CORAL COAST RESORT
MAUDS LANDING

PUBLIC ENVIRONMENTAL REVIEW

APPENDICES

Coral Coast

MARINA DEVELOPMENT PTY LTD

PUBLIC ENVIRONMENTAL REVIEW

CORAL COAST RESORT - MAUD'S LANDING

APPENDICES

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Guidelines for the Preparation of the PER

Department of Environmental Protection, 1994

GUIDELINES FOR THE PUBLIC ENVIRONMENTAL REVIEW FOR THE PROPOSED MAUDS LANDING CORAL COAST MARINA (Assessment No 335).

Overview

In Western Australia, all environmental reviews are about protecting the environment, which for this proposal means that the environmental values associated with Coral Bay coast and the nearshore marine environment are protected.

Guidelines for the preparation of a Public Environmental Review (PER) document were originally prepared in 1990 in response to a proposal forwarded to the Environmental Protection Authority (EPA) by Coral Coast Marina Development Pty Ltd to develop a marina at Mauds Landing. In view of the 4 year time delay since issuing of the original Guidelines, these amended Guidelines have been prepared. These amended Guidelines reflect the EPA's expectations of a PER document and supercede the original guidelines issued in January 1990.

The primary purpose of the PER is to provide information on the proposal to the Environmental Protection Authority (EPA) within a local and regional framework. The Authority will assess this information and then provide advice to the Government on the environmental acceptability of the proposal. An additional function of the PER is to communicate clearly with the public so that the EPA can obtain informed public comment. As such, environmental impact assessment is quite deliberately a public process. It also seeks to inform decision makers, to identify risks and minimise adverse environmental impacts, to achieve environmentally sound proposals through research, management and monitoring, and to manage potential conflict through the provision of the means for effective public participation.

It is the responsibility of the proponent to design and implement a proposal which protects the environment and to present this proposal for review by all interested members of the public. The proponent should describe what is proposed, discuss the potential environmental impacts of the proposal, and then describe how these environmental impacts are going to be managed so that the environment is protected.

These Guidelines have been prepared to assist the proponent in identifying issues which should be addressed within the PER. They are not intended to be exhaustive, and the proponent may consider that other issues should also be considered within the document.

The discussion in the PER should be concise, accurate, and easily understood. Specialist information should be included where it assists in the understanding of technical aspects of the proposal. Where possible, all information should be referenced. A copy of these Guidelines should be included in the PER.

Objectives of the PER

The PER should have the following objectives :

- to place this proposal in the context of the local environment;
- to explain the issues and decisions which led to the choice of this proposal at this location at this time;
- discuss the need for the proposal, including potential benefits of the proposed marina;
- to set out the environmental impacts that the proposal may have; and

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

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

Based on information available at this time the primary issues of interest to the EPA relate to water quality within the nearshore waters of Coral Bay, Ningaloo Marine Park and the proposed marina, and potential impact of the proposed development within the Exmouth Region.

1. Justification

- justification and objectives for the proposed development (reference should be made to other existing and proposed marina developments within the Exmouth region);
- an evaluation of alternatives, including location and alternative types/ forms of development, and constraints associated with these; and
- justification of the preferred site.

2. Proposal

This should include a discussion of the following points:

- history of the proposal;
- status of site;
- relevant statutory requirements and approvals;
- overall concept, location and layout;
- control, timing and staging of proposed development
- construction schedule and methods of construction (including sources of construction materials, disposal of wastes, stockpiling of bulk materials) ;
- proposed land uses, land tenures, land zonings, and a clear distinction between boundaries of private and public land;
- regional and local planning context;
- services and infrastructure, including power, water, drainage, sewerage disposal and roads;
- management structure and responsibilities; and
- context of proposal in relation to the Gascoyne Coast Strategic Planning Study.

3. Existing Environment

While there should be a description of the main components on the existing environment related to the development site, emphasis should be placed on those aspects where impacts and management requirements are identified later in the CER. These include:

- conservation significance of proposed marina site;
- offshore and on shore geology;
- existing infrastructure, including roads and services;
- onshore hydrogeology, including water quality, location of groundwater and direction of groundwater movement;
- terrestrial flora and fauna, including any declared rare flora or priority species;
- nearshore water quality within Coral Bay;
- marine flora and fauna which may be affected by marina construction;
- marine/coastal processes, ie. littoral drift, erosion and accretion points, water circulation;

- relevant climatic conditions, ie. prevailing winds, frequency of storm events including duration and wind velocity;
- description of existing communities in the vicinity of the proposed development;
- existing public and private recreational use of the area (including fishing, swimming, boat launching, sight seeing);
- historical, archaeological and ethnographic sites; and
- visual resource.

4. Key Environmental Impacts and Management

The potential impacts and their management for the development during the construction period and the longer term should be addressed, including the following specific issues.

- impact on water quality within Coral Bay and adjacent Ningaloo Marine Park;
- prediction and verification of flushing and internal circulation within proposed marina;
- details of refuelling facilities and contingency plans in the event of fuel spills;
- boat sullage pump out facilities;
- details of on-going monitoring mechanisms to ensure maintenance of appropriate water quality standards within proposed marina and adjacent marine environment;
- impact on marine flora and fauna during construction and operation of marina;
- impact on existing foreshore vegetation;
- details of any proposed on-going maintenance dredging within marina;
- ecological significance of the loss of seagrass in a local and regional context;
- impact on existing users of land and nearshore waters (particular reference should be made to projected permanent populations, and transient holiday populations);
- impact on historical, archaeological and ethnographic sites;
- cultural, recreational, and other community opportunities;
- affect on visual resource value of the Coral Bay area;
- traffic management;
- wastewater management;
- groundwater use;
- provision of permanent potable water supply
- drainage and stormwater discharge management;
- soil conservation management during development; and
- managing for climatic change, including changes in frequency and severity of extreme weather events and sea level.

5. Public Participation and consultation

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the PER. It should describe the activities previously undertaken or proposed to be undertaken to promote public awareness and support for the proposal, the dates, groups and individuals involved, and the objectives of the activities. This should include acknowledgment of any public awareness programmes undertaken for this proposal by the proponent.

Cross reference should be made with the description of the environmental management for the proposal which should clearly indicate how community concerns have been addressed. Where these concerns are dealt with via other departments or procedures, outside the Environmental Protection Authority process, these can be noted and referenced here.

6. Detailed list of environmental commitments

The commitments made by the proponent to protect the environment should be clearly defined and separately listed in the PER. 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:

(a). who will do the work;
(b). what the work is;
(c). when the work will be undertaken; and
(d). to whose satisfaction the work will be carried out.

All actionable and auditable commitments made in the body of the document should be numbered and summarised in this list.

APPENDIX B

Detailed Engineering Considerations

Ewing Consulting Engineers, 1994

CORAL COAST MARINA DEVELOPMENT PTY LTD

CORAL COAST RESORT - MAUDS LANDING

REPORT ON ENGINEERING CONSIDERATIONS

DECEMBER 1994

EWING CONSULTING ENGINEERS PTY LTD

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REFERENCES

1. MP Rogers and Associates Pty Ltd "Coral Coast Resort - Mauds Landing Coastal Engineering Study" - December 1994.

2. RC Jeffery, Principal Research Chemist (Soil Chemistry) Agricultural Chemistry Laboratory. "Report on The Chemical and Physical Properties of Soils from Mauds Landing, Coral Bay and Cardabia Station" - November 1994.

3. Woodward - Clyde (1993) "Coral Bay Townsite Water Supply Assessment - Report for The Water Authority of Western Australia".

ANNEXURES

A "Evaluation of Groundwater Conditions near Mauds Landing in the Coral Bay Area" - Rockwater Pty Ltd - November 1994.

B "Coral Coast Resort - Mauds Landing - Potable Water Supply and Sewage Disposal" - Hitech Water (Australia) Pty Ltd - November 1994.

C "Coral Coast Marina Resort" Electrical Services - Bassett Consulting Engineers - December 1994.

1.0 INTRODUCTION

Coral Coast Marina Development Pty Ltd (CCMD) proposes to develop a Resort Town at Mauds Landing Townsite in conformity with its agreement with the State Government of Western Australia. This report is prepared as part of the Public Environmental Review Documentation for the project and summarises preliminary investigations into servicing constraints and opportunities for the proposed Resort Town. The findings of this report will be incorporated with criteria which emerge from investigations of other relevant professional bodies, the public, and relevant authorities to produce a final proposal for progressive development of the land. Once the land is appropriately zoned a planning application is anticipated to result in Preliminary Approval to Subdivide in accordance with Department of Planning and Urban Development conditions. The site and other works necessary to satisfy these conditions to enable clearances for final approval of subdivision are proposed to commence in 1995 as permitted by approvals and weather constraints.

The proposal includes development of a Marina comprising about 45 hectares of open water connected by a channel to Batemans Bay to allow for access by recreation and other boating to the adjacent Ningaloo Reef and other attractions, tourist and commercial facilities including Club Resort, Resort Hotel, Country Club, Caravan Park, back-packers, associated commercial centre and community services together with approximately 1,100 single and similar residential units. Coastal and harbour engineering considerations are covered in a separate report by MP Rogers & Associates Pty Ltd (Ref 1). This report provides details of engineering considerations for the development of services including earthworks, roadworks, stormwater drainage and management, potable and irrigation water supplies, effluent disposal, power, gas and communication facilities.

A primary objective of CCMD in compliance with its agreement with Government is that its development proposals will identify, locate and develop the most effective and efficient service headworks for the locality. The area under consideration therefore includes the Mauds Landing and existing Coral Bay Townsites. The Townsites have a separation of about 3.5km. The service infrastructure is proposed to be located to best service both Townsites commensurate with meeting appropriate environmental and economical objectives and to best integrate with the pastoral activities of adjacent Cardabia Station.

The Master Plan prepared by Koltasz Smith and Partners (KSP) for Mauds Townsite identifies proposed land uses. This plan has been used to predict development staging over the anticipated 21 year construction programme and a schedule developed from that plan has been used as a basis for predictions of service demands. Service demand populations exceed actual population predictions from the KSP plan to ensure that a factor of safety is inbuilt in designs. All services will be developed to accord with relevant authority standards and where appropriate these will be modified to minimise maintenance requirements to best suit the demands placed by climate, isolation and environmental protection for development in this unique and beautiful location in the Gascoyne Region of Western Australia.

Any services installed as part of the development will, by agreement, be maintained and operated for a minimum of 5 years by CCMD or a subsidiary utilities company or until relevant authorities wish to take over these activities. Charges for services will be made at commercial rates to the approval of the relevant authorities.

Service infrastructure will be developed in such a way that the existing Coral Bay Townsite can link in to services such as water, sewerage, power. CCMD could provide headworks at the service industry site to allow for connection by Coral Bay and would levy a charge for that service at appropriate commercial rates.

2.0 DESCRIPTION OF THE PROPOSAL

2.1 RESIDENTIAL/ACCOMMODATION

The residential and other accommodation units within the development are proposed to be provided by CCMD at the time of the development with :

* sites filled, levelled and stabilised to allow for dwelling construction without the need for further substantial site works.

* a fully constructed and maintained public access road linked to constructed roads within the locality.

* land and associated roadworks shaped to ensure that properties are protected from stormwater runoff and seawater storm surges in accordance with appropriate industry standards

* potable and non potable water supplies for normal household and landscaping uses

* reticulated sewerage to remove and treat wastewater

* reticulated underground electricity distribution

* gas supplies by either gas piped from strategically located storage units or individual bottle gas supplies installed with recommendations specific to the locality

* telecommunications including telephone, television, security and other appropriate services serviced from centrally located facilities to maximise reception opportunities whilst minimising visual intrusion into the built environment.

2.2 MARINA AND BULK EARTHWORKS

2.2.1 Excavation Of Waterway

The Coral Coast Resort Concept includes excavation of a waterway area of about 45 hectares surrounded by resort/residential nestled generally behind the frontal dunes. Preliminary site investigations indicate that excavation to completed depths varying from minus 2.5m AHD to about minus 3.5m AHD will be within sands and relatively weakly cemented calcarenite.

Topsoils and vegetation will be stripped prior to commencement of earthworks and stockpiled for respreading at completion of works. Excavation will be carried out most efficiently using large scrapers and excavators as necessary. This work will be carried out within the dry. Dewatering will thus be required for excavation below sea level.

2.2.2 Dewatering For Construction

The method of disposal of water extracted during dewatering will be selected from a number of options available. An assessment of likely extraction volumes will be made from investigations to be carried out at the project design stage. These investigations will include assessment of the absorptivity of soils within and adjacent to the project area. However, it is envisaged that the water will be pumped to swales to be created behind the beach ridges in the proposed disturbance areas such as the golf course. Water will be allowed to settle and infiltrate into the swales for return to the unconfined groundwater aquifer. Any overflow will be directed initially to the low-lying area to the east and, if necessary, clear water overflow back to the adjacent ocean waters. The absorption rate will be constantly monitored to ensure that dewatering flow is disposed of correctly

The entrance to the harbour will be opened by excavation by floating dredge as required. Turbidity control will be exercised by final excavation during neap tides where possible.

2.2.3 Fill Placement

Earth excavated from Marina construction will be placed and compacted as fill for the access road in from Coral Bay Road, for the Resort and residential areas around the harbour and as required for the Golf Course and other areas.

Strict controls will be maintained on movement of earth moving and other machinery outside the works areas to ensure maximum retention of existing vegetation.

Excavation spoils from the construction of the Marina are expected to be about 2 million cubic metres and will be used to fill the building and other sites sufficient to ensure adequate protection of the buildings and other improvements from design storms both from seawater surges and accumulation of stormwater runoff from the town and adjacent land. The primary objective to be met will be to absolutely minimise any inter-mixing of land runoff with seawater to maximise protection of the adjacent Marine Park waters.

2.3 GOLF COURSE

The Golf Course is proposed as a high standard, links style course. The course will be moulded into the existing land forms with minimal land alterations so that the land form meets appropriate playing and other criteria. The course will generally be lower than adjacent land uses to ensure that during the occasional extreme rainfall events the course provides stormwater runoff storage and routing to augment the storage capacity of adjacent inland lakes and low lying land.

Topsoil and seedstock won at the commencement of earthworks operations will be stockpiled for re-spreading over completed works as appropriate to enhance and encourage regrowth of natural vegetation in Public Open Space, Golf Course roughs and other areas denuded during construction.

Course irrigation will make best use of the available artesian water sources. Local soils, modified where appropriate, have been shown to produce, in conjunction with this water, an excellent growing environment for appropriate grasses (Ref 2). An irrigation system will be developed to ensure the amenity of the area is enhanced both visually and by ensuring permanent stabilisation of soils. Subject to final designs it is envisaged that the irrigation system will distribute cooled artesian water via a system designed to ensure reliability and to minimise maintenance requirements commensurate with constraints imposed by the harsh environment and the mineralisation of the available water. Irrigation and distribution systems will be developed drawing on the experience and expertise gained through the successful use of similar water for developing landscaping throughout the existing Coral Bay Townsite.

Grasses and landscaping vegetation will be chosen to minimise water requirements. Species such as saltene couch, zoysia and other appropriate grasses will be considered. The quantities used for irrigation will be limited to the minimum necessary to maintain adequate ground cover and growth for the proposed purposes. As stated above the use of the natural artesian waters in conjunction with local soils provides an excellent growing medium for grasses, so that any supplementation of nutrients by fertiliser applications will be absolutely minimised.

Any fertilisers stored on site will be stored so as to be above anticipated maximum flood levels and will be provided with adequate weather protection to ensure that fertiliser spills into the natural environment do not occur.

Fertiliser application will not be a major requirement for landscaping and residential garden propagation and maintenance provided plants are irrigated with the artesian waters. Nevertheless an education programme will be put in place to ensure that residents are made aware and kept aware of requirements in regard to nutrient control and management within the Resort.

2.4 SUPPLY OF CONSTRUCTION MATERIALS AND CONSTRUCTION MANAGEMENT

2.4.1 Materials

Rock for construction of breakwaters, walling, road making materials and building materials as necessary will be won from Trialla Limestone quarries similar to that at existing quarries within 70kms of the site. Quarry excavation and rehabilitation will be carried out in accordance with pre-agreed quarrying procedures. Transport of rock will be by road trucks.

Other construction materials will be sourced from Carnarvon, Exmouth and other areas within the region as possible, with the balance of materials being trucked to the area from Perth or other sources as necessary. Supply of necessary construction materials is readily available within the industry.

2.4.2 Materials Storage

Storage on site will be effected such as to minimise impact on existing flora. In particular construction works will be kept away from near-shore areas wherever possible. Where possible storage will be at the Service Industry Area.

2.4.3 Coastal & Near Shore Land Form Modifications

Coastal works will be limited to construction of the entrance channel and associated breakwaters, removal of piles from the Old Mauds Landing Jetty, and building of a small replica jetty on shore.

Works which impinge on the near coastal area such as the links-style Golf Course, residential accommodation and parking areas and accesses will be constructed in such a way as to minimise alterations to the existing land forms commensurate with appropriate design practices, and to ensure that restabilisation and on going stability of the landform is maintained.

2.4.4 Traffic

Access to the Townsite for construction purposes will be via the main entry road off Coral Bay Road. This entry will be constructed to a trafficable stage as the first construction activity.

Subject to final planning it would be logical to provide initial workers accommodation and storage in the service industries area with access via the road ultimately to provide primary access to that site. Traffic generated by construction activities will thus be kept away from existing Coral Bay Townsite and Cardabia Station.

2.4.5 Noise and Dust

The existing Coral Bay Townsite is about 3km from the closest part of Coral Coast Resort and 2½km from the Service Industry area. Cardabia Station is about 1km from the nearest part of Mauds Townsite. Construction noise will thus be largely muted for these existing land users.

Excavated material will for the most part be damp but any dust likely to be generated during construction activities will be minimised by watering as required. Water will be applied for compaction and dust suppression purposes utilising the available unconfined aquifer brackish supplies, and water from dewatering activities during harbour construction.

3.0 ROAD ACCESS

3.1 EXISTING ROADS

The existing Coral Bay Townsite is well serviced by the good standard Coral Bay Road which was reconstructed and upgraded in 1990. It extends some 14km from the Learmonth to Minilya main road. This turnoff is 86km north of Minilya and about 140km south of Exmouth. Good road access is thus possible to the North West Cape and to the North West of the State by the Learmonth Minilya Road and the recently upgraded Birkett Road to the North West Coastal Highway. Areas to the south towards Carnarvon are accessible by North West Coastal Highway.

Additional traffic generated by the proposed resort town should thus be efficiently and effectively carried by the existing main road infrastructure.

3.2 MAIN ACCESS ROAD

Main road access into Mauds Landing is proposed to intersect with the Coral Bay Road about 5km before Coral Bay Townsite and about 1km beyond the turnoff to Cardabia Station. This location has been chosen to minimise the effect of increased traffic close to Coral Bay Townsite, to best suit the vertical and horizontal geometry of the existing road to provide adequate site distances at the intersection, and to make best use of the existing topography to minimise the need for landfill whilst raising road levels to ensure all weather access into the Resort.

3.3 INTERNAL ROADS AND CONSTRUCTION TECHNIQUES

Internal public roads will be constructed in accordance with Shire of Carnarvon and relevant industry standards. Road reserve widths will be kept low to minimise public land requiring stabilisation and landscaping commensurate with demands for service installations. It will thus be appropriate to make best use of common trenching practices wherever possible throughout the development.

Road pavement construction criteria will be developed to suit the needs of the locality and drawing on the experience of the Shire of Carnarvon and the regional Main Roads WA officers. Road making material will be obtained from quarries developed in local limestone and high lime content ridges where possible. These supplies could be augmented from Trialla Limestone quarries to be developed or expanded for the purpose of construction of marina breakwaters, walling, building materials and other uses within the Resort town. Existing quarries within 70kms of Coral Bay would provide suitable rock for these purposes.

Road construction techniques will need to recognise the constraints imposed by the generally higher salinity waters available for compaction purposes. This will necessitate completion of construction in cooler months and particular attention being paid to bitumen and final aggregate application rates.

Particular attention will be paid to the final appearance of road pavements to ensure that colours blend in with the natural and built environments. Adequate sources of final seal aggregates have been identified as being available in adequate quantities from existing North-West Cape quarry operations.

4.0 STORMWATER AND STORM SURGE MANAGEMENT

4.1 RAINFALL, STORM EVENTS AND BUILDING LEVELS

Rainfall in the area is low and inconsistent. Of the order of 150mm average falls in the May/June period with erratic falls of high intensity, high volume rainfall during cyclone events.

Evidence exists from the major cyclone Elsie of June 1967 that resultant flood waters reached about R.L. 1.8m AHD (pers. comm. Surveyor D. Shepherd 1994). This historical data will be used to set final minimum building floor and road levels within and adjacent to the development. On the basis of this evidence a minimum building floor level of R.L. 2.3m AHD will be set for buildings in the eastern part of the Resort.

Maximum storm sea water levels from predicted cyclone events will necessitate that minimum building floor levels adjacent sea and Marina be set at R.L. 2.7m AHD (Ref 1).

4.2 RESORT STORMWATER DRAINAGE

In order to minimise capital investment, and more particularly maintenance requirements piped stormwater systems within Resort town roadworks will only be used where absolutely necessary.

Stormwater generated from the infrequent rain fall events in the area will generally be absorbed into the landfill and existing dunal system with runoff occurring dependant on the intensity and duration of the storms. During the majority of rain fall events any runoff will be directed to the specially constructed swales or local compensation areas away from the Marina edge and to the low lying area to the east (see figure 1). Disposal of stormwater will thus be managed by storage and absorption/evaporation in the lake areas and adjacent lands.

A primary design objective in determining final fill and drainage structures will be to ensure that only in major flood events will there be any discharge of stormwater towards the Marina and the sea. Regular monitoring of the harbour waters will take place, particularly in the areas set aside for coral gardens and similar. This monitoring could be undertaken by installation of piezometer sampling tubes to intersect groundwater and by sampling of marina waters at strategic locations.

In general all stormwater runoff will be directed away from the Marina. The minimum building and fill levels to be set from consideration of sea water and flood water storm surges are consistent with this objective.

Minimal quantities of runoff will be into the harbour waters where they will be inter-mixed and diluted with harbour waters before mixing and further dilution into the adjacent sea.

In major storm events (cyclones) some overflows may occur into the harbour but in these circumstances substantial dilution would have taken place prior to any of the waters entering the harbour. The majority of runoff will still be directed in-land away from the coast.

4.3 STORMWATER RUN-OFF STORAGE

Previous storm events have resulted in inundation of the lakes and low lying area east of the development for some time (see Fig.2). This area extends into the Mauds Townsite. Development of Coral Coast Resort will affect approximately 10% of this total low lying area, and no substantial alteration is proposed to the mainly dry lake within the Townsite. The 1:25000 scale Australian Survey Corps mapping of 1982 indicates that some 740 hectares of land is now available for flood water storage below R.L. 1.8m AHD. Although detailed level information is not available over all this low lying land if it is assumed that this full area is available for storage from R.L. 0.2m then a 10% reduction in area available for the storage would result in a rise of 0.18m under same storm event.

This is in practice a very conservative prediction as the land to be filled by Coral Coast Resort is in the high part of the lower area at the western extremity and the actual increase in flood level would be less than 180mm. The allowance of 500mm above cyclone Elsie level to R.L. 2.3m AHD is thus considered conservative and to include an adequate factor of safety against flooding in future storm events. The small increase in flood levels will have no significant impact on existing improvements at Cardabia Station.

Main access road levels will need to be raised to permit stormwater levels to equalise across the road. Some areas east of the Resort fall below sea level and following major storm events water is expected to lie for some time, particularly in the lake areas now mainly dry.

4.4 HYDROGEOLOGY

4.4.1 Surface Drainage

Approximately 45% of the Mauds Townsite is comprised of sand dunes. Rainfall onto this land form then infiltrates directly into the dunal soils with excess water collecting in localised low areas for eventual infiltration, evaporation or takeup by native vegetation.

The balance of the site east of the dunes is generally low lying and storm runoff drains south east generally towards the usually dry lake areas in the large inland swale amongst the dunes. The capacity of this inland swale and lake system is such that stormwater and runoff from major storm events is collected and stored for eventual dispersion by evaporation and infiltration into the unconfined groundwater aquifer.

4.4.2 Groundwater

Discussion of the unconfined shallow aquifer at and adjacent Mauds Landing is contained within Rockwater 1994 report Section 2.1 (Annexure A). Only very small supplies of fresh to brackish water are considered likely to be available around the Mauds Townsite. Construction of the Marina is anticipated to allow penetration of more saline seawater into the shallow groundwater aquifer up to 1km inland from the coast, however given the existing predominantly high salinity of this groundwater this entry of seawater is not seen to be environmentally detrimental.

The nutrients from surface runoff from the Coral Coast Resort will generally be directed inland to the low lying land/lake system where nutrients have the opportunity to be absorbed within the local soil before entering the unconfined groundwater system.

5.0 WATER SUPPLIES

5.1 POTABLE WATER SUPPLY

Development at Coral Coast Resort at Mauds Landing, and the existing residential and accommodation facilities at Coral Bay Townsite and its proposed expansion will all demand development and expansion of an adequate potable water supply for all users. Standards of treated water will need to meet World Health Organisation and relevant Public Health standards.

Population trends and water demands for the existing Coral Bay Townsite were subject to an extensive report prepared for the Water Authority of Western Australia by AGC Woodward Clyde in September 1993 (Ref 3). That report did not include Mauds Landing within its scope.

5.1.1 Water Supply Options

The median annual rain fall for Coral Bay as determined by records taken over some 14 years at Cardabia Station is about 200mm. The rainfall events are highly irregular and characterised by falls of up to 100mm over the May/June period with the balance being made up of irregular falls usually associated with cyclonic activity. Provision of potable water supply based on storage of rainfall runoff is therefore not considered viable.

Although freshwater to potable standards is not available locally, raw water for treatment to suitable standards is available from

* unconfined aquifer groundwater supplies

* Artesian aquifer groundwater supplies

* Sea water

These options were examined.

Treatment of sea water for drinking purposes is relatively expensive hence raw water sources considered were from the unconfined local aquifers, and from the artesian Birdrong formation. These alternatives were examined by hydrogelogists Rockwater Pty Ltd and the findings are presented in the attached report of November 1994 (Annexure A). The report confirms that the Birdrong sand stone is the only practical source for large supplies of groundwater in this region and that the water will need to be desalinated for drinking and domestic water purposes.

The estimated water supply requirements for Coral Coast Resort are presented in Table 2 of Annexure A. These demands assume growth of the Resort to be in accordance with the development schedule with appropriate adjustments for service factors of safety.

The artesian water from the Birdrong formation flows at a temperature of around 60 degrees centigrade. Experience with use of this water in the existing Coral Bay Townsite has shown that use of this water, perhaps cooled as necessary, is quite acceptable in its raw form for other than drinking purposes. The mix of mineralisation is such that use of untreated water is quite acceptable for bathing, clothes washing, dishwashing, irrigation and similar purposes. A number of options exist for supply of water to the Resort, residential accommodation and other purposes and will be subject of detailed review as the project progresses. These options include :

* supply of only fresh water

* supply of fresh water for drinking and cooled artesian water for other purposes

* supply of fresh water for drinking and other purposes and cooled and raw artesian water for landscaping only.

Determination of the option to be installed will be dependant on factors such as

* final planning and land use allocation

* market evaluation of consumer demand

* economic analyses including capital cost but with particular emphasis on operation and replacement costs.

5.1.2 Potable Water Demand

For the purpose of this review, peak potable water demands have been assumed at 250 litres per person per day with annual average of half that consumption.

5.1.3 Potable Water Treatment

Options for treatment of the water have been considered in the report by Hi-Tech Water (Australia) Pty Ltd of November 1994. (Annexure B). This report concludes that reverse osmosis is the most practical treatment method for the raw water from the Birdrong Formation. Subject to final design, an allowance of 50% system recovery has been allowed in determining source water volumes required throughout the growth of the Resort.

5.1.4 Storage and Reticulation of Potable Water

Finished ground levels within the Resort Town are likely to vary from about R.L. 2.3m up to R.L. 14m AHD dependant on final planning layouts. It is proposed that potable and perhaps cooled artesian water be reticulated by gravity to all lots within the development. A gravity reticulation system would require a storage at an elevation of about R.L. 30m to ensure that water is supplied to meet Water Authority of W.A. standards.

A suitable site exists to construct a ground level storage tank just off the peak of Mauds Hill adjacent the development. This tank would be of a size sufficient to meet peak demands with major ground storage being constructed elsewhere with water pumped to the higher level storage. Dependant on final design determinations the main storage could either be at the service industry area, integrated within the development, or with storage split between the two. The ultimate storage requirements will be influenced by the demands of the Coral Bay Townsite.

It is noted that artesian water from the Birdrong formation produces a static head of 42m AHD - in excess of minimum requirements for pressures within the Resort.

5.2 LANDSCAPING AND GOLF COURSE WATER SUPPLIES AND MANAGEMENT

Detail records of average pan evaporation were not available for the Mauds Landing site, however, it is assumed for the purpose of this review that records maintained since 1975 at Learmonth will provide good evidence as to evaporation to be expected at Mauds Landing. Average annual pan evaporation is expected to exceed 3,000mm. Hence the average evaporation significantly exceeds the average rainfall for all months of the year. In order to ensure land stabilisation, to enhance the aesthetics of the Resort, and to ensure an appropriate micro-climate within the built environment, landscaping is proposed. In addition it is proposed to develop a high class 18 hole links style Golf Course. Irrigation of grasses and vegetation will be required to maintain this landscaping.

By minimising lot and road reserve areas, maximising use of appropriate paved surfaces, and minimising the areas to be grassed in the Golf Course total water demand will be minimised. Nevertheless the Resort will ultimately require a substantial supply of water to satisfy landscaping requirements. Allowances for these supplies are shown in table 2 of Annexure A.

Suitable grasses and vegetation have been shown to flourish and thrive at the existing Coral Bay Townsite when irrigated with the Birdrong artesian water (Ref 2). Irrigation management techniques specific to this area are required to ensure satisfactory irrigation, however the valuable lessons learnt to date confirm that it is practical to irrigate appropriate grasses such as saltene couch, zoysia or similar direct from the artesian water.

It is desirable to reduce the level of soluble iron within the water and to reduce its temperature before irrigation to prevent staining and to minimise irrigation system maintenance requirements. It is proposed that these objectives be accomplished by passing raw artesian water along artificial stream beds incorporated within the landscaping and storage of irrigation water in sealed ponds strategically located throughout the development. Cooled aerated water will then be distributed throughout the Resort for irrigation as required.

Investigations by Government Chemical Laboratories (Ref 2) indicate that with proper management artesian water used in conjunction with the existing soils will provide an excellent growing medium for grasses. The water effectively supplies a slow-release fertiliser with nutrients being taken up by the grasses in such a way that only minor supplementation of nutrients may be required to achieve optimal grass growth. With only minimal or no application of supplementary fertilisers required to maintain the grass, strict controls to be placed on nutrient supplementation for gardens can be easily enforced. The likelihood of transport of nutrients into the unconfined groundwater, and either directly or indirectly into Marina waters is thus extremely low.

Examination of soils in areas subject of long term irrigation in Coral Bay Townsite indicates very low conductivity so there is no apparent salts build up in the soils matrix (Ref 2). Some surface build up occurs over the irrigated areas but this is removed during grass mowing. The rate of grass growth varies seasonally, however except for careful attention to length of grasses mowing periods are not considered excessive in comparison with the Perth metropolitan area. Grass clippings may be removed from the Resort area when not used for mulching and disposed of in a controlled manner such as at the rubbish disposal site to be developed in the service industry area.

5.3 GENERAL

Readily available technology exists to allow development of efficient readily maintained equipment for supply of adequate potable and irrigation water supplies for the proposed Resort.

Three bores penetrating the Birdrong formation are likely to be required to service the ultimate needs of the development. Construction of two bores within the Mauds Townsite and a further bore near the service area would adequately provide for the Resorts supplies whilst maintaining appropriate spacing to minimise aquifer draw-down (See Annexure A).

Construction of a further bore near the service industry site would provide standby capacity and would allow for the existing Coral Bay Townsite to connect into the Mauds water supply. This complies with the long term objective as outlined in the Coral Bay Planning Strategy to co-ordinate services for the two Townsites. Management techniques and usage patterns for Coral Bay water supplies will need to be well established to obtain maximum benefit from this service co-ordination.

6.0 WASTE WATER TREATMENT AND DISPOSAL

6.1 WASTEWATER COLLECTION

Disposal of wastewater and treated effluent away from the sea is seen as of paramount importance in this development.

It is proposed that each lot to be developed be provided with a sewerage connection. Wastewater will then be collected and pumped away from the site for treatment at the service industry area located to the south-west of Mauds and east of Coral Bay adjacent the service industries area as shown on Fig 2.

Collection will be by reticulated sewerage constructed to meet Water Authority of W.A. standards. Reticulated sewerage would either be by gravity or vacuum sewerage dependant on the outcome of economic analyses with particular reference to ongoing maintenance and running costs. Wastewater collected at the Resort would be pumped via a pressure main to the treatment facility.

A sewage pump-out facility for boats will be provided at a convenient location within the marina and wastewater collected will be discharged to the main reticulation system.

For the purpose of this review, peak wastewater generation of 230 litres per person per day has been adopted. The salinity of this wastewater will vary dependant on the proportions of fresh and artesian water used within the household and as determined by the supply systems finally adopted for water supply.

6.2 Wastewater Treatment

The treatment processes available and disposal considerations are described in Annexure B prepared by Hi-Tech Water (Australia) Pty Ltd.

The extended aeration activated sludge process proposed for treatment can be developed in a number of forms. These include oxidation ponds or ditch or package treatment plant which can be developed in modules as demand grows. Initial and ultimate land requirements can be determined so that expansion of the plant can occur within a site sized correctly at the commencement of development.

The relatively slow increase in population within the Resort will mean that wastewater generated will increase relatively slowly over the life of the development. Every effort will be made to re-use treated effluent water and excess solids. The slow growth rate will most likely mean that treated by-products will initially be reused for horticultural or similar purposes adjacent the service industry area rather than within the Resort. Ultimately it may be seen as feasible to pump treated waters back to either Mauds or Coral Bay Townsites for reuse for landscaping purposes. Certainly the ultimate treated effluent output could satisfy a substantial proportion of estimated landscaping requirements within the Coral Coast Resort which would assist in minimising demand on the Birdrong formation aquifers. With proper management and careful husbanding of these water resources a positive impact can be made on the local environment.

Development of common, efficient wastewater treatment and disposal systems are seen as a major opportunity for upgrading of existing facilities at Coral Bay Townsite. The treatment area will be about 3km by road east of the Coral Bay Townsite and at slightly greater distance from the Mauds Townsite.

Treated effluent will be initially disposed of by infiltration and evaporation at ponds to be constructed near the service industry area. The site is about 2½km inland from the sea and at an elevation of about minimum 12m above sea level. The existing soils and long travel paths associated with effluent infiltration will ensure minimal environmental impact.

Monitoring of the minimal unconfined aquifer waters in the area can be accomplished by periodic observation of water quality from bores constructed into this shallow aquifer perhaps in conjunction with construction of the potable water source water supply bores into the artesian aquifer.

7.0 POWER GENERATION AND TRANSMISSION, AND GAS SUPPLIES

7.1 ENERGY SOURCES

Energy requirements of the Resort are expected to be met from reticulated electricity supplies augmented by gas supplies. A number of options for electricity supply were considered, and those options and staging of power generation installations are discussed in the accompanying report by Bassett Consulting Engineers (Annexure C).

7.1.1 Power Generation

Power generation will be by diesel generators. Modular units will be installed progressively to meet increasing load demands of Coral Coast Resort and Coral Bay Settlement. Hence the efficiency of operation of the plant will be maintained. Permanent on site staff will be available to continuously monitor and maintain the equipment to ensure that it operates at peak efficiency thus minimising any emissions.

Diesel fuel storage will be located adjacent the plant within the service industries area. Such storage will be maintained and operated in accordance with normal industry standards.

7.1.2 Power Station Emissions

Diesel power generators have been identified as being the most efficient and economical power generators for the Coral Coast Resort. It is proposed to locate these facilities at the service industry area and to allow access to those facilities by the existing Coral Bay users at commercial rates. It will thus be possible to co-ordinate and integrate power services for the region.

Subject to final anticipated loads and development staging, generation equipment can be installed in modules to best suit the rate of development and the progressive load increases. Plant must be designed to operate near peak efficiency and with use of modern high technology diesel generation equipment noise and air borne emissions from the equipment will be minimised. The plant will be located in excess of 2km from existing and proposed developments and will be sited behind sand ridges to maintain the visual amenity of the area whilst ensuring that noise from generating equipment is not significant.

7.2 ELECTRICITY RETICULATION

Reticulation within the Resort is proposed to be by underground cable distribution to ensure that aesthetic demands are met and to maintain reliability of supply.

7.3 GAS SUPPLIES

The natural gas pipeline from the North West to the South West of the State runs well east of Coral Bay and Mauds Landing. Gas demand likely for even the combined Townsites is not seen as sufficient to warrant extension of the service from this facility for in the foreseeable future. Nevertheless the electrical load projections based on predicted populations assume that cooking facilities will generally utilise gas to minimise electricity generation demands.

The mix of electrical and gas powered facilities within the Resort will be subject to future economic analyses with particular reference to minimising maintenance and running costs. Options for gas supply include :

* supply by bottle gas to individual residences and developments

* reticulation within the Townsite from a number of strategically located bottled gas storages
* reticulation of the complete Townsite at the time of development with storage and or generation at a suitable location to suit storage regulations and aesthetic standards.

8.0 TELECOMMUNICATIONS

Telecommunications, telephony, television and radio services are commented on in the report by Bassett Consulting Engineers (Annexure C). It is proposed to make available the most up to date technology possible in the area for provision of such services.

Installation and upgrading of the facilities will be carried out in such a way as to maximise the opportunities for extension of the existing Coral Bay Townsite facilities.

9.0 MUNICIPAL REFUSE DISPOSAL

9.1 DISPOSAL METHOD

A number of methods of disposal of solid wastes generated from the Resort and from the existing Coral Bay Townsite were considered. The most appropriate method of solid waste disposal from both the Mauds and Coral Bay Townsite is seen as by land fill. A suitable site has been identified adjacent the service industries area and its progressive development should service the combined Townsites for many years. Allowing access to this tip by existing Coral Bay operators and residents will enable the existing tip to be closed. The existing site is well west of the site now chosen and near the existing Coral Bay Townsite.

Consolidation of sites will enable proper management techniques to be used to ensure continuous compaction and fill. The opportunity exists to use some reject water from the nearby reverse osmosis potable water treatment units to assist with compaction and suppression of dust and airborne rubbish.

The proposed landfill solid waste disposal operations can be monitored in conjunction with effluent disposal monitoring. The co-ordinated approach to waste disposal for both Coral Coast Resort and Coral Bay Townsite will maximise operational efficiencies whilst minimising environmental impact.

9.2 DISPOSAL SITE

The site chosen is about 2½km inland from the sea and at an elevation of about 12m above sea level. By augmenting existing dunal ridges with a low, revegetated sand mound adjacent the main Coral Bay Road it will be possible to visually shield the service industry and associated solid and effluent disposal areas from that road. The natural sand ridges will provide adequate visual shielding from the common access into the service industries area and the airstrip. The availability of bypass water from the near-by water treatment plant and effluent water in the early stages of development will ensure that dust and air borne material nuisance can be controlled continuously.

Integration of Coral Bay Townsite and Coral Coast Resort waste disposal facilities will ensure maximum efficiency of operation of waste disposal in the area.

10. AIRCRAFT LANDING GROUND

The existing rough formed landing strip which services Coral Bay, is midway between Coral Bay and Mauds Landing in the western part of the low lying flood prone area. This landing ground is subject to occasional inundation and the flight path for aircraft using this strip will be directly over the Coral Coast Resort. This is inappropriate and the airstrip should be relocated.

A suitable alternative site could be developed south of the Coral Bay Road and about 1km west of the proposed service industry site within Cardabia Station. This air strip could be serviced by an access road developed in conjunction with access to the service industries area. A suitable intersection position for this access road has been selected on site, and the position of these facilities is shown on Fig 2.

The relocated landing strip would be constructed with an unsealed surface sufficient to meet the demands of proposed incoming aircraft. Final design requirements may indicate that a part of this strip should be bitumen sealed dependant on aircraft type and frequency of use.

11. MANAGEMENT STRUCTURES, MAINTENANCE AND RESPONSIBILITIES

CCMD has given an undertaking that infrastructure established as part of the Coral Coast Resort development will be operated and maintained for a minimum period of 5 years from construction or until the relevant Authorities, such as the Local Authority and Service Authorities, wish to take over responsibility for operation and maintenance of the facilities.

It is likely that a separate utilities company will be established to operate and maintain these facilities. The costs for provision of services to owners of freehold lots within Coral Coast Resort and to Coral Bay Townsite would be met by charging for services at commercial rates. These rates would be determined in consultation with relevant service Authorities, and the method of charging will be determined similarly by consultation and as determined by statutory requirements.

12. FIRE MANAGEMENT

A primary objective of development will be to ensure maximum retention of existing vegetation. Protection of this vegetation will be of paramount importance to ensure continued stabilisation of the adjacent dunal and other land forms. Building construction boundary management techniques will be such as to minimise fire risk with fire breaks established in conjunction with relevant Bush Fire Control Authority requirements.

In particular the proposed Golf Course will act as a substantial fire break between the Resort Town and adjacent Cardabia Station.

The reticulated water system throughout the Resort will be constructed with fire hydrants to normal Western Australian Industry Standards to provide normally accepted standards of fire protection to the built environment of the Resort.

Access to the waters of the harbour will be maintained to allow fire fighting equipment to draw on this source in an emergency.

GH Locke B.E. MIE (Aust)
FOR EWING CONSULTING ENGINEERS PTY LTD

FIGURE 1

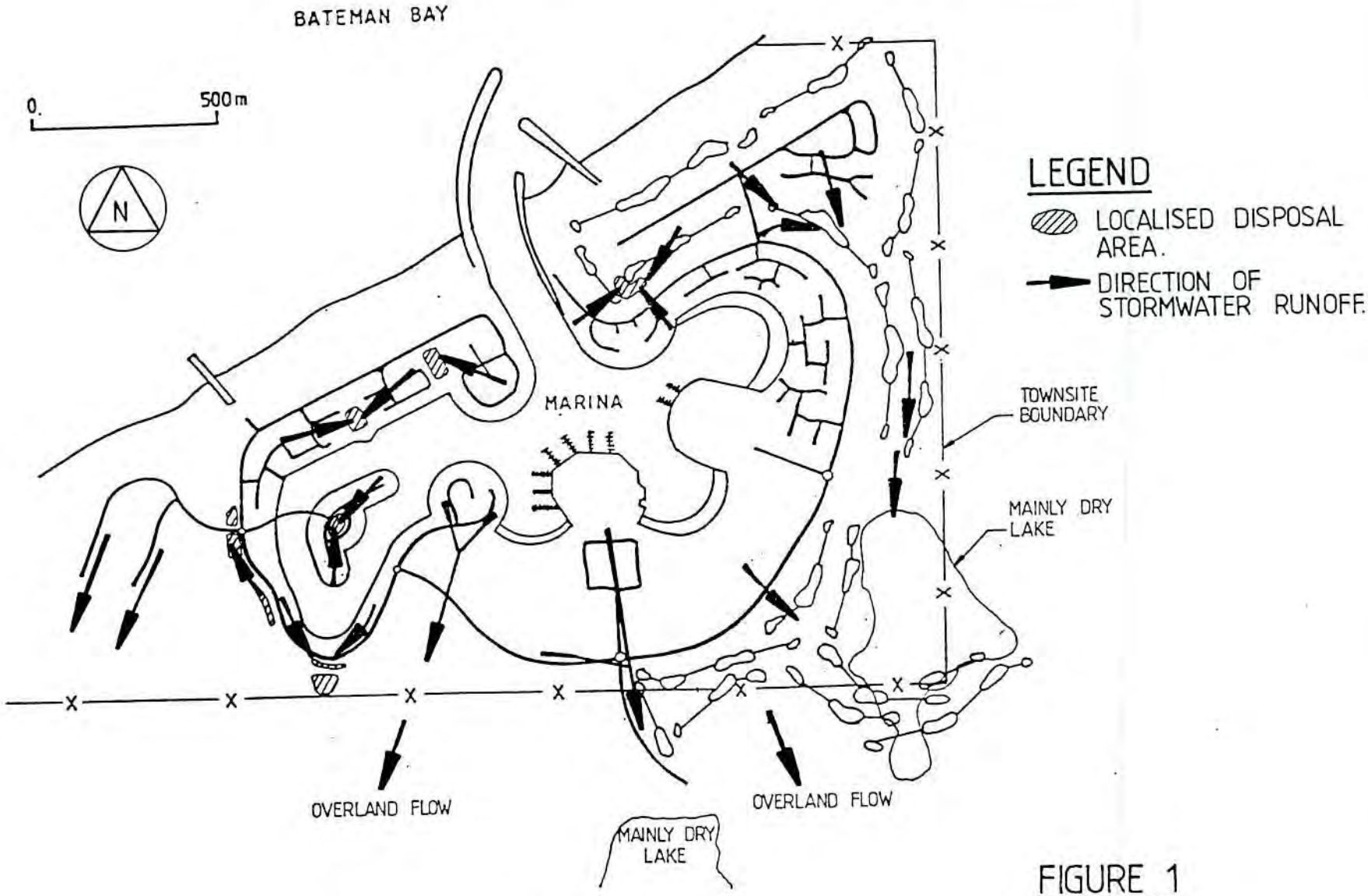
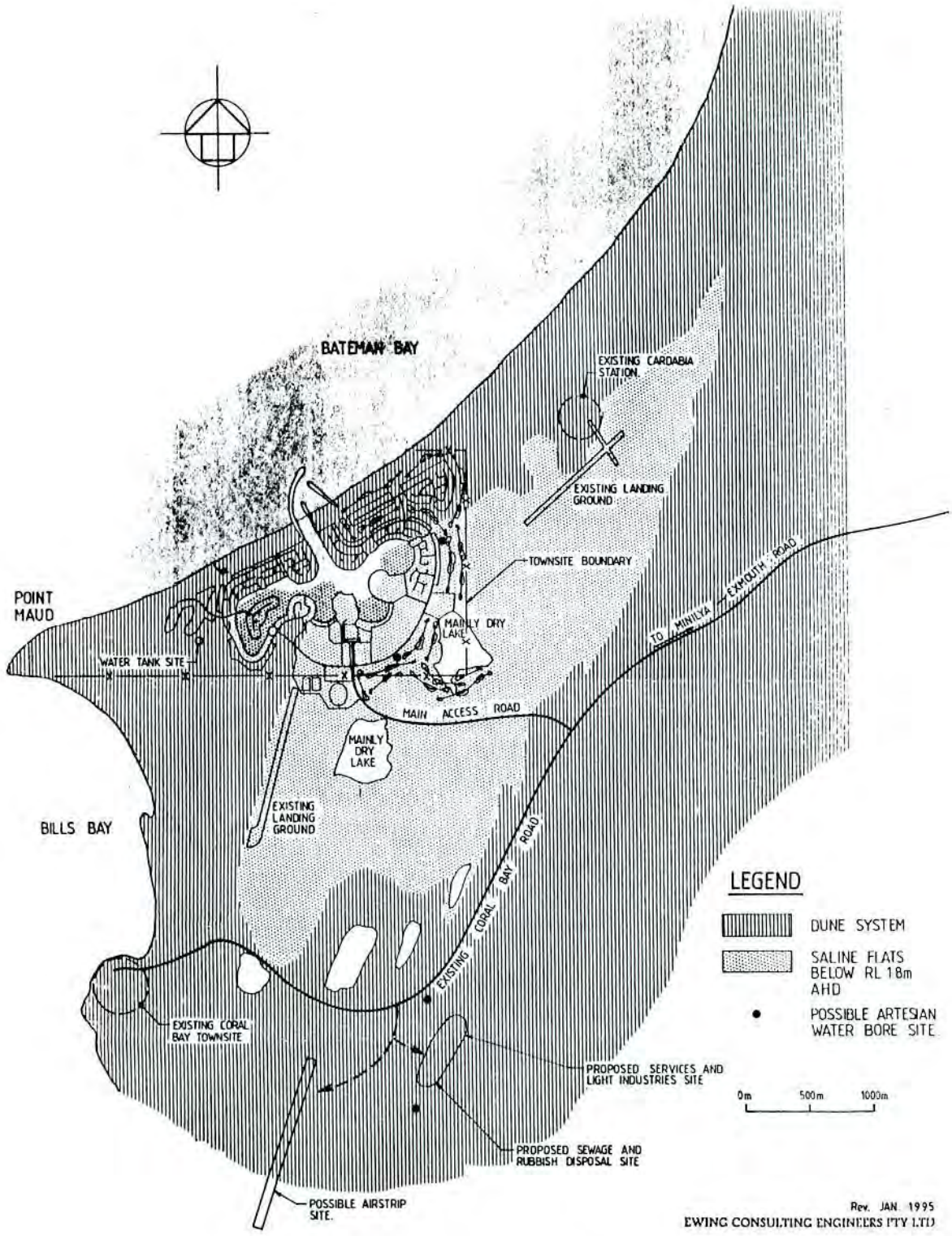


FIGURE 1

STORMWATER RUNOFF DISPOSAL STRATEGY

EWING CONSULTING ENGINEERS PTY LTD

FIGURE 2



CORAL COAST RESORT — RESORT SERVICING LAYOUT

FIGURE 2

PLEASE REFER TO APPENDIX C OF THIS DOCUMENT

PLEASE REFER TO APPENDIX D OF THIS DOCUMENT

PLEASE REFER TO APPENDIX F OF THIS DOCUMENT

APPENDIX C

Evaluation of Groundwater Conditions Near Mauds Landing.

Rockwater Pty Ltd, 1994

Annexure A

Rockwater
PROPRIETARY LIMITED

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CORAL COAST MARINA DEVELOPMENT PTY LTD

EVALUATION OF GROUNDWATER CONDITIONS NEAR MAUDS LANDING, IN THE CORAL BAY AREA FOR PUBLIC ENVIRONMENTAL REVIEW

NOVEMBER 1994

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NOVEMBER 1994

1. INTRODUCTION

The proposed marina and land development near Mauds Landing occupies a triangular segment of coastal country extending 3.5 km east and 1.7 km north of Point Maud. It is 2.4 km north of the existing township of Coral Bay.

Water supplies will be needed for domestic use, urban landscaping, and golf-course irrigation. The rates and volumes of water required have been calculated on the basis that brackish groundwater will be used for landscaping and golf-course irrigation, and that such groundwater will be desalinated for domestic use at 50 per cent recovery rate.

It is estimated that the average and peak water demands will be, respectively, 3,950 and 5,690 cu m/d in the first two years, rising to 6,030 and 9,320 cu m/d after 15 years.

This evaluation of the groundwater conditions in the area, prepared for the Public Environmental Review document, comprises descriptions of the groundwater systems, groundwater availability, and environmental factors.

2. HYDROGEOLOGY

The hydrogeology of the area is determined by the nature of the shallow strata, coastal features, and the structure of the deep strata of the Carnarvon Basin (Allen, 1987). There are two relevant aquifer levels: shallow unconfined aquifers and a deep confined aquifer (the Birdrong Sandstone).

2.1 SHALLOW AQUIFERS

Extending along the coastline are coastal dunes and beach ridges of calcareous sand. These form a strip of generally 1 km width, although from Point Maud they cover the peninsula for 2 km inland. Further inland the surface deposits are coastal lacustrine deposits: calcareous and gypsiferous clay, silt, and sand; and saline deposits in playas (dry lakes). These extend to 4.3 km east (inland) of Point Maud.

The surface deposits described above are underlain by the Bundera Formation, a variably cemented calcarenite forming the ground surface in a broad strip 4 to 9 km east of Point Maud (Hocking et al, 1985). The Bundera Formation is correlated with the Tamala Limestone located further south. It is interpreted to be a highly permeable aquifer, based on the proven characteristics of the Tamala Limestone, which is lithologically similar.

Most of the shallow groundwater in the Mauds Landing - Coral Bay area is saline. Bores drilled into the Bundera Formation to depths of 13 to 60 m at distances up to 10 km inland from Point Maud encountered water in the salinity range 10,000 to 14,000 mg/L TSS. Salinities would increase from east to west, and reach 35,000 mg/L at depth near the coast, where a wedge of sea-salinity water underlies the less saline water. Beneath the playas there could be groundwater lenses of even higher salinity. The quantities of saline groundwater in the Bundera Formation are apparently very large.

There is a thin layer of fresh groundwater over saline, in the coastal sand dunes at some localities. Wells at Mauds Landing and Cardabia Station homestead are reported to contain water of salinities 1,100 to 5,500 mg/L. Only very small supplies of such fresh and brackish water would be available, because the underlying saline water would 'up-cone' if a well or bore was pumped consistently. Individual bores or wells could probably supply only 0.5 cu m/d of low-salinity water.

There are two or three additional wells in the Point Maud dune system, but data are not available. It is assumed that conditions are similar to those described above.

2.1.1 Groundwater Recharge and Flow

The shallow aquifers receive recharge at infrequent intervals, by direct infiltration of rainfall and run-off from hills and ranges, such as Giralia Range located 27 km inland from Point Maud. Evidently the rainfall frequency and intensity are such that only small amounts of fresh water penetrate through the soil to the water table. Apart from a small area west of Giralia Range and the shallowest water at Point Maud, all the unconfined groundwater in the area is saltier than 6,000 mg/L TSS - indicating that the saline groundwater is being diluted very slowly, if at all.

Shallow groundwater flows from east to west through the area i.e. towards the sea. From Giralia Range to the sea the water table declines 70 m (Allen, 1987) i.e. the average hydraulic gradient is 0.0026. This is two to four times steeper than the water-table gradient over the rest of the Carnarvon Basin, and is the result of structural and recharge effects of the Giralia Range.

2.2 BIRDRONG SANDSTONE

The Birdrong Sandstone is the basal formation of the Cretaceous-age strata (the Winning Group) in this area, overlying Devonian-Carboniferous strata. It is quartzose, weakly lithified sandstone, silty, generally 10 to 30 m thick. It is overlain by a thick sequence of other Winning Group formations (Muderong Shale, Windalia Radiolarite, and Gearle Siltstone), and the younger strata of calcareous composition.

The Sandstone is an aquifer extending over a wide area of the Carnarvon Basin: about 77,000 sq km of the on-shore part of the basin. It is the main source of groundwater between Kalbarri and the Fortescue River. Generally the aquifer is confined by the overlying shaley strata, and when tapped by bores it produces artesian flows of brackish, relatively hot, water.

A bore 17 km inland from Mauds Landing is reported to have intersected the aquifer at 682 to 704 m depth, and to have produced flowing water of salinity 5,200 mg/L TSS at 2,970 cu m/d. This bore, constructed in 1909, is reported to be no longer functioning.

At the Bayview caravan park in Coral Bay a bore intersected the Birdrong Formation at 798 to 832 m depth. This section was predominantly sandstone, with 10 m of shale. The bore produced a flow of 1,670 cubic metres/day of water of salinity 5,800 mg/L TSS with a static head of 42 m above ground surface. Water temperature was 58°C. A chemical analysis of a water sample taken in September 1980 is presented in Table 1. The iron concentration is noted to be 2 mg/L (soluble) and 3.4 mg/L (total) which is sufficient to cause some brown staining when used for irrigation. Subsequent analyses of water from the bore indicated salinities of 5,100 mg/L TSS (in August 1992) and 5,350 mg/L TSS (in August 1994).

A bore at the adjacent Peoples Caravan Park produced a flow of 2,160 cu m/d from a similar aquifer zone. Its salinity is reported to have been 5,420 mg/L TSS in April 1992 and 5,300 mg/L TSS in August 1994.

The Birdrong Sandstone is the only practical source of large supplies of groundwater in this region. Its groundwater is brackish to slightly saline, and would need to be desalinated for drinking and domestic water.

2.2.1 Groundwater Recharge and Flow

Groundwater recharge to the Birdrong Formation takes place along the eastern edge of the Cretaceous strata in the Carnarvon Basin. This is 80 km east of Point Maud, although over much of the basin it is 100 km or more from the coast. Here, the Birdrong Formation outcrops, subcrops, or occupies palaeochannels.

Water infiltrates through outcrops, river beds or overlying superficial deposits. It follows the structure of the Birdrong Formation to below -1000 m AHD locally, and evidently discharges to the sea some distance offshore from the Coral Bay Area. In some other areas there appears to be discharge near-shore and on-shore (Exmouth Gulf, Lake MacLeod, and Shark Bay).

Water-level contours of the Birdrong Formation aquifer are known broadly (Allen, 1987). In general, the water levels decrease from east to west across the Carnarvon Basin, reflecting the overall westerly groundwater flow. There appears to be a water-level mound at 60 m AHD at the Giralia Range, from where there are downwards hydraulic gradients to the west, north, and south. Thus, in the region east of Point Maud there are components of groundwater flow north-westerly and south-westerly.

Estimation of the rates of groundwater flow through the aquifer requires the knowledge of hydraulic gradients determined from measurement of water levels in non-pumping bores. Such information is not currently available. An approximate value applicable to this area is 0.0005.

TABLE 1

CHEMICAL ANALYSIS OF WATER
FROM CORAL BAY (BAYVIEW) CARAVAN PARK
20 SEPTEMBER 1994

Constituents	Unit	Value
Calcium	mg/L	124
Magnesium	"	22
Sodium	"	1950
Potassium	"	32
Chloride	"	2471
Sulphate	"	820
Bicarbonate	"	368
Iron (soluble) Iron (total)	"	2 3.4
Nitrate	"	<0.03
Fluoride	"	1.9
pH	-	7.5
TSS (sum of ions)	mg/L	5791

2.3 OTHER AQUIFERS

Between the Bundera Formation and the Birdrong Formation aquifers, the strata of about 750 m thickness comprise mainly limestone, calcarenite, and marl to about 500 m then siltstone and shale to about 800 m depth.

In the upper section there are several aquifer intervals: limestone and calcarenite which are locally vuggy and cavernous, and minor sands. In the lower section, the siltstone/shale strata are predominantly impermeable, but locally there are thin sandstone beds that are minor aquifers.

2.4 DISCUSSION

The groundwaters in the various layers shallower than the Birdrong Formation are essentially all saline. They are corrosive, and need to be controlled by cement-grouting techniques when bores are constructed. Because of the corrosion and collapse of casings, a number of bores have become saline and/or are leaking without control.

3. WATER SUPPLIES

The estimated water-supply requirements for the land development project are listed in Table 2 below.

TABLE 2

ESTIMATED WATER-SUPPLY REQUIREMENTS

	Development Period	0-2 yrs	3-5 yrs	6-10 yrs	11-15 yrs	16-21 yrs
1.	Peak potable output (treated) (m^3/day)	545	854	1476	1774	1890
2.	Average potable (m^3 p.a.)	99,000	156,000	269,000	324,000	345,000

	Cumulative Total Demands	0-2 yrs	3-5 yrs	6-10 yrs	11-15 yrs	16-21 yrs
3.	Allow for treatment plant recovery - potable (m^3 p.a.)	198,000	312,000	538,000	648,000	690,000
4.	Landscaping ('untreated') (m^3 p.a.)	245,000	325,000	430,000	485,000	500,000
5.	Golf Course ('untreated') (m^3 p.a.)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
	Cumulative Total Demand	1,443,000	1,637,000	1,968,000	2,133,000	2,190,000

Notes:

1. Full development total 2,190,000 m^3 p.a.

2. Distribution for landscaping and golf course.

January - March	April - June	July - September	October - December
32%	17%	17%	34%

3.1 WATER SOURCE

Subject to approval by the Water Authority of W.A., the water would be available from the Birdrong Formation. Production rates from individual bores would fall in the range 2,000 to 4,000 cu m/d, depending on the nature of the formation (eg. thickness, grain size) at the bore site(s) and the details of bore construction. The bore at the Bayview caravan park at Coral Bay was constructed of 117 mm internal diameter casing with 20 m of perforations at 9 holes per metre; it flowed at 1,670 cu m/day. The bore at the Peoples caravan park was similarly constructed, and flowed at 2,160 cu m/d. Bores at the Lake MacLeod salt project are constructed of 203 mm internal diameter casing with stainless steel screens (about 20 m in length); they have flowed at rates up to 3,400 cu m/d and have been pumped at rates up to 4,600 cu m/d.

To provide the estimated peak water demands, supplies of brackish groundwater would need to be 5,690 cu m/d in the first year, increasing to 9,300 cu m/d after 15 years. For a residential water supply a stand-by bore would be required. Therefore a borefield for the project would comprise two bores initially and three in the long term.

3.2 DOMESTIC WATER

Water supplies for domestic consumption generally have an upper salinity limit of 1,000 mg/L TSS, or in extenuating circumstances 1,500 mg/L. It is evident that the groundwater available in the project area will need to be treated i.e. desalinated, for domestic use.

Some of the factors that will apply are:

(1) Feed water supply needs to be about double the product supply.

(2) Pre-treatment of the feedwater is required, prior to desalination.

(3) Reverse osmosis is the most suitable method for an operation of the throughput envisaged.

(4) Discard water from the desalination process will be saline; the estimated average supply rate is 0.12×10^6 cu m/yr, 330 cu m/d. It could be discharged into the shallow saline groundwater system, subject to assessment of environmental acceptability taking into account its chemical composition.

4. GROUNDWATER EFFECTS OF DEVELOPMENT

The effects, on local groundwater, of the proposed marina development are primarily the drawdown of water levels in the Birdrong Formation aquifer, and changes to the shallow groundwater regime.

4.1 BIRDRONG FORMATION AQUIFER

Extraction of groundwater from an aquifer creates a cone of depression in the potentiometric surface (i.e. the imaginary surface of water-level elevations) around a pumping point. In utilising an aquifer such as the Birdrong Formation it is desirable that water levels generally remain above sea level so that sea water does not intrude into the aquifer. Local, deeper, water levels in the immediate vicinity of production bores are quite acceptable.

Water levels in the aquifer in the project area are naturally about 40 m above sea level, therefore the main criteria will be that drawdown from pumping does not exceed 40 m over a wide area.

Calculations made here are based on aquifer transmissivity of 110 sq m/d as indicated for the Birdrong Formation at Lake MacLeod, and an adopted storage coefficient of 0.0001. It is assumed that groundwater production at Coral Bay will average 1,300 cu m/d in the future, and that the average production from bores at Point Maud is 6,000 cu m/d. The calculated one-year drawdown at a point half way between the two pumping centres (3.5 km apart) is 30 m. This would be an acceptable drawdown. Aquifer coefficients need to be verified for this locality, and this would be achieved by test-pumping any new production bores near Mauds Landing or Coral Bay.

4.2 SHALLOW AQUIFER

The construction of a marina will allow entry of sea water into the shallow aquifer up to one kilometre inland from the coast. Given the predominantly high salinity of the shallow groundwater, the local entry of sea water is not seen to be environmentally detrimental. The minor fresh groundwater in the shallow sands in adjacent areas, such as Point Maud, will not be significantly affected.

Nutrients and other contaminants that might be produced by urban development will tend to flow towards the coastline and the marina. It is understood that locations of and procedures for effluent and rubbish disposal will be planned to provide adsorption or containment of potential contaminants. It will be desirable to locate such facilities as far inland as practical.

5. CONCLUSIONS

Water supplies for the proposed marina and land development near Mauds Landing will be available from the Birdrong Formation aquifer at a depth of about 800 m. Water salinity will be about 5,300 mg/L TSS. Desalination will be required, to obtain fresh water for domestic use.

Preliminary calculations suggest that water-level drawdowns caused by pumping the estimated average long-term requirements of 2.2×10^6 cu m/annum (6,030 cu m/d) from the aquifer are calculated to be not excessive with respect to sea-water intrusion. Aquifer coefficients used in the calculations need to be established by test-pumping bores to be constructed in the area.

The shallow groundwater is predominantly saline, and no significant fresh groundwater resource will be affected by the marina and township development. Groundwater flow of any nutrients or contaminants will need to be prevented or controlled.

DATED: 18 NOVEMBER 1994 ROCKWATER PTY LTD

J. R. PASSMORE
PRINCIPAL HYDROGEOLOGIST

REFERENCES

Allen, A.D., 1987. Groundwater in Geology of the Carnarvon Basin, Western Australia, by Hocking, R. M., Moors, H. T., and Van de Graaff, W.J.E. Geological Survey of Western Australia Bulletin 133.

Hocking, R.M., Lavaring, I.H., and Williams, S.J., 1984. Winning Pool-Minilya 1:250,000 Geological Sheet, second edition.

APPENDIX D

Options for Water Supply and Treatment

Hi-Tech Water (Australia) Pty Ltd, 1994

HI-TECH WATER
(Australia) Pty Ltd

ACN 009 004 228

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POTABLE WATER SUPPLY

1. Volume Requirements

If a design basis of 250 L/person.day is used, the volume projections over the term of the development are:

0-2 years	545m³/day
3-5 years	854m³/day
6-10 years	1476m³/day
11-15 years	1774m³/day
16-21 years	1890m³/day

The above volumes do not represent an onerous demand on the design and construction of desalination plants which can be supplied in modular form to cater for the expansion of the resort.

2. Water Treatment

The most common approach for desalination is to use reverse osmosis to provide potable water from brackish water or seawater sources. Other techniques which may be employed are:

Electrodialysis
Evaporation

Electrodialysis is more expensive than reverse osmosis and can be applied to very high salinity water sources, reverse osmosis is not applicable due to the unacceptably high osmotic pressure of the feedwater. In this application where brackish water and seawater is available there is no advantage in selecting electrodialysis.

Evaporation techniques are again more expensive than reverse osmosis and are best employed where excess heat and high volumes of cooling water are available. Approximately 130kW of waste heat are needed for each $1m^3$ of produced water. For the full scale development, 5 megawatts of waste heat will be required. Another factor that has to be considered is the use of seawater for cooling in the condensation section of the plant. Because of the sensitive nature of the Ningaloo Reef it is envisaged that this cannot be taken from the ocean and that a dedicated land based cooling circuit will be necessary. The overall capital cost and operating costs of an evaporation system would be more expensive than reverse osmosis and therefore this option has not been considered.
Reverse osmosis will be used as the method of producing potable water.

3. Water Source

The available water sources are:

Seawater from the ocean
Artesian bore water

The analysis of the bore water indicates that there are no contaminants present that would prohibit the use of this water as feed to a desalination plant. Factors that have to be considered are the water temperature which will have to be reduced to 40°C and the iron concentration which will have to be reduced to less than 0.1mg/L. These demands are not arduous.

The recommendation is that bore water is used. Seawater desalination systems are more expensive and operate at much higher pressures, therefore energy costs will be significantly higher. Seawater systems also operate at lower recovery, typically 33%, this means that for each $100m^3$/day of potable water produced, $200m^3$/day of reject water at a salinity of 55,000 mg/L would have to be returned to the ocean or discharged to evaporation ponds.

4. Scale Up

Reverse osmosis systems are of modular construction and the design lends itself to

easy scale up to cater for the staged increase in potable water supply.

Referring to the water demand given in Section 1 it is suggested that a 1000m³/day system is for the first stage of the development considered with respect to the mechanical design. Initially a fewer number of membranes will be installed, these will cater for the lower water demand. More membranes can be added at a later date as required. Importantly it will not be necessary to change the pumps, instrumentation or pipeline sizes.

5. Reject Disposal

On the basis of the use of bore water, a system recovery of 50% might be expected. This means that the reject quantity that will have to be disposed of is equal to the volume of potable water produced by the system.

The reject salinity will be approximately double that of the feed water, namely 10,000 mg/L.

6. Pretreatment

The pretreatment requirements for the bore water to comply with the feedwater quality requirements for reverse osmosis are:

Temperature Reduction
Iron Removal
Polishing Filtration

The small amount of heat extracted from the bore water could be used to provide heat for other water facilities if required.

Iron removal is accomplished by oxidation of the ferrous ions to the more insoluble ferric form followed by filtration. A factor that will have to be considered is the disposal of backwash water from the filtration system. This will not be toxic but could provide aesthetic problems if disposal is considered within the resort development.

SEWAGE DISPOSAL

1. General

Sewage and wastewater from the development operations will have to be disposed of by acceptable methods, for design purposes there will be no industrial waste component in the sewage.

As a design basis, a discharge volume of 230 litres/person.day can be anticipated. Relating this to the population in the resort this equates to the following projected volumes:

0-2 years	307m³/day
3-5 years	581m³/day
6-10 years	1106m³/day
11-15years	1361m³/day
16-21 years	1468m³/day

Factors that have to be considered are the disposal of this volume and the method of handling the excess sludge and solids produced by the process.

2. Standard of Treatment

A minimum of secondary treatment will be necessary to treat the wastewater to an acceptable quality that may be disposed. This will produce an effluent with a BOD of less than 20mg/L and a suspended solids concentration of less than 30mg/L.

Depending upon the point of disposal or re-use it might also be necessary to practice some form of tertiary treatment to remove any residual nitrogen and phosphorus from the secondary effluent. Nitrogen would have to be removed by biological denitrification, phosphorus can be removed either chemically or biologically. The former is the traditional approach and is well defined. Recently some biological processes have been modelled to reduce both nitrogen and phosphorus.

The secondary effluent will still have a considerable bacterial population and this can be controlled by the addition of either sodium hypochlorite or gaseous

chlorine. A typical design to comply with Public Health Regulation has to give a free chlorine residual of 0.5mg/L after a contact time of 1 hour.

3. Methods of Treatment

The flow rate from the resort is not very large by municipal standards, it is therefore not considered necessary to install primary treatment and anaerobic digestion before secondary treatment. This would make the process much more complex, more maintenance intensive and unnecessarily expensive.

The form of treatment proposed is an activated sludge system operating in the extended aeration mode. The long sludge age makes this process relatively stable and produces less excess solids than higher rate activated sludge processes.

Several forms of the extended aeration process are commercially available, these all use the same design basis, they essentially differ in the method of aeration, cell geometry and cyclic control of the process.

The only pretreatment prior to the extended aeration system will be coarse screening.

4. Point of Disposal

The secondary effluent is able to be used for irrigation, the only factor that will need to be addressed is the bacteriological content of the water. If the irrigated crop has a requirement for nutrients then the presence of small concentrations of nitrogen and phosphorus may be considered to be an advantage.

5. Excess Solids Production

Excess biological solids are a result of all treatment systems, these solids are essentially biomass resulting from synthesis of the incoming organics. The weight of excess solids produced in the first 2 years of operation might be expected to be 40kg/day.

The easiest method of dewatering these solids is through the use of drying beds which would be applicable to the climate in this region. Alternatively more intensive forms of mechanical dewatering, such as filter presses, could be used.

The dewatered excess solids would make an ideal soil conditioner.

6. Maintenance Considerations

Extended aeration treatment processes are simple aeration systems and the maintenance requirements are not demanding.

To control the plant it is not necessary to have an operator with a detailed knowledge of water chemistry and microbiology.

R.O. SYSTEM

Preventative Maintenance

The factors affecting the performance of reverse osmosis systems are now widely understood and would be incorporated into the overall system design. Maintenance therefore predominantly relates to the checking of instrumentation and electrical and mechanical equipment. No special skills are required for this service.

The performance of the reverse osmosis system can be analysed by the instrumentation incorporated into the system design. In a comprehensive system the data would be transferred as an analogue signal to a chart recorder or a data logger. A more basic design would require an operator to take daily logs, this would not be an onerous demand. Occasionally a sample of the feed water would be taken for analysis to confirm the original design basis. The results of the systems performance can be analysed with reference to an Operational and Maintenance manual or interpreted by the system designers. Occasionally it might be required to carry out a chemical cleaning exercise, this is essentially the recycle loop whereby a chemical cleaning agent is recycled through the membrane. A chemical clean can easily be carried out by the maintenance personnel and no special knowledge or skills are required.

It is anticipated that the maintenance demand will be less than one hour per day.

BIOLOGICAL SYSTEM

Preventative Maintenance

A biological treatment system is a natural process and the maintenance demand will predominantly relate to ensuring that the operational parameters are conducive to the well-being and growth of aerobic bacteria. The factor that governs this requirement is the dissolved oxygen level in the system which in turn relates to the mechanical performance of the aeration device.

Preventative maintenance would therefore address the performance of the mechanical and electrical equipment within the system. For a system of this size, a dissolved oxygen monitor would control and record the dissolved oxygen level within the system. No other monitoring instrumentation is required.

The daily requirements of the operator would be to monitor the suspended solids concentration in the activation cell and usually inspect the clarity of the clarifier overflow. In the ambient conditions in this location the growth of algae in the clarifier overflow weir will be unpreventable. It would therefore be necessary to ocasionally clean the weir with a sodium hypochlorite solution.

It is anticipated that the maintenance demand for the process would be less than one hour per day. There would not be a requirement for the operator to have a detailed knowledge of water chemistry or microbiology.

APPENDIX E

Report on the Chemical and Physical Properties of Soils from Mauds Landing, Coral Bay and Cardabia

Chemistry Centre of WA, 1994

REPORT ON THE CHEMICAL AND PHYSICAL PROPERTIES OF SOILS FROM MAUD'S LANDING, CORAL BAY AND CARDABIA STATION

FOR

BOWMAN, BISHAW & GORHAM
ENVIRONMENTAL CONSULTANTS
and
CORAL COAST MARINA DEVELOPMENT PTY LTD

BY

R C JEFFERY
PRINCIPAL RESEARCH CHEMIST (SOIL CHEMISTRY)
AGRICULTURAL CHEMISTRY LABORATORY

November 1994

INTRODUCTION

This survey was carried out to provide information for the Environmental Consultants and the Developers to assist in preparation of the Public Environmental Review for the proposed development of a marina, resort and residential complex at Maud's Landing near Coral Bay.

The aims of the survey were :

- To assess the chemical and physical properties of reclaimed soils which will form the golf course fairways and parklands under irrigated turf.
- To assess the suitability of the calcareous dune soils on the coast and the red dune soils on Cardabia Station for fairway topdressing, greens construction or use as potential nutrient stripping materials in the management of WWTP effluent.
- To consider problems of irrigated turf management given the need to maintain adequate levels of nutrition while minimising nutrient export.
- To assess potential problems with respect to turf management associated with the use of irrigation water with a very high salinity hazard rating.

SAMPLE COLLECTION

The areas was surveyed and samples were collected on 14 and 15th October 1994.

Golf Course Fairway Soils

Soils from the area to be excavated for the proposed marina are to be used to form the fairways of the golf course and other parklands.

Samples were taken from auger holes to a depth of 2 metres at 4 sites along a transect between Maud's Hill and Cardabia Station Homestead (refer sketch map)

Hole 1	Sample	1.1	5 - 20 cms
		1.2	20 - 40
		1.3	40 - 60
		1.4	100 -150] saturated
		1.5	150 - 200] zone
Hole 2	Sample	2.1	25 - 50 cms
		2.2	75 - 100
		2.3	100 - 150] saturated
		2.4	150 - 200] zone

Hole 3	(pale brown)		0 - 10 cm
	(V hard calcrete)		10 - 20
	Sample	3.1	40 - 60
		3.2	75 - 100
		3.3	100 - 150] saturated
		3.4	150 - 175] zone
Hole 4	same as Hole 3		
	Sample	4.1	0 - 10 cms

Soils under Established Turf at Coral Bay

Saltene couch is readily established on the calcareous dune soils at the Coral Bay settlement, using reticulated artesian water, and without applications of fertiliser.

Samples were taken from the area under lawn at the property of Neil Wise, and from a nearby undeveloped dune.

Hole 5	Sample	5.1	5 - 15 cm
		5.2	15 - 30
		5.3	30 - 45
		5.4	virgin 10-50

Sample of grass clippings

Sample of artesian water (hot) from a sprinkler under continuous use.

Soils from Cardabia Station

Samples were taken from a dune and nearby swale at a point approximately 10 Km east of the main Exmouth road.

Cardabia dune : deep red siliceous fine sand

Sample	6.1	0 - 10 cm
	6.2	90 - 100
	6.3	180 - 200

Cardabia swale : red brown loamy sand over dark brown loamy sand at 1 metre, over red brown calcareous loamy sand

Sample	7.1	0 - 10 cm
	7.2	90 - 110
	7.3	180 - 200

CHEMICAL ANALYSIS AND PARTICLE SIZE DISTRIBUTION

Samples 1.1 - 4.1 Fairway soils

Soil solution was separated from samples from the saturated zone and analysed for pH and electrical conductivity (EC). Dried soils were analysed for calcium carbonate ($CaCO_3$) content, pH and EC. Selected samples were assessed for particle size distribution (coarse sand, fine sand, silt and clay).

Samples 5.1 - 5.4 Wise lawn soils

Dried soils were analysed for pH, EC, $CaCO_3$, extractable phosphorus, potassium, ammonia and nitrate, phosphorus retention index (PRI) and particle size distribution.

Samples 6.1 - 6.3 Cardabia dune

Analyses were pH, EC, extractable phosphorus and potassium, PRI and detailed (ten category) particle size distribution.

Samples 7.1 - 7.3 Cardabia swale

Analyses were pH, EC and PRI

RESULTS AND DISCUSSION

Soil solutions from the saturated zone of holes 2 & 3 have electrical conductivities of ~6000 mS/m, indicating a salt concentration of ~36000 mg/l which is similar to that for sea water. The salt would be readily leached from reclaimed soils because, in general, the proportion of coarse plus fine sand exceeds 95%.

The proportion of silt and clay in the topsoils 1.1 and 4.1 were not assessed because the relatively high soluble salt content (4% estimated from EC) caused flocculation in the test solutions. It is expected that the topsoils would have similar silt and clay contents to soils 1.2 and 1.3 which have larger proportions of silt and clay sized particles compared with soils deeper in the profile.. These fines may have the potential to become dispersive when soluble salts are leached although the very high salinity of the irrigation water should ensure that a stable soil structure is maintained. It may be advisable to place the top 1/2 metre of excavated soil at the bottom of the fairway mounds to avoid any possibility of dispersive soils causing restrictions to drainage.

Reclaimed soils are very high in calcium carbonate (69-86% $CaCO_3$) and have similar particle size distributions to the calcareous dune soils at the Coral Bay settlement (5.1.-5.4). When leached of salt, these reclaimed soils may be suitable for direct establishment of turf and may not need topdressing. Apart from the addition of trace elements and possibly organic matter (eg pelletised poultry manure) saltene couch may establish as readily on reclaimed soils as it does on the dune soils at Coral Bay. This should be determined, as a matter of priority,

with turf establishment trials, as soon as approval for development is given. If topdressing proves to be necessary the dunes to be excavated at the marina entrance may provide sufficient topdressing material similar to the dune soil at Coral Bay. This may obviate the need to bring in soil for topdressing from Cardabia Station.

Soil will need to be imported for golf course greens construction. The particle size distribution of the fine red sand from the dune system in Cardabia Station (6.1-6.3)shows a much higher proportion of sand smaller than about 0.2 mm compared with that recommended for greens construction by USGA and Australian authorities, as shown below.

Particle size distribution for greens sand

	USGA	**Cardabia**
coarse sand (.5-2mm)	<30%	<1%
medium sand (.2-.5)	>55%	35-45%
fine sand (<.2)	<25%	53-62%
silt + clay	< 5%	<5%

The golf course architect will need to decide whether the Cardabia dune sand is suitable. If not other sandy soils in the region will need to be assessed.

The soil samples from Cardabia Station have only low to moderate capacity to retain phosphate (PRI 2-3 for dune samples, PRI 4-8 for swale samples). This is surprising given the deep red-brown colour of the swale samples which suggested to the sampling team that the PRI could be more likely greater than 50. The potential for these soils to be used as nutrient-stripping material in WWTP effluent management systems is therefore limited.

Results of analyses of lawn clippings, soils and irrigation water from the Wise property at Coral Bay indicate that saltene couch can be established and maintained with no extra nutrient input to that naturally present in soil and artesian water. The nutrient concentrations in the grass are generally adequate except for phosphorus which may be sub-optimal. Sodium and sulphur are relatively high but do not appear to affect grass growth and the results may be reflecting the accumulation of salt on the surface of grass (Neil Wise, personal communication) rather than uptake by the grass. The concentrations of copper, iron, manganese and zinc are surprisingly high given the very low levels in the artesian water and the relatively common occurrence of trace element deficiencies in turf grown on calcareous soils around Perth. It is possible that with large amount of irrigation water (say 5 metres/year) the contribution from even small concentrations of trace elements, applied directly onto the foliage, are significant and effective. For example 0.1 mg/l of manganese in water is equivalent to 5 Kg Mn/ha/yr with 5 metres of irrigation.

Nitrogen (N) is present in the irrigation water as ammonium at a concentration of 5 mg/l. If ~5 metres of water is applied annually (evaporation rate is 3 metres) this represents ~250 KgN/ha. There is no evidence of accumulation of N in the soil under established lawn (samples 5.1-5.3). Given the adequate level of N nutrition in the lawn (2.79%N db) and the vigorous root system of the lawn (personal observation) to a depth of at least 20 cms, the indications are that most of the N applied is taken up by the grass and removed in clippings. For the golf course turf the amount of irrigation water is unlikely to exceed 3 metres (ie ~150 KgN/ha) and supplementary N (eg pelletised poultry manure) may be necessary for establishment and maintenance of turf. Recycling WWTP effluent to supplement N (& P) may also be an option.

Phosphorus (P) nutrition is possibly sub-optimal in the grass (0.22% P db). There is negligible P in the artesian water and P is supplied by the soil reserves. There appears to have been depletion of available P in soil under the lawn (4-5 ppm) compared with virgin soil (10 ppm). Extra P would be necessary for establishment and maintenance of turf for the golf course but the moderate capacity of the calcareous soils to retain P (PRI 8-10) coupled with regular use of soil and grass clippings analysis to monitor P nutrition would ensure that the potential for P movement beyond the root zone is minimised.

The concentrations in the grass clippings of potassium, calcium, magnesium and sulphur are all adequate to high. The concentration of potassium in artesian water is at the luxury level of application (~1500 KgK/ha for 5 metres of irrigation water). The fact that the grass does not accumulate luxury levels may be due to competition from high concentrations of sodium in the irrigation water.

One further aspect is relevant to nutrient management for irrigated turf on the proposed golf course. It is normal practice at Coral Bay to remove clippings from lawn. If left on the surface, new growth can be burnt due to interactions between the clippings layer and the hot artesian water. The return of clippings to fairways is practiced on Perth golf courses, resulting in a beneficial increase in soil organic matter and the recycling, and thus more efficient use of fertiliser nutrients. It is anticipated that, for the proposed golf course, artesian water will be cooled prior to reticulation and combined with a greater frequency of mowing (compared with management at Coral Bay), may allow clippings return to be practiced. This will affect the amount of supplementary N and P required to maintain adequate nutrition of fairway turf.

The artesian water has an electrical conductivity of ~900 mS/m (~5000 mg/l) and is a mixture of 80% sodium chloride and 20% sodium sulphate. It is classified (US Soil Salinity Laboratory) as having a very high salinity hazard and a very high sodium hazard (sodium absorption ratio ~50).

Use of this water to irrigate an established lawn at Coral Bay has resulted in some accumulation of salt in the soil. EC(1:5) has increased from 15 mS/m in the virgin soil to 60 mS/m in the top 15 cms of lawn soil. The results for EC (1:5) are used to estimate EC_{SE}, the electrical conductivity of the saturation extract (which approximates the soil solution) upon which the salinity tolerance criteria of turfgrasses are based. The lawn soil samples have EC_{SE} of 500-900 mS/m. The growth of many turfgrasses is restricted at these levels and suitable species, such as saltene couch, display moderate salt tolerance (chapter 6 Salinity and Turfgrass Culture, in Turfgrass, US Agronomy Series No32, 1992).

Give the (probable) luxury rates of application of irrigation water to the Wise lawn, there is very likely to be greater degree of accumulation of salt in soils under fairway turf where irrigation rates are likely to more closely match rates of evaporation. There will need to be regular flushing events to prevent excessive salt accumulation in the root zone.

Saltene couch is not suitable for the golf course greens. Selection of a suitable, moderately salt tolerant species of grass and the development of irrigation management strategies is for others to consider, although the regular monitoring of soil solution salinity will be necessary to ensure that the strategies are successful.

DEPARTMENT OF
MINERALS AND ENERGY
WESTERN AUSTRALIA

CHEMISTRY CENTRE
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125 HAY STREET
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TELEPHONE (09) 325 5544
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/
94A0656; 2.1.1
Robert Jeffery

Bowman Bishaw Gorham
PO BOX 946
West Perth
WA 6872
Attention : M Bowman

Report on:

24 samples of received on 21 October 1994

CCWA ID		94A0656/001	94A0656/002	94A0656/003	94A0656/004	94A0656/005
Client ID		1.1	1.2	1.3	1.4	1.5
Sampled		15/10/94	15/10/94	15/10/94	15/10/94	15/10/94
Analyte	Unit					
pH (H2O)		8.5	8.6	8.8	9.3	9.4
EC (1:5)	mS/m	1300	530	440	330	310
CaCO3	%	69	83	73	84	84
Stones	%	0.6	1.2	1.2	2.0	3.1
C. Sand	%	-	48.5	50.0	84.5	82.0
F. Sand	%	-	32.5	24.0	13.5	15.5
Silt	%	-	11.0	11.0	2.0	2.5
Clay	%	-	8.0	15.0	-	-

CCWA ID		94A0656/006	94A0656/007	94A0656/008	94A0656/009	94A0656/010
Client ID		2.1	2.2	2.3	2.4	3.1
Sampled		15/10/94	15/10/94	15/10/94	15/10/94	15/10/94
Analyte	Unit					
pH (H2O)		9.4	9.6	9.5	9.6	9.6
EC (1:5)	mS/m	120	280	220	250	260
CaCO3	%	84	86	86	86	85
Stones	%	6.9	2.7	4.2	2.7	6.1
pH (SS)		-	-	-	7.7	-
EC (SS)	mS/m	-	-	-	5600	-
C. Sand	%	-	-	-	-	70.0
F. Sand	%	-	-	-	-	27.5
Silt	%	-	-	-	-	2.5

CCWA ID		94A0656/011	94A0656/012	94A0656/013	94A0656/014	94A0656/015
Client ID		3.2	3.3	3.4	4.1	5.1
Sampled		15/10/94	15/10/94	15/10/94	15/10/94	15/10/94
Analyte	Unit					
pH (H2O)		9.3	9.5	9.6	8.7	9.6
EC (1:5)	mS/m	300	310	250	1300	60
CaCO3	%	85	85	85	73	-
Stones	%	6.0	6.2	4.9	4.8	1.7
C. Sand	%	78.0	80.0	80.5	-	75.5
F. Sand	%	19.5	18.5	17.5	-	19.5
Silt	%	2.5	1.5	2.0	-	5.0
pH (SS)		-	7.6	7.6	-	-
EC (SS)	mS/m	-	6400	6300	-	-
P (PRI)	mL/g	-	-	-	-	7.6
P (HCO3)	ppm	-	-	-	-	5
K (HCO3)	ppm	-	-	-	-	35
N (NH4)	ppm	-	-	-	-	<1
N (NO3)	ppm	-	-	-	-	3

CCWA ID		94A0656/016	94A0656/017	94A0656/018	94A0656/019	94A0656/020
Client ID		5.2	5.3	5.4	6.1	6.2
Sampled		15/10/94	15/10/94	15/10/94	15/10/94	15/10/94
Analyte	Unit					
pH (H2O)		9.8	9.7	9.4	8.7	8.5
EC (1:5)	mS/m	35	37	15	2	1
CaCO3	%	81	82	82	-	-
P (PRI)	mL/g	9.5	8.0	6.0	2.2	2.3
P (HCO3)	ppm	4	8	10	3	<2
K (HCO3)	ppm	43	39	10	72	75
N (NH4)	ppm	<1	<1	<1	-	-
N (NO3)	ppm	3	3	2	-	-
Stones	%	0.4	0.3	0.1	0.0	0.1
C. Sand	%	67.0	79.0	79.0	-	-
F. Sand	%	28.0	16.0	16.5	-	-
Silt	%	5.0	5.0	4.5	0.5	2.5
size (a)	%	-	-	-	0.0	0.0
size (b)	%	-	-	-	0.0	0.1
size (c)	%	-	-	-	5.0	7.4
size (d)	%	-	-	-	40.5	28.1
size (e)	%	-	-	-	15.7	12.3
size (f)	%	-	-	-	21.1	22.8
size (g)	%	-	-	-	11.4	19.3
size (h)	%	-	-	-	4.9	8.0

CCWA ID		94A0656/021	94A0656/022	94A0656/023	94A0656/024
Client ID		6.3	7.1	7.2	7.3
Sampled		15/10/94	15/10/94	15/10/94	15/10/94
Analyte	Unit				
pH (H2O)		8.6	8.9	9.8	9.8
EC (1:5)	mS/m	1	7	27	59
P (PRI)	mL/g	3.0	4.5	8.0	7.8
P (HCO3)	ppm	6	-	-	-
K (HCO3)	ppm	63	-	-	-
Stones	%	0.0	1.0	0.1	14.0

CCWA ID		94A0656/021	94A0656/022	94A0656/023	94A0656/024
Client ID		6.3	7.1	7.2	7.3
Sampled		15/10/94	15/10/94	15/10/94	15/10/94
Analyte	Unit				
Silt	%	3.5	-	-	-
size (a)	%	0.0	-	-	-
size (b)	%	0.1	-	-	-
size (c)	%	9.5	-	-	-
size (d)	%	32.7	-	-	-
size (e)	%	10.7	-	-	-
size (f)	%	17.9	-	-	-
size (g)	%	15.1	-	-	-
size (h)	%	11.0	-	-	-

Analyte	Method	Description
pH (H2O)	S-PHEC	pH (1:5) in water. ACL Method S01.
EC (1:5)	S-EC	Electrical conductivity (1:5) at 25 deg C. ACL Method S02.
CaCO3	S-CACO3	Calcium carbonate, soluble in dilute acid
Stones	S-STONES	Stones, greater than 2 mm
C. Sand	S-CSFS	Coarse sand, >0.180 mm. ACL Method S06
F. Sand	S-CSFS	Fine sand, <0.180 mm. ACL Method S06
Silt	S-CLAY	Silt, 0.002 to 0.02 mm. ACL Method S06.
Clay	S-CLAY	Clay, less than 0.002 mm. ACL Method S06.
pH (SS)	S-SSpH	pH on soil solution
EC (SS)	S-SSpH	Electrical Conductivity on soil solutions
P (PRI)	S-PRI	Phosphorus Retention Index ACL Method S15
P (HCO3)	S-BICP	Phosphorus P, extracted in 0.5 M NaHCO3 (1:100) ACL Method S12
K (HCO3)	S-BICK	Potassium K, extracted in 0.5M NaHCO3 (1:100) ACL Method S17.0
N (NH4)	S-KCLN	Ammonium nitrogen N, extracted in 1 M KCl. ACL Method S11.0
N (NO3)	S-KCLN	Nitrate nitrogen N, extracted in 1 M KCl. ACL Method S11.0
size (a)	S-SIZING	Particle sizing, 1.0 - 2.0 mm. ACL Method S07.
size (b)	S-SIZING	Particle sizing, 0.6 - 1.0 mm. ACL Method S07.
size (c)	S-SIZING	Particle sizing, 0.3 - 0.6 mm. ACL Method S07.
size (d)	S-SIZING	Particle sizing, 0.18 - 0.3 mm. ACL Method S07.
size (e)	S-SIZING	Particle sizing, 0.15 - 0.18 mm. ACL Method S07.
size (f)	S-SIZING	Particle sizing, 0.106-0.15 mm. ACL Method S07.
size (g)	S-SIZING	Particle sizing, 0.075-0.106 mm. ACL Method S07.
size (h)	S-SIZING	Particle sizing, 0.020-0.075 mm. ACL Method S07.

Where silt only is reported (eg sample 1.5), the value shown is actually for silt + clay.
The result for CaCO3 in sample 940656/015 is 80%.

N E Rothnie
Chief
Agricultural Chemistry Laboratory

21 November 1994

DEPARTMENT OF
MINERALS AND ENERGY
WESTERN AUSTRALIA

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Report on 1 sample of grass clippings from Coral Bay
received on 21-OCT-1994

1-NOV-1994

LAB NO	SAMPLE	N	P	K	Na	Ca	Mg	S
94A		%db	%db	%db	%db	%db	%db	%db
653001	WISE 1	2.79	0.22	1.64	2.18	2.33	0.26	1.03

N = Nitrogen,N
P = Phosphorus,P
K = Potassium,K
Na = Sodium,Na
Ca = Calcium,Ca
Mg = Magnesium,Mg
S = Sulphur,S
%db = per cent dry basis

The results apply only to samples as received.

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LAB NO	SAMPLE	Copper,Cu	Iron,Fe	Manganese,Mn	Zinc,Zn
94A		ppm	ppm	ppm	ppm
653001	WISE 1	38	530	71	55

ppm = parts per million dry basis
The results apply only to samples as received.

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Report on 1 sample of water from Coral Bay
received on 21-OCT-1994 18-NOV-1994

LAB NO	SAMPLE	pH (SS)	EC (SS)	N (NH4)-SS	N (NO3)-SS	Ca (SS)	Mg (SS)	Na (SS)
			mS/m	ppm#	ppm#	ppm#	ppm#	ppm#
94A 657001	1	7.5	890	5	1	81	18	1200

pH	(SS)	= pH on soil solution
EC	(SS)	= Electrical Conductivity of soil solution
N	(NH4)-SS	= Ammonium nitrogen N in soil solution
N	(NO3)-SS	= Nitrate nitrogen N in soil solution
Ca	(SS)	= Calcium in soil solution
Mg	(SS)	= Magnesium in soil solution
Na	(SS)	= Sodium in soil solution
ppm#		= parts per million as received
mS/m		= milliSiemens per metre

The results apply only to samples as received.

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W.A. 6005

Report on 1 sample of water from Coral Bay
received on 21-OCT-1994 18-NOV-1994

LAB NO	SAMPLE	K (SS)	S (SS)	P (SS)	Cu (SS)	Fe (SS)	Zn (SS)	Mn (SS)
94A 657001	1	36 ppm#	250 ppm#	<0.1 ppm#	<0.1 ppm#	<1.0 ppm#	<0.1 ppm#	<1.0 ppm#

K (SS) = Potassium in soil solution
S (SS) = Sulphur in soil solution
P (SS) = Phosphorus P, in soil solution
Cu (SS) = Copper in soil solution
Fe (SS) = Iron in soil solution
Zn (SS) = Zinc in soil solution
Mn (SS) = Manganese in soil solution
ppm# = parts per million as received
The results apply only to samples as received.

N.E.ROTHNIE
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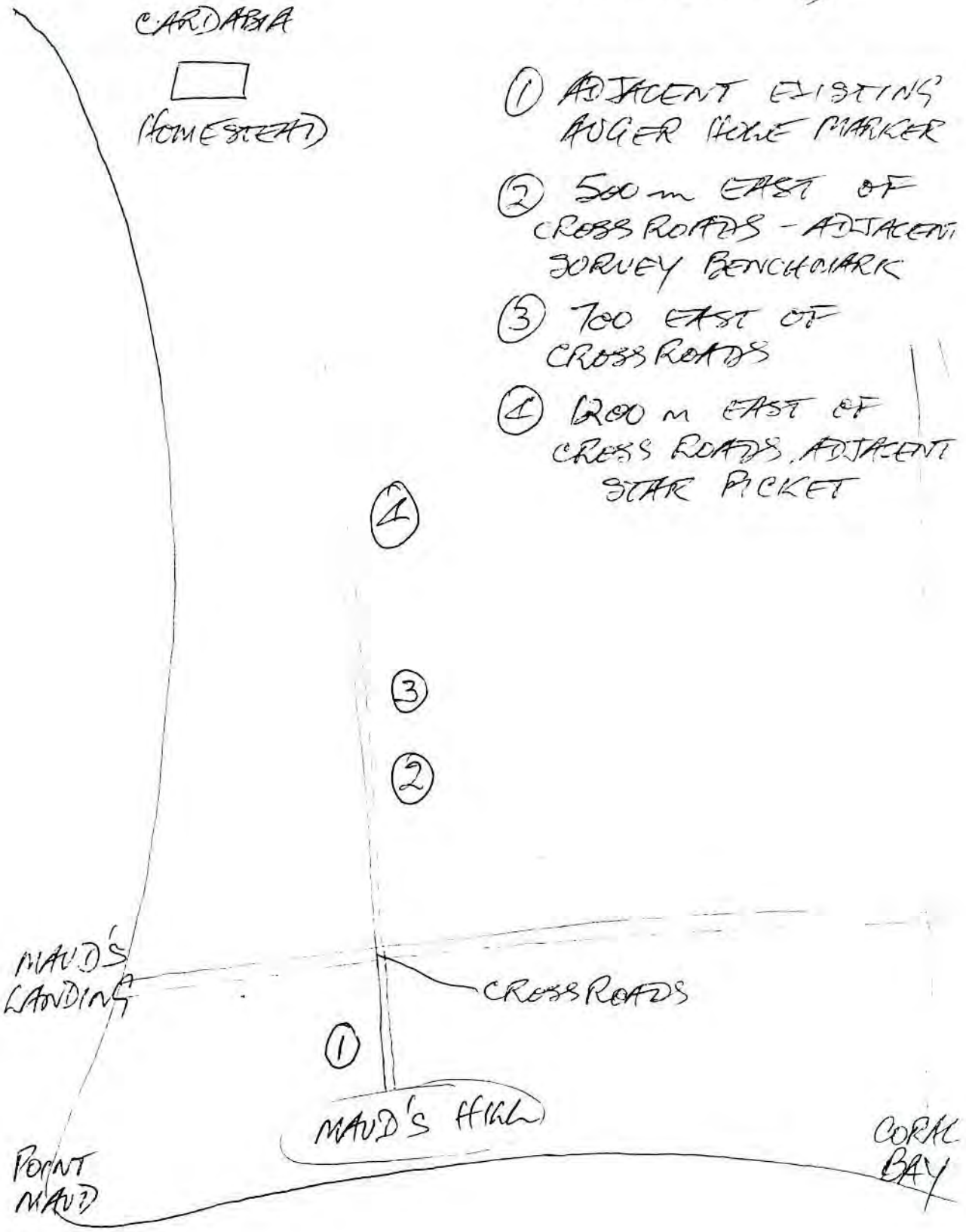
SKETCH MAP – SOIL SAMPLING LOCATIONS
14 OCTOBER 1994
(RC JEFFERY)



APPENDIX F

Options for Electrical Supply

Bassett Consulting Engineers, 1994

Bassett
CONSULTING ENGINEERS
MELBOURNE · SYDNEY · ADELAIDE · CANBERRA · PERTH · BRISBANE · TOWNSVILLE · ROCKHAMPTON

CORAL COAST MARINA RESORT
MAUDS LANDING
REPORT FOR PUBLIC ENVIRONMENTAL REVIEW 1994
ELECTRICAL SERVICES

MJH:LSN:1447A/2:RA
20 December 1994

GENERAL

Electricity supplies for the development will be provided by an electricity power generation facility located in the service area.

Electricity distribution throughout the development will be installed using underground cabling for low voltage and high voltage distribution.

Switchgear and transformers in residential areas will be located at ground level in kiosk pad mount style enclosures, similar to conventional metropolitan Perth residential sub-division systems.

Street lighting poles will be provided in residential areas to appropriate industry standard for enhanced road safety and security.

SUPPLY SYSTEM

A number of supply alternatives were examined for the development:-

- Aerial high voltage supply from Exmouth
  This option was discarded due to capital cost, environmental and supply reliability considerations.

- Natural gas/gas turbine generation
  This option was discarded due to the operational problems of running gas turbines on the anticipated load profile. For efficient operation a more consistent base load would be required.

- Diesel fuel generation
  This option is preferred and is consistent with normal practice for electricity generation in regional areas. Local generation will minimise distribution energy losses and permit load control energy conservation strategies to be implemented.

GENERATION PLANT

A preliminary analysis of the building and land development program has been carried out to determine requirements for electricity. It is expected that the anticipated demand growth rate for the development will be further examined during design development to ensure optimal sizing of the generation plant.

The generation plant is expected to initially comprise of 2 diesel generators supplying power via a high voltage distribution system. Additional machines will be added as required to suit the progressive load increases of the development. For supply reliability and maintenance one spare diesel generator is proposed, controlled by the load control system.

The generation plant will be serviced with diesel fuel oil. Above ground fuel storage tank(s) will be located at the generation facility. The design of the storage will be further analysed during design development.

COMMUNICATIONS

Communications infrastructure for the development will be provided by a carrier such as Telecom Australia or Optus. Telecom have reviewed the proposal and have confirmed that services can be provided to the townsite.

Services provided will include standard telecommunications telephone services linking to a small telephone exchange facility.

Telecommunications services utilising cable technology will be installed using underground pipes as for conventional metropolitan Perth residential sub-division systems.

TELEVISION

Methods of delivery of television services to the development will be further examined during design development. The developer is investigating use of a cable television infrastructure linking to all residential lots in the development.

If viable, the cable television service is expected to carry free to air broadcast television services to residential lots. The system will also cater for future cable pay television distribution to the development.

Regards,

M.J. HILL
PRINCIPAL
BASSETT CONSULTING ENGINEERS

APPENDIX G

Mauds Landing Coastal Engineering Study

M.P. Rogers and Associates, 1994

Coral Coast Marina Development Pty Ltd
December 1994

Coral Coast Resort
Mauds Landing
Coastal Engineering Study

M P ROGERS & ASSOCIATES PTY LTD
Report R006 Rev 0

Coral Coast Marina Development Pty Ltd
December 1994

Coral Coast Resort
Mauds Landing
Coastal Engineering Study

Job J123
Report R006 Rev 0

Prepared by: MPRogers Date: 16/12/94
Reviewed by: Date: 21/12/94.
Approved by: MPRogers Date: 21/12/94

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Contents

1. Introduction

Coral Coast Marina Development Pty Ltd (CCMD) has an agreement with the State of Western Australia for the proposed development of a new town at Mauds Landing in Bateman Bay, about 2 km north of Coral Bay. The site is about 200 km north of Carnarvon and 140 km south of Exmouth. The town site is wholly within the Shire of Carnarvon.

The proposed new town development is known as the Coral Coast Resort and will be an integrated residential and commercial development. When fully developed, it will include fully serviced residential lots, a caravan park, backpackers' hostel, country club, club resort, hotel, commercial centre, and a marina and golf course (refer to Figures 1.1 and 1.2).

As part of the planning and design process, CCMD has engaged M P Rogers & Associates Pty Ltd (MPRA) to examine the coastal engineering issues of:

* water quality in the marina,
* ocean storm surge and building levels,
* coastal stability and development set back, and
* marine structures.

This report outlines the investigations completed and the results of the study.

2. Meteorology and Oceanography

2.1 General Meteorology and Winds

The general circulation of the lower atmosphere over Australia is largely dominated by the position of the Subtropical High Pressure Belt and the migratory low pressure systems that exist on the poleward side of the high pressure belt. The high pressure belt is a series of discrete anticyclones (high pressure cells) which encircle the southern hemisphere at subtropical latitudes.

The high pressure cells are continuously moving, throughout the year, from west to east across the southern portion of Australia. A notional line joining the centres of these cells is known as the High Pressure Ridge, or the Subtropical Ridge, and is oriented predominantly in an east-west direction.

In the southern hemisphere, the winds circulate in an anti-clockwise direction about the centres of the high pressure cells. Consequently, on the northern side of the High Pressure Ridge the winds tend to be easterly, while on the southern side of the ridge the winds are predominantly westerly.

In winter, the ridge lies across the Australian continent at between 25°S to 30°S. In summer, the ridge is typically 35°S to 40°S. This seasonal change in the location of the High Pressure Ridge is responsible for the seasonal change in the wind patterns in the Carnarvon region.

In winter the ridge is located immediately south of the Mauds Landing area (23° 05'S) and the synoptic winds are generally easterly and southeasterly. Successive high pressure cells do little to disturb the direction of the wind, but can have a marked effect on the speed of the winds. The wind speed increases in response to an increasing pressure gradient, and decreases as the pressure gradient relaxes.

In the summer months, the High Pressure Ridge is well south of Mauds Landing and the Australian continent. Over the north of Australia, a zone of low pressure develops due to the considerable heating of the Earth's surface. This effect causes the direction of the winds to be predominantly west to southwesterly.

In addition to these synoptic scale effects, the mesoscale phenomenon of the diurnal sea/land breezes has an important influence on the local wind patterns in the region. The sea/land breeze system results from a marked atmospheric temperature difference that develops during the day between the land and the nearby sea. During the afternoon when the land becomes hotter than the ocean, the hot air over the land rises. This lowers the pressure and induces a replacement by the cooler air over the sea. This process (the sea-breeze) continues until the evening when the temperature difference decreases. The land-breeze results from early morning conditions when the sea temperature may be higher than the land temperature, in which case a reverse flow occurs.

Locally, the wind climate of the area primarily results from the superposition of the diurnal sea/land breezes over the prevailing synoptic winds. As a result, throughout the year the prevailing winds are generally from the south, with strong southerly sea-breezes occurring on approximately three quarters of the afternoons.

To date there have been no systematic wind measurements taken at Coral Bay or Mauds Landing. However, the Bureau of Meteorology has measured the wind speed and direction at the Carnarvon Airport since 1945. This data is believed to be reasonably representative of the winds experienced at Mauds Landing. Using this data, winter and summer wind roses were prepared for the morning and afternoon readings. These are shown in Figures 2.1 to 2.4. The winter roses show the dominance of easterly winds in the morning which shift to southerly in the afternoons. The wind speeds are typically between 6 and 16 knots.

The summer wind roses in Figure 2.3 and 2.4. show southerly winds in the mornings and southwesterly winds in the afternoons. The summer winds tend to be slightly stronger than in winter, and are usually between 11 and 21 knots.

2.2 Tropical Cyclones

The storm winds of high intensity in the area are associated with the passage of tropical cyclones, thunderstorms and pressure gradient intensifications. The most severe conditions are caused by tropical cyclones which occur between November and April. Steedman Science &

Engineering (1989) reports that 27 cyclones have passed within 200 km of Mauds Landing in the period from 1960 to 1986. This is approximately one cyclone per cyclone season.

The effects of any one cyclone depends upon the intensity of the central pressure deficit, the radius to maximum wind, and the actual track of the cyclone. Differences in these features between cyclones result in significant variations between the physical effects of each event (wind and wave conditions, storm surge, etc.).

Steedman Science & Engineering (1989) examined the severity of the 27 cyclones experienced between 1960 and 1986 and concluded that Tropical Cyclone Hazel, in March 1979 was very severe and had an approach track that would cause extreme wave conditions at Mauds Landing. It was assessed as being representative of the 100 year return period wave conditions.

The Standards Association of Australia Loading Code, Part 2 Wind Loads (AS1170.2-1989) shows the site to be in an area subject to severe tropical cyclones. This engineering design code recommends that structures should be designed using a basic regional wind gust speed for serviceability, Vs, equal to 50 m/s.

2.3 Tides and Storm Surges

The Department of Transport, Western Australia (DOT) has measured the tidal variations at Monck Head between 1990 and 1993. This site is only 5 km south of Mauds Landing and the tides are believed to be virtually identical for all practical purposes, (per. comm. Don Wallace, DOT).

The astronomical tides are semidiurnal (two cycles per day). DOT has established the following tidal levels.

* Highest Astronomical Tide (HAT) = 1.92 m Chart Datum (CD)
* Mean High Water Springs (MHWS) = 1.44 m CD
* Mean High Water Neaps (MHWN) = 1.21 m CD
* Mean Sea Level (MSL) = 0.99 m CD

* Australian Height Datum (AHD) = 0.86 m CD

* Mean Low Water Neaps (MLWN) = 0.80 m CD

* Mean Low Water Springs (MLWS) = 0.54 m CD

* Lowest Astronomical Tide (LAT) = 0.11 m CD

From this it can be seen that during spring tides the daily range is typically about 0.9 metres, and that during neap tides the daily range is about 0.4 metres.

Figure 2.5 has been prepared by DOT, and shows the percentage of time that various levels are exceeded (submerged). This figure also shows that during the measurement period, (less than three years), the highest water level recorded was 2.07 metres above Chart Datum which is about 1.2 metres above AHD. The lowest recorded water level was 0.01 metres above Chart Datum which is about 0.85 metres below AHD.

In addition to the astronomical tide, tropical cyclone storm conditions can cause significant increases in the ocean water level through the combined effects of low atmospheric pressure, strong onshore winds and large waves breaking nearshore. This increase in the water level is known as storm surge.

Steedman Science & Engineering (1989) used various techniques to examine the storm surges in the region. This work concluded that tidal residuals from 20 years (mid 1966 to mid 1986) of record from the Carnarvon tide gauge provide the best guide to storm surge at Coral Bay and Mauds Landing. The 100 year return period storm surge at Carnarvon was estimated by extreme analysis to be 1.65 metres. Other calculations suggest that the storm surge at Coral Bay and Mauds Landing could be slightly more severe than at Carnarvon because of the nearshore reef system and the effects of wave induced set-up. It was reckoned that the storm surge at Mauds Landing may be roughly 15% higher than that at Carnarvon. Using this factor, it is estimated that the 100 year return period storm surge at Mauds Landing would be about 1.9 metres.

2.4 Current Regime

Measurements reported in Hearn & Parker (1988) indicate that in Osprey Bay, about 120 km further north of Mauds Landing on the Ningaloo Reef, the lagoon has a flushing time of less than 24 hours. The action of waves breaking onto the reef was shown to cause significant transfer of ocean water across the reef and then drive the currents along the lagoon to the north. In this location the wave-driven current is strongly modulated by tidal changes in water level.

Bateman Bay is generally wider and more shallow than Osprey Bay. This will tend to reduce the relative importance of the wave-driven transport across the reef in the nearshore currents. Currents in Bateman Bay are believed to be controlled by the relative magnitude of the wind, tide and wave forcing.

The surface currents in the nearshore lagoon of Bateman Bay have been measured by a brief drogue tracking exercise carried out during flood and ebb spring tides. During the drogue tracking exercise the winds varied from 10 to 15 knots from the southwest. Drogues release near the proposed marina entrance during an ebb tide, travelled at about 0.1 m/s directly downwind. The drogues released from the same location during the flood tide and southwesterly winds showed little movement during the tracking exercise.

The largest currents in the southern portion of Bateman Bay are believed to be caused by the persistent and strong southerly winds and the mass transport of water over the Ningaloo Reef caused by wave breaking onto the shallow reefs. It is estimated that mild currents would often be present in Bills Bay (see Figure 1.1) and the southern portion of Bateman Bay. They would be primarily driven by wave and wind forcing and modulated by tidal action.

Typically the currents would be in the order of 0.1 to 0.2 m/s. Some of the water would flow out of the reef gaps in Bills Bay and the rest would continue north into Bateman Bay. It is reasonable to expect a localised increase in the current speed through the narrow channel near Point Maud. Rough estimates indicate that in this narrow channel, the currents may reach 0.5 m/s.

The above estimate of the current regime would mean that Bills Bay is regularly flushed with new ocean water, and water from the northern portions of Bills Bay would flow north into the southern portion of Bateman Bay, and then out to sea through Cardabia Passage (see Figure 2.6).

2.5 Wave Climate

No detailed directional wave measurements have been collected near the site. The most relevant data are the visual estimates of wave height, period and direction taken from ships passing through the ocean to the west of Point Maud. These are reported in the US Navy Marine Climate Atlas (1976). Naturally, ships try to avoid storm areas, especially severe tropical cyclones, so the data have a bias that tends to underestimate the severe storm wave conditions.

The most applicable data is for Site 26, which covers a large area of the ocean about 400 nautical miles to the west of Point Maud. The data for this site has been aggregated into frequency of occurrence tables of wave height versus wave direction for the four seasons. These are included on Figure 2.7. These visual estimates of the offshore wave conditions are in accord with the non-directional, wave measurements taken by the Department of Transport in 1988 offshore from Tantabiddi Creek, about 120 km north of Bateman Bay.

As site 26 covers an area hundreds of kilometres from the shore, waves can approach from any direction. Only the wave directions from north through west to south are relevant to the conditions at Mauds Landing.

Although this data is very limited and based on visual estimates they do indicate that the offshore waves mainly come from the south during summer and the heights are typically 1 to 2 metres. During winter the direction shifts to southwest and the heights increase slightly to be generally between 2 and 3 metres.

These waves from the south and southwest are believed to include a significant proportion of long period (10 to 16 seconds) swell waves. These waves are generated by distant and severe storms in the southern Indian Ocean.

In addition to the background swell, the sea-breeze winds would generate short, steep sea waves. These would have heights between 1 and 2 metres, and because of fetch limitation the periods would be expected to be roughly 4 to 6 seconds.

A third class of waves in the offshore area would be the extreme waves generated by tropical cyclones as they travel through the area.

Steedman Science & Engineering (1989) completed numerical modelling of the waves generated by Tropical Cyclone Hazel. This storm was reckoned to create wave conditions representative of the 100 year return period condition for the Mauds Landing site. These were estimated to be significant wave heights of more than 6.2 metres immediately outside the reef-line and 3.7 metres in 7 metres of water near Mauds Landing.

This illustrates the effect of the reef-line in attenuating waves as they travel from the deep offshore waters towards the shore at Mauds Landing. The principal physical mechanisms include:

* refraction, by varying bathymetry;

* diffraction through reef gaps;

* breaking on to reefs and in shallow water;

* reflection from submerged reef faces, and

* dissipation due to turbulence in the bottom boundary layer.

The reef-line also provides significant protection from the more usual wave conditions of southerly swell and sea-breeze seas. The 1 to 4 metre southerly swells would be refracted to the west-southwest and travel through the gap in the reef known as Cardabia Passage where they would be further refracted by the bathymetry in Bateman Bay and reach the shore with crests almost parallel to the shore. They would break near the shore having been reduced generally to 0.5 to 1 metres in height.

Because this beach is a north facing beach, the southerly sea-breeze seas would have little effect in Bateman Bay.

3. Climate Change

Although the so called "Greenhouse Effects" receive much publicity there is still no definitive evidence available that proves that the Greenhouse changes are occurring or will occur. There is certainly clear evidence that the amount of Carbon Dioxide and other "Greenhouse Gases" has increased dramatically over the last century and is continuing to rise. However, the link to global warming and associated sea level rise is still largely based on predictive numerical models of the global atmospheric and oceanic processes. These general circulation models are currently run on coarse grids and have rather rudimentary treatment of ice melting, cloud over and albedo feed back links and impacts. Pielke (1991) presents a good review of the scientific uncertainty with the present predictions of "Greenhouse Effects".

Some of the possible impacts on the southwest coast of Western Australia of Greenhouse Gas Warming could be:

* increase in cyclone frequency;

* increase in sea level; and

* change in position of synoptic features causing a changed wave climate.

The current knowledge about such possible changes is extremely limited. This coupled with the uncertainty about global warming, has lead many organisations and authorities to take a low key approach to the issue until more definitive proof is available.

The Institution of Engineers, Australia (1991) put forward suggestions for assessing the impacts of possible climate change on coastal engineering projects. The report is aimed at ensuring that a responsible review of the possible impacts is made. Designs should be robust and minimise future risk. This document does not say that climate change will happen but merely it may happen and therefore engineering design should take this risk into consideration.

The issue of possible climate change and resultant effects on coastal processes is quite complex. Unfortunately, the present knowledge concerning possible effects on the coast of Western Australia is somewhat limited. Given this, only a relatively simple assessment of the possible changes can be made. The impacts of the possible increase in sea level are considered in this study.

The Institution of Engineers, Australia (1991) presents three scenarios for possible (not necessarily probable) changes in the Global Mean Sea Level. These are reproduced in Table 3.1.

Table 3.1 Possible Global Sea Level Rise (metres)

Year	2030	2050	2100
Low Scenario	0.10	0.16	0.32
Medium Scenario	0.20	0.32	0.68
High Scenario	0.32	0.51	1.13

Notes 1. Source: Institution of Engineers Australia (1991).

Considering the uncertainty of these scenarios, the design of life of foreshore facilities and the frequency of storm attack, it is appropriate at this stage to allow for a 0.2 to 0.3 metres rise in sea level. This is believed to be a reasonable compromise between present day cost and inconvenience, and future risk.

The impacts on coastal processes of a small rise in sea level would be quite site specific. To date, there have been no specific studies done for the coast of Western Australia. The most relevant works are in Bruun, (1962) which presents the results of some generalised work and Gordon, (1988) which presents some of the results of research on the New South Wales coast. In very coarse and general terms, both papers suggest that a rise in sea level would generally lead to recession of the coastline at a ratio of roughly 100 to 1. That is, a 0.2 metre rise in sea level may eventually cause a 20 metre recession of the coastline.

This tendency for shoreline recession could be offset by other local effects. For example, in Bateman Bay the southern beaches are presently generally accreting at rates between 0.3 and 0.9 m/year (refer Section 6.3). Consequently, it is reasonable to anticipate that in Bateman Bay, a rise in sea level of 0.2 to 0.3 metres over the next 50 to 100 years would not necessarily cause a nett recession of the shoreline but merely decrease the rate of advance.

In view of these factors, it is believed that if climate change does occur in the next 50 to 100 years, the effects on the beaches in the southern portion of Bateman Bay are likely to be minor and manageable.

4. Water Quality in the Marina

4.1 General

The intended uses of the Marina and associated waterways are:

* direct contact recreation (eg. swimming and fishing);
* boating;
* adjacent residential development; and
* passive recreation (eg. enjoying the scenery).

The Department of Conservation & Environment (1981) put forward various categories of beneficial use for marine and estuarine waters in Western Australia. The above falls in the category titled "Beneficial Use No. 1 - Direct Contact Recreation). A copy of the Marine and Estuarine Water Quality Criteria for Direct Contact Recreation is included in Appendix A. The marina and associated waterways will be designed and managed to meet these requirements for Direct Contact Recreation.

The resultant water quality in the marina and associated waterways is dependent upon the following:

* the quality of the source water;
* the management of nutrient and pollutant inflow; and
* the mixing and exchange processes.

4.2 Source Water

The source water for the marina and associated waterways will be the ocean water of the southern portion of Bateman Bay. As outlined in Section 2.4 above, this area is flushed by tidal and wind driven currents and the influx of ocean water caused by waves breaking on the nearby Ningaloo Reef. These persistent flushing mechanisms will ensure that the source water is clean and clear ocean water. The only possible source of pollution would be from the flow of nutrient rich ground water from the sewerage ponds that service Coral Bay. The extent of such pollution is presently unknown, but with the development of the Coral Coast Resort,

the existing settlement at Coral Bay will be able to be connected to a comprehensive, reticulated sewerage system. This would remove the need for the sewerage ponds and remove this potential source of nutrients flowing into Bills Bay.

4.3 Management of Nutrient and Pollutant Inflow

The influx of nutrients and pollutants into the Marina and associated waterways will be minimised by careful design and management of the water bodies.

The design elements include the following:

* The development will be serviced with a reticulated sewerage system.

* A sewage pumpout facility will be available in the Marina.

* All storm water run off from the roads will be collected and piped to soakage areas incorporated in the golf course to the east of the Marina.

The ongoing management of nutrient and pollutant inputs will include the following:

* Rubbish disposal and effluent discharge into the marina and associated waterways will be banned and policed by the waterways manager.

* The use of plant species that require minimal watering and fertilising will be encouraged.

* The use of tributyl tin oxide antifoulants on boats is prohibited under State Law.

* The golf course will be strictly managed to ensure minimal flow of nutrients into the waters of the Marina and associated waterways.

4.4 Water Mixing and Exchange

The water bodies of the marina and waterways will be mixed by winds, waves, advecting currents and boat traffic. All of these mechanisms will ensure that the water bodies are regularly mixed.

There are several physical processes that cause water exchange between harbours and the adjacent source waters. These include:

* density currents;
* inflow of ground water;
* astronomical tidal fluctuations; and
* wind induced currents.

The density of the marina water is expected to be almost identical to that of the source water in Bateman Bay. Consequently, there will be little or no density gradients between the marina and the bay that could set up density driven currents. Although density driven currents are important elsewhere, they will not be a significant mechanism in the water exchange at Coral Coast Resort.

Rockwater (1994) predicts the ground water flow into the marina to be very small with very low levels of nutrients. In view of the small magnitude of the groundwater inflow, this is not expected to be a means of significant water exchange with the source water.

The most important water exchange mechanisms will be wind induced currents and the astronomical tidal fluctuations. These are discussed below.

4.4.1 Astronomical Tidal Fluctuations

As outline in Section 2.3, the astronomical tides in Bateman Bay are semidiurnal (two cycles per day) with the typical spring and neap ranges being 0.9 and 0.4 metres respectively.

The tidal prism ration (TPR) is defined as the ratio of the volume of tidal flow entering the waterway from low to high tide to the total volume of water in the marina and waterways. This gives a measure of the potential for tidal flushing For the proposed development the TPR has been calculated to be about 25% for a 0.9 metre tidal range (spring tides) and about 10% for a 0.4 metre tidal range (neap tides).

Falconer (1980) indicates that under some conditions not all of the incoming source water will mix with the water in the marina and associated waterways. The geometry can have a significant effect on the efficiency of mixing and exchange. Falconer (1980) defines an exchange coefficient as the product of the TPR and an efficiency coefficient to account for these effects.

Exchange Coefficient = Tidal Prism Ratio x Efficiency Coefficient.

Based on the work by Falconer et al (1976) these "efficiency coefficients" (see Table 4.1) were estimated for the various parts of the marina and associated waterways. These factors have then been multiplied by the above tidal prism ratios to obtain an estimate of the effective water exchange and flushing caused by the spring and neap tides.

Table 4.1 Estimated Tidal Exchange

Location	Estimated "Efficiency Coefficient"	Estimated Tidal Exchange Springs	Neaps
1. Marina	0.7	18%	7%
2. Coral Garden	0.4	10%	4%
3. Eastern Swimming Beach	0.4	10%	4%
4. Southwestern Waterway	<0.05	<1%	<0.5%

Note 1. The estimates of tidal exchange are for one tidal cycle. There are two tidal cycles each day.

These estimates indicate that the Marina, Coral Garden and Eastern Swimming Beach will all be well flushed by the action of the astronomical tides. The Southwestern Waterway, which extends up to 800 metres from the Marina, will not be well flushed by the action of the astronomical tides.

4.4.2 Wind Induced Currents

Winds blowing over closed-end waterways are known to create water motions that are important for water mixing and exchange. McKeehan (1975) specifically studied the effects of wind on water motion in man-made waterways. This work included a theoretical approach as well as presenting extensive measurements taken in existing residential canal estates. This study shows that wind blowing over a closed-end waterway causes:

* a slope of the water surface, raising the level at the down-wind end of the waterway; and
* surface water movement in the down-wind direction, and an opposite motion in the bottom layer.

These features are shown on Figure 4.1. The expression for the water velocity as a function of depth and surface velocity was given as:

$$U(z) = Us\,(1 - 4(z/h) + 3(z/h)^2)$$

where $U(z)$ = water velocity at depth z,
Us = water velocity at the surface,
z = distance below the surface, and
h = the total depth of water.

The water flow at the surface is usually taken to be in the range of 2 to 5% of the wind speed, refer to Wu (1973), Bishop (1979), and McKeehan (1975). The above suggests that the water speed decreases rapidly with depth and reaches zero at about one-third of the total depth. Underneath this level, there is a reverse flow to ensure a conservation of mass.

As outlined in Section 2.1, there are strong sea-breezes at Mauds Landing during most afternoons. The speed is typically about 10 knots (20 kph) or more. The Southwestern Waterway has been aligned to take full benefit of these persistent winds. Local topography and the layout of the buildings along the waterway will funnel the southerly and southwesterly winds along this waterway and cause strong wind induced currents and associated water exchange.

These commonly occurring southerly winds will be an important mechanism in the flushing of the Southwestern Waterway. Using the methods outlined in McKeehan (1975) it was calculated that a southwesterly wind of 20 kph would cause the top one-third of the water column to move at an average rate of 0.08 m/s. This would be accompanied by a return flow of equal volume in the bottom two-thirds of the water column. As this waterway is about 800 m long, it would take about two to three hours for the top one-third of the water column to travel the length of the waterway. This will result in exchange of about one-third of the volume of the waterway with the Marina water. As the sea-breezes often last up to 6 hours, these events would cause significant exchange between the waterway and the Marina.

4.5 Resultant Water Quality

As outline in the previous sections, the Marina and associated waterways have been designed and will be managed to achieve minimal inflow of nutrients and pollutants. Of the possible sources of nutrients and pollutants, the most significant will be from the antifoulant treatment on boats moored in the development, and accident situations which may release oil and fuel.

It was estimated that the typical boat moored in the Marina would release about 0.5 to 1.0 g/day of copper from its antifoulant treatment. It is planned to initially have 100 boat pens increasing with demand to a maximum of about 200 pens. When fully developed, and assuming the unlikely event of 100% occupancy, the boats in the Marina would release about 200 g/day of copper into the marina water body. With the strong and persistent flushing outlined in Section 4.4, it was calculated that the resultant concentration of copper in the marina water would be about 1 to 3 µg/L. This is well within acceptable limits.

The proponent intends to establish a comprehensive oil spill response plan to minimise any impacts from any accidental spills in the marina. A key element of this, will be the rapid deployment of floating oil barriers across the marina entrance channel. This will prevent the spill moving out into Bateman Bay and onto the adjacent Ningaloo Reef.

Skimmers and oil dispersants would then be deployed to remove and treat the spilt oil.

5. Building Levels

In assessing the minimum finished floor levels for buildings in Coral Coast Resort, various physical processes and the design of the development must be considered. The physical processes are:

* astronomical tides;

* severe ocean storm surge;

* possible 'Greenhouse' induced Climate Change; and

* wave run-up.

The design of the development incorporates a built-up area around the Marina and associated waterways, and connecting back into the high coastal dunes. This built-up area will provide protection from the full effects of severe ocean storm surge to the development behind it. Consequently, in the proposed development, the buildings can be categorised into three distinct classes of exposure to ocean storm surge flooding.

* Buildings on coastal dunes;

* Marina and waterway buildings; and

* Buildings behind the built-up coastal area.

The first category covers the buildings along the coastal dunes. The waves in Bateman Bay during the severe storm attack are quite significant and will cause appreciable run up on the beaches. The following is an assessment of the minimum finished floor levels for these buildings on the coastal dunes.

Buildings on Coastal Dunes

Astronomical tide = MSL	+ 0.1 m AHD
Climate change allowance	+ 0.3 m
100 year return period storm surge	+ 1.9 m
Wave run-up	+ 1.5 m
Freeboard	+ 0.4 m
Recommended minimum finished floor level	+ 4.2 m AHD

The second category covers buildings behind the coastal dunes and around the marina and associated waterways. Here, the waves during the severe storm will be greatly reduced by the protection of the marina breakwaters, and therefore wave run-up effects would be negligible. The following is an assessment of the minimum finished floor levels for these buildings around the marina.

Marina and Waterway Buildings

Astronomical tide = MSL	+ 0.1 m AHD
Climate change allowance	+ 0.3 m
100 year return period storm surge	+ 1.9 m
Freeboard	+ 0.4 m
Recommended minimum finished floor level	+ 2.7 m AHD

The built-up area around the Marina and associated waterway should also be + 2.7 metres AHD at its lowest point. This will provide a protective barrier against ocean storm surge to the development behind it.

The development behind the built-up area is protected from the full influence of ocean storm surge, but must be able to accommodate the rainfall runoff generated in infrequent but torrential downpours. This aspect is covered in the work completed by Ewing Consulting Engineers (refer Ewing Consulting Engineers, 1994).

6. Coastal Processes and Shoreline Stability

6.1 General

The coastal geomorphology is briefly described by the Department of Planning and Urban Development (DPUD) (1991). Figure 6.1 has been taken from that report and shows that there are parabolic dunes to the southeast of Point Maud. The active parabolic dune extending north in line with the prevailing southerly winds is also shown. Recent foredunes have formed at Point Maud and on the coast northeast of the old jetty known as Mauds Landing. These more northern foredunes are back by a relic foredune plain.

The background current regime in the southern portion of Bateman Bay is generally mild and is believed to play only a minor role in the beach dynamics of this area. Wave induced processes are believed to be dominant in the active coastal processes of the beaches in the southern portion of Bateman Bay. These can be categorised as longshore drift and cross shore movement.

6.2 Longshore Drift

The transport of sand along the coast is one of the fundamental mechanisms in beach dynamics. A simplistic description of this mechanism is that in the surf zone of sandy beaches, the breaking waves agitate the sand and place it in suspension. If the waves are approaching at an angle to the beach, then a longshore current can form and this can transport the suspended sand along the beach. This suspended load is accompanied by bed-load transport where sand is rolled over the bed by the shear of the water motion.

As described in Section 2.5, the prevailing waves in Bateman Bay are refracted swell waves that pass through Cardabia Passage. In order to assess the influence of these refracted swell waves, a refraction / diffraction analysis was completed for swell waves approaching the Ningaloo Reef fringing the southern portion of Bateman Bay. This analysis indicated that the southwest swell is refracted significantly and approaches the shore with wave crests virtually parallel to the beach. This means that the angle of approach would be close to zero and there would be little longshore sand transport along the beach.

In the portion of beach 0.5 to 5 km northeast of Point Maud, beach cusps were observed during the August 1994 site visit and can be seen on a variety of aerial photographs. These beach cusps were about 1 metre from crest to trough and have wave lengths in the range of 30 to 50 metres.

When low swell waves approach beaches with steep slopes and the wave crests are parallel to the shore, sub-harmonic edge waves can form. The calculated response to low amplitude swell waves with periods between 10 and 14 seconds is sub-harmonic edge waves with wavelengths ranging from 25 metres to 50 metres. This fits very well with observed conditions of swell period and beach cusp wavelength. The period of the incident swell waves typically varies in the range of 10 to 14 seconds. As the period changes, the wavelength of the edge wave and beach cusps will also change from 25 metres to 50 metres. This will result in the reworking of the beach sands to form the new cusp formation. This reworking will keep the crests of the beach cusps loosely packed and boggy.

The presence of the edge waves is a good indicator that the prevailing swell waves are arriving at the shore with wave crests parallel to the shore. In turn, this means that the prevailing swell waves that enter Bateman Bay through Cardabia Passage would cause little longshore transport along beaches of the southern portion of Bateman Bay.

In section 2.5, it was also outlined that the common southerly breezes would be blowing offshore from the north facing beaches of the southern portion of Bateman Bay. Consequently, these winds would have little influence on the waves that approach the beaches near the proposed development.

Port and Harbour Consultants (1989) examined the issue of longshore sediment transport in Bateman Bay during extreme cyclone events. Numerical modelling was used to assess the amount of longshore sediment transport during Tropical Cyclone Hazel. This storm was assessed by Steedman Science & Engineering (1989) as being representative of the 100 year return period wave conditions.

This analysis indicated that sediment transport during the cyclone storm conditions is generated in a southerly direction along the Maud Townsite coastline. The calculated sand transport decreases from a maximum of about 30,000 m^3 at the northern extremity of the sandy shore, to a negligible amount at Point Maud.

At the marina entrance site, the sediment transport potential in a southerly direction across the entrance was calculated to be about 10,000 m^3 during Tropical Cyclone Hazel. Further south at the western extremity of Point Maud the calculated longshore sediment transport was close to zero.

The above work indicates that during the very common conditions of southerly swells and local winds, the longshore sediment transport is reckoned to be very small. The extreme cyclone storms would create conditions that would transport sand in a southerly direction along the sandy shore of Bateman Bay towards Point Maud. At the proposed marina entrance the calculated transport was about 10,000 m^3 during an extreme cyclone, such as Tropical Cyclone Hazel.

This episodic movement of sand along the beach during rare storms can readily be accommodated by the proposed breakwaters that form the marina entrance.

6.3 Cross Shore Transport

Wave action can cause sediment to be moved onshore or offshore depending upon the wave characteristics and ocean water levels.

Long, low swell waves tend to move sand from the nearshore area onto the beach. The measured beach profiles in the southern portion of Bateman Bay are in line with swell build profile slopes. Onshore movement of sand from the fringing reef and the bay area is likely to be the main feed mechanisms for these sandy beaches.

During storm conditions, the strong winds generate high steep waves. The associated storm surge raises the ocean water level and permits the waves to attack the high portions of the beach. Initially during the storm, the width of the surf zone is not sufficient to dissipate increased energy in the storm waves. The surplus energy is spent in eroding the beach, foredune, and sometimes the primary dunes. The eroded sand is carried offshore and is deposited to form an offshore bar. Eventually this bar may grow large enough to cause the storm waves to break further offshore and spend most of their energy in the surf zone such that no further erosion takes place. This action is described in the Shore Protection Manual (US Army Corps of Engineers, 1984) and is shown diagrammatically in Figure 6.2.

Swart (1976) put forward a technique for calculating the amount of offshore transport during storm events. This method was used to assess the storm profile and the amount of coastal recession that would occur during a very severe storm. The storm conditions used were those calculated for Tropical Cyclone Hazel.

Figure 6.3 shows the calculated erosion during this rare and extreme storm. The calculated erosion extends 70 metres from the present water line at mean sea level. In total, about 50 metres of vegetated coastal dune would be eroded during this extreme storm.

6.4 Shoreline Movement Plan

Using aerial photographs taken in 1949 and 1981, the longer term trends of shoreline stability were examined. Controlled photogrammetry was used to plot the vegetation line along the shore of the southern portion of Bateman Bay from both photographs. The shoreline movement plan, Figure 6.4, indicates that from Mauds Landing to about 1.8 km northeast, the shore has advanced over the 32 years between photographs. This accretion varies between 5 and 65 metres, and represents rates of between 0.1 and 2 m/year. Most of this section of coast has advanced between 10 and 30 metres over the period between photographs which are rates between 0.3 and 0.9 m/year.

For the first 300 metres to the southwest of Mauds Landing the coast has also advanced at comparable rates. Closer to Point Maud the coast has generally shown little change, although, there are a few areas of recession. These are believed to result from mobile dune sand covering the foredune vegetation in the later photograph.

The shoreline movement plots also show that the tip of Point Maud itself has advanced seaward about 80 metres between 1949 and 1981. This is a rate of about 2.5m/year.

6.5 Shoreline Stability and Recommended Set-back

The above work on coastal stability indicates that the southern shores of Bateman Bay are quite stable. In recent decades, there has been a trend of mild accretion of this coast.

The largest movements of sand are believed to occur under the action of severe tropical cyclones. In the work completed by Port & Harbour Consultants (1989) the longshore transport during an extreme cyclone was examined. This analysis indicated that during a very severe cyclone, there was significant transport of sand along the sandy beaches in the southern portion of Bateman Bay. The calculated sand transport was to the south toward Point Maud and varied from about 30,000 m^3 opposite Cardabia Passage to about 10,000 m^3 at the proposed Marina site to a negligible amount at Point Maud.

The cross shore transport during such a storm would also be significant. Calculations of the storm erosion during a very rare cyclone event were estimated to cause erosion of up to 50 metres from the present vegetation line. In the months and years that follow such an extreme storm, the persistent, low amplitude, background swell would bring some of this eroded sand back onshore and naturally build up the beach.

In order to allow for possible inaccuracies in these coastal engineering calculations, gradients in the longshore drift, and to provide an appropriate buffer as a factor of safety, it is recommended that the development line be set-back at least 100 metres from the present vegetation line on the coastal dunes. The set-back north of the Marina breakwaters should be between 120 and130 metres to ensure that the buildings in the development are located on the relic foredune plain shown in Figure 6.1.

7. Marine Structures

7.1 Assessment of Demand

The development of the Coral Coast Resort involves the provision of suitable infrastructure. As the Ningaloo Reef will be a significant attraction to the development, it is appropriate that a variety of marine related facilities be provided. In planning for these facilities, an assessment of the likely numbers and sizes of the boats is needed.

By law, all boats with motors must be registered with Department of Transport (DOT). In November 1994, the DOT records show the 'current' registrations at about 52,000. Undoubtedly, there would be a small number of boat owners that disregard the law and do not register their boats. In addition, there are numerous small sailing boats that do not have motor power and are not required to be registered. Nevertheless, the 'current' registration figures do provide a reasonable basis for assessing the likely demand at the Coral Coast Resort. Table 7.1 has been compiled using the 'current' boat registration statistics kept by DOT and the estimates of population from the Australian Bureau of Statistics. The data has been compiled for the state, Exmouth, Mandurah and Busselton.

Table 7.1 Boat Ownership Statistics

Location	Number of Boats	Estimated Population	Boats per 1,000 People
Western Australia	52,000	1,695,700	30.7
Shire of Exmouth	199	2,334	85.3
City of Mandurah	3,415	34,202	99.8
Shire of Busselton	1,133	16,333	69.3

In an analysis of the boating numbers and sizes throughout the state, PA Australia (1981) concluded that about 80% of the boats in WA are on trailers and about 75% of all boats are kept at home.

Using the available data, and making a few simplifying assumptions, an assessment was made of the boat numbers that would be likely in Coral Coast Resort when fully developed. The results are shown in Table 7.2 below.

Table 7.2 Assessment of Boat Numbers

Item	Boats on Trailers	Boats in Pens	Total Boats
1,100 Residential Units	343	64	407
Caravan Parks	50	0	50
Commercial Operators	50	20	70
CALM & Dept of Fisheries	3	2	7
Totals for Resort	446	86	532

As the projected population of the resort is about 5,000 when fully developed, the 532 boats would represent about 106 boats per 1,000 people. This is about 25% higher than the figure for Exmouth and 7% higher than the figure for Mandurah in Table 7.1 above. The projected number of boats per 1,000 people is over three times the average for the state.

In order to cater for this number of boats, it was assessed that the following marine infrastructure would be needed for the ultimate development.

* 4 lanes of boat launching ramps with associated trailer parking.
* 100 to 200 boat pens in the marina and associated waterways.
* 100m of public jetties for general use.
* 1 refuelling jetty with appropriate safety measures.

As the boat number would increase progressively with the development, the provision of the marine infrastructure should be staged to suit the demand. An approximate analysis suggests that the actual number of boats in use on any one day would typically be in the range of 150 to 250 boats.

7.2 Marina Entrance Breakwaters

The breakwaters that define the entrance to the Marina, have been designed to provide suitable protection to the Marina and associated waterways during severe storms. The layout is shown on Figure 1.2 and

the breakwaters will prevent the incoming waves from penetrating into the Marina. A preliminary diffraction analysis of the entrance configuration indicates that during the 100 year return cyclone, the significant wave height at the Marina pens would be about 0.8 metres.

The construction of the breakwaters must be able to withstand the force of tropical cyclone storms. Port & Harbour Consultants (1989) completed a preliminary design of the breakwater cross sections. These are shown on Figure 7.1. The breakwaters will be conventional rubble mound breakwaters with two layers of large amount stone protecting a core of smaller mixed rock.

The adopted preliminary design utilises 5 to 9 tonnes armour stone and corestone that could be run of quarry rock. This method is economic because it will utilise the produce of nearby quarries in Trealla Limestone. All fractions of the quarry rock can be used in the proposed breakwater design, thereby minimising any need for over quarrying.

Although the final choice of quarry has not been made, the existing quarries within 70 km of Coral Bay are the most attractive sources of rock for the breakwaters. Figure 7.2 shows the rock face of one of the existing quarries that would be suitable for the breakwater construction work.

The quarried rock would be transported to site on private and public roads at a rate of up to 1500 tonnes per day. This will involve about 6 to 8 trucks completing a total of about 35 round trips per day. The construction of the breakwaters will take about 6 months to complete.

7.3 Edge Walling and Internal Beaches

The boundary between the land and the water of the Marina and associated waterway, will be either a simple rock revetment or a sandy beach to suit swimming. Preliminary designs for these edge treatments have been completed as part of the planning studies. The simple rock revetment is shown on Figure 7.3 and the proposed sections for the internal beaches are shown on Figures 7.4 and 7.5.

Both of these edge treatments have been used in many other developments throughout the state over the last few decades. They use locally available materials and provide an effective and economical edge to the water areas.

8. Summary and Recommendations

The oceanographic conditions vary markedly from the open ocean to the sheltered conditions behind the Ningaloo Reef. The position and extent of the reef provides substantial protection to the southern portion of Bateman Bay. The most severe conditions will occur during the passage of Tropical Cyclones. The 100 year return period storm surge is estimated to be about 1.9 metres above the astronomical tide. The wave conditions during an extreme cyclone with a similar return period are estimated to reach significant wave heights of about 6.2 metres outside the reef and about 3.7 metres in 7 metres of water near the proposed Marina entrance.

The waters of Bateman Bay would be regularly flushed by the wind, tide and wave forced currents. Because of the wave-driven water transfer across the Ningaloo Reef and tidal flows through the reef gaps the nearshore water will be regularly mixed and exchanged with new ocean water. Except for the possible influx of pollutants and nutrients from the waters of Bills Bay, the water in Bateman Bay should be virtually identical in composition to that of the near by ocean.

The Marina and associated waterways have been designed and will be managed to ensure that there will be minimal inflow of pollutants and nutrients. There will be strong and persistent mixing and exchange of the new water bodies through the action of tidal currents and wind induced currents. The resultant water quality in the Marina and associated waterways will be better than the requirements for the intended use of direct contact recreation.

The 100 year return period storm surge was estimated to be 1.9 metres. Based on this, and accounting for the astrological tide, wave run-up during the cyclone, and making an allowance for the possible increase in mean sea level due to possible climate change, the minimum finished floor levels were recommended to be 4.2 metres above AHD for the buildings behind the coastal foredunes on Bateman Bay and 2.7 metres above AHD for the buildings around the Marina and associated waterways.

The work on coastal stability indicates that the southern shores of Bateman Bay are quite stable. In recent decades, there has been a trend of mild accretion of this coast.

The largest movements of sand are believed to occur under the action of severe tropical cyclones. An analysis indicated that during a very severe cyclone, there would be significant transport of sand along the sandy

beaches in the southern portion of Bateman Bay. The calculated sand transport for the 100 year cyclone was to the south toward Point Maud and varied from about 30,000 m^3 opposite Cardabia Passage to about 10,000 m^3 at the proposed Marina site to a negligible amount at Point Maud.

The cross shore transport during such a storm would also be significant. Calculations of the storm erosion during a 100 year cyclone event were estimated to cause erosion of up to 50 metres from the present vegetation line. In the months and years that follow such an extreme storm, the persistent, low amplitude, background swell would bring some of this eroded sand back onshore and naturally build up the beach.

In order to allow for possible inaccuracies in these coastal engineering calculations, gradients in the longshore drift, and to provide an appropriate buffer as a factor of safety, it is recommended that the development line be set-back at least 100 metres from the present vegetation line on the coastal dunes. The set-back north of the Marina breakwaters should be between 120 metres and130 metres to ensure that the buildings in the development are located on the relic foredune plain.

The Coral Coast Resort will be a significant attraction for boating activities. It was assessed that when fully developed, there would be in the order of 530 boats in the various sectors of the development. This is about 106 boats per 1,000 people, which is about three times the average for the state. As most of the boats are expected to be trailerable boats, the ultimate development will have four lanes of launching ramps. The ultimate demand for pens in the Marina and associated waterways has been estimated to be between 100 and 200. It was also estimated that on a typical day, about 150 to 250 boats would be in use.

The breakwaters that define the entrance to the Marina, have been designed to provide suitable protection to the Marina and associated waterways during severe storms. The breakwaters will be conventional rubble mound breakwaters with two layers of large amount stone protecting a core of smaller mixed rock. Suitable rock can be sourced from quarries in the area.

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Figures

Figure 1.1 - Bateman Bay

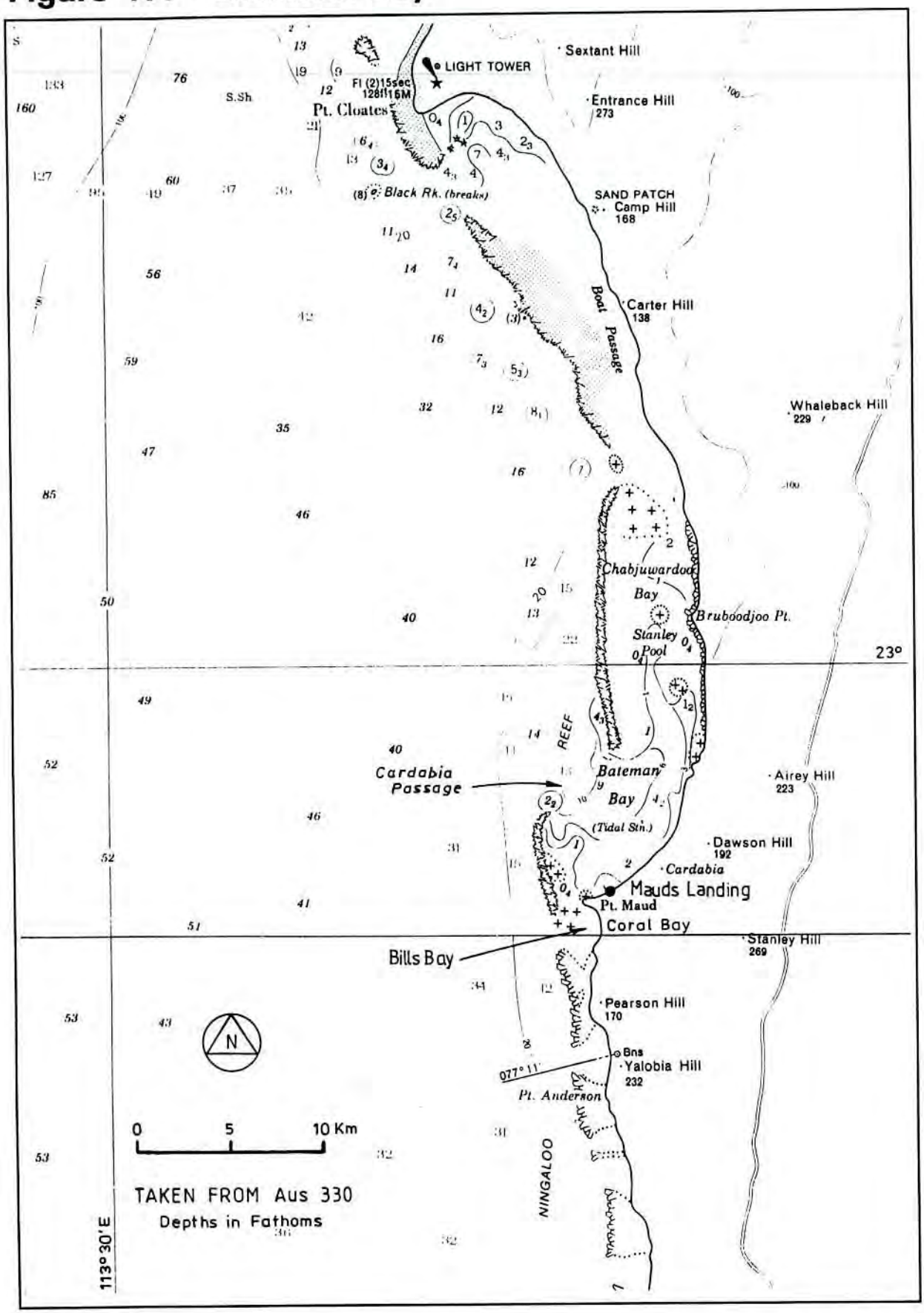


Figure 1.2 - Proposed Development Layout

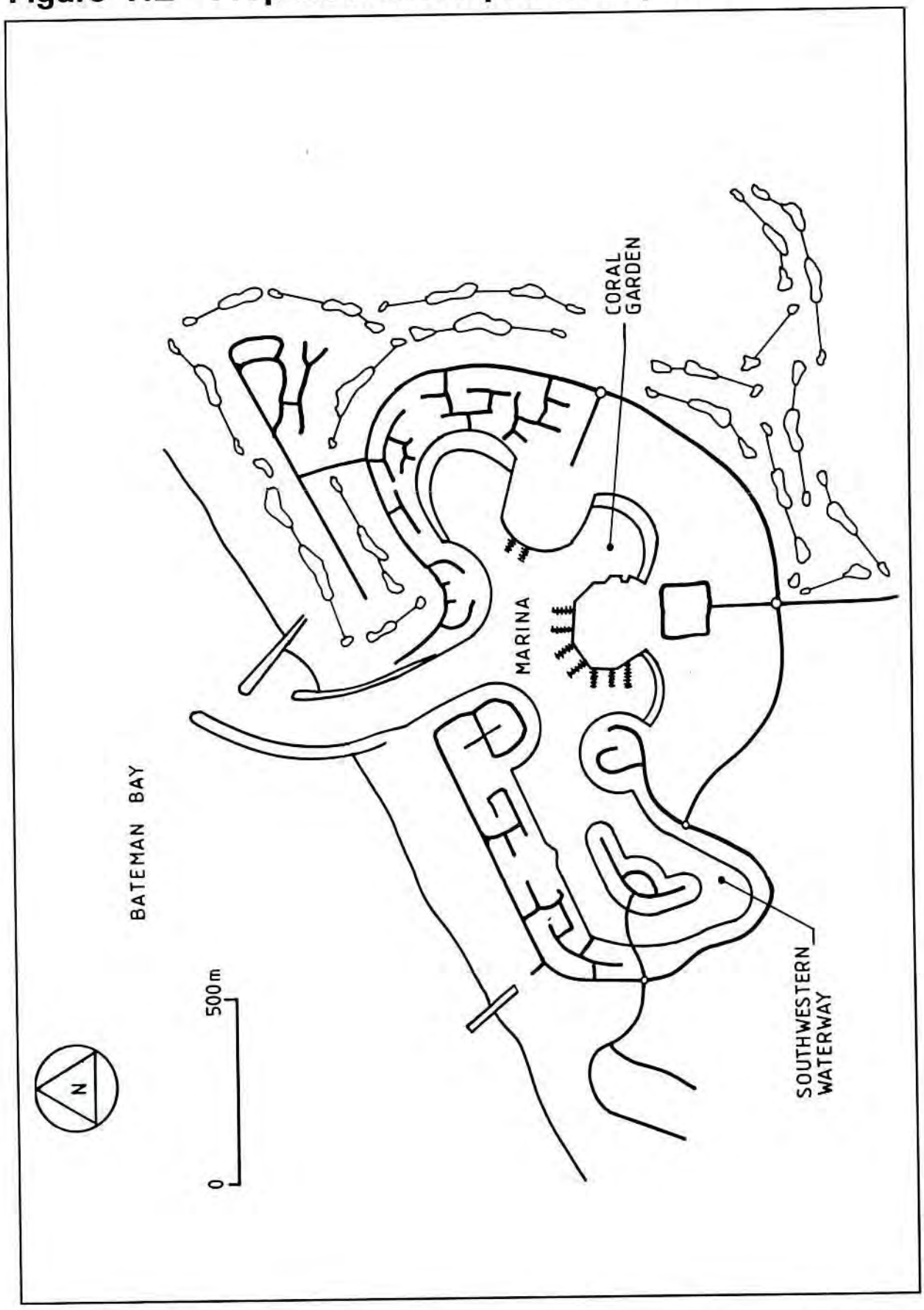
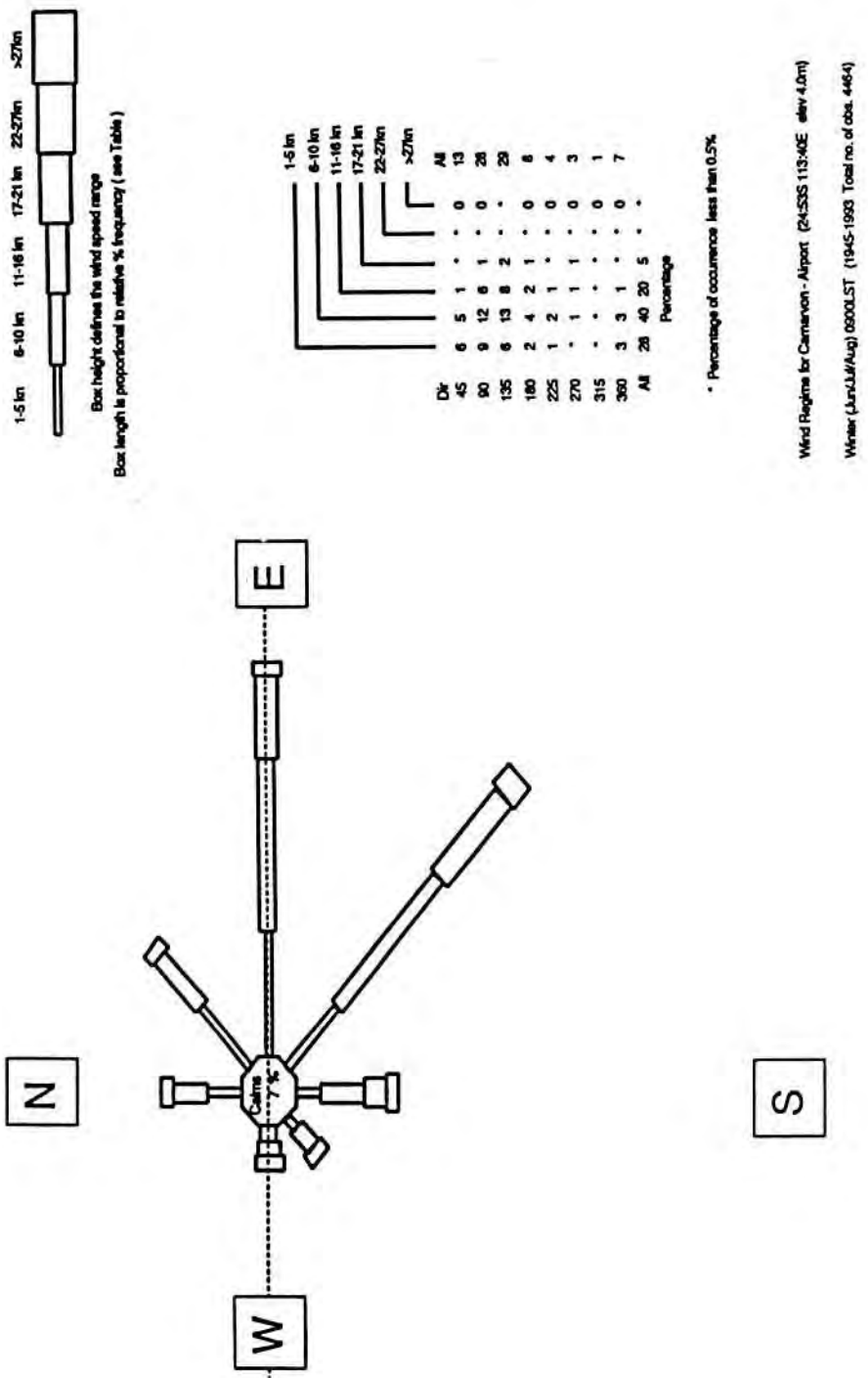
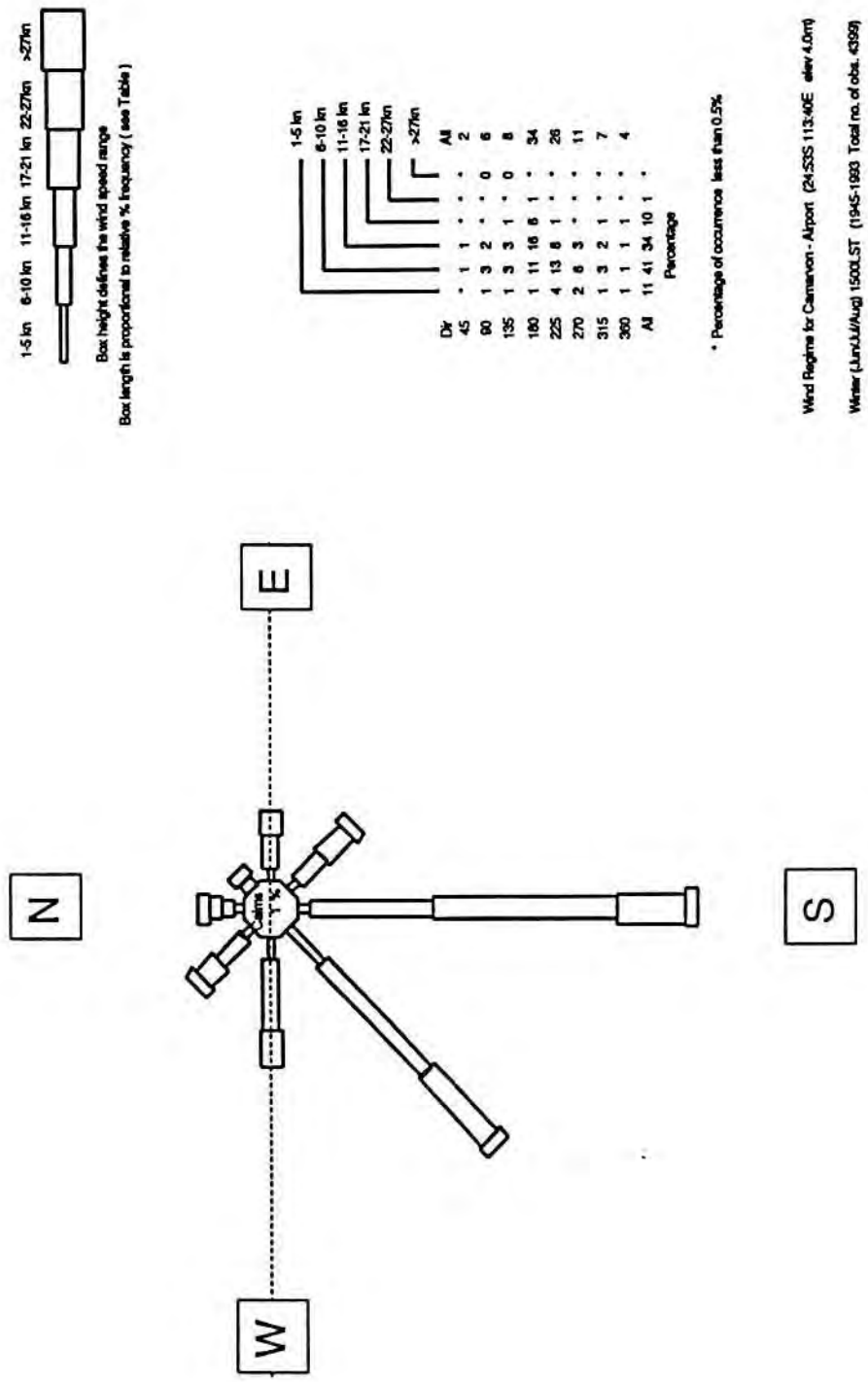


Figure 2.1 - Wind Rose, Winter Mornings



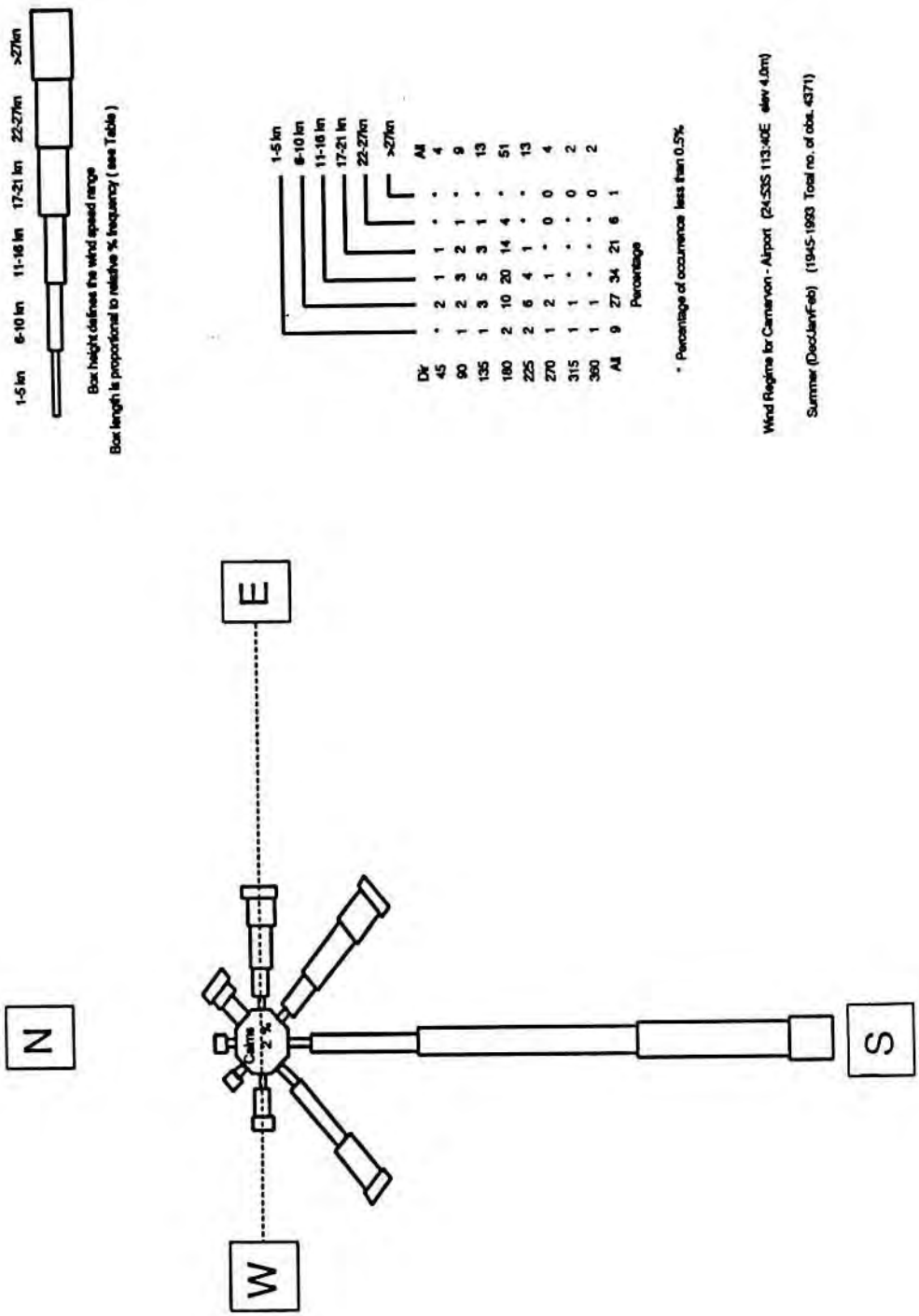
Source: Bureau of Meteorology

Figure 2.2 - Wind Rose, Winter Afternoons



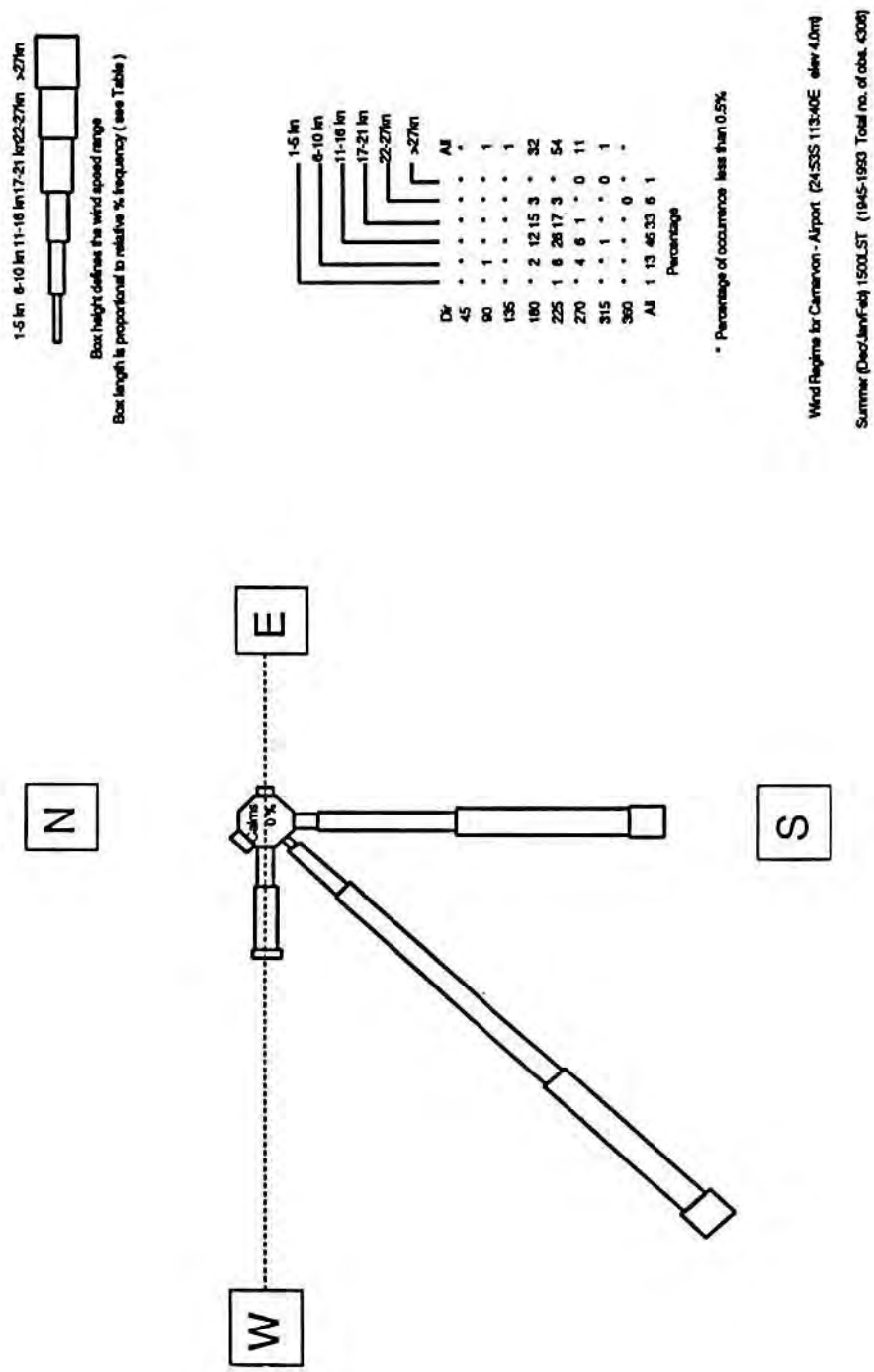
Source: Bureau of Meteorology

Figure 2.3 - Wind Rose, Summer Mornings



Source: Bureau of Meteorology

Figure 2.4 - Wind Rose, Summer Afternoons



Source: Bureau of Meteorology

Figure 2.6 - Estimated Typical Currents

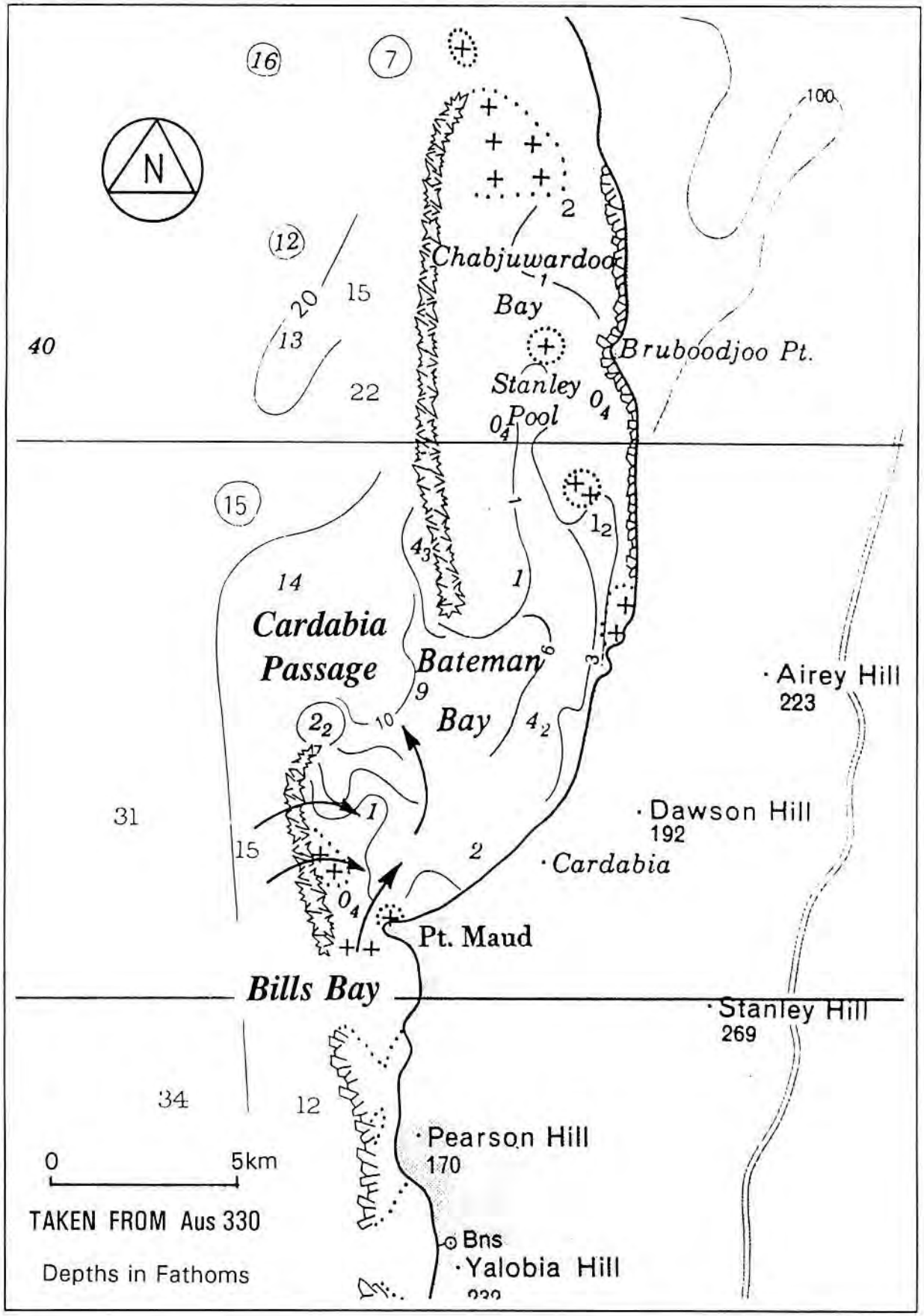


Figure 2.7 - Offshore Wave Climate

WAVE HEIGHT AND DIRECTION FREQUENCY DISTRIBUTION (SITE 26)

SUMMER

	Significant Wave Height (m)								
Direction	0 - 1	1 - 2	2 - 3	3 - 4	4 - 6	6 - 8	8 - 10	> 10	Total
N	1	0	0	0	0	0	0	0	1
NE	0	0	0	0	0	0	0	0	0
E	1	0	0	0	0	0	0	0	1
SE	2	17	10	6	0	0	0	0	34
S	4	23	16	6	1	0	0	0	50
SW	1	3	4	3	0	0	0	0	11
W	0	1	0	1	0	0	0	0	2
NW	0	0	0	0	0	0	0	0	0
Indet	0	0	0	0	0	0	0	0	0
Total	10	43	30	16	1	0	0	0	100
									(n = 196)

AUTUMN

	Significant Wave Height (m)								
Direction	0 - 1	1 - 2	2 - 3	3 - 4	4 - 6	6 - 8	8 - 10	> 10	Total
N	0	1	0	0	0	0	0	0	1
NE	0	0	0	0	0	0	0	0	1
E	0	1	3	0	0	0	0	0	5
SE	2	15	16	12	2	0	0	0	47
S	0	14	10	5	2	0	0	0	31
SW	0	3	5	3	0	0	0	0	10
W	0	1	0	0	0	0	0	0	2
NW	1	1	0	0	0	0	0	0	2
Indet	0	1	1	0	0	0	0	0	2
Total	4	37	35	20	4	0	0	0	100
									(n = 164)

WINTER

	Significant Wave Height (m)								
Direction	0 - 1	1 - 2	2 - 3	3 - 4	4 - 6	6 - 8	8 - 10	> 10	Total
N	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0
E	0	2	2	1	0	0	0	0	4
SE	0	6	9	1	1	0	1	0	19
S	0	10	15	10	0	0	0	0	35
SW	0	7	12	10	0	3	0	0	31
W	0	5	1	1	0	0	0	0	7
NW	0	0	0	0	0	0	0	0	0
Indet	1	0	3	0	0	0	0	0	4
Total	1	29	42	23	1	3	1	0	100
									(n = 83)

SPRING

	Significant Wave Height (m)								
Direction	0 - 1	1 - 2	2 - 3	3 - 4	4 - 6	6 - 8	8 - 10	> 10	Total
N	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0
E	0	3	0	0	0	0	0	0	4
SE	1	9	20	5	0	0	0	0	35
S	0	12	17	8	0	0	0	0	37
SW	2	8	5	2	2	0	0	0	19
W	0	0	2	0	0	0	0	0	2
NW	0	0	0	0	0	0	0	0	0
Indet	1	2	1	0	0	0	0	0	3
Total	5	34	45	14	2	0	0	0	100
									(n = 116)

Source: US Navy (1976)

Figure 4.1 - Wind Induced Circulation

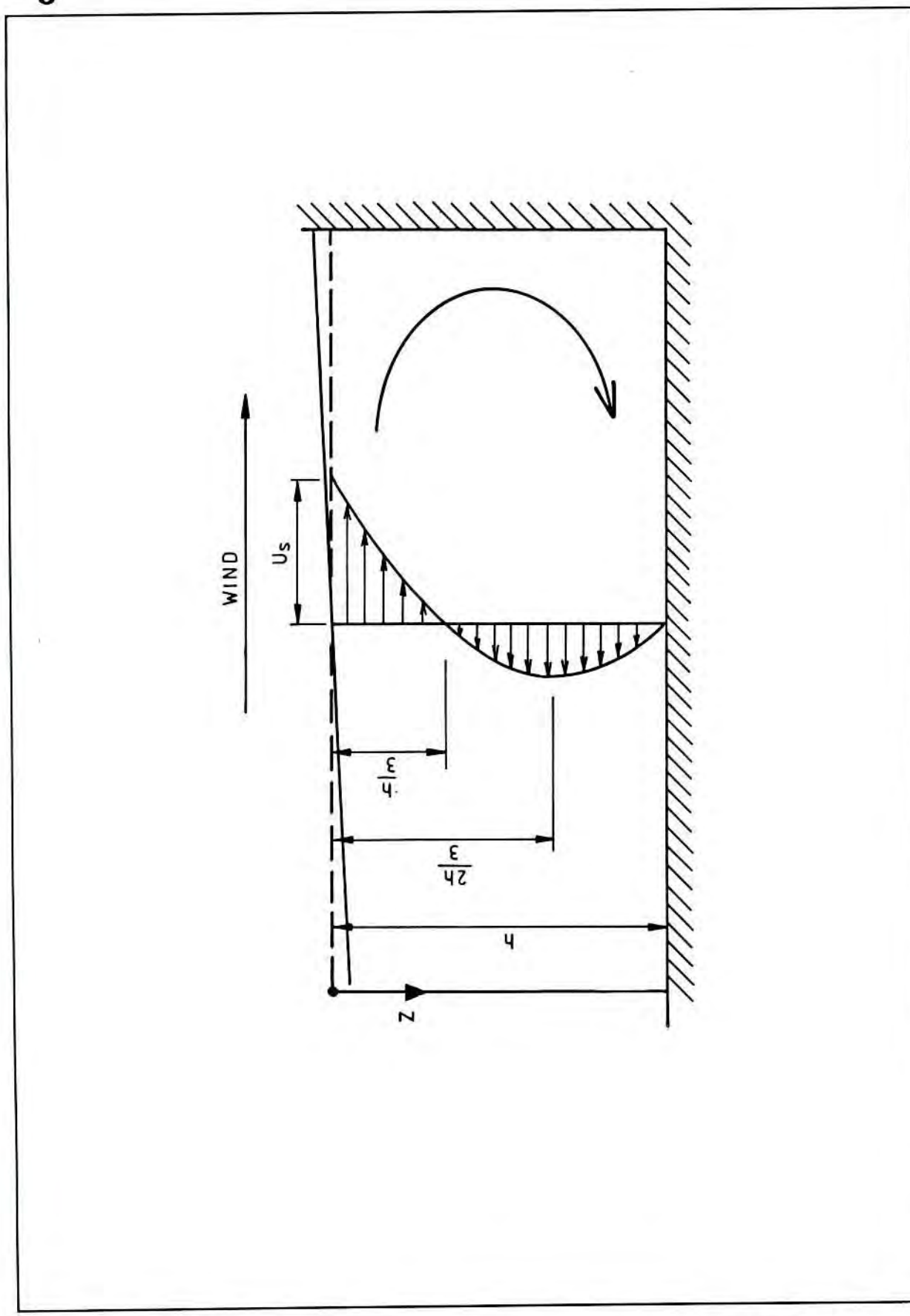
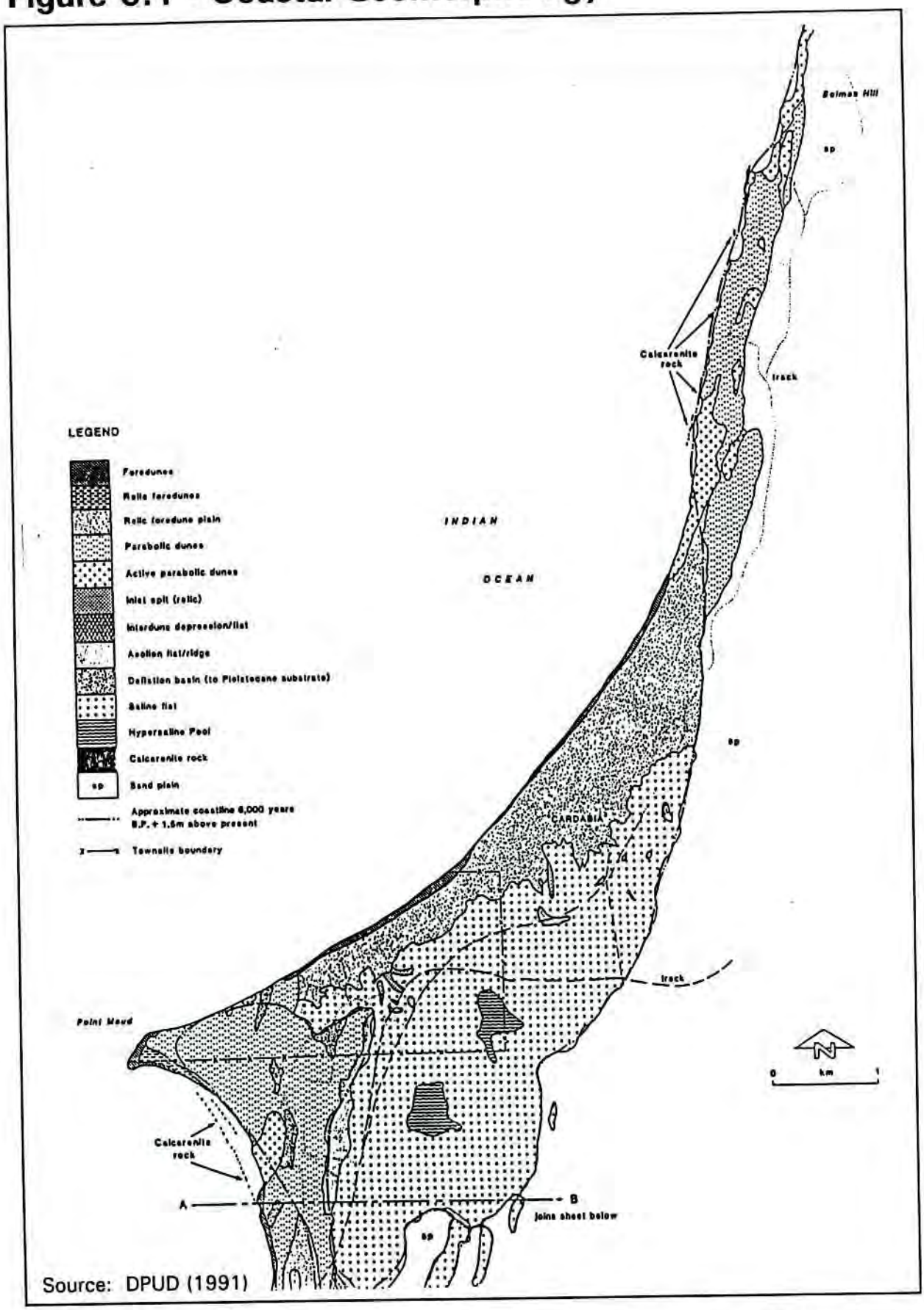
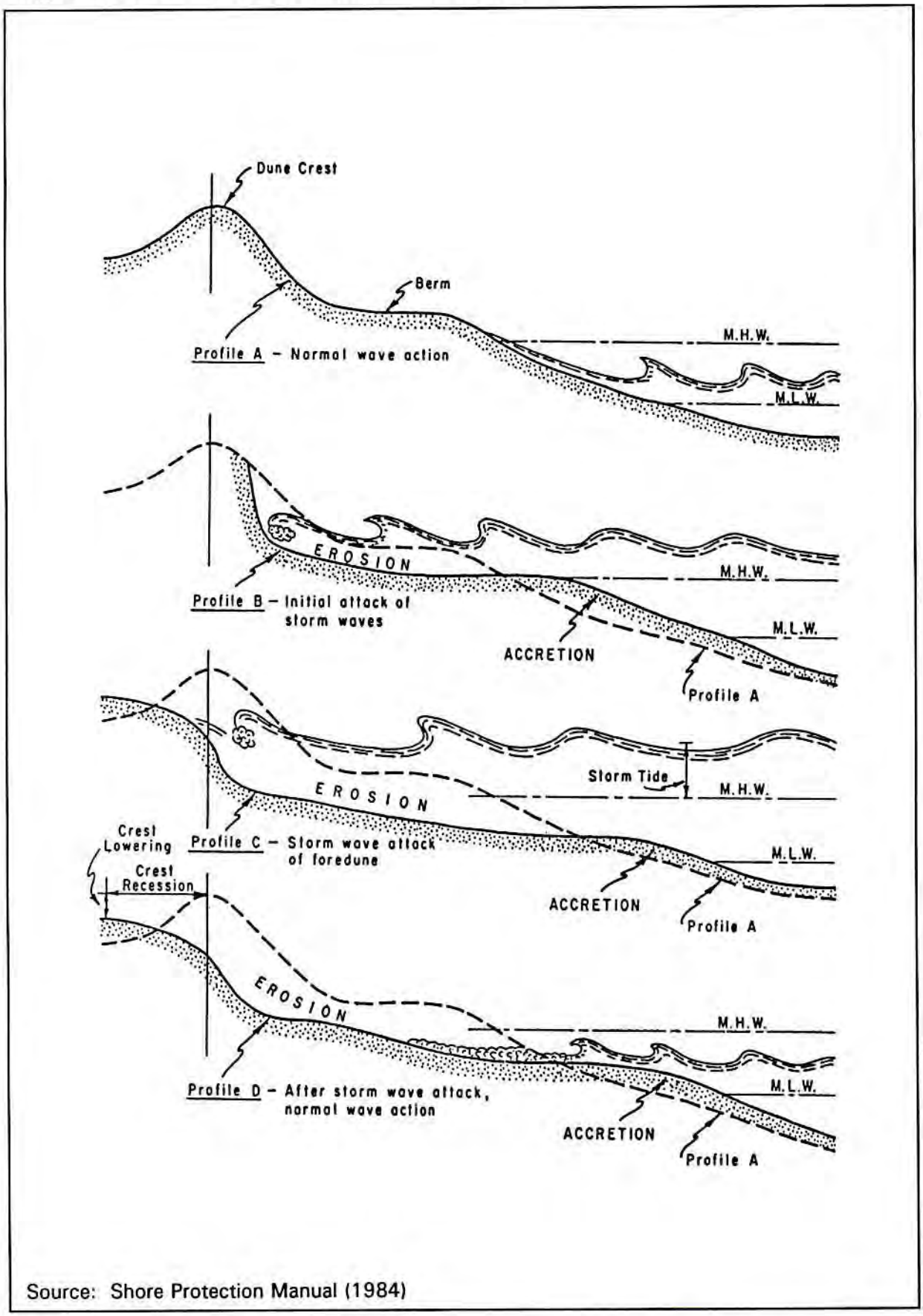


Figure 6.1 - Coastal Geomorphology



Source: DPUD (1991)

Figure 6.2 - Storm Wave Attack



Source: Shore Protection Manual (1984)

Figure 6.3 - Extreme Storm Erosion

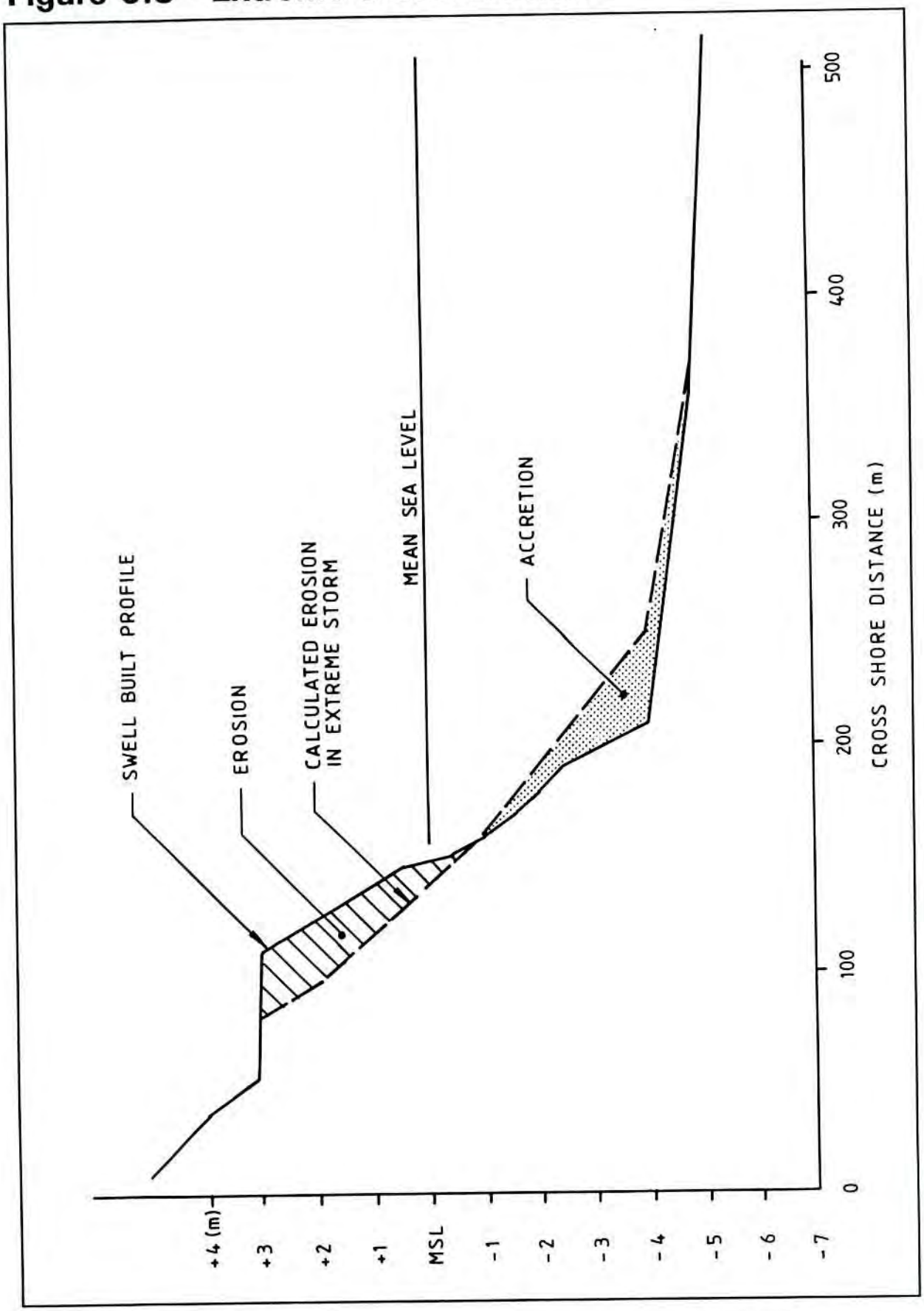


Figure 6.4 - Shoreline Movement Plan

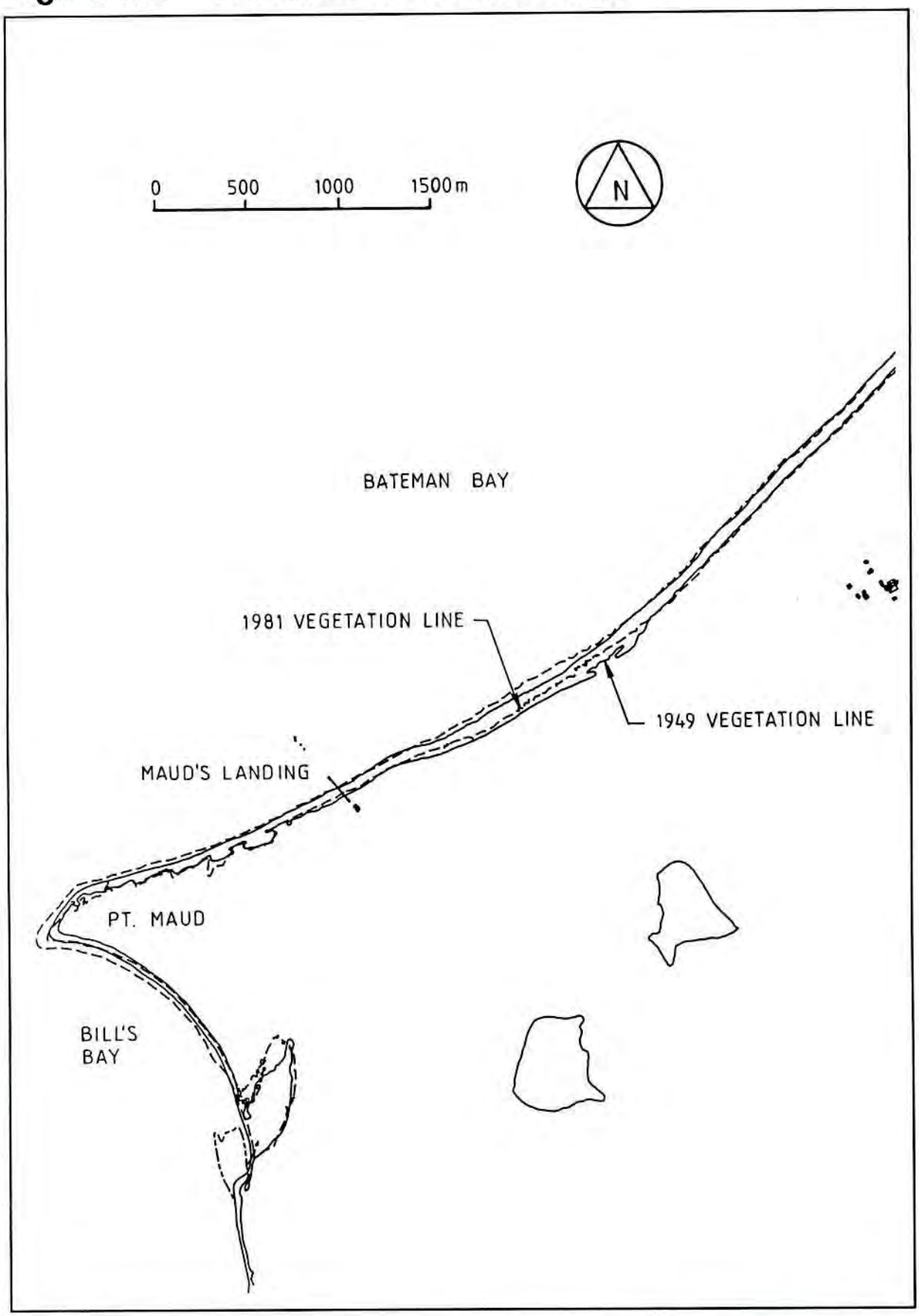
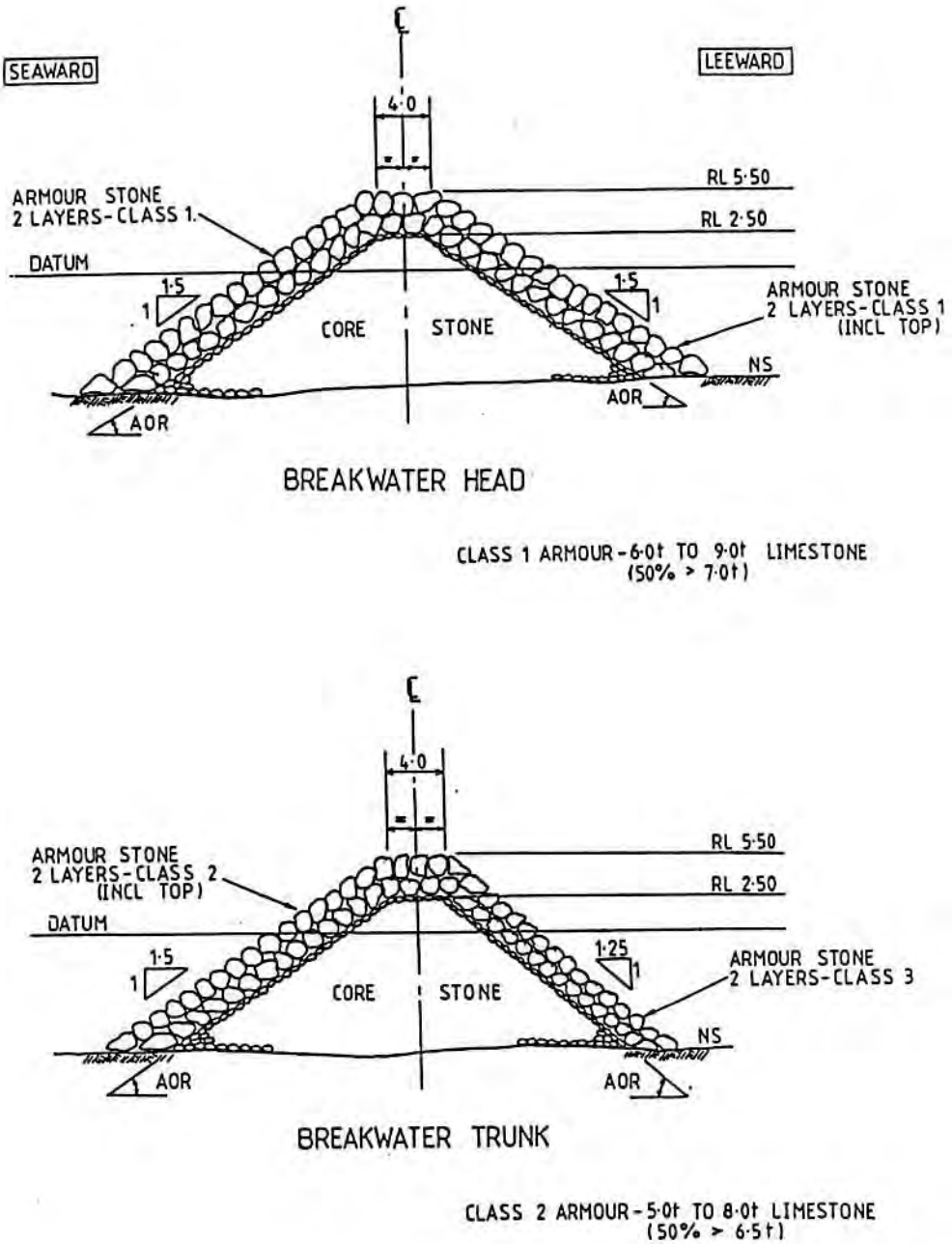


Figure 7.1 - Breakwater Cross Section



Source: Port & Harbour Consultants (1989)

Figure 7.2 - Existing Quarry

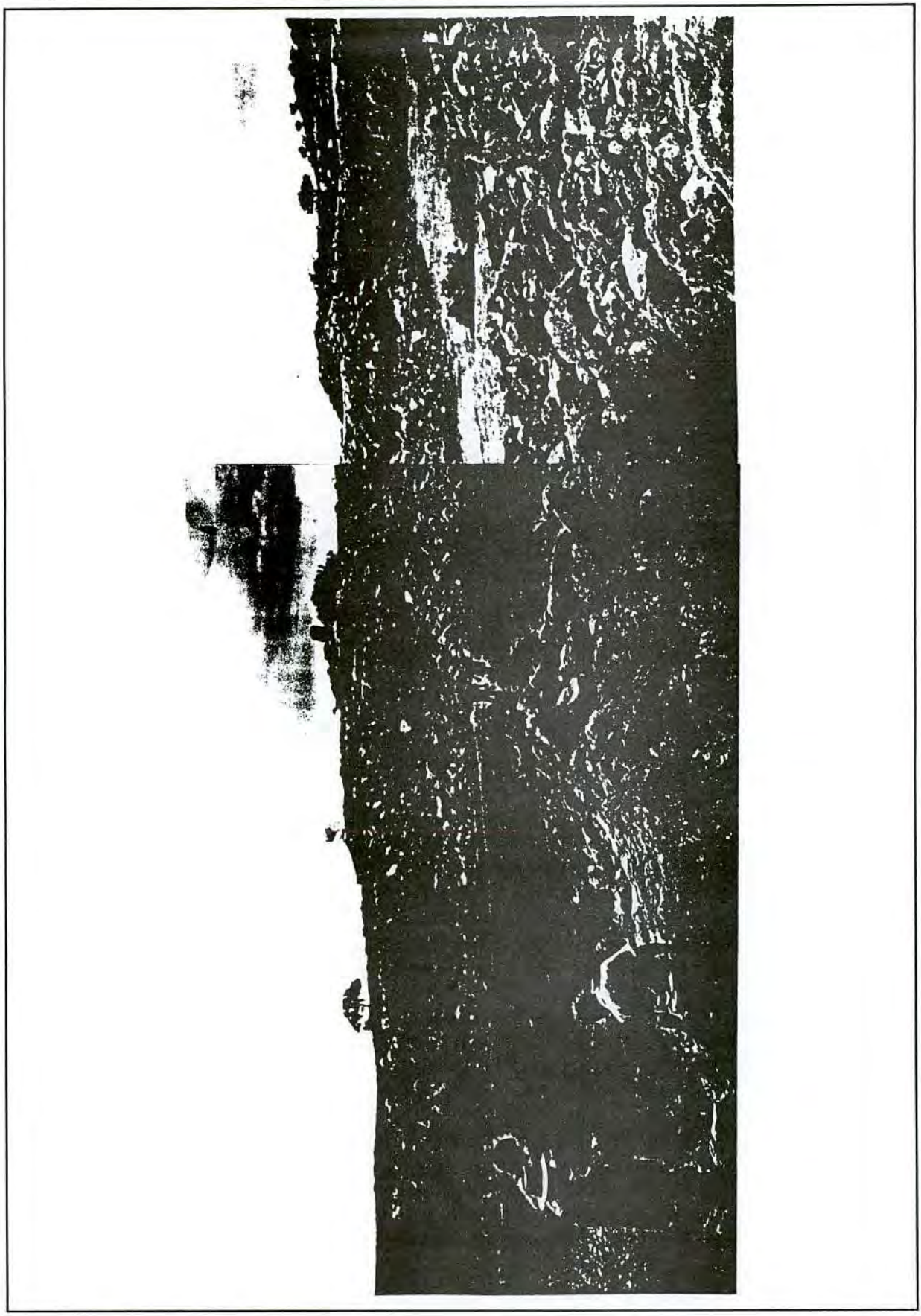


Figure 7.3 - Rock Revetment

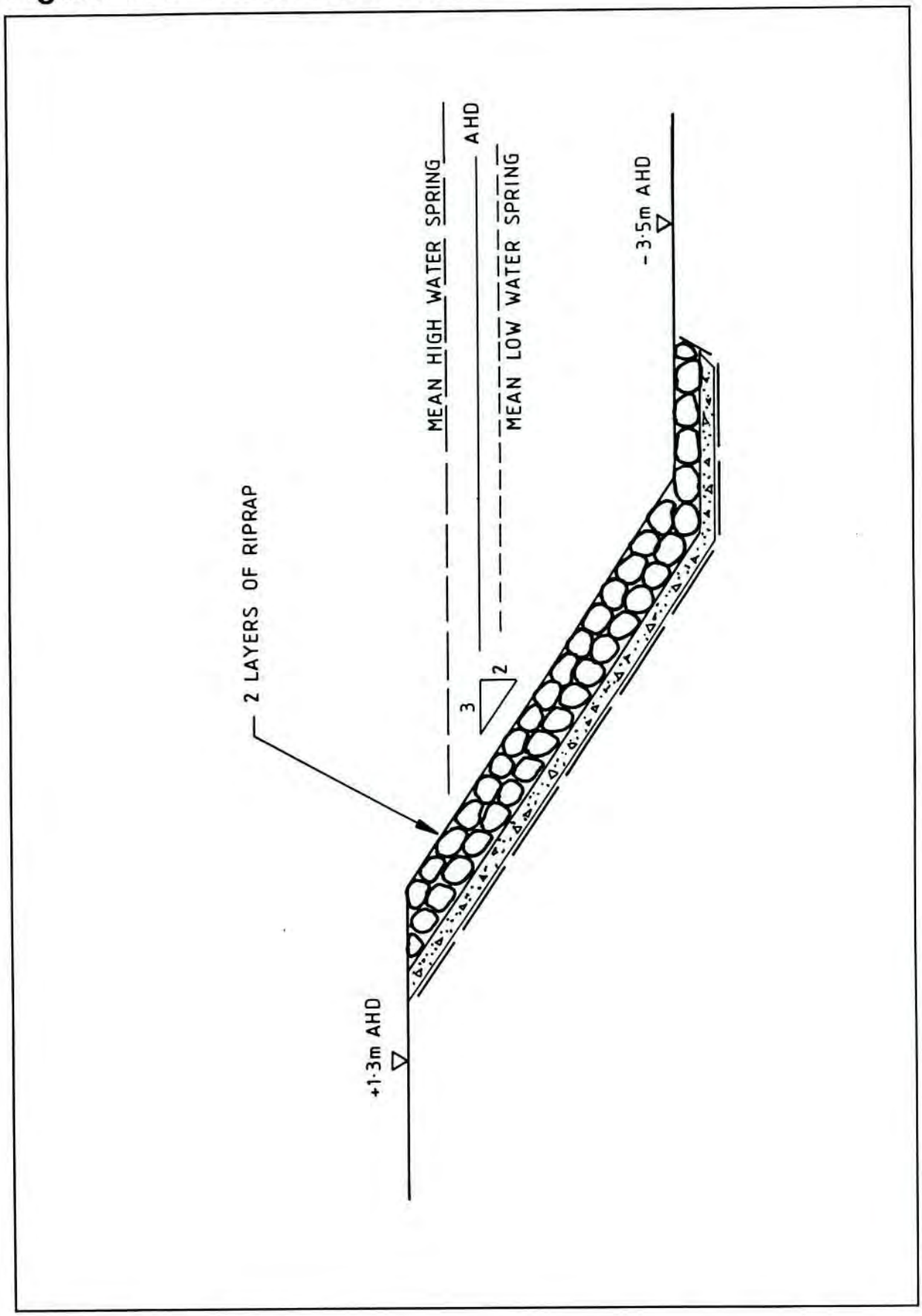


Figure 7.4 - Cross Section Through Internal Beach

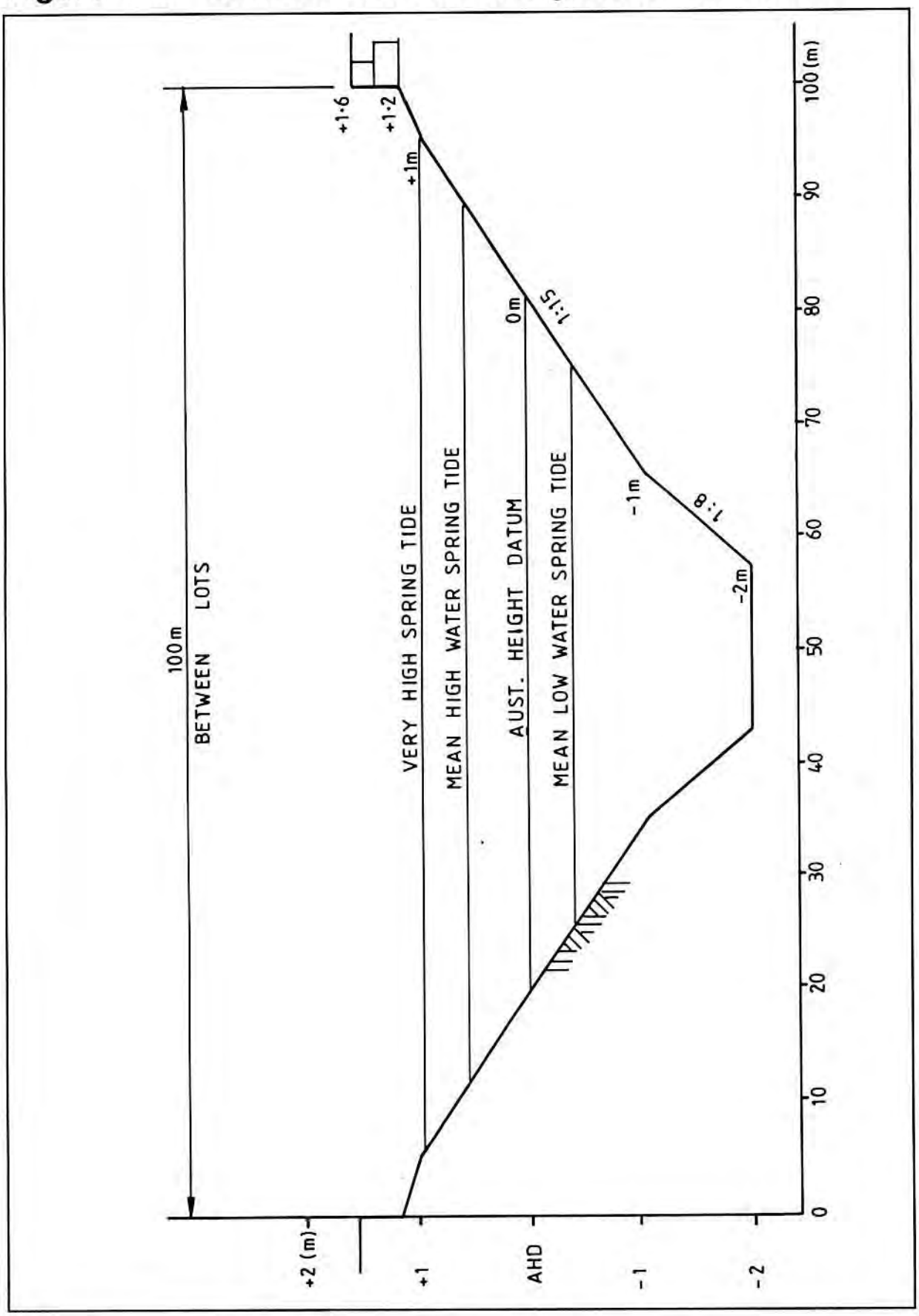
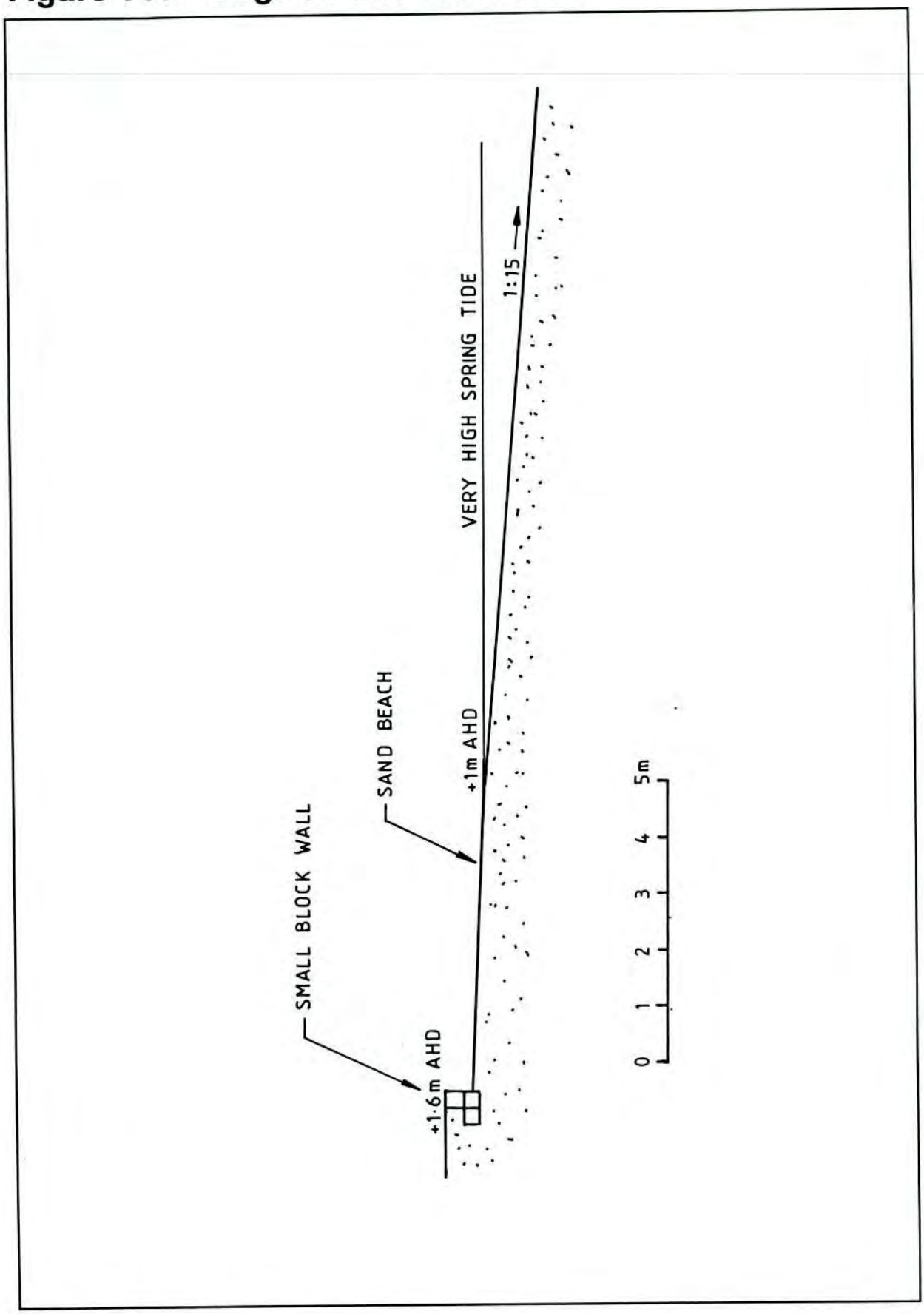


Figure 7.5 - Edge of Internal Beach



Appendices

Appendix A Water Quality Criteria

WATER QUALITY CRITERIA

for

MARINE AND ESTUARINE WATERS

of

WESTERN AUSTRALIA

Edited by

V Talbot (EPA) D Williams (EnviroData)

and

B P Kennedy (EPA)

2nd EDITION

Environmental Protection Authority

Perth, Western Australia

BULLETIN No 103 1991

BENEFICIAL USE NO.1

DIRECT CONTACT RECREATION

For the purpose of this schedule, recreation is considered to include all activities relating to sport, pleasure and relaxation which for the purpose of these guidelines depend on water resources. Water orientated leisure pursuits dominate recreation in Western Australia. Most of the State's population is concentrated near the coast and especially within 200km north and south of Perth. The importance of water for recreation in Western Australia reinforces the need to establish effective water quality criteria as guidelines for the proper management of this resource.

In considering this schedule, the Editors drew heavily upon the NH&MRC Australian guidelines for recreational use of waters (NH&MRC, 1990). This was done as an attempt to standardise schedules which have little relation to the physiography and ecology of any particular part of Australia. Other criteria have also been included from other sources, however.

During revision of the criteria a common question which was raised was "how far from the high tide mark seawards does the criteria apply for direct contact recreation"?. The answer can only be given on a site specific basis and hence should be addresses by the management agency when designating water bodies for various benificial uses. However, it is pointed out that where water depth increases rapidly from the high tide mark, Schedule 1(1) would be applicable to a ribbon shaped segment of water parallel to and along side the beach. On the other hand, in the case of platform reefs, Schedule 1(1) would cover a much wider area depending on water depth.

Primary contact recreation for humans.

Criteria in Schedule 1(1) are intended to protect marine and estuarine waters for direct contact recreation involving bodily immersion or submersion, including bathing, diving, water-skiing, surfing and other similar activities.

(a) Health criteria

People engaged in primary contact recreation may swallow significant amounts of water, absorb toxic chemicals through the skin or acquire a range of infections. The amount of water that may be accidently swallowed varies considerably but in practice probably does not exceed 100 mL for any individual per day.

Depending on the levels of control exercised over the open water resource, effort should be made to either warn the public or control access and use when water is found to be heavily polluted.

Faecally contaminated water may expose swimmers to a range of infectious gastrointestinal diseases. Norwalk virus has been commonly cited as the most likely disease causing organism. The protozoans *Giardia* and *Cryptosporidium* may also be a cause for concern, particularly if farm, animal and sewage wastes are dumped into streams or lakes which drain to upper estuaries.

(b) Safety and aesthetic criteria

Water should be free of floating or submerged objects which may cause physical injury. In terms of water quality control, floating debris, oil, grease, scum, foam, and other floating materials originating from waste discharges or of natural origin are of concern. Ideally, water should have a low turbidity and have low colour. For many activities, for example, swimming and diving, it is important that the bottom be clearly visible.

Formulation of criteria to ensure that water is universally appealling is difficult. Aesthetic preferences are subjective and dependent upon cultural conditioning.

Waters should conform to the general health, safety and aesthetic criteria for marine and estuarine waters. They should also be protected against loads of nutrients and other biostimulants capable of causing excessive or nuisance growths of algae or other aquatic plants.

Water quality criteria recommended for primary contact recreation relating to human health, safety and aesthetics are provided in Schedule 1(1).

SCHEDULE 1(1)

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR PRIMARY CONTACT RECREATION

Primary Contact: Criteria relating to human health, safety and aesthetics

Parameter	Criterion	Source
Aesthetic Considerations	As on page immediately preceeding Schedule 1	USAEPA (Comp.) (1978)
Floatable and settleable matter	Floating debris, grease, oil, scum and foam should not be visible. The bottom should be safe to walk on.	NH&MRC (1990)
Physical Hazards (Dangerous objects)	Water should not contain floating or submerged objects which might injure, tangle or obstruct users.	NH&MRC (1990)
Odours, taints colour	The water should be free of objectionable odours and taints, and colour should not exceed 30 Pt-Co units	WG2(1900) VicEPA (1983)
Light Penetration (Water Clarity)	Secchi disc (a circular plate painted black and white) visible at a depth of 1.2m except in "learn to swim" areas where a Secchi disc should be visible on the bottom.	NH&MRC (1990)
pH	6.5-8.5, except for estuarine waters with a low buffer capacity where a pH range of 5.0 and 9.0 may be tolerated.	NH&MRC (1990)
Turbulent and high velocity flows	Flow rates should be less than 1.5 m/sec at waist or greater depth.	NH&MRC (1990)
Plant nutrients		
a) Marine	Nutrients should not promote excessive aquatic macrophyte and algae growth or growth of toxic cyanobacteria. Nor should they cause a deleterious reductions in dissolved oxygen concentrations in water.	WG2(1990)/ NH&MRC (1990)
Ammonia (expressed as Nitrogen)	6 month median not to exceed 600 ug/L. No single reading to exceed 2000 ug/L.	K&S(1977)
b) Estuarine	Nutrients should not promote excessive aquatic macrophyte and algae growth or growth of toxic cyanobacteria. Nor should they cause a deleterious reductions in dissolved oxygen concentrations in water.	WG2(1990)/ NH&MRC (1990)
Phosphorus (Total)	Not to exceed 0.02 mg/L	WG2 (1990)
Nitrogen (Total)	Not to exceed 0.2 mg/L	WG2 (1990)
Bacteria		
a) Total Coliforms	The geometric mean of total coliforms in not less than 5 samples taken over a period of not more than 42 days should not exceed 1,000 organisms per 100 ml.	VicEPA (1983)
b) Faecal Coliforms and indicators	The median value not exceeding 150 faecal coliforms organisms/100mL for a minimum of 5 samples taken at regular intervals not exceeding 1 month with 4 out of 5 samples containing less than 600 faecal coliforms per 100mL. However, where possible, a site specific criterion should be developed. High temperature and high salinity adversely affects faecal coliform survival and may indicate the	NH&MRC (1990)

	need to adopt a more stringent faecal coliform criterion. Since some human viruses may survive chlorination, the criterion must be applied with caution for assessing health risk where effluent of human origin is chemically disinfected.	
c)Enterococci	Geometric mean not to exceed 33 organisms per 100mL	NH&MRC (1990)
Faecal Material	The water in bathing and swimming areas should be protected against direct contamination with fresh faecal material of human or domesticated animal origin.	WG1(1981)
Salmonella	95 percentile should have zero organisms/L. This may be established on the basis of a minimum of five samples taken over not more than a 30-day period under conditions representative of the water quality to which users are commonly exposed.	WG2(1990)/ WRC(1989)
Enteroviruses	95 percentile should have zero organisms/10L. This maybe established on the basis of a minimum of five samples taken over not more than a 30-day period under conditions representative of the water quality to which users are commonly exposed.	WG2(1990)/ WRC(1989)
Blue Green Algae	No quantitative figures have been produced. Waters with obvious algal blooms can be considered unsuitable for primary contact recreation.	NSWSPCC (draft)(1989)
Harmful organisms	Dangerous aquatic parasites are almost unknown in Australia. Waters should have only low levels of cercarial stages of avian schistosomes. Direct contact with a range of bottom dwelling animals on reefs should be avoided; water should be reasonably free of poisonous coelenterates such as box jelly fish and blue bottles. In estuarine areas, freshwater leeches should be avoided where possible as they can enter body orifices and cause considerable damage.	WG2(1990)/ NH&MRC (1990)
Protozoans	Pathogenic free-living protozoans should be absent from warm (greater than 24 ^{o}C) upper estuarine water bodies used bodies bodies used for primary contact recreation.	WG2(1990)/ NH&MRC (1990)
Staining		
Iron	95 percentile not to exceed 500 ug/L	WG2 (1990)
Manganese	95 percentile not to exceed 100 ug/L	WG2 (1990)
Temperature	15-35^{o}C	NH&MRC (1990)
Radioactive Substances	The waters should not contain radioactive substances in such concentrations as to be deleterious to humans if small quantities are ingested.	WG1 (1981)
	TOXICANTS: FOR HUMAN PROTECTION	
In General	Waters containing chemicals which are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation.	NH&MRC (1990)
(Elements)		
Arsenic	95 percentile not to exceed 500 ug/L	WRC (1989)
Cadmium:		
Estuaries	Annual average not to exceed 5 ug/L	WRC (1989)
Other Coastal Waters	Annual average not to exceed 2.5 ug/L	WRC (1989)
Chromium	95 percentile not to exceed 500 ug/L	WRC (1989)
Copper	95 percentile not to exceed 500 ug/L	WRC (1989)

Lead	95 percentile not to exceed 500 ug/L	WRC (1989)
Mercury:		
Estuaries	Annual average not to exceed 0.5 ug/L	WRC (1989)
Other Coastal Waters	Annual average not to exceed 0.3 ug/L	WRC (1989)
Nickel	95 percentile not to exceed 500 ug/L	WRC (1989)
Zinc	95 percentile not to exceed 50 mg/L	WRC (1989)
(Organics)		
Phenols	Not to exceed 50 ug/L	WRC (1989)
Hydrocarbons:		
Visual and odour	No visible film or odour	WG2 (1990)
Dissolved or emulsified	90 percentile not to exceed 300 ug/L	WRC (1989)
Chloroform extractible substances	90 percentile not to exceed 300 ug/L	WRC (1989)
(Other Toxicants)		
Hydrogen sulphide (undissociated H_2S)	95 percentile not to exceed 40 ug/L	WRC (1989)

APPENDIX H

A Flora and Vegetation Survey of the Conservation Values for Flora and Vegetation in the Area Proposed for the Coral Coast Marina

Malcolm Trudgen, 1994

A FLORA
AND VEGETATION
SURVEY AND ASSESSMENT OF
CONSERVATION VALUES FOR FLORA AND
VEGETATION OF THE AREA OF THE PROPOSED
CORAL COAST MARINA

PREPARED FOR

BOWMAN BISHAW GORHAM

ENVIRONMENTAL MANAGEMENT CONSULTANTS

BY

MALCOLM TRUDGEN

CONSULTANT BOTANIST

NOVEMBER 1994

CONTENTS

1.0 INTRODUCTION

1.1 Location

The study area is located on the coast of Western Australia, just north of the township of Coral Bay. It is about 160 kilometres south of Exmouth and 250 kilomtres north of Carnarvon (DPUD 1992). Ningaloo Marine National Park abuts the study area.

1.2 Topography and geomorphology

The study area has two major landform units in it. These are a relict mud flat and areas of Holocene dunes (DPUD 1992). The dunes lie behind a long gently curved bay which is separated from Bill' Bay (on which the township of Coral Bay is situated) by Point Maud.

The relict mud flat has some low relief that has allowed the development of some clay pans (areas bare of vegetation, a little lower than the surrounding flats but probably only holding water for a very short time), a few small sinkholes, a low embankment and a hypersaline pool. The hypersaline pool is much better defined than the claypans, is deeper and probably holds water for longer periods (it is located in the south-east corner of the study area. There are some small areas of relict inlet spits on the flat (DPUD 1992).

The Holocene dunes include an area of parabolic dunes and a relict beach ridge plain. The parabolic dunes reach heights of up to 30 metres above sea level and are irregular in shape while the dunes in the relict beach ridge plain are more or less parallel to the coast the tallest are about 9 metres above sea level. As well, there are some minor components in the Holocene dunes, including a narrow strip of low foredunes, deflation basins and a small area of aeolian flat or ridge (DPUD 1992).

1.3 Climate

"The climate of Coral bay is characterised by warm to hot temperatures and low rainfall year round. Rainfall can occur in summer and winter. Cyclonic disturbances are a major contribution to rainfall in February and March..." (DPUD 1992).

2.0 METHODS AND LIMITATIONS

2.1 Methods

Sites were selected in the field partly by using an aerial ortho-photograph and partly during traverses made by foot and vehicle. The structure and floristics of the vegetation was then recorded using releve sites. In this technique, a formal plot is not used but, in this study releves were usually roughly circular areas of about 30 metres diameter. In some situations (e.g. narrow strips of vegetation at the edges of the dunes and saline flats and on dune crests) releves had to be different shapes. The location of the releves were marked on the aerial ortho-photograph. At each releve, the structure of the vegetation was recorded and at most releves all species present were recorded.

The system used in the description of the vegetation types is a modified usage of the system of Specht as given by Aplin (1979, see Appendix three). This system is usually used to define vegetation on the upper storey only. However, vegetation with similar upper storey composition and abundance can have very different lower stories. To fully describe the vegetation, each layer present was described. Sometimes, within a Specht height class (e.g. 0-1 metre) there are actually two layers, when this happened both were described. Vegetation descriptioons ae usually based on the prennial flora, and because of this one species was omitted from vegetation descriptions although it was at times significant. This was Trichodesma zeylanica, which is usually an annual but the form on present in the study area may be prennial.

Where species at the releves were well known to the author they were not collected but their presence was recorded. Other species were collected, pressed, dried and identified using keys and by comparison to previously named material at the Western Australian Herbarium. Where appropriate, assistance from specialists was sought to enable identification of difficult material.

At each releve, the condition of the vegetation was assessed using a scale ranging from excellent to completely degraded. This scale is given in appendix two.

2.2 Limitations

There are some limitations inherent in the approach used in this study, these are:

The survey was restricted to one site visit of three days in October, and as the preceding season had been fairly dry, very few annual species were available for collection. However, partly due to the small number of habitat sites in the study area, it was felt that a large proportion (more than 90%) of the perennial flora of the site was recorded even if a much smaller proportion of the annual flora was recorded.

The releve method does not provide as accurate data as the careful use of plots (the fact that the releves were larger than plots would have been if they had been used counteracts this to some extent), but was practical in the time available with the diversity of vegetation in the study area.

Assessment of the condition of vegetation is more difficult in the absence of knowledge of the fire history. In the study area it is possible that fires may have reduced the abundance of fire sensitive species such as Olearia dampieri and Olearia axillaris ssp. obovatus. If this were the case, then some sites would need to assessed as in slightly poorer condition than the assessments made for this report.

3.0 FLORA OF THE SURVEY AREA

3.1 Flora recorded

One hundred and six native flowering plant species from thirty-three plant families were recorded in the study area, including one aquatic species from the hypersaline pool. In addition, one introduced species, *Cenchrus ciliaris (buffel grass), was recorded. This species was common (in places abundant) on the sand dunes in the study area.

The flora recorded probably represents about 85% of the flora of the site, with those species not being recorded being either present in very low numbers or being annuals not available at the time of the survey.

Given the relatively small size of the study area and the low number of habitat types, the number of species recorded seems to indicate an average diversity, that is neither low nor high for an area on the coastline. In contrast, Kieghery and Gibson (1992) recorded six hundred and thirty taxa of vascular plants (in 86 families, excluding those with only weed and marine species) from the Cape Range peninsula, but this is a much larger area with many more habitat types.

The plant families with the most species recorded for the sudy area were: Poaceae (grass family) 12 species; Chenopodiaceae (saltbush family) 15 species; Mimosaceae (wattle family) 7 species; Malvaceae (Hibiscus family) 5 species; Goodeniaceae (Leschenaultia family) 8 species and Asteraceae (daisy family) 12 species.

Poaceae, Malvaceae, Asteraceae and Mimosaceae are usually major components of floras in arid areas in Western Australia and Chenopodiaceae in the floras of saline areas, so these families would be expected. The relative abundance of Goodeniaceae is a result of the presence of several coastal species, with the small size of the study area skewing their affect on the size of the family in the study area. Kieghery and Gibson (1992) had a similar list of families with many species, with differences (such as the inclusion of Myrtaceae and Papilionaceae) being readily explained by the small range of habitats in the study area of the current survey area.

3.2 Biogeographical relationships of the flora of the study area

The flora of the study area has groups of species that can be ascribed to different regions in their relationships. For example, species such as Rhynchosia cf. minima and Launea sarmentosa are tropical in their relationships; species such as Acanthocarpus preissii, Thryptomene baeckeacea and Pileanthus limacis are south-western in their relationships, species such as Spinifex longifolius, Scaevola spicigera, Acacia coriacea ssp. coriacea and Acacia rostellifera are coastal in their distribution; and species such as Sida cf. fibulifera, Abutilon cf. exoneum are eremaean in their relationships. In addition, there is a significant group of species, including the Halosarcia species and the Atriplex species that are associated with saline habitats.

Given the coastal nature of the study area, the latitude it occurs in and the presence of an extensive saline area, the biogeographical makeup of the flora recorded seems to be much what would be expected.

3.3 Significant flora recorded

Species discussed in this section are those that are considered to possibly be at risk, or for which the population in the study area has some particular significance. No declared rare flora were recorded.

3.3.1 Priority species

Priority species are those which the Department of Conservation and Land Management (CALM) considers may need to be gazetted as declared rare flora after proper surveying, or which are not currently threatened but which require regular monitoring.

Two priority species were recorded from the study area, they are:

Acacia ryaniana and Eremophila glabra ssp. Dirk Hartog (M. Manning 6/9/64). Both are common in the study area, with populations generally being found in the lower parts of the dunes, close to the saline flats, where the sand layer is thin. However the Eremophila was recorded in some sites located further up in the dunes but, at lower densities.

Acacia ryaniana and Eremophila glabra ssp. Dirk Hartog (M. Manning 6/9/64) are both priority two species, these are: "Taxa which are from one or a few (generally < 5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora' but are in urgent need of further survey (Atkins, September 1994).

3.3.2 Species at ends of range

Populations of species which are at the end of their range are generally considered important by biologists because they give informaion about the response of the species to its environment. Collections of four species made during the survey significantly extended their known range to give them new northern limits. These species were:

Halosarcia peltata: range extension, previous northern limit was at Shark bay.
Acacia rostellifera: range extension, previous northern limit was at the Zuytdorp Cliffs.
Stipa elegantissima: previous northern limit was near Carnarvon.
Podolepis microcephala: previously only known from Shark Bay and the southern end of Lake McLeod.

3.3.3 Other significant species present

Another species worthy of comment found in the study area was Launea sarmentosa, a prostrate member of the daisy family with long creeping stems. This species was recorded in the foredunes next to the Mauds landing track and, is only known in Australia from a few records from beaches on the Pilbara coastline and from adjacent offshore islands (it has a wide distribution outside Australia on tropical islands). The area of suitable habitat for this species in W.A. does not appear to be very large and it may deserve to go on the CALMpriority list

3.3 Potential for other Rare/Priority flora to be present

There are in the order of 80 priority and declared rare flora species in the CALM Gascoyne region but systematic checking of the CALM Declared Rare and priority Flora List (Atkins, Septmber 1994) indicates that it is unlikely that priority species other than those recorded would occur in the study area. The reason for this is the

small range of habitat that occurs in the study area (saline flats and younger coastal dunes) and the fact that most of the declared rare and priority flora species are not from these habitats. However, it is not impossible that a few other priority species could occur in the study area, especially as the number of annual species recorded was low due to a lack of sufficient rain prior to the survey to promote growth of these species.

4.0 VEGETATION OF THE SURVEY AREA

4.1 General description

The vegetation of the survey area is described below in relation to the geomorphic units occurring in the survey area (DPUD 1992). As is typical of many coastal areas with relatively young geologies, the vegetation of the dunes varied in the combinations of the more abundant species but, has relatively few of them. This makes the vegetation appear more uniform than it is, with different sites having vegetation that varies significantly in the proportion of the species present rather than the species present. The vegetation of the saline flats varies in a similar manner, although in this case the controlling factor in the low diversity of dominant species is the salinity of the soil rather than the uniformity of the soil.

Most of the vegetation of the survey area is in very good to excellent condition (see Appendix three for definition of scale), with the exception of some areas of the dunes with heavy invasion of *Cenchrus ciliaris (buffel grass) and some parts of the saline flats where there are a number of tracks.

Note that it has not been possible to map the distribution of all the units on the dunes and so they have not been given codes but that the units on the saline flats have been mapped in more detail and so have been given codes.

4.2 Plant communities observed on the site

4.2.1 Foredunes

This section includes the actual foredune and a low dune behind it with similar height and with different vegetation to the taller dunes of the relict foredune plain behind them. The foredunes at Mauds Landing have:

> Spinifex longifolius hummock grassland over Launea sarmentosa open herbland

Similar vegetation extends into the swale behind the foredune and sometimes onto the low dune behind the foredune. Associated species recorded were Senecio lautus, Trichodesma zeylanica and Atriplex isatidea. The soil was light grey-brown calcareous sand with white shell fragments and the site recorded was assessed as in

very good condition. (Site 66.) The low dune behind the foredune can have quite different vegetation to the foredune, e.g.:

Eulalia aurea tussock grassland over Carpobrotus "septentrionalis", Launea sarmentosa open herbland.

Associated species recorded were Trichodesma zeylanica, Calandrinia polyandra, Angianthus cunninghamii, Spinifex longifolius, Rhagodia preissii ssp. obovata, Corynotheca flexuosissima, Ptilotus villosiflorus, Chamaescyce drummondii ssp. drummondii, Senecio lautus and Eremophila glabra ssp. Dirk Hartog. In places this dune had patches of Acacia coriacea over the Eulalia. If Trichodesma was treated as a perennial rather than an annual, then a layer of open shrubland of this species would be included in the vegetation description. (Site 64.) This vegetation can extend over the swale behind the low dune onto the base of the first of the larger relict foredunes or there can be a stand of :

Pileanthus limacis low open heath with Eulalia aurea tussock grassland.

Associated species recorded in this vegetation stand were Trichodesma zeylanica, Rhagodia preissii ssp. obovata, Spinifex longifolius, Chamaescyce drummondii ssp. drummondii, Euphorbia boopthona, Calandrinia polyandra, Corynotheca flexuosissima, Eremophila glabra ssp. Dirk Hartog, Threlkeldia diffusa and Cassytha aurea var. aurea. If the Trichodesma zeylanica were treated as a perennial then an open shrubland layer of this species would need to be added to the vegetation description. This vegetation was in very good condition (site 65) however, it was noted that there was some disturbance close to the track between the relict foredune plain and the beach.

4.2.2 Relict foredune plain

The vegetation of the relict foredune plain is dominated by Acacia coriacea and Acacia tetragonophylla in the taller shrub layer and Pileanthus limacis and Acacia spathulifolia in the lower shrub layer. The lower slopes are similar in their vegetation to the aeolian flat/ridge, deflation basin and relict inlet spits. Vegetation developed includes:

Crests

Acacia coriacea ssp. coriacea, Olearia axillaris var. obovata shrubland over Acacia ryaniana, Pileanthus limacis low shrubland and Eualia aurea grassland over Carpobrotus "septentrionalis" open herbland.

Associated species were Rhagodia preissii ssp. obovata, Scaevola spicigera, Threlkeldia diffusa, Commicarpus australis, Dampiera incana ssp. incana, Salsola kali, Spinifex longifolius, Trichodesma zeylanica and Ptilotus villosiflorus. (Site 67.) This site was assessed as in excellent condition. If the Trichodesma was treated as a perennial, then it would be included in the upper shrub layer in the vegetation description. Further north-east along the same dune, the vegetation was similar but, had slight differences including absence of the Olearia axillaris ssp. obovata and less Acacia ryaniana, being described as:

Acacia coriacea shrubland over Pileathus limacis low shrubland to low open heath and Eulalia aurea, *Cenchrus ciliaris tussock grassland.

Associated species recorded were Santalum spicatum, Acacia tetragonophylla, Commicarpus australis, Carpobrotus "septentrionalis, Indigofera aff. brevidens, Olearia dampieri ssp. dampieri, Senna glutinosa ssp. chatelainiana, Trichodesma zeylanica, Rhagodia preissii ssp. obovata, Heliotropium crispatum, Corynotheca flexuosissima, Dampiera incana var. incana, Erachycome latisqamea, Chamaescyce drummondii ssp. drummondii, Salsola kali, Exocarpos aphyllus, Zygophyllum fruticulosum, Threlkeldia diffusa, Acacia ryaniana, Ptilotus villosiflorus, Acanthocarpus preissii and Eragrostis falcata. (Site 31.) There was less than 5% of the *Cenchrus present and the stand was rated as in very good to excellent condition rather than excellent condition because of its presence.

Swales

A swale behind the dune crest described above had somewhat different vegetation, although the dominants were the largely same:

Acacia coriacea shrubland over Pileanthus limacis, Olearia dampieri ssp.

dampieri low shrubland over Eualia aurea open tussock grassland.

Associated species recorded were Exocarpos aphyllus, Santalum spicatum, Acacia gregorii, Acanthocarpus preissii, Carpobrotus "septentrionalis", Scaevola cunninghamii, Chamaescyce drummondii ssp. drummondii, Indigofera cf. brevidens, Podolepis canescens, Gnephosis tenuissima, Eragrostis falcata, Swainsona calcicola, *Cenchrus ciliaris and patches of Whiteochloa airoides. There was no Fileanthus in the lower parts of the swale. The stand was rated as in very good to excellent condition. (Site 34.)

A swale near the eastern edge of the relict foredune plain and between a low dune and a very low dune had:

Acacia tetragonophylla open shrubland to shrubland over Eulalia aurea open grassland.

Associated species were Acacia coriacea ssp. coriacea, Pimelea microcephala, Carpobrotus "septentrionalis", Eragrostis falcatus, Scaevola cunninghamii, Acanthocarpus preissii, Whiteochloa airoides, Aristida holathera ssp. holathera, Zygophyllum fruticulosum and Sclerolaena uniflora. Similar vegetation occurs on low sand drifts on the salt flats (see below), where the amount of Scaevola cunninghamii can much higher. The site recorded in this unit was assessed as being in excelent condition. (Site 35.) Some areas of the same vegetation unit had small patches of Triodia pungens in them.

East facing slopes

An east facing slope of the extension of the dune crest with site 31 on it, had a variant with Thryptomene baeckeacea in the lower shrub layer:

Acacia coriacea ssp. coriacea, Acacia tetragonophylla, Santalum spicatum open shrubland to shrubland over Fileanthus limacis, Thryptomene baeckeacea low shrubland to low open heath.

This variant was only localised, with the Thryptomene being more common in the

taller dunes. Associated species were Eulalia aurea, *Cenchrus ciliaris, Carpobrotus "septentrionalis", Ptilotus villosiflorus, Salsola kali, Acacia ryaniana and Commicarpus australis. (Site 39.) This site was assessed as in very good condition rather than excellent because of the presence of *Cenchrus ciliaris and evidence of rabbits being present.

A gentle slope behind the dune site 31 was recorded on (above a small patch of saltflat and possibly lower than site 34) had vegetation that was similar to that of the aeolian flat/ridge, deflation basin and relict inlet spits. The vegetation was dominated by different species, although small amounts of these were in the preceding units:

> Exocarpos aphyllus, Acacia tetragonophylla, Acacia coriacea open shrubland over Acacia spathulifolia low open heath and Eulalia tussock grassland.

Associated species recored were Brachycome latisquamea, Pimelea microcephala, *Cenchrus ciliaris, Carpobrotus "septentrionalis", Chamaescyce drummondii ssp. drummondii, Scaevola tomentosa, Rhagodia preissii ssp. obovata, Olearia axillaris ssp. obovata, Threlkeldia diffusa, Lawrencia viridi-grisea, Alectryon oleifolius, Commicarpus australis, Podolepis canescens, Gnephosis tenuissima and Solanum cleistogamum. (Site 33.) This site was assessed as very good to excellent in condition, rather than excellent because of the presence of a small amount of *Cenchrus ciliaris.

Low sand drifts at rear of relict foredune plain

These areas are gently undulating and the sand layer is quite thin. Vegetation developed is intermediate between that of the dunes of the foredune plain and that of the inland spits, with the presence of Sporobolus in the grasslayer indicating an influence of the underlying salt flat soils. The vegetation developed was:

> Acacia coriacea ssp. coriacea, Exocarpos aphyllus open shrubland over Eulalia aurea, Sporobolus virginicus grassland.

Some patches had Olearia axillaris var. obovata to 10% cover, others had

Whiteochloa airoides as the grass layer. Associated species were Carpobrotus "septentrionalis", Frankenia pauciflora var. pauciflora, Scaevola cunninghamii, Eremophila glabra ssp. "Dirk Hartog", *Cenchrus ciliaris, Acacia tetragonophylla, Ptilotus exaltatus, Zygophyllum fruticulosum, Calandrinia polyandra, Acanthocarpus preissii, Acacia gregori, Cassytha aurea var. aurea, Panicum decompositum, Dampiera incana var. incana, Senecio lautus var. dissectifolius ? and Solanum cleistogamum. The stand recorded had a belt of Acacia ryaniana along its edge and was assessed as being in very good to excellent condition, with some patches of *Cenchrus ciliaris reducing the condition. (Site 29.)

4.2.3 Parabolic dunes

The vegetation of the parabolic dunes was observed to vary with the position (dune crests, slopes, swales) with crests generally having somewhat lower vegetation, although the dominant shrub (Acacia coriacea ssp. coriacea) was generally the same, with local dominance by Alectryon oleifolius or Santalum spicatum. Variation included the presence or absence of Pileanthus limacis and Thryptomene baeckeacea in the lower shrub layer, the degree of invasion by *Cenchrus ciliaris and the amount of Eulalia aurea present. The *Cenchrus seems to be more succesful in swales than dune crests and may be replacing Eulalia aurea (the most abundant local grass) or invading spaces not taken up by it.

Crests

The vegetation on the highest crest examined (near Maud Hill) was:

> Acacia coriacea ssp. coriacea, Santalum spicatum low open shrubland over Thryptomene baeckeacea, Pileathus limacis, Dampiera incana var. incana, Rhagodia preissii ssp. obovata Acanthocarpus preissii low shrubland and *Cenchrus ciliaris grassland.

The presence of the Santalum is localised, whereas the Acacia coriacea ssp. coriacea is ubiquitous. Associated species were Carpobrotus "septentrionalis", Trichodesma zeylanica, Acacia spathulifolia, Senna glutinosa ssp. chatelainiana, Rhynchosia cf. minima, Calandrinia polyandra, Eragrostis falcata, Indigofera cf. brevidens, Cassytha aurea var. aurea, Brachycome latisquamea, Euphorbia boopthona, Commicarpus

australis, Portulaca sp. Swainsona calcicola, Ptilotus villosiflorus, Senecio lautus and Eulalia aurea. (Site 21.) This site was assessed as in very good condition. Maud Hill has similar vegetation on the crest but has Pileanthus limacis to 10% cover and a few species not recorded at site 21.

A crest nearer to the beach and some what lower than site 21 had:

> Acacia coriacea ssp. coriacea, Acacia spathulifolia low shrubland over Eulalia aurea grassland and Carpobrotus "septentrionalis" open herbland.

Associated species were; Brachycome latisquamea, Scaevola spicigera, Acanthocarpus preissii, *Cenchrus ciliaris, Indigofera cf. brevidens, Rhagodia preissii ssp. obovata, Santalum spicatum, Pileanthus limacis, Ptilotus villosiflorus, Salsola kali, Eragrostis falcata, Calandrinia polyandra, Eremophila glabra ssp. "Dirk Hartog", Threlkeldia diffusa, Euphorbia boopthona, Heliotropium crispatum, Commicarpus australis, Chamaesyce drummondii ssp. drummondii, Zygophyllum fruticulosum and Dampiera incana var. incana. The site was assessed as being in very good condition. (Site 1.)

Westerly facing slopes

The westerly facing slope near site 1 (near the beach south of the Mauds Landing track) had similar vegetation to the crest, except there was more Acacia spathulifolia than Acacia coriacea ssp. coriacea, more Pileanthus limacis and more Santalum spicatum, the vegetation being:

> Acacia spathulifolia, Santalum spicatum, Acacia coriacea ssp. coriacea, Pileanthus limacis low shrubland to low open heath over Eulalia aurea open grassland.

Associated species recorded were: Acanthocarpus preissii, Olearia axillaris ssp. obovata, Dampiera incana var. incana, Carpobrotus "septentrionalis", Scaevola spicigera, Brachycome latisquamea, Salsola kali, Calandrinia polyandra, Euphorbia boopthona, Euphorbia drummondii spp. drummondii, Rhagodia preissii ssp. obovata and Commicarpus australis. This site was assessed as being in very good condition. (Site 2.)

Another slope nearby (more south-westerly) had rather different vegetation:

> Olearia axillaris ssp. obovata, Acacia coriacea ssp. coriacea low shrubland to shrubland or open heath over Acacia spathulifolia, Pileanthus limacis low open shrubland to low shrubland over Eualalia aurea open grassland.

This vegetation extended onto the nearby crest, and was noteworthy for the dominance of the Olearia (up to 35% cover). This species is not common in the study area but occurs sporadically near the coast. Associated species were: Carpobrotus "septentrionalis", Brachycome latisquamea, Euphorbia drummondii spp. drummondii, Eremophila ssp. "Dirk Hartog", Indigofera cf. brevidens, Dampiera incana var. incana, Rhagodia preissii ssp. obovata, Santalum spicatum and Calandrinia polyandra.

A westerly facing slope well back from the beach had somewhat different vegetation to sites 2 and 5, having:

> Acacia coriacea ssp. coriacea, Acacia tetragonophylla open shrubland over Senna artemisioides ssp aff. helmsii, Rhagodia preissii ssp. obovata low open shrubland over *Cenchrus ciliaris grassland.

Associated specis were: Trichodesma zeylanica, Rhynchoisa cf. minima, Eremophila glabra ssp. "Dirk Hartog", Sclerolaena uniflora, Alectryon oleifolius, Ptilotus obovatus, Carpobrotus "septentrionalis", Solanum cleistogamum and Eragrostis falcata. This site was assessed as being in poor condition because of the high level of invasion by *Cenchrus ciliaris. However, the area in poor condition was quite small with the adjoining crest and areas along the slope (site 17, see below) being in very good condition. (Site 16.) Around the slope from site 16, the vegetation was in better condition and was described as:

> Acacia coriacea ssp. coriacea open shrubland over Thryptomene baeckeacea low open heath to low heath.

Associated species were: Eremophila glabra ssp. "Dirk Hartog", *Cenchrus ciliaris, Carpobrotus "septentrionalis", Eragrostis falcata, Dipteracanthus australasicus ssp. australasicus, Rhynchosia cf. minima, Exocarpos aphyllus, Sida cf. fibulifera, Scaevola cunninghamii, Scaevola spicigera, Senna glutinosa ssp. chatelainiana, Dianella revoluta ssp. divaricata, Trichodesma zeylanica, Alectryon oleifolius, Indigofera cf. boviperda, Acanthocarpus preissii, Threlkeldia diffusa, Calandrinia polyandra, Corynotheca pungens and Zygophyllum fruticulosum. This site was assessed as in very good to excellent condition and had patches of Eulalia aurea and *Cenchrus ciliaris. (Site 17.)

Similar vegetation to that at site 16 was observed on the lower parts and in the gullies of the northerly facing slopes just north of Maud Hill Maud Hill while the upper slopes had vegetation similar to site 17.

An upper westerly facing slope south of Maud Hill had vegetation somewhat more like that of the crests, having:

> Acacia coriacea ssp. coriacea low open shrubland to low shrubland over Thryptomene baeckeacea low open heath.

Associated species were Podolepis canescens, Brachycome latisquamea, Gnephosis tenuissima, Scaevola spicigera, Eulalia aurea, Eragrostis falcata, Calandrinia polyandra, Acacia ryaniana, Euphorbia drummondii ssp. drummondii, Carpobrotus "septentrionalis", Heliotropium crispatum, Corynotheca flexuosissima, Dampiera incana var. incana, Indigofera cf. brevidens and Zygophyllum fruticulosum. This site was assessed as in excellent condition. (Site 62.) The adjoining crest had similar vegetation, except that it had some Fileanthus limacis as well. The lower third of the slope on which site 62 was situated varied in a different way, having no Thryptomene baeckeacea and significant amount of Eulalia aurea (< 20%) and Trichodesma zeylanica, the vegetation developed being:

> Acacia coriacea ssp. coriacea open shrbland over Acacia ryaniana, Dampiera incana var. incana, Khagodia preissii ssp. obovata low open shrubland over Eualalia aurea grassland.

If the Trichodesmma was treated as a perennial, then this species would be included in the first stratum of the vegetation.

Lower north facing slope adjacent to salt flat

One stand of vegetation dominated by Acacia rostellifera was seen in the survey area. This stand was quite narrow, and occurred on the lower slope of the parabolic dunes adjacent to the salt flats and north of Maud Hill. As noted in the flora section, this population represents a significant northern extension of the known range of Acacia rostellifera. The vegetation developed was:

> Acacia rostellifera high shrubland to open scrub over Rhagodia preissii ssp. obovata open shrubland to shrubland over Eulalia aurea grassland.

Associated species were Threlkeldia diffusa, Zygophyllum fruticulosum, Trichodesma zeylanica, Commicarpus australis, Eragrostis falcata, Lawrencia densiflora, Eremophila glabra ssp. "Dirk Hartog", Ptilotus villosiflorus, Acacia coriacea ssp. coriacea, Olearia dampieri ssp. dampieri, Portulaca sp., Carpobrotus "septentrionalis", Indigofera cf. brevidens, Alectryon oleifolius and Heliotropium crispatum. This stand was assessed as being in excellent condition. (Site 22.)

A stand of similar vegetation was observed near Pt. Cloates (on a lower dune slope at the east of the parabolic dunes) and this vegetation type probably occurs sporadically along the coast. It is certainly not common and the number of stands is likely to be quite low.

East facing slope

A somewhat irregular, east facing, dune slope at the east of the parabolic dunes was sampled, the vegetation developed being:

> Acacia coriacea ssp. coriacea open shrubland over Thryptomene baeckeacea low open heath with *Cenchrus ciliaris, Eragrostis falcata grassland.

This vegetation extended upslope to the crest. Associated species were: Rhagodia preissii ssp. obovata, Carpobrotus "septentrionalis", Sida cf. fibulifera, Pimelea microcephala, Threlkeldia diffusa, Rhynchosia cf. minima, Senna glutinosa ssp.

chatelainiana, Commicarpus australis, Santalum spicatum, Alectryon oleifolius, Dipteracanthus australasicus ssp. australasicus, Sclerolaena uniflora, Calandrinia polyandra, Dianella revoluta ssp. divaricata, Corynotheca flexuosissima, Acacia tetragonophylla, Senna artemisioides ssp. oligophylla X helmsii and Ptilotus obovatus. (Site 12.)

Another east facing slope but, closer to the coast was also sampled. It was steeper than the one above and had somewhat different vegetation, being described as;

> Acacia coriacea ssp. coriacea low open shrubland to open shrubland over Acacia spathulifolia, Dampiera incana var. incana, Pileanthus limacis low shrubland over Eualaia aurea grassland.

Associated species were: Carpobrotus "septentrionalis", Corynotheca flexuosissima, Indigofera cf. brevidens, Podolepis canescens, Calandrinia polyandra, Scaevola spicigera, Salsola kali, Euphorbia boopthona, Heliotropium crispatum, Brachycome latiuscula, *Cenchrus ciliaris, Ptilotus villosiflorus, Portulaca sp., Flaveria australasica. The site was assessed as being in good to very good condition. (Site 6.) At the foot of this slope there was a gentler slope, also easterly facing, with somnewhat different vegetation:

> Acacia coriacea ssp. coriacea low open shrubland to open shrubland over Olearia dampieri ssp. dampieri low open shrubland over Eulalia aurea, *Cenchrus ciliaris grassland.

Some patches within the stand had Scaevola spicigera to 15% cover. Associated species were: Indigofera cf. brevidens, Carpobrotus "septentrionalis", Portulaca sp., Brachycome latiuscula, Commicarpus australis, Euphorbia drummondii ssp. drummondii, Trichodesma zeylanica, Threlkeldia diffusa, Rhagodia preissii ssp. obovata and Pileanthus limacis. This site was assessed as being in poor to good condition, and was unusual in this regard as most of the dunes were in significantly better condition. (Site 7.)

Swales

The large swale in the parabolic dunes south-west of Maud Hill had similar vegetation to parts of the adjacent westerly facing slope slopes (see site 62, above), having:

> Acacia coriacea ssp. coriacea open shrubland to shrubland over Thryptomene baeckeacea low open heath and Eulalia aurea open grassland over Carpobrotus "septentrionalis" open herbland.

Associated species were: Exocarpos aphyllus, Zygophyllum fruticulosum, Euphorbia boopthona, *Cenchrus ciliaris, Eragrostis falcata, Rhagodia preissii ssp. obovata, Indigofera cf. brevidens, Santalum spicatum, Lawrencia densiflora, Threlkeldia diffusa, Acacia spathulifolia, Eremophila glabra ssp. "Dirk Hartog", Salsola kali, Commicarpus australis, Trichodesma zeylanica and Portulaca sp. This site was assessed as being in very good to excellent condition. In the absence of the *Cenchrus it would have been assessed as in excellent condition. (Site 63.) Within the swale there were patches were there was almost no Thryptomene and which had Eulalia to 30% cover.

The vegetation in the lower parts of a swale near the beach and south of the track to Mauds Landing was similar , being described as:

> Acacia coriacea ssp. coriacea open shrubland to shrubland over Thryptomene baeckeacea low shrubland to low open heath over *Cenchrus ciliaris, Eualalia aurea grassland.

This vegetation extended up the adjoining easterly and westerly facing slopes. Associated species were: Olearia dampieri ssp. dampieri, Carpobrotus "septentrionalis", Eragrostis falcata, Rhagodia preissii ssp. obovata, Trichodesma zeylanica, Dampiera incana var. incana, Commicarpus australis, Sida cf. calyhymenia, Indigofera cf. brevidens, Euporbia boopthona, Dianella revoluta ssp. divaricata, Threlkeldia diffusa, Acanthocarpus preissii, Salsola kali, Rhynchosia cf. minima, Portulaca sp. and Heliotropium crispatum. This site was assessed as being in very good condition, it would have been assessed as higher except for the

significant infestation of *Cenchrus ciliaris. (Site 4.) If the Trichodesma was treated as a perennial then it would have been included in the lower shrub layer in the description of the vegetation. The swale was gently sloping along its axis and the vegetation was rather different in the upper part, being described as:

> Acacia coriacea ssp. coriacea open shrubland over Acacia spathulifolia, Rhagodia preissii ssp. obovata low shrubland over Eulalia aurea open grassland to grassland.

Associated species were: Carpobrotus "septentrionalis", Threlkeldia diffusa, Salsola kali, Santalum spicatum, Commicarpus australis, Euporbia boopthona, Brachycome latiuscula, *Cenchrus ciliaris, Ptilotus villosiflorus, Indigofera cf. brevidens, Euphorbia drummondii ssp. drummondii, Dampiera incana var. incana, Scaevola spicigera and Pileathus limacis. The site was assessed as being in very good condition. (Site 3.)

4.2.4 Deflation basins, aeolian flats/ridges and inlet spits (relict)

These geomorphic units have in common that they are quite low-lying. This is presumably the controling factor in much of their, vegetation (through affecting water relations), as they have in common that Acacia tetragonophylla is the dominant or co-dominant shrub on them.

Deflation basin

One deflation basin was sampled, it had the form of a small irregulrly surfaced plain on the western side of the most easterly parabolic dune in the survey area. The vegetaitn developed was;

> Acacia tetragonophylla, Acacia coriacea, Exocarpos aphyllus shrubland over Thryptomene baeckeacea, Diperacanthus australasicus ssp. australasicus, Scaevola cunninghamii, low open to low open heathshrubland over *Cenchrus ciliaris, Eragrostis falcata grassland.

The stand was quite variable, with small patches of Whiteochloa airoides and Triodia pungens and the Thryptomene varying from less than 10% up to 50% cover.

It also was one of the more diverse sites recorded. Associated species were: Carpobrotus "septentrionalis", Ptilotus obovatus, Sida cf. fibulifera, Rhagodia preissii ssp. obovata, Dampiera incana var. incana, Rhynchosia cf. minima, Lawrencia densiflora, Euphorbia boopthona, Sclerolaena uniflora, Euphorbia drummondii ssp. drummondii, Calandrinia polyandra, Dianella revoluta ssp. divaricata, Acanthocarpus preissii, Brachycome latisquamea, Sida cf. calyxhymenia, Goodenia microptera, Zygophyllum fruticulosum, Olearia dampieri ssp. dampieri, Salsola kali, Indigofera cf. brevidens and Commicarpus australis. (Site 18.)

Aeolian flats/ridges

A small area of the geomorphological unit described as "aeolian flat/ridge" (DPUD 1992) occurs in the survey area. It has quite varied vegetation, with stands dominated by several different species. There are obvious similarities with the vegetaion of the deflation basin described above, but there are also other vegetation types. The lowest slope (very slight next to edge of salt flat) had:

> Acacia tetragonophylla, Exocarpos aphyllus open shrubland over Acanthocarpus preissii, Scaevola cunninghamii, Frankenia puaciflora var. pauciflora, Eremophila glabra ssp. "Dirk Hartog" low open shrubland with Eulalia aurea, Sporobolus virginicus open grassland to grassland.

This site (like site 18 on the deflation basin) was quite diverse compared to many others on the dunes in the study area. Associated species were: Lawrencia densiflora, Rhynchosia cf. minima, Aristida holathera ssp. holathera, Spinifex longifolius, *Cenchrus ciliaris, Brachycome latiuscula, Threlkeldia diffusa, Carpobrotus "septentrionalis", Salsola kali, Indigofera cf. brevidens, Eragrostis falcata, Sclerolaena uniflora, Euphorbia boopthona, Abutilon cf. exoneum, Zygophyllum fruticulosum, Ptilotus exaltatus, Commicarpus australis, Rhagodia preissii ssp. obovata, Dianella revoluta ssp. divaricata, Euphorbia drummondii ssp. drummondii and Senna glutinosa ssp. chatelainiana. (Site 8.)

Southwards along the slope next to a small area of salt flat cut off from the main salt flat there was a small area of quite different vegetation:

Whiteochloa airoides grassland.

This stand did have some shrubs but only at very low cover. Associated species included: Acacia coriacea, Exocarpos aphyllus, Acanthocarpus preissii, Brachycome latiuscula, Eulalia aurea, Eragrostis falcata, Carpobrotis "septentrionalis" and Lawrencia densiflora. (Site 9.) Similar small areas of Whiteochloa grassland were seen on the thinner areas of sand at the eastern side of the relict foredune plain.

Slightly upslope from sites 8 and 9 (to the west of the small area of salt flat) was a larger area of a variant of the vegetation found at site 8. It was described as:

Acacia coriacea, Acacia tetragonophylla, Exocarpus aphyllus shrubland over Eulalia aurea, Spinifex longifolius, Sporobolus virginicus grassland.

Associated species included: *Cenchrus ciliaris, Commicarpus australis, Sida cf. fibulifera, Brachycome latiuscula, Rhynchosia cf. minima, Threlkeldia diffusa, Diplopeltis intermedia var. incana and Acacia ryaniana. The site was assessed as being in very good to excellent condition, rather than excellent condition because of the presence of a small amount of *Cenchrus ciliaris. (Site 11.) At the upper edge of the vegetation stand there was a narrow belt of *Cenchrus ciliaris (this site and other sites indicate the *Cenchrus is exploiting niches where it can be more successful but is not as competetive in sites where the vegetation is denser).

Inlet spit (relict)

This geomorphic form presents as a low dune or sand drift on the salt flats. The vegetation is similar to that of the lower edges of the relict foredune plain, the deflation basin and the aeolian flat/ridge in the dominance of Acacia tetragonophylla, being described as:

Acacia tetragonophylla open shrubland to shrubland over Scaevola cunninghamii low shrubland and Sporobolus virginicus open grassland.

Associated species were Rhagodia preissii ssp. obovata, Calandrinia polyandra, Carpobrotus "septentrionalis", Salsola kali, Frankenia pauciflora ssp. pauciflora,

Acacia coriacea ssp. coriacea, Sclerolaena uniflora, Eulalia aurea, Acacia ryaniana, Lawrencia densiflora, Whiteochloa airoides (in patches), Acanthocarpus preissii, Dianella revoluta var. divaricata and Eremophila glabra ssp. "Dirk Hartog".

4.2.6 Saline flats

The saline flats in the study area are generally very low in relef but, there are some slight slopes up to the edges of dunes, a few very slight rises and a "bank" where there may have been a linear collapse of the surface. As well as the main flat there are several smaller areas that have been cut off from it by the encroachment of the parabolic dunes and the relict foredune plain. The condition of the vegetion on the saline flats in the study area was rated as very good to excellent, without the numerous tracks most of the area would have been rated as excellent.

The vegetation of saline flats often has numerous units, some of which are similar, and which have relatively few species and this is the case in the study area. Although, the units at the edges of the flats are richer in species. It should be noted that the boundaries between different units in the field is usually quite marked and most stands are relatively uniform, even though some units may have only one or two dominants that are different.

FL Frankenia pauciflora ssp. pauciflora, Lawrencia viridi-grisea low shrubland to low open heath over Sporobolus virginicus open grassland to grassland.

This unit occurs around the edge of the parabolic dunes and the relict foredune plain and in a small areas of salt flat cut off by the parabolic dunes. Associated species at one site (site 10) were: Carpobrotus "septentrionalis", Eremophila glabra ssp. "Dirk Hartog", Portulaca sp., Halosarcia indica ssp. aff. bidens, Sclerolaena uniflora, Eragrostis falcata, Ptilotus exaltatus, Threlkeldia diffusa, Angianthus cunninghamii, Scaevola cunninghamii, Calandrinia polyandra, Euphorbia drummondii ssp. drummondii and Aristida holathera ssp. holathera. This site was assessed as being in very good to excellent condition (tending towards excellent). A second site (site 32) was not recorded in detail but also had Rhagodia preissii ssp. obovata and Lawrencia densiflora. A third site (site 30, on the salt flats) had very little Lawrencia viridi-grisea and was more open. Associated species at this site not at the other sites

were: *Cenchrus ciliaris, Commicarpus australis, Calandrinia polyandra, Zygophyllum fruticulosum, Goodenia microptera and Swainsona calcicola.

Fp Frankenia pauciflora ssp. pauciflora low open shrubland over Sporobolus virginicus, Carpobrotus "septentrionalis" grassland/herbland.

This unit is a variant of the unit above, and was observed on the lower slope of one of the parabolic dunes. It was more open, with very little Lawrencia viridigrisea and more Carpobrotus. Associated species were Calandrinia polyandra, Hemichroa diandra, Eremophila glabra ssp. "Dirk Hartog", Sclerolaena uniflora, Rhynchosia cf. minima and Portulaca sp. (Site 15.)

FH Frankenia pauciflora ssp. pauciflora, Hemichroa diandra low shrubland.

This unit is also a variant of the unit based on sites 10 and 32 (see two units above). It is different in having more Hemichroa diandra and less Lawrencia viridi-grisea, as well as being less diverse. Associated species were: Lawrencia viridi-grisea, Carpobrotus "septentrionalis, Sporobolus virginicus and Lawrencia densiflora. (Site 23.)

MF Muellerolimon salicorniaceum, Hemichroa diandra, Frankenia pauciflora ssp. pauciflora, Frankenia cinerea low open heath.

This unit was near the edge of the flat and this shows up in the larger number of associated species than recorded for most other units on the flats. Associated species: Sporobolus virginicus, Lawrencia viridi-grisea, Carpobrotus "septentrionalis", Angianthus cunninghamii, Lawrencia densiflora, Scaevola spinescens, Sclerolaena uniflora, Calandrinia polyandra, Euphorbia boopthona Scaevola cunninghamii and Ptilotus exaltatus. (Site 24.) Another site (site 30A) was similar but did not have Hemichroa diandra and Frankenia cinerea and had more Sporobolus virginicus.

HM Halosarcia halocnemoides ssp. tenuis, Muellerolimon salicorniaceum low shrubland to low open heath (rarely low closed heath).

This unit was one of the more widespread on the flats and was quite variable in the total cover of the plants. Associated species (at site 13) were: Sporobolus virginicus, Frankenia cinerea and Hemichroa diandra. (Note the Muellerolimon could be treated as a herb on its form but, is somewhat stiff and so has been treated as a shrub here.)

MH Muellerolimon salicorniaceum, Halosarcia halocnemoides ssp. tenuis low shrubland with Sporobolus virginicus grassland.

Two of the dominant species in this unit are the same as the preceding unit (but reversed in relative amount present. The third species was present but only at low amounts in the preceding unit. Associated species were: Hemichroa diandra, Lawrencia viridi-grisea, Frankenia pauciflora ssp. pauciflora and Frankenia cinerea. (Site 26.)

AF Angianthus cunninghamii, Frankenia pauciflora ssp. pauciflora low open heath over Sporobolus virginicus, Carpobrotus "septentrionalis" grassland/ herbland.

This unit (like the unit based on sites 10 and 32) occurs on the very slight slopes near the edges of the sand dunes and inlet spits and is more diverse in species than the units dominated by Halosarcia species. Associated species were: Eremophila glabra ssp. "Dirk Hartog", Streptoglossa liatroides, Sclerolaena uniflora, Rhagodia preissii ssp. obovata, Calandrinia polyandra, Lawrencia densiflora, Senecio lautus ssp. dissectifolius?, Podolepis microcephala, Euphorbia coghlanii ? and Eragrostis dielsii. In the upper part of the stand, Scaevola cunninghamii becomes significant in cover. (Site 29.)

Hh,p Halosarcia halocnemoides ssp. nov., Halosarcia peltata low shrubland to low open heath.

This unit was very simple floristically (no associated species were noted at site 14). It was also noted that the stand was taller at the edges. There is sometimes a lower layer of Muellerolimon salicorniaceum low shrubland.

Hpt Halosarcia pterygosperma ssp. pterygosperma low shrubland to low open heath over Muellerolimon salicorniaceum, Halosarcia halocnemoides ssp. tenuis low shrubland.

Associated species were: Sporobolus virginicus, Hemichroa diandra, Samolus sp. "Shark Bay" and Frankenia cinerea. This unit was recorded in a slight depression on the salt flat. (Site 25.). A second site referred here was similar but had a much more open lower layer, additional associated species here were: Lawrencia viridi-grisea and Frankenia pauciflora ssp. pauciflora. (Site 46.)

HL Halosarcia pterygosperma ssp. pterygosperma low open shrubland over Lawrencia viridi-grisea, Hemichroa diandra low shrubland and Sporobolus virginicus grassland.

Associated species: Streptoglossa liatroides, Podolepis microcephala, Frankenia pauciflora ssp. pauciflora, Calandrinia polyandra, Samolus sp. "Shark Bay" and Myoporum montanum. This unit has some similarities to the unit described above from sites 10 and 32, but that has no Halosarcia, much more Frankenia and had more species. (Site 27.)

HF Halosarcia peltata, Halosarcia pterygosperma ssp. pterygosperma, Frankenia cinerea, Hemichroa diandra low shrubland.

This unit was observed on a very gently sloping site next to the hypersaline pool. Associated species were: Angianthus acrohyalinus, Eragrostis dielsii, Muelerolimon salicorniaceum, Lawrencia viridi-grisea, Lawrencia densiflora, Podolepis microcephala and Eulalia aurea. (site 44.)

Hh,s Halosarcia halocnemoides ssp. nov., Halosarcia sp. low open heath to low closed heath over Muellerolimon salicorniaceum, Samolus sp. "Shark Bay" low shrubland/herbfield.

This unit is quite variable in the cover of the Halosarcia layer and in the lower layer, with some stands having little Muellerolimon and no Samolus. Associated species

were: Sporobolus virginicus and Hemichroa diandra. (Site 36, 36A.) This is one of the more extensive units on the salt flats and intergrades with the unit below (possibly rather than intergrades, contains a number of similar units: it is a matter of scale as to which you choose). Similar vegetation but, somewhat denser and taller occurred along a bank (presumably caused by a subsurface soil collapse) on the saltflat. This stand had a narrow, linear presentation. (Site 45.)

HFM Halosarcia halocnemoides ssp. nov. low open shrubland over Frankenia cinerea, Hemichroa diandra, Muellerolimon salicorniaceum low shrubland.

This unit was recorded on a slight slope on the salt flats. Associated species were: Podolepis microcephalus, Sporobolus virginicus and Eragrostis dielsii. (Site 37.) This unit is fairly variable, with another stand having a similar lower layer in species composition but, having much less of the Hemichroa diandra and Frankenia cinerea (site 40, in a slight depression). Additional associated species at this site were Frankenia pauciflora ssp. pauciflora, Sclerolaena uniflora and Lawrencia viridi-grisea.

Hct Halosarcia halocnemoides ssp. cordata, Halosarcia halocnemoides ssp. tenuis low shrubland

This unit was observed on a slight rise between two claypans on the salt flats. The only associated species was Muellerolimon salicorniaceum. (Site 41.)

Hp Halosarcia peltata low open heath to low closed heath.

This unit was observed in a slight depression between the unit above and one of the claypans. Associated species were: Halosarcia halocnemoides ssp. tenuis, Eragrostis dielsii and Muellerolimon salicorniaceum. (Site 42.)

4.2.7 Hypersaline pool

There is one "claypan" on the flats that is better defined, with more pronounced banks, than the others. This was described in the geomorphological study (DFUD

1992) as a "hypersaline pool". While it was dry at the time of the current survey, over the entire floor there was a white fibrous material that was obviously the dried and bleached remnant of an aquatic plant species. It has not been possible to identify this unequivocably but, it seems likely that it is the remains of a Ruppia species or a similar aquatic plant.

R? Ruppia ? aquatic herbfield (seasonal).

While the material seems fiarly uniform, it contains both a seedcase and what appears to be a spore case. this indicates that there may also be a second species involved (possibly a Chara, or stonewort). (Site 45.)

While claypans and saltlakes are relatively common in Western Australia, it is quite uncommon for them to have an aquatic vegetation over them and this site must be considered to be of some particular interest.

5.0 CONSERVATION VALUE FOR FLORA AND VEGETATION

5.1 Conservation value for flora

The study area obviously has conservation value for the populations of the plant species found on it. However, except for the species discussed in detail above (see section 3) this is a general value rather than a specific and localised value. That is , given the small size of the area, the fairly extensive distribution of many of the flora species found in it and the limited degree of disturbance of much of their ranges, the overall conservation value for flora of the study area should be ranked as low to moderate.

The value for the priority species recorded is obviously higher, but it must also be taken into consideration that these species have not been specifically surveyed and that they may be more common than current herbarium collections suggest.

The value for species at the ends of their range is hard to assess, particularly in the absence of more detailed surveys of adjoining areas. It is a significant part of the value of those species from a conservation viewpoint but, the value of a population of a widespread species at the end of its range is obviously much less than the value of a population of a rare species.

Untill better material is available, no definite comment can be made on the conservation value of the population of the aquatic species from the hypersaline pool. However, it is unlikely to be a common species.

5.2 Conservation value for vegetation

The conservation value of the two major vegetation types in the study area, i.e of the coastal dunes and the saline flats needs to assessed separately.

5.2 Conservation value for vegetation of the coastal dunes in the study area

To fully assess the conservation value of the coastal dune vegetation in the survey area, it is necessary to understand that there are two scales of variation within what is an apparently uniform vegetation. These are the local scale where on different (but near to each other) slopes and crests, a relatively small suite of species swap dominance to make different vegetation types (some of which are very similar and

others more markedly different) and a more significant scale of variation at a sub-regional level where there are significant changes in the total species complement and in what species are dominant.

The first scale of variation means that at a local level there is more variation than there at first appears to be, with variations from dune to dune in the abundance of different species. This scale of variation is not highly significant from a conservation viewpoint but does have value.

The second scale of variation includes variation between different locations along the coast but in the same region, such as between those in the study area, those about three kilometres south of Coral Bay and those at Point Cloates. Generally this type of variation is more substantial the further apart areas are but, may be occur as separate subregions (i.e. subregions may be relatively uniform but have significant differences between them).

For example, Banksia ashbyae is present on some of the dunes south of Coral Bay in sufficient quantity to be included in the vegetation description but, is not present on those in the study area. Otherwise these dunes seem very similar to those at Mauds Landing and and a detailed study would probably include them in the same subregion.

In contrast, the most abundant native grass in the study area is Eulalia fulva but, at point Cloates, Whiteochloa airoides is the most abundant native grass and there is very little Eulalia fulva; a complete reversal of the situation in the study area. There are also other differences in the species composition between the dunes at Mauds Landing and those at Pt. Cloates and a more detailed study would probably put them in different subregions. This scale of variation is quite significant from a conservation viewpoint.

When the variation in the vegetation of the dunes is coupled with the fact that in a regional context the dunes system is fairly narrow (i.e. does not have a large total area). Then, the vegetation of the coastal dune system as a whole obviously has significant value for conservation. However, the area of dunes in the study area is a

relatively small portion of this system. Consequently, its value for the conservation of vegetation (taking both the size of the area and the regional and local variation of the vegetation into account) should be assessed as moderate. It should be noted however, that if the coastal system became fragmented then the value of remaining areas would increase.

5.3 Conservation value for vegetation of the saline flats in the study area

The saline flats in the study area are part of a series of such flats (relict tidal flats) found along the coastline from at least Mauds Landing to Point Cloates but, probably extending further north and south. While it was not possible during this survey to examine many of these, it was possible to briefly examine some between Mauds Landing and Pt Cloates. They are disjunct and variable in size and in the vegetation found on them. Their total area in a regional contex is quite small.

The flat at Mauds Landing was the biggest seem and had the largest range of vegetation types. It was noted by Beard (1975) as "a large samphire marsh" and is one of three such marshes behind coastal dunes large enough to be shown on his map between Carnarvon and the tip of North West Cape (including one at the tip of the Cape). Beard's map does shows similar vegetation adjoining Lake MacLeod but does not give sufficient detail to assess the degree of similarity.

It was noted when inspecting other saline flats behind the dunes between Mauds Landing and Pt. Cloates that some had only the vegetation types found at the outer edges of the Coral Bay flat, i.e they are dryer. Others, although smaller than the flat at Mauds Landing had stands of the larger Halosarcia species as well as the vegetation types found at the dryer edges.

While the vegetation of these saline flats is similar in appearance to succulent shrublands around many saltlakes in the interior of Western Australia there are somewhat separate suites of species in coastal and inland areas (P. Wilson pers comm.). This suggests that their conservation value should be assessed as part of a series of coastal samphire flats, rather than simply as part of a broader, more widely distributed categorey of succulent shrublands.

Given the relatively small proportion of the region occupied by saline flats formed from relict coastal salt flats, the large size of the Mauds Landing flat, the variability of the vegetation on it and the good condition of the vegetation on it (excepting where affected by tracks) the vegetation of this flat must be considered to have significant conservation value for vegetation. Obviously, the study area only includes part of this Mauds Landing saline flat and the value of this area is less than that of the whole flat but, is still significant.

Possibly of particular value is the hypersaline pool with its Ruppia ? aquatic herbland. While it is difficult to assess this vegetation without better material (and more knowledge of other possible occurences), it is quite unusual and as such until better information is available should be considered to have significant conservation value.

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Mr G.J. Kieghery (of the Dept of CALM) gave advice on the conservation value of the Ruppia ? vegetation of the hypersaline pool.

APPENDIX ONE: Flora recorded for the study area

FLOWERING PLANTS (Angiospermae)
MONOCOTYLEDONS

POTAMOGETONACEAE
Ruppia ? (On floor of salt pan; very dessicated)

POACEAE
Aristida holathera var. holathera
*Cenchrus ciliaris
Cymbopogon ambiguus
Eragrostis dielsii
Eragrostis eriopoda
Eragrostis falcata
Eulalia aurea
Panicum decompositum
Spinifex longifolius
Sporobolus virginicus
Stipa elegantissima
Triodia pungens
Whiteochloa airoides

DASYPOGONACEAE
Acanthocarpos preissii

PHORMIACEAE
Dianella revoluta var. divaricata

ANTHERICACEAE
Corynotheca flexuosissima
Corynotheca pungens

DICOTYLEDONS

SANTALACEAE
Exocarpos aphyllus
Santalum spicatum

CHENOPODIACEAE
Atriplex isatidea
Atriplex vesicaria ssp. incompta
Atriplex vesicaria ssp. variabilis
Halosarcia ssp. cordata (First record from a coastal site.)
Halosarcia ssp. tenuis
Halosarcia halocnemoides ssp. nov. (Not uncommon.)
Halosarcia indica ssp. leiostachya forma "benthamii" (Probably a separate taxon.)
Halosarcia indica ssp. aff. bidens
Halosarcia peltata (Range extension from Shark Bay, new northern limit.)
Halosarcia sp. nov. aff. pruinosa

Halosarcia pterygiosperma ssp. pterygiosperma
Rhagodia preissii ssp. obovata
Salsola kali
Sclerolaena uniflora
Threlkeldia diffusa

AMARANTHACEAE
Hemichroa diandra
Ptilotus exaltatus
Ptilotus obovatus
Ptilotus villosiflorus

NYCTAGINACEAE
Commicarpus australis

GYROSTEMONACEAE
Gyrostemon ramulosus

AIZOACEAE
Carpobrotus "septentionalis" (An undescribed species, found from north of Kalbari to Exmouth - G. Kieghery pers comm.)

PORTULACACEAE
Calandrinia polyandra
Portulaca sp. (Mauds Landing on lower dune crest south of track.)

LAURACEAE
Cassytha aurea var. aurea

BRASSICACEAE
Lepidium rotundum

MIMOSACEAE
Acacia coriacea ssp. coriacea
Acacia gregorii
Acacia rostellifera (Large range extension to new northern limit; previously Zuytdorp Cliffs.)
Acacia ryaniana
Acacia sclerosperma
Acacia spathulifolia
Acacia tetragonophylla var. (Broad phyllode form restricted to NW Cape and nearby.)

CAESALPINIACEAE
Senna artemisioides ssp aff. helmsii
Senna artemisioides ssp. oligophylla X helmsii (Hybrids between ssp. oligophylla and ssp. helmsii are very common.)
Senna glutinosa ssp. chatelainiana

PAPILIONACEAE
Indigofera cf. brevidens

Lotus australis (forma!)
Rhynchosia cf. minima
Swainsona calicola

ZYGOPHYLLACEAE
Zygophyllum fruticulosum

EUPHORBIACEAE
Euphorbia boophthona?
Euphorbia drummondii ssp. drummondii
Euphorbia coghlanii ?

SAPINDACEAE
Alectryon oleifolius ssp. oleifolius
Diplopeltis intermedia var. incana

MALVACEAE
Abutilon cf. exoneum
Lawrencia densiflora
Lawrencia viridi-grisea
Sida cf. fibulifera
Sida cf. calyxhymenia

FRANKENIACEAE
Frankenia cinerea
Frankenia pauciflora var. pauciflora

THYMELEACEAE
Pimelea microcephala

MYRTACEAE
Pileanthus limacis
Thryptomene baeckeacea

PRIMULACEAE
Samolus sp. Shark Bay (M.E. Trudgen 7410)

PLUMBAGINACEAE
Muellerolimon salicorniaceum

ASCLEPIADACEAE
Sarcostemma viminale ssp. australe

BORAGINACEAE
Heliotropium crispatum
Heliotropium strigosum
Trichodesma zeylanicum

SOLANACEAE
Solanum cleistogamum
Solanum lasiophyllum

ACANTHACEAE
Dipteracanthus australasicus ssp. australasicus

MYOPORACEAE
Eremophila glabra ssp. Dirk Hartog (M.Manning 6/9/64)
Myoprum montanum

GOODENIACEAE
Dampiera incana var. incana
Goodenia micropiera
Goodenia sp. (Inadequate for identification.)
Leschenaultia subcymosa
Scaevola cunninghamii (Poorly collected.)
Scaevola spicigera
Scaevola spinescens
Scaevola tomentosa

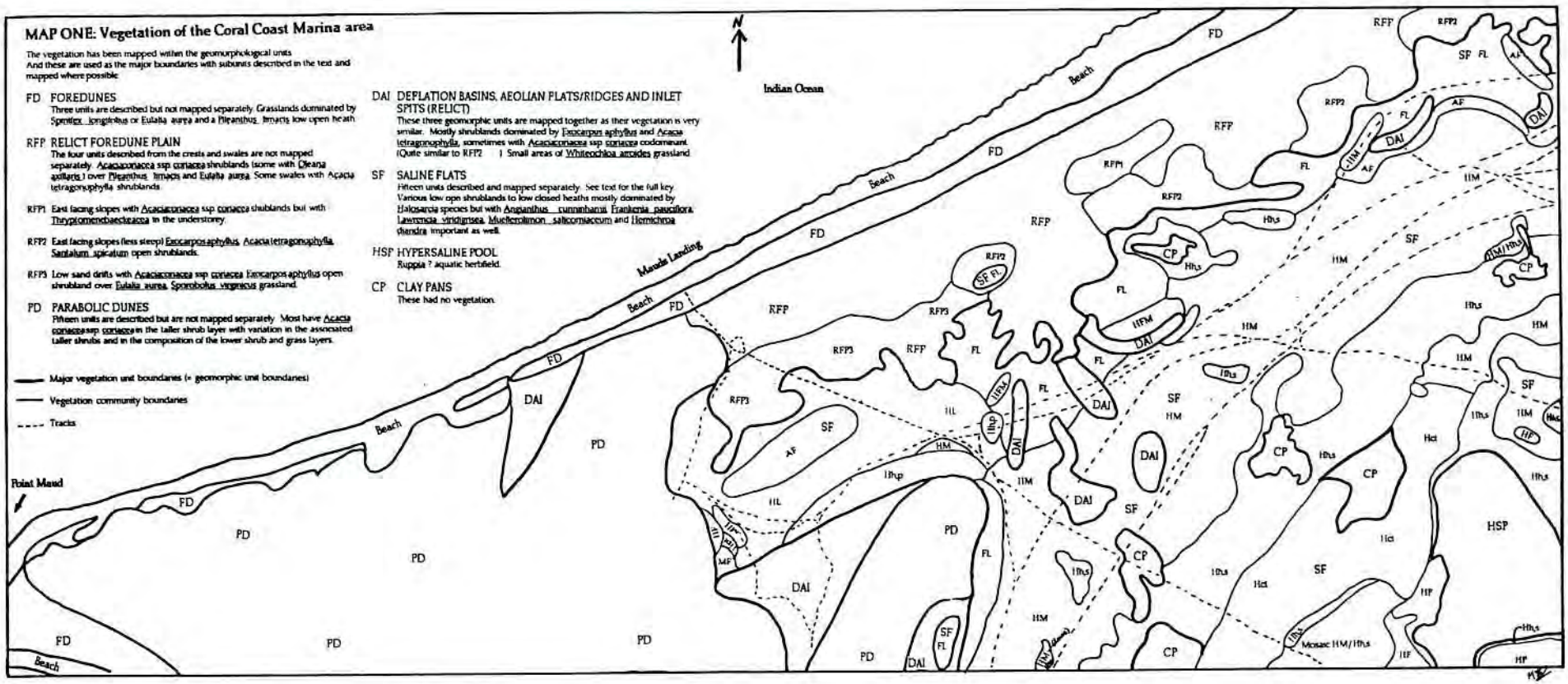
ASTERACEAE
Angianthus acrohyalinus
Angianthus cunninghamii
Brachycome latisquamea
Flaveria sp.
Gnephosis tenuissima
Launea sarmentosa (In Australia restricted to Pilbara coastline an offshore islands.)
Olearia axillaris var. obovata
Olearia dampieri ssp. dampieri
Podolepis canescens
Podolepis microcephala (A large range extension; previously only known from Shark Bay to the south end of Lake Mcleod.)
Senecia lautus var. dissectifolius ?
Streptoglossa liatroides

(A few additional species were seen on the dunes south of Coral Bay: Banksia ashbyae and Ptilotus divaricatus. And some others at Pt. Cloates e.g Phyllanthus sp.)

Appendix Three

Plant communities—major structural formations

Life-form and height of tallest stratum	*Projective foliage cover of tallest stratum, as per cent*	*Description*
Trees over 30 m	70-100	High closed forest
	30-70	High open forest
	10-30	High woodland
	under 10	High open woodland
Trees 10-30 m	70-100	Closed forest
	30-70	Open forest
	10-30	Woodland
	under 10	Open woodland
Trees under 10 m	70-100	Low closed forest
	30-70	Low open forest
	10-30	Low woodland
	under 10	Low open woodland
Shrubs over 2 m	70-100	Closed scrub
	30-70	Open scrub
	10-30	High shrubland
	under 10	High open shrubland
Shrubs 1-2 m	70-100	Closed heath
	30-70	Open heath
	10-30	Shrubland
	under 10	Open shrubland
Shrubs under 1 m	70-100	Low closed heath
	30-70	Low open heath
	10-30	Low shrubland
	under 10	Low open shrubland
Herbs	70-100	Closed herbland, closed tussock grassland, closed sedgeland, etc.
	30-70	Herbland, tussock grassland, sedgeland, etc.
	10-30	Open herbland, open tussock grassland, open sedgeland, etc.
Hummock grasses	10-30	Hummock grassland
	under 10	Open hummock grassland


MAP ONE: Vegetation of the Coral Coast Marina area
The vegetation has been mapped within the geomorphological units
And these are used as the major boundaries with subunits described in the text and mapped where possible
FD FOREDUNES
Three units are described but not mapped separately. Grasslands dominated by Spinifex longifolius or Eulalia aurea and a Pleuranthus fimaris low open heath
RFP RELICT FOREDUNE PLAIN
The four units described from the crests and swales are not mapped separately. Acacioniacea ssp coriacea shrublands (some with Cleana axillaris) over Pleuranthus fimaris and Eulalia aurea. Some swales with Acacia tetragonophylla shrublands.
RFP1 East facing slopes with Acacioniacea ssp coriacea shublands but with Thrypomenebaeckeacea in the understorey.
RFP2 East facing slopes (less steep) Exocarpos aphyllus, Acacia tetragonophylla, Santalum spicatum open shrublands.
RFP3 Low sand drifts with Acacioniacea ssp coriacea Exocarpos aphyllus open shrubland over Eulalia aurea, Sporobolus virginicus grassland.
PD PARABOLIC DUNES
Fifteen units are described but are not mapped separately. Most have Acacia coriacea ssp coriacea in the taller shrub layer with variation in the associated taller shrubs and in the composition of the lower shrub and grass layers.
Major vegetation unit boundaries (= geomorphic unit boundaries)
Vegetation community boundaries
Tracks
DAI DEFLATION BASINS, AEOLIAN FLATS/RIDGES AND INLET SPITS (RELICT)
These three geomorphic units are mapped together as their vegetation is very similar. Mostly shrublands dominated by Exocarpus aphyllus and Acacia tetragonophylla, sometimes with Acacioniacea ssp coriacea codominant. (Quite similar to RFP2) Small areas of Whiteochloa arcoides grassland
SF SALINE FLATS
Fifteen units described and mapped separately. See text for the full key. Various low open shrublands to low closed heaths mostly dominated by Halosarcia species but with Anganthus cunninhamii, Frankenia pauciflora, Lawrencia viridgrisea, Muelleroilmon salicornioiceum and Hemichroa diandra important as well.
HSP HYPERSALINE POOL
Ruppia ? aquatic herbfield.
CP CLAY PANS
These had no vegetation.
N
Indian Ocean
Beach
Mauvia Landing
Point Maud
Mosaic HM/Hhs

APPENDIX I

Coral Coast Marina Project - Vertebrate Fauna and Habitats Assessment

ecologia, 1994

CORAL COAST MARINA DEVELOPMENT PTY LTD

CORAL COAST MARINA PROJECT

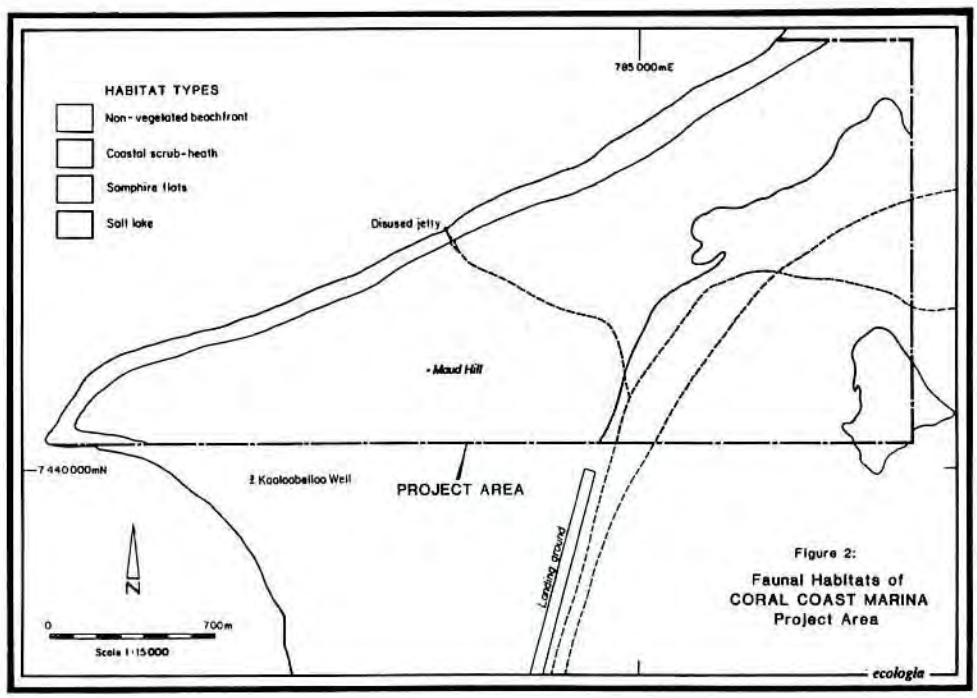


Figure 2:
Faunal Habitats of
CORAL COAST MARINA
Project Area

VERTEBRATE FAUNA & HABITATS ASSESSMENT

OCTOBER 1994

ecologia

ENVIRONMENTAL CONSULTANTS

CORAL COAST MARINA DEVELOPMENT PTY LTD

CORAL COAST MARINA

VERTEBRATE FAUNA AND HABITATS ASSESSMENT

OCTOBER 1994

Prepared for

BOWMAN BISHAW GORHAM
ENVIRONMENTAL MANAGEMENT CONSULTANTS

by

ecologia
ENVIRONMENTAL CONSULTANTS

Restrictions on Use

This report has been prepared specifically for Coral Coast Marina Development Pty Ltd. Neither the report nor its contents may be referred to or quoted in any statement, study, report, application, prospectus, loan, or other agreement document, without the express approval of *ecologia* Environmental Consultants, the Coral Coast Marina Development Pty Ltd and/or Bowman Bishaw Gorham.

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SUMMARY

The Coral Coast Marina Project proposed by the Coral Coast Marina Development Pty Ltd is located approximately three km north of Coral Bay. In accordance with the Environmental Protection Authority the study will be formally assessed at the level of Public Environmental Review. The guidelines for the PER require the documentation of the existing biota of the project area. *ecologia* Environmental Consultants was commissioned by Bowman Bishaw Gorham to compile a desk top study documenting the terrestrial vertebrate fauna and habitats.

The project area falls within the Coastal Dunes Landform Unit of the Carnarvon Basins formed from recent Holocene dunes. The dominant soil type is a coastal calcareous sand forming dunes on the seaward fringe, all overlaying a core of aeolianate limestone. Dispersed throughout the area are small patches of strongly coherent loamy soils associated with the salt lakes.

The Point Maud area lies within the Carnarvon Botanical District of the Eremaean Botanical Province which extends from Shark Bay northwards to the Exmouth Gulf Area. Within the project area, there are five distinct vegetation associations comprising;

1) beachfronts sparsely vegetated,

2) dune and swale areas bearing open *Acacia coriacea* shrublands over *Pileanthus/Thryptomene/Baeckia* heaths,

3) sand drifts featuring *Acacia tetragonophylla* and *A. coriacea,*

4) salt flats surrounding salt lakes supporting a low open samphire formation and,

5) salt lakes with some sedges and water weeds.

Faunal Habitats

The Coral Coast Marina project area encompasses four faunal habitat types;

1) sparsely vegetated beachfront,

2) coastal scrub-heath,

3) samphire flats and,

4) salt lakes.

Based on previous capture records, known distributions and habitat preferences as many as 189 different vertebrate species potentially occur in the project area. This total includes 18 mammals, 116 birds, 51 reptiles and four amphibians. However, it is unlikely that all potential species would co-occur within the project area at any one time due to spatial constraints and various temporal variations in the physical environment. Numerous nomadic or migratory species may only be occur in the area after substantial rain or at certain times of the year.

The beachfront habitat comprises three zones, the intertidal zone used for foraging by waders, the beach area used for roosting and nesting by birds and for foraging by foxes and varanids, and bands of tidal debris, used for foraging by birds. Thirty one species potentially occur in this habitat, including one mammal, four reptiles and 23 birds. The low species richness is entirely attributable to the lack of significant vegetative cover and absence of any structural diversity.

The coastal scrub-heath habitat is the most structurally diverse habitat within the project area and as a consequence is expected to exhibit the greatest species richness. A total of 108 species potentially occur in this habitat, comprising 18 mammalian, 62 avian and 47 reptilian species. The coastal dunes is the preferred habitat of the cryptozoic surface burrowing reptiles such as the legless lizards while the accumulated leaf litter constitutes an important microhabitat for fossorial species of reptiles. The relatively dense shrub and grass layer affords suitable shelter and a regular food supply for reptiles and for small mammals while tall shrubs and small trees are utilised by arboreal lizard species and small insectivorous birds.

The samphire flats habitat is structurally less complex than the surrounding coastal scrub-heath habitat and as such is expected to support fewer species. A total of 60 species potentially occur in this habitat; 15 mammalian, 27 avian, 14 reptilian and four amphibian species. Typically plant species of samphire flats grow to 0.5 m tall although some may grow to one metre. The resulting low, open habitat represents a suitable environment for Richard's Pipits *Anthus novaeseelandiae*, Orange Chats *Ephthianura aurifrons* and Crimson Chats *E. tricolor,* all of which forage amongst low vegetation for insects. Aerial species occurring over this habitat are generally those which are hawking insects. Unlike the loose sand layers of the coastal scrub-heath habitat, the soils of samphire flats are heavy textured and unsuitable for surface burrowing cryptozoic fauna species.

The saline conditions of salt lakes constitute a harsh environment that is generally devoid of vertebrate fauna life when dry. However following heavy rains, such as those experienced during cyclones, it may support up to 26 species of birds, typically waders, gulls and terns. One of the lakes appears to hold water for some time as evidenced by the presence of Brine Shrimp *Artemia* spp. and algae. Such lakes would provide important food resources for both local and migratory species.

Vertebrate Fauna

Fourteen native mammalian species from seven families potentially occur in the project area. Forty three percent are Eyrean in biogeographic affinities with the major proportion of their distributions in arid central Australia. Of the Torresian species the bats Western Cave Eptesicus *Eptesicus finlaysoni* and Yellow-bellied Sheath-tail Bat *Saccolaimus flaviventris* are near the southern limits of their range. Many of the remaining species, such as the Dingo *Canis familiaris dingo* and Gould's Wattled Bat *Chalinolobus gouldii* have Australia-wide distributions. Four species of introduced mammal potentially occur within the project area; the Cat *Felis catus*, the Fox *Vulpes vulpes*, the House Mouse *Mus domesticus* and the Rabbit *Oryctolagus cuniculus*. All four species are widely distributed over most of Australia and would undoubtedly occur within the project area.

Based on preferred habitat and distribution records, 116 species of birds from 45 families may occur in the project area. The majority of birds recorded or expected to occur in the project area have distributions which extend into all the zoogeographic sub-regions of Australia, included in this group are most of the migratory and highly nomadic species. For other species the project area lies near the northernmost extension of their range, like the Chestnut-rumped Thornbill *Acanthiza uropygialis*, or the southern limit such as the Beach Thick-knee *Burhinus neglectus*.

The project area encompasses habitats suitable for, and is within the distributions of, 51 species of reptiles from eight families. Particularly well represented are the skinks and geckos with 13 and 11 species respectively. In contrast the varanids (monitor lizards) are poorly represented with only one species expected in the area. Three species of marine turtles may use the beaches during their nesting season, October through to February. The largely arid Eyrean component of the mammal and bird faunas of the Murchison region is repeated in the terrestrial reptiles. Twenty one species (44%) have Eyrean biogeographic affinities only, while a further 21 species (44%) such as *Lerista meulleri* and Thorny Devil *Moloch horridus* have a predominately arid distribution with range extension into the South West. Of the Eyrean species, 6% are endemic to the North West Cape, including the gecko *Diplodactylus rankini*, the skink *Lerista haroldi* and the legless lizard *Aprasia rostrata*. Five species including the Tree Dtella *Gehyra variegata*, Bynoe's Gecko *Heteronotia binoei* and Burton's Snake Lizard *Lialis burtonis* have Australia-wide distributions occurring mainly in arid and semi-arid habitats. Only one species, the Spotted Dragon *Ctenophorus maculatus* is mesic Southwestern in distribution, with the project area being on the northern limits of their range.

Four species of amphibians from two families potentially occur within the project area and are largely confined to the Samphire Flats habitat. Three of the four species Main's Frog *Cyclorana maini*, Water Holding Frog *C. platycephala* and Tawny Trilling Frog *Neobatrachus fulvus* have entirely Eyrean biogeographic affinities. The fourth species the Shoemaker Frog *Neobatrachus sutor* has most of its range within the arid zone of Western Australia but also extends into the South West. All species with the exception of *Neobatrachus fulvus* are widely distributed. The distribution of *Neobatrachus fulvus* includes the area of the central west coast from Wooramel River, near Shark Bay, to North West Cape.

CONSERVATION SIGNIFICANCE

The samphire flats of *Arthrocnemum* sp. and associated salt lakes are widely distributed on a regional scale from Carnarvon in the south to Onslow in the North. The largest such area is to the south in the Lake McLeod vicinity. It is currently included in a mining lease with the option that once the mining lease becomes available, the ponds and adjacent areas of Lake McLeod are to be vested with the National Parks and Nature Conservation Authority as a Class 'A' park.

The sparsely vegetated beach front and coastal heath/scrub habitats are also widely distributed on a regional scale. Both habitats are encompassed by the Cape Range National Park. The primary conservation significance of the sparsely vegetated beachfront habitat is as potential nesting locations for marine turtles, particularly the Loggerhead Turtle *Caretta caretta* which is listed as Schedule 1 Fauna. Additionally, the habitat provides feeding grounds and resting sites for migratory birds protected under the CAMBA and JAMBA agreements. Significantly though, no records exist of marine turtle species nesting in the Coral Bay area.

The Coral Coast Marina project area is expected to contain fauna species which are generally widespread and abundant in similar habitats through out the region. Based upon the current study, the project area is not expected to contain regional endemics or locally restricted species. However, the constraints associated with the current study must be acknowledged.

Rare Fauna

Fauna species which have been formally recognised as rare, threatened with extinction or as having high conservation value are protected by law under the Western Australian Wildlife Conservation Act 1950 and the China & Australia Migratory Bird Agreement (CAMBA). In addition fauna are covered under the April 1991 Australian & New Zealand Environment & Conservation Council (ANZECC) convention.

Under the Wildlife Conservation Act 1950 three Schedule 1 vertebrate taxa potentially occur within the project area. These are the Red-tailed Tropic-bird *Phaethon rubicauda,* Grey Falcon *Falco hypoleucos* and Loggerhead Turtle *Caretta caretta*. Additionally one Schedule 4 species, the Peregrine Falcon *Falco peregrinus*, may occur in the project area. Historically a further three gazetted rare and currently extant species may have occurred in the area. The Western Barred Bandicoot *Perameles bougainville,* Bilby *Macrotis lagotis* and the Burrowing Bettong *Bettongia lesueur* are now considered to be extinct in the region.

The China & Australia Migratory Bird Agreement between the Federal Government of Australia and the government of the Peoples Republic of China binds the signatory governments to the protection of migratory birds and their environment. Fifteen species of transequatorial migratory bird which potentially occur in the project area are listed under the annex of CAMBA.

The ANZECC convention lists fauna as "Endangered - Species in danger of extinction and who's survival is unlikely if the causal factors continue to operate" and "Vulnerable - species believed likely to move into the "Endangered" category in the near future if the causal factors continue to operate." Three species of marine turtle, Loggerhead Turtle *Caretta caretta*, Green turtle *Chelonia mydas* and Hawksbill Turtle *Eretmochelys imbricata* listed under the ANZECC convention potentially occur in the Coral Coast Marina project area.

1.0 INTRODUCTION

The Coral Coast Marina Project proposed by the Coral Coast Marina Development Pty Ltd is located within the town boundaries of Point Maud, approximately three km north of Coral Bay. In accordance with the Environmental Protection Authority (EPA) the study will be formally assessed at the level of Public Environmental Review (PER). The guidelines for the PER require the documentation of the existing biota of the project area. *ecologia* Environmental Consultants was commissioned by Bowman Bishaw Gorham to compile a desk top study documenting the terrestrial vertebrate fauna, incorporating:

- the representative faunal habitat types based on mapping and photography of the area;
- the conservation significance of similar habitat types on a local and regional scale;
- an inventory of vertebrate fauna species likely to utilise the habitats present; and
- an assessment of the conservation status of the anticipated vertebrate fauna of the project area on both a local and regional scale.

1.1 Land Use History

Point Maud has been gazetted as a townsite. The Point Maud locality is encompassed by the Cardabia pastoral lease which is currently unused.

1.2 Biophysical Environment

1.2.1 Climate

The climate of the area is arid with two seasons, a hot summer extending from October to April and a mild winter from May to September. Mean annual maximum temperature for Learmonth (the nearest recording location, 100 km NNW of the project area) is 31.8 °C with average maximum temperatures ranging from 23.9 °C during July to 38.0°C in January (Figure 1; Table 1). Although Learmonth represents the closest recording station, some differences in temperature in the project area would be expected as Learmonth is protected by the high relief of the Cape Range.

Rainfall is seasonal and influenced by both northern rainfall systems of tropical origin and southern winter rainfall systems. The mean average annual rainfall is 266 mm over an average of 24 rain days. A major feature of the rainfall is the unreliability and variation in annual recordings (Muir, 1983). The capricious nature of rainfall is of biological significance. While the sporadic summer rainstorms are intense, prolonged and sufficient for plant growth, the light winter rains are often ineffective for growth other than herbs and grasses.

1.2.2 Landform and Soils

The project area falls within the Coastal Dunes Landform Unit of the sedimentary basin known as the Carnarvon Basin. Most of the Carnarvon Basin is low-lying, however low ranges of hills occur close to the west coast, the largest being the nearby Cape Range (Beard, 1975). From Carnarvon to the Cape Range, the shoreline is backed by up to four kilometres of recent Holocene dunes usually with an additional belt of sandhills and sandy country behind the dunes (Beard, 1975).

The dominant soil type is a coastal calcareous sand which forms dunes on the seaward fringe, overlaying a core of aeolianate limestone. Dispersed throughout are small patches of calcareous loams of either a weakly coherent or strongly coherent nature (Bettenay *et al.*, 1967). Strongly coherent loamy soils are characteristic of the salt lakes.

LEARMONTH Elevation: 5 m Location: 22° 14' S, 114° 5' E

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.	Year
TEMPERATURE (°C)													
Daily max. - mean	38	37.7	36.5	33.4	28.2	24.7	23.9	25.7	29.2	32.2	34.5	371	31.8
Daily min. - mean	23.1	24.3	23.1	20.7	16	13.2	11.4	12.4	14	16.2	18.5	20.7	17.8
RAINFALL (mm)													
Mean	39	40	38	16	45	40	23	15	2	3	2	3	266
Mean # raindays	2	3	2	2	4	5	3	2	1	0	0	0	24

TABLE 1: Summary of climatic data for Learmonth, approximately 100 km NNW of the Coral Coast Marina project area.

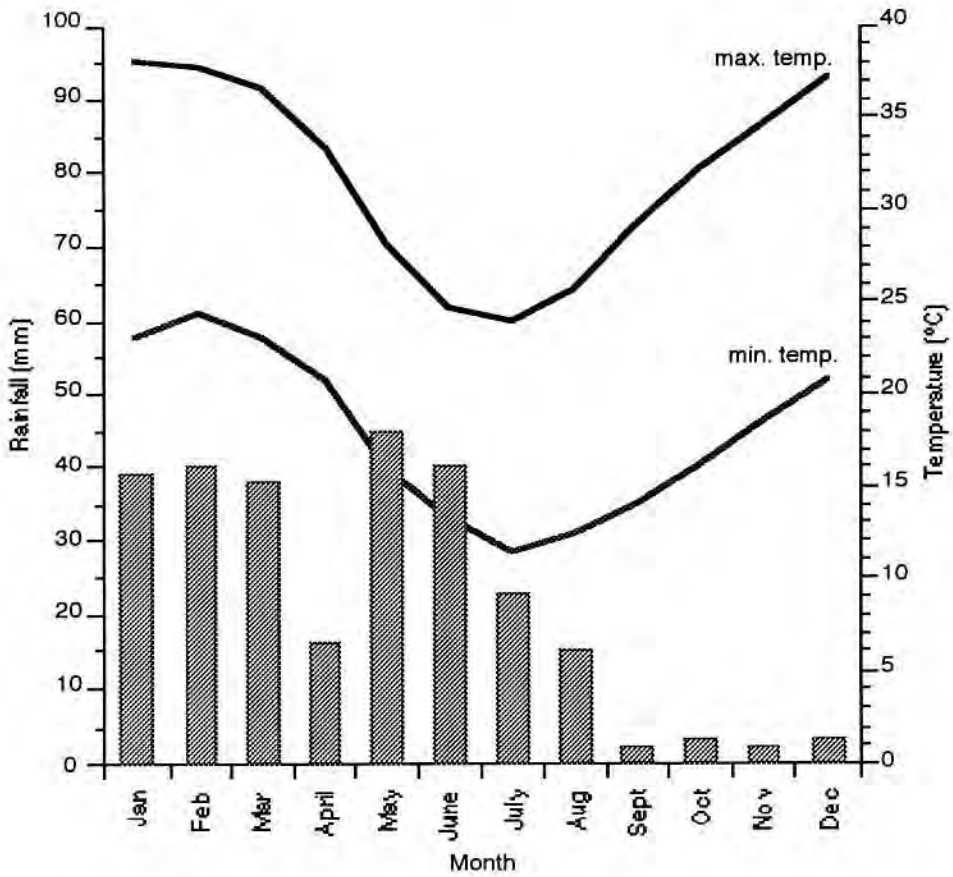

Figure 1: Summary of climatic data for Learmonth (1945 to 1994).

1.2.3 Vegetation

The Point Maud area lies within the Carnarvon Botanical District of the Eremaean Botanical Province which extends from Shark Bay northwards to the Exmouth Gulf Area. Within the project area, there are five distinct vegetation associations (M. Trudgen, pers. comm.):

- Dunes
  Dune areas bear open *Acacia coriacea* shrublands over *Pileanthus/Thryptomene/Baeckia* heath above the grasses form the genus *Eulalia*.
- Swales
  These areas are again dominated by *Acacia coriacea/Thryptomene* open shrublands, however *Pileanthus* is absent and *Olearia* species may be present above a moderate cover of the grass *Eulalia*.
- Sand drifts
  These areas feature *Acacia tetragonophylla* and *A. coriacea*.
- Salt flats
  The areas surrounding salt lakes support a low open samphire formation: common species include *Halosarcia* species, *Frankenia* species and *Muellerolimon salicorniaceum*.
- Salt lakes
  Sedges and the water weed *Ruppia* are present, together with other aquatic herbs and brine shrimps, indicating that the salt lakes hold water for at least 1-2 months.

An additional vegetation type can also be identified:

- Beachfront vegetation
  The sparsely vegetated area of beachfront is a harsh environment, exposed to high levels of salt, wind and shifting sands. These areas are characterised by sparse and species depauperate vegetation, however some beach *Spinifex* spp. are able to survive under these conditions.

2.0 STUDY APPROACH

The approach taken for the study involved a desk top study comprising:

- an extensive literature review relevant to the project area; and
- a description of habitat types from ground photography and site mapping.

2.1 Literature Review and Unpublished Databases

The following authorities and persons were consulted to access datasets and reports containing relevant fauna data for the project area.

Authorities

Conservation and Land Management	CALM
Department of Environmental Protection	DEP
Royal Australasian Ornithologists Union	RAOU

Persons

Mr Jim Lane	CALM - Woodvale
Dr Robert Prince	CALM - Woodvale

2.2 Study Limitations

The current study is based solely upon review of relevant literature including both published and unpublished data. Assessment of vertebrate faunal habitats within the project area was based upon ground and aerial photography supplied by the client and vegetation association descriptions supplied by Mr M. Trudgen, the project Botanist.

The assessment of vertebrate fauna species potentially occurring in the project area was based upon the known preferred habitat and distribution records for all species as determined from the literature review.

While the study encompassed an extensive review of the literature, no field work was undertaken within the project area. Therefore no site specific information exists for the project area. The lack of site specific field surveys limits the confidence of predictions made for both the composition of faunal communities and habitats present in the Coral Coast Marina project area to some degree.

The primary limitations of the study lie with the lack of predictability concerning;

a) undocumented species range extensions;

b) the local presence of subspecific variants or races;

c) the presence of new undescribed species or poorly known species.

3.0 FAUNA OF THE PROJECT AREA

3.1 Faunal Habitats

From the photography and detailed mapping provided it is apparent that the project area encompasses four faunal habitat types: 1) Sparsely vegetated beachfront, 2) coastal scrub-heath, 3) samphire flats and 4) salt lake (Figure 1; Table 2). For the purposes of this study, the dune, swale and sand drift vegetation types are collectively grouped under the "coastal scrub-heath" faunal habitat due to the structural similarity of the vegetation.

Table 2 : Faunal habitats in the Coral Coast Marina Project Area with approximate percent occurrence.

Habitat	Description	% Occurrence
Beach Front	sparsely vegetated foredune & intertidal zone	5
Coastal Scrub-heath	*Acacia* shrublands covering primary dunes and swales	65
Samphire Flats	low open samphire formation surrounding salt lakes	25
Salt Lake	temporary saline wetlands	5

Based on previous capture records, known distributions and habitat preferences as many as 189 different vertebrate species potentially occur in the project area. This total includes 18 mammals, 116 birds, 51 reptiles and four amphibians (Appendix A). However it is unlikely that all potential species would co-occur within the project area at any one time due to spatial constraints and various temporal variations in the physical environment. For example, several species of bird are nomadic or migratory and may only be expected in the area after substantial rain, such as waterfowl, or at certain times of the year. Migratory species such as the Fork-tailed Swift and Rainbow Bee-eater would be expected only between late September and April). Other species would only be likely to occur in the area after local proliferation in food resources. Birds such as honeyeaters are more abundant during extensive and prolific flowering of shrubs in good seasons.

3.1.1 Sparsely Vegetated Beachfront

The Beachfront habitat can be divided into three parts:

- the intertidal zone, used for foraging by waders;
- the beach area, used for roosting/nesting by birds and for foraging by foxes and varanids; and
- bands of tidal debris, used for foraging by birds.

Thirty one species potentially occur in this habitat, including one mammal, four reptiles and 23 birds (Appendix A). The low species richness is entirely attributable to the lack of significant vegetative cover and absence of any structural diversity (Plate 1).

The Fox *Vulpes vulpes* is the only mammal expected to utilise this habitat. Foxes forage for food such as eggs and chicks of beach-nesting birds and turtle hatchlings. In addition to taking turtle hatchlings, foxes have been known to excavate turtle nests in search of eggs. Similarly varanid species have also been observed excavating turtle nests.

Of the avian species which utilise this habitat the majority are waders (Families Charadriidae and Scolopacidae), gulls and terns (Family Laridae) and cormorants (Family Phalacrocoracidae). Other species include the Australian Pelican *Pelecanus conspicillatus*, Eastern Reef Egret *Egretta sacra*, Brahminy Kite *Haliastur indus*, White-bellied sea eagle *Haliaeetus leucogaster*, Caspian Tern *Hydroprogne caspia* and the Silver Gull *Larus novaehollandiae*. The intertidal zone and bands of beach debris provide an important source of food for many of the species such as the Red-capped Plover *C. ruficapillus*) which feed on small seeds of aquatic plants and a variety of invertebrates including insects, small crustaceans, worms and molluscs. The Ruddy Turnstone *Arenaria interpres* turns over small stones, dead seaweed and other plant debris in search of invertebrate species.

Additionally some species including the Pied Oystercatcher *Haematopus longirostris* and Beach Thick-knee *Burhinus neglectus* construct nests in or adjacent to the tidal debris. The majority of avian species utilise the beach as either a roosting or resting site.

Three species of marine turtle, the Green Turtle *Chelonia mydas*, Loggerhead Turtle *Caretta caretta* and Hawksbill Turtle *Eretmochelys imbricata* may potentially use the beach as a nesting site. The locations of turtle nests are readily discernable as they are accompanied by large depressions in the sand.

3.1.2 Coastal Scrub-heath

The coastal scrub-heath habitat is the most structurally diverse habitat (Plate 2) within the project area and as a consequence is expected to exhibit the greatest species richness. A total of 108 species potentially occur in this habitat, comprising 18 mammalian, 62 avian and 47 reptilian species. However for the reasons mentioned above it is unlikely that all of these species would occur within the project area concurrently.

The loose sand of the white coastal dunes is the preferred habitat of cryptozoic surface burrowing reptiles such as the legless lizard *Aprasia rostrata* and the skinks *Lerista lineopunctulata, L. preapedita* and *L. uniduo*. These species inhabit the upper loose layers of soil beneath leaf litter, fallen branches and rocks. Accumulated leaf litter constitutes an important microhabitat for fossorial species of reptiles including *Lerista muelleri*, *Menetia greyii* and *Morethia lineoocellata*.

The relatively dense shrub and grass layer affords suitable shelter and a regular food supply for reptiles and for small mammals such as the Sandy Inland Mouse *Pseudomys hermannsburgensis* and the Spinifex Hopping Mouse *Notomys alexis*. These mammalian species construct burrow systems and favour sandy soils, although *P. hermannsburgensis* and to a lesser extent *N. alexis* also occur on loamy soils. Both species are nocturnally active, feeding on seeds, grass roots and tubers and *Notomys alexis* will also take insects. The coastal scrub habitat represents a marginal habitat for Pilbara Ningaui *Ningaui timealeyi* which may expand into the area during good seasons, contracting again during poorer times (Strahan, 1983).

Tall shrubs and small trees provide shelter during the day for the Euro *Macropus robustus* and Red Kangaroo *Macropus rufus*. They are also utilised by arboreal gecko species such as *Diplodactylus ciliaris*, *D. rankini, D. strophurus* and *Gehyra variegata,* skinks *Cryptoblepharus plagiocephalus* and agamids *Lophognathus longirostris*. Where the taller shrubs occur as thickets the resulting microhabitat provides suitable shelter for small insectivorous birds such as the Fairy-wrens (Family Maluridae) and Thornbills (Family Acanthizidae).

The bats (Order Chiroptera) contribute the greatest number of species to the native mammalian tally with seven species. The scrub-heath habitat would serve primarily as a food source for these aerial species. For the Lesser Long-eared Bat *Nyctophilus geoffroyi* it may also include roosting locations. This species has been found roosting under the bark of trees and under a rock on the ground (Strahan, 1983).

3.1.3 Samphire Flats

The samphire flats habitat (Plate 3) is structurally less complex than the surrounding coastal scrub-heath habitat and as such is expected to support fewer species. A total of 60 species potentially occur in this habitat; 15 mammalian, 27 avian, 14 reptilian and four amphibian species.

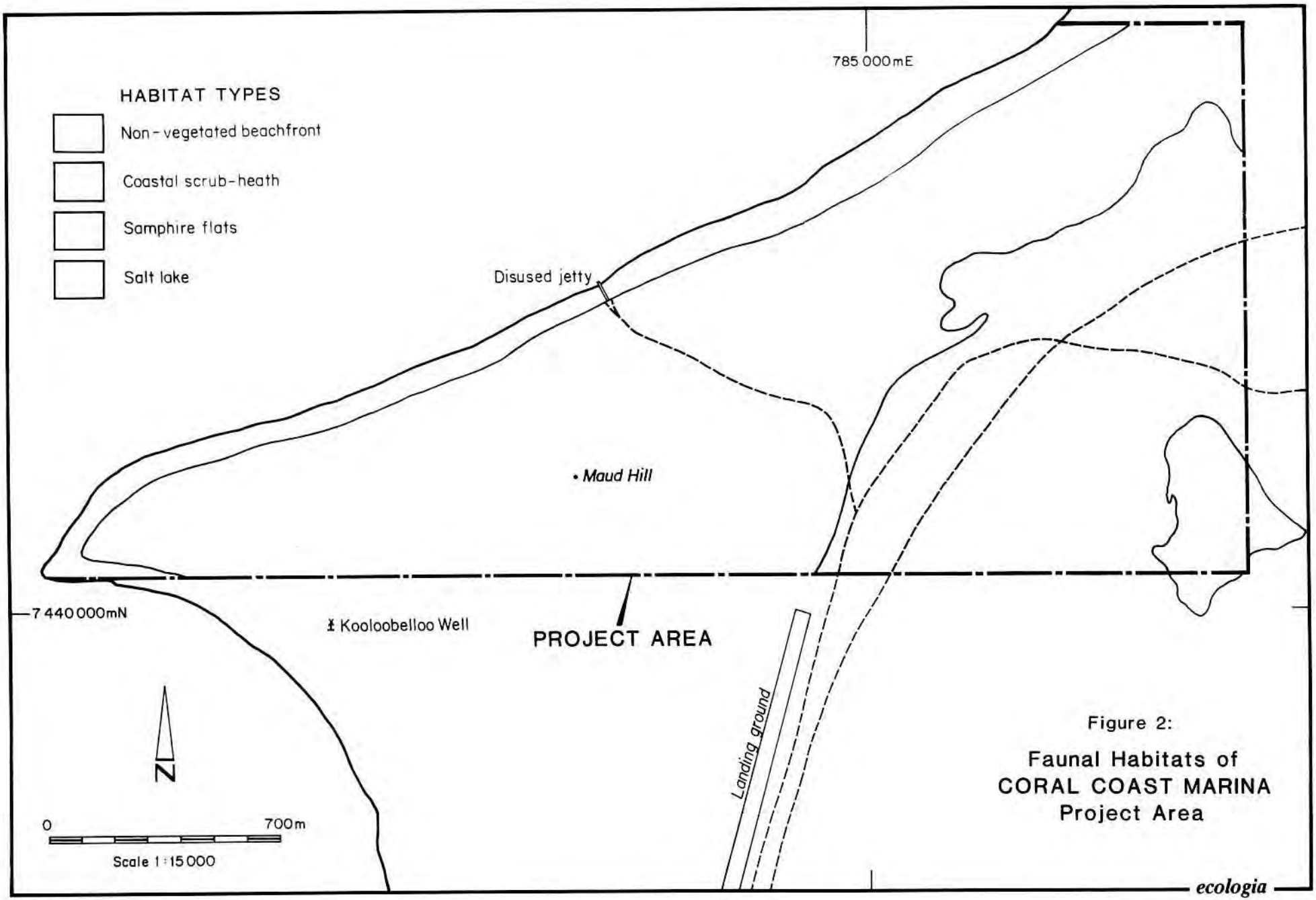

Figure 2:

Faunal Habitats of CORAL COAST MARINA Project Area

Plate 1: Sparsely vegetated beachfront habitat

Plate 2: Coastal heath vegetation

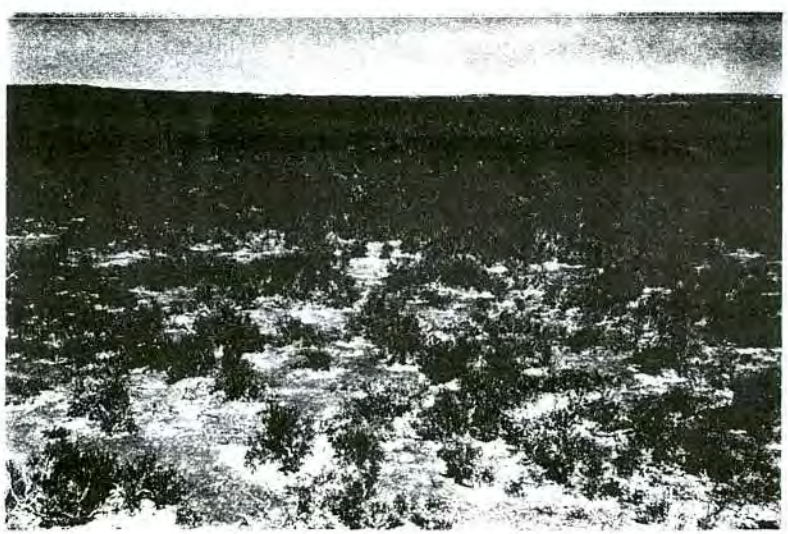

Plate 3: Samphire vegetation

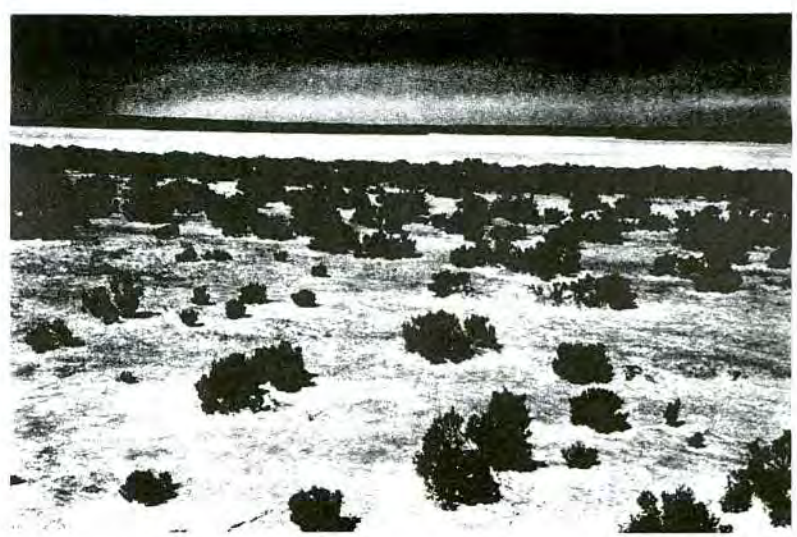

Plate 4: Salt lake habitat (with samphire flats in foreground)

Typically plant species of samphire flats grow to less than 0.5 m tall although some may grow to one metre. The resulting low, open habitat represents a suitable environment for Richard's Pipits *Anthus novaeseelandiae*, Orange Chats *Ephthianura aurifrons* and Crimson Chats *E. tricolor,* all of which forage amongst low vegetation for insects, although the Crimson Chat also drinks nectar. Aerial species occurring over this habitat are generally those which are hawking insects, for example the Swallows and Martins (Family Hiruninidae) and Woodswallows (Family Artamidae). Unlike the loose sand layers of the coastal scrub-heath habitat, the soils of samphire flats are heavy textured and unsuitable for surface burrowing cryptozoic fauna species.

The amphibians inhabiting this environment are typically explosive breeders which emerge from underground burrows after heavy rains, such as those of cyclonic origin. As the water dries up, these species burrow back beneath the soil. The presence or absence of these species would depend on the salinity levels as amphibians cannot tolerate high salt concentrations. It is expected that few frogs would be present due to the high subsurface, < 0.5 m, salinities.

3.1.4 Salt Lakes

The saline conditions of salt lakes (Plate 4) constitute a harsh environment that is devoid of vertebrate fauna life when dry. However following heavy rains such as those experienced during cyclones it may support up to 26 species of birds, typically waders, gulls and terns. One of the lakes appears to hold water for some time as evidenced by the presence of Brine Shrimp *Artemia* spp. and algae (M. Trudgen, pers comm.). Such lakes would provide important food resources for both local and migratory species.

TABLE 3: Number of fauna species expected to occur in habitats of the project area.
(Habitat Codes: UB = Sparsely Vegetated Beach, CS = Coastal Scrub-heath, SF = Samphire Flats, SL = Salt Lakes)

FAUNA HABITAT	UB	CS	SF	SL
Mammals				
Native	0	14	11	0
Introduced	1	4	4	0
Bird Species	31	68	21	26
Reptile Species	4	46	14	0
Amphibian Species	0	0	4	0
Total Species	**36**	**132**	**54**	**26**

3.2 Stygofauna

The Cape Range Peninsula to the immediate north of the project area contains a rich stygofauna or cave dwelling fauna (Knott, 1993). The stygofauna include two Schedule 1 fish species, the Blind Cave Eel *Ophisternon candidum* and Blind Gudgeon *Milyeringa veritas,* and two Schedule 1 crustaceans *Stygiocaris lancifera* and *S. stylifera*.

The Blind Gudgeon Fish *Milyeringa veritas* is thought to be widely distributed and relatively common throughout the subterranean groundwater. The range of both the Blind Gudgeon and the less common Blind Cave Eel extends south to Yardie Creek. The two shrimps *Stygiocaris lancifera* and *S. stylifera* have only been collected from the northern end of the peninsula (Knott, 1993).

The stygofauna of the Cape Range region are only known from the limited fresh groundwaters on the Peninsula. This habitat is absent from the project area due to the presence of the saline lake system. Therefore it is considered that stygofauna species are unlikely to be present in the Coral Coast Marina project area.

3.3 Vertebrate Fauna

3.3.1 Mammals

Fourteen native mammalian species from seven families potentially occur in the project area (Figure 3) (Appendix A1). Forty three percent are Eyrean in biogeographic affinities with the major proportion of their distributions in arid central Australia. Of the Torresian species *Eptesicus finlaysoni* and *Saccolaimus flaviventris* are near the southern limits of their range. Many of the remaining species, such as the Dingo *Canis familiaris dingo* and Gould's Wattled Bat *Chalinolobus gouldii* have Australia-wide distributions.

Four species of introduced mammal potentially occur within the project area; the feral cat *Felis catus*, the fox *Vulpes vulpes*, the house mouse *Mus domesticus* and the rabbit *Oryctolagus cuniculus*. All four species are widely distributed over most of Australia and would undoubtedly occur within the project area.

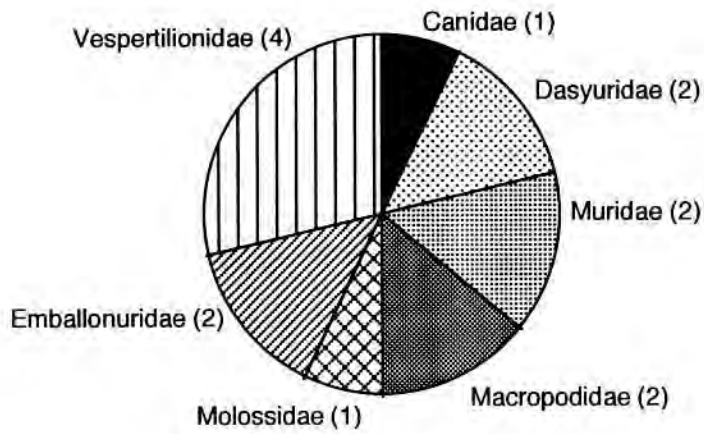

Figure 3: Species richness of mammalian families within the Coral Coast Marina project area.

3.3.2 Birds

Based on preferred habitat and distribution records, 116 species of birds from 45 families may occur in the project area (Appendix A2). The majority of birds recorded or expected to occur in the Coral Coast Marina project area have distributions which extend into all the zoogeographic sub-regions of Australia. Included in this group are most of the migratory and highly nomadic species. For other species such as the Chestnut-rumped Thornbill *Acanthiza uropygialis* and the Beach Thick-knee *Burhinus neglectus,* the project area lies near the northern or the southern extremes respectively of their ranges.

3.3.3 Reptiles and Amphibians

The project area encompasses suitable habitats, and is within the distributions of, 51 species of reptiles from eight families. Particularly well represented are the skinks and geckos with 13 and 11 species respectively. In contrast the varanids are poorly represented with only one species expected in the area. Three species of marine turtles may use the beaches during their nesting season, October through to February (Dr R. Prince, CALM Woodvale, pers. comm.) although no records of this exist.

Four species of amphibians from two families potentially occur within the project area and are largely confined to the Samphire Flats habitat (Appendix A3). Three of the four species, *Cyclorana maini*, *C. platycephala* and *Neobatrachus fulvus*, have entirely Eyrean biogeographic affinities. The fourth species *Neobatrachus sutor* has most of its range within the arid zone of Western Australia but also extends into the South West. All species, with the exception of *Neobatrachus fulvus,* are widely distributed. The distribution of *Neobatrachus fulvus* includes the area of the central west coast from Wooramel River, near Shark Bay, to North West Cape.

The largely arid Eyrean component of the mammal and bird faunas of the region is repeated in the terrestrial reptiles. Twenty one species (44%) have solely Eyrean biogeographic affinities, while a further 21 species (44%) such as *Lerista meulleri* and *Moloch horridus* have a predominately arid distribution with range extension into the South West. Of the Eyrean species, 6% are endemic to the North West Cape, including the gecko *Diplodactylus rankini*, the skink *Lerista haroldi* and the pygopid *Aprasia rostrata*. Five species including *Gehyra variegata*, *Heteronotia binoei* and *Lialis burtonis* have Australia wide distributions occurring mainly in arid and semi-arid habitats. Only one species, *Ctenophorus maculatus* is mesic Southwestern in distribution, with the project area being on the northern limits of their range. Within the Eyrean fauna, eight species including *Lerista lineopunctulata*, *L. planiventralis* and *Diplodactylus ornatus* have coastal distributions with the North West Cape representing the northernmost limit of their range.

The Exmouth Gulf region which lies immediately north of the project area represents one of the most important Green Turtle *Chelonia mydas* rookeries on the west coast of Australia. Similarly the Muiron Islands represent the second largest recorded rookery of the Loggerhead Turtle *Caretta caretta*, the largest being on Dirk Hartog Island to the south. Less abundant although still recorded from the Exmouth Gulf region is the Hawksbill Turtle *Eretmochelys imbricata*. The main rookery for this species appears to be further north on Rosemary Island which is part of the Dampier Archipelago and to a lesser extent Varanus Island, part of the Lowendal group. These species nest on the beaches between October and February, hawksbills appearing first in early October followed by loggerheads and greens, with the latter species reaching its greatest concentration in late December early January.

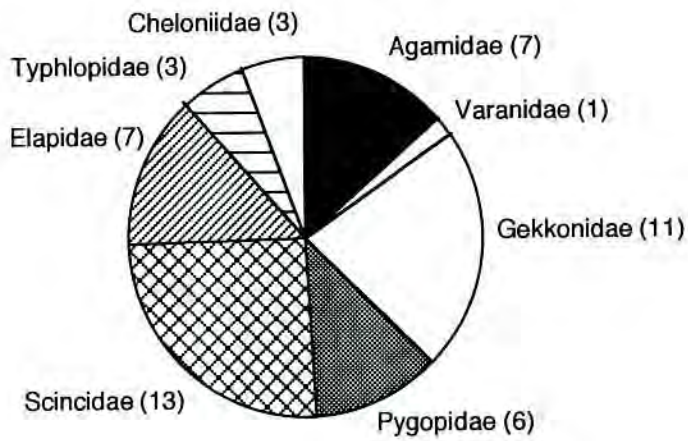

Figure 4: Species richness of the major reptile families within the Coral Coast Marina project area.

4.0 CONSERVATION SIGNIFICANCE

4.1 Faunal Habitats

The samphire flats of *Arthrocnemum* sp. and associated salt lakes are widely distributed on a regional scale from Carnarvon in the south to Onslow in the North. The largest such area is to the south in the Lake McLeod vicinity. It is currently included in a mining lease with the option that once the mining lease becomes available, the ponds and adjacent areas of Lake McLeod are to be vested with the National Parks and Nature Conservation Authority as a Class 'A' park (EPA, 1993).

The remaining two faunal habitats, sparsely vegetated beach front and coastal heath/scrub are also widely distributed on a regional scale. Both habitats are encompassed by the Cape Range National Park. The primary conservation significance of the sparsely vegetated beachfront habitat is as potential nesting locations for marine turtles, particularly the Loggerhead Turtle *Caretta caretta* which is listed as Schedule 1 Fauna. Additionally, the habitat provides feeding grounds and resting sites for migratory birds protected under the CAMBA and JAMBA agreements. To date however, no records exist of marine turtle species nesting in the Coral Bay area.

4.2 Vertebrate Fauna

The Coral Coast Marina project area is expected to contain fauna species which are generally widespread and abundant in similar habitats through out the region. Based upon the current study, the project area is not expected to contain regional endemics or locally restricted species. The limitations associated with the current study are given in Section 2.2.

4.3 Rare Fauna

Fauna species which have been formally recognised as rare, threatened with extinction or as having high conservation value are protected by law under the Western Australian Wildlife Conservation Act 1950 and the China & Australia Migratory Bird Agreement (CAMBA). The Japan & Australia Migratory Bird Agreement (JAMBA) has now been incorporated into the Wildlife Conservation Act 1950. In addition fauna are covered under the April 1991 Australian & New Zealand Environment & Conservation Council (ANZECC) convention.

Classification of rare and endangered fauna under the Wildlife Conservation 1950 (Specially Protected Fauna) Notice 1994, recognises four distinct schedules such that all taxa specified in;

(a) Schedule 1, are "fauna which is rare or are likely to become extinct, are declared to be fauna in need of special protection";

(b) Schedule 2, are "fauna which is presumed to be extinct, are declared to be fauna that is in need of special protection";

(c) Schedule 3, are "birds which are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction, are declared to be fauna that is in need of special protection"; and

(d) Schedule 4 are declared to be "fauna that is in need of special protection, otherwise than for the reasons mentioned in paragraphs (a), (b) and (c)."

Three Schedule 1 vertebrate taxa potentially occur within the project area. These are the Red-tailed Tropic-bird *Phaethon rubicauda,* Grey Falcon *Falco hypoleucos* and Loggerhead Turtle *Caretta caretta.* Additionally one Schedule 4 species, the Peregrine Falcon *Falco peregrinus*, may occur in the project area (Table 4).

Historically a further three gazetted rare and currently extant species may have occurred in the area. The Western Barred Bandicoot *Perameles bougainville*, Bilby *Macrotis lagotis* and the Burrowing Bettong *Bettongia lesueur* are now considered to be extinct in the region.

Table 4: Rare and endangered fauna species protected under the Wildlife Conservation Act 1950 that potentially may be present in the Coral Coast Marina project area.

Red-tailed Tropicbird *Phaethon rubricauda* (Schedule 1)
This species is described as a "possibly regular visitor to coastal waters north of Perth..." (Pizzey, 1983). The Tropicbird lives in the Indian and Pacific Oceans; two subspecies breed round Australia (Blakers, Davies and Reilly, 1984) at scattered locations. Nests are made on cliffs or under bushes on shore (Pizzey, 1983).

Grey Falcon *Falco hypoleucos* (Schedule 1)
Described as "Rare, sedentary or nomadic" (Pizzey, 1983), this species utilises open habitats, grassy inland plains and semi-deserts, often near waterholes. While potentially occurring in the project area it is a wide ranging species and is not dependent on any local habitats.

Loggerhead Turtle *Caretta caretta* (Schedule 1)
This species nests on beaches from north of Shark Bay around to the Queensland coast. Although potentially occurring within the project area the preferred rookery site for this species appear to be further north on the Muiron Islands and south on Dirk Hartog Island.

Peregrine Falcon *Falco peregrinus* (Schedule 4)
This species is widely distributed throughout Australia and is aerial over all vegetation types, roosting on granite hills and taller woodlands. Its status is considered to be "generally uncommon, probably declining in settled regions; still well established in remote areas" (Pizzey, 1983). Storr (1984) describes the species as scarce in the region, occurring either singularly or in pairs. The peregrine was recorded in low numbers by the Hamersley Ranges fauna survey (Muir, 1983).

The China & Australia Migratory Bird Agreement (CAMBA) between the Federal Government of Australia and the government of the Peoples Republic of China binds the signatory governments to the protection of migratory birds and their environment. Fifteen species of transequatorial migratory bird which potentially occur in the study area are listed under the annex of CAMBA (Table 5).

Table 5: Transequatorial migratory birds which may occur in the project area that are protected by the China & Australia Migratory Bird Agreement.

Great Egret	*Egretta alba*
Eastern Reef Egret	*Egretta sacra*
White-breasted Sea Eagle	*Haliaeetus leucogaster*
Grey Plover	*Pluvialis squatarola*
Mongolian Dotterel	*Charadrius mongolus*
Whimbrel	*Numenius phaeopus*
Eastern Curlew	*Numenius madagascariensis*
Greenshank	*Tringa nebularia*
Ruddy Turnstone	*Arenaria interpres*
Red-necked Stint	*Calidris ruficollis*
Sharp-tailed Sandpiper	*Calidris acuminata*
Curlew Sandpiper	*Calidris ferruginea*
Sanderling	*Calidris alba*
Caspian Tern	*Hydroprogne caspia*
Fork-tailed Swift	*Apus pacificus*

The ANZECC convention lists fauna as "Endangered - Species in danger of extinction and who's survival is unlikely if the causal factors continue to operate" and "Vulnerable - species believed likely to move into the "Endangered" category in the near future if the causal factors continue to operate." Three species of marine turtle listed under the ANZECC convention potentially occur in the Coral Coast Marina project area (Table 6).

Table 6: List of species protected by the ANZECC agreement that potentially occur in the Coral Coast Marina project area.

Endangered species

Loggerhead Turtle *Caretta caretta*
This species nests on beaches from north of Shark Bay around to the Queensland coast. Although potentially occurring within the project area the preferred rookery site for this species appear to be further north on the Muiron Islands and south on Dirk Hartog Island.

Vulnerable Species

Green turtle *Chelonia mydas*
The most abundant of the marine turtles in the region. This species nest from early October to late January and like the Loggerhead, the main rookeries for this species are further to the north.

Hawksbill Turtle *Eretmochelys imbricata*
This species is rarely recorded on the beaches of the Exmouth gulf and there are no recorded large mainland rookeries. Rosemary Island, Dampier Archipelago and Varanus Island represent the largest rookeries for this species.

PROJECT TEAM

The Coral Coast Marina Project wildlife and habitats assessment was planned, co-ordinated and executed by;

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120 McKenzie St.,
Wembley W.A. 6014

Project Staff

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R.J. Teale	BSc.(Zool/Bot) (Hons Zool)	Zoologist

In addition;

1. Mr. Malcolm Trudgen kindly provided descriptions of the vegetation of the project area.
2. The Bureau of Meteorology, Perth supplied the climatic data for Wittenoom.

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APPENDIX A

Coral Coast Marina Project Area
Fauna Species List

Appendix A: List of Vertebrates that are Expected to Occur Within the Habitats Present in the Coral Coast Marina Project Area.

KEY

\+ = Species expected to occur
* = Aerial Species

Faunal habitats

1 Sparsely vegetated beach front
2 Coastal scrub-heath
3 Samphire flats
4 Salt lake

APPENDIX A1: MAMMAL SPECIES WHICH OCCUR OR ARE EXPECTED TO OCCUR IN THE CORAL COAST MARINA PROJECT AREA.

		Fauna Habitats			
		1	2	3	4
MARSUPIALIA					
DASYURIDAE					
Ningaui timealeyi	Pilbara Ningaui		+		
Sminthopsis macroura	Stripe-faced Dunnart		+		
MACROPODIDAE					
Macropus robustus	Euro		+	+	
Macropus rufus	Red Kangaroo		+	+	
CHIROPTERA					
EMBALLONURIDAE					
Saccolaimus flaviventris	Yellow-bellied Sheath-tail-bat*		+	+	
Taphozous georgianus	Common Sheath-tail Bat*		+	+	
MOLOSSIDAE					
Nyctinomus australis	White-striped Mastiff Bat*		+	+	
VESPERTILIONIDAE					
Chalinolobus gouldii	Gould's Wattled Bat*		+	+	
Eptesicus finlaysoni	Western Cave Eptesicus*		+	+	
Nyctophilus geoffroyi	Lesser Long-eared Bat*		+	+	
Scotorepens greyii	Little Broad-nosed Bat*		+	+	
RODENTIA					
MURIDAE					
Notomys alexis	Spinifex Hopping-mouse		+		
Pseudomys hermannsburgensis	Sandy Inland Mouse		+	+	
CARNIVORA					
CANIDAE					
Canis familiaris dingo	Dingo		+	+	
	Expected Species Richness =	**0**	**14**	**11**	**0**
INTRODUCED MAMMALS					
Felis catus	Feral Cat		+	+	
Mus domesticus	House Mouse		+	+	
Oryctolagus cuniculus	European Rabbit		+	+	
Vulpes vulpes	Fox	+	+	+	
	Expected Species Richness =	**1**	**4**	**4**	**0**

APPENDIX A2: BIRD SPECIES WHICH OCCUR OR ARE EXPECTED TO OCCUR IN THE CORAL COAST MARINA PROJECT AREA.

		Fauna Habitats			
		1	2	3	4
CASUARIDAE					
Dromaius novaehollandiae	Emu		+		
PELECANIDAE					
Pelecanus conspicillatus	Australian Pelican	+			+
ANHINGIDAE					
Anhinga melanogaster	Darter	+			
PHALACROCORACIDAE					
Phalacrocorax carbo	Great Cormorant	+			
Phalacrocorax melanoleucos	Little Pied Cormorant	+			
Phalacrocorax sulcirostris	Little Black Cormorant	+			
Phalacrocorax varius	Pied Cormorant	+			
ANATIDAE					
Anas rhynchotis	Australasian Shoveller				+
Anas superciliosa	Pacific Black Duck				+
Chenonetta jubata	Maned Duck				+
Cygnus atratus	Black Swan	+			+
Malacorhynchus membranaceus	Pink-eared Duck				+
Tadorna tadornoides	Australian Shellduck				+
PHAETHONTIDAE					
Phaethon rubricauda	Red-tailed Tropic Bird	+			
ARDEIDAE					
Ardea pacifica	Pacific Heron				+
Ardea novaehollandiae	White-faced Heron				+
Egretta alba	Great Egret				+
Egretta garzetta	Little Egret				+
Egretta sacra	Eastern Reef Egret	+			
PLATALEIDAE					
Platalea flavipes	Yellow-billed Spoonbill				+
Platalea regia	Royal Spoonbill				+
Threskiornis spinicollis	Straw-necked Ibis				+
PANDIONIDAE					
Pandion haliaetus	Osprey	+			
ACCIPITIRIDAE					
Elanus scriptus	Letter-winged Kite*		+		
Aquila audax	Wedge-tailed Eagle*		+		
Circus assimilis	Spotted Harrier*		+		
Elanus notatus	Black-shouldered Kite*		+		
Haliastur indus	Brahminy Kite*	+			
Haliastur sphenurus	Whistling Kite*		+		
Hiraaetus morphnoides	Little Eagle*		+		
Lophoictinia isura	Square-tailed Kite*		+		

		Fauna Habitats			
		1	2	3	4
ACCIPITIRIDAE (cont.)					
Haliaeetus leucogaster	White-bellied Sea Eagle*	+			
Accipiter cirrhocephalus	Collared Sparrowhawk*		+		
Accipiter fasciatus	Brown Goshawk*		+		
Hamirostra melanosternon	Black breasted Buzzard*		+		
Milvus migrans	Black Kite*		+		
FALCONIDAE					
Falco berigora	Brown Falcon*		+		
Falco cenchroides	Australian Kestrel*		+		
Falco longipennis	Australian Hobby*		+		
Falco peregrinus	Peregrine Falcon*		+		
TURNICIDAE					
Turnix velox	Little Button-quail		+		
RALLIDAE					
Rallus philippensis	Banded Land Rail		+		
OTIDIDAE					
Ardeotis australis	Australian Bustard		+		
GRUIDAE					
Grus rubicundus	Brolga				+
BURHINIDAE					
Burhinus neglectus	Beach Thick-knee	+			
HEAMATOPODIDAE					
Haematopus longirostris	Pied Oystercatcher	+			
CHARADRIIDAE					
Pluvialis squatarola	Grey Plover	+			
Pluvialis dominica	Eastern Golden Plover	+			
Charadrius melanops	Black-fronted Plover	+			
Charadrius ruficapillus	Red-capped Plover	+			
Charadrius veredus	Oriental Plover	+			
Charadrius mongolus	Mongolian Plover	+			+
Vanellus tricolor	Banded Lapwing		+		+
Arenaria interpres	Ruddy Turnstone	+			
Numenius madagascariensis	Eastern Curlew	+			
Numenius phaeopus	Whimbrel	+			
RECURVIROSTRIDAE					
Cladorhynchus leucocephalus	Banded Stilt			+	+
Himantopus himantopus	Black-winged Stilt			+	+
SCOLOPACIDAE					
Calidris alba	Sanderling	+			
Calidris acuminata	Sharp-tailed Sandpiper				+
Calidris ferruginea	Curlew Sandpiper	+			
Calidris ruficollis	Red-necked Stint	+			+
Tringa nebularia	Greenshank				+
Tringa stagnatilis	Marsh Sandpiper				+

		Fauna Habitats			
		1	2	3	4
LARIDAE					
Chlidonias hybrida	Whiskered Tern	+			+
Gelochelidon nilotica	Gull-billed Tern	+			+
Hydroprogne caspia	Caspian Tern	+			
Larus novaehollandiae	Silver Gull	+			+
COLUMBIDAE					
Geopelia cuneata	Diamond Dove		+		
Geopelia placida	Peaceful Dove		+		
Ocyphaps lophotes	Crested Pigeon		+		
CACATUIDAE					
Cacatua roseicapilla	Galah		+		
Cacatua sanguinea	Little Corella		+		
CUCULIDAE					
Chrysococcyx basalis	Horsefield's Bronze Cuckoo		+	+	
Chrysococcyx osculans	Black-eared Cuckoo		+		
Cuculus pallidus	Pallid Cuckoo		+	+	
AEGOTHELIDAE					
Aegotheles cristatus	Owlet-nightjar		+		
CAPRIMULGIDAE					
Caprimulgus guttatus	Spotted Nightjar		+		
ALCEDINIDAE					
Halcyon pyrrhopygia	Red Backed Kingfisher		+		
Halcyon sancta	Sacred Kingfisher		+		
APODIDAE					
Apus pacificus	Fork-tailed Swift		+	+	
MEROPIDAE					
Merops ornatus	Rainbow Bee-eater		+		
ALAUDIDAE					
Mirafra javanica	Singing Bushlark		+		
HIRUNDINIDAE					
Cheramoeca leucosternum	White-backed Swallow		+	+	
Hirundo ariel	Fairy Martin		+	+	
Hirundo neoxena	Welcome Swallow		+	+	
CAMPEPHAGIDAE					
Coracina novaehollandiae	Black-faced Cuckoo-shrike		+	+	
MOTACILLIDAE					
Anthus novaeseelandiae	Richard's Pipit	+	+	+	
MUSCICAPIDAE					
Melanodryas cucullata	Hooded Robin		+		
Oreocica gutturalis	Crested Bellbird		+	+	

		Fauna Habitats			
		1	2	3	4
MUSCICAPIDAE (cont.)					
Petroica goodenovii	Red Capped Robin		+		
Rhipidura fuliginosa	Grey Fantail		+		
Rhipidura leucophrys	Willie Wagtail		+	+	
TIMALIIDAE					
Pomatostomus superciliosus	White-browed Babbler		+		
SYLVIIDAE					
Cinclorhamphus cruralis	Brown Songlark		+		
Cinclorhamphus mathewsi	Rufous Songlark		+		
MALURIDAE					
Malurus lamberti	Variegated Fairy-wren		+		
Malurus leucopterus	White-winged Fairy-wren		+	+	
ACANTHIZIDAE					
Acanthiza uropygialis	Chestnut-rumped Thornbill		+	+	
Sericornis brevirostris	Weebill		+		
Sericornis brunneus	Redthroat		+		
Sericornis fuliginosus	Calamanthus		+	+	
MELIPHAGIDAE					
Lichenostomus virescens	Singing Honeyeater		+		
Lichmera indistincta	Brown Honeyeater		+		
EPHTHIANURIDAE					
Ephthianura aurifrons	Orange Chat		+	+	
Ephthianura tricolor	Crimson Chat		+	+	
DICAEIDAE					
Dicaeum hirundinaceum	Mistletoe Bird		+		
PLOCEIDAE					
Poephila guttata	Zebra Finch		+		
GRALLINIDAE					
Grallina cycanoleuca	Australian Magpie-lark		+		
ARTAMIDAE					
Artamus cinereus	Black-faced Woodswallow		+	+	
Artamus leucorhynchus	White-breasted Woodswallow		+	+	
Artamus minor	Little Woodswallow		+	+	
Artamus personatus	Masked Woodswallow		+	+	
CRACTICIDAE					
Cracticus nigrolgularis	Pied Butcherbird		+		
CORVIDAE					
Corvus bennetti	Little Crow		+		
Corvus orru	Torresian Crow		+		
	Expected Species Richness	**31**	**68**	**21**	**26**

APPENDIX A3: REPTILES AND AMPHIBIANS WHICH ARE EXPECTED TO OCCUR IN THE CORAL COAST MARINA PROJECT AREA.

		Fauna Habitats			
		1	2	3	4
Lizards					
GEKKONIDAE					
Crenadactylus ocellatus	Clawless Gecko		+		
Diplodactylus alboguttatus			+	+	
Diplodactylus conspicillatus			+	+	
Diplodactylus ornatus			+	+	
Diplodactylus rankini			+		
Diplodactylus squarrosus			+	+	
Diplodactylus stenodactylus			+	+	
Diplodactylus strophurus			+		
Gehyra variegata	Tree Dtella		+		
Heteronotia binoei	Bynoe's Gecko		+		
Nephrurus levis			+		
PYGOPODIDAE					
Aprasia rostrata			+		
Delma butleri			+		
Delma nasuta			+		
Delma tincta			+		
Lialis burtonis	Burton's Snake Lizard		+		
Pygopus nigriceps	Hooded Scaly-foot		+		
AGAMIDAE					
Ctenophorus maculatus	Spotted Dragon		+	+	
Ctenophorus nuchalis				+	
Diporiphora winneckei			+		
Lophognathus longirostris			+		
Moloch horridus	Thorny Devil		+		
Pogona minor	Dwarf Bearded Dragon		+		
Tympanocryptis parviceps			+		
SCINCIDAE					
Cryptoblepharus carnabyi			+		
Cryptoblepharus plagiocephalus	Fence Skink		+		
Eremiascincus richardsonii	Broad-banded Sand Swimmer		+		
Lerista haroldi			+		
Lerista lineopunctulata			+		
Lerista meulleri			+		
Lerista planiventralis			+		
Lerista praepedita			+		
Lerista uniduo			+		
Menetia greyii	Grey's Skink		+		
Menetia surda			+		
Morethia lineoocellata			+	+	
Tiliqua occipitalis	Western Blue-tongued Lizard		+		
VARANIDAE					
Varanus gouldii	Gould's Monitor	+	+		

		Fauna Habitats			
		1	2	3	4
Turtles					
CHELONIIDAE					
Caretta caretta	Loggerhead Turtle	+			
Chelonia mydas	Green Turtle	+			
Eretmochelys imbricata	Hawksbill Turtle	+			
Snakes					
TYPHLOPIDAE					
Rhamphotyphlops diversus			+	+	
Rhamphotyphlops grypus			+	+	
Rhamphotyphlops hamatus			+		
ELAPIDAE					
Demansia psammophis	Yellow-faced Whipsnake		+	+	
Furina ornata	Orange-naped Snake		+	+	
Pseudonaja modesta	Ringed Brown Snake		+	+	
Pseudonaja nuchalis	Gwardar		+	+	
Simoselaps littoralis	West Coast Banded Snake		+		
Suta fasciata	Rosen's Snake		+		
Amphibians					
Cyclorana maini	Main's Frog			+	
Cyclorana platycephala	Water-holding Frog			+	
Neobatrachus fulvus	Tawny Trilling Frog			+	
Neobatrachus sutor	Shoemaker Frog			+	
	Expected Species Richness	**4**	**46**	**18**	**0**

Sources:

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APPENDIX J

An Archaeological and Ethnographical Survey of the Proposed Coral Coast Development Area, Point Maud, Western Australia

Morse and Wright, 1989

FAXED

Australian museum
Francis Street Perth
Western Australia 6000
Telephone (09) 328 4411
Facsimile (09) 328 8686

Date: 11 December 1989

Your Ref: 2W2/NS/405/87

Our Ref: 77132
RF:CS
Enquiries: R.Fry

Department of Marine & Harbours
PO Box 402
Fremantle WA 6160

Attention: Mr N Siragusa

Dear Mr Siragusa,

MAUD'S LANDING - PROPOSED MARINA/TOURIST DEVELOPMENT

Thank you for the copy of the Notice of Intent submitted to EPA by Coral Coast Marina Development Pty Ltd.

The Department of Aboriginal Sites has also received a copy of the report by Morse and Wright *An Archaeological and Ethnographic Survey of the Proposed Coral Coast Development Area, Point Maud, Western Australia*, September 1989. The Department supports the recommendations of this report, as included in the Notice of Intent.

The report records five Aboriginal sites located within the survey area. All Aboriginal sites are covered by the provisions of the *Aboriginal Heritage Act 1972-80*, whether known to the Department or not. Section 17 of the Act makes it an offence to alter an Aboriginal site in any way without written permission from the Minister for Aboriginal Affairs.

It is our preference that your client modifies their development plans to avoid impacting sites. If however, this is not possible, and in order to avoid a breach of Section 17, the landowner can submit a notice in writing to the Trustees of the Western Australian Museum seeking the Minister's consent to use the land in question.

It should be emphasised that it is possible that burials may be uncovered once disturbance of the ground begins. Should this occur, work should cease immediately and the procedure clearly outlined in Section 6.0 of the report by Morse and Wright followed.

It is understood that the development will not encroach on the small sand dunes to the north of the proposed harbour entrance cut (Morse and Wright, p.18). This area is of concern to Aboriginal people. When

Branches:
Fremantle Museum
Finnerty Street, Fremantle
Western Australia, 6160
Telephone (09) 335 8211

Western Australian Maritime Museum
Cliff Street, Fremantle
Western Australia, 6160
Telephone (09) 335 8211

Geraldton Museum
Marine Terrace,
P.O. Box 112, Geraldton
Western Australia, 6530
Telephone (099) 21 5080

Albany Residency Museum
Residency Road, Albany
Western Australia, 6330
Telephone (098) 41 4844

the survey for the cut is completed, the developer is strongly advised to consult with the senior Aboriginal man referred to in recommendation (j) in Morse and Wright to ensure that no areas of significance to Aboriginal people are disturbed.

Kate Morse or myself would be pleased to meet with the Maud's Landing Working Group on Friday 19 January. Could you please advise on the time and place nearer the date.

If you have any further enquiries, please contact me.

Yours sincerely,

Robert Reynolds
Acting Assistant Registrar
DEPARTMENT OF ABORIGINAL SITES

c.c. EPA
Coral Coast Marina Development Pty Ltd
c/- Alan G Smith
Port & Harbour Consultants Pty Ltd
1 High Street
Fremantle wa 6010.

AN ARCHAEOLOGICAL AND ETHNOGRAPHIC SURVEY OF THE PROPOSED CORAL COAST DEVELOPMENT AREA, POINT MAUD, WESTERN AUSTRALIA.

PREPARED FOR CORAL COAST MARINA DEVELOPMENT PTY. LTD.

By KATE MORSE, Western Australian Museum and
GUY WRIGHT, G. and K. Wright Research Associates
SEPTEMBER 1989

1.0 Introduction

In June 1989 staff of the Department of Aboriginal Sites and the Department of Anthropology, Western Australian Museum attended a meeting of the Maud's Landing Working Group at the Department of Marine and Harbours, to discuss the proposed Coral Coast development near Point Maud, Western Australia. Museum staff explained that very little was known about Aboriginal sites in the development area, and that under the conditions of the Aboriginal Heritage Act (1972-1980; Appendix 1), it was the developer's responsibility to ascertain the nature and significance of the Aboriginal cultural resources before development should go ahead. It was also noted that the area was potentially sensitive for Aboriginal people as several burial sites were recorded in the Museum site register.

In response to this meeting Mr. Alan Smith, director of Port and Harbour Consultants, acting on behalf of Coral Coast Marina Development Pty. Ltd., the developers of the proposed Coral Coast Marina, contacted the Department of Aboriginal Sites to arrange for a survey of Aboriginal sites in the area. In August 1989 the archaeological component of the survey was undertaken by Kate Morse of the Department of Anthropology with Lynda Strawbridge. The ethnographic survey was undertaken by consultant anthropologist Mr. Guy Wright.

This report present the results of both the archaeological and ethnographic surveys of the proposed Coral Coast development area and makes recommendations about Aboriginal sites located during the survey.

2.0 Archaeological survey

2.1 The Area

The coastal region around the Maud's Landing- Coral Bay area is dominated by a wide relict foredune plain which lies seaward of an extensive relict tidal flat. Along the coast east of Point Maud, lightly vegetated foredunes parallel the shore. Behind the foredunes are a series of relict dunes vegetated in part with salt tolerant coastal heath. Active blowouts are exposed intermittently in the relict dunes (Hesp 1986).

To the west and south west of the proposed development area, extensive partially vegetated parabolic dunes backed by aeolian flats form an environment highly susceptible to natural erosion and human disturbance (Hesp 1986).

2.2 Previous archaeological research in the North West Cape area.

No systematic archaeological investigations have ever been carried out in the Point Maud - Coral Bay area. Despite this, at least three Aboriginal sites in the area are recorded in the Museum's Register of Aboriginal Sites. Two of these sites are burials (P5715; P2064) one of which has an ethnographic component. The other is an ethnographic site (P5716) recorded during preliminary ethnographic investigations undertaken in 1985 for the area encompassed by the Ningaloo Marine Park (Turner 1985).

Extensive archaeological investigations have been carried out on the more northerly section of the Cape Range peninsula since 1985 (Fig. 1; Morse and Kee 1985; Morse and Fry 1989; Morse 1988). Preliminary results indicate that Aboriginal people with a well developed and diversified coastal economy lived there intermittently from 25,000 years ago to

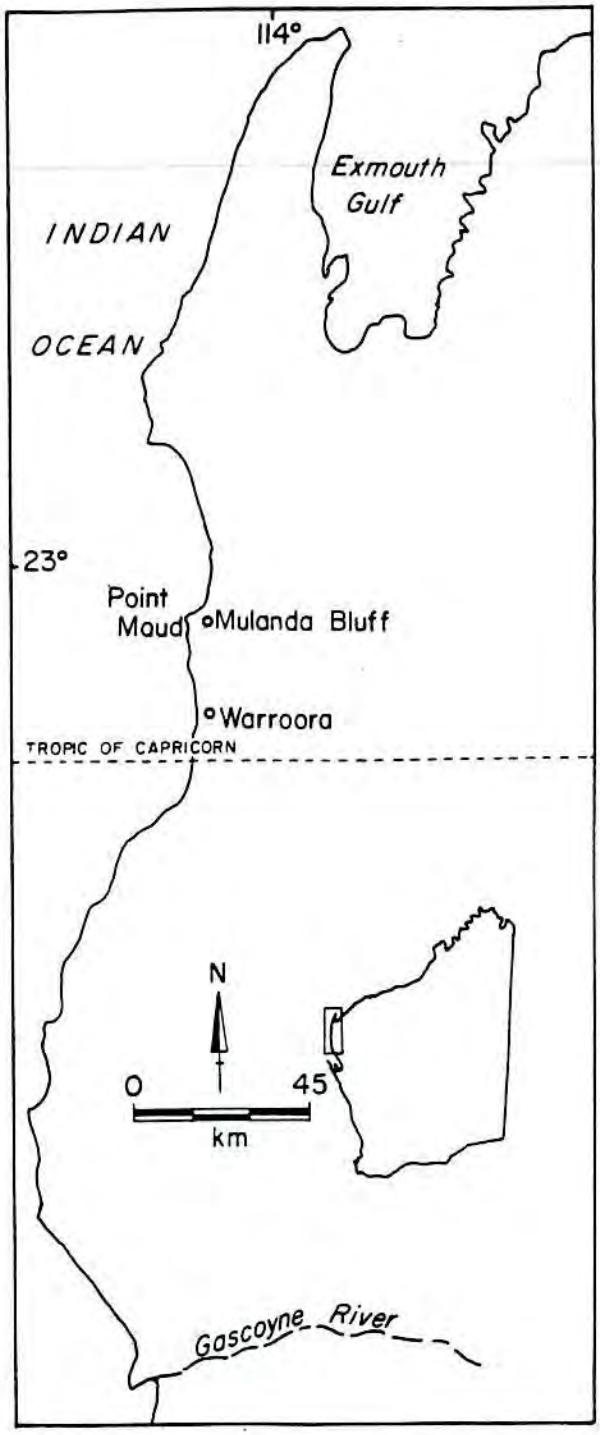

Figure 1. Map showing locations mentioned in the text.

modern times. Research in 1989 has demonstrated that the area was occupied by at least 33,000 years ago (Morse *in prep.*) In 1982, a shell midden, on the coast near Warroora Station, some 20 km south of Point Maud, was dated to c. 7000 years ago (Kendrick and Morse 1982). Another similar site, Mulanda Bluff midden, has recently been recorded some 3 km south east of the proposed Coral Coast development area. Radiocarbon dating of a sample of marine shells from this site has also yielded an age of nearly 7000 years.

Archaeological material from both Mulanda Bluff and Warroora midden sites indicate that when they were occupied during middle Holocene times, they were in close proximity to a well established mangrove community. Today the nearest significant mangrove formations occur at the mouth of the Gascoyne river some 130 km to the south, and in Exmouth Gulf nearly 80 km to the north. Research suggests that at the time these sites were occupied the relict tidal flat at Coral Bay was a flourishing mangrove environment which was cut off from marine exchange c. 5000 years ago and developed into the extensive hypersaline evaporative pan it is today (Kendrick and Morse *in prep.*). This data is important as it contributes to the growing body of evidence in Australia and South East Asia for the widespread development and sudden decline of mangrove environments during the middle Holocene (Woodroffe *et al.* 1985; Allen 1987).

2.3 The Survey

The survey area is a 70 ha. tract of land which more or less fits into the natural contours of the coastal landscape to the north-east of Point Maud. All major development is planned to be concentrated on the coastal flats. The modern and relict dunes which parallel the shoreline are largely to be fenced off with access tracks to the beach constructed at selected locations. The main disturbance to the coastal dune system will occur at the entrance to the proposed inland marina/harbour development (Fig.2). This will cut through the dunes at a point corresponding to deep water

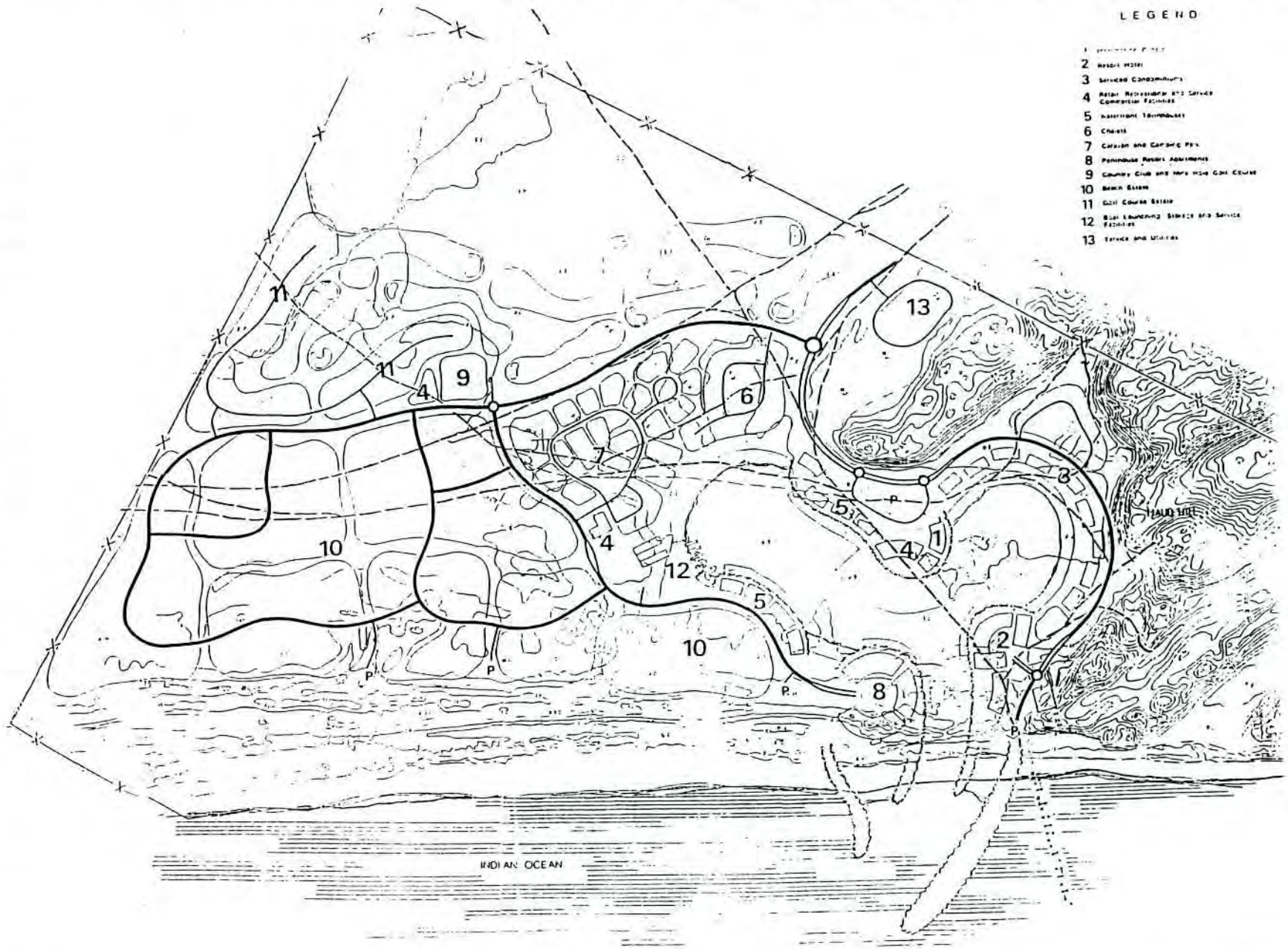

Figure 2. Proposed development of Point Maud area by Coral Coast Marina Development Pty. Ltd.

offshore and open up an area on the coastal flat as the main focus for development. The extensive vegetated parabolic dune system to the west of the development area will not be impacted by proposed developments and will be fenced off as part of dune stabilization and management plans.

The proposed development area was completely unmarked at the time the archaeological survey was undertaken. The approximate boundaries of the development were pointed out by Mr Ken Ryan, resident of Coral Bay and executive director of Coral Coast Marina Development Pty Ltd.

The archaeological survey was done on foot. A transect survey of the immediate foreshore and relict dune systems was completed. For the coastal plain all apparent features were inspected and several transects were walked at random intervals to complete an adequate coverage of the proposed development area. Archaeological sites as defined under the Western Australian Aboriginal Heritage Act (1972-80), were recorded and located using maps and aerial photographs provided by Mr Alan Smith of Port and Harbour Consultants. No archaeological material was collected.

2.4 Survey Results

2.4.1 Coastal Dunes

Archaeological material including marine shell, bone and occasional stone and glass artefacts is scattered very sparsely throughout the coastal dune system. In places the dunes are badly disturbed with modern European camps, hearths and associated rubbish and some of the shell and bone material noted during the survey probably has a European origin. The area is also littered with storm beach material, including numerous

scatters of fragmented shells and other beach debris. Despite this disturbance, much of the material recorded during this survey can be identified as resulting from Aboriginal occupation. Three sites were located in the coastal dune system (Fig. 3; Table 1).

P 6180 Mulanda Site 1.

This site is located in a small blowout in the secondary dunes some 80m from the modern shoreline. A walking trail east from the Point Maud beach parking area runs directly to this site. A sparse scatter of fragmented shell and bone material covers an area of approximately 25 m E-W and 41 m N-S. The site is quite badly disturbed. There is a modern hearth with beer bottle caps and burned cans on the eastern dune slope and concentrations of apparently very recent fish bone and oyster shell . Only two stone artefacts were recorded. The first, a triangular piece of sandy limestone with a very flat, smoothed face is probably a fragment of a basal grinding stone. The other artefact is a partially silicified limestone flake. The shell material includes large fragments of baler shell (*Melo* sp.), and several large bivalves. At many Aboriginal midden sites in the North West Cape area intact baler shell carrying dishes have been found. It is possible that the baler fragments at this site are remains of a broken shell dish.

The site is considered to be a mixture of Aboriginal and European material and is of low archaeological significance.

P 6257 Mulanda Site 2.

Mulanda Site 2 is located in an extensive and active east-west running blowout clearly visible on aerial photographs. Like site P 6180 this site is littered in places with European material, and the presence of numerous tiny bivalves and broken coral and shell fragments indicates that this site also includes a component of storm beach material. Material identified as

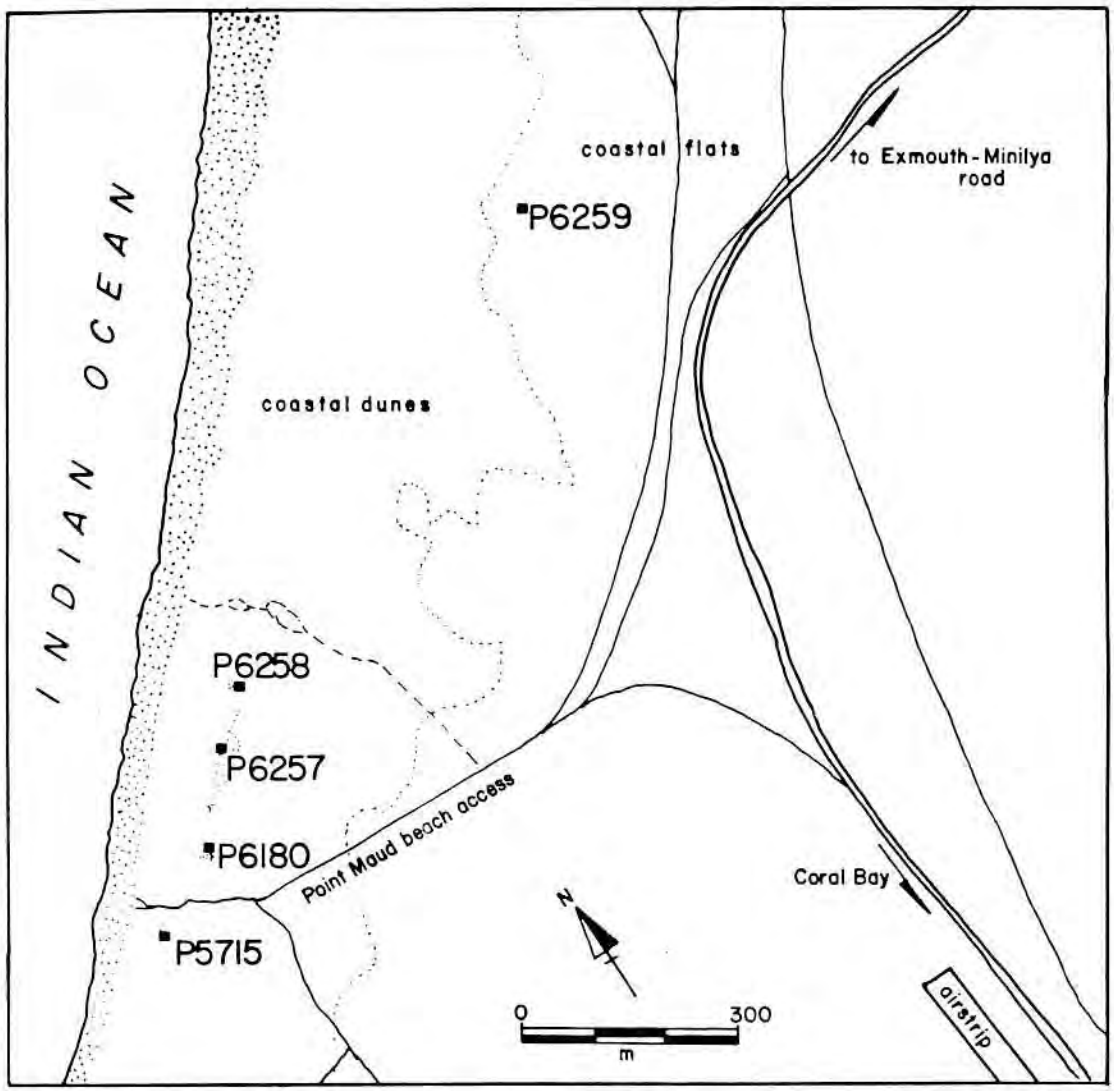

Figure 3. Archaeological sites located in the survey area.

having a probable Aboriginal origin is scattered sparsely throughout the blowout and covers an area of approximately 65 m N-S and 10-15 m E-W.

An interesting feature of this site was the presence of several broken bottle bases made from thick dark green glass. Glass of this type was commonly used to make bottles in the early-mid nineteenth century (Patricia Summerfield pers. comm.). The bottle glass was located at the eastern end of the blowout and concentrated in an area of about $2m^2$. Some 30 metres from these fragments, two pieces of glass which had evidently been humanly flaked and used were found. Other archaeological material recorded includes fragments of baler and clam shell (*Tridacna maxima*), as well as other shells commonly found on midden sites in the area, a fragment of a large sea urchin (species unidentified), charred turtle shell and bones and one chalcedony flake.

This site is considered to be a mixture of Aboriginal, European and storm beach material. The bottle glass artefacts suggest Aboriginal people camped there in the early contact period. Turner's 1985 preliminary ethnographic survey notes that many Aboriginal people from Carnarvon remember camping at Maud's Landing in the early station days (Turner 1985:24).

P6258 Mulanda Site 3.

Mulanda Site 3 is located in a blowout east and immediately adjacent to site P6257. Archaeological material consists of a single discrete scatter of baler and turtle shell which is eroding down the westerly dune slope. Several fragments of bottle glass and an intact sand-blasted old bottle were located in the same area. Some 45 m north west of this concentration, fragments of charred turtle shell and a broken baler shell were recorded. The presence of numerous tiny bivalve and coral fragments indicates a storm beach element is mixed in with the archaeological material.

Turtles are abundant along the coast near Maud's Landing and the site is identified as a probable turtle butchering site. The presence of glass suggests that the site was occupied during the early contact period.

2.4.2 Isolated finds

In the north-easterly part of the survey area the coastal dune system is less developed. The foreshore and relict dunes grade into one and other and the dune landscape is generally much flatter than it is in the more south-westerly part of the survey area. No discrete midden sites were located in this eastern stretch of coast. However fragments of a large and thick baler shell were noted scattered in amongst the dunes. Several large fragments of baler shell were also exposed in vehicle tracks which run across the coastal plain to the edge of the relict dune system. A fragment of sandy limestone conglomerate 12 cms long, 10 cms wide and 6 cms thick which had a smoothed depression on one surface was also found. This is considered to be a fragment of basal grindstone. No other artefacts were found.

2.4.3 Coastal Flats

The coastal flats behind the dune system are densely vegetated with salt tolerant coastal heath vegetation and as such archaeological visibility is reduced. Transect surveys were walked from the main Coral Bay road to the base of the secondary dune system. Like the adjacent coastal dunes a sparse scattering of archaeological material was noted on the coastal flats. Occasional fragments of large baler shell and a single valve of a chiton shell (*Accanthopleura gemmata*) were noted. These are considered to be manuports that have been carried and eventually dropped as people made their way to and from the coast. Several fragments of clear glass were also noted; none appeared to have been humanly modified. One site was recorded on the coastal flats.

P6259 Mulanda Site 4.

This is a discrete scatter of marine bivalve shells concentrated in a sandy patch about 3 x 2 m^2 on the western edge of the coastal flats (Fig. 3). The scatter consists of some 17 largely intact shells and numerous fragments. The bivalves are clearly selected for species and size and many appear to have a distinctive fracture pattern. No artefactual material was noted in the shell scatter and apart from human collection and transportation no other explanation for the shells presence can be found. No modern or European material was found and the site is considered to be a "dinner time camp" - a place where someone has sat and eaten a collection of shells.

3. 0 Archaeological Conclusions and Recommendations

3.1 Sites P6180, P6257 and P6258 are located directly in the path of the proposed marina/harbour entrance. All three sites have been adequately recorded and are considered to have low archaeological significance.

It is recommended that subject to approval being granted to the developer under Section 18 of the Aboriginal Heritage Act (1972-80), these sites should be allowed to be disturbed and development should go ahead.

3.2 It is likely that "isolated finds" on the coastal dunes will inadvertently be disturbed once the proposed development increases tourist pressure on the beach and adjacent dunes. Fencing of the coastal dunes may prevent some disturbance of this area. Archaeological material in the dunes is considered to be of low significance.

3.3 Site P6259 and "isolated finds" on the coastal flats will be disturbed once development is underway.

Site P 6259 has been adequately recorded and has low archaeological significance. It is recommended that subject to approval under Section 18 of the Aboriginal Heritage Act, development of the coastal flats should proceed as planned.

3.4 Site P5715 , a soak recorded during the preliminary 1985 ethnographic survey is located just outside the direct impact area of the proposed development. However, in view of the size of the project and the presence of large earthmoving equipment it seems likely that this site may be inadvertently or unavoidably disturbed.

It is recommended that the developers apply under Section 18 of the Aboriginal Heritage Act for permission to disturb this site before developments proceed as planned.

3.5 It is possible that further archaeological material will be uncovered once disturbance of the ground begins. In the coastal dune area in particular it is possible that Aboriginal burials may be found.

It is recommended that if archaeological material is uncovered the developer should contact the Department of Aboriginal Sites. If skeletal material is found, procedures outlined in section 6.0 of this report should be followed.

3.6 A visitor information centre is planned as part of the Coral Coast development. It is recommended that information relating to the Aboriginal traditional and historical use of the Maud's Landing- Coral Bay area should be included as part of educational displays presented for the public.

Table 1.0
Archaeological sites located during survey of proposed Coral Coast Marina Development.

Site Number	Site Name	1:250,000 map ref. SF 49-16	1:100,000 map ref. Sheet 1651
P6180	Mulanda Site 1	151 117	845 410
P6257	Mulanda Site 2	151 117	846 410
P6258	Mulanda Site 3	151 117	847 411
P6259	Mulanda Site 4	152 117	851 412

4.0 Ethnographic survey -- Introduction

In August 1989, the management of Coral Coast Marina Development Pty. Ltd., commissioned myself, Guy Wright, of G. and K. Wright Research Associates to conduct a survey for ethnographic sites at their proposed development at Maud's Landing, north of Coral Bay. The ethnographic survey coincided with the archaeological survey described in this report, conducted by Kate Morse of the W.A. Museum.

The Ethnographic survey had a twofold purpose: 1) To scout for previously unidentified Ethnographic sites as defined under the Aboriginal Heritage Act (1972-80) and 2) to identify and liaise with relevant Aboriginal people in the Carnarvon area who may have a knowledge of or interest in, burial material that could be uncovered during the excavations for the proposed Coral Coast development.

The survey comprised three basic stages. In the first stage, academics with experience working with Aboriginal people in the region were contacted, as were relevant Aboriginal organizations. The purpose of the survey was explained and advice as to who would be the most appropriate people to speak for the Aboriginal interest in the area was canvassed. In the second stage, appropriate Aboriginal people were located in the Carnarvon area and interviewed to determine whether they had an interest in the area which will be disturbed by the proposed development. Several people who clearly had substantial knowledge of the area were unable to visit the site due to work commitments and ill health. However, there was clear approval from these people that a senior man[1] living in Carnarvon was regarded as having appropriate knowledge and authority to represent the Aboriginal interest in the area.

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1 The identities of Aboriginal scouts is not normally given in Aboriginal site survey reports. Their identities are lodged, separately and in confidence, with the Aboriginal Sites Department of the W.A. Museum. This practice will be followed here.

The senior man was taken to the Maud's Landing site, where he made a thorough inspection of the area, accompanied by myself and Mr. Ken Ryan of Coral Coast Developments. After discussing the proposed development in detail, he said that the proposal as presently constituted was not likely to disturb places or material of significance to Aboriginal people. However, he was concerned that the development plans only narrowly miss features of Aboriginal interest in the eastern edges of the coastal dunes, and has requested that he be able to have a second look at the development site when the area has been surveyed, prior to excavation.

There is one previously registered Aboriginal Site in the proposed disturbance area. It is recommended that the company seek permission of the Minister for Aboriginal Affairs for permission to disturb this site, under the provisions of Section 18 of the Aboriginal Heritage Act (1972-80).

4.1 Ethnographic background

The area of the proposed Coral Coast development is within the area identified by Tindale (1974) as the land traditionally occupied by the Baijunju linguistic unit. According to Tindale, the Baijunju people inhabited an area roughly between Pt. Cloates and Quobba Pt., and inland to approximately Mia Mia (see Fig.1). Neighbours to the North were the Jinigudira and to the south, the Maia.

Probably during the latter portion of the nineteenth century the Jinigudira were wiped out by an epidemic of some sort, likely introduced by pearlers and others working in the Exmouth Gulf area. Jan Turner, who conducted a survey for ethnographic sites in the area to be affected by the Ningaloo Marine Park (Turner 1985), quotes an elderly man from Onslow, who describes the sickness in these words:

> Then Jinigudi. The sickness began with the dogs, just like distemper, with shaking all over. Shake, shake. They died. The Old People tried to nurse them and they died too. Whole families died. Skeletons everywhere Cardabia[1].

The epidemic undoubtedly also affected the Baijunju, the direct neighbours of the Jinigudjira. Cardabia Station, mentioned above, is only a couple of kilometres from the proposed Coral Coast Development, and there are seven burial sites recorded between Gnarraloo Bay and Point Maud. A blowout on the southern side of Point Maud is locally refered to as "Skelly Beach."

Turner (1985) provides an outline of the possibilites for early European contact. The Ningaloo region was clearly within reach of the great Dutch navigation track up the West coast of Australia to Batavia. Yarrow (1980) notes that Yardie Creek was marked on Dutch charts from the early 17th century as "Jacob Remessen's River (quoted from Turner 1985:5). In 1875, the *Stephano* wrecked near Pt. Cloates, and Aboriginal people gave water, food and, surprizingly, navigational charts to two surviving sailors. They guided the survivors towards Tien Tsin Harbour (now Cossack) but saw the *Jessie* en-route. The Aborigines lit large signal fires, and the sailors were picked up. Knives and axes were later sent to the Aboriginal people in appreciation (Ibid:6)

In spite of the auspicious beginnings however, contact with European based culture had a devastating effect upon the traditional cultures of the area, as was true for most of Australia. The frontier existence provided incentives for Aboriginal people to drift into station work, providing a much needed pool of labour for the growing Northwest pastoral industry. Tea, sugar, flour, tobacco and alcohol were traded for work and the sexual services of many of the women. A large number of "half caste" children were produced, many of whom were taken away to be raised in missions

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1 Turner, 1985 p.21

and other foster care arrangements where they learned to be members of neither culture. Under the domineering Christianity of the time, much of the formal knowledge of Aboriginal culture was lost.

For the current generation, re-establishing as much as possible of the old culture has become a priority. The recognition that Aboriginal culture is an important focus to give hope and direction to young Aboriginal people is a driving force behind agencies, such as the Kuwinywardu Aboriginal Resource Agency in Carnarvon.

5.0 Conducting the ethnographic survey

5.1 Initial investigations:

After being informed by Mr. Alan Smith of Port and Harbour Consultants that the survey was to go ahead as discussed, I contacted Dr. Alan Dench, a linguist with the Deparment of Anthropology, U.W.A. and Dr. Chris Birdsell, who has conducted doctoral research among Aboriginal people in the Carnarvon area. They gave me background information and told me that to their knowledge there were no disputes among Aboriginal people in the Carnarvon region that would be likely to affect the study. They agreed that the Kuwinywardu Aboriginal Resource Agency (KARU) should be the point of contact for the study. I later spoke with Mr. Joseph Wallam of the Aboriginal Sites Department also who confirmed this.

I then contacted Mrs. Mary Franklin, of Kuwinywardu, faxed her a map showing the area of the proposed development and sent a letter explaining the intentions of the survey. I arranged to meet with her on the morning of August 7.

5.2 Finding and interviewing informants:

Mrs. Franklin is well known among the Aboriginal people of Carnarvon. She is Baijunju herself, and knew the appropriate people to contact.

Mrs. Franklin first introduced me to Mr. Rod Belotti, who works for the Aboriginal Medical Service. He is a former Aboriginal police officer and was aquainted with the normal police procedures that follow discovery of a burial. The usual procedure, he said, was for the police to investigate and to take an appropriate member or members of the local Aboriginal community to give their opinion as to what should happen with the remains. The Department of Aboriginal Sites is contacted, and a sites officer is sent to investigate. Mr. Belotti said the local police were well experienced in this procedure, and that Coral Coast Developments could expect quick and efficient response from the police and the Aboriginal community should a burial be discovered in their construction work.

Mrs. Franklin and Mr. Belotti then told me the names of about five people who ought to be consulted and Mrs. Franklin offered to help me find them and introduce me. The first person we contacted was the senior man who eventually conducted the field survey. After showing him the plans for the Coral Coast marina, he agreed to accompany me to the site the next day. We discussed the participation of a number of other people who would likely have an interest in the survey, but most of these people were known to have other commitments or were ill.

Mrs. Franklin and I then drove out to meet with an elderly woman living on the north side of the river. This woman had worked for many years at Cardabia station, and said the area near the Pt. Maud jetty was a favoured camping place for Aboriginal people. After viewing the plans, she agreed that it was possible that excavations for the harbour entrance would unearth some Aboriginal remains, but she said that she thought the project would not otherwise disturb significant Aboriginal sites. "That should be okay," she said. At the end of the interview, she pointed out

that it was possible that the grandmother of a brother and sister currently living in Onslow may be buried within the development area. I told her I would try to contact these people. I asked if the woman would like to drive up to view the development site the next day, but she declined the offer, saying she had a bad cold that needed looking after. Mrs. Franklin and I mentioned that the senior man had agreed to view the area. The elderly woman concurred that he would be an appropriate person to give a first hand opinion of whether the development would infringe on things of Aboriginal significance.

After lunch, Mrs. Franklin and I went to Mungullah Village hoping to meet with a man who had accompanied Ms. Jan Turner on an ethnographic sites survey of the Ningaloo region in 1985. We knew this person was ill, but I wanted to make him aware of the project, especially since he had probably identified the Mulanda soak site (P5715) at Maud's Landing. Mrs. Franklin spoke to the man and told him of the project, while I waited in the vehicle. "He's pretty sick," she said on returning to the vehicle. "Doesn't want to go." She said that the sick man was satisfied that the senior man would be viewing the area, and representing Aboriginal interests.

5.3 The field survey

The next day the senior man and I drove to Coral Bay. Along the way we discussed the project area. The man said the base of the hills near the Point Maud jetty was a favoured camping place, and that he and his family had used it since he was a boy. "It was the place to come when we had holidays from working on the station," he said. "We used to roll a big tyre up the sandhill, then get in it and roll all the way down."

He said that people had probably used the camping place in prehistoric times as well. The presence of midden material discovered in the archaelogical component of this study supports this observation.

My informant made it plain that he did not want to specifically identify Aboriginal sites unless they were in immanent danger of desecration. He was willing to tell the company where it might go without disturbing sites as defined under the Aboriginal Heritage Act (1972-80) (AHA). I was not surprized at this reluctance to specify sites, as Mrs. Fanklin had warned me that in the recent past the man had objected to researchers who had probed him for specific cultural information. This attitude is in line with current trends in Aboriginal site survey methodology. Aboriginal people are becoming increasingly wary of surveys which map the precise location of sites. There are a number of reasons for this trend.[1]

1) By identifying specific sites, Aboriginal people in effect give away much of the protection and control that the Aboriginal Heritage Act (AHA) otherwise gives them. The purpose of a survey for Aboriginal sites is usually to indemnify a developer against desecration of sites. Once the sites are known, the developer can work around them and so long as he does not disturb the actual site, he need take no further heed of the AHA.

2) Generally speaking, Aboriginal people feel they have a right to be consulted about developments on land which until quite recently -- in their reckoning -- was subject to the constraints of Aboriginal cultural proscriptions. By refusing to specify sites, but by demanding that Aboriginal permission be obtained before development proceeds, they can retain some measure of control over land matters of interest to them.

3) Precise identification of sites is not always culturally appropriate. Many sites are only to be viewed by initiated people of the appropriate sex. Aboriginal people often consider that this knowledge should be held by themselves, and they are distrustful of the management of site knowledge in centralized registers of sites.

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1 See Lawrence (1989), and Veth (1989). Both in Wright (ed.).

Given the strong public denunciation of "Land Rights" a few years back, and the State Government's subsequent refusal to re-endorse the concept, it is not surprising that Aboriginal people are trying to use whatever legislative devises they can, to re-assert Aboriginal cultural integrity.

The above notwithstanding, the senior man appeared to be impressed by the concept of the proposed development at Pt. Maud. I explained that the company thought that the effect of the development would be to concentrate tourist activity in a restricted area, potentially reducing tourist induced environmental stress on the coastal areas adjacent the Ningaloo Marine Park. These stresses were obvious when we parked at the access to the old jetty. After walking around the area, and having a reminiscence about the times spent at holidays there, and showing me the hill down which he once rolled, the man mentioned that in the past half hour over a dozen vehicles had passed through the small parking bay.

With these things in mind, we drove into Coral Bay and found Ken Ryan of Coral Coast Developments. Mr. Ryan went over the plans for the marina with the man, and explained that the constructions would be very careful to avoid damaging vegetation on existing sand dunes. This, he explained, was in the company's clear self interest, since disturbing the dunes would likely cause erosion which would be difficult to control in the windy climate. The senior man said that most things of Aboriginal interest would be in the dunes and thus would not be subject to disturbance by the project.

Mr. Ryan and his wife then accompanied the man and myself to the development area, where we went over the proposal in detail. The man clearly understood where the harbour entrance was planned, and agreed that nothing of Aboriginal significance, which he was aware of, would be disturbed by the proposed cut. He was concerned, however, that the proposed development should not encroach upon the small dunes on the

landward side of the main dunes to the north of the proposed harbour entrance cut.

The man showed us the site of the Mulanda soak, and showed us where the favoured camping areas were, in the lee of the dunes. He did not offer to re-enact his roll down the dunes, but there did not appear to be a tyre available in any case. Mr. Ryan, in turn, told us some of the experiences he had had while camping at the site.

The man told Mr. Ryan that so long as the development did not encroach on the dunes, it was not likely to affect anything of Aboriginal interest. However, he said that he would like to have a further inspection of the area after the surveying has been done, but before actual digging begins, especially in those areas near the dunes.

There remained the problem of the burial which the elderly woman referred to. The man said he did not believe the burial was in the development area, and that the grandchildren would have been too young when their grandmother died to have remembered. He said he believed the grandmother to be buried on a station in the interior. I later contacted the granddaughter and explained the project and its location. She said she had no objection to it proceeding. She also indicated that so far as she was concerned, the senior man had authority to speak for Aboriginal interest in the area.

6.0 Process to be followed in the event of discovering skeletal material

Those Aboriginal people who should be contacted in the event that an Aboriginal burial is discovered while excavating the Coral Coast Marina, have now been alerted to the development and they have expressed their willingness to cooperate to make the formalities associated with such a discovery procede as efficiently as possible.

Should human skeletal material be found during excavation, it should be assumed to be of Aboriginal origin. The remains should be left where found, and any machinery being used in the immediate area should be re-deployed to another portion of the project. The Carnarvon Police should be contacted, as should the Department of Aboriginal Sites of the W. A. Museum. The company should explain any urgency to these agencies. Both the Police and the Museum should contact the Kuwinywardu Resource Agency in Carnarvon who should in turn contact the senior man who participated in this survey, or another person who is considered to have some authority to speak for Aboriginal interests near Pt. Maud. In consultation with the Police and the Museum, this person should determine what should be done with the remains.

It is suggested that Mrs. Mary Franklin be the contact person at Kuwinywardu. The Kuwinywardu telephone number is: 099-412-328.

7.0 Ethnographic conclusions and recommendations

There do not appear to be any objections by relevant Aboriginal people to the proposed Coral Coast Development. Since the majority of the development will take place on the coastal flats behind the dunes, it does not appear likely to conflict with sites of Aboriginal interest which are probably located in the dunes. The exception is the previously registered site at Mulanda soak (P5715).

The Mulanda soak is likely disturbed by the proposed development. Although it appears to be outside the area of planned direct impact, it is hard to believe that it would not be disturbed given the size of the project and the equipment that will be used. It is recommended therefore, that Coral Coast Developments apply under Section 18 of the Aboriginal Heritage Act for permission to disturb a registered site.

The Mulanda soak does not appear to be of any great significance to Aboriginal people, except that it may have some sentimental attachment for those who used to camp at Mauds Landing. It is therefore recommended that permission be granted to Coral Coast Developments to disturb site P5715 (Mulanda soak).

It is suggested that Coral Coast Developments maintain the excellent relations it currently enjoys with the Baijunju people by facilitating the request of the senior man that he re-inspect the area when the survey has been completed.

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Appendix 1. Obligations relating to sites under the Aboriginal Heritage Act (1972-80)

Report of findings - Section 15.

"Any person who has knowledge of the existence of any thing in the nature of Aboriginal burial grounds, symbols or objects of sacred, ritual or ceremonial significance, cave or rock paintings or engravings, stone structures or arranged stones, carved trees, or of any place or thing to which this Act applies or to which this Act might reasonably be suspected to apply shall report its existence to the Trustees, or to a police officer, unless he has reasonable cause to believe the existence of the thing or place in question to be already known to the Trustees".

Offences relating to Aboriginal Sites - Section 17.

A person who-

(a) excavates, destroys, damages, conceals or in any way alters any Aboriginal site; or

(b) in any way alters, damages, removes, destroys, conceals, or who deals with in a manner not sanctioned by relevant custom, or assumes the possession, custody or control of, any object on or under an Aboriginal site,

commits an offence unless he is acting with the authorization of the Trustees under section 16 or the consent of the Minister under section 18.

Consent to certain uses - Section 18.

(1) For the purposes of this section, the expression "the owner of any land" includes a lessee from the Crown, and the holder of any mining tenement or mining privilege, or of any right or privilege under the Petroleum Act 1967, in relation to the land.

(2) Where the owner of any land gives to the Trustees notice in writing that he requires to use the land for a purpose which, unless the Minister gives his consent under this section, would be likely to result in a breach of section 17 in respect of any Aboriginal site that might be on the land, the Trustees shall, as soon as they are reasonably able, form an opinion as to whether there is any Aboriginal site on the land, evaluate the importance and significance of any such site, and submit the notice to the Minister together with their recommendation in writing as to whether or not the Minister should consent to the use of the land for that

purpose, and, where applicable, the extent to which and the conditions upon which his consent should be given.

(3) Where the Trustees submit a notice to the Minister under subsection (2) of this section he shall consider their recommendation and having regard to the general interest of the community shall either-

(a) consent to the use of the land the subject of the notice, or a specified part of the land, for the purpose required, subject to such conditions, if any, as he may specify; or

(b) wholly decline to consent to the use of the land the subject of the notice for the purpose required,

and shall forthwith inform the owner in writing of his decision.

(4) Where the owner of any land has given to the Trustees notice pursuant to subsection (2) of this section and the Trustees have not submitted it with their recommendation to the Minister in accordance with that subsection the Minister may require the Trustees to do so within a specified time, or may require the Trustees to take such other action as the Minister considers necessary in order to expedite the matter, and the Trustees shall comply with any such requirement.

(5) Where the owner of the any land is aggrieved by a decision of the Minister made under subsection (3) of this section he may, within the time and in the manner prescribed by rules of court, appeal from the decision which shall have effect as if it were the decision of the Minister to the Supreme Court which may hear and determine the appeal.

(6) In determining an appeal under subsection (5) of this section the Judge hearing the appeal may confirm or vary the decision of the Minister against which the appeal is made or quash the decision and substitute his own decision of the Minister, and may make such order as to the costs of the appeal as he sees fit.

(7) Where the owner of any land gives notice to the Trustees under subsection (2) of this section, the Trustees may, if they are satisfied that it is practicable to do so, direct the removal of any object to which this Act applies from the land to a place of safe custody.

(8) Where consent has been given under this section to a person to use any land for a particular purpose nothing done by or on behalf of that person pursuant to, and in accordance with any conditions attached to, the consent constitutes an offence against this Act.