	Henrard	Erect Kerosene Grass
		Aristida contorta	F Muell	Bunched Kerosene Grass
		* Cenchrus ciliaris	L	Buffle Grass
		* Cenchrus setigerus	M Vahl	Birdwood Grass
		Chrysopogon fallax	S T Blake	Ribbon Grass
		Chloris pectinata	Benth	Comb Chloris
		Chloris pumilio	R Br	
		Cynodon dactylon	(L) Pers.	Couch
		Dactyloctenium radulans	(R Br)P Beauv	Button Grass
		Enneapogon caerulescens	(Gaudich)N Burb	Limestone Grass
		Eragrostis eriopoda	Benth	
		Eragrostis setifolia	Nees	Plain Grass
		Eragrostis xerophila	Domin.	Roebourne Plains Grass
		Eriachne aristidea	F Muell	Three-awned Wanderrie
		Eriachne Benthamii	(Domin)Hartley	Swamp Wanderrie
		Eriachne flaccida	Hartley	
		Eriachne Gardneri	Hartley	
		Eulalia fulva	(R Br) Kuntze	Silky Browntop
		Panicum decompositum	R Br	Native Millet
		Paspalidium jubiflorum	(Trin)Hughes	Warrego Grass
		Plectrachne schinzii	Henrard	Oat-eared Spinifex
		Sorghum plumosum	P Beauv ex. Roemer	Plume Sorghum
		Sporobolus mitchellii	(Trin) CE Hubb.	
		Sporobolus virginicus	(L)Kunth	Sea Couch
		Triodia angusta	N Burb	
		Triodia lanigera	Domin	

FAMILY & No.		GENUS SPECIES	AUTHOR	COMMON NAME
Poaceae	31	Triodia pungens	R Br	Soft Spinifex
		Triodia wiseana	C Gardner	Hard Spinifex
		Whiteochloa airoides	(R Br) Lazarides	
Cyperaceae	32	Cyperus vaginatus	R Br	Sedge
		Cyperus cunninghamii	(CB Clarke) C Gardner	
Commelinaceae	47	Commelina ensifolia	R Br	
Anthericaceae	54F	Anthropodium ?strictum	R Br	
Proteaceae	90	Grevilleaeriostachya	Lindley	Kalinkalinpa
		Grevilleastenobotrya	F. Muell	
		Hakea suberea	S Moore	Corkwood
Loaranthaceae	97	Amyema sp.		Mistletoe
Chenopodiaceae	105	Atriplex bunburyana	F Muell	Silver Salt Bush
		Atriplex semilunaris	Aellen	Annual Salt Bush
		Atriplex codonocarpa	(F Muell) PG Wilson	
		Dysphania plantaginella	F Muell	
		Dysphania rhadinostachya	(F Muell) AJ Scott	
		Enchylaena tomentosa	R Br	Ruby Saltbush
		Halosarcia auriculata	P G Wilson	
		Halosarcia halocnemoides	(Nees) PG Wilson	
		Halosarcia indica	P G Wilson	
		Maireana ? scleroptera	(J Black) PG Wilson	
		Rhagodia eremaea	P G Wilson	Tall Saltbush
		Salsola kali	L	Roly Poly

FAMILY & No		GENUS SPECIES	AUTHOR	COMMON NAME
Amaranthaceae	106	* Aerva javanica	(Burm f) Juss ex. Schultes	Kapok
		Amaranthus pallidiflorus	F Muell	
		Gomphrenaaffinis	F Muell ex Benth	
		Gomphrenacunninghamii	(Moq) Druce	
		Ptilotus aervoides	(F Muell) F Muell	
		Ptilotus axillaris	(F Muell ex Benth) F Muell	Mat Mulla Mulla
		Ptilotus clementii	(Farmar) Benl	
		Ptilotus exaltatus	Nees	Tall Mulla Mulla
		Ptilotus polystachyus	(Gaudich) F Muell	
		Ptilotus villosiflorus	F Muell	Beach Mulla Mulla
Nyctaginaceae	107	Boerhavia repleta	H J Hewson	
		Boerhavia sp.		
Gyrostemonaceae	108	Gyrostemon ramulosus	Desf	
Portulacaceae	111	Calandrinia polyandra	Benth	
		Calandrinia sp.		
		Portulaca conspicua	Domin	March Buttercup
		Portulaca oleraceae	L	Purslane
Lauraceae	131	Cassytha aurea	J Z Webber	
		Cassytha filiformis	L	Dodder
Capparaceae	137a	Cleome viscosa	L	
Surianaceae	160	Stylobasium spathulatum	Desf	Pebble Bush

FAMILY & No.		GENUS SPECIES	AUTHOR	COMMON NAME
Mimosaceae	163	Acacia bivenosa	DC	Two Nerved Wattle
		Acacia coriacea	DC	Leather Leaved Wattle
		Acacia farnesiana	(L)Willd	Sweet Mimosa
		Acacia gregorii	F Muell	Gregory'sWattle
		Acacia inaequilatera	Domin	Camel Bush
		Acacia pachycarpa	F Muell ex Benth	
		Acacia sclerosperma	F Muell	Limestone Wattle
		Acacia tetragonaphylla	F Muell	Kurara
		Acacia trachycarpa	E Pritzel	Sweet Scented Minni-Ritchi
		Acacia translucens	Cunn ex Hook	Poverty Bush
		Acacia victoriae	Benth	Prickly Acacia
		Acacia synchronicia	Maslin sp. nov	Prickly Acacia
		Acacia wanyu	Tind	Wanyu
		Acacia xiphophylla	E Pritzel	Sankewood
		Acacia sp.1		
		Dichrostachys spicata	(F Muell) Gardner	Pied Piper Bush
		Neptunia dimorphantha	Domin	
Caesalpinaceae	164	Senna glutinosa subsp. glutinosa	(DC) BR Randell	
		Senna artemisioides subsp. oligophylla	(F Muell) BR Randell	
		Senna glutinosa subsp. pruinosa	(F Muell) BR Randell	
		Cassia notabilis	F Muell	
		Cassia venusta	F Muell	
		Cassia sp. (? desolata)		
Papillionaceae	165	Clianthus formosus	(G.Don) Ford & Vick	
		Crotalaria medicaginea	Lam	
		Crotalaria cunninghamii	R Br	GreenBirdflower
		Indigofera monophylla	DC	
		Indigofera trita	L f	
		Rhynchosia minima	(L) DC	Clover-leafed Yellow Pea
		Sesbania cannabina	(Retz) Poiret	
		Swainsona kingii	F. Muell	

FAMILY & No.		GENUS SPECIES	AUTHOR	COMMON NAME
Papillionaceae	165	Swainsona pterostylis	(DC) Bakh	
		Tephrosia eriocarpa	Benth	
		Vigna lanceolata	Benth	Yam
Geraniaceae	167	Erodium angustilobium	Carolin	Crows foot
Zygophyllaceae	173	Tribulus occidentalis	R Br	Caltrop
Euphorbiaceae	185	Adriana tomentosa	Gaudich	
		Euphorbia coghlanii	Bailey	
		Euphorbia drummondii	Boiss	
		Euphorbia tannensis	Sprengel	
		Flueggea virosa	(Roxb ex Willd) Voigt	
Tilaceae	220	Corchorus walcotti	F Muell	Northern Buttercup
Malvaceae	221	Abutilon sp.		
		* Malvastrum americanum	(L) Torrey	
		Sida fibulifera	Lindley	
		Sida sp. rohlenae	Domin	
		Sida sp.		
Sterculiaceae	223	Melhania oblongifolia	F Muell	
Frankeniaceae	236	Frankenia ambita	Ostenf.	
Violaceae	243	Hybanthus aurantiacus	(F Muell ex Benth)F Muell	Flag Violet

FAMILY & No.		GENUS SPECIES	AUTHOR	COMMON NAME
Myrtaceae	273	Eucalyptus aspera	F Muell	
		Eucalyptus camaldulensis	Dehnh	River Red Gum
		Eucalyptus coolabah	Blakey & Jacobs	Coolabah
		Eucalyptus centralis	F Muell	Bloodwood
		Eucalyptus sp.		
		Melaleuca glomerata	F Muell	
		Melaleuca leucadendra	(L)L	Cajeput
Apiaceae	281	Trachymene oleraceae	Burtt	
Asclepiadaceae	305	Sarcostemma viminali subsp. australe	(RBr) Forster	Caustic Bush
Convulvulaceae	307	Evolvulus alsinoides	(L) L	
		Ipomoea muelleri	Benth	Poison Morning Glory
		Operculina brownii	Ooststr	Bush Potato
		Polymeria ambigua	R Br	Tangled Morning Glory
Boraginaceae	310	Heliotropium crispatum	F. Muell	
		Heliotropium ovalifolium	Forsstal	
		Heliotropium heteranthum	(F. Muell) Ewart	
		Heliotropium tenuifolium	R Br	
		Trichodesma zeylanicum	(Burm f) R Br	Rough Bluebell
Chloanthaceae	311A	Pityrodia paniculata	(F Muell) Benth	
Solanaceae	315	Nicotiana accidentalis	Wheeler	Native tabacco
		Solanum diversiflorum	F Muell	
		Solanum lasiophyllum	Dunal ex Poiret	Flannel Bush
		Solanum sturtianum	F Muell	
		Solanum phlomoides	Cunn. ex Benth	

FAMILY & No.		GENUS SPECIES	AUTHOR	COMMON NAME
Scrophulariaceae	316	Stemodia grossa	Benth	
		Stemodia sp. "Onslow"	W R Barker (2145)	
Myoporaceae	326	Eremophila forrestii	F. Muell	
Cucurbitaceae	337	Mukia maderaspatana	(L) M Roemer	
Lobeliaceae	340	Lobelia heterophylla	Labill	
Goodeniaceae	341	Goodeniamicroptera	F Muell	
		Goodeniaheterochila	F Muell	
		Scaevola spinescens	R Br	Currant Bush
		Scaevola crassifolia	Labill	
		Scaevola cunninghamii	DC	
		Scaevola amblyanthera		
Asteraceae	345	Angianthus milnei	Benth	
		Centipeda minima	(L) A Braun	
		Minuria Cunninghamii	(DC)Benth	
		Olearia sp.* (Eurybia dampieri DC)		
		Pterocaulon sphaeranthoides	(DC)F Muell	

TABLE 2

BIRD SPECIES RECORDED ALONG TURBIDGI PIPELINE ROUTE

Emu	*Dromaius noveahollandia*
Australian Pelican	*Pelecanus conspicillatus*
Eastern Reef Heron (Grey)	*Egretta sacra*
Pacific Heron	*Ardea pacifica*
Black-necked Stork (Jabiru)	*Ephippiorhynchus asiaticus*
Straw-necked Ibis	*Threskiornis spinicollis*
Black Swan	*Cygnus atratus*
Spotted Harrier	*Circus assimilis*
Whistling Kite	*Haliastur sphenurus*
Wedge-tailed Eagle	*Aquila audax*
Little Eagle	*Hieraaetus morphnoides*
Black-shouldered Kite	*Elanus notatus*
Brown Falcon	*Falco berigora*
Australian Kestrel	*Falco cenchroides*
Australian Bustard	*Ardeotis australis*
Brown Quail	*Coturnix australis*
Grey-tailed Tattler	*Tringa hypoleucos*
Common Sandpiper	*Tringa hypoleucos*
Wood Sandpiper	*Tringa glareola*
Silver Gull	*Larus novaehollandiae*
Tern	*Sterna sp.*
Spinifex Pigeon	*Petrophassa plumifera*
Diamond Dove	*Geopelia cuneata*
Peaceful Dove	*Geopelia striata*
Crested Pigeon	*Ocyphaps lophotes*
Galah	*Cacatua roseicapilla*
Little Corella	*Cacatua sanguinea*
Cockatiel	*Nymphicus hollandicus*

Table 2 con't

BIRD SPECIES RECORDED ALONG TURBIDGI PIPELINE ROUTE

Ringnecked Parrot	*Platycerus zonarius*
Budgerigar	*Melopsittacus undulatus*
Blue-winged Kookaburra	*Dacelo leachii*
Sacred Kingfisher	*Halcyon sancta*
Welcome Swallow	*Hirundo neoxena*
Tree Martin	*Cecropis nigricans*
Richard's Pipit	*Anthus novaeseelandiae*
Brown Songlark	*Cinclorhamphus cruralis*
Black-faced Cuckoo-Shrike	*Coracina novaehollandiae*
Spinifex Bird	*Eremiornis carteri*
Yellow-throated Miner	*Manorina flarigula*
Grey-headed Honeyeater	*Lichenostomus keartlandi*
White-plumed Honeyeater	*Lichenostomuspenicillatus*
Painted Firetail Finch	*Emblema pictum*
Zebra Finch	*Poephila guttata*
Little Woodswallow	*Artamus minor*
Masked Woodswallow	*Artamus personatus*
White-breasted Woodswallow	*Artamus leucorhynchus*
Magpie Lark	*Grallina cyanoleuca*
Pied Butcherbird	*Cracticus nigrogularis*
Australian Black-backed Magpie	*Gymnorhina tibicen*
Torresian Crow	*Corvus orru*
Little Crow	*Corvus bennetti*

TABLE 3

TUBRIDGI PIPELINE FAUNA

VERTEBRATES			
	AMPHIBIANS		*Neobatrachus sp.*
			Cyclorana maini
	REPTILES	AGAMIDAE	*Ctenophorus caudicinctus*
			Ctenophorus inermis
			Ctenophorus reticulatis
			Ctenophorus rubens
		ELAPIDAE	*Pseudonaja nuchalis*
			Rhinocephalus puntatus
		GEKKONIDAE	*Diplodactylus conspicillatus*
			Gehyra variegata
			Heteronotia binoei
		LEPTODACTYLIDAE	*Neobatrachus sp.*
		SCINCIDAE	*Ctenotus hanloni*
			Ctenotus iapetus
			Lerista bipes
			Morethia ruficauda
		VARANIDAE	*Varanus brevicauda*
	MAMMALS	DASYURIDAE	*Sminthopsis macroura*
		MACROPODIDAE	*Macropus robustus*
INVERTEBRATES			
	SPIDERS	LYSOSIDAE	*Lycosa sp.*
		CTENIDAE	
	INSECTS		
	ANTS	MUTILLIDAE	*Ephutomorpha sp.*
		FORMICIDAE	*Melophorus sp.*
	BEETLES	CARABIDAE	*Gigadema sp.*
		TENEBRIONIDAE	*Helaeus sp.*
			Celibe sp.
	SILVERFISH	LEPISMATIDAE	
	CENTIPEDES	SCOLOPENDRIDAE	*Scolopendra laeta*

APPENDIX 5

GRIFFIN GAS PIPELINE DEVELOPMENT

A SUMMARY OF TERRESTRIAL SURVEYS AND DESCRIPTION OF PIPELINE ROUTING BETWEEN THE PLANT SITE AND THE COAST

Prepared by PJ & VL Long
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September 1992

Job No. 805 *cfr: 927\dr\drrev803* *Report No. 803*

A SUMMARY OF TERRESTRIAL SURVEYS AND A DESCRIPTION OF PIPELINE ROUTING BETWEEN THE PLANT SITE AND THE COAST

1. INTRODUCTION

BHP Petroleum, on behalf of its joint venture partners, is proposing to install a pipeline to transport gas between the offshore Griffin Field and the Dampier to Perth Gas Trunkline.

To minimise disturbance to land form and vegetation, it has been decided to locate the proposed onshore Griffin plantsite adjacent the existing Tubridgi plantsite, on Urala Station. For the same reason, the Griffin pipeline will follow the Tubridgi Gas pipeline easement back to Compressor Station 2, on the Dampier to Perth gas trunkline. Terrestrial pipe alignments therefore only require consideration between the plant site and the coast

To enable choice of an appropriate offshore gas pipeline route, seafloor surveys have been undertaken along four possible corridors. Both of these possible routes crosses the coast at one of three locations between Tubridgi Point and the Ashburton River. The preferred offshore route has its landfall at a location slightly west of Rocky Point, about 4 km from Urala homestead.

This report summarises terrestrial surveys conducted to evaluate possible routes from the plant site to the coast and describes the reasoning behind the proposed alignment.

2. CONSTRAINTS

Coastal conditions are similar along the mainland shoreline where pipe crossings may occur. As a result pipe alignment evaluation has not included tidal and current studies, stratigraphic test bores or other engineering investigations which will be required before pipeline installation can begin. The following parameters were considered relevant for terrestrial pipeline route assessment:-

1. Disturbance to vegetation and landform.
2. Soil type.
3. Pastoral value of disturbed land.
4. Hydrology
5. Archaeology and Ethnography
6. Rare vegetation.
7. Susceptibility to erosion.
8. Disruption to pastoral activities.

Fauna was not considered to be of major significance in the route assessment as the pipeline will be buried and will cause only temporary disturbance during construction. Loss of habitat is important, but this will be minimised through vegetation impact management techniques, and the fact that less than 20 ha of virgin country is likely to be disturbed. A separate report, (Appendix 4 of this CER), has evaluated fauna in the vicinity. One species which may inhabit the vicinity of the pipeline route, *Pseudomys chapmani*, (Pebble Mound Mouse), is classified under the Wildlife Conservation Act as "Vulnerable". This is a Schedule 1 classification, but because the proposed route is utilising land previously disturbed for the Doral pipeline, it is not anticipated to be a problem.

3. COASTAL GEOMORPHOLOGY

The ocean frontage of Urala Station in the vicinity of the possible pipeline crossing points is a sandy beach, with Holocene dunes varying in height from 4 to 16 metres above sea level. The area between Baresand and Rocky Points consists of low, parallel, linear dunes with some significant salt-flat intrusions. This dunal area varies in total width from 2 km to 3 km. Between Rocky Point and Urala homestead the coastal dune strip is narrower, but higher (10 - 16 m). West of Urala homestead, the dunes merge into a low, (3 - 4 m) comparatively well vegetated sandy plain. Saline flats intrude on the sandy areas, however, and are more-or-less contiguous between the Ashburton River and Tubridgi Point. These flats are consistently 2 m above sea level and are broadest (3 km) at the Tubridgi Gas Field. Behind the saline flats is a ridge of partially cemented dunes which are probably of Pleistocene age and which peak at an elevation of 12 m. The existing Tubridgi Plant Site is sited in a landward swale of one of these dunes.

4. PIPE ROUTE ALTERNATIVES

Onshore pipe routes were only considered in detail after the preferred offshore route was decided upon. Although the eastern and western landfalls could be accommodated, both had significant disadvantages. The eastern coastal crossing (near Baresand Point) is 8 km from the plant and requires the gas pipeline to negotiate the wide parallel dune area and the creek at Rocky Point. These dunes also contain many aboriginal sites which would have to be avoided. The western landfall is 9 km distant and south of the plant. The pipeline would therefore have to "back-track" north through the tussock grassland plain which is a productive part of Urala Station.

The central crossing, which was on the preferred offshore route is much more direct (4.6 km from the plant), and has the advantage of being able to access existing Tubridgi flowline easements, which are already disturbed. Although the dunes are high at this point, the sandy area is by far the narrowest.

The preferred offshore route actually makes its landfall between Rocky Point and Kapock Well. The Company was reluctant to go further west because of the proximity of Urala homestead. The region of Rocky Point itself was also out of the question because of outcropping rock in the area. Field surveys therefore concentrated on the coastal strip between Rocky Point and Kapock Well.

5. COASTAL TOPOGRAPHY AND HYDROLOGY

Detailed topographic maps for the proposed landfall areas have been compiled by Doral Resources for the Tubridgi Gas Field Development. The coastal strip between Rocky Point and Kapock Well features a low (4 m) foredune, a wide (300 m) berm of elevation 3 - 4 m, a high (10 - 16 m) secondary foredune and a series of lower dunes and swales which drop to the saline mud flat 1 km from the coast. At the proposed pipe alignment the highest point is 12.5 m, the hind dune is of 7 m elevation and there is a gentle back slope. (See Fig. 4.7).

Underneath the coastal dunes and presumably sealed by a clay strata at about sea level, is a freshwater aquifer. After heavy rains, this aquifer surfaces in depressions along the berm. As a result there are dense stands of Acacia and other shrubs on the berm, only 100m from the sea. The aquifer is a prime source of water for Urala homestead and for stock. Previous drilling programs have resulted in its contamination by salt water so the pastoralist is anxious that this does not re-occur during the Griffin Project. The extent of the aquifer is not known.

6. ARCHAEOLOGICAL AND ETHNOGRAPHICAL CONCERNS

Several archaeological sites were known to occur along the coastal strip between Rocky Point and Kapock Well. (Veth et. al. 1990). These sites limited the corridor along which the pipes could be run to a 1 km strip, 1.5 km west of Rocky Point. There were no benefits in shifting the shore crossing along the coast in either direction as previous surveys had recorded numerous sites in the vicinity, including burials. A survey of the pipeline corridor was undertaken in June 1992, (Wright & Veitch, 1992) along a route which bisected the ground between sites P5569 and P5570. This survey revealed a large number of shell scatters, both on the proposed pipe route and for several kilometres along the coastal strip west of Rocky Point. The middens constituted an Aboriginal site as defined by the Aboriginal Heritage Act 1972-80. There were no ethnographic concerns and the archaeological consultants recommended Doral seek Ministerial consent to disturb the sites, subject to a detailed archaeological survey and recording program. This was done and approval to disturb the sites was granted in July, 1992

7. VEGETATION DESCRIPTION

The vegetation in the area is classified as coastal and is reasonably salt tolerant. The area could generally be described as dune shrubland, consisting of a moderately dense overstorey of *Acacia coriacea* and *A. translucens* over *Spinifex longifolius* (Beach Spinifex) and *Triodia pungens* (Soft Spinifex) with frequent patches of *Cenchrus ciliaris* (Buffel Grass).

Vegetation species are fairly uniform across the area, with minor variations as described below. Density of species varies to a great extent.

On the beach vegetation is very sparse. Isolated tussocks of *Spinifex longifolius* occur with very rarely occurring *Scaevola crassifolia*.

On the foredune, *Spinifex longifolius* and *Eulalia fulva* tussocks occur occasionally with frequent but isolated *Acacia coriacea* shrubs. The annual herb *Euphorbia australis* and ephemeral *Ptilotus villosiflorus* are also occasional here.

Vegetation is abundant within depressions on the berm and in the interdune swales. *Acacia coriacea* dominates these areas and dense thickets occur with shrubs growing to 5m tall. Frequent *Acacia translucens*, and occasional *A. tetragonaphylla* are the other shrub species to be found here along with *Pityrodia paniculata*. The grasses *Triodia pungens*, *Cenchrus ciliaris* and *Spinifex longifolius* are all frequent, along with occasional *Eriachne benthamii*. The annual herbaceous species *Sida rohlenae* and

Solanum lasiophyllum are frequent, as is the ephemeral Ptilotus villosiflorus. Fresh water pools occur within depressions on the berm, and fresh water species are to be found there, notably Cyperus vaginatus. The currently classified "Rare and Poorly Known" species, Stemodia sp. "Onslow", (WH Barker 2145) also occurs in these depressions.

Acacia coriacea occurs frequently on the secondary, but less so on the hind dunes, along with occasional A. translucens. These dunes are frequently grassed with Triodia pungens and Cenchrus ciliaris. Solanum lasiophyllum is frequent here along with Sida rohlenae. Herbs Euphorbia australis and E. coghlanii and the ephemerals Nicotiana occidentalis and Ptilotus villosiflorus are also common. The more uncommon stemless herb, Arthropodium strictum, (Chocolate Lily) also occasionally occurs here.

The backslope is dominated by Buffel Grass, (Cenchrus ciliaris). Shrubs become sparse. A. coriacea is only occasional and eventually gives way to Acacia sclerosperma, A. tetragonaphylla and A. synchronicia, all of which only occur rarely towards the edge of the saline flats. The low shrub Senna artemisioises subsp. oligophylla and dwarf shrub Frankenia pauciflora occur occasionally here with ephemeral Brachycome latisquamea.

8. RARE AND POORLY KNOWN SPECIES

One of the Scrophulariacae family, recognised as a Stemodia was recorded during the vegetation survey of the coastal crossing. Specimens collected could not be determined against any available descriptions, so they were sent to the current author of the species, Dr W H Barker, at the Adelaide Botanic Gardens State Herbarium. Dr Barker has indicated that the plant is currently being described as a new species, (nomenclator will not be given until his work is published). For the purpose of this report, he has stated that it should be referred to as Stemodia sp. "Onslow" (Ref. WH Barker 2145). Because it is a new species and its occurrence appears to be restricted between Onslow and

Carnarvon along the coast, it has been classified as "Rare and Poorly Known" until further investigation and collections can be made. (pers. comm. W R Barker, SA State Herbarium). For this reason, its extent was mapped along the coastal strip (See Fig 6.6) and its presence recorded elsewhere in the area when observed.

9. SOIL CONDITIONS AND EROSION

An extensive area of sandy soils could not be avoided at the coastal crossing point. Difficulties with sand include susceptibility to wind and traffic erosion, poor nutrient load (causing revegetation problems), poor surface compaction and an inability to retain moisture. Sand does have some advantages - such as resistance to water erosion, and its ability to be readily re-contoured - and its ubiquity in coastal environments means considerable experience exists for rehabilitation. The most productive grazing land on Urala Station is, in fact, tussock grassland on the sand plains which typify the area (Payne et al., 1988).

Tests on the sand along the proposed pipe route indicate the material is of limited and uniform grain size (94%, by weight, between 0.85mm and 0.1mm), of pH 8.45 with low nitrate and phosphorous content (=/< 1ppm). Salinity levels in the swales of 20ppm will not inhibit revegetation.

To check whether long-term soil movement had occurred at the coast, aerial photographs dating from 1973 were obtained. No significant sand movements were noted in this period and, in fact, vegetation has increased. Surface sand movement was obvious in bare sand areas photographed in 1984 with lateral (perpendicular to the coast) ridges forming. The overall shoreline has not changed in this period, however, and the only recognisable variation in features is the tidal creek mouth at Rocky Point, which in 1973 opened at the centre of the point, rather than to the west as now occurs.

With correct management, the dunal area can be successfully rehabilitated but traffic must be prohibited along the easement after pipeline installation is complete. A detailed rehabilitation plan will be required to ensure correct procedures are employed.

The other soil type on this route is the fine-grained clay soil of the mudflats. This is boggy when wet, but dries to a hard surface which becomes dusty when trafficked. Revegetation will be required after pipeline installation, but no problems with this material are anticipated.

10. PIPE ALIGNMENT

The proposed alignment was chosen to minimise sand erosion and damage to vegetation, especially that classified as "Rare". The short coastal crossing to the Tubridgi 5 well achieves this aim and minimises the effects on the pastoral activities. At the coastal berm, dense stands of Acacia around water holes were avoided, while scattered Acacia areas with grassed understorey typical of the hind dune and swales were purposely impacted. The existing spread of Buffel Grass *(Cenchrus ciliaris)* will greatly assist revegetation of disturbed dunes and swale areas. A few shrubs of the rare Stemodia species will be lost and several shell scatters will be disturbed, but none of the unique dense vegetation on the berm will be impacted. Although the presence of archaeological sites limited lateral movement alternatives, an alignment to the west would have crossed a large expanse of movable sand which could have caused problems of stabilisation.

To minimise the risk of contamination of Ground Water, the alignment needed to be reasonably distant from aquifer tapping points. The chosen route is 2 km from Kapock Well, used by the pastoralist for stock water, and is 4 km from Urala homestead. Although contamination of groundwater will be avoided, these distances provide some extra insurance should inadvertent contamination occur.

The route will cross about 100 m of moderately vegetated saline flat before reaching the Tubridgi 5 Well and disturbed flowline easement. From this point it will follow the Tubridgi 5 Flowline 5.0 km back to the plant. Impact on the saline flat vegetation is therefore minimal.

The pipe route has been determined with consideration for all the constraints listed above. It is short, largely on disturbed ground, avoids rare and unique vegetation, does not impact significant archaeological sites and will cause little disruption to the pastoralist. Further studies will be done in future to delineate the aquifer and determine ground conditions. From this information an appropriate environmental management plan will be produced

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APPENDIX 6

SAND DUNE MOBILITY, EXCAVATION AND REHABILITATION PROCEDURES

<u>GRIFFIN ONSHORE PIPELINE</u>

By:Dames & Moore

22nd September, 1992

SAND DUNE MOBILITY, EXCAVATION AND REHABILITATION PROCEDURES GRIFFIN ONSHORE PIPELINE

by

Dames & Moore

1.0 SAND DUNE MOBILITY

The probable mobility of the sand dunes in the vicinity of the pipeline crossing has been assessed primarily through the examination of aerial photographs taken in 1973, 1986 and 1990. The aerial photographs indicate that the dunes are underlain by silty material at about the level of the interdunal troughs and would probably not easily erode past that level. However, any estimates of erosion based on photographic interpretation can only be qualitative.

Comparison of aerial photographs taken in 1973 and 1990 suggests that the dunes are moving inland (in places). The rate of this movement appears to be low - perhaps 20 metres over 17 years. The major dune lines along the pipeline route did not move a detectable amount during that time. The photographs suggest that the dunes did not erode significantly and, in fact, the depth of sand cover within 500m of the shoreline appears to have increased during the period. Vegetation cover on the dunes also appears to have increased, which would tend to increase the stability of the dunes.

Most of the individual shrubs visible on the 1973 aerial photograph appear to be still present in 1990, suggesting that the life span of the shrubs is at least 17 years. This also suggests that any localised accumulation or loss of sand in that time would have been minor, in the order of a metre or less. There seems no reason this should change, providing that synoptic weather conditions remain similar to those experienced since 1973 and that nothing happens to the plants that would reduce their life span.

Wave erosion of the shoreline under normal conditions is unlikely because, based on the evidence of the aerial photographs, the shoreline appears to be accreting sand.

Synoptic weather conditions are unlikely to change dramatically during the life of the pipeline. However, extreme storm events such as cyclones have the potential to cause significant changes to the profile of the dunes or the shoreline. This does not appear to have occurred between 1973 and 1990 despite the occurrence of several cyclones, so the probability of this happening appears to be low.

A more remote possibility is the occurrence of tidal waves (tsunamis), which could cause severe erosion. Their occurrence cannot be predicted. The eruption of Krakatau in the 1800s caused extreme tides (2m plus over normal tide levels) at Cossack, an earthquake at Corona Shoals in 1978 caused a 1.5m wave at Dampier and a 0.5m wave was recorded at Broome on 1 January 1992. None of these waves were large enough to have caused damage to the pipeline dune systems near the pipeline route.

2.0 EXCAVATION AND REHABILITATION PROCEDURE

2.1 Stripping of Topsoil and Vegetation

Stripping of topsoil and vegetation should be confined to the areas where the ground surface is to be disturbed - that is, the pipe trench and the areas where trench spoil is to be stored. Topsoil storage areas and vehicle tracks should not be stripped. However, the areas subject to heavy vehicle traffic may need to be ripped during decommissioning if they become significantly compacted. This should not be necessary on sandy areas.

Recommendations for stripping are as follows:

o Bare sand areas
  Strip topsoil only if significant topsoil development is apparent in the top 10cm or so of soil.

o Acacia Vegetation areas
  Strip vegetation and top 10cm of soil.

o Grassed areas
  As for Acacia areas.

o Bare mudflats
  Strip top 10cm of soil.

o Dune areas
  Because there is unlikely to be significant topsoil development on the dunes, there would be only minor benefits to be gained from separate stripping of topsoil. However, if, as indicated, there is little extra cost or effort involved in stripping topsoil in these

areas then it would be worth doing. It is difficult for us to give precise recommendations on this without having inspected the site. A final decision should be made by the site supervisor in the light of an examination of the local soil conditions.

2.2 Excavation

We understand that the depth of trenching (and depth of final cover over the pipeline) will range from 0.75m on the inland flats to 2.5m on the dune crests. The depths proposed in the draft Design Basis Report appear suitable. Stabilisation and revegetation of disturbed areas is expected to be at least as important as the depth of cover in ensuring that erosion does not cause the pipeline to become exposed.

2.3 Backfilling and Compaction

After pipe laying, the trench will be backfilled with spoil. The backfilling should aim to recreate the original profile of the dunes as closely as possible. It is proposed that the surface of the backfilled trench will be compacted by driving a wheeled loader or similar machine back and forth along or across the fill. This method appears suitable. The compaction should be carried out before the spreading of topsoil, if possible. In dune areas where an open-cut trench has been formed and backfilled, it would be preferable for the backfill to be compacted progressively, say in 1.5m stages. The compacted fill should be left with a rough surface (the tyre ruts of the loader should be sufficient to accomplish this), as this will aid in the retention of topsoil and seeds that are spread after compaction.

2.4 Brush Matting

Following the spreading of topsoil, brush matting should be spread over the surface to help stabilise the sand in the short term and to trap applied and windblown seed. In areas where the natural vegetation was dense, the vegetation stripped and reapplied along with the topsoil should be sufficient for this purpose. In sparsely vegetated areas, brush may have to be imported. The adjacent vegetated dunes should not be used as a source of brush matting. In the hind-dune areas, this brush matting may be unnecessary.

2.5 Seeding

Seed of locally-occurring species should be spread on the dunes, troughs and vegetated flat areas following topsoiling and brush matting. Suggested seed mixes for the dunes and inland flats are:

- Sand Dunes
  - *Cenchrus ciliaris* (Buffel grass)
  - *Spinifex longifolius*
  - *Triodia pungens*
  - *Acacia coriacea* (scarified seed)
  - *A. translucens* (scarified seed)

- Inland Flats
  - *Atriplex bunburyana*
  - *Halosarcia auriculata*
  - *H. halocnemoides*
  - *Salsola kali*

The seed mixes should consist of about equal quantities of each type of seed (if suitable seed is available) and should be applied at a rate of about 1.5kg/ha. Early growth may be enhanced by the application of a general purpose fertiliser such as "Agras" at a rate of 200kg/ha.

The above seed mixes and application rates are suggestions only. We recommend that a reputable seed supplier and/or seeding contractor with local experience should be consulted before the seed is ordered.

We recommend that bare sand dune areas should be seeded the same as the vegetated dunes, as the backfilled trench will be less stable than it was in its undisturbed state. Completely bare saline mudflats will not require seeding.

2.6 Hydromulching

Hydromulching would involve the stabilisation of the disturbed area by the application of bitumen emulsion, paper mulch, fibre mulch or some other material. Seeds can be incorporated into the mulch and would germinate and develop in place. This option is probably less effective than brush matting, but may be a viable option if sufficient quantities of cut scrub are not available. The process is available commercially but the distances involved and the small area to be treated may make mobilisation cost-inefficient.

3.0 CONCLUSIONS

Based on the above considerations, the following conclusions have been drawn.

1. It is not possible to state with any certainty to what depth erosion would occur if the sand dunes became destabilised. Theoretically, the dunes could blow out down to the level of the interdunal troughs. This, however, could take a very long time, possibly in the order of several decades.

2. The areas most susceptible to erosion would be:

   - near-shore areas (most exposed to the wind);
   - the crests of the highest dunes (highly exposed); and
   - sandy areas where there is little or no vegetation.

   Areas behind the highest line of dunes would have significantly less erosion risk.

3. Burying the pipe deeply in an attempt to avoid exposure through erosion may increase the risk of sand blowouts due to the necessity to excavate a deep, wide trench. It could also increase the requirement for dewatering during pipeline installation, with consequent impacts on the fresh water aquifer. It is therefore considered preferable to bury the pipe to moderate depths, as proposed in the draft Design Basis Report, and to pay close attention to rehabilitation and stabilisation of the trench.

4. Backfilling and compaction should be carried out as described in the draft Design Basis Report and this document.

5. Topsoil spreading, brush matting (using imported materials where necessary) and seeding should be carried out as described. These measures will minimise the risk of erosion.

6. Hydromulching is considered unlikely to be as effective as brush matting/seeding in promoting regeneration and is unlikely to be a cost-efficient option. However, its use may be called for if sufficient quantities of cut scrub are unavailable for brush matting.

7. The route should be monitored at regular intervals and after severe storm events to detect erosion. This should give plenty of warning to enable remedial measures such as brush matting, reseeding or refilling of eroded areas to be undertaken if necessary.

8. Based on the above, and given adequate rehabilitation and monitoring of the pipeline route, we consider that the depths of cover over the pipeline as proposed in the draft Design Basis Report should be adequate.

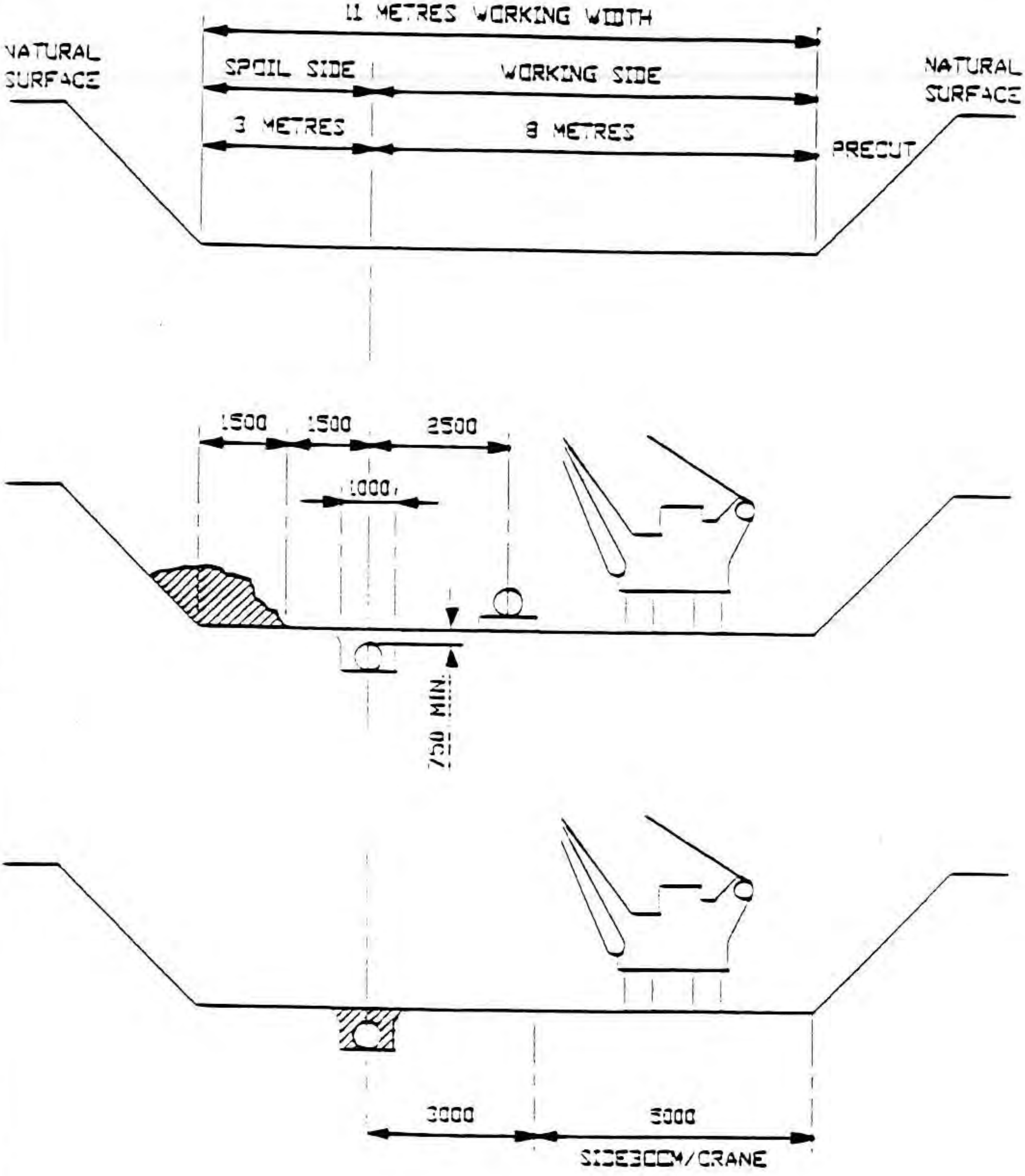
9. In summary, the approach to construction and rehabilitation should be one of ongoing monitoring and maintenance, rather than over-engineering.

VOL.	TAB. No.	PROCEDURE No.		REV. No.
1		**Quality Manual**		
	1	WGP0015	Quality Manual	Rev
	2	WGP-COR-02	Melbourne Branch Organisation Manual	0
	3	WGP-QA-01	Preparation, Style, Format and Revision	0
	4	WGP-QA-02	Management Review	0
	5	WGP-QA-03	Internal Quality Audits	0
	6	WGP-QA-04	Control of Non-conformance and Corrective Action	0
	7	WGP-QA-05	Quality Records	0
	8	WGP-QA-06	Quality Improvement Proposals	0
2		**Project Operation**		
	1	WGP-PO-01	Contract Review	1
	2	WGP-PO-02	Project Execution Plan	0
	3	WGP-PO-03	Design/Calculation Verification	0
	4	WGP-PO-04	Design Changes	1
	5	WGP-PO-05	Document Control	Rev
	6	WGP-PO-06	Computer Software Verification and Control	1
	7	WGP-PO-07	Project Close-Out Report	0
	8	WGP-PO-08	Training	0
	9	WGP-PO-09	Drawing Office Administration and Drafting Procedures	1
	10	WGP-PO-10	Sub-Contract Services	0
	11	WGP-PO-11	Handling, Storage, Packaging and Delivery	0
	12	WGP-PO-12	Archiving of Documentation	0
	13	WGP-PO-13	Progress Reporting	Rev
	14	WGP-PO-14	Proposals	0
3		**Project Administration**		
	1	WGP-ADM-01	Correspondence and Communication	0
	2	WGP-ADM-02	Meetings	0
	3	WGP-ADM-03	Telecon Records	Rev
	4	WGP-ADM-04	Recording of Photocopying	1

NB:
- COR - Corporate Procedure
- QA - Quality Assurance Procedure
- PO - Project Operation Procedure
- ADM - Project Administration Procedure
- REV - Currently being revised

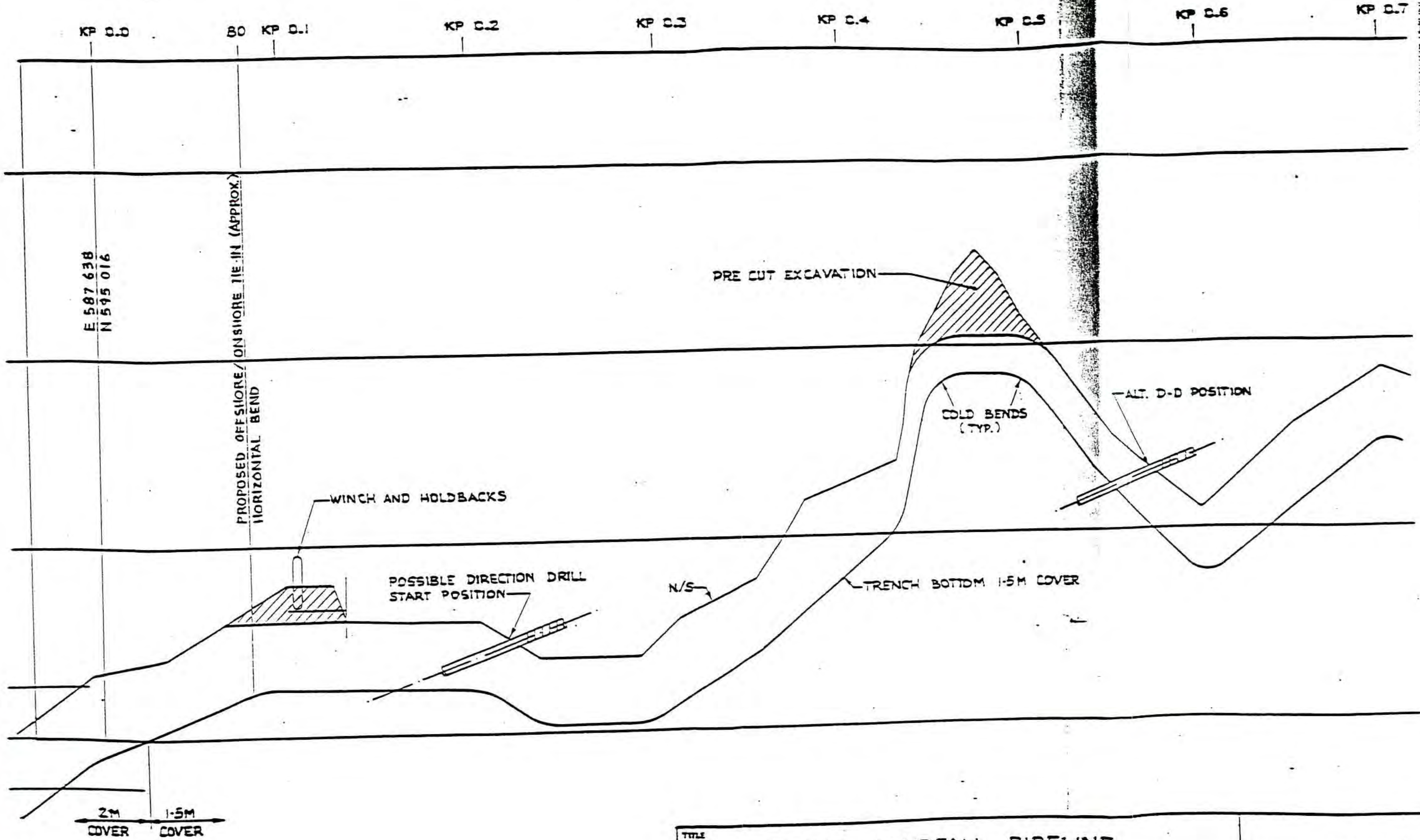
FIG 1

INSTALLATION THROUGH SANDHILLS



GRIFFIN LANDFALL PIPELINE
SHORELINE/DUNE AREA – SECTION
FIG. 3

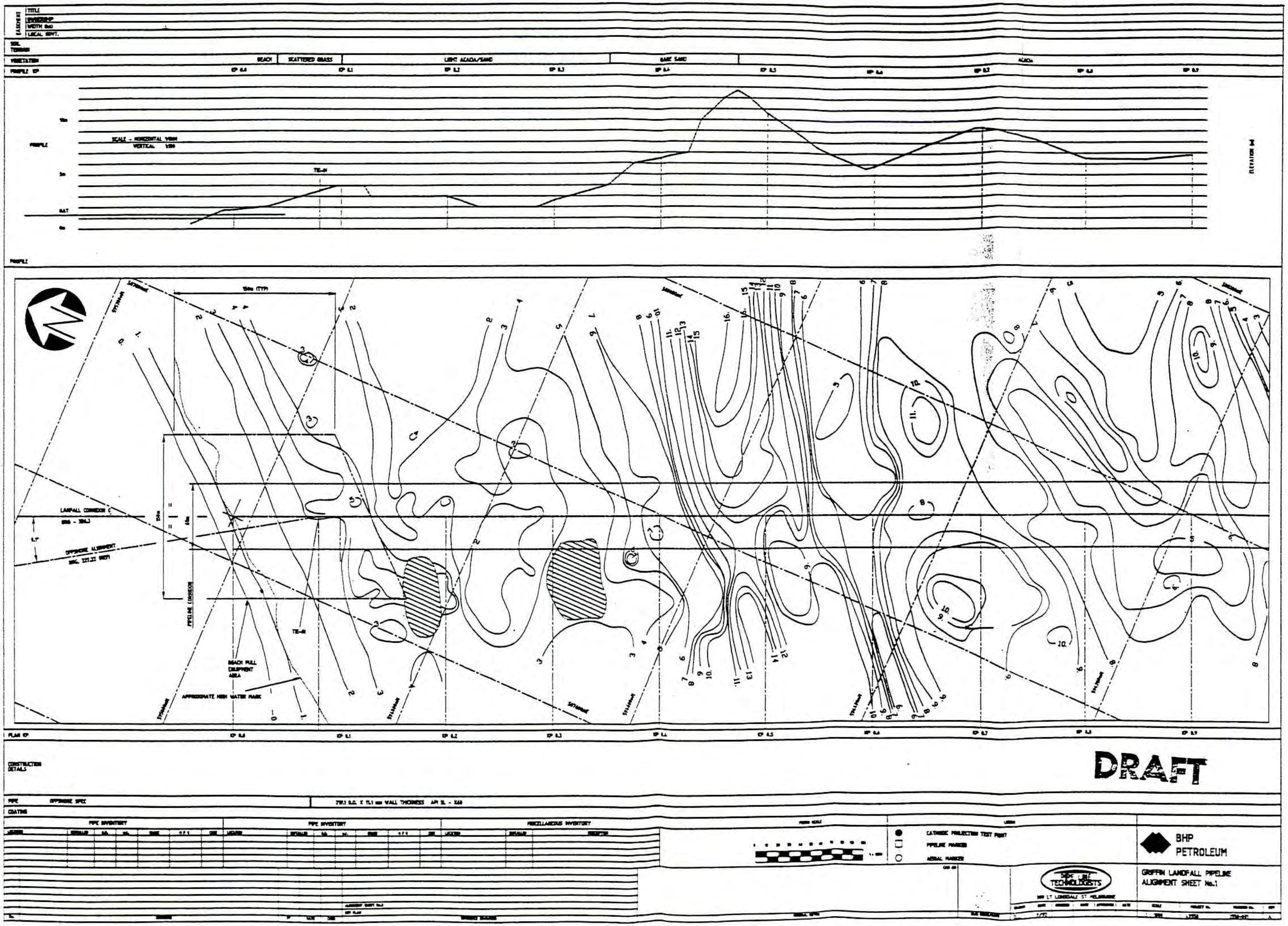
PIPE LINE TECHNOLOGISTS



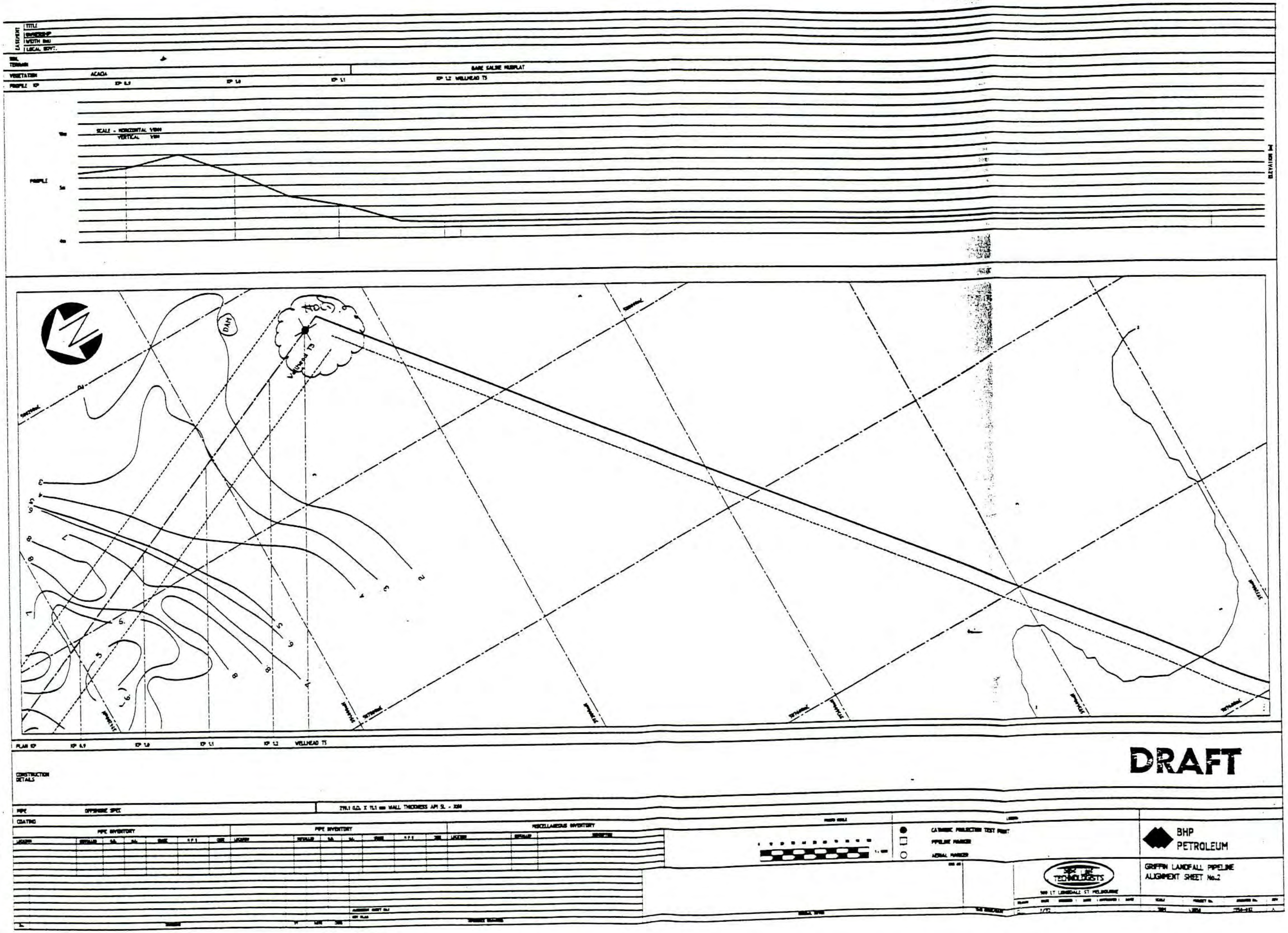
TITLE

GRIFFIN LANDFALL PIPELINE
SHORELINE / DUNE AREA - PROFILE
FIG. 2

PIPE LINE TECHNOLOGISTS



TITLE
OWNERSHIP
WIDTH (m)
LOCAL GOVT.
SOIL
TERRAIN
VEGETATION
BEACH
SCATTERED GRASS
LIGHT ACACIA/SAND
BARE SAND
ACACIA
PROFILE KP
PROFILE
SCALE - HORIZONTAL 1:500
VERTICAL 1:100
TIE-IN
ELEVATION (m)
LANDFALL CORRIDOR
OFFSHORE ALIGNMENT
PIPELINE CORRIDOR
BEACH PULL EQUIPMENT AREA
APPROXIMATE HIGH WATER MARK
PLAN KP
CONSTRUCTION DETAILS
DRAFT
PIPE
OFFSHORE SPEC
COATING
PIPE INVENTORY
MISCELLANEOUS INVENTORY
CATHODIC PROTECTION TEST POINT
PIPELINE MARKER
AERIAL MARKER
BHP PETROLEUM
GRIFFIN LANDFALL PIPELINE
ALIGNMENT SHEET No.1



EASEMENT
TITLE
OWNERSHIP
WIDTH
LOCAL GOVT.
SOIL
TERRAIN
VEGETATION
ACACIA
BARE SALINE MUDFLAT
PROFILE KP
KP 0.9
KP 1.0
KP 1.1
KP 1.2 WELLHEAD T5
SCALE - HORIZONTAL
VERTICAL
PROFILE
ELEVATION
DAM
Wellhead T5
PLAN KP
KP 0.9
KP 1.0
KP 1.1
KP 1.2
WELLHEAD T5
DRAFT
CONSTRUCTION DETAILS
PIPE
OFFSHORE SPEC
COATING
PIPE INVENTORY
PIPE INVENTORY
MISCELLANEOUS INVENTORY
CATHODIC PROTECTION TEST POINT
PIPELINE MARKER
AERIAL MARKER
BHP
PETROLEUM
GRIFFIN LANDFALL PIPELINE
ALIGNMENT SHEET No.2