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ESTUARY DEEPENING

COX BAY, FALCON

PUBLIC ENVIRONMENTAL REVIEW

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INVITATION

The Environmental Protection Authority (EPA) invites people to make a submission on this proposal.

This Public Environmental Review (PER) has been prepared in accordance with Western Australia Government procedures. The PER proposes the deepening of part of Cox Bay, south of Mandurah, and the filling and redevelopment of the adjacent foreshore for public recreation. The report will be available for comment until 16 March 1991.

Following receipt of comments from government agencies and the public, the EPA will prepare an assessment report with recommendations to government, taking into account issues raised in public submissions.

Why write a submission ?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless confidentiality is requested, and may be quoted either in full or in part in each report. It will assist the EPA in its handling of submissions if your submission can be used in this way is clearly stated.

Why not join a group ?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the PER or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

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When making comments on specific proposals in the PER:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable;
- suggest recommendations, safeguard or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that the issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the PER;
- if you discuss different sections of the PER, keep them distinct and separate, so there is no confusion as to which section you are considering;
- attach any factual information you wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name
- address
- date

The closing date for submission is: 16 March 1991

Submissions should be addressed to:

The Chairman,
Environmental Protection Authority,
1 Mount Street,
PERTH WA 6000.

Attention: Ms G. Corbett

ESTUARY DEEPENING

COX BAY, FALCON

PUBLIC ENVIRONMENTAL REVIEW

Report to: Meiyu Australia Pty Ltd,
26 Riverside Road,
EAST FREMANTLE WA 6158

by: LeProvost Environmental Consultants,
Suite 2, 175 Labouchere Road,
COMO WA 6152.

24 December 1990

LEC Ref: J192

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ESTUARY DEEPENING

COX BAY, FALCON

PUBLIC ENVIRONMENTAL REVIEW

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5 Waterbird Usage and the Conservation Status of Cox Bay.

6 Report on a Survey for Aboriginal Sites, Estuary Gardens Project.

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8 Foreshore Management Plan.

SUMMARY

THE PROPOSED PROJECT

Meiyu Australia Pty Ltd is the owner of Pt Murray Location 1147 (Estuary Gardens), which it plans to develop as a tourist and residential area, and for which it has already received conditional approval from the Environmental Protection Authority. The estuary foreshore adjacent to this land is in a degraded state. The area also has an algal problem whereby weed collects in the shallows and on the foreshore where it decays and emits foul odours. At present the algae is removed by front-end loader and truck from about 2 km of the Falcon shoreline where shallow water and the presence of limestone outcrops prevents the use of floating weed harvesters. Consequently, a large proportion of the algae cannot be removed until it has been washed ashore and stranded on the beaches. The algae is then removed by a front-end loader equipped with rakes and scoops. This activity has resulted in the destruction of the marginal vegetation, especially rushes, and has resulted in erosion of the shoreline.

To increase recreational opportunities and improve algal management in Cox Bay, the proponent proposes to deepen part of Cox Bay to provide boating access and water-based recreational opportunities to this land and adjacent areas at Falcon and reduce the local algal problems by providing for improved management including the use of floating weed harvesters.

The development will involve the excavation of approximately 112,500 m^3 of material from the estuary floor of Cox Bay in the Peel Inlet near Falcon to create a permanent water-filled embayment along the foreshore. Excavation will be undertaken by an excavating machine and front-end loaders. The excavated material will be used to fill and widen the existing foreshore and construct an offshore island.

The estuary bed for a distance of 1,150 m along the shore and up to 380 m offshore will be excavated to depths of up to 0.45 m below the existing estuary floor. This will create a permanent water filled embayment with a minimum depth of 1.1 m below Australian Height Datum (AHD) at the toe of the beach, deepening offshore until it reaches the natural basin depth of -1.3 m below AHD which occurs approximately 350 m offshore.

Approximately 59,500 m^3 of excavated sandy sediment will be used to create an offshore island approximately rectangular in shape, located 350 m offshore, and aligned parallel to the beach. It is intended that the island be used exclusively for bird habitat and will be vegetated accordingly.

Approximately 40,000 m^3 of sediment will be used for fill material on the existing foreshore and 13,000 m^3 for beach extensions. The foreshore will be planted with indigenous native trees and recreational facilities will be constructed. These will

include a dual use pathway along the foreshore, and construction of a new boat ramp and carpark adjacent to the existing Falcon boat ramp.

ALTERNATIVES CONSIDERED

A number of alternative developments to the proposed project were considered including channel dredging only; a small embayment with no offshore islands, and the no development option. The channel option would improve boating opportunities in the local area, but would not generate a foreshore area suitable for other recreational interests or reduce the local algal problem. The small embayment option would not generate sufficient fill material to create the offshore island and would be likely to become a trap for drifting algae, negating the recreational advantages of the development. The no development option would not alleviate the current demand for recreational areas adjoining the Peel Inlet, so the negative environmental effects on the foreshore vegetation, associated with concentrated human use would continue. The local weed management problem would also persist, together with the foreshore erosion caused by present harvesting operations.

THE RECEIVING PHYSICAL ENVIRONMENT

The study area is located within the Peel-Harvey Estuary system which is situated on the Swan Coastal Plain. The region experiences a Mediterranean climate similar to Perth, with hot dry summers and mild wet winters.

The waters of the Peel-Harvey estuarine system are nutrient enriched (eutrophic), as a result of a large input of phosphorus to the system from fertiliser applied to the soils of the catchment area. Consequently, the estuarine system periodically experiences algal blooms.

The Peel Inlet is bathymetrically differentiated into a central basin 1.5-2 m deep, and a shallow marginal shelf. The marginal shelf surrounds the central basin extending for up to 3 km offshore and stands at an average level of 1 m above the central basin. On the western side of Peel Inlet, which includes the study area, the shelf varies between 300 m and 800 m in width and slopes more or less uniformly from the shore to the basin floor. The morphology of the slope and basin of the Peel-Harvey Estuary are the result of sedimentation and erosion processes acting along the shoreline and still occurring at present.

BIOLOGICAL ENVIRONMENT

The estuarine biota of Peel Inlet comprises an abundant widespread infauna of molluscs, worms and crustaceans; a nektonic fauna of estuarine fish and crustaceans; and an aquatic flora of various seagrasses and algae.

Wetland habitats peripheral to the Peel Inlet support a fringing paperbark and salt marsh vegetation, and a variety of avifauna utilise the estuarine habitats as feeding, breeding and loafing grounds. The Peel-Harvey estuarine system provides habitat for many migratory species of waders and is recognised as the single most important water bird site in the south-west of Western Australia.

The major aquatic plant groups of the Peel Inlet include microalgae (microscopic aquatic plants), macroalgae seagrasses (seaweed), and marsh vegetation (samphire and rushes).

The microalgae, together with detritus, form the basis of the food web upon which many of the estuary's life forms depend. The seagrasses are highly productive, providing organic matter which has a high food potential for a range of animals including molluscs, prawns and fish, and important nursery areas for these animals. Seagrass plants stabilise bottom sediments because they have roots and rhizomes which bind the sediments. The seagrasses *Halophila ovalis* and *Ruppia megacarpa* are widespread around the marginal platforms of Peel Inlet. *Halophila* occurs in the deeper water of the shelves while *Ruppia* is restricted to the shallows.

Several species of macroalgae (large attached seaweeds) grow in the estuary, although the dominant species has varied over time. The most commonly occurring macroalgae include *Cladophora* (goat-weed), *Chondria, Chaetomorpha* (rope-weed), *Enteromorpha, Chloridia* and *Ulva* (sea lettuce). Under normal nutrient regimes the estuary supports limited populations of these plants, and these plants provide important feeding and sheltering sites for young fish. The existing elevated nutrient concentrations in the estuary have caused these plants to grow to excess which has been to the benefit of some fish populations, but has created significant management problems as the algae dies, decomposes and washes up on the beaches near residential and recreational areas.

When mature, these macroalgae are taller than seagrass and their upper branches float near the surface so that they are not disadvantaged by a lack of light. In this way they are gradually replacing the seagrasses in some parts of the estuary.

The faunal diversity of the Peel Inlet is influenced by wide fluctuations in salinity related to freshwater supply from the rivers during winter months, and saline flow through the entrance channel combined with high rates of evaporation during summer months. Few aquatic animals are capable of living and reproducing in such a variable environment. Some highly mobile species including some fish move from place to place as the salinity varies.

The Peel-Harvey System is the single most important waterbird habitat in the south-west of Western Australia. The waterbirds of the estuary system include migratory waders, resident waders, fish-eating birds, long-legged waders and water fowl. The migratory waders feed mainly in intertidal areas at low tide and in shallow water on inland, non-tidal wetlands. Their principal food item is benthic fauna, and they roost on sandy cays and spits. They are rarely found in estuaries with a marked tidal influence. The fish-eating birds, which include pelicans,

cormorants and terns, occur in the estuarine system all year round. They feed in the deeper water and roost on sandy areas above high tide. The long-legged waders feed in shallow waters on small fish, crustaceans and benthic invertebrates, and roost in trees near the waters edge. The water fowl, which include ducks, swans and coots, are found in large numbers in the estuarine system. They feed on large aquatic plants (especially *Ruppia* and some macroalgae) and benthic invertebrates.

The project area represents an intertidal and shallow subtidal sandy habitat. This supports a relatively high diversity and abundance of benthic invertebrates, which provide the food for wading birds, water fowl, crustaceans and fish. However, this ecosystem has been modified by presence of large accumulations of weed and from weed harvesting practises.

The offshore water areas of Cox Bay, deeper than 0.5 m, have been identified as one of the principal areas of algal growth in the estuary. This has resulted in large accumulations of decomposing macroalgae occurring along the western shoreline of Peel Inlet.

HUMAN ENVIRONMENT

An attitudinal survey of Mandurah implied that the values of the area for residents are largely based on natural environment and lifestyle considerations. The variety of natural landscapes and water settings offer a range of recreational opportunities which are fundamental to the aesthetic value of the region. Several large areas within the Peel-Harvey Estuary system are considered to be regionally significant for conservation and the estuary and its margins are recognised as internationally significant as a waterbird habitat. However, at a local scale there are no formally identified areas of conservation significance within or immediately adjacent to the project site.

The Mandurah region is one of the State's major tourist and holiday destinations. The main visitor attraction identified in the Mandurah region is the attraction of the estuary and associated activities. Water-based activities include boating, sailing, swimming, fishing, crabbing and prawning, while land based activities include picnics, barbeques and scenic walks.

Public access to the project area is provided via the public boat ramp and carpark located on the north-west corner of the proposed development area. The major constraint is the shallowness of the broad expanse of water which extends from the shoreline for several hundred metres into Peel Inlet. Aerial photography of the channel approach to the boat ramp shows scars where boat propellers have disturbed the bottom. This factor, and the periodic accumulation of algae within the bay, limits usage of the bay by boats and restricts the use of the water for swimming or other forms of direct contact recreation.

Generally, there is very little provision of sites suitable for boat launching and storage around the Peel Inlet which has led to indiscriminate use of the foreshore

for these purposes. This has led to disturbance of the foreshore vegetation and erosion problems which will worsen without the provision of formal access. The Waterways Commission, in its recently released review of the Peel Inlet Management Programme, has recommended that a programme of dredging and filling, involving deepening of the nearshore region and widening of the foreshore reservation with dredge spoil, be designed to overcome these boat launching problems. Cox Bay, the site of this proposal, was identified as a location potentially suitable for such development.

POTENTIAL IMPACTS OF THE PROJECT

The adverse impacts predicted for the physical, biological and human components of the environment, as a result of the proposed development, are summarised in Table I (p.xii). The table outlines each major potential impact and comments on the management actions to be undertaken by the proponent to mitigate the each impact.

The beneficial impacts of the proposed development are summarised in Table II (p.xiii).

MANAGEMENT PROGRAMME

A comprehensive management programme is proposed, comprising an estuary management plan and a foreshore management plan. The proponent undertakes to abide by the following management commitments to minimise and mitigate the environmental impacts of the development:

(i) Access to the construction site will be provided from Old Coast Road through the Estuary Gardens project area to minimise traffic and noise impacts on local residents.

(ii) Construction activity will be confined to daylight hours for six days per week to minimise noise impacts on local residents. Periodic background noise emissions for 24 h/day may result from the use of pumps during construction.

(iii) Any dry material used in the earthworks for the proposed development and the adjacent Estuary Gardens project will be watered if necessary to prevent dust emissions in the short period prior to undertaking permanent stabilisation works.

(iv) The soil surfaces of the offshore island and the foreshore will be stabilised and vegetated following earthworks.

(v) Public access to the project area will be denied during construction for safety reasons. However, access to the Falcon jetty and boat launching facility will be available for most of the construction period.

(vi) Excavation of Cox Bay will take place within an encompassing bund wall to prevent turbid and nutrient-enriched waters from entering the main body of Peel Inlet.

(vii) The offshore island will be surrounded by a relatively large area of shallows to maximise waterbird habitat. No boat landings or other recreational facilities will be provided in an attempt to discourage human visitation and thereby maximise the potential of the island as a bird refuge.

(viii) Recreational facilities will be provided on the foreshore including a foreshore dual use pathway and construction of a new boat launching ramp and carpark.

(ix) Water quality in the embayment and adjacent Peel Inlet waters will be monitored during construction and on a six monthly basis for two years following construction.

(x) A monitoring programme will be undertaken for a period of two years after completion of the project to determine the construction impacts of the development on benthic invertebrate, seagrass and algal populations in Cox Bay, and to monitor recolonisation of the area by these biota.

(xi) The project has been designed to allow for changes in environmental conditions associated with the Greenhouse Effect and the proposed Dawesville Channel.

(xii) Sediment movement and stability of the new shoreline and offshore island will be monitored.

(xiii) The results of the monitoring programmes will be reported on an annual basis to the Environmental Protection Authority (EPA), Waterways Commission and Peel Inlet Management Authority (PIMA). At the end of the two year monitoring programme, a final report will be prepared showing the results of the complete programme.

(xiv) The proponent will lodge a bond of $20,000 with the State to guarantee completion of the proposed project as described in this document.

CONCLUSION

It is concluded that the potential environmental impacts of this proposal can be successfully managed by the implementation of the management programmes outlined in this report. The development will improve environmental characteristics and recreational opportunities at Cox Bay, provide a valuable avifauna refuge, and enable better management of both the nearshore waters and the foreshore.

TABLE I

SUMMARY OF THE POTENTIAL IMPACTS ON THE ENVIRONMENT

POTENTIAL ADVERSE IMPACTS	COMMENTS
Changes in water quality due to the release of nutrients from suspended sediments.	Main excavation will be carried out within bund walls to minimise the release of suspended sediments and contained nutrients to Peel Inlet.
Changes in water movement patterns.	The project has been designed to maximise water exchange of the embayment with Peel Inlet.
Erosion of the newly constructed foreshore due to natural longshore sediment transport processes.	Sediment movement is small (10 m^3/y) and beaches will be allowed to establish a naturally stable alignment.
Release of turbid water to the Peel Inlet during construction and removal of the bund walls.	The chosen construction method will minimise the emissions of turbid waters.
Permanent loss of 40 ha of intertidal benthic habitat.	Intertidal habitat will be replaced by shallow water habitat. Construction of the island will create new areas of intertidal habitat. Overall there will be some loss of shore and wading bird habitat. There will be a corresponding increase in water fowl habitat.
Increased potential for algal growth immediately following construction due to nutrients released from suspended sediments.	The nutrient level is not expected to be higher than that presently occurring in this area.
Loss of access to the development site during construction.	Warning signs and fences will be erected to prevent public access to the construction site.
Temporary (one week) loss of access to the Falcon jetty and boat ramp during deepening around these facilities.	A construction programme will be advertised prior to the commencement of construction and boat users will be advised of times when use of these facilities will be restricted.
Noise impacts for local residents during construction.	Construction will be confined to daylight hours only.
Increased traffic on local roads during construction of the project.	The onshore development will provide access between the project site and the Old Coast Road. All construction vehicles will access the site from the onshore area.
Permanent alterations to the landscape of Peel Inlet offshore from Falcon.	The island will be planted with vegetation indigenous to the Inlet.

TABLE II

SUMMARY OF THE BENEFITS OF THE PROPOSED DEVELOPMENT

POTENTIAL BENEFITS	COMMENTS
Provision of a permanent body of water suitable for boating and swimming.	Recreational areas of this nature are limited in Peel Inlet.
Provision of a managed foreshore recreation area.	Development of this part of the Peel Inlet foreshore for recreation will reduce pressure on other parts of the foreshore which are proposed to be set asside for conservation purposes.
The development will enable more effective weed harvesting which will allow the removal of algae for the length of the embayment.	The effect of odours from decomposing weed on the beach in Cox Bay will be reduced.
Infilling of mosquito breeding grounds in Cox Bay.	Reduction in the mosquito breeding problem and lowering of the potential for the transmission of Ross River Virus.
The offshore island will provide areas of bird habitat relatively isolated from human activities.	This will mitigate the loss of intertidal refuge caused by the foreshore development.

ESTUARY DEEPENING

COX BAY, FALCON

PUBLIC ENVIRONMENTAL REVIEW

1 INTRODUCTION

1.1 THIS DOCUMENT

This document is a Public Environmental Review (PER), which Meiyu Australia Pty Ltd (Meiyu) has commissioned LeProvost Environmental Consultants (LEC) to prepare, for submission to the Environmental Protection Authority (EPA) of Western Australia, in accordance with the provisions of the *Environmental Protection Act, 1986* (WA).

The PER provides a detailed environmental assessment of Meiyu's proposal to deepen the nearshore area of Cox Bay (in the Peel Inlet near Falcon), and to use the spoil to create a small island approximately 300 m offshore and to re-construct the foreshore and eroded shoreline. The PER has been drafted according to guidelines provided by the EPA after it reviewed the proposal application (a document which outlined the project). The EPA guidelines are reproduced in Appendix 1.

The PER format, which broadly follows that suggested by the guidelines, comprises three main parts:

(i) summary;

(ii) main text; and

(iii) technical appendices.

The main text of the PER consists of eight sections. Section 1 describes the structure of the PER, introduces the proponent and briefly outlines the nature, timing and need for the project. This Section also describes the approval procedure, defines the responsible authorities, lists the various studies that have been conducted, and acknowledges those individuals who have provided information or technical advice.

Section 2 discusses alternatives to the proposed development (including the 'no development' option), while Section 3 presents the proposed option in detail, including construction methods and timing. Section 4 describes the existing physical, biological and human environment on both regional and local scales so that the proposal can be placed into perspective within the Peel Inlet and Mandurah region.

Section 5 identifies the effects of the project, and assesses their potential impacts on the on the physical, biological and social elements of the development site and regional environment. The management programme to be implemented by the proponent, to avoid or minimise the potentially adverse effects identified in this document, is described in Section 6. Section 7 summarises the overall environmental acceptability of the project and Section 8 lists all of the commitments made in respect of this proposal by the proponent. Reports and publications cited in the text are referenced in Section 9.

The technical appendices detail the results of the various studies which have been undertaken to investigate the effects of the proposal on the environment. These reports contain information supporting the conclusions which have been drawn, and are provided for those wishing to review the technical data and methodology.

1.2 PROPONENT AND PROJECT

The proponent for the development is Meiyu Australia Pty Ltd. The company owns 27 ha of land adjacent to Cox Bay, upon which a residential and resort development incorporating a hotel, country club, retirement village and housing sites is proposed. Conditional environmental approval for this development, named the Estuary Gardens Estate, has been given by the EPA, subject to recommendations relating to nutrient input, sewage disposal and management of the foreshore.

The proposal described in this document comprises the deepening of a shallow nearshore portion of Cox Bay which occupies an 1150 m stretch of the Peel Inlet shoreline from north of Olive Road up to the boat ramp at Falcon (Fig. 1, p.68). The aim of excavating the nearshore embayment is to create an area where inshore water depths will range from 0.4 to 0.8 m under almost all tidal and meteorological conditions. The excavation works will not create a dip or hole in the embayment floor, as excavation will extend to approximately 380 m offshore to ensure that water depth will gradually increase and merge with the existing -1.3 m AHD contour (Figs 1 & 2. pp.68, 69). The excavated sand will be used to widen the existing foreshore by approximately 6 m and stabilise and improve the beach, and to construct an offshore island.

The objective of deepening the nearshore portion of Cox Bay is to improve the amenity value of Cox Bay and foreshore area by:

- enabling accumulations of decomposing algae and weed to be harvested by the floating harvesters operated by the Peel Inlet Management Authority (PIMA);

- providing a permanent body of water at the shoreline suitable for boating, swimming, sailing, prawning, crabbing and other water-based recreational activities;

- constructing an offshore island to provide a feeding and sanctuary area for water birds; and

- facilitating the widening and improvement of the foreshore reserve that has been proposed for public open space and recreational amenities.

1.3 NEED FOR PROJECT

Foreshore reserves along the Peel Inlet are typically narrow because of the limited space between the waterline and freehold properties or roads. The wide shallow banks along the margins of the Peel Inlet and Harvey Estuary make boating, swimming and other recreational activities difficult. The lack of formalised nearshore recreational areas has led to indiscriminate use of the narrow foreshores, in turn leading to disturbance and loss of natural vegetation as well as beach erosion problems.

Provision of accessible and comparatively deep (i.e. 0.5 - 1.5 m) areas of water adjoining broader, developed foreshore areas provide foci for recreational activities that can be managed more effectively. Such areas also reduce the pressure on more pristine or less stable portions of the foreshore which can be conserved and/or rehabilitated.

The only way that aquatic weed can currently be harvested in Cox Bay is with front-end loaders operating along the beach line. The nearshore waters are too shallow for the floating weed harvesters which require a minimum water depth of 0.6 m when loaded.

Complaints have been made to PIMA regarding the accumulations of decomposing algae which lie beyond the reach of the front-end loaders on the shallow nearshore banks. Such accumulations occur because of the sheltered aspect of Cox Bay and the lack of strong water movements within the Bay (see Section 4). Since the existing area of shallow water and presence of isolated rocky outcrops prevent the use of floating harvesters, deepening of this area and removal of the outcrops would enable far more efficient harvesting of the weed.

The concept of deepening the nearshore waters of Cox Bay to improve both water quality and public amenity of this area was recently proposed by PIMA in a management study of the western foreshores (Waterways Commission, 1990a) and in the Draft Peel Inlet Management Programme Review (Waterways Commission, 1990b). This recommendation was in part based on a public survey, which identified a demand for additional recreational space. Of the various areas examined by the report for improved water-based activities, those in the Falcon-Novara area were placed in a high priority category.

1.4 PROJECT OUTLINE AND TIMING

Spoil excavated from the development area will first be used to construct a temporary bund wall that will enclose the work site. The bund will prevent the release of turbid water during the main excavation period, when on average the top 0.26 m of the estuary bed will be removed to a depth of -1.1 m AHD (i.e. depth below the Australian Height Datum). Note that in Peel Inlet the Chart Datum (CD), or Sounding Datum (SD), is equivalent to -0.45 m AHD.

The estuary floor will be deepened to produce a gentle grade in the offshore direction, with a depth of -1.3 m AHD being attained approximately 380 m beyond the existing beach line. (Fig. 2, p.69). Excavation will not create a depression or 'hole' within Cox Bay since the -1.3 m AHD contour corresponds to the existing estuary floor at this point, where it merges with the Peel Inlet basin.

The 112,500 m^3 of excavated spoil will be used for shoreline stabilisation and extension, as well as to create an island which will be approximately 2.6 ha in area (at mean sea level) and roughly rectangular in shape (Fig. 3, p.70). The island, which will be located approximately 300 m offshore and parallel to the beach, has been designed to provide visual amenity and a habitat for water birds and will be vegetated accordingly. The island is not designed to provide a recreational area, and facilities such as barbeques and tables will not be installed.

The construction period, which involves development of the temporary bund walls, excavation of the inshore area of Cox Bay, island formation, foreshore works and removal of the bunds, will take 16 weeks. Replanting and the development of recreational facilities on the foreshore area would proceed immediately after this period, and take a further 10 weeks to complete. Planting of vegetation on the island will be undertaken before the bund walls have been removed, so that advanced vegetation, which will supplement seed planting and hydromulching, can be transplanted from those parts of the foreshore where filling will take place.

1.5 STATUTORY REQUIREMENTS

Approval for the project to proceed is required from the State Government, the Shire of Murray, the Mandurah City Council and the Peel Inlet Management Authority (PIMA, which acts on behalf of the Waterways Commission).

Statutory procedures associated with the environmental approval process comprise the following stages:

(i) release of this PER for an eight week period for public review and comment;

(ii) examination by the EPA of the PER, the public submissions and any advice received from other relevant Authorities or Departments;

(iii) consideration by the EPA of the proponent's responses to questions raised during the public submission period;

(iv) EPA recommendations to State Government (via the Minister for the Environment) as to whether or not the project is environmentally acceptable;

(v) Ministerial review of the EPA's recommendations and determination of conditions.

1.6 RESPONSIBLE AUTHORITIES

The proponent will be responsible for all aspects of project construction, including vegetating the filled and widened foreshore and the new island. It is proposed that following project completion, both the foreshore reserve and the island will be vested with the Waterways Commission.

It is envisaged that the day-to-day management of the foreshore reserve (i.e. care and maintenance) will be undertaken according to the provisions of an approved management plan by a local Residents Association whose members will comprise the residents of the Estuary Gardens Estate, and that the costs of such management can be funded by a small annual levy paid by all households in the Estuary Gardens Estate.

1.7 STUDIES CONDUCTED

Concerns that have been identified with the proposed development are as follows:

- effects of emissions of turbid water and potential release of nutrients from suspended sediments during the deepening of Cox Bay;
- stability of the new offshore island;
- potential deleterious changes to water circulation and sedimentation patterns in Peel Inlet after project completion;
- loss of possible valuable habitat for water birds as a result of both excavation and infilling;
- lack of recovery of disturbed benthic habitat; and
- possible impact on the Peel Inlet commercial fishery.

A number of field and desk studies were undertaken to investigate these concerns and identify potential issues. Literature on dredging operations and spoil disposal in estuarine environments was reviewed, and the sediments and benthic biota at the development site have been compared with those from similar sites elsewhere in

Peel Inlet, some of which have already been subject to dredging. Water quality in the Cox Bay area has been examined, and the pattern of water circulation within Cox Bay both before and after its deepening has been modelled.

The effects of the proposed excavation technique were also examined during a field trial at Cox Bay. This trial included the construction of a bund wall and the deepening of the boat channel which leads to the Falcon boat ramp immediately adjacent to the northern boundary of the project site (Fig. 2, p. 69). During this trial, particular attention was paid to turbidity effects and the potential for nutrient release (see Appendix 7), as well as to the behaviour, porosity and stability of the temporary bund.

The value of the offshore habitats for water birds was investigated, and information was sought from the Western Australian Museum on the likelihood of Aboriginal sites being encountered on the foreshore and beach area.

The methods and results of the various studies are detailed in the technical appendices, as follows:

Appendix 1 EPA guidelines for the PER;
Appendix 2 Coastal engineering study (Riedel & Byrne);
Appendix 3 Cox Bay water quality (LEC);
Appendix 4 Benthic fauna and fisheries resources (LEC);
Appendix 5 Water bird habitats (Ninox Wildlife Consultants);
Appendix 6 Report on a survey for Aboriginal sites (R. O'Connor and G. Quartermaine);
Appendix 7 Effects of trial excavation (LEC); and
Appendix 8 Draft Foreshore Management Plan (LEC).

In addition to the studies described in the appendices, representatives of the Mandurah City Council, the Shire of Murray, the local professional fishermen, and officers of the Waterways Commission and Peel Inlet Management Authority have been consulted by the study team.

1.8 ACKNOWLEDGMENTS

The assistance of the following people in providing information for this report is gratefully acknowledged:

Mr G. Leyland, Western Australian Fishing Industry Council Inc.

Mr Colin Chalmers, Waterways Commission, Perth

Mr B. Toussaint, Professional fisherman, Bouvarde

Mr J. Watts, Professional fisherman, Falcon.

2 DEVELOPMENT OPTIONS

2.1 'NO DEVELOPMENT' OPTION

The project site is currently an undeveloped section of the shoreline and shallow embayment on the western side of Peel Inlet. Much of the nearshore area is exposed or very shallow during summer and inundated during winter, with water depths remaining in excess of 0.5 m for most of the time. The site provides limited social amenity, although used for crabbing under suitable tidal conditions. The area is also used by professional fishermen who set nets for cobbler during periods of high water between March and July (Section 4.3). The nearshore shallow water areas provide feeding areas for water birds and the shoreline is used for roosting and loafing by these birds (Section 4.2).

The Falcon boat ramp is immediately adjacent to the northern boundary of the development site and where the weed harvesters, used to collect floating algae from the offshore waters, are often moored. The channel which runs out from the boat ramp has recently been lengthened and deepened (refer Section 3.2.1.1 and Appendix 7) at the proponent's expense during testing of the proposed construction technique.

Cox Bay has been identified as one of the principal areas within the Peel-Harvey system where substantial amounts of decomposing algae accumulate (Hodgkin et al., 1985). The decomposing algae releases odours which offend local residents, however the harvesting of weed from the beaches with front-end loaders has promoted beach erosion and degradation of foreshore vegetation.

There is a recognised need for the establishment of formal recreational areas around the estuary shores to prevent the indiscriminate use of the foreshores that currently exists (Waterways Commission, 1990a).

Continuation of the present situation at Cox Bay would mean that:

- beach erosion will continue as a result of the need to continue to use earthmoving equipment to clear the rotting weed from the shoreline;
- visual and odour problems associated with both the offshore and shoreline algae accumulations will continue;
- marine animals colonising the sediments of Cox Bay (benthic fauna) will continue to be adversely affected each summer by the rotting weed which produces anoxic (deoxygenated) conditions;
- the beach will remain unsuitable for swimming; and
- Cox Bay will remain unsuitable for sailing, canoeing and other water-related activities.

The 'no-development' option also warrants consideration with respect to predicted water level changes after the completion of the Dawesville Cut. Since the Dawesville Cut is expected to cause the mean low tide level in Peel Inlet to fall by 0.10 - 0.15 m with little or no change to high tide levels (Kinhill Engineers, 1988), it is likely that a larger part of Cox Bay will form a trap for drifting algae and weed.

It can therefore be argued that the 'no development' option is detrimental to both the social and biological resources of the Peel Inlet, regardless of whether or not the Dawesville Cut is undertaken.

2.2 PROPOSED OPTION

The proposed option has been outlined in Section 1 and is described in detail in Section 3.

The proposed deepening, foreshore filling and widening and beach stabilisation will provide considerably improved amenity for water-based recreational activities, and enable more efficient weed harvesting without the current problems of beach erosion. The proposed offshore island will in part offset the loss of shallow water waterbird habitats which will be caused by the excavation. It is expected that overall water quality will improve, and that the number of fish and crabs utilising Cox Bay will be enhanced, particularly during the summer months.

2.3 ALTERNATIVE SITES

The proposed deepening at Cox Bay lies within one of two areas on the western side of Peel Inlet that have been nominated by Waterways Commission (1990a) as potential dredged recreation areas. The other area is at Cadadup which, surrounding the entrance to the proposed Dawesville Cut, will probably be deepened after, or at the time of, the Dawesville Cut excavation.

2.4 NO OFFSHORE ISLAND

The vegetated offshore island could be omitted from the proposed works without serious alteration to the feasibility of the project as it would be possible to use the spoil generated by the excavation in other areas. Omission of the island is preferred by professional fishermen, who view the island as occupying part of the existing cobbler netting grounds in Cox Bay (G. Leyland, pers. comm.). However, omission of the island would negate a number of potential benefits, listed as follows:

- creation of a feeding and sanctuary area for water birds which will assist in offsetting the habitat loss brought about by modification of the existing shoreline and nearshore habitat;

- creation of a visual aesthetic feature within Cox Bay; and
- provision of a beneficial and cost-efficient use of material, excavated from further offshore in Cox Bay.

The Proponent would however be prepared to undertake the excavation work if the authorities were to recommend against construction of the island. In this case the excess spoil would be used to fill the Proponent's land to a level suitable for construction.

2.5 NEARSHORE DEEPENING ONLY

Creation of only a nearshore stretch of water that is sufficiently deep for bathing, canoeing and crabbing would result in the formation of a trench or 'hole' in Cox Bay. This would become a trap for drifting algae, and would promote siltation and stagnation. This option is therefore regarded as unacceptable.

2.6 ADDITIONAL DEEPENING

Removal of additional estuary bed material from Cox Bay to expand and/or increase water depths such that the bay becomes suitable for large boats or for sports such as water skiing has been rejected for a number reasons:

(i) While the substrate of Cox Bay comprises well graded sands to approximately 350 m beyond the shoreline, further offshore the sediments become much finer and, as these silty muds are unsuitable for excavation or dredging from both an engineering and environmental aspect, it is not feasible to expand the area excavated offshore.

(ii) Similarly, it is impractical to connect a basin excavated to a depth of greater than 1.3 m AHD within Cox Bay to water of similar depth in Peel Inlet, as this would require the dredging and maintenance of a channel approximately 300m long through the soft, silty basin sediments.

(iii) The offshore silty sediments which would be generated by excavation are not suitable for beach improvement or land fill and thus their disposal would be impractical.

(iv) Motor boat activities, such as water skiing, would reduce the value of the proposed offshore island bird sanctuary, and are considered to detract from the aesthetic amenity provided by Cox Bay.

3 DESCRIPTION OF PROJECT

3.1 CONCEPT AND LOCATION

3.1.1 Scope

The preferred option involves excavation of the nearshore embayment of Cox Bay, with the excavated sands being used to fill and widen parts of the foreshore, to stabilise the beach, and to create an offshore island (Figs 1 & 2, p.68, 69). These operations, which will be carried out at a cost to Meiyu of approximately $1 million, involve the excavation of a total of approximately 112,500 m^3 of sandy sediments behind temporary bund walls within Cox Bay, using an excavating machine and front-end loaders. Of the sandy spoil excavated from Cox Bay, approximately 59,500 m^3 will be used for construction of the offshore island, 40,000 m^3 will be used to level, grade and extend the foreshore reserve and 13,000 m^3 will be placed on the beachface.

The deepened embayment and offshore island are intended to become permanent features of the Peel Inlet. Recreational facilities to be located on the proposed foreshore reserve are designed for an expected lifetime of 50 years.

3.1.2 Embayment Deepening

The proposed site, which is described in Section 1.4 of the PER, extends along the shoreline of Cox Bay for a distance of 1,150 m and offshore to a maximum distance of 380 m (Fig. 2). Within this area the estuary bed will be deepened to depths ranging from -1.1 m AHD, at the toe of the beach slope, to -1.3 m AHD, the existing depth at the offshore boundary (Fig. 3, p.70). This excavation will, on average, involve the removal of the top 0.26 m of the existing sandy sediments (Fig. 4, p.71) and provide a continuous slope from the shoreline outwards to the limit of excavation.

It is proposed also that the embayment deepening should be allowed to extend into the area immediately surrounding the existing Falcon jetty and boat ramp, which lie alongside the northern boundary of the site (Fig. 2). It is also proposed that the existing limestone boat ramp be widened on its southern side at the proponent's expense. These operations will improve water access to and from these facilities, and thereby ensure that their potential as a public amenity is maximised.

The deepened embayment will provide a safe and permanent area of water that will improve boating access, enable a wide variety of water-based recreational activities such as bathing, crabbing, sailing and canoeing, and allow algal harvesting to be undertaken more efficiently.

3.1.3 Offshore Island

Approximately 59,500 m^3 of the sediment excavated from Cox Bay will be used to create an offshore island, approximately rectangular in shape and aligned parallel to the beach (Fig. 3, p.70). The island, which will be formed about 330 m offshore, will occupy approximately 2.6 ha and have a maximum elevation of approximately 1 m AHD.

The island is designed partly to protect the embayment and shoreline from onshore winds, and partly to provide a variety of habitats for water birds. It is expected that areas of shallows will form due to progressive shoaling on the more sheltered western side of the island. These will increase the available feeding areas for birds and the shallow water will discourage boat access to the island. The island will be planted with native vegetation of similar composition to that occurring on the present foreshore to provide roosting and loafing habitats. In addition to the use of seeds and seedling stock planting will incorporate some of the mature vegetation (e.g. rushes and paperbarks) which will be transported from those parts of the existing foreshore which are intended to be filled and graded to promote drainage and removal of mosquito breeding areas.

3.1.4 Foreshore Stabilisation and Regrading

Foreshore widening, beach improvement and filling and regrading of extensive areas of the foreshore, including parts of three wetlands, is proposed to be undertaken concurrently with the construction of Meiyu's Estuary Gardens Estate which is located between the nearshore boundary of the project site and the Old Coast Road. This development, which comprises a residential and tourist resort complex, has previously received conditional environmental approval from the EPA, subject to recommendations on nutrient input management, sewage disposal and foreshore maintenance and access, following a recent informal assessment.

In conjunction with the foreshore extension undertaken during embayment deepening, Meiyu intends to provide a public foreshore reserve along the boundary of its Estuary Gardens development (see Fig. 4 of Appendix 8). The average width of the foreshore open space will be extended from its present width of 30 m (varying from 0 to 50 m) to an average of approximately 70 m (varying from a minimum of 50 m to a maximum of 110 m). Beyond the north-eastern corner of the Estuary Gardens Estate the width of the proposed foreshore reserve, which is land currently owned by the Proponent, will increase to 130 m to allow for the development of recreational facilities alongside the existing Falcon boat ramp and car park.

Approximately 53,000 m^3 of the sand excavated from Cox Bay is proposed to be used for the beach and foreshore works. This will result in a substantial strengthening of the beach reserve and will extend the width of the foreshore by a further 6 m on average (Fig. 3). In addition to the proposed widening of the beach a large part of the foreshore will also be filled in order that it can be developed as a public recreation area. The principal area to be filled is shown in Figure 5 (p.72).

In addition to this area selective filling will also take place in the proposed southern conservation area to provide more efficient drainage and thereby eradicate existing mosquito breeding sites. The typical extent of filling along each of the sections indicated in Figure 5 (p.72) is shown in Figures 6 and 7 (pp73,74), however, fill levels will be varied as required in order to protect existing trees.

The foreshore will consist of sandy beaches backed by areas containing the original native vegetation or grassed areas with shade trees. Trees and shrubs indigenous to the area, such as Flooded Gums (*Eucalyptus rudis*), paperbarks (*Melaleuca cuticularis and Melaleuca rhaphiophylla*), Swamp Sheoak (*Casuarina obesa*) and Western Australian Peppermint (*Agonis flexuosa*) will be planted. Existing foreshore trees, particularly the Saltwater Paperbark (*Melaleuca cuticularis*), will be maintained wherever possible.

To provide further public access to the water's edge (including access for the disabled), the construction of two jetties each between 20 m and 50 m in length is also envisaged. These structures, which could also be used to provide temporary mooring points for visitors by boat, would be constructed either as open pile jetties or as solid structures using limestone boulders with an inner core of sand, and be covered by wood and/or concrete platforms. As longshore transport of sand is very limited in Cox Bay (refer Appendix 2), the provision of such jetties and groynes is considered likely to have minimal impact on shoreline stability.

3.1.5 Public Access and Facilities

The foreshore reserve and beach front will be a public open space primarily for the purpose of recreation. Public access to the reserve and improved beach will be via the existing Falcon boat ramp carpark, two smaller public carparks within the Estuary Gardens Estate, and by boat from the main body of Peel Inlet.

Public access to the offshore island will not be encouraged because this island is designed primarily as a sanctuary area for water birds. No recreational facilities will be installed on the island. If it is deemed necessary, signs could be erected at those points on the island which offer the easiest access.

As part of the foreshore improvement works, it is proposed to construct a dual-use pedestrian and bicycle pathway (refer to Fig. 4 of Appendix 8). The waterside edge of the path will feature a low wall which will differentiate between those areas of the foreshore that will remain covered by native vegetation, and will dissuade casual access to the beach at these points, particularly in the southern section of the foreshore reserve where areas of native vegetation will be more extensive.

The dual-use path will meander behind the beach front and could also connect with the short groynes or jetties described in Section 3.1.2. Such jetty platforms would provide temporary mooring space, and/or provide foci for other recreational activities such as swimming or fishing.

Recreational facilities will be provided in the north-western corner of the development site and will include improvements to the existing Falcon boat ramp and carpark.

3.2 CONSTRUCTION METHODS AND SCHEDULE

3.2.1 Offshore Works

Deepening of the 1,150 m long by 380 m wide portion of Cox Bay will be undertaken behind temporary bund walls. A bund wall was recently used for lengthening and deepening the channel leading from the Falcon boat ramp, and proved very successful. This test is described in Section 3.2.1.1 (below) and Appendix 7.

The offshore works consist of the main excavation, described in Section 3.2.1.2, and the formation of the island, described in Section 3.2.1.3. Full details of the work proposed is provided in Appendix 2.

3.2.1.1 Description of the trial excavation

A trial excavation was recently undertaken (refer Appendices 2 and 7 for details) involving the improvement of the access channel to the Falcon boat ramp. A tracked excavating machine was used to simultaneously remove material from the edge and floor of the channel and build a bund wall with the spoil (Plates 1 & 2, p.77). The bund was initiated at the water's edge and was extended progressively offshore for 325 m.

The completed bund supported articulated dump trucks which were filled with spoil from the channel and from the subsequent removal of the bund. The trucks moved the spoil to the foreshore for replenishment of the beach north of the Falcon boat ramp.

The trial was a success from an engineering viewpoint for the following reasons:

- the spoil was a well graded sand (refer Appendix 7) which was found to be highly suitable for bund construction, haulage by truck and for beach or land fill;
- good quality sandy sediments were found to extend to at least 360 m offshore (most of the proposed excavation lies within 350 m of the shoreline);
- the excavation was conducted wet (i.e. without dewatering), yet no problems were encountered with the 30 tonne excavating machine.

Environmental aspects of the proposed technique are discussed in Section 5, with results from the environmental monitoring of this test detailed in Appendix 7.

3.2.1.2 Main excavation

An excavating machine of a similar type to that used for the trial will be used for the main excavation. The first operation is the construction of the main bund wall that will enclose the area to be excavated, as shown in Figure 4.4 of Appendix 2. The bund will be progressively extended outwards from the shoreline by excavating material from the inner side of the bund wall. The crest of the wall will be well above the high water mark and will form a track for haulage trucks.

Additional temporary bunds will be formed to divide the main area into a number of smaller basins. The surface water within the sub-basins will then be pumped into adjacent basins allowing the use of larger earth moving machinery. The exact number of these compartments will depend on the permeability of the bund walls versus the rate of both construction progress and pumping efficiency. The probable scenario (with six compartments) is shown in Figure 4.4 (Appendix 2). Only one compartment will be excavated at a time, with water being pumped into the other areas enclosed by the main bund wall.

The proposed construction process involves the following steps:

(i) constructing the main bund enclosure;

(ii) building a bund to isolate the first compartment;

(iii) removal of surface water from the first compartment by pumping to the lagoon behind the encompassing bund;

(iv) excavating the first compartment using excavating machines and front-end loaders, and carting the material to either the foreshore or area of the new island;

(v) forming the next compartment with a new bund wall and removing the bund wall on the estuary side of the excavated compartment;

(vi) nearshore excavation may be undertaken by scrapers to improve the rate of excavation and to provide greater control over surface grading.

If the sub-basins cannot be pumped dry for any reason, wet excavation will proceed in the same manner as was used to form the channel to the boat ramp.

The total time required for the project is estimated at 26 weeks, with the time required for the deepening works and island construction being 16 weeks. The main bund wall will take approximately four weeks to construct. Internal excavation, construction of the island, filling of the foreshore and beach line replenishment will take a further 10 weeks. Two weeks will be required to

complete the excavation, foreshore works and island construction and remove the bund walls with the exception of the island connection bund wall at the north end.

A further 8 weeks will be required to construct the boat ramp and boat ramp carpark, construction of the boundary wall and dual use path and for landscaping and replanting of the foreshore and the island.

The final two weeks will be required for the removal of the remaining bund wall once planting on the island is completed.

3.2.1.3 Formation of the island

The island will be constructed with approximately 59,500 m^3 of spoil excavated from the centre and offshore compartments. The island form will be created initially by the internal bunds and main bund wall (Appendix 2, Fig. 4.4).

During the main excavation, the isolated limestone outcrops, which are distributed throughout the bunded compartments, will be collected. This material, supplemented if necessary by imported limestone, will be used to armour the northern and southern shorelines of the island. A typical section is shown in Figure 4 (p.71).

The western and eastern sides of the island will lie parallel to the shoreline and will form sand beaches contained at either end by the limestone armour. The beach alignments will be slightly scalloped and the beaches, initially established with 1 in 10 gradients, are intended to equilibrate with incident wave regimes.

It can be expected that the area of shallow water on the more protected western beach will gradually enlarge as wave action will be less due to the short (300 m) fetch from the shoreline. The eastern beach, which will be exposed to waves generated by easterly winds, may adopt a slightly steeper profile.

It is not expected that the shape of the island and its beach contours will remain totally unaltered following construction. Rather, it is intended that the island and its beaches be allowed to adopt a dynamically stable natural form. The southern and northern rock armouring will, however, ensure that the island will remain in its constructed position.

The position of the island has been chosen with respect to the pattern of water circulation within Cox Bay, which tends to form a large, gentle eddy during both flooding and ebbing tides (Appendix 2). The island is located virtually in the centre of the eddy, and therefore should enhance rather than hinder such water movements.

The island will be planted with native vegetation to provide additional waterbird habitats and to improve its aesthetic quality. Initially the island will be planted with vegetation removed from areas of the foreshore destined for fill and grading. These plants will be removed under the supervision of a landscaping contractor and

transplanted directly onto the island, before the last connecting bund wall is removed.

The survival rate of vegetation transplanted is difficult to estimate, and will depend on rainfall and other climactic factors operating at this stage of the construction period. Mulch will be spread over the area to be planted to increase plant survival and growth rate and assist in stabilising soil surfaces.

Species which may be transplanted include *Casuarina obesa* (Swamp Sheoke), *Melaleuca cuticularis* (Saltwater Paperbark), *Melaleuca rhaphiophylla* (Swamp Paperbark), *Sarcocornia quinquiflora* (samphire), *Bulboschoenus caldwellii* (rush) and *Juncus krausii* (rush).

These species were also used for planting on Boundary Island, which was created on the northern side in the Peel Inlet during the dredging of the Mandurah Channel.

Other species considered for additional planting include *Eucalyptus rudis* (Flooded Gum), *Agonis flexuosa* (Peppermint), *Acacia rostellifera, Acacia cyclops, Acacia cochlearis, Jacksonia furcellata, Templetonia retusa, Olearia axillaris, Atriplex paludosa.*

Seed of native grasses would also be introduced with hydromulching, to stabilise the island surface and provide additional breeding sites (see recommendations, Appendix 5). The choice of plant species to be used will be dependent on the type of waterbird habitat to be created and consequently advice will be sought from the proposed reserve manager, the Waterways Commission, on this aspect.

3.2.2 Foreshore Works

3.2.2.1 Landform modification

The 112,500 m^3 of sand generated by the excavation will be used in the construction of the island and reconstruction of the foreshore and beach. Approximately 59,500 m^3 of spoil will be used to raise the average level of the existing foreshore from 0.3 m above AHD to 1.0 m above AHD, and to improve and extend the existing beach face 6 m in the offshore direction. Typical sections showing the distribution and extent of fill proposed within the foreshore are shown in Figures 6 and 7 (pp. 73, 74). The area and sites of the Sections are shown in Figure 5 (p.72).

Of this volume, some 40,000 m^3 will be used to raise and grade the level of the foreshore reserve, to provide for public recreation and to allow drainage of low-lying areas in which temporary pools form that are utilised as mosquito breeding sites. The remaining 13,000 m^3 will be spread over the beach face, including those areas that have been eroded, to a stable gradient of 1 in 10.

The newly created foreshore is shaped to minimise the effects of natural longshore sediment transport processes, although these are of low magnitude owing to the sheltered nature of Cox Bay (refer Appendix 2). Longshore transport has been estimated to be only 10 m^3 per year in either direction, with possibly the same amount being moved during a severe storm.

It is therefore considered that if 12 m^3/m of sand is placed uniformly along the beach, any structures set back at least 10 m from the beach face are unlikely to be affected by any shoreline movements (Appendix 2). This is because the proposed effective 13,000 m^3 reservoir of additional sand will be more than sufficient to allow the beach face contours to equilibrate with the new conditions.

3.2.2.2 Design criteria

The foreshore works have been designed to incorporate elements of the natural foreshore vegetation. Existing trees, particularly the larger Casuarinas and Melaleucas will be retained as shade trees, while the vegetation around the three nominated wetland areas, particularly the Saltwater Paperbarks in the southern end of the proposed reserve, will be preserved as far as possible.

Vegetation to be planted on the foreshore reserve is similar to that proposed for the offshore island, although shrubs will not be planted in the areas to be grassed. Grassed areas will however be planted with trees in order to provide shelter and shade.

The proposed draft management plan for the Estuary Gardens foreshore is discussed in Appendix 8 of this report.

4 DESCRIPTION OF ENVIRONMENT

4.1 INTRODUCTION

The 40 ha water development site is located immediately offshore from Part Murray Location 1147 in Cox Bay, which is in the north-western portion of Peel Inlet. The site is approximately rectangular in shape extending 1,150 m along the foreshore and between 300 and 380 m offshore. The north-western boundary of the site is adjacent to the Falcon boat ramp and channel (Fig. 1), although it is also proposed to deepen the estuary around the jetty, which is located immediately north-east of the boat ramp, in order to make this facility more useable.

The following description details salient physical, biological and social features of the local (Cox Bay) and regional environment (Peel-Harvey system and Mandurah) Much of the information has been obtained from reviews of the following literature.

The climate of the Mandurah region has been described by Wilson Sayer Core (1988) and details of the geology and geomorphology discussed by LeProvost, Semeniuk & Chalmer (LSC) (1981) and Brown et al. (1980). Water quality and hydrodynamic characteristics of the Peel-Harvey estuarine system have been described by Schwinghammer (1978) and more recently by the EPA (1989).

Information on the aquatic biota of the region has been obtained from Chalmer and Scott (1984), Hodgkin et al. (1985), Kinhill (1988), LSC (1981) and the Waterways Commission (1990a & b). Information on water birds, ecosystem considerations and the nutrient and algal bloom cycles in the estuary was obtained from the EPA (1988a) and Hodgkin et al. (1985).

The social environment has been described in detail by Wilson Sayer Core (1988) and community concerns and requirements have been identified and discussed by the EPA (1983, 1988b, 1989) and Kinhill Steams Pty Ltd (1985). Recreational and Beneficial Uses for the Peel-Harvey estuarine system have been listed by the Department of Conservation and Environment (1981), Riedel & Byrne (1990) and the Waterways Commission (1990b).

4.2 PHYSICAL ENVIRONMENT

4.2.1 Climate

The Mandurah region experiences a Mediterranean climate similar to Perth, with hot dry summers and mild wet winters (Wilson Sayer Core, 1988). Rainfall is moderate (annual mean is 825 mm) and falls mainly in May to October. This is the main period when onshore groundwater reservoirs are recharged, and when waterlogging of estuarine peripheral flats and important fluvial discharges occur.

The mean daily temperature varies from a maximum of 29.5°C in summer to 17.2°C in winter. The mean minimum temperature is 16.8°C in summer and 8.5°C in winter. Extreme summer temperatures have exceeded 42°C. The mean annual evaporation is 1980 mm.

Two wind systems affect the Peel-Harvey region; cyclone-anticyclone winds and the landbreeze-seabreeze system (Wilson Sayer Core, 1988). Anticyclone winds are related to the anticyclone belts that traverse the continent of Australia. During summer, the centre of the anticyclone belt is to the south of the continent and winds affecting the Peel Inlet region are derived from eastern sectors. In winter, winds originate from north-west to south sectors since the belt is located to the north of region. In winter there are also periodic storms that impinge on the coast and are derived mainly from the north-west and west.

In summer a landbreeze-seabreeze system operates in response to solar heating followed by cooling of land surfaces. Strong south-westerly seabreezes occur in the afternoon and moderate easterly landbreezes are common in the morning. Wind roses for the area are shown in Figure 3.3 of Appendix 2.

4.2.2 Offshore Geology and Geomorphology

The Peel-Harvey estuary system is situated on the Swan Coastal Plain, which has developed by the accumulation of a parallel series of ridges of marine, lacustrine and fluvial sediments that form discrete geomorphic units.

The origins of the Peel-Harvey estuaries, which cover approximately 300 km^2, are attributed to Holocene marine flooding of a pre-existing terrain developed mainly on four Pleistocene sediment units (the Spearwood Dunes, Bassendean Dunes, Pinjarra Plain and Yoongarillup Plain). The estuarine hinterlands comprise Spearwood Dunes to the west, Bassendean Dunes to the east, and the fluvial lowlands of Pinjarra Plain sediments. The fluvial terrain of the three main rivers (Murray, Serpentine and Harvey) is typically low.

The Peel-Harvey estuary system consists of shallow central basins (approximately 2 m deep) which are surrounded by generally subtidal platforms and sills, in addition to the shoreline cheniers and beach ridges.

4.2.3 Bathymetry of Peel Inlet

Peel Inlet is differentiated into a central basin and surrounding marginal subtidal platform and shoal area. The platform areas extend up to 3 km offshore and typically range between 0.5 and 1 m in depth. On the western side of Peel Inlet this shelf varies between 300 and 800 m in width, and slopes almost uniformly from the shoreline with an average gradient of about 1 in 1000 (Brown et al., 1980).

4.2.4 Geomorphic Processes and Estuarine Sediments

The shoreline and shallow water areas of the Peel-Harvey system are the result of sedimentary and erosional processes acting along the shoreline and still occurring at present (LSC, 1981). Deltas have formed where the rivers enter the estuary waters, and both fluviatile and marine sediments have formed a tidal delta complex near the Mandurah Channel. Shoreline erosion and the redistribution of sediment has resulted in the development of a peripheral system of shallow marginal platforms, spits and shoals alternating with low cliffed foreshores.

As part of the feasibility studies necessary to establish the viability of the proposal a sediment sampling programme in Cox Bay, involving the collection of 20 sediment cores on a 200 m grid pattern was undertaken.

The cores were analysed by the Engineering Research Station of the Water Authority of Western Australia (WAWA) to determine the particle size distribution and organic matter content of the sediments. A representative core, from Site 9 at the centre of the survey area (Appendix 7, Fig. 2)) was also analysed for Total Phosphorous, Kjeldahl Nitrogen, calcium carbonate and organic content, in two strata by the Nutrient Analysis Laboratory of the Centre for Water Research, Murdoch University (Appendix 7, Table 1).

These investigations showed the presence of two major sediment units within Cox Bay, a shallow nearshore sand shelf unit which extends outward from the shoreline for a distance of up to 400 m, and an offshore clayey silty sand basin unit which commences at the outer margin of the sand shelf and extends into the main basin of Peel Inlet. The boundary between the two units is abrupt and marked by a drop-off between the sand shelf and the basin.

Chemical analysis of sediments from two intervals within a typical shelf unit core (Site 9) (Appendix 7, Table 1) show that the shelf sands are typically low in organic matter and carbonate content, both at the surface and at depth. Sediment composition is consistent throughout the column in terms of particle size and nutrient levels as well as organic matter and carbonate content.

4.2.5 Hydrodynamic Characteristics of Peel Inlet

Low salinity water enters Peel Inlet via the Murray and Serpentine Rivers and from the Harvey River which discharges into the southern end of the Harvey Estuary. Other sources of fresh to brackish water include agricultural drains, groundwater seepage and direct runoff from rainfall.

Ocean water enters through the Mandurah Channel. The influence of diurnal tides on water levels in the Peel Inlet is small and these astronomical influences usually alter levels by less than 20 cm. Meteorological influences are stronger, and operate with a period between five and nine days. Water levels in the Peel Inlet therefore do not represent tidal levels in the conventional sense, since barometric changes

can lead to water levels that are more 20 cm above the highest astronomical tide (e.g. 0.42 m versus 0.19 m AHD for Cox Bay). Water levels are also boosted by storm flooding; the 1 in 25 year flood level is estimated at 1.1 m AHD (Appendix 2).

The seawater entering Peel Inlet in winter is of greater salinity and density than the estuary water because of the high river flows. In summer, however, the incoming sea water has a lower salinity and density than the estuary water, since this becomes hypersaline owing to minimal river flow and high evaporation. The more saline (higher density) water flows under the less dense water, a process which can lead to stratification in deeper areas during periods of calm weather.

The principal forces affecting mixing of the density layers are tidal flow, river flow, density currents and wind stress. Tidal exchange is estimated to cause waters to be flushed from the western Peel Inlet in approximately four to five weeks (Schwinghammer, 1978). A dye-release experiment carried out by the EPA in February 1978 showed that wind stress has a limited effect on circulation in the Peel Inlet. However, turbulence caused by wind stress aids mixing and can break down stratification. Strong winds can also cause water levels to be set up at onshore beaches. For example, there is a 10 cm set up at Coodanup during south-westerly winds of 40-50 kn (Schwinghammer, 1978) which promotes a decline in water levels at Cox Bay. The opposite effect occurs during strong easterly winds.

Storm surge and wave run-up on the eastern shores of Peel Inlet, resulting from cyclonic or very strong westerly storms, probably exceed 1 m above normal tide levels. Such an event at Cox Bay would require unusually strong easterly winds to be produced by a cyclone that crosses the coast immediately to the north of Mandurah (Appendix 2).

4.2.6 Human Modifications to Physical Processes

Land clearing in both the immediate vicinity of the Peel-Harvey system and within its catchment, public dams, drainage schemes together with the widespread use of superphosphate fertilisers have resulted in markedly reduced freshwater flushing, increased sedimentation rates and high levels of nutrient input. These features comprise a substantial change to the estuary in terms of its physical and biological characteristics.

An example of increased sedimentation in the Peel Inlet was noted by Hodgkin et al. (1985), in which seaweed accumulating in shallow areas in Austin Bay (where it was not harvested) resulted in accelerated shallowing. In the case of Cox Bay, where offshore weed accumulations cannot be harvested, this mechanism is opposed by beach erosion when the shoreline accumulation is removed by front-end loader.

The most serious change to the hydrological system of the Peel-Harvey is undoubtedly the increased level of nutrient input coupled with the decline of

natural flushing rates. The biological and social effects arising from these changes are described in Sections 4.3 and 4.4 respectively.

4.2.7 Cox Bay

Cox Bay is a moderately sheltered and shallow embayment on the north-western side of Peel Inlet. The shallowness of the bay (less than 1.5 m deep) and its aspect make it susceptible to the action of wind-waves driven directly from eastern quadrants or indirectly from the south and south-west.

Tidal currents moving past Cox Bay are thought to generate a weak eddy within Cox Bay, which would revolve in a clockwise direction during flood tides and anti-clockwise during ebb tides (Appendix 2). Currents during periods of flood from the Serpentine River system tend to move almost directly towards the Sticks and could be expected to produce an anti-clockwise eddy in Cox Bay during strong flows. Whilst these eddies tend to circulate water they do not tend to introduce any new water into the bay (Appendix 2).

The most important source of currents are those due to winds and waves. Winds tend to produce currents within the Peel Inlet with a magnitude of about 3% of the wind velocity. These current magnitudes are significantly higher than those due to tidal currents.

During summer, morning winds are predominantly from the east to south-east averaging about 3-4 m/s which probably produces a surface current of about 0.1 m/s into Cox Bay. In the afternoon, Cox Bay is relatively sheltered from the south-west with the result that the currents induced by the south-westerly seabreeze probably tend to flow across the head of Cox Bay and thereby form an anti-clockwise eddy which again would tend to trap algae within Cox Bay.

During winter, winds tend to be more northerly with light north-easterlies predominating in the morning. Less frequent, but stronger, winds from the south-west through to the north occur as fronts pass over the Western Australian coast. In the afternoons, winds tend towards stronger south-west to north-westerlies. Except for the south-westerly wind each of the other wind conditions will not produce noticeably persistent current patterns in Cox Bay because either the winds are weak or are blowing offshore (into Peel Inlet) and have not had the opportunity to develop a water current.

The overall effect is that exchange of water between Cox Bay and the main body of Peel Inlet is poor and effectively restricted to that produced by the tides, consequently materials entering the bay tend to become trapped.

As a consequence of wind patterns there is a seasonal entrapment and deposition of algal and weed material in the nearshore shallow areas of the Bay. This material is derived from both decaying phytoplankton blooms in spring and drifting macroalgae (frequently *Chaetomorpha* and *Ulva* sp.) in summer and autumn and

occasionally in early winter. The decomposing plants contribute significantly to the depth at which the substrate becomes anoxic, with anaerobic conditions typically varying from 0.8 cm below the surface in winter to 1.5 cm in early summer.

The sediments forming the floor of Cox Bay have been described in Section 4.2.4. Top layer sediments in the area are generally well sorted and are dominated by medium-grained sands (0.2-0.6 mm) and coarse-grained sands (0.6-2.0 mm; 16%), with fine-grained sands (0.06-0.2 mm) and silts and clays (<0.002-0.06 mm) comprising only 8% and 4% respectively (Appendix 7).

Detrital organic matter varies from 1.5% of the sediment in winter to 2.0% in the summer (Appendix 4). Sporadic outcrops of limestone 'pinnacles' protrude up to 0.3 m above the substrate at various points beyond 200 m from the shoreline (Appendix 2).

Bottom salinities in Cox Bay range from 11 ppt in winter to 40 ppt in summer and autumn, with water temperatures ranging from 13°C in winter to 26°C in summer, and dissolved oxygen concentrations typically fluctuating from 8.0 ppm in winter to 6.8 ppm in summer (Appendix 3). Oxygen values of zero have been recorded in hot still conditions at night during summer (Appendix 3).

The presence of decomposing macroalgae generally reaches its peak in autumn and this can reduce oxygen levels to zero immediately beneath the depositions, but values of 0.5 mg/L are common for the whole embayment.

4.3 BIOLOGICAL ENVIRONMENT

4.3.1 Overview

Compared with the Swan-Canning estuarine system and some other estuaries in the south-west of Western Australia, the Peel-Harvey system has a less diverse plant and animal population. This is largely the result of two factors. Firstly, the system experiences high variations in salinity which restrict the number of species that can tolerate these changes. Secondly, the relatively homogeneous soft and shallow floor of the estuary provides a limited range of habitats that is far more uniform than those of the Swan-Canning estuary (Kinhill, 1988).

While the diversity of organisms in the Peel-Harvey system is not high, their numbers and densities are typically far higher than in coastal and offshore marine environments. For example, there is an abundant benthic fauna (i.e. animals living within, on or close to the floor of the estuary) comprising molluscs, worms and crustaceans. This represents an important food source that supports fish, crabs and prawns as well as wading birds. The flora comprises both aquatic flowering plants (seagrasses and *Ruppia*) as well as a variety of macroalgae (seaweed).

The nearshore shallows and the peripheral wetlands (which contain a fringing paperbark and salt marsh vegetation) provide important habitats for various water birds which use these areas for feeding, breeding and loafing. The Peel-Harvey system provides habitats for a variety of migratory wading birds, and is recognised as the single most important water bird site in the south-west of Western Australia (Hodgkin et al., 1985).

4.3.2 Flora

The major aquatic plant groups comprise microalgae (microscopic single-celled plants), macroalgae (seaweeds), aquatic angiosperms (seagrasses and *Ruppia*), and a peripheral salt marsh vegetation (samphire and rushes).

The microalgae include diatoms, dinoflagellates and blue-green algae that are frequently dispersed throughout the water column. The blue-green algae are capable of fixing nitrogen to make nitrate, which is an essential nutrient for growth. Together with other plants, they form the foundation of the estuarine food web.

The microalgae can grow and reproduce very quickly under certain conditions to form blooms which significantly alter the estuary's water quality (Waterways Commission, 1990b). The aquatic angiosperms are not only productive (producing organic matter with a high food value for a range of animals), but also stabilise the bottom sediments with their rhizomes and root mats. In Peel Inlet, the seagrass *Halophila ovalis* and the flowering aquatic plant *Ruppia megacarpa* occur in the deeper and shallower parts of the shelving platforms respectively (Chalmer & Scott, 1984).

Several species of macroalgae (seaweed) grow in the estuary, with the abundance of the dominant species varying over the past decades due to changes to the nutrient regime. Common macroalgae include *Cladophora* (goat-weed), *Chondria, Chaetomorpha* (rope-weed), *Enteromorpha, Chloridia* and *Ulva* (sea lettuce).

Under natural nutrient regimes (in which plant growth is restricted by the lack of phosphate nutrients), the estuary would support only limited amounts of macroalgae that provide feeding and sheltering sites for various animals including juvenile fishes. While the elevated nutrient regime and subsequent increased plant growth has benefited of some fish populations in the Peel Inlet, it has also created significant deleterious changes that are difficult to manage, such the accumulations of rotting algae near residential and recreational areas and the seasonal blooms of noxious and toxic phytoplankton blooms. The proliferation of macroalgae is also causing the decline of seagrasses by smothering and preventing sufficient light from reaching the leaves.

The salt marsh vegetation is important for shoreline stabilisation and acts as a buffer for nutrient inflow. Salt marshes occupy approximately 13 km^2 or 10% of the total open water of the Peel Inlet. Important areas occur along the western shoreline of Peel Inlet between The Chimneys and Dawesville. The major

components of the fringing vegetation are the *Sarcocornia* (samphire) marsh, and meadows of *Scirpus maritimus* and *Juncus krausii* (rushes). The samphire marsh is the most extensive, with *Atriplex paludosa* (saltbush) growing toward the landward edge of these wider marshes. Extensive areas of rushes are limited in the Peel Inlet, but are common in the southern Harvey Estuary where much of the shoreline supports a narrow band of rushes some 3-10 plants wide (Waterways Commission, 1990b).

4.3.3 Water Quality

The Peel-Harvey estuary system is presently highly eutrophic. Eutrophication and algal blooms have severely degraded the water quality of the estuarine system as phosphate nutrient loads have exceeded the natural assimilative capacity of the system.

The annual cycle of algal blooms in the Peel-Harvey estuarine system has been relatively consistent in recent years (Kinhill, 1988). The cycle includes alternating periods of blooms and decay of phytoplankton (typically diatom blooms often followed by *Nodularia*). Decaying blooms can remove oxygen from the surface sediments and causes further release of phosphorus. *Nodularia* blooms die as salinity increases in summer, and are then replaced by further diatom blooms which flourish in the warm salty water of summer and autumn (EPA, 1988a).

Despite these conditions, however, the Peel-Harvey waterways continue to support a high diversity of waterbird species, particularly migratory waders, and remain an important source of fish, crabs and prawns.

Three principal factors, which vary with season, influence the present water quality of Peel Inlet; these are salinity, wind and temperature. Seasonal salinity changes can influence the appearance, longevity and severity of *Nodularia* phytoplankton blooms, while low wind speeds coupled with warm water temperatures in summer promote stratification and a reduction in oxygen levels.

The dredging of the Mandurah Channel has created more favourable conditions for flushing and has resulted in improved water quality within Peel Inlet (EPA, 1989). Further increasing the flushing mechanism by opening the Dawesville Cut should lead to a decline of macroalgae in both the Peel Inlet and Harvey Estuary, and will encourage the recolonisation and spread of seagrasses.

4.3.4 Aquatic Fauna

The Peel Inlet aquatic fauna are influenced by the wide seasonal fluctuations in water salinity. Mobile species such as fish, crabs and prawns move within or leave the Inlet in response to salinity changes. Sessile or burrowing species must either cope with these changes or possess a short life cycle that relies on environmental cues such as salinity and temperature.

The fauna of the estuary comprises small floating and drifting animals (components of the zooplankton), bottom dwelling animals (benthic species such as molluscs, small crustaceans and worms), and larger and more mobile animals such as fish, crabs and prawns (Waterways Commission, 1990b).

Planktonic animals feed on microalgae and other zooplankton. Small crustaceans (including shrimps and amphipods) and gastropod molluscs (snails) feed on microalgae, zooplankton and/or detritus. These animals provide typical food items for a variety of fish as well as resident and trans-equatorial water birds.

Crabs feed on detritus and various invertebrates, whilst prawns tend to ingest more detritus and planktonic organisms. Sea mullet ingest mainly detritus, while cobbler, yelloweye mullet and whiting prefer small crustaceans, molluscs or worms (Waterways Commission, 1990b).

4.3.5 Birds

The Peel-Harvey System has been recognised as the single most important area for waterbirds in the south-west of Western Australia. Species supported by this system include migratory and resident waders, fish-eating birds such as pelicans and shags, and a variety of waterfowl (EPA, 1988a).

At times the estuary supports up to 83 species of waterbirds and greater than 20,000 individuals, including 27 species cited in the Japan and Australia (JAMBA) and China and Australia (CAMBA) Migratory Birds Agreement (Appendix 5).

Migratory waders feed on benthic animals mainly in intertidal areas at low tide and in shallow water on inland, non-tidal wetlands. They roost on sandy cays and spits. Resident waders are usually found in the shallow inland, non-tidal wetlands, and are not common in estuaries with a marked tidal influence. Long-legged waders feed in shallow waters on small fish, crustaceans and benthic invertebrates, and roost in trees near the waters edge.

The fish-eating birds (pelicans, cormorants and terns) are found in the estuarine system all year round, where they feed in the deeper waters and roost on sandy areas above high tide. The water fowl (ducks, swans and coots) are present in large numbers and feed on aquatic vegetation including *Ruppia* and some types of macroalgae, as well as small benthic animals.

4.3.6 Biological Resources of Cox Bay

4.3.6.1 Flora

The aquatic flora in Cox Bay is dominated by the growth of algae such as *Ulva* and *Chaetomorpha*. Seagrasses and *Ruppia* do not occur within the project site

because of the past extensive accumulations of decomposing seaweed. Cox Bay has been identified as one of the principal areas of algal growth in the estuary (Hodgkin et al., 1985), while its nearshore shallows accumulate large masses of decomposing macroalgae. Algae stranded along the shoreline is removed by front-end loader fitted with rakes and scoops.

The nearshore terrestrial vegetation in the vicinity of the project site has also been modified by human influences. Clearing some 10 years ago has resulted in the loss of much of the mature vegetation and large parts of the area are now dominated by the colonising species *Jacksonia furcellata*, while operations to remove the algae have promoted the degradation and loss of the fringing vegetation (especially rushes), as well as causing beachline erosion.

The vegetation of the foreshore presently comprises three major vegetation assemblages as follows:

- freshwater paperbark (*Melaleuca rhaphiophylla*) woodland, located predominantly in the northern section of the project site (Plates 4 & 5, p.79 and Figure 3 of Appendix 8), where it fringes a seasonal wetland;

- *Jacksonia/Melaleuca* woodland/shrubland, located in the central section of the foreshore. A rush fringe is typically present along less disturbed parts of the shoreline and there are some mature Casuarinas, particularly in the vicinity of Karanga St. Generally, the species composition within this assemblage varies depending on the depth to groundwater and the presence or absence of a freshwater lens overlying more saline groundwater. Although pools of water may be present following rainfall the majority of this area would be regarded as a terrestrial rather than a wetland environment. The exception is the small semi-permanent water body and surrounding Melaleuca thicket located in the centre of this area (refer Figure 3 of Appendix 8); and

- the saltwater paperbark (*Melaleuca cuticularis*) with an associated understorey of rushes and salt tolerant samphires located at the southern end of the site. This is an area in which slow regrowth has occurred since the site was cleared approximately 10 years ago.

4.3.6.2 Aquatic fauna

Information on Cox Bay has been obtained by field survey and from research data supplied by Mr T. Rose (Murdoch University; see Appendix 4).

The limestone outcrops are colonised mainly by the suspension-feeding serpulid polychaete, *Ficopomatus enigmaticus*, while the sandy sediments of Cox Bay contain a macrobenthic community which is low in species richness and typically patchy in distribution. Nevertheless, the abundance of this relatively impoverished suite of invertebrates can be high, but is punctuated by periods of rapid decline and

even denudation when extreme estuarine conditions such as anoxia occur for extended periods. Recovery of the benthic fauna is quick because patches which are not disturbed contain species which have populations that are eruptive in nature and often do not live longer than a year, although several species of polychaetes (nerids, orbinids) and some bivalve molluscs (tellinids and mytilids) live much longer (Appendix 4).

Most polychaetes, amphipods, pericarids and microbivalves (e.g. *Arthritica* sp.) are fecund throughout the year (Appendix 4). Drifting algae also provides a temporary refuge and foraging area for many benthic organisms (particularly amphipod crustaceans), and therefore promote recolonisation of denuded sediments. Peak abundances of crustaceans usually occur in autumn while capitellid polychaete worms are more abundant in winter and spring. Larger and longer living polychaete worms (e.g. *Certaoneris* sp.) generally reach peak densities in summer. In contrast the small bivalve mollusc *Arthritica* displays no apparent seasonal trends (Appendix 4).

The benthic organisms and epifauna associated with accumulations of weed provide a food source that is utilised by a variety of fish including sea mullet, yelloweye mullet and cobbler (Appendix 4).

4.3.6.3 Water birds

In 1988 the Mosquito Control Review Committee (MCRC) of the Waterways Commission contracted Ninox Wildlife Consulting to carry out a study of Peel Inlet to define the significance of mosquito breeding areas to waterbirds. Nearby offshore locations were also assessed. A total of 38 sampling sites were established of which three lay within or close to the project area. A report on the survey results for these sites is contained in Appendix 5.

In Cox Bay, 29 species were recorded and 4,379 individual birds were counted, representing 48% of the species and 10% of the individuals logged in Peel Inlet during the survey (Appendix 5). Nearshore shallow water areas (<30 cm deep), beach front areas and sandspits were found to be the most important waterbird habitats in Cox Bay. Deeper water areas were relatively poorly used despite the large area available.

The survey concluded that the freshwater paperbark woodlands at the northern end of the site was of intermediate significance to waterbirds, its primary attribute being the presence of sufficiently dense vegetation to act as a refuge area for secretive species such as crakes and rails.

4.4 SOCIAL ENVIRONMENT

4.4.1 Mandurah and Peel Inlet

The Mandurah region is one of Western Australia's largest tourist and holiday destinations (Wilson Sayer Core, 1988). The main attraction is the estuary and associated recreational activities. Water-based activities include boating, sailing, canoeing, swimming, fishing, crabbing and prawning, whilst activities along the water's edge include picnics, barbeques, camping and scenic walks and drives.

Attitudinal surveys suggest that the values of the area to residents in the region are largely based on natural environment and lifestyle considerations (Kinhill Stearns Pty Ltd, 1985). The variety of natural landscapes and water settings are perceived as offering a range of recreational or aesthetic amenities that form the foundation of the region's attractiveness.

4.4.2 Use of Peel Inlet (Beneficial Uses)

Bulletin 103 of the Environmental Protection Authority (DCE, 1981) describes water quality criteria to ensure the protection of identified Beneficial Uses of marine and estuarine waters in Western Australia. From the list of Beneficial Uses listed in Bulletin 103, those applicable to Peel Inlet are as follows:

Beneficial Use 1	-	Direct Contact Recreation;
Beneficial Use 2	-	Harvesting of Aquatic Life (excluding Molluscs) for Food;
Beneficial Use 5	-	Passage of Fish and Other Aquatic Life;
Beneficial Use 7	-	Maintenance and Preservation of Aquatic Ecosystems;
Beneficial Use 8	-	Maintenance and Preservation of Foreshores and Banks;
Beneficial Use 9	-	Scientific and Educational Uses;
Beneficial Use 10	-	Flushing Water and Water Replenishment; and
Beneficial Use 16	-	Navigation and Shipping.

4.4.2.1 Community concerns

(i) Water quality and nuisance organisms

Community concern for the water quality of the Peel Inlet, with particular regard to the algal problem, was identified in an attitudinal survey of 155 people conducted in the Mandurah region (Kinhill Stearns Pty Ltd, 1985).

The macroalgae and planktonic blooms cause the following problems (Hodgkin et al., 1985):

- accumulations of decomposing weed foul the shallows and beaches of Peel Inlet and decay to a black sludge;
- hydrogen sulphide gas is given off during decomposition which causes discomfort to people living near the beaches, while decaying *Nodularia* produces a distinctive and obnoxious odour both in the water and in shore accumulations. Such odours have been blamed for illness in local residents;
- occasional mass mortality of fish and crabs has occurred following blooms of the toxic *Nodularia*, while commercial catches are frequently depressed when these blooms occur;
- thick strings of *Chaetomorpha* (rope weed) and clumps of Cladophora can entangle propellers or block cooling water intakes;
- several species of alga readily foul amateur and professional fishing nets, making hauling and cleaning difficult; and catches are poor when there are severe *Nodularia* blooms.

These problems are perceived to have had an adverse effect on tourism, the business community, and property values adjacent to the estuary. The attitudinal survey produced the following results :

- 86% of those surveyed indicated that the algal and weed growth was a problem in the Peel-Harvey estuary.
- 83% of respondents thought that the problems affecting the recreational use of the Peel Inlet and Harvey Estuary were smells, algae and weed growth, mosquitos and dirty water.
- When prompted, 70% of the 30% who had not mentioned problems with the system (or who had not identified weed or algal growth), did indicate that such growth was a problem.

- Some 62% thought that the algae problem was very serious, while 33% thought it was fairly serious and only 4% thought that it was not very serious.

The other major concern to residents living near the waterways of the Peel-Harvey system has been the recent increase in the incidence of Ross River virus, which is carried by mosquitoes that breed on the swampy margins of the estuary. Ross River Virus causes a disease in humans known as epidemic polyarthritis. The symptoms of the disease in humans include joint and muscle pain of varying intensity, fever and occasionally the development of a rash (Wright, 1988). In Western Australia, the disease is most prevalent in the Mandurah-Bunbury corridor of the Swan Coastal Plain due to numbers of residents and visitors, the types of mosquitos, and the abundance of suitable breeding habitat, that occur in this region (M. Lindsay, pers. comm., 27 September 1990).

(ii) Conservation

The conservation of the Peel-Harvey estuary system and associated ecosystems is another important concern of the regional community, although the concern is often expressed indirectly via concerns towards degradation of the recreational value of the estuary, and in the many public submissions to recent developments proposed for the region (EPA, 1988b; EPA, 1989). Many of these submissions related to the conservation of ecosystems and their components.

(iii) Recreation

The shallow sub-littoral bathymetry of the Peel Inlet imposes a major constraint on access to swimming and all forms of boating and associated activities. Foreshore reserves are typically restricted by the narrow space between the estuary and adjacent roads or freehold property. There are few places where trailer boats can be launched safely or without damage to native vegetation, and this situation has led to indiscriminate use of the foreshore. It is likely that the disturbance to foreshore vegetation and erosion problems will worsen in the future unless improved access points are provided. To deal with this problem, the Waterways Commission has proposed a programme of dredging and filling at key areas to create deeper nearshore waters for access and wider foreshore reserves (Waterways Commission, 1990a).

4.4.3 Conservation Resources

The System 6 recommendations C50, C51 and C52 of the EPA cover several areas within the Peel-Harvey system identified as open space of regional significance due to their high conservation and recreational values (EPA, 1983). The Peel-Harvey Estuary system as a whole constitutes the most significant estuarine-based fish resource in Western Australia, and possibly Australia (Australian Marine Sciences

Association, 1986). The estuarine system is also an important regional habitat for water birds including migratory wading birds. Australia is obliged to ensure measures for migratory wading bird preservation are undertaken under the RAMSAR, Japan and Australia (JAMBA) and China and Australia (CAMBA) Migratory Birds Agreement treaties.

4.4.4 Commercial Fishery

The Peel-Harvey fishery presently comprises 30 licensed units and contributes a major proportion of the State's annual catch of finfish and crabs. The total catch for the years 1985/86 and 1987/88 was 382 tonnes and 613 tonnes, respectively, with sea mullet, yellow eye mullet, cobbler, crabs and prawns comprising the largest components (Fisheries Department, 1988). During the past decade there has been an overall decline in this important fishery which has been attributed to several factors including the *Nodularia* blooms, reduced levels of macroalgal biomass and possibly excessive levels of fishing and climactic factors (Fisheries Department, 1988).

The increasing usage of the estuary for activities such as boating and amateur fishing and crabbing is also viewed as having the potential to affect adversely the catches made by commercial fishermen, who use gill nets and seine nets in a variety of locations within the Peel Inlet and Harvey Estuary (Fisheries Department, 1988). However, while amateur netting has recently been banned from the Swan-Canning system, amateur nets are still allowed to be left unattended in various parts of the Peel-Harvey system.

4.4.5 Social Environment of Cox Bay

4.4.5.1 Existing public facilities

Public access to the project area is provided via the public boat ramp and carpark located at Owen Street, Falcon, on the north-west corner of the proposed development area. There is currently little area of foreshore reserved as public open space, and the extensive area of nearshore shallows within Cox Bay makes boat access to and from the shoreline difficult. For example, outboard motors on dinghies tend to start grounding about 300 m offshore. Access to the beach is slow and also unpleasant when algal accumulations are present (Appendix 2).

4.4.5.2 Weed harvesting

Floating weed harvesters operated by PIMA are often moored at Novara on the northern side of Cox Bay. However, their use in Cox Bay itself is severely restricted by the shallow water and sporadic limestone outcrops. Occasionally they have been operated during periods of high tide near the Falcon boat ramp, but have

been unable to operate south near Olive Road (Wills, 1987). When fully laden the harvesters require at least 60 cm of water, and attempts to operate them at only half capacity within shallow areas proved inefficient owing to the inordinate amount of time that was required for the harvesters to return to off-loading facilities at Novara (Wills, 1987).

The use of front-end loaders has been restricted to shoreline operations after attempts to use these machines in shallow water but further away from the firmer beach sediments proved hazardous to both machine and operator (Wills, 1987). Damage was sustained to the blades and tyres and corrosion problems to the electrical system and articulated parts (Wills, 1987). Present harvesting operations are therefore highly restricted.

4.4.5.3 Commercial fishing grounds

Cox Bay contains areas which are utilised by commercial fishermen for netting sea mullet, yelloweye mullet and cobbler (Mr B. Toussaint and Mr J. Watts, pers. comm.). The project site contains part of the netting ground for cobbler, which are taken during periods of high water between March and July (Fig. 6, p. 68). Mullet catches are made to either side of the site between late December and July.

4.4.5.4 Recognised conservation areas

At the local level, Cox Bay area has not been formally recognised as an area of high conservation value and as yet there are no detailed plans in place which define acceptable uses in this area. The recently released Draft Peel Inlet Management Programme Review (Waterways Commission, 1990b) does however make recommendations for this area including the need to acquire adequate foreshores at the time of subdivision, to protect valuable fringing vegetation and to provide for increased levels of public recreation. There is also increasing public awareness over the general value of all natural resources and the need to conserve and protect environmentally sensitive localities wherever possible.

4.5 SYNTHESIS OF EXISTING ENVIRONMENT

4.5.1 Important Resources

The Peel-Harvey estuarine system contains large fish and crustacean populations that support one of the largest commercial estuarine fisheries in Western Australia and are also an important recreational resource. In addition to fishing the waterways provide for a diverse range of recreational pastimes which attract both residents and tourists to the region.

The Peel Harvey is also recognised as being of international importance for waterbird conservation, and supports many migratory wading bird species which are protected under international treaties.

4.5.2 Biological and Physical Processes

Physical processes influencing the aquatic ecosystem within the Peel-Harvey estuary include winter river flows which provide nutrients to the system and cause large fluctuations in salinity; tidal input and circulation regimes which control the patterns of water flushing and exchange; and the release and adsorption of phosphorous from the sediments.

Dominant biological processes include large algal blooms, especially those of *Nodularia* which tend to occur in late spring and early summer. The decomposition of the algae provides the detrital food store for the estuarine system. The fringing salt marsh vegetation of the tidal delta is important for shoreline stabilisation and nutrient cycling.

4.5.3 Social Issues

The main issues surrounding the Peel-Harvey system are the conservation of the natural environment, concern for its degraded water quality (including odour and aesthetic considerations), the mosquito problem and the associated threat of Ross River Virus, the impact of these factors on lifestyle, recreation and tourism in the region, and the potential impact of increased recreational boating and fishing pressures on the livelihood of licensed commercial fishermen.

5 ASSESSMENT OF PROJECT EFFECTS

5.1 INTRODUCTION

This section of the PER assesses the environmental significance of the proposed works which were described in Section 3, and then identifies those features of the project that will require management to minimise the risk and/or scale of potential impacts. The management actions that will be taken by the proponent are listed and discussed in Section 6.

The effects of the project on the local and regional environment are divided into those which only relate to the construction phase and are thus of short-term duration (e.g. effects of increased water turbidity); and those which are a consequence of carrying out the project and are therefore considered permanent, but capable of modification by various management techniques.

The most potentially detrimental effects to the physical, biological and social environment are those which occur during the construction phase, but these will be temporary. These are described and assessed in Section 5.2, whilst Section 5.3 identifies and assesses the long-term effects brought about by the proposed works.

5.2 CONSTRUCTION EFFECTS

5.2.1 Scope of Effects

Effects on the environment during construction will result from the construction of the bund walls, excavation of the project site and spoil dumping on the foreshore and site of the new island. The main effects can be listed chronologically as follows:

- plant and machinery movements and noise;
- generation of sediment plumes during the construction and removal of the main bund wall;
- temporary closure of the Falcon boat ramp and jetty;
- temporary isolation of the project site from the remaining waters of Cox Bay;
- removal of an average of 0.26 m of the existing sandy sediments;
- disturbance to beach and foreshore area during spoil dumping and relocation of low-lying parts of vegetation to new island; and

- re-introduction of estuary water into the deepened embayment.

5.2.2 Plant and Machinery

Noise emissions will arise from the earthmoving equipment and haulage trucks. Construction will involve excavators, front-end loaders and haul trucks working during daylight hours over the estimated 16 week construction period.

The noise will be greater than that generated by weed harvesting operations. In addition, one or two dewatering pumps may be required to be operated for 24 h/d during the dry excavation of offshore compartments where leakage rates may be high. These pumps will produce a low, but continuous background noise.

Apart from the arrival and departure of machinery at the start and finish of the construction period, there will be no heavy truck movements to and from the development site since all spoil is being dumped on location.

There are no houses alongside or behind the foreshore of the development site except those in streets behind the boat ramp and jetty in the north-western corner of the development site. The distance to the closest house will be approximately 120 m. Noise will be most noticeable during the short period when the area surrounding the jetty and ramp will be excavated. This part of the operation is expected to take five to 10 days.

5.2.3 Sediment Plumes

5.2.3.1 Extent of turbid emissions

Construction activity will generate sediment plumes and cause turbidity in local waters only during the initial construction and final removal of the main enclosing bund wall. Sediment plumes will not be generated during the dewatering operations in the main excavation period, since the turbid water within each compartment will be pumped into the lagoon created by the main bund wall.

Observations and aerial photographs taken at the time of the trial excavation of the adjacent boat channel (see Appendix 7) show that the turbidity plumes generated by construction activity can be expected to extend up to 100 m from the excavator. The suspended sandy sediments were observed to settle within 30 m of the point of excavation under average weather conditions. The dominance of fine to coarse-grained quartz sands in the sediments of the project site is the major reason why large plumes are unlikely to be generated (see Section 4.2.2).

The plumes will therefore have only a localised and temporary effect, with the extent and intensity of turbid emissions being far smaller in magnitude than those which can be naturally generated in the Peel Inlet by storm events.

5.2.3.2 Potential effects of turbidity

Impacts from turbidity associated with deepening operations in estuaries have been described by Bohlen (1980), Jones (1981), Bennett (1984) and Poiner and Kennedy (1984). Local experience has been also been gained in Cox Bay by an investigation of turbidity generation and nutrient release during a recent test of bund wall construction, which was used to the lengthen and deepen the boat channel at the Falcon boat ramp (Appendix 7).

In highly turbid waters primary production may be limited by reduced light penetration in water. Dredging and filling activities may increase the natural background levels of turbidity beyond environmentally acceptable levels.

In the shallow well mixed waters of Cox Bay the water was found to remain well oxygenated during the trial excavation and elevated turbidity was confined to a relatively small area. This is considered to be largely due to the low level of organic matter present within the sediments (Appendix 7).

This impact will occur during the four week construction period for the main bund wall, and for its subsequent removal. During these periods the generation of turbidity will be confined to the area surrounding the excavating machine.

As a result the potential adverse impacts on water quality as a result of excavation are expected to be confined to a small area (<100 m radius) around the construction point.

5.2.4 Temporary Closure of Falcon Ramp and Jetty

These facilities will have to be closed for only a short time during the construction period. During this time, the surrounding nearshore floor will be deepened and the ramp widened with a concrete extension to its south side.

5.2.5 Isolation of Nearshore Embayment

The development site will be isolated from the remaining open waters of Cox Bay for almost 16 weeks. The main bund wall will isolate approximately 40 ha of shallow water, nearshore benthic habitat. This area, however, comprises less than 1% of the shallow water (less than 0.5 m deep) habitat in the Peel-Harvey, which has been estimated to include 44% (or 5764 ha) of the 131 km^2 water area.

Waters contained within the main bund wall are expected to become turbid due to the creation of the inner bund walls and water pumping operations. Consequently, nutrient release from the disturbed sediments is not expected to cause algal blooms within the lagoon because of the turbidity which will significantly reduce light availability to algae.

Water pumping operations and subsequent excavation will lead to the death of fish and other aquatic organisms that become trapped behind the main bund wall.

Part of the cobbler ground utilised by professional fishermen will be inaccessible during the construction period as the ground will be lying behind the bund wall. The effects of construction of the bund walls on the abundance of fish within the remaining area of Cox Bay is expected to be restricted to the vicinity of the construction area.

Some birds will leave the site during the construction period while others will be attracted by the temporary exposure of new food resources as the areas within the bund walls are pumped dry.

5.2.6 Removal of Surficial Sediments

5.2.6.1 Changes to bathymetry

The existing bathymetry of the development site will be modified by:

- deepening of the 40 ha project site by an average of 0.26 m;
- addition of a 200 m long by 130 m wide by 1 m high island that occupies 2.6 ha of the eastern boundary of the site; and
- an extension to the existing shoreline averaging 6 m width.

Excavation depths within the embayment are designed so that water circulation and exchange will tend to be enhanced rather than restricted. For example, bottom friction will be reduced as a result of the deeper water column, and the island is placed so that any large eddies within Cox Bay are not disturbed (Appendix 2). The speed of water movement is not expected to increase (Appendix 2).

Excavation of the various compartments will remove much of the benthic fauna from the project site, and expose a new embayment floor of denuded sands.

5.2.6.2 Formation of the new island

Spoil placement to create the island will smother approximately 2.6 ha of existing sandy shallow water benthic habitat which supports a benthic infaunal and algal population (Appendix 4). The sand island will replace the shallow water habitat with shallow subtidal, intertidal and terrestrial habitats which will provide feeding area for wading birds, and roosting and breeding areas for a range of waterbirds. The precise areas of the new habitats will depend on minor movement of the shorelines of the new island during the development of a stable beach

configuration, but will initially comprise 2.6 ha of terrestrial habitat, 2500 m^2 of intertidal habitat and a similar area of shallow sub-tidal <0.5 m deep) habitat.

There will be no turbidity impacts associated with the creation of the island as it will be formed behind the main bund wall.

5.2.6.3 Foreshore grading and beach widening

Effects of foreshore grading and beach widening include infill of temporary pools, foreshore filling, levelling and grading to provide for recreational use and to improve drainage, beach widening and transplantation of vegetation to the island.

Foreshore works will involve extensive levelling operations and necessitate the clearing of vegetation. However, existing trees will be retained on the foreshore and the extended foreshore area will be landscaped with local native plant species following earthworks.

The impacts of these works will include permanent as well as temporary disturbance to water birds, and the loss of native vegetation, particularly in the central part of the proposed foreshore reserve. However, careful placement of fill will enable the majority of the paperbarks to be retained at the southern and northern ends of the site, and larger trees throughout the site.

5.2.7 Re-Introduction of Estuary Water

5.2.7.1 Potential for nutrient release

The level of nutrients in the deep, but newly exposed, sediments will be similar to that measured in the surface sediments (Appendix 7). However, it is considered unlikely that extensive algal growth will occur within Cox Bay immediately following the re-introduction of estuary water, since any thin layers of highly-enriched sediments (typically found in the top 2 cm of the substrate) will have been removed to the foreshore and island during the excavation operations. The period of aerial exposure following water pumping and excavation will also oxygenate the new surface sediments so that there will be no anaerobic release of nutrients upon re-flooding of the area.

5.2.7.2 Colonisation of sediments

Colonisation of deepened areas by benthic animals depends upon the nature of the habitat and biota that was initially removed, the new depth that is attained, changes in water currents or water quality, the type of substrate that is exposed, the extent

to which animals remain after deepening, and the extent to which sediment slumping (if any) occurs following the completion of deepening (Jones, 1986).

Slumping will not occur as the beach face and offshore island will be formed with a stable, low (1 in 10) gradient, while the deepened floor of the nearshore embayment will have a gentle and uniform gradient sloping downwards offshore.

Re-establishment of benthic invertebrates in sandy substrate is usually most successful if the resultant sediments remain coarse, where water depth is not altered appreciably, and where the substrate remains level without deep holes (Wallace, 1977). For example, a study of dredged areas in the Swan River found that any new substrate in more than 2 m of water will have a less diverse and less abundant fauna than that which previously existed before deepening (Wallace, 1977).

Monitoring of dredging operations in the Sticks Channel area of the Peel Inlet system has shown that recovery of benthic flora and fauna is very rapid and that the species that returned to disturbed areas were the same as those in adjacent undisturbed areas (EPA, 1986). A boat channel dredged from the original estuarine floor at Yunderup was examined in 1974 to determine the effects of dredging on the benthic fauna. The floor of the deep channel was filled with filamentous green algae and contained little fauna, but the substrate immediately adjacent to the channel contained a similar fauna to that at comparable sites in Peel Inlet (Chalmer & Scott, 1984).

Results of a survey which compared the benthic fauna of Cox Bay with other areas in the Peel Inlet, together with research data on seasonal fluctuations also support the view that colonisation will be rapid and successful (Appendix 4).

The removal of the limestone pinnacles protruding from the original floor of the development site will not result in the loss of substrate for existing serpulid worms, since these outcrops will be utilised for the north and south facing sides of the island. Hard substrates are not common in the Peel Inlet.

5.3 POST-CONSTRUCTION EFFECTS

5.3.1 Introduction

The potential post-construction effects are identified as changes to the sediment and current dynamics, alteration of water bird habitats, disturbance to professional fishing activities, and effects on the local and regional societies. The effects are discussed in the following sections.

5.3.2 Potential Changes to Sediment and Current Dynamics

5.3.2.1 Changes to circulation, exchange and water quality

Local water quality is not expected to deteriorate as a result of the project. Riedel and Byrne Consulting Engineers have investigated the flushing and circulation characteristics of Cox Bay and have made predictions for the existing and altered embayment (Appendix 2).

Deepening of the embayment floor together with the construction of the island is predicted to have little impact on existing current patterns. The existing eddies will persist since the island will be located in the centre of their usual path. Due to the deeper water, the current velocities will be slightly reduced (by 20-30%) but the volume of water circulated will remain the same. The estuary floor will be sloped continuously into Peel Inlet so there will be no tendency for stagnation of water.

The fundamental water circulation problem due to the eddy will remain so that algal wrack will continue to accumulate in the Bay as it does now. However, the deeper water will allow more efficient harvesting of the algal wrack so that overall water quality can be improved compared to existing conditions (Appendix 2).

5.3.2.2 Stability of sediments, shoreline and island

(i) Design background

The underwater slopes of the excavated area and the foundations of the islands will not exceed gradients of 1:10 which will ensure that slumping of the estuary floor does not occur.

Sediment transport calculations carried out for the Cox Bay foreshore indicate that longshore sediment transport is in the order of 10 m^3/y in either direction. With such low sediment transport rates the best design procedure for the new beach is to allow it to realign itself to the new offshore conditions. The 13,000 m^3 of sand to be placed on the beach (12 m^3/m run) will be more than sufficient compared to annual transport rates. Given that facilities and structures will be set back from the beach face by at least 10 m, there will be no problem in accommodating any shoreline movements.

The sediment transport rates computed for the Cox Bay foreshore will apply equally well to the offshore island (Appendix 2). If the island beaches are not aligned in equilibrium with the ambient wave climate the quantity of sand moved each year from one end of the beach to the other will be of the order of 10 m^3. This movement is insignificant for an island created from approximately 59,500 m^3. There will no impact even if there is a loss of sand from the island as no structures are planned on the island.

(ii) Effects of storm conditions

It has been estimated that during a severe storm of 24 hours duration, water levels in Peel Inlet could increase by 1-1.5 m and waves in Cox Bay could persist at 0.6 m height for 12 hours (Appendix 2). During such a storm event (e.g. Cyclone 'Alby') there would be sand movement along the beach of the order of 25 m^3. There may also be some sand movement off the beach into deeper water which will be reflected on the beach as an erosion scarp. The 12 m^3/m run of sand placed on the beach is sufficient to accommodate two to three storms of the magnitude of Cyclone 'Alby'.

The island would be inundated by severe storm events and may become awash. Sand would tend to be removed from the island and deposited on the lee side of the island. Vegetation, depending on its salt tolerance, would be damaged. Similar impacts would occur on all of the estuary islands and foreshores and would be regarded as part of the process of natural landform modification.

(iii) Dawesville Channel

The main impact of the proposed Dawesville Channel will be an increased tidal range and improved water exchange.

The increased tidal range will be accommodated by the widened and higher beach along the foreshore reserve. Water depths at low tide would be reduced by up to 10 cm and this has been allowed for in the extent of excavation of the estuary bed.

Whilst there will be some improvement in water exchange at the project site, the nature of the Cox Bay eddy will remain essentially the same as at present (Appendix 2). However, excavation of the embayment and disposal of spoil on the foreshore will stabilise a section of the foreshore that has previously suffered erosion from artificial weed removal.

Measures proposed for the management and protection of the shoreline to prevent further erosion are listed in Section 6 and in the Foreshore Management Plan (Appendix 8).

5.3.3 Algal Growth and Accumulation Within Cox Bay

Macroalgal growth may become more luxurient within Cox Bay following excavation as the deeper water will provide a more stable habitat. In particular, fluctuations in water temperatures will be less extreme and exposure during low tides will not occur. This situation could persist until such time as nutrient levels are reduced by improved flushing following construction of the Dawesville Cut.

Irrespective of any increased insitu growth the embayment will still tend to accumulate algal material as a result of natural circulation patterns. However, the

excavation will allow more efficient removal of algal accumulations by underwater harvesters.

5.3.4 Altered Water Bird Habitats

5.3.4.1 Permanent loss of shoreline water bird habitats

Although the length of the foreshore will not be changed by the project, excavation of the proposed embayment will result in a change of feeding habitat for water birds through the deepening of intertidal areas which currently are periodically accessible to wading birds and through the increased disturbance to birds on the shoreline and within the proposed foreshore reserve as the area becomes more developed and is used by more people.

5.3.4.2 Value of the new island

Provision of the offshore island will help to offset this impact by providing new areas of feeding habitat and roosting and loafing areas that are more isolated from human interference. The island will be relatively isolated and will be free of predators, so it has a particular value as breeding habitat and as nesting, roosting and loafing sites for birds (see Soots & Landin, 1978).

5.3.5 Effects on Professional Fishing

Fish and crab numbers in Cox Bay may remain low within the project area until the exposed substrate is colonised by benthic fauna. In the long term, however, the overall abundance of fish and crabs is expected to increase as a result of improved summer conditions in the deepened embayment. This is because the ability to use the floating weed harvesters will improve weed harvesting operations in the bay and thereby assist in preventing the accumulation of the large masses of macroalgae which currently occur in the shallow water. This will aid in the development of well oxygenated sandy sediments which should support a more stable and abundant benthic infauna than currently occurs during this season (Appendix 4).

The value of the area as a fish and prawn nursery is not expected to change, since the proposed deepening will not produce water depths greater than 1.3 m, and much of the development site will continue to contain waters less than 0.9 m deep

Direct adverse effects of the project will be loss of area for netting around the island, but the beneficial effects will comprise improved netting grounds without the pinnacles and improved water depths and boat ramp access.

Indirect effects of the project on the commercial fishing operations will be disturbance caused by increased recreational boating and fishing activities in Peel Inlet. Disturbance in the Cox Bay fishing grounds could be considerable if power boating is allowed in the area around the island. It would be preferable for the deepened part of the embayment to be reserved for daylight catamaran sailing and canoeing, and for power boating activities within Cox Bay to be confined to the boat channel. Action on this issue would be implemented by the Department of Marine and Harbours on the recommendation of the Waterways Commission.

The development will in part help promote increased recreational fishing activities in Peel Inlet, which are viewed by the professional fishermen as conflicting with their livelihood. However the development will also provide a focal point for recreational boat users along the western side of the Peel Inlet which should enable more effective implementation of any educational or enforcement programme aimed at managing fish stocks. The ultimate responsibility of the management of the estuarine fishery lies with the Department of Fisheries, which has the authority to regulate exploitation of the resource.

5.3.6 Local and Regional Social Effects

The excavation development will affect the social environment on both local and regional scales. At the local level, the development will involve a significant increase in the recreational use of the site. Issues of concern include construction impacts on the local community and public access to foreshores.

On a regional scale, the development will provide improved recreational facilities including improved parking and boating and access to the estuary.

The proponent recognises in proposing this development within the Peel-Harvey that the estuary is recognised as a region of identified conservation and landscape value and consequently the project has been designed to minimise the potential impacts on the environment of Peel Inlet.

5.3.6.1 Recreational usage of Peel Inlet waters

The development will result in increased use of the embayment area for recreational purposes such as canoeing, windsurfing and sailing dinghies, and cycling and walking on the dual use pathway along the estuary foreshore.

The development will also result in increased boating traffic in the north-western side of Peel Inlet by providing a greater number of facilities for the boating public. Greater usage of Peel Inlet for recreational activities such as fishing, crabbing and boating can conflict with the netting activities of the commercial estuarine fishermen. However, it can be argued that such pressures will occur with natural population growth in the area and use of the estuarine waters by visitors to the region, irrespective of whether the proposed excavation development proceeds.

5.3.6.2 Aesthetic considerations

The development will improve the landscape by transforming a very shallow area into a permanent water body with extended foreshore areas and vegetated offshore island. Planting of native vegetation along the foreshore and on the islands will ensure that the development blends in with the natural appearance of the Peel Inlet.

On a regional scale, the development will not have any adverse impacts on landscape and aesthetics of the Peel Inlet in the long term. However, based on observations of Boundary Island in the Sticks Channel, the island will be a conspicuous feature of Cox Bay during the first few years following completion of the project, until the vegetation is well established.

5.3.6.3 Conservation values

The impact of the development on the recognised regional conservation values of the Peel-Harvey estuarine system is considered to be small, given that the habitats to be created will be complementary, and generally similar, to those presently occurring in the area, In particular the offshore island is expected to provide valuable sheltered habitat areas for the waterbirds of Cox Bay.

5.3.6.4 Use of adjacent nearshore waters

Use of adjacent nearshore waters will increase as a result of the development. Larger boats will be able to launch from the Falcon boat ramp. It is anticipated that surfcat and canoe hire facilities will operate in daylight hours only from the embayment in addition to swimming, fishing and crabbing activities. The proponent is not in favour of the deepened area being used for ski-boat and jet-ski activities (since these will conflict with the island sanctuary for water birds), and considers that power boats within the project area should be restricted to the boat channel during their entry and exit from the boat ramp.

5.3.6.5 Mosquitoes

The proposed foreshore works will involve the filling of several low lying areas which are breeding grounds for mosquitos (Plates 4 & 5, p.79). The development will therefore contribute to a reduction in both the levels of nuisance mosquitos and the risk of spread of Ross River Virus in the Falcon area.

5.4 SUMMARY

The impacts predicted to occur as a result of the proposed development on the physical, biological and social components of the environment are summarised in Tables 1 to 3 (pp.64-66). The beneficial impacts of the proposal are summarised in Table 4 (p.67).

6 ENVIRONMENTAL MANAGEMENT

6.1 INTRODUCTION AND OBJECTIVES

A management programme is proposed to mitigate the environmental impacts of the proposed development.

The objectives of the management programme are:

(i) to minimise the environmental impact of the development; and

(ii) to adopt adaptive management practices which will maintain and enhance the recreation, aesthetic and general conservation values of the project area.

6.2 MANAGEMENT PLANS

It is proposed that the overall management programme be comprised of two management plans, an estuary management plan and a foreshore management plan.

6.2.1 Estuary Management Plan - Overview

As the development is located in the Peel Inlet, water quality characteristics of the embayment and Peel Inlet will be important management considerations. Management controls to the satisfaction of the Peel Inlet Management Authority will be implemented by the proponent during the construction phase in order to minimise the impact of turbid water on Peel Inlet resulting from excavation operations.

To ensure the ongoing maintenance of acceptable water quality within the embayment, a comprehensive monitoring programme will be implemented by the proponent. Analyses of monitoring results will indicate whether amendments to management techniques are required. Contingency plans will be documented for use in emergency situations, should they arise.

Further details of the proposed Estuary Management Plan are provided in Section 6.3.

6.2.2 Foreshore Management Plan - Overview

The foreshore reserve will be enhanced for passive recreation by filling and landscaping recreation areas, retaining the existing vegetation in designated areas, providing extensions and improvements to the Falcon boat ramp and carparking

area, providing additional access points through the proposed development and the construction of a dual use pathway along the length of the foreshore.

In order to stabilise the shoreline, parts of which are currently eroding, the shoreline will be renourished with sand from the excavation programme and allowed to develop a stable profile.

Further details of the Foreshore Management Plan are provided in Section 6.4 and in Appendix 8.

6.3 ESTUARY MANAGEMENT PLAN

6.3.1 Objectives

The objectives of the estuary management programme are to:

(i) minimise impacts to the water quality of Peel Inlet during the construction phase of the project;

(ii) minimise inconvenience to local residents from construction operations; and

(iii) develop and manage the offshore islands to create bird habitat and refuge areas.

6.3.2 Construction Impacts

Details of construction are provided in Section 4. In summary, construction of the project will require:

- bund wall construction and excavation of the embayment;
- construction of an offshore island;
- foreshore filling, extensions and stabilisation work;
- bund wall removal; and
- island and foreshore planting.

Details of management activities that will be implemented to reduce inconvenience to nearby residents are outlined in the following sections.

6.3.2.1 Construction traffic and noise

A construction track accessing the site will be established from Old Coast Road through the Estuary Gardens site, which is adjacent to the project area and also being developed by the proponent. This will avoid the use of local residential roads. Construction activity will be confined to daylight hours to minimise disturbance to local residents.

6.3.2.2 Dust Control

Spoil used to create the island and for extensions and stabilisation of the foreshore will be excavated from the floor of Cox Bay. Disposal of this spoil material, which will be wet or damp, will not produce any dust emissions. However in the event that this material can not be permanently stabilised by vegetation or other means immediately, temporary stabilisation in accordance with recommendations contained within the Dust Control Guidelines issued by the EPA will be implemented.

6.3.2.3 Water turbidity - excavation

Excavation of the embayment will take place within an encompassing bund wall. Suspended sediments will only be released to the Peel Inlet during construction and removal of the perimeter bund walling.

6.3.2.4 Soil stabilisation

The soil surface of the island will be stabilised with limestone, planting of advanced vegetation and hydromulching following construction.

The soil surface of the foreshore will be stabilised by the planting of native vegetation, construction of recreation facilities (paths, car parks etc.) and grassing following the completion of earthworks.

6.3.2.5 Public access to adjacent foreshore

Public access to the Falcon boat launching facility and the adjacent foreshore will not generally be affected by construction activity. However, for safety reasons, public access to the work site and adjoining onshore areas will be denied during the construction period.

The jetty and boat launching ramp at the Falcon boat launching facility will be closed to the public only during the proposed deepening works adjacent to this structure. This work is expected to take five to ten days to complete.

6.3.3 Post-Excavation Management

6.3.3.1 Island soil stability

The island shape and shoreline profiles have been designed to be stable in relation to the natural sedimentation processes of the project area (refer to Appendix 2 for details). Limestone stabilisation, the planting of advanced vegetation and hydromulching will prevent soil erosion by the prevailing winds.

6.3.3.2 Vegetation planting

Following completion of the island and prior to foreshore works, existing foreshore vegetation such as samphire and rushes, and smaller Melaleucas will be transplanted to the shorelines of the island. Areas of the island not planted with the advanced vegetation will be hydromulched and planted with seedlings. As discussed in Section 3.2.1.3 a diversity of vegetation types will be planted to create varied bird habitat.

6.3.3.3 Public access to the island

The proposed island is designed primarily as a waterbird refuge and not for recreational purposes. It will be surrounded by a relatively large area of shallows to maximise the area of shallow wading bird feeding area and discourage boat access. No jetties or other boat landing facilities will be provided.

6.3.3.4 Carparks and boat launching areas

The proposed development includes the construction of a new boat ramp and car and trailer park adjacent to the existing Falcon boat ramp.

6.3.4 Contingency Plans

The design of the project indicates that it will be stable under even quite severe storm events. Changes to tidal levels and circulation patterns brought about by the construction of the Dawesville Channel have been taken into consideration in designing the project.

6.3.5 Construction and Ongoing Monitoring Programmes

The objective of the monitoring programmes is to define a flexible programme designed to monitor aspects of the project which have the potential to give rise to adverse impacts, and which is responsive to monitoring results. The proponent proposes to undertake the monitoring programmes described in the following sections.

6.3.5.1 Water quality during construction

Water quality will be monitored at selected sites in Cox Bay during construction of the project. The parameters to be monitored include:

- chlorophyll 'a' (midway between top and bottom of water);
- suspended solids (midway between top and bottom of water);
- dissolved oxygen (surface and 0.5 m from bottom of water);
- biochemical oxygen demand;
- inorganic nitrogen;
- inorganic phosphorus;
- salinity (throughout water column to check for stratification);
- temperature; and
- light attenuation (by Secchi disk).

6.3.5.2 Water quality and circulation - post dredging

The excavated embayment will be monitored for the same parameters listed in section 6.3.5.1 following completion of the project on a six monthly basis for two years following construction.

6.3.5.3 Recolonisation of excavated area

Benthic surveys of the dredged area and the shallow areas surrounding the island will be undertaken on an annual basis for the first two years following construction. The results will be compared with the same area prior to construction and control sites of intertidal and shallow areas.

6.4 FORESHORE MANAGEMENT PROGRAMME

6.4.1 Objectives

The objectives of the foreshore management programme are:

(i) to maintain the foreshore adjacent to Peel Inlet such that the integrity of the natural waterway is secured; and

(ii) to enhance the value of the foreshore for passive recreation.

The foreshore will be managed in conjunction with the management plan prepared by LEC on behalf of Meiyu Australia Pty Ltd, for the Estuary Gardens development on the land immediately adjacent to the project site (see Appendix 8).

The foreshore will comprise three major components: sandy beaches, passive recreation areas and conservation zones. However, the principle uses of the site will be for passive recreation and for the provision of access to the estuary.

6.4.2 Foreshore Protection and Stabilisation Work

The existing foreshore beaches are dynamic being subject to longshore sediment accretion and erosion. Following renourishment of the beaches, the shoreline will be allowed to find its own equilibrium position; the annual volume of sand movement being only in the order of 10 m^3 (refer Appendix 2).

6.4.3 Tree Planting

The vegetation planted on the foreshore will be separated into landscaped areas and natural areas. A wall will be constructed within the foreshore area with an average height of 0.5 m which will be used to provide this separation. Planting will commence as soon as practical following earthworks.

The excavated material used to create sandy beaches will not require any planting. The area of foreshore to be used for passive recreation will be planted with grasses having a low water and nutrient requirement and suitable native tree species that will provide shelter and shade and blend with the natural vegetation of the estuary.

The areas of the foreshore proposed for retention as natural vegetation areas will be enriched with plantings of indigenous species.

The existing larger trees on the foreshore will be preserved wherever practical.

6.4.4 Public Access

Access will be provided to pedestrians and cyclists along the length of the foreshore by means of a dual use pathway. The path will meander along the foreshore with its alignment generally following that of the low retaining wall separating the landscaped and natural vegetation sections of the foreshore. The pathway will link into adjacent parkland at the Falcon boat ramp to the north, and into the open space at Olive Road to the south.

The beach area will provide a continuous link with the existing beaches on either side of the development site.

During construction, public access to the excavation area and the adjacent foreshore will be denied. Fences and warning signs will be erected to this end.

6.4.5 Monitoring Programme - Shoreline Stability

Beach width and profile will be measured on a six monthly basis following construction and following storm events for two years. The results of this monitoring will be used to determine whether sand renourishing will be required and the need for any erosion protection measures identified.

6.5 ADMINISTRATIVE DETAILS

6.5.1 Reporting Schedule

6.5.1.1 Items to be reported

The following components of project management will be reported upon:

(i) estuary management programme; and

(ii) foreshore monitoring programme.

Monitoring reports will include the results of all aspects of the monitoring programme as follows:

(i) Estuary Management Plan

- water quality and the extent of turbidity during construction;
- crustacean and benthic invertebrate recolonisation of the dredged area and shallow water areas surrounding the islands; and
- the bathymetry of the dredged area.

(ii) Foreshore Management Programme

- beach profiling and shoreline stability including the islands;

6.5.1.2 Timing

The results of the monitoring programme will be reported on an annual basis. At the end of the two year monitoring period, a final report will be prepared showing the results of the complete programme.

6.5.1.3 Reporting authorities

Results of the water quality monitoring, and the benthos and crustacean surveys will be reported to the EPA, Waterways Commission and PIMA. The results of construction monitoring including the bathymetry of the embayment, and sedimentation within the embayment will be reported to the Shire of Murray, City of Mandurah, EPA, Waterways Commission and PIMA.

The analyses of monitoring results for shoreline stability and vegetation surveys on the foreshore and island will be reported to the EPA, Waterways Commission, PIMA and the City of Mandurah.

6.5.2 Authorities Responsible for Management

6.5.2.1 The proponent

The proponent will be responsible for all aspects of the development, including the management programmes detailed in Sections 6.3 and 6.4. Responsibility for management will revert to the local authority and the State after an operating period of two years, subject to detailed arrangements to be finalised in the project agreement.

6.5.2.2 Waterways Commission

Upon completion of the project, the Waterways Commission will be responsible for the management of the offshore island and the embayment between the island and the Falcon foreshore.

It is anticipated that the proposed foreshore reserve will also be vested in the Waterways Commission and be leased at a nominal rental to the proposed Estuary Gardens owners association, who will be responsible for ongoing management of the foreshore according to the provisions of an approved foreshore management plan.

6.5.3 Commitments

The commitments made by the proponent in respect to this proposal are listed in Section 7.

7 LIST OF COMMITMENTS

7.1 INTRODUCTION

This section of the report lists all of the commitments made by the proponent and described in this report and identifies the authorities to whose satisfaction those commitments must be carried out.

The proponent will undertake to abide by all commitments made in this PER. Specifically this refers to undertaking all management actions detailed in the two management programmes outlined in the preceding sections. These commitments will be incorporated into the project agreement, which is to be established between the proponent and the State.

The following commitments are made by the Proponent for the satisfactory completion of this project:

7.2 COMMITMENTS

7.2.1 Bank guarantee

A bond of $20,000 will be lodged with the State for completion of the proposed project as described in this PER. The total amount to be refunded to the proponent upon completion of the earthworks for the project, initial vegetation planting of the foreshore and islands, and shoreline stabilisation works.

7.2.2 Commitments by the Proponent in relation to the adjacent development on Part Location 1147

(i) The development will be connected to a reticulated sewerage system.

(ii) Stormwater will be retained within the development area to a 1 in 10 year storm extent in compensating basin/s, with retention times of three to four days, and with no direct outfall to Peel Inlet or the proposed foreshore reserve with the exception of 1 in 100 year flood events.

(iii) Existing trees will be retained where feasible over the site.

(iv) A nutrient management programme will be developed and implemented over the development area.

(v) Public access to the estuary will be provided through the development at two locations, which will include public car parking areas, in accordance with EPA recommendations.

(vi) Physical and visual separation between the development and the foreshore reserve will be achieved by means of a retaining wall constructed to a level of 2.0 m AHD along the development boundary.

7.2.3 Excavated bay area management

(i) Construction will be confined to daylight hours only.

(ii) Excavation and island construction will take place within bund walling to minimise the generation of turbid plumes during construction.

(iii) Public access to the foreshore south of the Falcon boat launching facility will be denied only during the construction phase for safety reasons, with appropriate fencing and signage, as required by the City of Mandurah.

(iv) All exposed soil surfaces will be stabilised as necessary, to prevent the formation of a dust nuisance.

(v) Deposition of the dredge spoil for filling of the foreshore and renourishment of the beaches will take place to the satisfaction of the Waterways Commission and Peel Inlet Management Authority.

(vi) Water quality in the embayment and Cox Bay, and sedimentation processes in the embayment and local area will be monitored by the proponent to the satisfaction of the Waterways Commission and Peel Inlet Management Authority and reported annually.

Note: Following completion of the project debris and algal wrack accumulating within the embayment will continue to be removed by the Peel Inlet Management Authority.

7.2.4 Island management

(i) The island will be fully planted with native vegetation, supplemented with seeding and hydromulching as required, to the satisfaction of the Waterways Commission.

7.2.5 Foreshore management

(i) Foreshore filling will take place to the satisfaction of the Waterways Commission. All vegetation to be retained on the foreshore will be identified and marked prior to the commencement of filling.

(ii) Foreshore protection and stabilisation work will be undertaken to the satisfaction of the Waterways Commission prior to the establishment of suitable public access areas.

(iii) The shoreline will be constructed to a stable profile and stability will be monitored to the satisfaction of the Waterways Commission.

(iv) The foreshore conservation areas will be rehabilitated with native vegetation to the satisfaction of the Waterways Commission.

(v) The proponent will construct a new boat ramp and car and trailer park adjacent to the existing Falcon boat ramp, subject to agreement with the relevant authorities.

(vi) A dual-use pathway will be constructed along the length of the foreshore around the embayment on an alignment acceptable to the Waterways Commission and the City of Mandurah.

(vii) Two jetty/groyne structures for public recreational purposes will by constructed by the proponent subject to approval of the relavent authorities and granting of jetty licences.

7.3 REPORTING SCHEDULE

The following components of project management will be reported upon:

(i) estuary management programme; and

(ii) foreshore monitoring programme.

Monitoring reports will include the results of all aspects of the monitoring programme as follows:

7.3.1 Estuary Management Plan

- water quality and the extent of turbidity during construction.
- crustacean and benthic invertebrate recolonisation of the dredged area and shallow water areas surrounding the island; and
- the bathymetry of the dredged area;

7.3.2 Foreshore Management Programme

- beach profiling and shoreline stability including the islands;
- vegetation surveys of the foreshore.

7.3.3 Timing

The results of the monitoring programme will be reported on an annual basis. At the end of the two year monitoring period, a final report will be prepared showing the results of the complete programme.

7.3.4 Reporting authorities

Results of the water quality monitoring, and the benthos and crustacean surveys will be reported to the EPA, Waterways Commission and PIMA. The results of construction monitoring including the bathymetry of the embayment, and sedimentation within the embayment will be reported to the Shire of Murray, City of Mandurah, EPA, Waterways Commission and PIMA.

The analyses of monitoring results for shoreline stability and vegetation surveys on the foreshore and island will be reported to the EPA, Waterways Commission, PIMA and the City of Mandurah.

8 CONCLUSION

8.1 BENEFITS

The proponent's objectives are to improve boating access and water-based recreational opportunities at Falcon, and facilitate a reduction in local algal problems by providing for improved management including the use of floating weed harvesters.

The development will involve the excavation of approximately 112,500 m^3 of sandy sediment from the estuary floor of Cox Bay in the Peel Inlet near Falcon to create a permanent water-filled embayment along the foreshore. The excavated material will be used to widen the existing foreshore and construct an offshore island.

The foreshore will be largely filled and grassed and planted with indigenous native trees and recreational facilities will be constructed. These will include a dual use pathway along the foreshore, and extensions to the existing boat ramp carpark. Natural vegetation will be retained in defined areas.

The offshore island is intended to be used exclusively for bird habitat and will be vegetated accordingly. It will also trap some of the drifting algae that currently accumulates on the shore at Falcon where it decomposes and emits foul odours.

8.2 ENVIRONMENTAL IMPACTS

The potential impacts of the project on the local and regional environments have been identified and discussed.

The major adverse impacts, which are identified as loss of onshore and intertidal feeding habitats for water birds, and reduction in the netting area available for professional fishermen, have been minimised consistent with meeting the objectives of the project.

Temporary adverse impacts of the project, which include elevations of noise levels during construction, emission of turbid plumes during construction and dismantling of the bunds, isolation of the nearshore embayment, and closure of the Falcon boat ramp, are considered to be manageable.

8.3 MANAGEMENT OF IMPACTS

Management programmes have been designed to address the potential impacts associated with:

- construction activities;

- stabilisation of earthworks;
- release of turbid and nutrient-enriched water;
- water quality of the embayment;
- populations of benthic invertebrates, fish and water birds in Cox Bay; and
- stability of the new shoreline and offshore island.

It is considered that the identified adverse impacts can be managed to avoid unacceptable environmental degradation.

The proponent has accepted responsibility for the management of all impacts associated with the construction of this project and is committed to implement the monitoring and management programmes identified in this report to the satisfaction of the relevant authorities. The proponent will also lodge a bond of $20,000 with the State for completion of the proposed project as described in this document.

8.4 CONCLUSION

It is concluded that the potential environmental impacts of this proposal can be successfully managed by the implementation of the management programmes outlined in this report. The development will improve environmental conditions and recreational opportunities within Cox Bay.

9 REFERENCES

Australian Marine Sciences Association, 1986. Letter replying to invitation to comment on the conservation value of the Peel-Harvey Estuary.

Bennett, R.H., 1984. *The Environmental Effects of Dredging*. Hollinsworth Consultants, Brisbane, Queensland, 21 pp.

Bohlen, W.F., 1980. A Comparison between Dredge Induced Sediment Resuspension and that Produced by Natural Storm Events. In: *Coastal Engineering-1980*. Chapter 103, pp. 1700-1707.

Brown, R.G., Treloar, J.M. & Clifton, P.M., 1980. *Draft Report on Sediments and Organic Detritus in the Peel-Harvey Estuarine System to the Peel-Harvey Estuarine System Study Group*. Sedimentology and Marine Geology Group, Department of Geology, University of Western Australia, Perth, Western Australia.

Chalmer, P.N. & Scott, J.K., 1984. *Fish and Benthic Faunal Surveys of the Leschenault and Peel-Harvey Estuarine Systems of South-Western Australia in December 1974*. Bulletin No. 149, Department of Conservation & Environment, Perth, Western Australia.

Department of Conservation & Environment, 1981. *Water Quality Criteria for Marine and Estuarine Waters of Western Australia*. Report of the Working Group Established by the Environmental Protection Authority. Bulletin No. 103, Department of Conservation & Environment, Perth, Western Australia.

Environmental Protection Authority, 1983. *Conservation Reserves for Western Australia as Recommended by the Environmental Protection Authority - 1983. The Darling System - System 6. Part II: Recommendations for Specific Localities.* Report No. 13, Department of Conservation and Environment, Perth, Western Australia.

Environmental Protection Authority, 1986. *Mandurah Channel Dredging Department of Marine and Harbours. Report and Recommendations by the Environmental Protection Authority Part 3*. Bulletin No. 231, Department of Conservation and Environment, Perth, Western Australia, 20 pp.

Environmental Protection Authority, 1988a. *Peel Inlet and Harvey Estuary Management Strategy Environmental Review and Management Programme Stage 2. Department of Marine and Harbours, Department of Agriculture. Report and Recommendations of the Environmental Protection Authority Parts I and II.* Bulletin No. 363, Environmental Protection Authority, Perth, Western Australia.

Environmental Protection Authority, 1988b. *Point Grey Development. Report and Recommendations of the Environmental Protection Authority*. Bulletin No. 306, Environmental Protection Authority, Perth, Western Australia, 82 pp.

Environmental Protection Authority, 1989. *Port Mandurah Development, Esplanade (Mandurah) Pty Ltd. Report and Recommendations of the Environmental Protection Authority*. Bulletin No. 378, Environmental Protection Authority, Perth, Western Australia, 105 pp.

Estuarine and Marine Advisory Committee, 1976. *Anticipated Effects of Dredging in the Blackwood River Estuary*. A report by the Estuarine and Marine Advisory Committee to the Environmental Protection Authority.

Fisheries Department, 1988. *State of the Fisheries 1988*. A Report to the Parliament of Western Australia. Fisheries Department of Western Australia, Perth, Western Australia, 26 pp.

Hodgkin, E.P., Birch, P.B., Black, R.E. & Hillman, K., 1985. *The Peel-Harvey Estuarine System. Proposals for Management.* Report No. 14, Department of Conservation and Environment, Perth, Western Australia, 54 pp.

Jones, A.R., 1986. The Effects of Dredging and Spoil Disposal on Macrobenthos, Hawkesbury Estuary, N.S.W. *Marine Pollution Bulletin* 17(1): 17-20.

Jones, G., 1981. Effects of Dredging and Reclamation on the Sediments of Botany Bay. *Australian Journal of Marine and Freshwater Resources* 32: 369-377.

Kinhill Engineers Pty Ltd, 1988. *Peel Inlet and Harvey Estuary Management Strategy. Environmental Review and Management Programme - Stage 2*. Kinhill Engineers Pty Ltd, Perth, Western Australia, 182 pp.

Kinhill Stearns Pty Ltd, 1985. *Report on Mandurah Attitudinal Survey*. Bulletin No. 235 Department of Conservation and Environment, Perth, Western Australia, 67 pp.

LeProvost, Semeniuk & Chalmer, 1981. Waterways Project - Halls Head Mandurah: Environmental Considerations. In Feilman Planning Consultants Pty Ltd. *Parry Esplanade Limited, Environmental Review and Management Programme, Volume 2, Appendices*. Feilman Planning Consultants, Perth, Western Australia.

Poiner, I.R. & Kennedy, R., 1984. Complex Patterns of Change in the Macrobenthos of a Large Sandbank Following Dredging. *Marine Biology* 78: 335-352.

Riedel & Byrne Consulting Engineers Pty Ltd, 1990. *Estuary Deepening - Cox's Bay. Preliminary Bund Construction*. Report No. R387. Riedel & Byrne Consulting Engineers, Perth, Western Australia.

Schwinghammer, T., 1978. *Peel Inlet Management: Fact Finding Study*. Waterways Commission, Perth, Western Australia, 106 pp.

Smith, H.K., 1978. *An Introduction to Habitat Development on Dredged Material. Dredged Material Research Programme.* Technical Report DS-78-18, Office, Chief of Engineers, U.S. Army, Washington, USA.

Soots, R.F. & Landin, M.C., 1978. *Development and Management of Avian Habitat on Dredged Material Islands.* Dredged Material Research Programme. Technical Report DS-78-18, Office, Chief of Engineers, U.S. Army, Washington, USA.

State Pollution Control Commission, 1979. *Effects of Dredging on Macrobenthic Infauna of Botany Bay. Environmental Control Study of Botany Bay.* State Pollution Control Commission, Sydney, New South Wales, 45 pp.

Wallace, J., 1977. *The Macrobenthic Invertebrate Fauna of Pelican Rocks March - April 1977.* Unpublished report to the Department of Conservation and Environment and the Public Works Department, Perth, Western Australia, 10 pp.

Waterways Commission, 1990a. *Draft Peel Inlet Management Programme Review. Part 1 - Study of the Western Foreshore of the Peel-Harvey Estuary.* Unpublished report prepared for the Peel Inlet Management Authority. Waterways Commission, Perth, Western Australia, 27 pp.

Waterways Commission, 1990b. *Draft Peel Inlet Management Programme Review.* Prepared for the Peel Inlet Management Authority. Report 18, Waterways Commission, Perth, Western Australia, 134 pp.

Wills, M.G., 1987. *Algae Harvesting/Retrieval Operation - Peel-Harvey Estuary.* Unpublished report to the Peel Inlet Management Authority.

Wilson Sayer Core Pty Ltd, 1988. *Mandurah Foreshore Land Use Study.* Draft Report to Mandurah Town Council and South West Development Authority. Wilson Sayer Core Pty Ltd, Perth, Western Australia.

Wright, A.E., 1988. *Report on the Mosquito Eradication Campaign, Survey of Mosquitos in the Mandurah Region, W.A.* Health Department of Western Australia, Perth, Western Australia, 145 pp.

TABLE 1

THE MAJOR POTENTIAL IMPACTS ON THE PHYSICAL COMPONENT OF THE ENVIRONMENT

PHYSICAL ENVIRONMENT			
POTENTIAL ADVERSE IMPACTS	**PROBABILITY OF IMPACT OCCURRENCE**	**PERCEIVED SIGNIFICANCE OF IMPACT**	**ENVIRONMENTAL MANAGEMENT PROGRAMME AND COMMITMENTS**
Changes in water quality due to the release of nutrients from suspended sediments.	Low	Low	Excavation within bund walls will minimise the release of suspended sediments to Peel Inlet
Changes in water movement and sedimentation patterns.	Low	Low	The project has been designed to maximise existing water circulation within Cox Bay.
Erosion of the newly constructed foreshore due to natural longshore sediment transport processes.	Low	Low	The shoreline will be allowed to adjust to a naturally stable alignment.
Release of turbidity to the Peel Inlet during construction and removal of the bund walls.	Inevitable	Low	The construction method adopted minimises the release of turbid water during construction.

TABLE 2

THE PREDICTED IMPACTS ON THE
BIOLOGICAL COMPONENT OF THE ENVIRONMENT

BIOLOGICAL ENVIRONMENT			
POTENTIAL ADVERSE IMPACTS	**PROBABILITY OF IMPACT OCCURRENCE**	**PERCEIVED SIGNIFICANCE OF IMPACT**	**ENVIRONMENTAL MANAGEMENT PROGRAMME AND COMMITMENTS**
Waterbird activity will be disrupted during construction.	Inevitable	Low	Duration of impact will be minimised by short construction time.
Conversion of a 40 ha of intertidal area to shallow subtidal area will reduce the feeding area available to shorebirds.	Inevitable	Moderate	Intertidal habitat will be replaced by shallow water habitat. Construction of the island will create some new areas of intertidal habitat.
Algal growth immediately following construction will be stimulated due to nutrients released from suspended sediments.	Low	Low	The released nutrients are expected to be rapidly mixed with the waters of Peel Inlet.
Creation of increased subtidal area could lead to additional growth of macroalgae in Cox Bay.	Uncertain	Low	Greater water depth will allow floating harvesters to more efficiently harvest macroalgae in Cox Bay.
Filling of the foreshore will reduce the area of existing natural vegetation.	Inevitable	Moderate	Most of the foreshore will be grassed. Native trees and shrubs will be used to provide shade in foreshore recreation areas. Development of this area for recreation will allow more valuable areas to be set aside for conservation.
The existing seasonal wetland at the north of the site, and parts of the wetlands in the centre and south of the site, will be filled to control mosquito breeding, potentially disadvantaging waterbirds sensitive to human presence.	Inevitable	Moderate, high in parts	Existing vegetation, particularly trees, surrounding the wetland basins will be retained as far as possible. The island will provide some replacement habitat suitable for more sensitive species.

TABLE 3

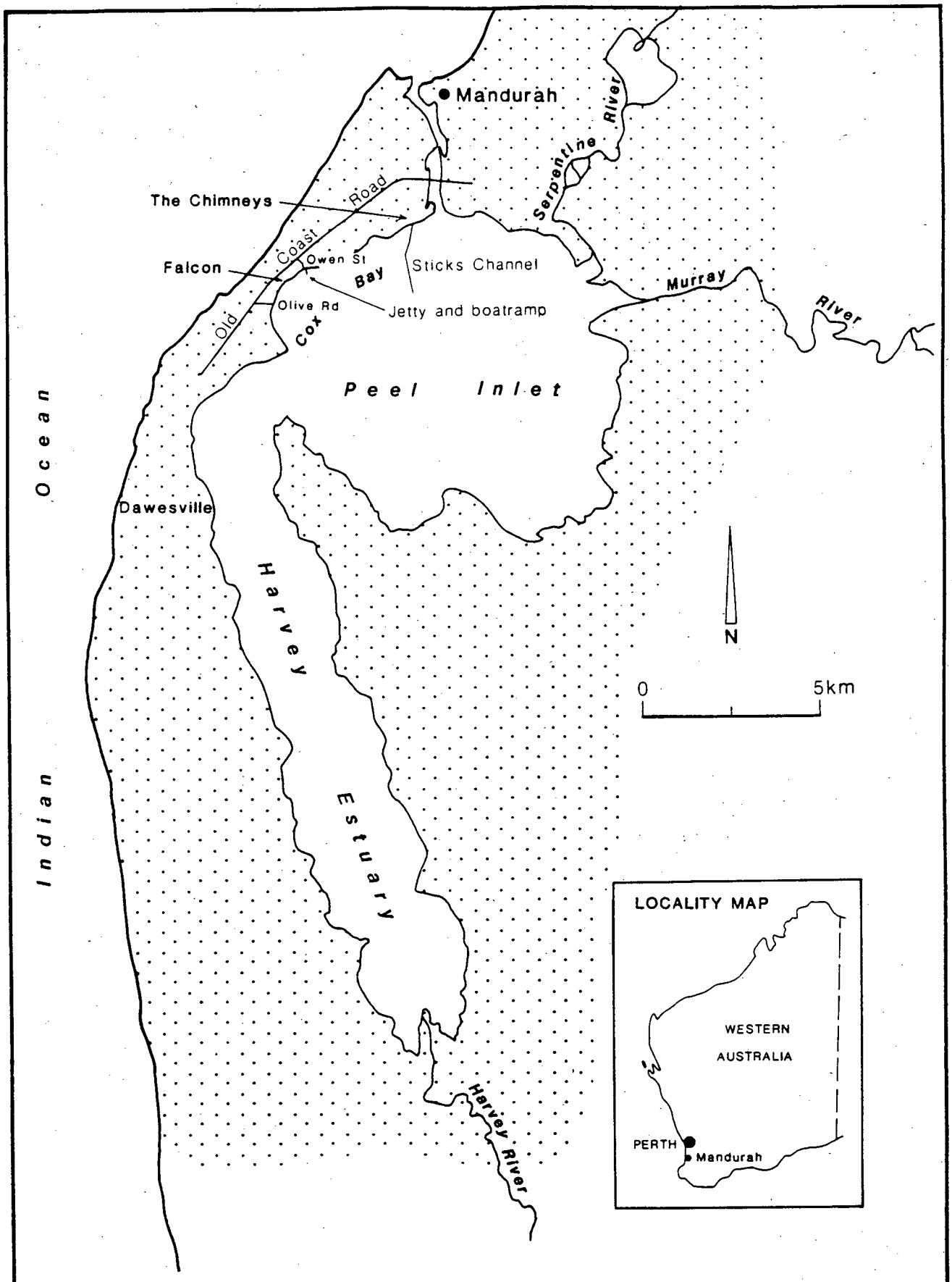
THE PREDICTED IMPACTS ON THE
HUMAN COMPONENT OF THE ENVIRONMENT

HUMAN ENVIRONMENT			
POTENTIAL ADVERSE IMPACTS	PROBABILITY OF IMPACT OCCURRENCE	PERCEIVED SIGNIFICANCE OF IMPACT	ENVIRONMENTAL MANAGEMENT PROGRAMME AND COMMITMENTS
Temporary loss of access to the development site during construction.	Inevitable	Low	The Falcon Boat Ramp will remain operational for all but one week during construction.
Noise impacts for local residents during construction.	Inevitable	Medium	Construction will be confined to daylight hours only. Maximum noise will only occur for a five to 10 day period in the north-west corner of the development site.
Dust nuisance caused by drying of excavated sediments.	Low	Low	Drying of the sediment will be monitored and dust control measures implemented as required.
Increased traffic on local roads during construction of the project.	Inevitable	Low	Construction vehicles will access the site from the onshore area only at the start and completion of the project.
Permanent alterations to the landscape of Peel Inlet offshore from Falcon.	Inevitable	Low	The island will be planted with vegetation indigenous to the inlet and has been designed to appear as a natural component of the regional environment.

TABLE 4

THE BENEFICIAL IMPACTS OF THE PROPOSAL

PREDICTED IMPACTS	PROBABILITY OF OCCURRENCE	PERCEIVED SIGNIFICANCE OF IMPACT	COMMENTS
Provision of a permanent nearshore body of water suitable for water based recreational activities such as boating, swimming, prawning and crabbing.	Inevitable	High	Recreational areas of this nature are currently limited in the Peel Inlet.
Focus of recreation in the local area on a single actively managed site	High	High	Indiscriminate use of the inlet foreshore has caused the loss of vegetation and contributed to erosion.
The development will enable local algal accumulations to be more effectively harvested.	High	High	The effects of odours from decomposing weed on local residents will be significantly reduced.
The beaches will be extended and the foreshore developed for passive recreation and planted with indigenous trees.	Inevitable	Moderate	New foreshore reserve will improve the total amenity value.
Infilling of mosquito breeding grounds	Inevitable	Moderate	Will reduce mosquito breeding and the risk of the occurrence of Ross River virus.
The offshore island will provide areas of bird habitat relatively isolated from human activities.	High	Moderate	Will mitigate the loss of the intertidal breeding and foraging grounds nearshore.



MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

LOCATION PLAN

Figure **1**

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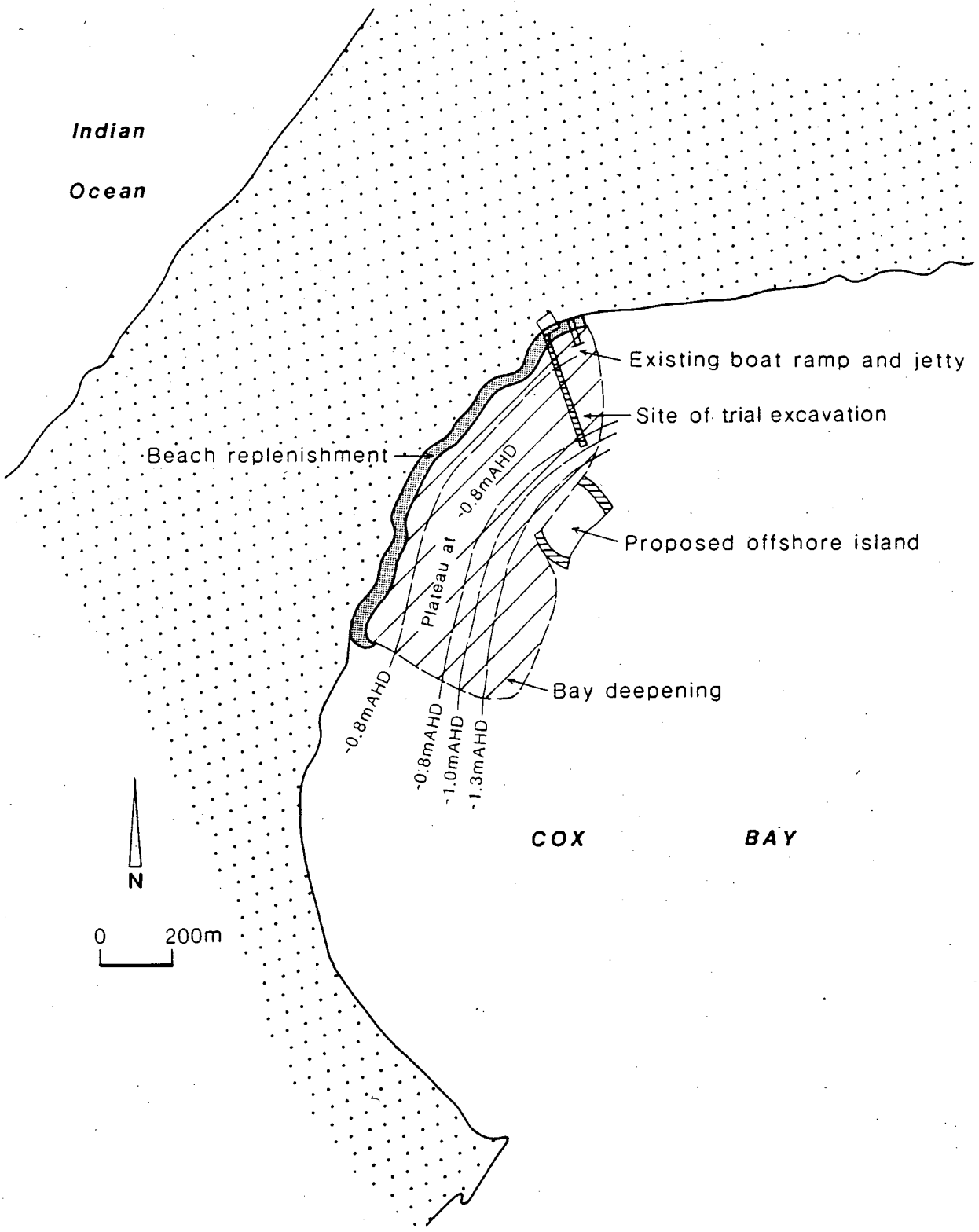

MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

PROJECT SITE

Figure **2**

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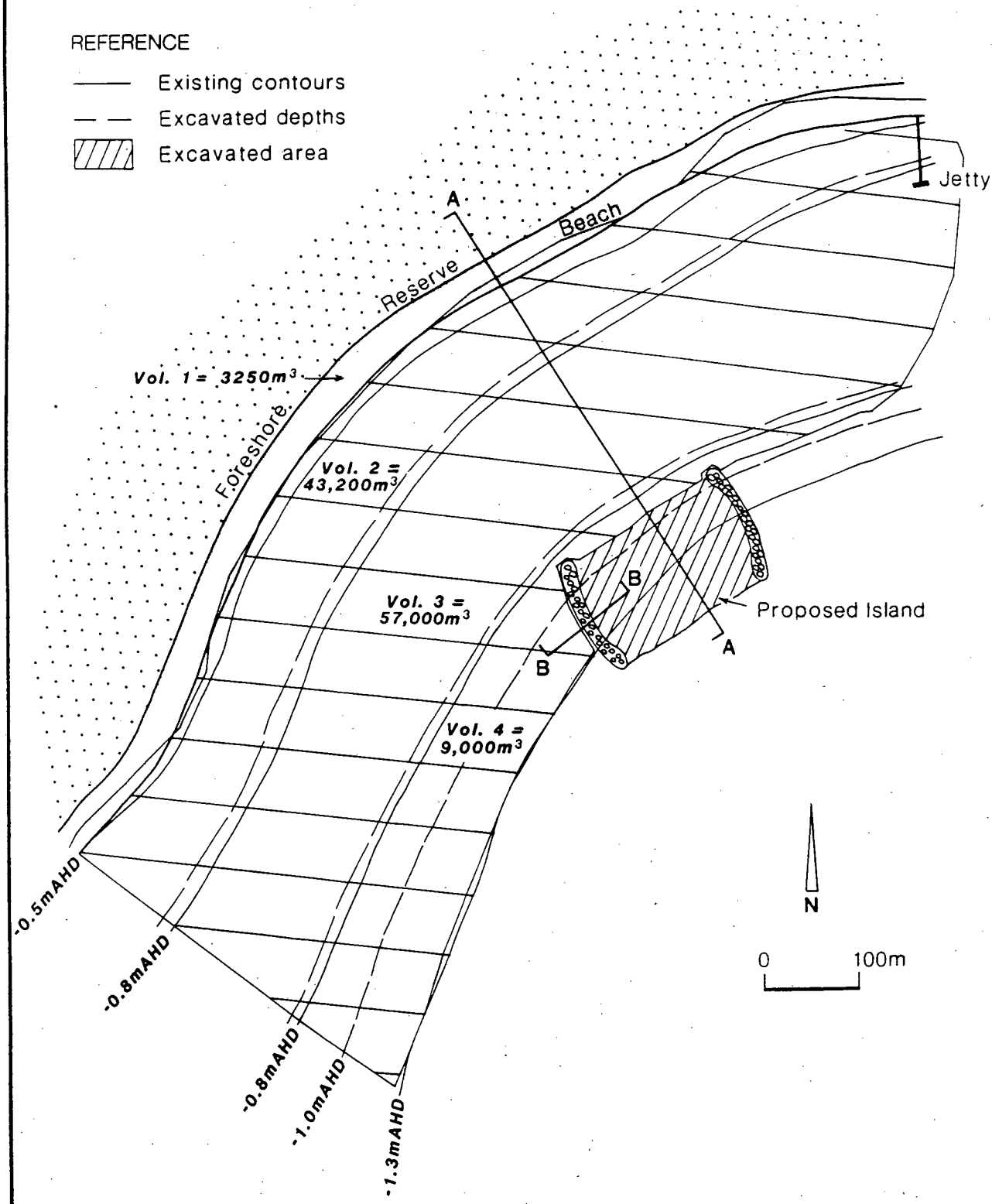

MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

PLAN OF PROPOSED WORKS

Figure **3**

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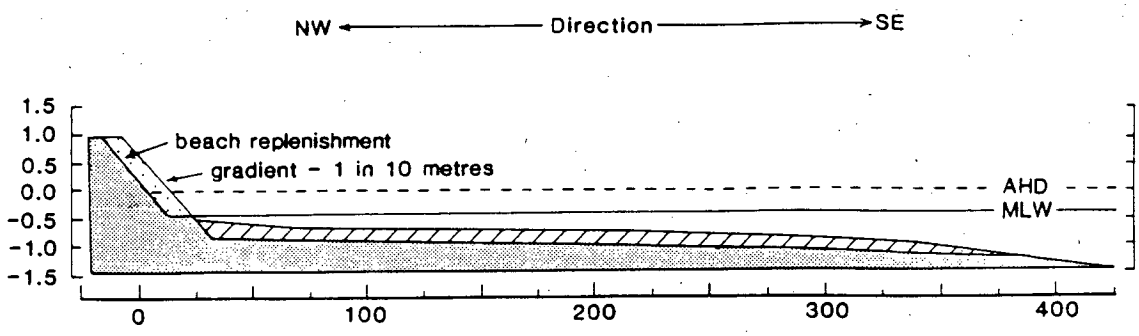
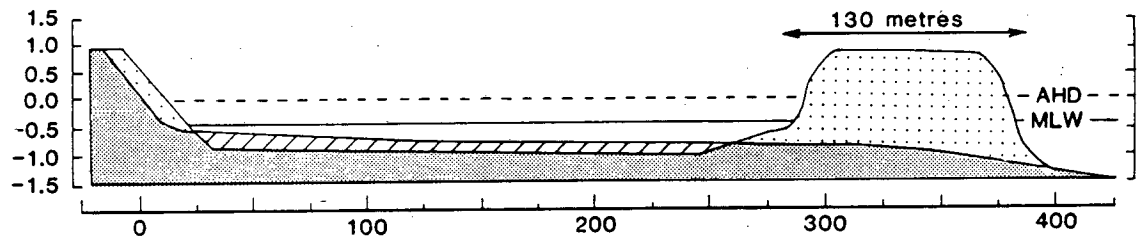


PROFILE OF RECONSTRUCTED BEACH AND NEARSHORE AREA



PROFILE OF PROPOSED PROJECT WORKS AND ISLAND CONSTRUCTION

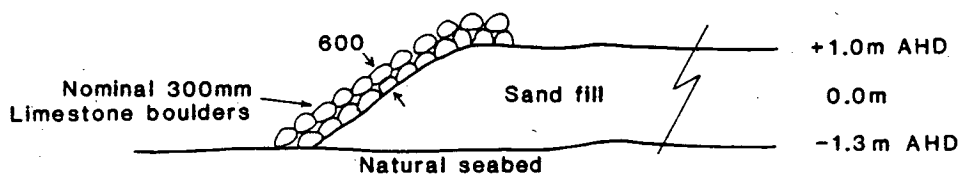
MLW - Mean low water level

AHD - Australian height datum

Existing wedge of sand material proposed to be removed

Underlying sediments (will remain in place)

Spoil material used for beach replenishment and creation of island bird sanctuary



TYPICAL WALL SECTION FOR THE ISLAND

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COX BAY, FALCON

PROFILES OF THE PROPOSED WORKS SITE

Figure

4

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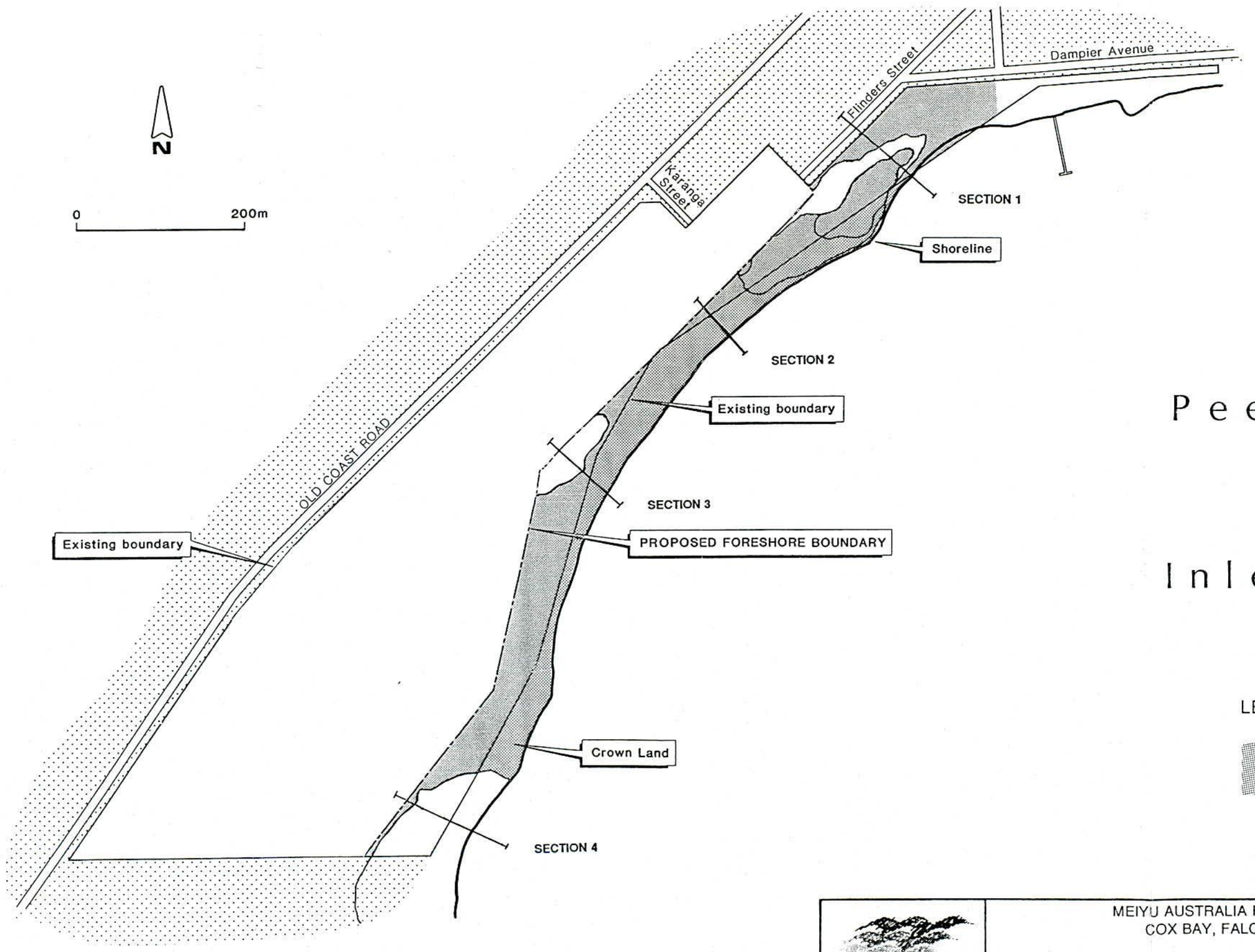

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MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

DISTRIBUTION OF FORESHORE FILL

Figure **5**

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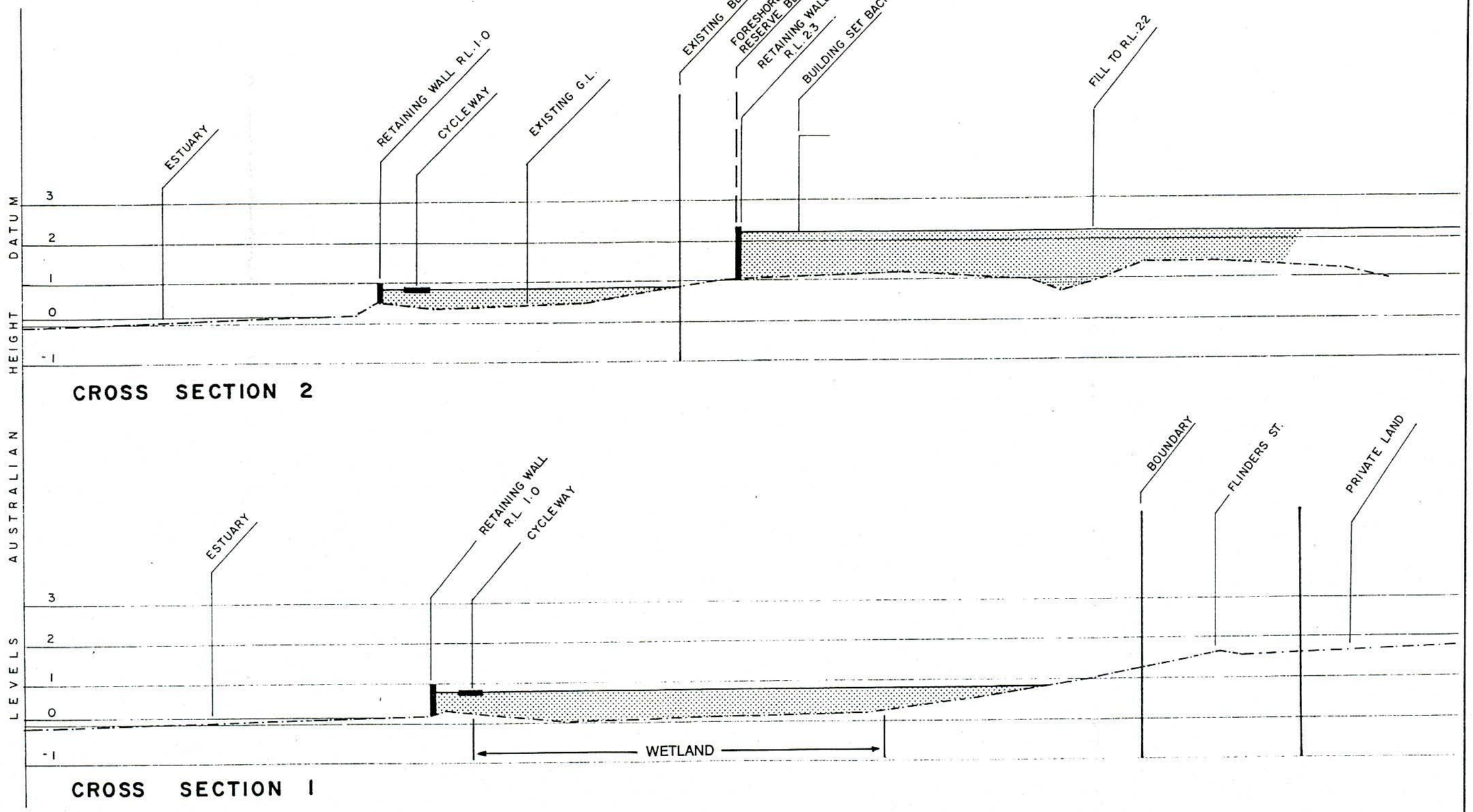


ZUIDEVELD BENNETT ,

HORIZONTAL SCALE — 1:500

VERTICAL SCALE — 1:100

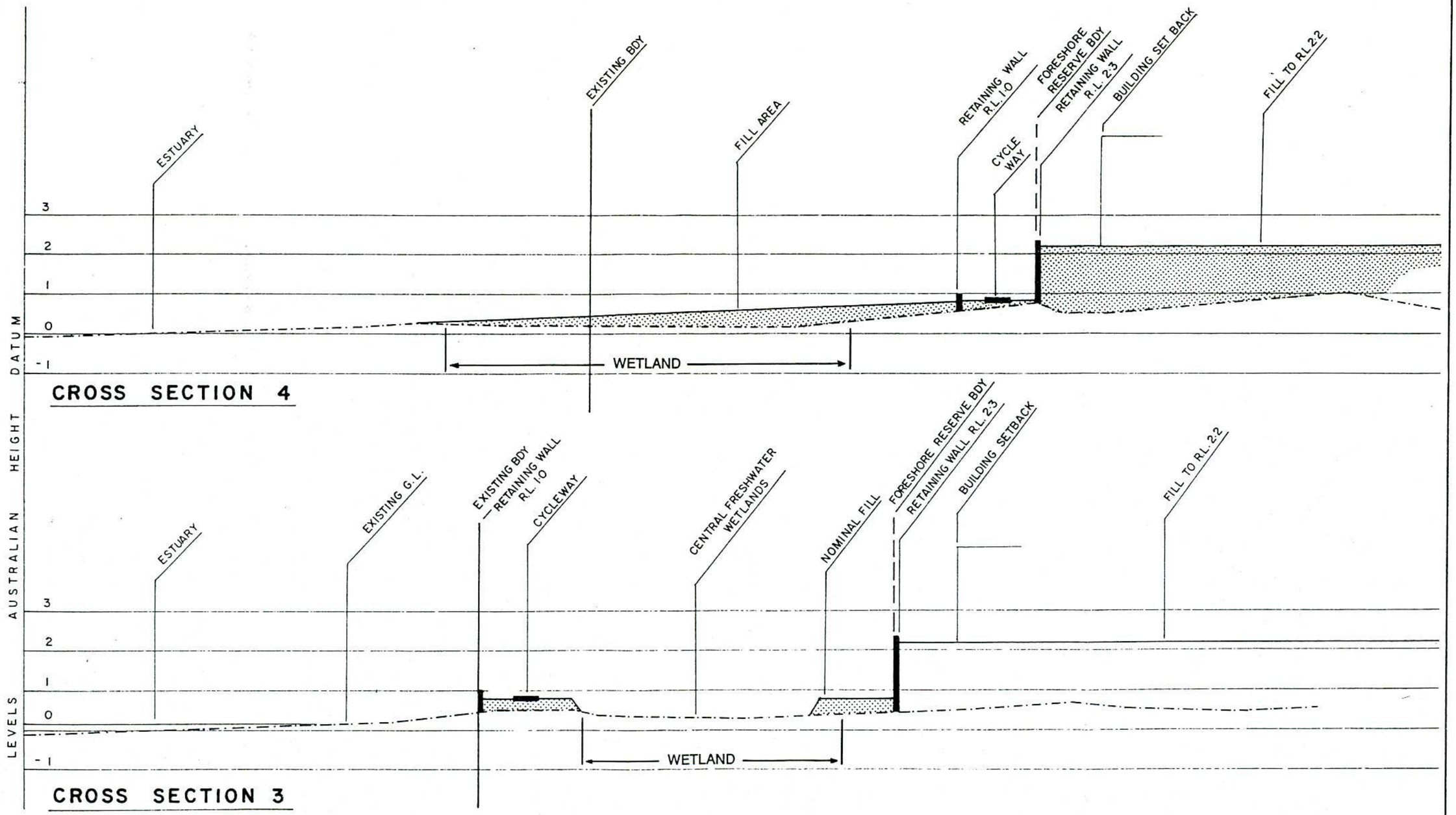
MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

FORESHORE FILL SECTIONS

Auth : PC | Date : 9/90

Figure 6

J192 R293



ZUIDEVELD BENNETT

HORIZONTAL SCALE —— 1:500
VERTICAL SCALE —— 1:100

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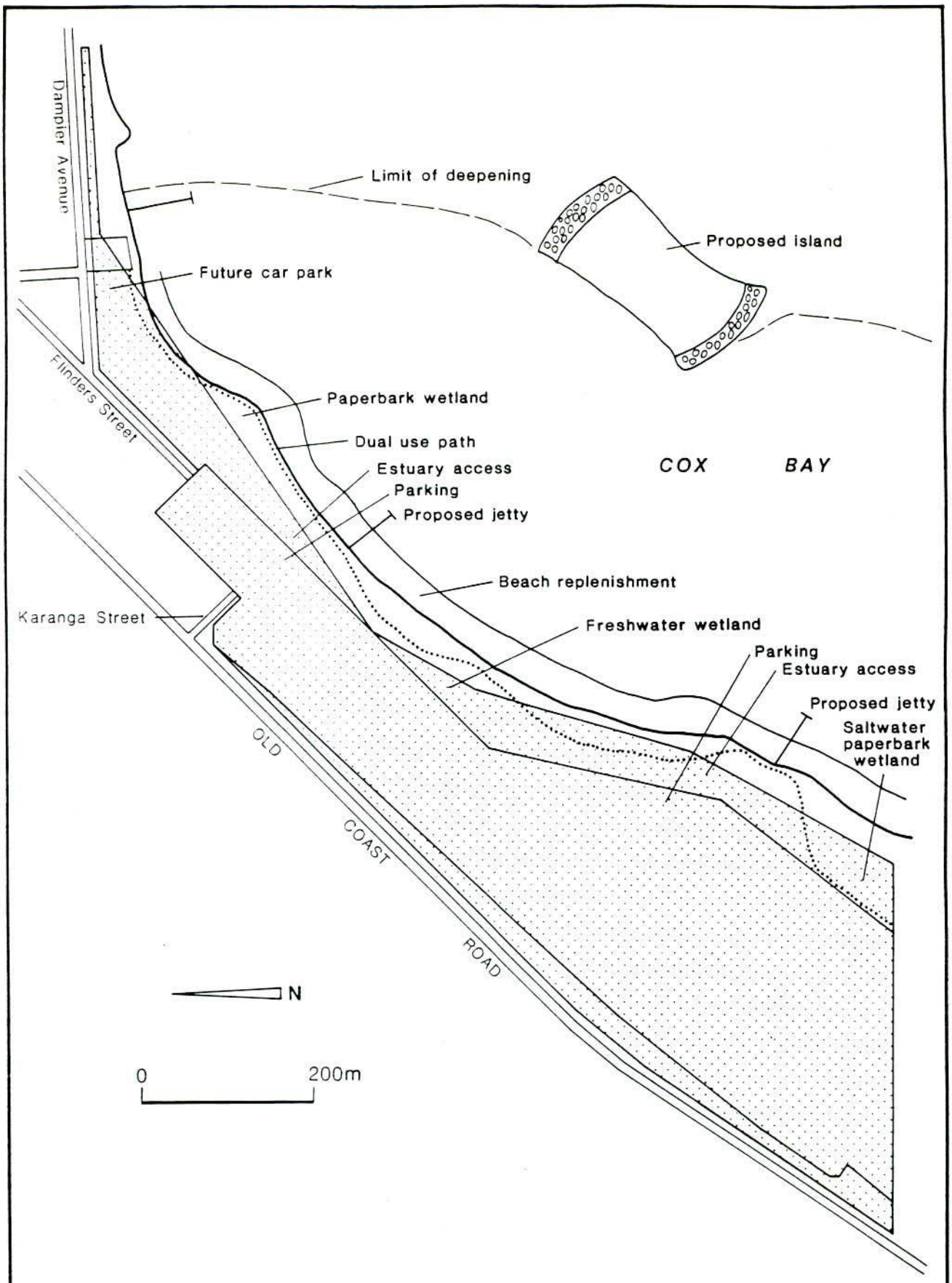
MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

FORESHORE FILL SECTIONS

Figure 7

J192 R293



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FORESHORE MANAGEMENT PLAN

Figure 8

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Geodraft

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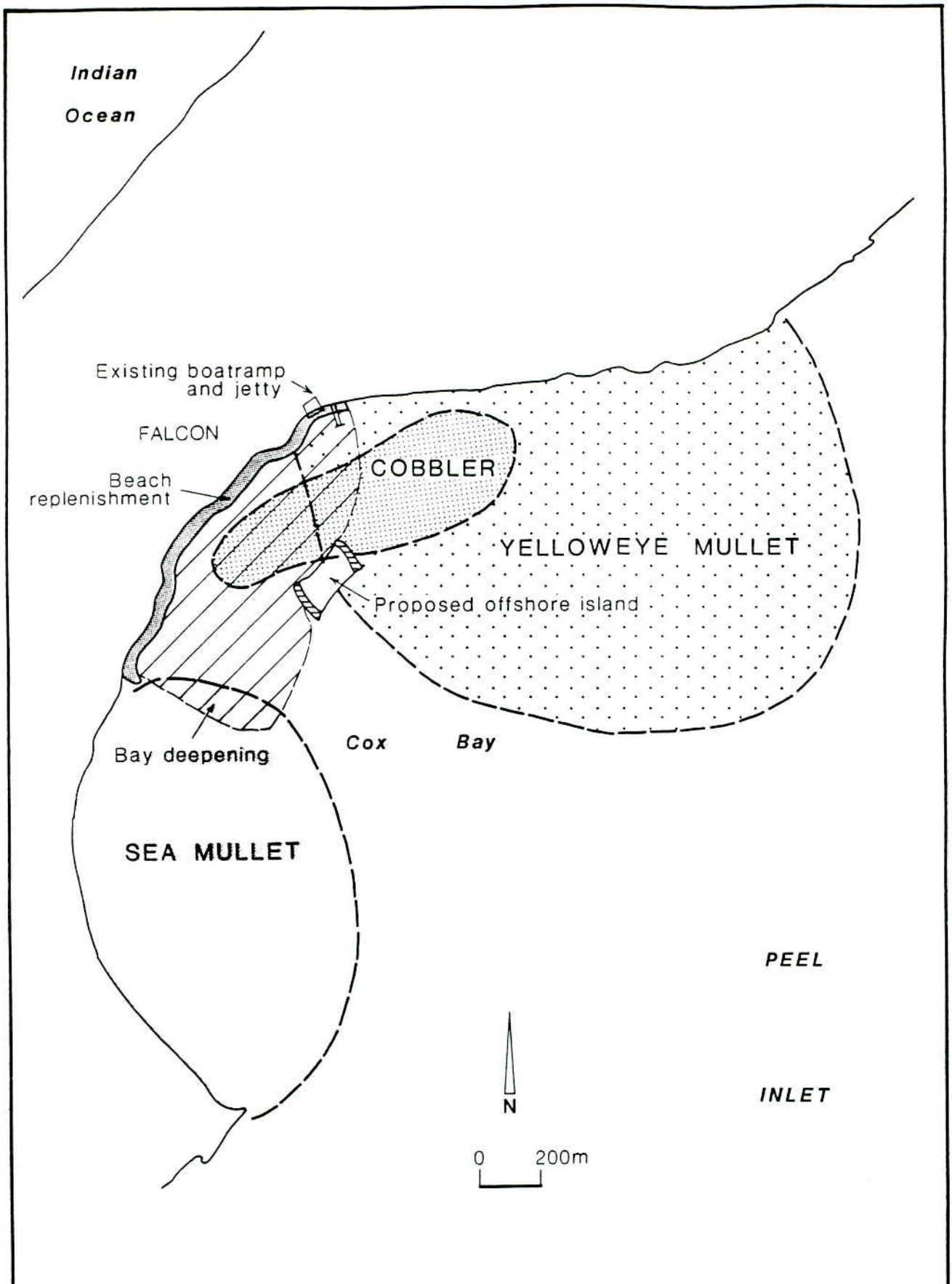

MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

AREAS UTILISED BY PROFESSIONAL FISHERMEN IN COX BAY

Figure 9

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Geodraft

J192 R293

Plate 1: Tracked excavator being used to construct the bund wall and excavate the new channel.

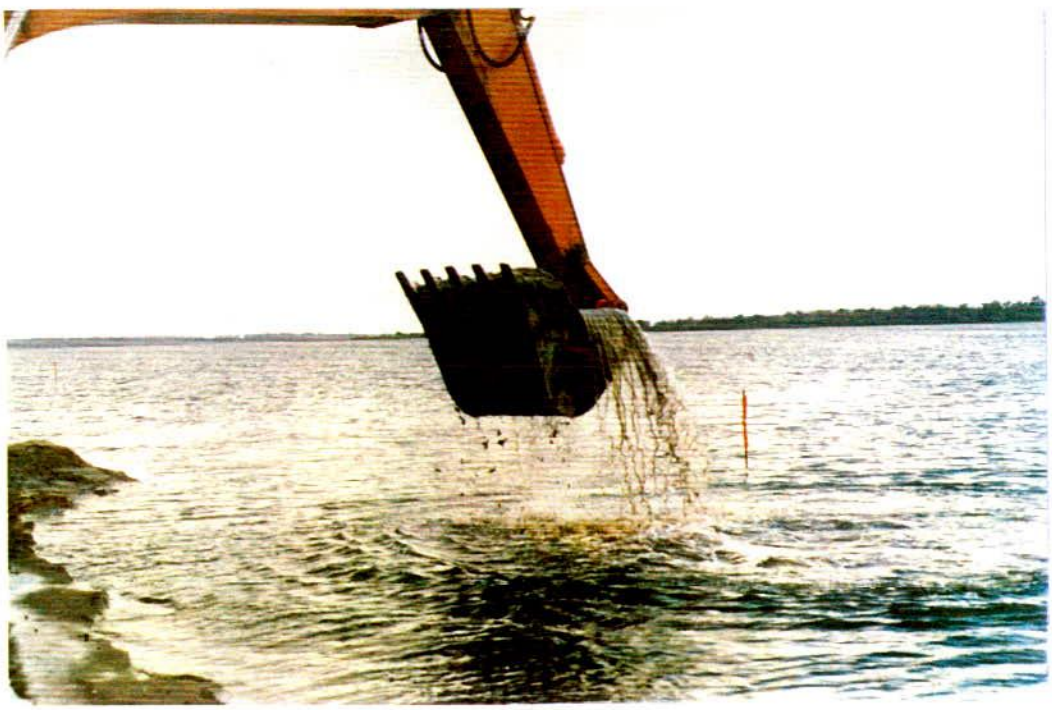

Plate 2: Filled excavator bucket which shows limited nature of turbid water discharge.

Plate 3: Photography of channel construction showing limited extent of plume formation. Bund wall was being removed and channel widened to final width at the time the photograph was taken. Finished part of channel and propellor scouring of the estuary floor are visible beyond the end of the bund wall.

Plate 4: Foreshore wetland area between Karanga Street and Falcon Boat Ramp. Photograph taken looking towards the north-east.

Plate 5: Central depression showing water filled wheel ruts which form mosquito breeding areas. Photograph taken looking towards the south-west.

Meiyu Australia Pty Ltd

Estuary Deepening

Cox Bay, Falcon

Public Environmental Review

APPENDIX 1

EPA GUIDELINES FOR THE PUBLIC ENVIRONMENTAL REVIEW (PER) FOR PROPOSED DREDGING AT FALCON

LEC REF: J192/R328

GUIDELINES FOR THE PUBLIC ENVIRONMENTAL REVIEW FOR PROPOSED DREDGING AT FALCON

In January 1990 the Environmental Protection Authority received a proposal by Meiyu Australia Pty Ltd to dredge an area offshore from Lot 1147 Falcon. The proposal stated that dredge spill accumulated by dredging activity would be used to create offshore islands in Peel Inlet.

The Environmental Protection Authority determined that the environmental implications associated with the proposed dredging and creation of offshore islands require formal environmental impact assessment as a Public Environmental Review (PER).

These guidelines identify issues associated with the proposed dredging that should be addressed within the PER. They are not intended to be exhaustive and the proponent may consider that other issues should also be included in the document. The PER is intended to be a brief document; its purpose should be explained, and the contents should be concise and accurate as well as being readily understood by interested members of the public. Specialist information and technical description should be included where it assists in the understanding of the proposal. It may be appropriate to include ancillary or lengthy information in technical appendices.

1 SUMMARY

The PER should contain a brief summary of:

- salient features of the proposal;
- alternatives considered;
- description of receiving environmental and analysis of potential impacts and their significance;
- environmental monitoring, management and safeguards and commitments thereto; and
- conclusions.

2 INTRODUCTION

The PER should include an explanation of the following:

- identification of proponent and responsible authorities;
- background and objectives of the proposal;
- brief details and timing of the proposal;
- relevant statutory requirements and approval procedures; and
- purpose and structure of the PER.

Reference should be made to the Draft Peel Inlet Management Review which is currently being prepared by the Waterways Commission.

3 NEED FOR THE DEVELOPMENT

The PER should examine the justification for the project and projected costs (in the broad sense) and benefits at local and regional levels.

4 EVALUATION OF ALTERNATIVES

The evaluation of alternatives is an important issue. A discussion of alternatives to the proposal including alternative sites and scales should be given. A comparison of these alternatives in the broad context of the stated objectives of the proposal should be included as well as the respective costs and benefits at both construction and operational stages. In this way the rationale and criteria used for choosing the preferred option should be clear.

5 DESCRIPTION OF PROPOSAL

This should include:

- Overall concept
- Precise location of dredging activity and depth of dredging;
- Details in relation to bunding the area to be dredged and timing of the dredging operation;
- Proposed location of the newly created islands;
- Disposal of any additional dredge spoil not used through the creation of islands (i.e. proposed to be deposited anywhere else other than on the proposed islands);
- Projected lifetime; and
- Management structure and responsibilities.

6 EXISTING ENVIRONMENT

The PER should provide an overall description of the environment and an appraisal of physical and ecological and social systems likely to be affected.

It should concentrate on the significant aspects of the environment likely to be impacted by the development (i.e. in particular the processes sustaining the system). Only the processes, habitats, resources and potential resources which could be influenced should be defined.

Wherever possible in the discussion of physical and biological processes that are essential determinants in the maintenance of habitats and resources, conceptual models or diagrams should illustrate and synthesise the interaction between the processes.

This discussion should include:

6.1 PHYSICAL

- Offshore geology and geomorphology, including recent shoreline movement (erosion and accretion) during recent years;
- nature of estuarine sediment;
- near shore estuarine water quality; and
- hydrodynamic characteristics of the subject and adjacent waters.

6.2 BIOLOGICAL

- Offshore biota (including rare or restricted species) and their ecosystems, set in regional context. Particular reference should be made to fish (juvenile and adult) found in the area.

6.3 SOCIAL

- Use of offshore estuarine waters in vicinity of proposal; and
- Impact on adjacent communities along foreshore areas in the vicinity of the proposal.

Where appropriate, this discussion should take cognisance of any other known proposals for the general area.

7 ENVIRONMENTAL IMPACTS

This is the most important part of the document and the results should show the overall effect on the total ecosystem and surroundings of the location both during and after construction.

The objective is to predict potential impacts upon the environment. This should include an assessment of the resilience of the systems identified in Existing Environment to natural and man-induced pressures. Impacts should be quantified where possible. Criteria for making assessments of their significance should be outlined. Compliance with relevant standards should be demonstrated. In some cases there will be advantage in discussing construction and operation impacts separately.

It will be necessary to determine impacts on individual components of the environment before an overall assessment of potential impact is made.

The following potential environmental impacts should be discussed:

- noise, dust and control during construction phase;
- emissions (air, water, waste disposal, noise) associated with dredging;

- water turbidity in the subject and adjacent waters associated with construction of the bund walls and dredging phase (including details in relation to impact on light penetration, alteration to water chemistry, release of nutrients from suspended sediments, and resuspension of organic matter);
- impact on estuarine biota caused by the disposal of dredged material and creation of artificial islands;
- impact on fishery (both recreational and professional);
- specific and cumulative impact on estuarine fish and other estuarine biota as a result of dredging (including short term affects, for example horizontally spreading turbidity plumes, and long term effects such as the modification of the estuary floor);
- severe storm events;
- water quality within the dredging area and adjacent waters (including seasonal flushing) characteristics;
- alteration to natural water circulation patterns within the dredged area and between proposed islands;
- details of likely stability of area post dredging;
- nature of sediments to be dredged;
- landscape aesthetics, including vegetation planting programme for the dredge spoil islands;
- use of islands including local and regional conservation and recreation aspects;
- effect of proposal on existing community and facilities; and
- use of adjacent offshore waters.

Other impacts that are identified during preparation of the document should also be addressed.

The significance and timing of the various potential impacts identified should be examined.

8 ENVIRONMENTAL MANAGEMENT AND MONITORING

A management and monitoring programme should be described on the basis of (and cross-referenced to) the potential environmental impacts described in 7 above.

The purpose of the management programme is to demonstrate the manner in which potential environmental impacts can be ameliorated.

Authorities responsible for management should be clearly identified as should management administration, costs and funding, including long-term financial contingencies. This should include:

- discussion and details of the ongoing vesting and management of the islands;
- management of public access to the islands;
- parks and boat launching areas;

- details regarding the ongoing monitoring of water quality and circulation within the dredged area and between the islands;
- ongoing monitoring and management of the dredged area in view of considerations such as the area silting up, and need and frequency of on-going maintenance dredging; and
- study of the long term impacts of dredging and creation of artificial islands within the estuary including recolonisation rate of dredged area and islands.

Emphasis should be placed on the manner in which monitoring results will lead, where appropriate, to amendments to the management programme.

Environmental safeguards, including contingency planning for untoward and/or infrequent events should also be included.

Procedures for reporting the results of monitoring and management to appropriate authorities should be given.

9 COMMITMENTS

Where an environmental problem has the potential to occur, the proponent should cover this potential problem with a commitment to rectify it. Where appropriate the commitment should include: (a) who will do the work, (b) what the work is, (c) when the work will be carried out and (d) to whose satisfaction the work will be carried out.

The list of commitments should include a guarantee that once dredging work is commenced that it shall be completed by the proponent.

A summary of all commitments in numbered form should be given.

10 CONCLUSION

An assessment of the environmental acceptability of the project in terms of its overall environmental impact and in the context of the proposed management programme should be given.

11 REFERENCES

GLOSSARY (definitions of technical terms, abbreviations)

PER GUIDELINES

APPENDICES

Meiyu Australia Pty Ltd

Estuary Deepening

Cox Bay, Falcon

Public Environmental Review

APPENDIX 2

ESTUARY DEEPENING COX BAY

COASTAL ENGINEERING ASPECTS

LEC REF: J192/R328

PROJECT	:	Estuary Deepening - Cox Bay
REPORT	:	Coastal Engineering Aspects
LOCATION	:	Peel Inlet, Western Australia
CLIENT	:	GRH Nominees Pty Ltd
DATE	:	December 1990
STATUS	:	Final

4 Walcott Street
Mt. Lawley WA 6050
Telephone: (09) 370 4122
Facsimile: (09) 370 4133

Job No.: J833
Report No: R404
Copy No:

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1. INTRODUCTION

Estuary deepening at Cox Bay, Peel Inlet is a project where an improved foreshore amenity is to be provided by the creation of an island, beach improvement and deepening of the bay to allow better management of algae and weed collection.

This report, which forms an appendix to the Public Environment Review for the project, was commissioned to study the coastal engineering issues influencing the project. The items covered in the report may be summarised under the following headings.

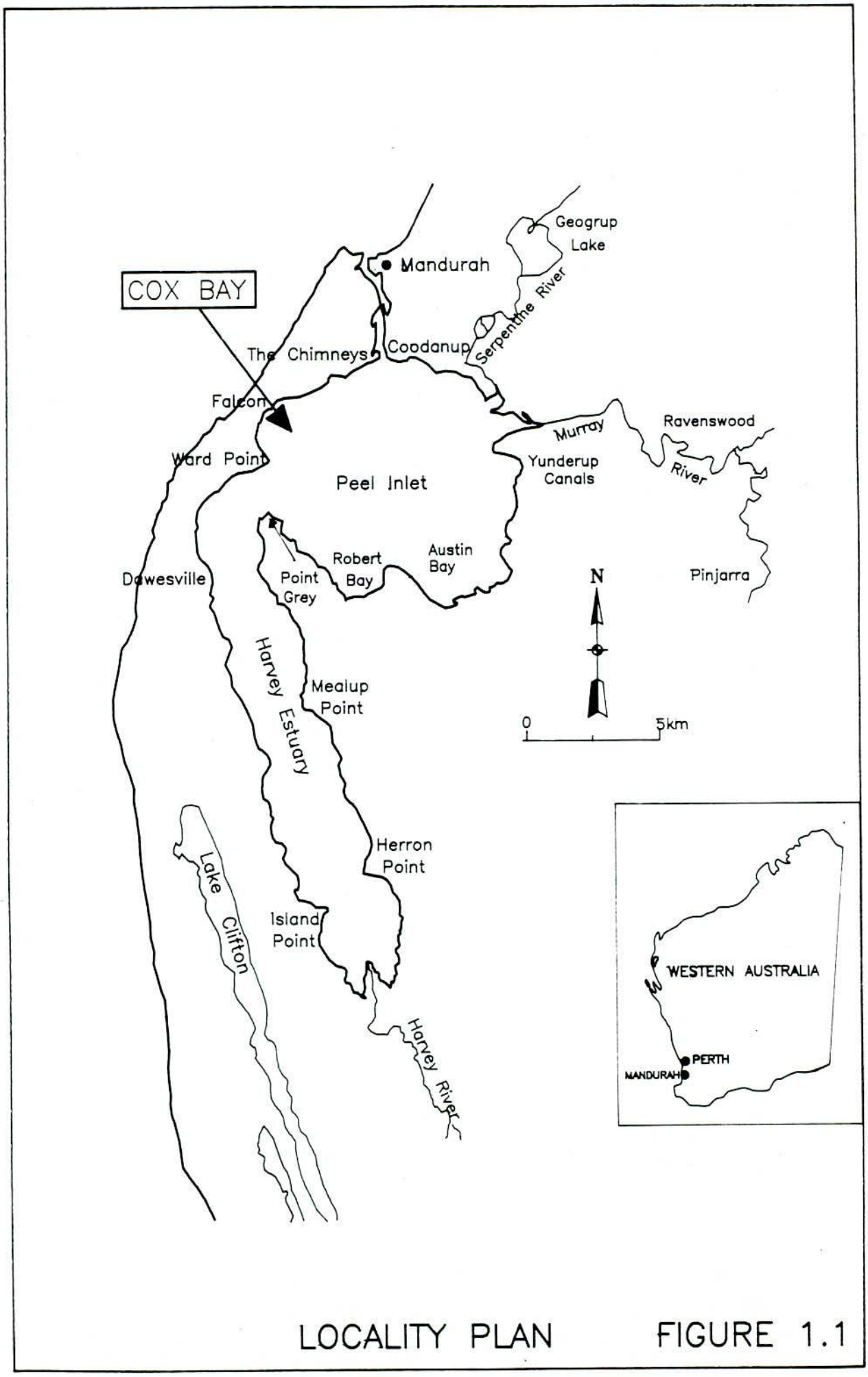
- Land development layout; preliminary design with respect to excavation, island and channel formation, and jetty/groyne requirements.

- Shoreline stability at Cox Bay and the new offshore island.

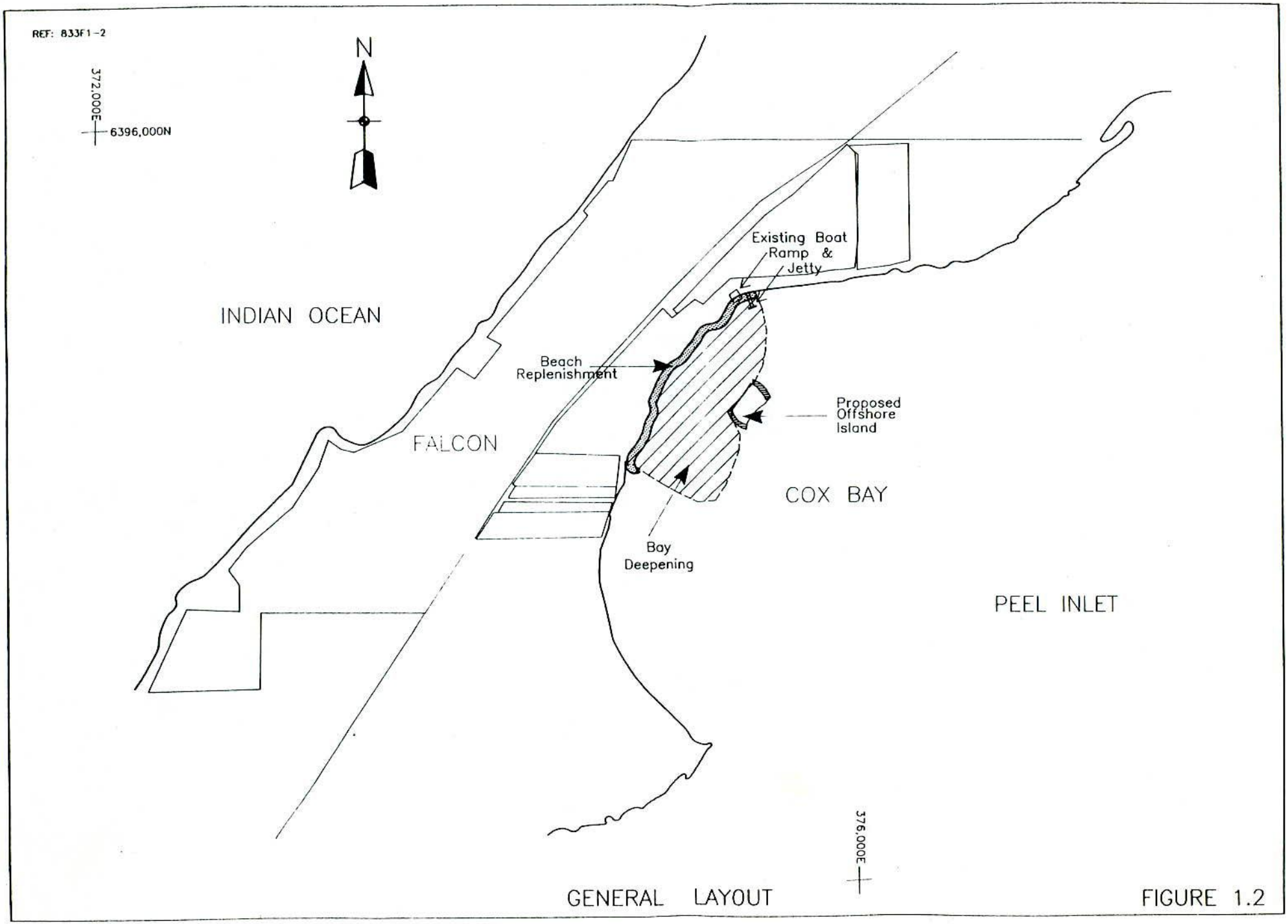
- Water quality and flushing.

- Environmental effects.

Figure 1.1 shows the location of the proposed development and its general layout is shown in Figure 1.2.



LOCALITY PLAN FIGURE 1.1



GENERAL LAYOUT

FIGURE 1.2

2. ALTERNATIVE PROJECT CONCEPTS

2.1 Bay Deepening and Island Formation

The proposal is to improve the public foreshore and Cox Bay in general so that algae problems are reduced, an improved beach is provided and small boat access to the shoreline is improved. The works would all be undertaken on the foreshore reserve and in Cox Bay adjacent to the proposed Estuary Gardens development for residential and tourist accommodation purposes.

At present Cox Bay is one of the principal areas where algae and weed collects. Its removal is difficult because of the shallow water in Cox Bay which means the offshore weed harvester cannot be used. Consequently the weed needs to be collected via bulldozer which is less satisfactory because:

a) The algae and weed are bulldozed to shore where they have to be partially drained before being trucked away. This causes both odour and visual amenity problems.

b) The bulldozing process also removes some sand so that there is a gradual erosion of the beach.

The shallow water in Cox Bay also means that boats have difficult access to the shoreline and outboard motors tend to start grounding about 300 metres offshore. Access to the beach is slow and also unpleasant when the algae and weed are present.

The proposed works for the favoured alternative is shown in Figure 1.2 and features:

- A deepening of Cox Bay for the full foreshore length of Estuary Gardens to a minimum depth of -1.1m AHD, the exception being the beach slope.
- The deepening continues seaward until it reaches the natural seabed depth of -1.3m AHD to ensure no stagnant hole effect is produced.
- Placement of some of the material to form an offshore island to provide a new bird habitat.
- Placement of the balance of the material (sand) on the foreshore to improve the beach.

All the material removed from the Cox Bay seabed is retained either on the offshore island or on the foreshore/beach area. It will not be used to build up land levels at Estuary Gardens. Materials for this purpose will be imported from the site of the proposed Dawesville Channel.

2.2 Deepening at the Existing Jetty

The existing jetty is practically unusable because of the shallow water at its head. The extent of area deepened in Cox Bay can readily be increased to include the jetty and its surrounds. The increased area to be deepened would be as shown in Figure 1.2. This extension of the bay deepening is recommended to provide dry access to boats via the jetty.

2.3 Additional Deepening for Landfill

Removal of additional seabed material for landfill purposes from Cox Bay was considered but has been rejected because it would be impractical to connect a deeper basin to water of the same depth in Peel Inlet. Deepening of the basin by say a further 0.5 metres would require a channel of some 300 metres length to reach the same water depth in Peel Inlet.

The seabed materials in Cox Bay are basically well graded sands to some 350 metres from the shoreline. Further out the material becomes silty mud which would be impractical to excavate from either engineering or environmental viewpoints. It is recommended that these potential problems be avoided by not considering this option further.

2.4 No Island Alternative

The island could be deleted from the proposed works without affecting the feasibility of the project. However it provides a number of benefits:

. An area of land which can become a bird habitat.

. An interesting visual feature offshore from Estuary Gardens.

. A more economical location to place material excavated from further offshore in Cox Bay.

2.5 Do Nothing to Cox Bay Seabed

This option may need to be considered if there are non-engineering issues that dictate excavation of the seabed should not occur. Continuation of the present management of the bay and foreshore means that:

i) Beach erosion will continue gradually as a result of losses during algae/weed collection.

ii) The visual and odour problems with algae and weed collection will remain.

iii) The beach is not suitable for any form of swimming.

iv) Use of Cox Bay for water sport activities will remain limited.

3. THE MARINE ENVIRONMENT

3.1 Water Levels

The variations in water level in Peel Inlet are the result of a number of influences with astronomical tide only providing less than 50% of the normal changes in water levels. During floods or major storms with strong winds there will be further significant increases in water level.

Specific detail studies have not been conducted at Cox Bay, but drawing together the available published Department Marine & Harbours (DMH) reports on water levels together with personnel communications with DMH officers, level estimates are as follows:

High Water Mark	0.42m AHD
Highest Astronomical Tide	0.19m AHD
Mean Water Level	0.00m AHD
Low Water (chart) Datum	-0.45m AHD

The increase in water level between Highest Astronomical Tide and High Water Mark is due to meteorological influences with about a 5-9 day cycle.

Low water datum is in effect an arbitrary level that does not reflect low water in the conventional tidal sense. The water level in Cox Bay is unlikely to reach this low water datum level under astronomical tidal situations even with the superimposition of the 5-9 day meteorological influences.

Water levels considerably in excess of 0.42m AHD can be reached under storm conditions. For present conditions, the Public Works Department plans of Peel Inlet show the 1:100 year flood level for Peel Inlet and Harvey Estuary to be 1.6m AHD and the 1:25 year flood level to be 1.1m AHD.

These levels do not allow for wind set-up across Peel Inlet. At Cox Bay there should be a negligible increase in the 1:100 or 1:25 year flood levels due to wind set-up because storms typically producing heavy rainfall and strong winds have wind directions from the south-west through to north-west. Strong easterly to south-easterly winds are required to produce a wind set-up at Falcon. Therefore on a probabalistic basis there should be no additional allowance for wind set-up along the Estuary Garden's foreshore.

Allowance also needs to be made for the potential future construction of the Dawesville Channel. Kinhill Engineers Pty Ltd (1988) indicated that the normal tidal range would increase by about 200 mm in Peel Inlet. This is likely to be reflected mainly in a decrease in low water level of 100 to 150 mm.

3.2 Water Circulation

Even though the Peel - Harvey system has been the subject of many biological and sedimentological studies followed by management strategy studies, there has been little work on the measurement and prediction or modelling of water circulation. The Department of Conservation and Environment (1980) published a figure showing circulation directions in Peel Inlet. It shows no detail of current patterns in Cox Bay.

Since the water depth throughout the Peel Inlet tends to less than 2 metres it is likely that currents will be mostly driven by water level variations at the Sticks, flood inflows from the rivers and by wind stress. Generally currents can be expected to be homogeneous with depth because of the shallow water. Each of these current sources will be considered in turn with respect to their influence or magnitude at Cox Bay.

Currents due to Water Level Variations at the Sticks

The tidal range at the Peel Inlet end of the channel from the ocean is higher than within Peel Inlet. This means that at high tide there will be flow into Peel Inlet and at low tide the opposite occurs. The resultant tidal currents within Peel Inlet are very small and would move past Cox Bay as shown in Figure 3.1. A weak eddy may be set-up within Cox Bay during both the ebb and flood tide as shown on Figure 3.2.

Currents during periods of flood from the Serpentine River system tend to move almost directly towards The Sticks. Again under strong river flows an anti-clockwise eddy could be expected in Cox Bay.

Whilst these eddies tend to circulate water they don't tend to introduce any new water into the bay. They are also a reason why once algae and weed find their way into Cox Bay, it is difficult for the accumulation to be removed again by natural means.

Wind-Induced Currents

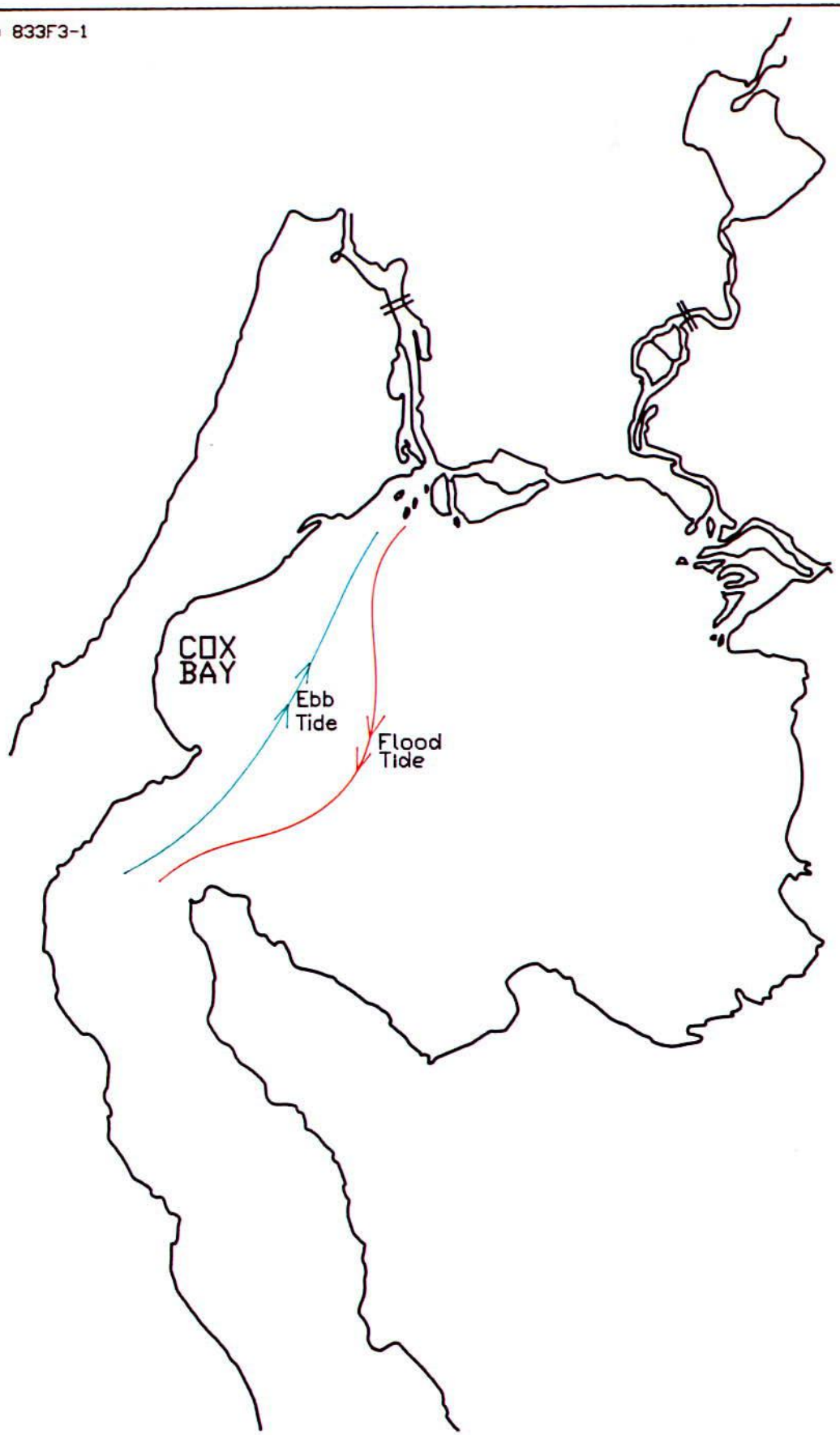
The most important source of currents are those due to winds and waves. Winds tend to produce currents with a magnitude of about 3% of the wind velocity. For example a wind of 10 m/sec strength will produce a surface current of about 0.3 m/sec. These current magnitudes are significantly higher than those due to tidal water level variations. Figure 3.3 shows seasonal wind roses for Mandurah. A seasonal description of the predominant current patterns at Cox Bay is as follows:

a) Summer - Autumn

Morning winds are predominantly from the east to south-east averaging about 3-4 metres per second which would produce a surface current of about 0.1 m/sec into Cox Bay. It would be these currents that tend to push the algae and weed inshore.

In the afternoons the winds strengthen and tend to be south-westerlies. Cox Bay is relatively sheltered from the south-west with the result that the south-westerly wind induced current flows across the head of Cox Bay and tends to form an anti-clockwise eddy which again traps algae and weed in Cox Bay.

REF: 833F3-1



TIDAL CURRENTS
PAST COX BAY

FIGURE 3.1

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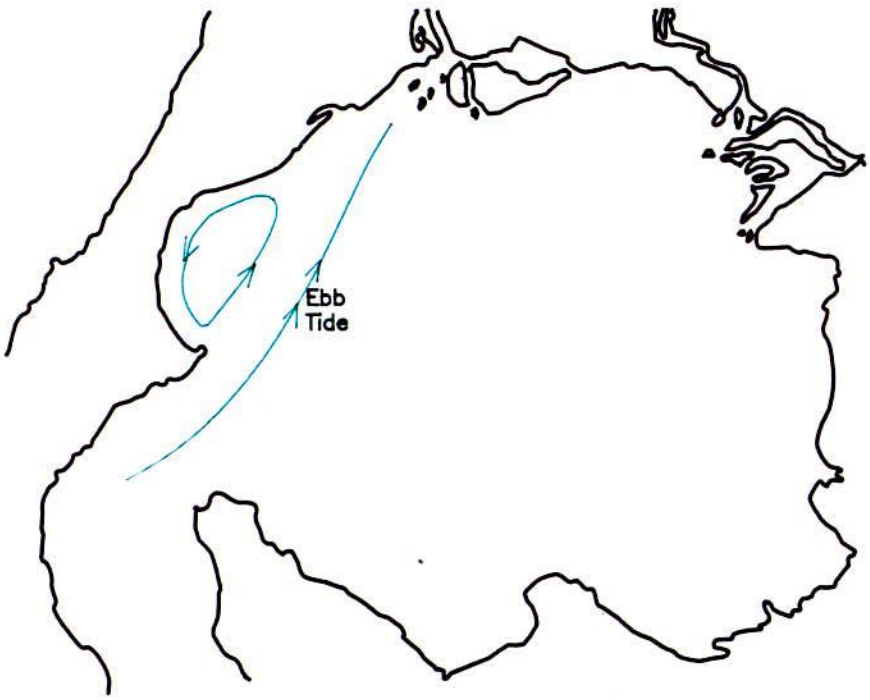
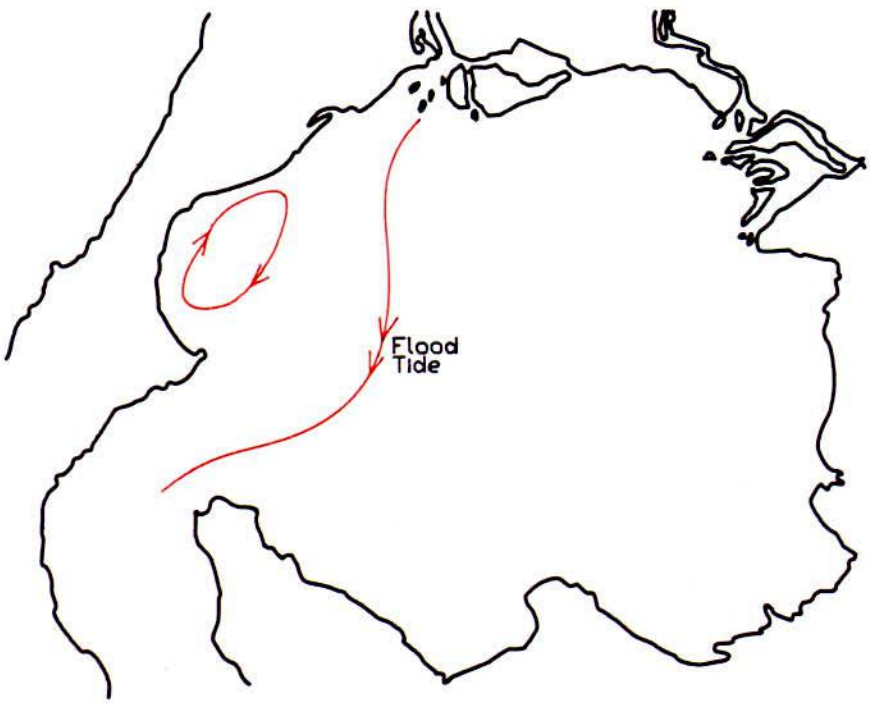


EBB TIDE EDDY FIGURE 3.2(a)



FLOOD TIDE EDDY FIGURE 3.2(b)

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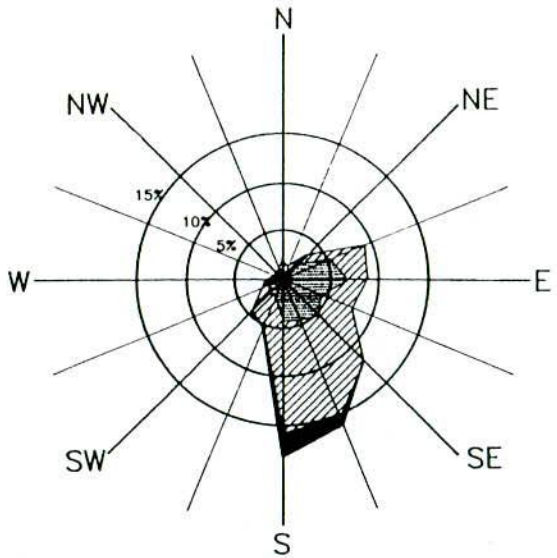
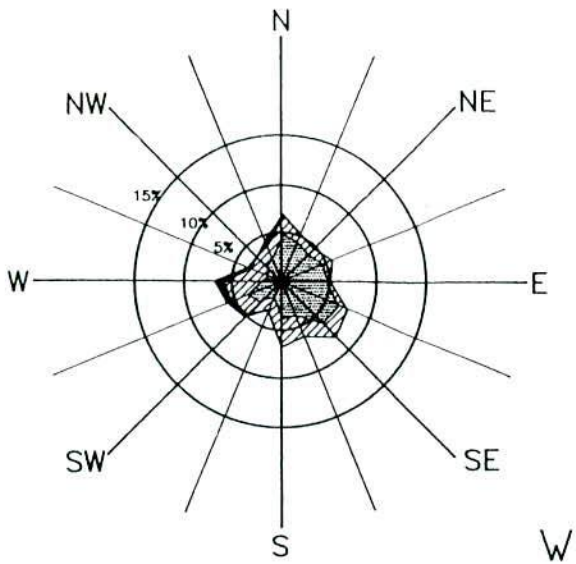
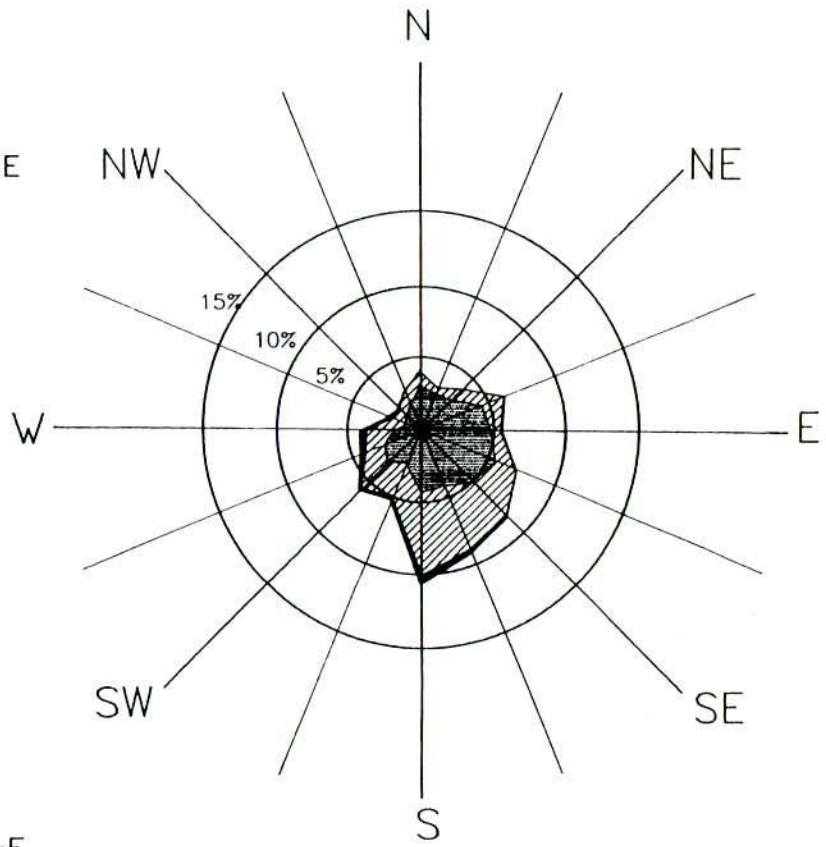
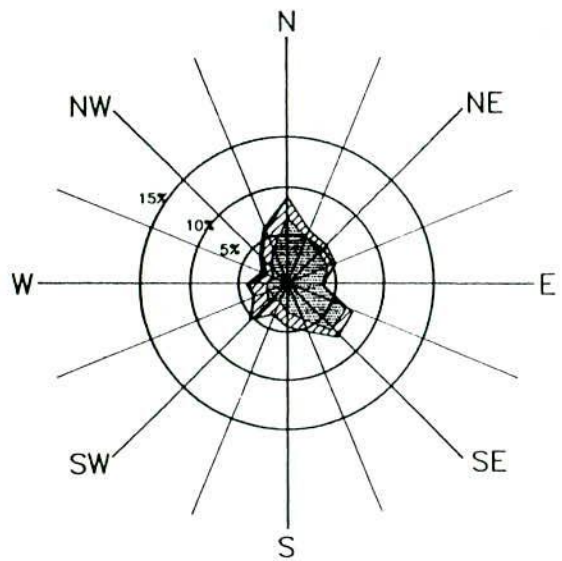


SUMMER WINDS

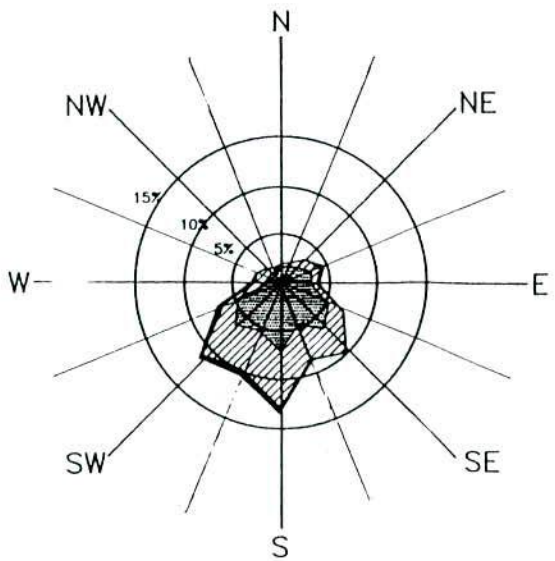


AUTUMN WINDS





WINTER WINDS



SPRING WINDS

WINDS FOR THE WHOLE YEAR

AUGUST 1986 TO SEPTEMBER 1987

MEASURED AT PORT MANDURAH

0 – 4 Km/h

4 – 8 Km/h

> 8 Km/h

PORT MANDURAH WIND ROSES

FIGURE 3.3

b) Winter

Winds tend to be more northerly with light north-easterlies predominating in the morning. The less frequent but stronger winds move from the south-west through to the north as fronts cross the Western Australian coast.

In the afternoon, winds tend towards stronger south-west to north-westerlies.

Except for the south-westerly winds, each of the other wind conditions will not produce noticeably persistent current patterns in Cox Bay because either the winds are weak or are blowing offshore (into Peel Inlet) and thus do not have the opportunity to develop a water current.

c) Spring

These wind and hence current patterns are a combination of the Summer-Autumn and Winter patterns.

The overall picture is that exchange of water between Cox Bay and the main body of Peel Inlet is poor and effectively restricted to that produced by the tides. Materials entering Cox Bay tend to be trapped within the Bay.

3.3 Wave Characteristics

Waves in Cox Bay will always be restricted in height because of the limited fetches and shallow water depths over which the wind blows. Onshore winds producing waves are only possible from the east, south-east and south. The wave direction frequency distribution is given in Table 3.1.

Table 3.1 - Wave Direction Distribution Frequency

	Wave Direction (from)						
Wave Height (m)	**ENE**	**E**	**ESE**	**SE**	**SSE**	**S**	**Calm Offshore**
< 0.05	6	6	6	8	9	10	38
0.05 - 0.10	1	0.7	2	1.5	1.3	2	
0.1 - 0.2	0.9	0.5	1.1	1.1	1.1	1.5	
0.2 - 0.3	-	0.1	1.1	0.3	0.4	.5	
> 0.3	-	-	*	*	*	*	

Note:

1. Wave periods will generally be in the range of 1 to 2 seconds.
2. * occasional but less than 0.1%.

High or extreme waves can only be produced by south-easterly winds. South-easterly winds from non-cyclonic conditions always tend to be moderate and wind observations of speeds greater than 30-40 km/hr are non-existent. Higher wind speeds from the south-east are possible if a cyclone were to cross the coast to the north of Peel Inlet.

However in the process of crossing the coast the winds from the south-east will already have begun to abate. A statistical analysis of extreme winds has not been attempted, but a south-east wind is unlikely to have a speed of greater than 25 m/sec for an event with a 1:100 year recurrence interval. The wind referred to is a steady wind. The corresponding wave conditions produced would have a H_S (significant wave height) of 0.6 metres and wave period of 3 seconds.

3.4 Sediments

A trial channel has been excavated from the shoreline for a distance of about 360 metres seaward at the existing boat ramp at Falcon (Appendix 4). The average depth of excavation was 0.8 metres which is the maximum likely depth for further excavation of Cox Bay. The materials encountered were well graded white, yellow and brown sand, except for about the last 10 to 20 metres of the channel. Several tube samples have been taken throughout the site and the indications are that the well graded sand occurs to a distance of 300 to 400 metres from the shoreline. This sand material is suitable for beach improvement or creation works.

4. PROJECT DESCRIPTION : MARINE ASPECTS

4.1 Concept and Layout

The project concept has been briefly described in Sections 2.1 and 2.2. It is proposed to include deepening around the existing jetty within the scope of the project. Figure 4.1 shows the existing conditions. Seabed contours are based on limited surveys.

The main problem area is the plateau at about -0.8 metres (AHD) which is about 200 metres wide. It typically has a water depth of about 300 to 400 mm which is too shallow for mechanical weed harvesters and also too shallow for boating and other water activities. The proposed development concept is shown in plan and sections on Figures 4.2 and 4.3. The main components are:

i) Excavation of approximately 112,500m^3 of sand from the floor of Cox Bay so that the minimum water depth at the toe of the beach (i.e. at low water) is 0.65 metres. In reality the water depth will be usually greater than 0.85 metres.

ii) Sloping of the seabed excavation so that there is a gentle grade in the seaward direction so that a hole is not created.

iii) Placement of approximately 40,000m^3 of the excavated sand on the foreshore reserve so as to increase it's average level from about 0.3m AHD to 1.0m AHD.

iv) Placement of approximately 13,000m^3 of additional sand on the beach to provide a buffer which will allow beach re-alignment to the changed offshore conditions.

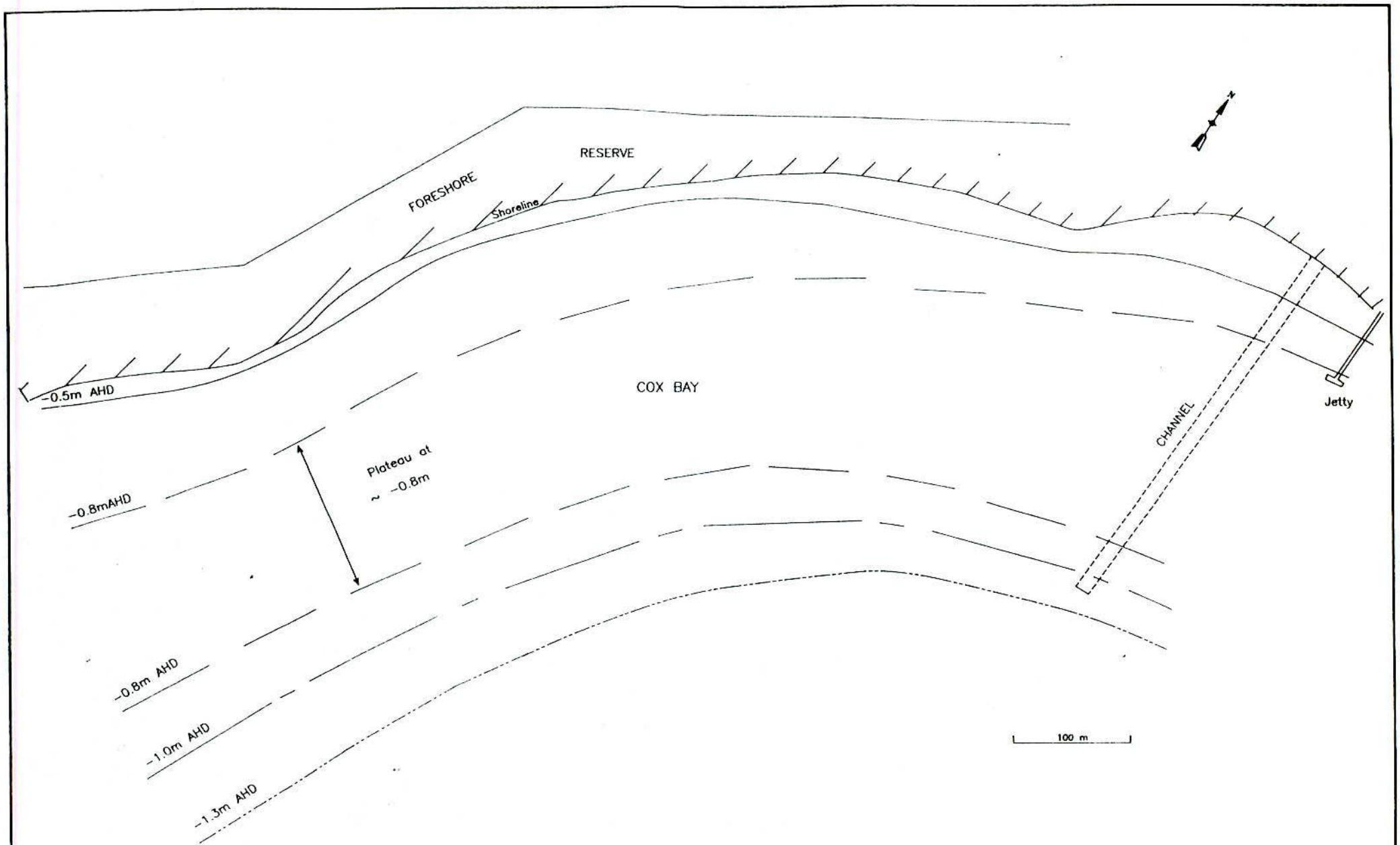
v) Creation of a low lying offshore island of some 2.6 hectares (measured at Mean Sea Level) as a visual feature and bird reserve. The island foreshore consists of beaches where they can be aligned so as to be stable and limestone armoured walls on other boundaries.

vi) Excavation around the existing jetty so that it becomes a usable facility.

4.2.1 Excavation of Cox Bay

As mentioned earlier a trial excavation has already been undertaken by forming an access channel to the existing boat ramp. This trial proved to be a success from the engineering construction viewpoint:

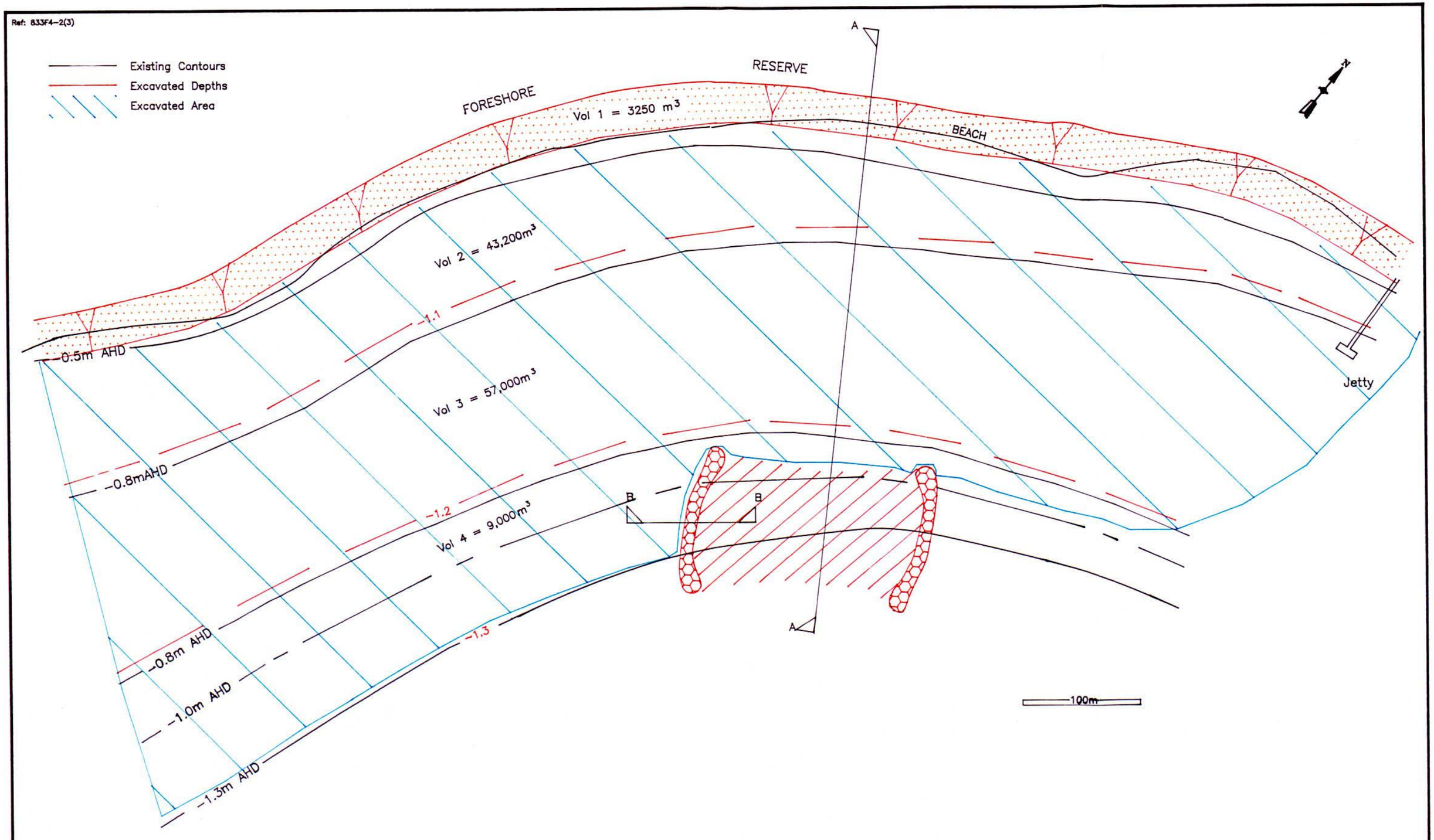
- The excavated material was a well graded sand which was suitable for bund construction and trafficable by haul trucks.
- This good quality material extended to a distance in access of 300 metres from the shoreline. Most of the proposed excavation is within 350 metres of the shoreline.
- The excavation was conducted wet, i.e. without dewatering and without any problems.



(NOTE: Seabed contors derived from limited sounding data)

EXISTING CONDITIONS

FIGURE 4.1



PLAN OF PROPOSED WORKS

FIGURE 4.2

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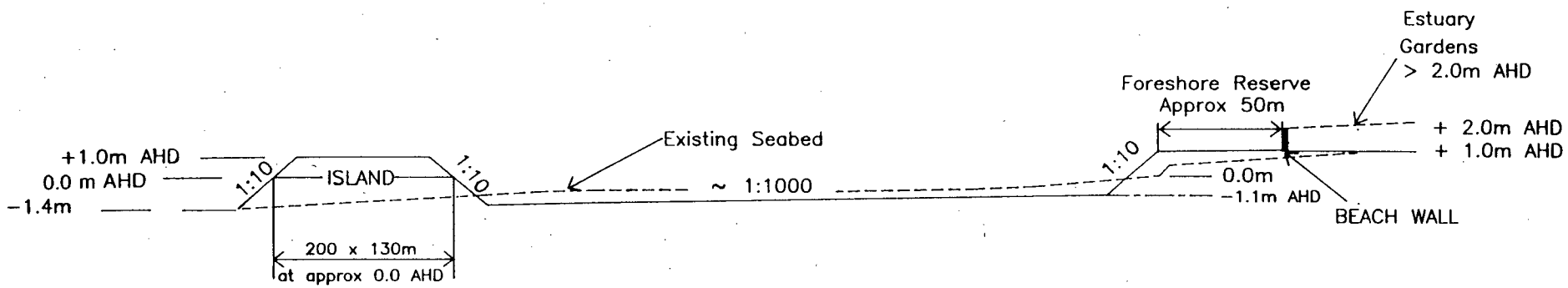
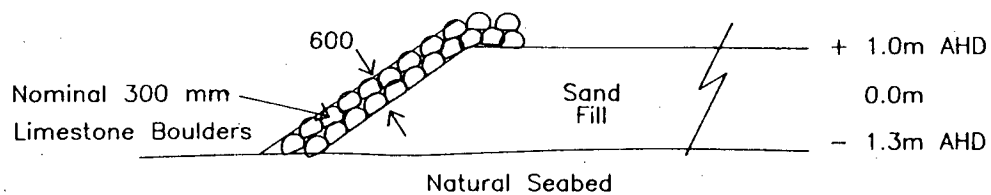


SECTION AA

Horiz. 1:2000
Vert. 1:200



SECTION BB

TYPICAL SECTIONS

FIGURE 4.3

16/25

- A small dewatering trial was carried out and proved successful so that it is envisaged that most of the excavation can be undertaken behind bunds in the dry.

The construction method envisaged is to create a bund enclosing most of the area to be excavated as shown in Figure 4.4. The bund would be formed by excavating material from the inside of the bund and progressively building the bund. Additional temporary bunds would be excavated to divide the area into a number of basins. The exact number will depend on the permeability of the bund walls and the rate of construction progress. Figure 4.4 shows a possible scenario with six compartments.

The construction sequence involves:

1. Construct the main enclosing bund.

2. Build temporary bund to segment off the first compartment.

3. Dewater the first compartment by pumping to the lagoon behind the main enclosing bund.

4. Excavate the first compartment in the dry and place material either on the island or on the foreshore reserve.

5. Build the second compartment with a new temporary bund wall. Remove the main enclosing bund wall on the seaward side of the excavated compartment.

6. Proceed in this manner until the last compartment is reached. It would be dewatered by pumping into a temporary bunded area within the previously excavated compartment.

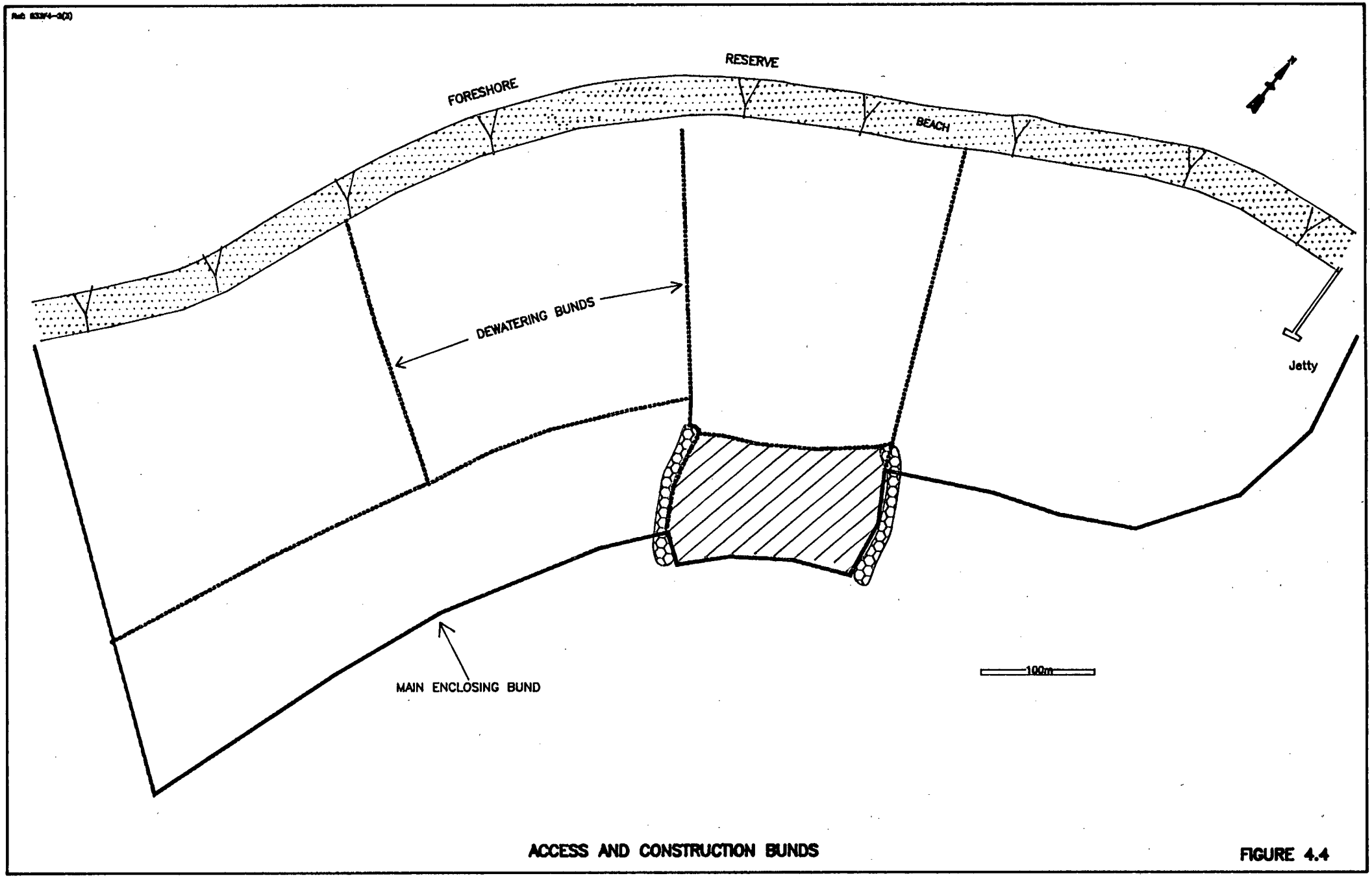
If dewatering cannot be achieved for some areas, the excavation would then proceed in the same manner (wet excavation) as was used to form the channel to the boat ramp.

4.2.2 Island

The island form will be produced initially by using the excavated basin material in the same manner as for a construction bund. The bund wall will be constructed from sand. During the excavation process there will be a quantity of limestone produced which appears in pinnacles in Cox Bay. The material, supplemented if necessary by imported limestone, will be used to form the armoured island walls. A typical wall section was shown in Figure 4.3.

The island sides which are approximately parallel to the shoreline will be sand beaches contained at either end by rock walls. The beach alignments have been chosen so that they should be in equilibrium with the incident wave regime. However there is no need to ensure that the island is totally stable since the concept is to leave it in its "natural" state for use by birds. The rock walls will ensure the island will remain basically in its constructed position.

During construction, the volume of material excavated from the floor of Cox Bay may vary due to the large area of works and relatively shallow depth of cut. Surveys and calculations done to date show that approximately 59,500m^3 of sand will be available for island fill. It is anticipated that actual island dimensions be adjusted to suit fill available during construction.



ACCESS AND CONSTRUCTION BUNDS

FIGURE 4.4

4.2.3 Foreshore Reserve Beach

Approximately 53,000m³ of the sand material excavated from the floor of Cox Bay will be placed on the foreshore and on the beach face. This sand will be trucked ashore, dumped and then bull-dozed into place.

The first aim is to raise the level of the foreshore reserve so that it drains. A volume 40,000m³ of sand is earmarked for this purpose. Then about 13,000m³ of sand will be left available to place on the beach face. Since the foreshore being treated has a total length of 1150 metres, the volume of sand effectively being placed on the foreshore/beach is about 46m³/m run. This represents a substantial strengthening of the beach reserve. The 13,000m³ will provide an additional beach width at RL +1.0 AHD of 6 metres on average over the foreshore length.

The construction of the island and the deepening of the bay will result in changes to the wave climate at the shoreline. However the total wave energy reaching the shoreline is very low and the volumes of sand moved along the beach each year is small. Simple sediment transport calculations have been carried out for Falcon Beach in its present state using Shore Protection Manual (1984). These show that the longshore sediment transport annually is only of the order of 10m³ in either direction. An individual severe storm may move a similar quantity of sand along the shore.

With such low sediment transport rates the best design procedure for the new beach is to allow it to realign itself to the new offshore conditions. There is more than sufficient sand placed on the beach (13,000m³) compared to annual transport rates of the order of 10m³. Therefore the sand placed on the beach face should be uniformly distributed at a rate of 12m³/m run.

Provided that facilities or structures are set back from the beach face by at least 10 metres there should be no problem in accommodating any shoreline movements.

4.2.4 Shoreline Structures

As part of the foreshore reserve improvement works it is proposed to provide a bicycle track behind the beach and construct two or three short pedestrian jetties about 50 metres long.

Since sediment transport rates are very low these jetties could be either solid (causeway style) or open depending on the aesthetic preference. If a solid structure is used it will tend to create separate beach compartments within which assumed longshore sediment transport rates would still be of the order of 10m³. Even if 100m³ of sand accumulated against one side of a jetty over a 10 year period it would clearly be a minor matter to remove it and place it on another part of the beach.

4.3 Operation Schedule

The total time for the described excavation work is expected to be 3.5 to 4 months. The work would be carried out at the same time as the proposed capital works for the construction of the land based development on Lot 1147.

5. COASTAL ENGINEERING ENVIRONMENTAL EFFECTS

5.1 Bathymetry

The trial excavation program showed that nearly all the excavation is in sand. Consequently deepening the bay will not release quantities of fine sediments that could be subsequently stirred up by storms. The seabed is expected to remain stable at its increased depth because:

a) The wave climate is very mild and most of the time the small seas generated will not feel the bottom of the bay. Therefore with its sandy base there is no scope for sediment movement.

b) Tidal and wind driven currents are low and will not initiate the movement of sand on the seabed.

The only mechanism for change of bathymetry is by either the deposition of silt during river floods or deposition of algae and weed. The deeper water in the bay will allow harvesting of algae and weed and this process would also tend to dissipate any deposited silt.

The new bathymetry is expected to be stable.

5.2 Shoreline Stability

Shoreline stability has already been fully discussed in Section 4. With or without the bay deepening and with or without the island, the rate of sediment transport along the beach can be counted in 10's rather than 100's of cubic metres per year. By providing an effective reservoir of 13,000m^3 of sand on the beach face, there will be more than sufficient sand available to allow the beach to align itself in equilibrium with the new conditions.

5.3 Stability of the Island

The sediment transport rates computed for Cox Bay foreshore will apply equally well to the offshore island. If the island beaches are not aligned in equilibrium with the ambient wave climate the quantity of sand moved each year from one end of the beach to the other will be of the order of 10m^3. This is insignificant on an island created from about 59,500m^3 of sand (See Section 4.2.2).

There is no impact even if there is a loss of sand from the island. No structures are planned on the island.

5.4 Water Quality - Circulation

Existing circulation problems were described in Chapter 3. Deepening of the seafloor together with the island will have little impact on those current patterns. The main feature, the eddy will persist with the island in the centre of it. Due to the deeper water the current velocities will be slightly reduced (20 - 30%) but the volume of water circulated will remain

the same. The seabed is sloped continuously into Peel Inlet so there will be no tendency for stagnation of water.

The fundamental water circulation problem due to the eddy will remain so that materials leading to algae and weed growth will tend to accumulate in the bay as it does now. Similarly, accumulated algae and weed will not be dissipated. In fact there will be a status quo position except that the deeper water will allow more efficient harvesting of the algae and weed so that overall water quality will be improved compared to existing conditions.

5.5 Impact of Severe Storm Events

Beach - Shoreline

During a severe storm of say 24 hours duration the following could happen:

- water levels in Peel Inlet could increase by 1 to 1.5 metres.
- waves at Cox Bay could persist at 0.6m height for 12 hours.

The nett effect would be flooding of the foreshore reserve and increased sand movement on the beach. During such a single storm event there would be sand movement along the beach of the order of $25m^3$, ie. about 250% that which occurs over a whole year under ambient conditions. This order of sediment movement would be expected for a storm such as Cyclone Alby.

There may also be some sand movement off the beach into deeper water which will be reflected on the beach as an erosion scarp. The $12m^3$ of sand placed on the beach per metre run is sufficient to accommodate 2 to 3 storms of the magnitude of Cyclone Alby.

Bathymetry

The seabed will feel the wave action, however with the near horizontal seabed there will be little nett movement of sand. There will be seaweed dislodged which will tend to end up at the shoreline. There will be a loss of depth locally at the toe of the beach where sand from the beach has been moved offshore.

Island

The island would be inundated and may be awash. Sand will tend to be removed from the island and deposited on the lee side of the island. Vegetation, depending on its salt tolerance will be damaged.

Water Quality - Circulation

There will be stronger than normal currents induced, as happens presently during storms. However there is no nett benefit because debris, algae and weed tend to collect in Cox Bay and then remain trapped. Clean up operations will be assisted by the greater water depth in the bay.

Foreshore Structures

Foreshore structures such as jetties and the bikeway can be designed to suffer minimal damage when they are flooded or subjected to waves, however there is a corresponding cost penalty. The choice of design criteria would be determined at the detail design phase of the project where capital costs can be compared with the maintenance costs of repairing lighter weight structures.

5.6 Impact of Dawesville Channel Construction

The impact on the area will be the same whether it remains in its present state or is modified as described in this report. The main impact will be an increased tidal range and improved water exchange.

The increased tidal range will easily be handled by the widened and higher beach along the foreshore reserve. Water depths at low tide will be reduced by up to about 100 mm but this has been allowed for in the extent of seabed excavation.

Whilst there will be some improvement in water exchange, the fundamental problem of the Cox Bay eddy will remain.

6. CONCLUSIONS

A study of the coastal engineering aspects of the proposed bay and foreshore improvements at Cox Bay has been carried out, the results of which may be summarised as follows.

Alternative Project Concepts

- The bay along the foreshore boundary of Estuary Gardens should be deepened and the deepened area grade towards deeper offshore water.
- The existing jetty should be included within the area to be deepened so that it can become functional.
- Additional deepening of Cox Bay to produce land fill material is not recommended.
- An offshore island can be constructed as a visual amenity and possibly a bird sanctuary area. No development would occur on the island.

The Marine Environment

- Meteorological tides are of equal importance to astronomical tides in Peel Inlet. The astronomical tide range is nearly 0.4 metres and the meteorological tide adds another 0.4 metres. In effect daily tidal ranges tend to be about 0.2 metres whereas weekly (meteorological) tides range at about 0.5 metres.
- The 1:100 year flood level is 1.6m AHD. No additional allowance for wind set-up is required.
- When the Dawesville Cut is completed the tidal range will increase by 0.1 to 0.2 metres.
- Cox Bay has poor water circulation because it tends to have an eddy formation in the bay that collects material pushed into the bay by wind stress currents.
- The strongest currents are those generated by winds blowing towards Cox Bay.
- Tidal currents are always weak but will tend to set up an eddy in Cox Bay.
- The summer south-west to south-east winds tend to push algae and weed into Cox Bay.
- The wave climate in Cox Bay is very mild due to the shallow water in Peel Inlet and limited wave generation fetches. Waves exceeding H_S = 0.3 occur less than 1% of the time.
- In extreme storms (Cyclone Alby) significant wave heights are unlikely to exceed 0.6 metres.
- Seabed sediments over the area to be excavated are mainly well graded sands.

Design and Construction

- The sandy seabed should be excavated to a minimum depth of -1.1m AHD grading seaward.
- The sand is suitable for beach and island construction.
- Excavation can be completed either from bunds or in 'the dry' by dewatering.
- Forty-six cubic metres of sand are available per metre run of beach to top up the foreshore reserve and widen the beach on average by 6 metres.
- Approximately Thirty-seven thousand cubic metres of sand are used to construct the island which will have an area of around 2 - 3 ha depending upon fill available from Cox Bay seafloor.
- The island has beaches where they can be aligned to be stable. Elsewhere limestone rock walls will be used to contain the island.
- All sand from Cox Bay will be used on the beach and island. Sand to raise levels at Estuary Gardens will be imported.
- Sediment transport rates along the foreshore are of the order of $10m^3$/year. Since $53,000m^3$ of sand will be placed along the beach it is recommended that the beaches be allowed to find their own equilibrium alignment.

Environmental Effects

- The new excavated seabed will be stable.
- The beach shoreline will move in response to the new wave climate. However changes will be slow and because of the extent of replenishment the beach-line will remain seaward of its pre-replenished position.
- The island may change its shape from storm action. This has no impact on anything but the shape of the island.
- Water quality and exchange in Cox Bay will be practically unchanged except that algae and weed harvesting will be more practical. More efficient removal of algae and weed will result in better water quality.

7. REFERENCES

1. Riedel and Byrne Consulting Engineers. "Estuary Deepening - Cox Bay, Preliminary Bund Construction". R387, April 1990.

2. Riedel and Byrne Consulting Engineers. "Waterside Mandurah, Water Quality and Exchange". R48, September 1981.

3. Riedel and Byrne Consulting Engineers. "Peel Inlet Entrance Channel, Hydraulic Study". R19, October 1980.

4. US Army Corps of Engineers. "Shore Protection Manual". 1984.

5. Department of Marine and Harbours, Western Australia. "Peel Inlet and Harvey Estuary, Management Strategy". Report No. DMH 5/88, May 1987.

6. Department of Conservation and Environment, Western Australia. "Management of Peel Inlet and Harvey Estuary". Bulletin 1970, May 1984.

7. Department of Conservation and Environment, Western Australia. "The Peel - Harvey Estuarine System Study (1976-1980)". Report No. 9, December 1980.

8. Kinhill Engineers Pty Ltd. "Peel Inlet and Harvey Estuary Management Strategy". May 1988.

Meiyu Australia Pty Ltd

Estuary Deepening

Cox Bay, Falcon

Public Environmental Review

APPENDIX 3

WATER QUALITY OF THE PEEL-HARVEY ESTUARINE SYSTEM AND COX BAY

LEC REF: J192/R328

WATER QUALITY OF THE PEEL-HARVEY ESTUARINE SYSTEM AND COX BAY

Report to: Meiyu Australia Pty Ltd,
26 Riverside Road,
EAST FREMANTLE WA 6158.

by: LeProvost Environmental Consultants,
Suite 2, 1st Floor,
175 Labouchere Road,
COMO WA 6152.

10 December 1990

LEC Ref: J192

WATER QUALITY OF THE PEEL-HARVEY ESTUARINE SYSTEM AND COX BAY

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WATER QUALITY OF THE PEEL-HARVEY ESTUARINE SYSTEM AND COX BAY

1 INTRODUCTION

The Peel-Harvey estuary system is presently highly eutrophic. Eutrophication and algal blooms have degraded the water quality of the estuarine system as nutrient loads have exceeded the natural assimilative capacity of the system.

The algal blooms comprise of both microalgae (microscopic single-celled plants) and macroalgae (seaweeds). The microalgae include diatoms, dinoflagellates and blue-green algae that are frequently dispersed throughout the water column. Several species of macroalgae (seaweed) grow in the estuary, with the abundance of the dominant species varying over the past decades due to changes to the nutrient regime. Common macroalgae include *Cladophora* (goat-weed), *Chondria, Chaetomorpha* (rope-weed), *Enteromorpha, Chloridia* and *Ulva* (sea lettuce). The algae can grow and reproduce rapidly under certain conditions to form blooms which alter the estuary's water quality (Waterways Commission, 1990).

Water quality monitoring in the Peel-Harvey estuarine system has been undertaken on a weekly basis since August 1977. The monitoring programme and analysis of results has been carried out by the Centre for Water Research at Murdoch University (formerly at the University of Western Australia) on behalf of the Waterways Commission. This report summarises the results of the monitoring programme and discusses the issues affecting the water quality of Cox Bay.

2 WATER QUALITY OF THE PEEL-HARVEY ESTUARINE SYSTEM

2.1 TEMPERATURE

Temperature readings in the Peel-Harvey system show a seasonal change from 11-12°C in winter, to 26-27°C in summer (Lukatelich & McComb, 1983). Surface and bottom temperatures rarely differ by more than 2°C, both closely following seasonal changes in air temperature (Lukatelich & McComb, 1986).

2.2 SALINITY

Salinity changes seasonally from about 5‰ to 45‰, with a minimum in winter and maximum in summer (Lukatelich & McComb, 1983). During spring and early summer, salinity rises because of evaporation and tidal exchange with the ocean (Lukatelich & McComb, 1986). Evaporation is so high and river flows so low that

in late summer both basins become hypersaline (salinity of seawater is typically 35 ‰).

The Harvey Estuary is less saline than the Peel Inlet in winter and spring, and more saline in autumn, because Harvey Estuary is more remote from the ocean entrance. During summer and autumn, the water column is well mixed. In winter and spring, the water column showed marked stratification under calm conditions because of intrusion of water of marine origin. Destratification of the water column generally occurs at least every five days due to wind-mixing, however, the water column may restratify during the calm periods between wind-mixing events if density differences between the Peel Inlet and Harvey Estuary are sufficient to drive density current underflows (Lukatelich & McComb, 1986).

2.3 CHLOROPHYLL

Chlorophyll levels vary markedly from 0 to 600 ug/L. The main peaks typically occur on an annual basis between July and March. The main peaks are due to massive blooms of the blue-green algae *Nodularia spumigena* and where these occur they are preceded by smaller peaks associated with diatom blooms. Typically, the blue-greens are at higher levels in Harvey Estuary than in Peel Inlet. However, during periods of large blooms, *Nodularia* does extend into the western half of Peel Inlet. The eastern half of the Peel Inlet generally has very low levels (Lukatelich & McComb, 1983).

2.4 LIGHT ATTENUATION

Light penetration is recorded as attenuation coefficients where the highest attenuation coefficient indicates maximum reduction of incident light as it passes through the water column. Overall, the peaks in light attenuation coefficients occur at the same time as the peaks in *Nodularia* blooms. Much of the variation not accounted for by chlorophyll is due to wind stirring in the system, which brings suspended material into the water column (Lukatelich & McComb, 1983).

2.5 pH

Readings of pH in the Peel-Harvey system range from 7.4-10.0. The maximum pH is encountered during the *Nodularia* blooms because of the depletion of dissolved inorganic carbon through uptake in photosynthesis by *Nodularia* (Lukatelich & McComb, 1983).

2.6 OXYGEN

Oxygen levels vary markedly, creating both anoxic and supersaturated conditions. Oxygen levels are recorded as both absolute concentration (mg/L) and as percentage saturation at the surface. Saturated conditions occur when oxygen levels in surface waters indicate equilibrium with air (e.g. 100%). Surface levels are often supersaturated (measured at concentrations up to 220% of saturated conditions) with peaks during *Nodularia* blooms, resulting from photosynthesis (Lukatelich & McComb, 1983). Minimum surface concentrations were recorded in late summer, after the collapse of the *Nodularia* blooms, when phytoplankton biomass was low (Lukatelich & McComb, 1986).

Bottom waters were found to contain less oxygen, but were not anaerobic (minimum of 50% recorded). Minimum values were recorded in winter, coinciding with high turbidity, poor light penetration, and more consistent stratification (Lukatelich & McComb, 1986). Lower levels at depth are presumably due the larger phytoplankton biomass present resulting in increased light attenuation and respiration (Lukatelich & McComb, 1984). The lower waters were below the photic zone during blooms, so levels must be maintained by down-mixing of oxygen rich surface water. Oxygen levels in the surface water were reduced from April-June when there was little phytoplankton, and when surface and bottom oxygen levels were approximately the same (Lukatelich & McComb, 1983). Bottom water oxygen concentrations were generally higher in Peel Inlet than in Harvey Estuary because of benthic macroalgal production there (Lukatelich & McComb, 1986).

2.7 NUTRIENTS

2.7.1 Phosphorus

Phosphorus is important in controlling algal populations in the system. Phosphate concentrations are related to river flow (and hence also correspond to the salinity regime). At times of low river flow, salinity is relatively high and phosphate concentration is relatively low. During winter, when river flows are high, salinity levels are relatively low and phosphate concentrations are high (Lukatelich & McComb, 1983). This leads to large *Nodularia* blooms in spring and summer.

There was generally little difference between surface and bottom phosphate concentrations in either estuary, except during winter, when concentrations were generally higher at the surface because of freshwater inflow. However, during periods of prolonged salinity stratification, phosphate concentrations in bottom water did exceed those at the surface, because of phosphorus release from the sediments (Lukatelich & McComb, 1986).

Organic phosphorus levels in the water are typically erratic due to the effects of wind-stirring. However, maximum concentrations coincide with maximum

phytoplankton biomass (Lukatelich & McComb, 1983). The concentration of organic phosphorus has increased over the study period, which suggests increased nutrient recycling is occurring.

2.7.2 Nitrogen

Nitrate concentrations are derived, in part, from river flow. There is also regeneration of nitrate in the summer-autumn period following the collapse of *Nodularia* blooms as a result of decomposition and remineralization of organic material (Lukatelich & McComb, 1984). This regeneration has been less prevalent in recent years as secondary diatom blooms now follow the *Nodularia* blooms.

Ammonium is present at very low concentrations in river water, and is largely produced in the system through the decomposition of organic material derived mainly from phytoplankton. Peaks observed following the collapse of *Nodularia* blooms have decreased recently as a result of secondary diatom blooms.

Organic nitrogen concentrations move mainly in sympathy with *Nodularia*, the peaks being in part due to nitrogen fixation by this organism (Lukatelich & McComb, 1983). Organic nitrogen levels have generally increased since the initial *Nodularia* bloom (in 1978), suggesting that a proportion of the nitrogen fixed by the *Nodularia* blooms has been trapped and subsequently recycled within the system (Lukatelich & McComb, 1986).

2.7.3 Silica

Silica is an essential nutrient for diatom growth, but is not required for the growth of blue-green algae. Silicate levels in both estuaries are inversely related to diatom chlorophyll levels. Silicate concentrations in Peel Inlet do not reach limiting concentrations, whereas they occasionally do in Harvey Estuary (Lukatelich & McComb, 1984).

2.8 ALGAE CYCLE

The magnitude of the *Nodularia* bloom in summer is related to the minimum salinity of the estuary (and hence total river flow), maximum phosphate concentration and total riverine phosphorus loading, in the previous winter. Diatom blooms trap phosphorus, which is deposited largely as faecal pellets, the phosphorus is recycled and supports *Nodularia* growth under warmer conditions and the amount available determines *Nodularia* biomass. *Nodularia* blooms generally collapse when summer salinities reach 30‰ (Lukatelich & McComb, 1986).

The prevalence of phytoplankton blooms following the collapse of the *Nodularia* blooms indicates nutrient recycling within the system. The phytoplankton blooms occur at a time of negligible riverine input, suggesting that recycling from sediments is becoming more marked with time (Lukatelich & McComb, 1984).

Light is the primary limiting factor for macroalgal growth, and increase in light attenuation is largely due to *Nodularia* (Lukatelich & McComb, 1986). Macroalgae growth is maximised by good light transmission through the water column coupled with high sediment loading of nutrients in a form which can be readily remineralised (Lukatelich & McComb, 1984).

3 WATER QUALITY OF COX BAY

Cox Bay has been historically identified as a principal area for macroalgal growth (Hodgkin et al. 1981). It has been predicted that the large and continuous phytoplankton biomass that occurs in the Peel-Harvey estuarine system will increase the nutrient status of the sediments in the Cox Bay area in particular (Lukatelich & McComb, 1984). This will continue the trend for heavy blooms of macroalgae in the shallows in that region.

The western area of Peel Inlet includes the only sites where there is any significant *Cladophora* biomass still found in the system. This algae virtually disappeared from the eastern area of Peel Inlet in 1979 but has continued to grow in the Falcon and Dawesville areas. This may be due to the more consistent and higher nitrogen and phosphorus loading from the Harvey Estuary in recent years, which includes nitrogen fixed by *Nodularia* (Lukatelich & McComb, 1986).

The western populations of macroalgae (e.g. Cox Bay) are close to Harvey Estuary, which supports large phytoplankton blooms as a result of the high nutrient loading of the Harvey River and associated drains, and the long residence time of the water in the estuary. Thus water flushed from Harvey Estuary to Peel Inlet will have a relatively high particulate nutrient load, which may sediment out of the water column near the mouth of the Harvey Estuary, affecting the western population of macroalgae more than the eastern (Lukatelich & McComb, 1986).

The western algae populations of Peel Inlet have slightly higher tissue nitrogen and phosphorus concentrations. The tissue nutrient levels in the western population increased after a *Nodularia* bloom (Lukatelich & McComb, 1986). It has been shown from satellite photographs that most of the water flushed from the Harvey Estuary flows out over the western side of Peel Inlet (Lukatelich & McComb, 1986). Results of a drifter bottle study suggest that floating *Cladophora* may be distributed to a number of shores around the inlet, in some cases far removed from their site of origin. The location of release of bottles with collection on the shores indicated transport by a wind-driven anti-clockwise gyre or surface water movement within Peel Inlet (Gordon et al., 1981).

A study of the flushing and circulation characteristics of Cox Bay by Riedel & Byrne Consulting Engineers (1990) suggests that the presence of a weak eddy in the bay contributes to algal accumulation. This eddy is caused by tidal movements and riverine flow through the Mandurah Channel, and by wind and wave effects. The eddy within Cox Bay and the larger anti-clockwise surface water movement in Peel Inlet make the shore area at Cox Bay susceptible to accumulation of drifting algae.

The Peel Inlet Management Authority (PIMA) receives numerous complaints each year from local residents at Falcon in response to local algal problems.

Complaints, in the form of letters or telephone calls to PIMA, are recorded on PIMA files. However, many more complaints are made on-site, on a personal basis to PIMA Inspectors and algae harvesting operators (J. Pszczola, pers. comm., 26 September, 1990). As these complaints are not formally recorded there have been no statistics compiled which would suggest that, on the basis of all complaints received from the public, the algal problem is of greater public concern at Cox Bay than at other locations in the Peel-Harvey estuarine system.

4 REFERENCES

Gordon D.M., Birch P.B. & McComb A.J., 1981. *A Technical Report to the Peel-Harvey Estuarine System Study (1976-1980). The Ecology of Cladophora in the Peel-Harvey Estuarine System.* Bulletin No. 91, Department of Conservation & the Environment, Perth, Western Australia, 204 pp.

Hodgkin E.P., Birch P.B., Black R.E. & Hillman K., 1985. *The Peel-Harvey Estuarine System. Proposals for Management.* Report No. 14, Department of Conservation & the Environment, Perth, Western Australia, 54 pp.

Lukatelich R.J. & McComb A.J., 1983. *Water Quality of the Peel-Harvey Estuarine System March 1981-August 1982.* Report No. 2, Waterways Commission, Perth, Western Australia, 11 pp.

Lukatelich R.J. & McComb A.J., 1984. *Water Quality of the Peel-Harvey Estuarine System September 1982-September 1983.* Report No. 5, Waterways Commission, Perth, Western Australia, 9 pp.

Lukatelich R.J. and McComb A.J., 1986. *Nutrient recycling and the Growth of Phytoplankton and Macroalgae in the Peel-Harvey Estuarine System.* Report No. ED-85-118, Waterways Commission, Perth, Western Australia, 76 pp.

Riedel & Byrne Consulting Engineers Pty Ltd, 1990. *Estuary Deepening - Cox Bay, Coastal Engineering Aspects.* Report No. R404. Riedel & Byrne Consulting Engineers, Perth, Western Australia.

Waterways Commission, 1990. *Draft Peel Inlet Management Programme Review. Part 1-Study of the Western Foreshore of the Peel-Harvey Estuary.* Unpublished report prepared for the Peel Inlet Management Authority. Waterways Commission, Perth, Western Australia, 27 pp.

Meiyu Australia Pty Ltd

Estuary Deepening

Cox Bay, Falcon

Public Environmental Review

APPENDIX 4

FISH RESOURCES OF THE PEEL-HARVEY SYSTEM AND BENTHIC INFAUNA OF COX BAY

LEC REF: J192/R328

FISH RESOURCES

OF THE PEEL-HARVEY ESTUARINE SYSTEM

AND

BENTHIC INFAUNA OF COX BAY

Report to : Meiyu Australia Pty Ltd,
26 Riverside Road,
EAST FREMANTLE WA 6158.

by : LeProvost Environmental Consultants,
Suite 2, 1st Floor,
175 Labouchere Road,
COMO WA 6152.

10 December 1990

LEC Ref: J192

FISH RESOURCES OF THE PEEL-HARVEY SYSTEM AND BENTHIC INFAUNA OF COX BAY

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FISH RESOURCES OF THE PEEL-HARVEY SYSTEM AND BENTHIC INFAUNA OF COX BAY

1 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Meiyu Australia Pty Ltd proposes to deepen a portion of the nearshore shallow area of Cox Bay in order to improve boating access and amenities in the north-west portion of Peel Inlet, and to enable more efficient harvesting of accumulations of rotting algae. The proposed deepening comprises the excavation of, on average, the top 0.26 m of the existing sandy sediments within an area 1150 m long by 380 m wide. During excavation this area will be enclosed by a temporary bund wall (see Appendix 2 of the Public Environmental Review).

The sediments will be excavated so that typical water depths at the toe of the beach will be 0.45 m, with the depth gently and uniformly increasing to reach the existing 1.3 m contour which is approximately 380 m offshore. The dry excavation method will preserve water quality within this region of the Peel Inlet and prevent plumes of sediment affecting nearby aquatic communities, but the removal of the top layer of sediment will result in the loss of the biota presently colonising these sediments.

Developments involving the removal or disturbance of bottom sediments have previously been undertaken within the Peel-Harvey estuary system, however, information detailing the subsequent colonisation of areas of new substrate is limited. Studies were therefore undertaken to assess the importance of the existing benthic community in Cox Bay to the Peel-Harvey fishery, and to determine whether the composition and/or abundance of the benthic community that will colonise the new sediments is likely to be significantly different.

Estuaries such as the Peel-Harvey form productive systems in which the shallow water benthic community provides a major food source for fish, crustaceans and many water birds. To place this into perspective the first section of this report briefly describes the fishery resource of the Peel-Harvey system, and how the fish and crustaceans utilise the shallow water habitat. The importance of the development site to water birds is discussed subsequently, in Appendix 5 of the PER.

In the second part of this report the benthic infaunal community, which comprises those animals which burrow within the sediments and generate a major part of the food resource for the higher consumers within the estuary, is also described.

Results of studies on the benthic infauna are presented whose objectives were as follows:

- to evaluate the importance of the existing benthic infauna at the project site;
- to obtain data enabling predictions to be made on the character of the infauna which will colonise the bare sediments exposed by the excavation; and
- to provide a set of baseline data for a subsequent monitoring programme.

These studies comprised a desk-top review of available information, and a brief field survey that compared samples of the benthic fauna from two sites within the project area with those from four sites in Peel Inlet. The limitations of short-term sampling at a restricted number of sites was offset by commissioning a report which summarises research data collected over a number of years by Mr T. Rose (Murdoch University) on seasonal and spatial variations of the benthic fauna in the Peel-Harvey system (this report is presented in full in Appendix A of this document).

1.2 ACKNOWLEDGMENTS

Mr D. Blackman	Department of Fisheries Inspector, Mandurah
Mr T. Rose	School of Biological and Environmental Sciences, Murdoch University.
Mr G. Hyndes	School of Biological and Environmental Sciences, Murdoch University.

2 FISH RESOURCES OF THE PEEL-HARVEY SYSTEM

2.1 INTRODUCTION

The Peel-Harvey estuary system is approximately 130 km^2 in area and contains a substantial fish fauna that presently supports one of the largest estuarine commercial and recreational fisheries in Western Australia. Many of the fish utilising this system are the juvenile stages of marine species which return to the sea to spawn. However, some of these remain in the basins of the Peel Inlet and Harvey Estuary long enough to grow to sizes suitable for exploitation (Lenanton et al., 1984). The ability of many of the marine species to remain throughout the year has been related to the fact that salinities in these wide and relatively very shallow basins typically remain above 15 ppt for most of the year (Loneragan et al., 1986).

The annual total commercial catch typically ranges between 500 and 1000 tonnes and is taken by up to 30 licensed fishing units, of which 24 are currently active for most or parts of the year (D. Blackman, pers. comm., 9 October 1990). In terms of live weight, the sea mullet, yelloweye mullet and cobbler together contribute between 70% and 90% of the total fish catch (Lenanton et al., 1984). Fish are caught from clear water areas by haul nets during daylight and from turbid water areas by setting gill nets at night. These operations are conducted throughout the large basin areas of the Peel Inlet and Harvey Estuary.

The blue crab and both the school and western king prawn are also important components of both the recreational and commercial fishery of the Peel-Harvey system (Fisheries Department, 1988). In some years the blue crab is probably the most important contributor to the annual recreational catch, while the commercial catch (taken predominantly during the summer months) is often made at rates exceeding 5 tonnes per month (Potter et al., 1983).

2.2 GROWTH AND DISTRIBUTION

Juvenile yelloweye mullet enter the Peel-Harvey system in winter, and feed and grow rapidly on the shallow banks surrounding the basins. They also move up the Murray and Serpentine Rivers. Most of these fish remain in the system for up to two years, with many attaining the legal minimum size for capture (230 mm) within 18 months after leaving the sea (Lenanton et al., 1984). As they increase in size, yelloweye mullet move off the banks and commence feeding in the slightly deeper basin areas.

Sea mullet are capable of growing to the legal minimum size for capture (240 mm) within a year of entering the Peel Harvey system, although growth rates can vary considerably between years. Commercial catches of sea mullet can therefore include fish within the 0+ age class, as well as older and larger fish representing the 1+ and 2+ year classes (Lenanton et al., 1984). As with the yelloweye, juvenile sea mullet also penetrate the rivers and prefer the shallow banks compared with the basin areas, which they eventually frequent when they increase in size.

Although the cobbler has also been classified with the two mullet species as an 'estuarine opportunist' (Loneragan et al., 1989), recent research data supports a long held view that this species can complete its life cycle without leaving the Peel-Harvey system (G. Hyndes, pers. comm., 3 October 1990). Spawning probably takes place in the spring and early summer, with the progeny reaching the legal minimum size for capture (320 mm) about 18 months later.

Blue crabs also grow fast within the Peel-Harvey system, with most reaching the legal minimum size for capture (127 mm across the carapace) early in their second year of life. However this species is much less tolerant of lowered salinities and most temporarily vacate the estuary during the winter months or find refuge in pockets of higher salinity water found along the bottom of the entrance channel at Mandurah (Potter et al., 1983). Females are thought to release their fertilised eggs both in this region and beyond the mouth of the estuary, with the smallest crabs first appearing in the entrance channel in February and March. As with the sea and yelloweye mullets, the younger stages tend to favour the shallow banks before moving into the 2 m deep basin areas as they increase in size (Potter et al., 1983).

2.3 EFFECTS OF EUTROPHICATION

The impacts of eutrophication on the Peel-Harvey commercial fishery (ie. effects of increased macroalgal growth and development of planktonic blooms of blue-green algae) have been described by Lenanton et al. (1984, 1985) and Potter et al. (1983).

Wide spread or 'massive' fish kills have not occurred either as a result of the autumnal dieback and decay of macroalgae, or from the appearance and subsequent collapse of blue-green algal blooms in spring/early summer. Apart from the fact that fish and crabs can avoid the accumulations of rotting macroalgae that are driven onto shallow banks and shorelines, wind-stirring of the shallow water column is usually sufficient to maintain adequate levels of oxygen (Lenanton et al., 1984).

However, minor kills have been reported within the Harvey Estuary and tributaries of the Peel Inlet at times when particularly severe blooms of blue-green algae (*Nodularia*) or diatoms are experienced. Such kills typically occur at night during periods of calm or light winds, when the decline in oxygen levels (brought about by the respiring phytoplankton) is so rapid that fish and crabs suffocate before reaching areas of cleaner water. In the case of *Nodularia* blooms, oxygen depletion in the water column is exacerbated by the release of toxins and the algal filaments which clog gills.

Nodularia blooms have been most prevalent in the Harvey Estuary, and usually only during the spring. These blooms have been shown to reduce the abundance of fish, many of which appear to move into the less turbid waters of the Peel Inlet during this period (Lenanton et al., 1985). Emigration of fish from the Harvey Estuary is probably also due to reduced oxygen levels, the production of algal

toxins, and the inhibitory effects of the filamentous *Nodularia* on swimming and respiratory activities (Lenanton et al., 1985).

In contrast to the deleterious effects of *Nodularia* blooms, the rise in macroalgae growth in the Peel-Harvey system during the 1970s and 1980s has appeared to have had an overall beneficial effect on the commercial fishery, although difficulties with weed such as *Cladophora* clogging the hauling nets have been experienced (Lenanton et al., 1984). Two reasons have been suggested for the beneficial impact, which was reflected by increased catches per unit of effort:

- predation of fish by birds has been reduced owing to the additional areas of 'cover' afforded by the macroalgae; and

- the decomposing weed enriches the detritus (detrital material is ingested by sea mullet and crabs), in turn leading to increased numbers of certain types of benthic animals (of which some are important food items to yelloweye mullet and cobbler).

Blue crabs are bottom scavengers and ingest various items including detritus and algae. Sea mullet ingest sand, detritus and mud together with some algae. Both yelloweye mullet and cobbler feed on algae and molluscs, although yelloweye mullet ingest to a much greater extent small crustaceans (amphipods) and midge larvae (chironomids) whilst cobbler consume large amounts of polychaete worms (Lenanton et al., 1984). Despite these differences, all these species share a common feature, i.e. a reliance on components of the benthos rather than on the small planktonic animals and plants that float within the water column.

3 BENTHIC INFAUNA IN COX BAY

3.1 INTRODUCTION

The characteristics of the benthic infauna in any given area are strongly influenced by factors such as substrate type, salinity, water depth and oxygen levels. Benthic infauna are usually more abundant in shallow sandy sediments than in deep areas with muddy substrates. In the Peel-Harvey system some areas which were previously sandy have been modified as a result of organic silt accumulation from past algal blooms and now contain more organic material.

The main effect of the proposed excavation at Cox Bay will be the exposure of bare sandy sediments that may not have as much detrital material as the top layer which is to be removed. The average increase in depth is small (0.26 m), and therefore existing salinity and oxygen regimes will not change.

3.2 METHODS OF FIELD SURVEY

The benthic infauna was sampled from six sites between 23 and 24 May 1990 (Fig. 1, p.11). Two shallow water sites (0.5 m) were sampled off Falcon and Olive Road in Cox Bay (sites where water depths exceed 1.3 m are not present within this Bay). A shallow water site (0.5 m) and a deep water site (1.5-2 m) were each sampled on the northern side of Ward Point and the south-west side of Boundary Island (Fig. 1). These sites were sampled in order to provide controls. Ward Point lies outside the proposed excavation site, while the site at Boodalan Island originally comprised a spoil site during the dredging of the Mandurah Channel.

At each site five samples were taken using a circular hand-held corer 8 cm^2 in diameter driven 10 cm into the sediment. Samples were sieved through a 1 mm aperture mesh screen and immediately placed in 70% alcohol. Samples were later sorted, identified and counted using a 5x magnifying lamp and dissecting microscope.

3.3 RESULTS AND DISCUSSION

A similar assemblage of benthic infauna was recorded at each of the six sample sites (Table 1, p.10). Between eight and eleven species were present in each area, with four species (*Capitella capitata, Arthritica semen, Corophium minor* and *Melita zeylanica*) being common to all six sites.

The small number of species recorded in this survey is typical of samples of benthic communities from estuaries, where fluctuations in environmental variables, such as salinity and temperature, limit the diversity of the benthic infauna (Chalmer & Hillman, 1985).

The abundance of the benthic infauna sampled from each of the shallow sites was considerably higher than those recorded from the two deep water sites (Table 1, p.10). The abundance at the deep water site at Boundary Island (775/m^2) was particularly low, and presumably reflects the nature of the sediments at this site, which comprised a deep layer of fine organic silt. Low numbers of benthic infauna have also been reported from the deeper and more silty areas of south-west Australian estuaries by Wallace (1977) and Atkinson and Edward (1984). The sediments at the deepwater site at Boundary Island can be viewed as providing an example of a worst-case situation for benthic infaunal colonisation within the Peel-Harvey system, as this site has been subjected to considerable deposition of fine silty sediments.

The lowest abundance of benthic infauna sampled from a shallow water site (10,875/m^2) was that recorded at Olive Road, where the greatest density of decaying macroalgae and detrital muds was observed. This site lies beside the southern boundary of the proposed development site. Compared with this site and the one at Falcon (in the northern area of the development site), the shallow water sites at both Ward Point and Boundary Island consisted of sandier sediments. Sandier sediments in the Leschenault Inlet were also found to contain higher numbers of benthic organisms by LeProvost, Semeniuk & Chalmer (1983).

The species composition and abundance in samples obtained during this survey are not dissimilar with those recorded during a more intensive and long term research study by T. Rose (see Appendix A). Research data for Boodalan Island, an artificial island located in the eastern portion of the Peel Inlet, where the sediments are derived from dredge spoil deposited in 1972, supports the view that in Peel Inlet benthic communities with a typical composition and abundance will eventually return to disturbed sediments, or colonise comparable shallow areas containing similar but 'new' substrates (see Appendix A). For example, samples from spoil grounds at Boundary Island contain 'opportunistic' species such as *Capitella capitata* and *Prionospio* sp. (these polychaete worms are typically the first benthic invertebrates to colonise disturbed areas). The presence of two other polychaetes (*Australonereis ehlersi* and *Malaceros* sp. suggests that colonisation of the Boundary Island spoil grounds has entered a second stage in which detrital material has begun to accumulate within the substrate (T. Rose, pers comm.).

4 CONCLUSIONS

Benthic communities in the shallow water areas of estuaries form an important food source for fish and water birds, and are characterised by an ability to cope with extreme environmental variation.

The proposed development site appears to support an assemblage of benthic organisms that is not markedly richer (in terms of species richness and abundance) than those colonising other comparable areas in the Peel Inlet. The benthic assemblage identified at Cox Bay contains species that are capable of recolonising areas of disturbed sediments and colonising areas of new sediments within a short space of time.

If the newly exposed substrate is sandy in composition and does not become smothered by thick layers of silty sediments, it is reasonable to predict that a benthic assemblage of similar composition and abundance to that presently occurring will eventually redevelop within the project area. Since large accumulations of decomposing weed will be removed from the deepened area by floating harvesters, it is also possible that the overall abundance of benthic organisms may eventually rise beyond that currently colonising the surface sediments of Cox Bay, which are presently subjected to periodic anoxic conditions beneath the decomposing macroalgae.

5 REFERENCES

Atkinson, M. & Edward, D.H., 1984. *The Macroinvertebrate Contribution to Community Metabolism in the Peel-Harvey Estuary*. Unpublished report to the Department of Conservation and Environment, Western Australia.

Chalmer, P.N. & Hillman, K., 1985. The Likely Impact of the Proposed Dawesville Channel on the Benthic Fauna of the Peel-Harvey Estuarine System. In: *Peel-Harvey Estuarine System Study - Management of the Estuary*. Bulletin No. 195, Department of Conservation and Environment, Perth, Western Australia.

Lenanton, R.C.J., Loneragan, N.R., & Potter, I.C., 1985. Blue-green algal blooms and the commercial fishery of a large Australian estuary. *Marine Pollution Bulletin* 16 (12): 477-482.

Lenanton, R.C.J., Potter, I.C., Loneragan, N.R., & Chrystal, P.J., 1984. Age structure and changes in abundance of three important species of teleost in a eutrophic estuary (Pisces: Teleostei). *Journal of Zoology* 203: 311-327.

LeProvost, Semeniuk & Chalmer, 1983. *Effects of Discharges of Acid-Iron Effluent From Production of Titanium Oxide on the Abundance of Benthic Biota of Leschenault Inlet*. Leschenault Inlet Management Authority Report No. 4.

Loneragan, N.R., Potter, I.C., & Lenanton, R.C.J., 1989. Influence of site, season and year on contributions made by marine, diadromous and freshwater species to the fish fauna of a temperate Australian estuary. *Marine Biology* 103: 461-479.

Loneragan, N.R., Potter, I.C., Lenanton, R.C.J. & Caputi, N., 1986. Spatial and seasonal differences in the fish fauna in the shallows of a large Australian estuary. *Marine Biology* 92: 575-586.

Potter, I.C., Chrystal, P.J. & Loneragan, N.R., 1983. The biology of the blue manna crab *Portunus pelagicus* in an Australian estuary. *Marine Biology* 78: 75-85.

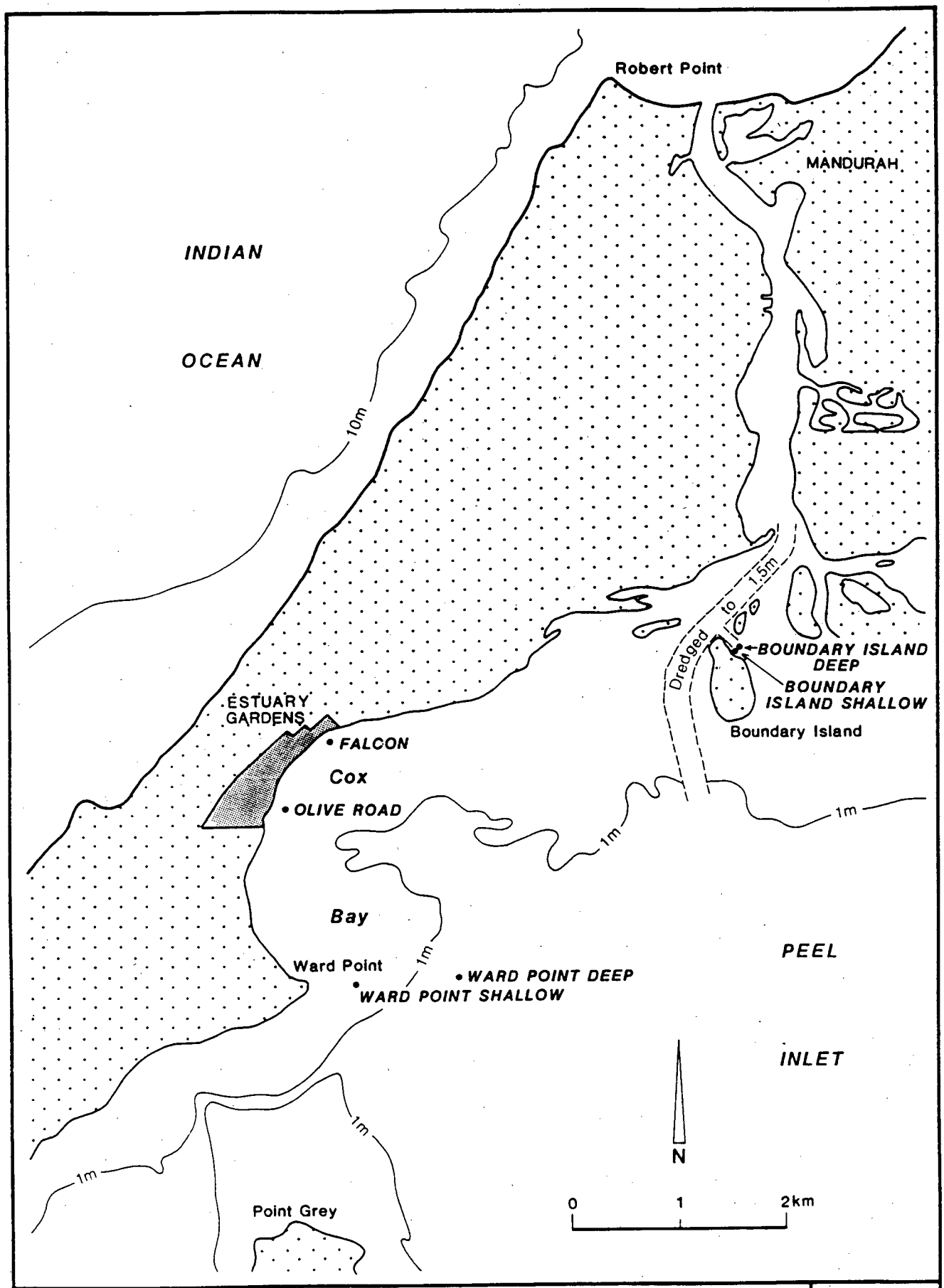
Wallace, J., 1977. *The Macrobenthic Invertebrate Fauna of Pelican Rocks, March-April, 1977*. Unpublished report to Department of Conservation and Environment and Public Works Department, Western Australia.

Table 1

Benthic Fauna Abundance at Cox Bay, Ward Point and Boundary Island During May 1990

	COX BAY				WARD POINT				BOUNDARY ISLAND			
	Olive Rd (N=5)		Falcon (N=5)		Shallow (N=5)		Deep (N=5)		Shallow (N=5)		Deep (N=5)	
SPECIES	x	x/m²	x	x/m²	x	x/m²	x	x/m²	x	x/m²	x	x/m²
Polychaetes												
Capitella capitata	17.8	2225.0	13.0	1625.0	10.4	1300.0	4.0	500.0	11.0	1375.0	1.8	225.0
Leitoscolopus normalis	0.2	25.0	-	-	1.0	125.0	0.4	50.0	7.8	975.0	-	-
Prionospio sp.	0.4	50.0	0.2	25.0	-	-	2.0	250.0	6.0	750.0	0.2	25.0
Malacoceros sp.	-	-	-	-	-	-	-	-	-	-	0.6	75.0
Certonereis aequisetis	-	-	10.4	1300.0	13.4	1675.0	2.0	250.0	37.4	4675.0	-	-
Australonereis ehlersi	-	-	-	-	1.0	625.0	0.2	25.0	20.4	2550.0	0.6	75.0
Total	**18.4**	**2300.0**	**23.6**	**2950.0**	**25.8**	**3225.0**	**8.6**	**1075.0**	**82.6**	**10325.0**	**3.2**	**400.0**
Molluscs												
Arthritica semen	6.8	850.0	37.6	4700.0	53.0	6625.0	18.2	2275.0	1.8	225.0	0.8	100.0
Sanguinolaria biradiata	-	-	-	-	-	-	-	-	0.2	25.0	-	-
Total	**61.4**	**850.0**	**37.6**	**4700.0**	**53.0**	**6625.0**	**18.2**	**2275.0**	**2.0**	**250.0**	**0.8**	**100.0**
Crustaceans												
Tanaeus dulongi	12.8	1600.0	69.8	8725.0	38.8	4850.0	1.6	200.0	0.8	100.0	-	-
Corophium minor	42.8	5350.0	73.0	9125.0	42.2	5275.0	1.2	150.0	15.6	1950.0	1.4	175.0
Melita zeylanica	1.6	200.0	2.2	275.0	30.8	3850.0	3.4	425.0	1.0	125.0	0.6	75.0
Tethygenia eleanora	4.2	525.0	-	-	-	-	0.2	25.0	-	-	0.2	25.0
Gastrosaccus dakini	-	-	-	-	-	-	0.2	25.0	0.2	25.0	-	-
Total	**61.4**	**7675.0**	**145.0**	**18125.0**	**111.8**	**13975.0**	**6.6**	**825.0**	**17.6**	**2200.0**	**2.2**	**275.0**
Miscellaneous												
Nemertean	0.4	50	-	-	-	-	-	-	-	-	-	-
OVERALL TOTAL	87.0	10875.0	206.2	25775.0	190.6	23825.0	33.4	4175.0	102.2	12775.0	6.2	775.0

Where: N = Number of samples taken;
x = Average number of individuals recorded;
x/m² = Average number of individuals per square metre; and
- = No individuals recorded.



MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

BENTHIC FAUNA SAMPLING SITES

Figure 1

Auth : AMS | Date : 9/90

Geodraft

Fish Resources of the Peel-Harvey System and Benthic Infauna of Cox Bay

APPENDIX A

REPORT ON BENTHIC MACROFAUNA AND REGIONAL SIGNIFICANCE OF COX BAY, PEEL INLET,

by

Tom Rose
Fisheries Group
Murdoch University, W.A.

LEC REF: J192

COX BAY, PEEL INLET

THE MACROBENTHOS

OBSERVATIONS/RESULTS OF REGULAR AND INFREQUENT SAMPLING 1985 - 1988

1 HABITAT CHARACTERISATION

Cox Bay is a moderately sheltered soft bottom shallow embayment of the south-western Peel Inlet. The shallow nature of the bay (<1.5 m) makes it susceptible to wind driven fetches either directly from the north and north-east or indirectly from the south and south-west. One result is that the sediments in the top 10 cm are generally well sorted and are dominated according to weight by medium sands (0.2 - 0.6 mm) 70%, coarse sands (0.6 - 2.0 mm) 16%, fine sands (0.06 - 0.2 mm) 8%, and silts and clays (<0.002 - 0.06 mm) 4%. Particulate organic matter varies from 1.5% of the sediment in winter to 2% in the summer. Neither wind induced turbidity or phytoplankton blooms reduced Secchi readings to less than 35 cm. The proximity of the bay to the deepened Entrance Channel means that physico-chemical conditions may be buffered by marine influences despite weak tidal movements. Bottom salinities thus range from 11 ppt in winter to 40 ppt in summer and autumn, temperatures from 13^0 C in winter to 26^0 C in summer, and dissolved oxygen concentrations from 8 ppm in winter to 6.8 ppm in summer, although values of zero were recorded in hot still conditions at night.

As a consequence of eutrophication, wind patterns and flushing of estuarine waters, there is seasonal entrapment and deposition of plant-derived material in the bay. Major phytoplankton blooms and deposition of material from these blooms occurs in winter and spring, mainly from diatoms and *Nodularia* respectively. Drifting macroalgae (*Chaetomorpha* and *Ulva* spp.) is entrapped or deposited during summer and autumn, and sometimes in early winter. Decomposing biological material contributes significantly to the oxygen reduction depths of the sediment and thus Redox depths vary from 0.8 cm deep in winter to 1.5 cm deep in summer. The presence of decomposing macroalgae generally reaches its peak in autumn and this can reduce the Redox depth to zero in the immediate area of deposition but values of 0.5 cm are common for the whole embayment.

Environmental conditions of this area are influenced by diurnal, weekly, biweekly, seasonal and annual events. For example, wind patterns generally last five to ten days, periods of hypoxia and anoxia the same or less and periods of freshwater flushing or reduced salinities several weeks to several months.

2 BIOTA AND REGIONAL SIGNIFICANCE OF COX BAY

Sediment, environmental conditions, eutrophication and abundant detritus has created a predominantly deposit feeding macrobenthic community. The only exception is the very limited areas of rock outcrops found near Falcon in the north of Cox Bay. These outcrops are generally covered by suspension feeding colonies of the serpulid polychaete, *Ficopomatus enigmaticus* (formerly *Mercierella enigmatica*). The macrobenthic community is patchy in distribution and low in species diversity but the productivity and abundance of this impoverished suite of invertebrates can be extremely high. Production is not continuous however, it is punctuated by periods of rapid decline and even denudation when extreme estuarine conditions such as anoxia occur for extended periods.

Recovery is quick because patches which aren't disturbed have species which are eruptive in nature (r-strategists) and often do not live longer than a year. Exceptions are found in several species of larger and longer living (= or >1 year) polychaetes (Nereids, Orbinids) and some bivalve molluscs (Tellinids, Mytilids). Most polychaetes, e.g. *Capitella* spp., amphipods, e.g. *Corophium* sp., pericarids, e.g. *Tanais* sp. and microbivalves, e.g. *Arthritica* sp. are fecund throughout the year. Furthermore evidence suggests that drifting macroalgae acts as a non-benthic refuge and focus for recolonisation of the benthos if the benthos is completely anoxic, particularly for amphipods. Peak abundances of crustaceans usually occur in autumn while capitellid polychaetes are more abundant in winter and spring. Larger and longer living polychaetes, e.g. *Ceratonereis* sp., generally reach peak densities in summer. In contrast the microbivalve, *Arthritica* sp., displays no apparent seasonal trends.

Preliminary classification analyses have indicated that the Cox Bay benthic community has a closer affinity to the benthic communities of the northern Harvey Estuary than to Boodalan Island in eastern Peel Inlet. Nevertheless the abundance and productivity of the macrobenthos combined with the abundant epifauna of the macroalgal drift (mainly amphipods) means that the area is extensively utilised by foraging teleosts, decapod crabs and shrimp and piscovorous birds. In biological terms Cox Bay is a valuable and productive habitat and probably representative of the shallows found near Coodanup and Robertsons Bay in the Peel Inlet. Care should however be taken when comparing Cox Bay to Boodalan Island, as the latter is rockier, has coarser sediments and numerous mussel beds.

Falcon Sticks - Cox's Bay, Peel Inlet

Peel-Harvey Estuarine System

Benthic Macrofauna Species List and Abundance per square metre

Winter, 1987 Total Number of Species: 14

Taxa	Abundance/m2
Polychaetes	
Nereididae	
1. Ceratonereis aequisetis	340
Orbiniidae	
2. Leitoscolopos normalis	280
Capitellidae	
3. Capitella capitata complex	9420
Spionidae	
4. Spionid sp.1	120
Serpulidae	
5. Ficopomatus enigmaticus (substrate limited)	<100
Crustaceans	
Amphipods	
Melitidae	
1. Melita zeylanica	340
Aoridae	
2. Grandidierella sp.1	2660
Corophiidae	
3. Corophium minor	5780
Eusiridae	
4. Tethygenia elanora	2720
Peracarideans	
Tanaidacea	
5. Tanais dulongi	4340
Molluscs - Bivalvia	
Leptonidae	
1. Arthritica semen	3780
Trapeziidae	
2. Fluviolanatus subtorta	20
Nemertines	
1. Nemertine sp.1	80
Anthozoa	
1. Anemone sp.1 (substrate limited)	<40

Summer, 1987 Total Number of Species: 18

Taxa	Abundance/m2
Polychaetes	
Nereididae	
1. Ceratonereis aequisetis	620
Orbiniidae	
2. Leitoscolopos normalis	180
Capitellidae	
3. Capitella capitata complex	6280
Spionidae	
4. Boccardiella limnicola	320
Serpulidae	
5. Ficopomatus enigmaticus	2060
Crustaceans	
Amphipods	
Melitidae	
1. Melita zeylanica	720
2. Melita matilda	160
Aoridae	
3. Grandidierella sp.1	1420
Corophiidae	
4. Corophium minor	1020
Peracarideans	
Tanaidacea	
5. Tanais dulongi	420
Isopods	
Sphaeromatidae	
6. Syncassidina aestuaria	80
Anthuridae	
7. Amakusanthura sp.1	40
Molluscs - Bivalvia	
Leptonidae	
1. Arthritica semen	2040
Mytilidae	
2. Xenostrobus securis	120
Trapeziidae	
3. Fluviolanatus subtorta	20
Tellinidae	
4. Tellina deltoidalis	40

Nemertines	
1. **Nemertine sp.1**	100
Anthozoa	
1. **Anemone sp.1**	80

Boodalan Island, Peel Inlet

Macrobenthic Species List and Abundance per square metre

Winter, 1987 Total Number of Species: 19

Taxa	Abundance/m2
Polychaetes	
Nereididae	
1. Ceratonereis aequisetis	920
Orbiniidae	
2. Leitoscolopos normalis	160
Spionidae	
3. Boccardiella limnicola	2200
4. Spionid sp.1	20
Capitellidae	
5. Capitella capitata complex	3940
Serpulidae	
6. Ficopomatus enigmaticus	20
Crustaceans	
Amphipods	
Melitidae	
1. Melita zeylanica	60
2. Melita matilda	260
Aoridae	
3. Grandidierella sp.1	100
Corophiidae	
4. Corophium minor	18240
5. Paracorophium excavatum	20
Eusiridae	
6. Tethygenia elanora	120
Peracarideans	
Tanaidacea	
7. Tanais dulongi	4780
Isopods	
Sphaeromatidae	
8. Syncassidina aestuaria	20
Molluscs - Bivalvia	
Leptonidae	
1. Arthritica semen	1060
Mytilidae	
2. Xenostrobus securis	780

Nemertines	
1. Nemertine sp.1	260
Anthozoa	
1. Anemone sp.1	500
Turbellarians	
1. Notoplana sp.	40

Boodalan Island, Peel Inlet

Macrobenthic Species List and Abundance per square metre

Summer, 1987 Total Number of Species: 11

Taxa	Abundance/m2
Polychaetes	
Nereididae	
1. Ceratonereis aequisetis	3940
Orbiniidae	
2. Leitoscolopos normalis	240
Spionidae	
3. Boccardiella limnicola	1240
Capitellidae	
4. Capitella capitata complex	500
Crustaceans	
Amphipods	
Aoridae	
1. Grandidierella sp.1	2720
Corophiidae	
2. Corophium minor	220
Peracarideans	
Tanaidacea	
3. Tanais dulongi	2940
Molluscs - Bivalvia	
Leptonidae	
1. Arthritica semen	5020
Mytilidae	
2. Xenostrobus securis	380
Anthozoa	
1. Anemone sp.1	220
Nematodes	
1. Nematode sp.1	20

Meiyu Australia Pty Ltd

Estuary Deepening

Cox Bay, Falcon

Public Environmental Review

APPENDIX 5

WATERBIRD USAGE AND CONSERVATION STATUS OF COX BAY

LEC REF: J192/R328

WATERBIRD USAGE AND CONSERVATION STATUS

OF COX BAY

Report to : LeProvost Environmental Consultants,
Suite 2, 1st Floor,
175 Labouchere Road,
COMO WA 6152.

by : Ninox Wildlife Consulting,
22 Civic Drive,
WANNEROO WA 6065.

September 1990

WATERBIRD AND CONSERVATION STATUS OF COX BAY

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WATERBIRD USAGE AND CONSERVATION STATUS OF COX BAY

1.0 INTRODUCTION

This report was commissioned by LeProvost Environmental Consultants and describes the waterbird usage and conservation status of the estuarine environment of Cox Bay adjacent to the Falcon settlement on Peel Inlet. Meiyu Australia Pty Ltd are proposing an excavation programme within the offshore shallows of this location. An area to the south of the Falcon boat ramp, some 1,150 m in length and extending up to 380 metres offshore will be excavated, involving a total area in the region of 43 ha. An island will be formed from part of the spoil spoil will also be constructed. Figure 1 (p.12) shows a plan of the project area. Detailed descriptions of the scope of the development are given in the text of the PER and in Appendix 2.

In 1988 the Mosquito Control Review Committee (MCRC) of the Waterways Commission contracted Ninox Wildlife Consulting, the authors of this current report, to carry out a study of Peel Inlet in order to define the significance of mosquito breeding areas to waterbirds. The study also required that where such areas were adjacent to the shoreline of the inlet, nearby offshore locations were to be assessed. Thirty-eight sampling sites were established, three of which lay within or very close to the area where dredging is planned (Waterways Commission, 1990). The data collected at each site included habitat sub-unit utilisation and the type of waterbird activity which took place within them.

All sites, including the three Falcon sites were monitored for waterbirds and shorebirds on nine occasions from November 1988 to December 1989; survey dates are given below:

Table 1: Survey periods conducted at Peel Inlet between November 1988 and December 1989.

SURVEY	DATE
1	November 18, 1988
2	January 7, 1989
3	February 21, 1989
4	April 13, 1989
5	June 1, 1989
6	July 25, 1989
7	September 11, 1989
8	October 25, 1989
9	December 12, 1989

A total of 61 species of bird and 45,969 individuals were recorded throughout northern Peel Inlet during the MCRC survey, with accessory habitat and activity data also noted for each record. This information was stored on computer for later retrieval by a database programme. The MCRC has generously allowed access to the relevant sections of this database prior to publication of their mosquito breeding area/waterbird report.

1.1 Study objectives

The primary objectives of this study are to:

- describe the existing environment and conservation status of the project area in terms of its waterbird and shorebird populations;
- document relative habitat sub-unit usage and describe the various waterbird and shorebird activities which take place within them;
- document any species or habitat sub-units of particular significance;
- assess the possible impact of dredging in a local and regional context; and
- recommend management strategies to reduce any potential impact of the project on birdlife.

2.0 METHODS

Since the MCRC mosquito study is the most current, comprehensive and relevant source which also includes accessory information on habitat sub-units and waterbird behaviour, this pre-existing database has been mainly used in the following report, rather than unnecessarily repeating an extensive field survey programme. Other reference sources used are: Blakers et al. (1984); Jaensch et al. (1988); Waterways Commission (1989); Wright (1986, 1988).

Mosquito breeding survey sites 35, 36, 37 which are located at Falcon (Waterways Commission, 1990) were sub-filed from the main Peel database and analysed in detail for this proposed dredging project. The following habitat sub-units and activities have been used in the text.

Habitats: beachfront, tidal flats, sandspits, shallows (<30 cm), inlet perches, deeper water (>30 cm).

Activities: feeding, roosting, loafing (i.e resting or directionless drifting), flying, breeding and "other", the latter referring to behaviour such as unseen birds calling, or birds that were flushed before their activity could be recorded.

3.0 RESULTS AND DISCUSSION

Twenty-nine species of waterbird (Table 1, p.1) were recorded in Cox Bay and on the shoreline adjacent to Falcon during the series of MCRC surveys; 4,379 individual birds were counted. These results represent 48% of all species and 10% of all individuals logged at Peel Inlet during the 1988-1989 MCRC surveys.

Table 2: List of waterbird species and number of individuals recorded at Cox Bay during the Peel Inlet waterbird study from October 1988 to December 1989.

= Species covered by international treaties.

BIRD SPECIES		NUMBER OF INDIVIDUALS
PODICIPEDIDAE		
Podiceps cristatus,	Great Crested Grebe	1
Poliocephalus poliocephalus,	Hoary-headed Grebe	26
PELECANIDAE		
Pelecanus conspicillatus,	Australian Pelican	335
ANHINGIDAE		
Anhinga melanogaster,	Darter	52
PHALACROCORACIDAE		
Phalacrocorax carbo,	Great Cormorant	4
P. varius,	Pied Cormorant	22
P. sulcirostris,	Little Black Cormorant	20
P. melanoleucos,	Little Pied Cormorant	473
ARDEIDAE		
Ardea novaehollandiae,	White-faced Heron	73
Egretta alba,	# Great Egret	30
E. garzetta,	Little Egret	11
ANATIDAE		
Cygnus atratus,	Black Swan	4
Tadorna tadornoides,	Australian Shelduck	264
Anas superciliosa,	Pacific Black Duck	165
A. gibberfrons,	Grey Teal	504
CHARADRIIDAE		
Pluvialis squatarola,	# Grey Plover	2

TABLE 2: continued

BIRD SPECIES		NUMBER OF INDIVIDUALS
RECURVIROSTRIDAE		
Himantopus himantopus,	Black-winged Stilt	217
Recurvirostra novaehollandiae,	Red-necked Avocet	23
SCOLOPACIDAE		
Arenaria interpres,	# Ruddy Turnstone	4
Tringa brevipes,	# Grey-tailed Tattler	1
T. hypoleucos,	# Common Sandpiper	3
T. nebularia,	# Greenshank	41
Limosa lapponica,	# Bar-tailed Godwit	10
Calidris tenuirostris,	# Great Knot	2
C. acuminata,	# Sharp-tailed Sandpiper	4
C. ferruginea,	# Curlew Sandpiper	35
LARIDAE		
Larus novaehollandiae,	Silver Gull	2009
Hydroprogne caspia,	# Caspian Tern	17
Sterna bergii,	Crested Tern	27
TOTAL		4379

3.1 Seasonality

Waterbird populations peaked in February 1989 with the arrival of trans-equatorial migratory shorebirds from the Northern Hemisphere then slowly declined until October of the same year when ducks from the arid zone arrived for the spring breeding period (Figure 2, p.13). In reality, the figures for January and December 1989 should be higher than they appear in this diagram; high tides and resulting deep water excluded many birds, particularly wading species from feeding zones during these survey periods.

3.2 Habitat utilisation

Figure 3 (p.13) shows the number of species recorded in each of the six habitat sub-units sampled in and adjacent to Cox Bay, and it can be seen that shallows (<30 cm) followed by the beachfront and sandspits are the three most species rich sub-units. Similarly, when the number of individual birds are graphed (Figure 4, p.14), shallows once again register as an apparently significant area for waterbirds, closely followed by sandspits. However, in terms of unit area, shallows dominate all other sub-units, are productive feeding areas and could therefore be expected to be both rich in both waterbird species and individuals because of their greater representation. Per unit area, the beachfront, inshore tidal flats and sandspits are

almost certainly the most significant habitats, although affecting one of these interdependent zones can have an impact on the other. Tidal flats, for example, can operate as shallows during high tides as can sandspits. Deeper water greater than 30 cm is relatively poorly used despite the large area available.

3.3 Activity patterns

Overall, waterbird behaviour patterns in the project area are dominated by roosting (51% of all activity) and feeding (31%); all other activities are negligible (Figure 5, p.14).

Waterbird activities have been further explored in Figure 6 (p.15) by expressing the behaviour categories recorded in each habitat sub-unit as a percentage of the total number of birds censused in that particular zone. This diagram shows that tidal flats and shallows are dominated by feeding behaviour, roosting is the main activity which takes place on the beachfront and equally so on sandspits and perches in the inlet. The next highest behaviour category is loafing or drifting which naturally occurs in shallows and deeper water. These activities within sub-units are not fixed but represent the broad trends apparent during nine sampling days in 1988 and 1989. The dates chosen for each survey were random within seasonal limits and the proportion of low tides to high tides was nearly equal.

4.0 CONCLUSIONS

4.1 Significant species

Significant species can be defined as those birds which are either:

- classified under the Wildlife Conservation Act (1950) as "rare, or otherwise in need of special protection";
- covered by international treaties for the protection of migratory birds and their environment (Japan/Australia or China/Australia Agreements); or,
- specialised in their behaviour such that they are sensitive to disruption.

No waterbirds known to occur in the project area are classified as rare under the current Act. Eleven waterbirds, mainly trans-equatorial migrants, are protected under previously-mentioned international treaties. Most waterbirds, and particularly shorebirds, are by their nature specialised but no single species which is known to occur in the project area is under any long-term threat from the development.

4.2 Significant habitats

Estuarine habitat sub-units are dynamic and interdependent. Each plays an important role in maintaining waterbird populations. The various zones are partitioned between groups of species with physical attributes which allows them to take advantage of particular depths of mud, sand, water, benthic invertebrates or, indeed move freely between a range of habitats. In many cases these zones are not fixed since the area of available intertidal resources can fluctuate from day to day making it difficult to allocate higher levels of significance to one element or another. However, if rich feeding areas are taken to be the most basic need of waterbirds, particularly for trans-equatorial migrant which need to rapidly gain condition before and after journeys of thousands of kilometres, intertidal flats and shallows therefore play a very significant role because of the richness of their littoral and sub-littoral invertebrate fauna.

4.3 Regional and local status

Peel Inlet has long been recognised as an extremely important conservation area and has therefore been designated as a wetland of international significance since it at times supports greater than 20,000 waterbirds including 27 species cited in the Japan/Australia (JAMBA) and China/Australia (CAMBA) Migratory Birds Agreement. A total of 83 species of waterbird and associated species have been recorded over time at the Peel Inlet and associated wetlands. Its importance is also highlighted by the extremely large numbers of Banded Stilts which occur during dry years and the frequent, large congregations of Black Swans, duck and

cormorant species. Up to 100,000 individual waterbirds have been recorded during a single survey.

The inlet is also extremely important for migratory wading birds, supporting up to 30,000 in February 1977. Large numbers of the less common or rarer species have also been recorded utilising the inlet. These include birds such as the Whimbrel, Eastern Curlew, Lesser Golden Plover, Large Sand Plover, Marsh Sandpiper, Pectoral Sandpiper and the Black-tailed Godwit. The following birds which have been recorded at Peel Inlet are listed in Jaensch et al. (1988) as being present in less then five wetland reserves during the course of their 1981-5 study: Grey-tailed Tattler; Whimbrel and White-winged Black Tern.

Of these rarer or uncommon species only one, The Grey-tailed Tattler, was recorded at Cox Bay during the MCRC surveys. This record represented one of the two individuals seen at Peel Inlet in the survey period but there is no reason to assume that the species has any particular link with the project area rather than the many other suitable sites available to this bird.

As indicated earlier, the project area supported, or was used by 48%, of all species and 10% of all individuals recorded during the 1988-1989 surveys. This is a fairly high proportion considering the habitat uniformity of the location and stands up well against other productive areas such as the Soldier's Cove, Sticks Channel and Lake Goegrup series of sites (Waterways Commission, 1990). However there are several more significant areas on Peel Inlet, with the Murray/Serpentine River delta being a typical example. Forty species of bird (66% of total) and 9290 individuals (20%) were noted in this location. The project area is therefore locally important but not necessarily significant. However, at least 11 of the 27 migratory species protected by international agreements use the area and account needs to be taken of these during the project design phase.

4.4 Impact of the project

The main impacts of the project are judged to be:

- a substantial loss of feeding habitat through deepening of previously accessible intertidal areas;

- increased disturbance to birds on the narrow shoreline as the area becomes more developed and the beach is used by people and dogs much more frequently than at present.

Noise, light and increased boat traffic are not seen to be significant impacts since there is local evidence clearly indicating that waterbirds and migratory shorebirds habituate to these disturbances provided that there are inaccessible areas where they cannot be approached too closely by humans and dogs. Soldier's Cove is a typical example and is one of the range of sites assessed during the MCRC surveys. Despite the small size of this area (relative to Cox Bay), 26 species and 1888

individual birds were recorded. Soldier's Cove is high-density development, noisy, well-lit and carries heavy boat traffic in the adjacent dredged channel. Its productivity is due to the presence of an offshore island which provides refuge to birds disturbed from the small area of shoreline available to them. This naturally begs the question as to how productive the area was pre-development, but graphically shows that waterbirds and development are not mutually exclusive, and that sensitively planned projects provided with refuge areas can assist in overcoming a significant proportion of adverse impact.

The impact of the project, while locally substantial in that it will alienate some 43 hectares of rich intertidal zone, is unlikely affect the inlet to the point that bird populations will show a marked reduction, considering that up to 100,000 birds have been recorded at Peel in one survey and that numbers naturally fluctuate in the normal course of events. It will, however, result in pressure being applied to adjacent, perhaps less-favoured areas as birds seek alternative feeding sites. Some competition for food supplies may therefore occur but it is clear that in most years the inlet supports less birds than its apparent capacity. The influx of several times the normal population level when inland droughts occur underlines this aspect, although it may well be that on these occasions, when competition for resources is higher, the impact of the loss of 43 ha of feeding grounds could have a greater short-term impact.

With projects such as this, it is generally not their low probability of adversely and permanently affecting a much wider area, but more the piecemeal contribution they make to the continuing attrition of valuable wetlands. For this reason, impact management techniques are an essential part of the development process.

5.0 IMPACT REDUCTION STRATEGIES

Timing of excavation: Figure 2 (p.13) shows that there is a marked reduction in the number birds using Cox Bay between May and September. This period coincides with the absence of migratory wading birds which are breeding in the Northern Hemisphere at this time. These species are covered by international agreements. Further, resident birds have also not commenced breeding. Excavation between May and September will minimise short-term disruption to species which may be attempting to gain condition before migration or, perhaps more importantly, already-stressed recent migrants which may not have the reserves to cope with being regularly disturbed from traditional feeding grounds by heavy equipment.

It is therefore recommended that the dredging programme commences and ends within the above period.

Post-dredging rehabilitation: it is inevitable that a large proportion of the Cox's Bay intertidal zone and shallows will be alienated by dredging, in that previously accessible areas will be too deep for a range of species, especially wading shorebirds. This represents a substantial, localised loss of rich feeding areas which needs to be taken into consideration during the works programme.

In order to reduce this effect, the following impact reduction strategies are recommended:

- Dredging spoil is used to construct islands as waterbird refuges. These should be planted with a range of trees and shrubs as well as native bunch grasses. Boodalan Island, due east of Cox Bay, was formed from the Yunderup Canal Project spoil and has a naturally re-vegetated ground cover of bunch grass which is used for nesting by a surprising number of ducks (W.K. Youngson, personal observation). The isolation of this island from terrestrial predators almost certainly accounts for this high density breeding.

- Some islands should be low relief and devoid of vegetation. These act as roosts and, if large enough, are used for breeding by Pelicans and Fairy Terns. Pelican breeding took place on Boodalan Island soon after its construction and the recently constructed Boundary Island near Sticks Channel has already encouraged substantial breeding by both the above species. Pelicans are not known to have bred on Peel Inlet except on these artificial islands and Fairy Tern colonies are very uncommon.

- During the construction of islands, a primary consideration should be to create extensive shallows at their base in order to encourage some of the waterbirds which will be disadvantaged by dredging.

- Sandspits are not disturbed during dredging operations and are not used as spoil dumping areas. These are traditional roosting areas for large numbers of birds (Figure 4, p.14). However if it is possible to extend spoil from the

existing limits of sandspits without disturbing their integrity, this may be advantageous.

- Where excess spoil can be used to lessen the depth of water away from the project area and create shallows or an intertidal zone, this could eventually assist in overcoming the adverse impacts of the development when the new area is re-colonised by invertebrates.

REFERENCES

Blakers, M., Davies, S.J.J.F. & Reilly, P.N. (1984). The Atlas of Australian Birds. Melbourne University Press.

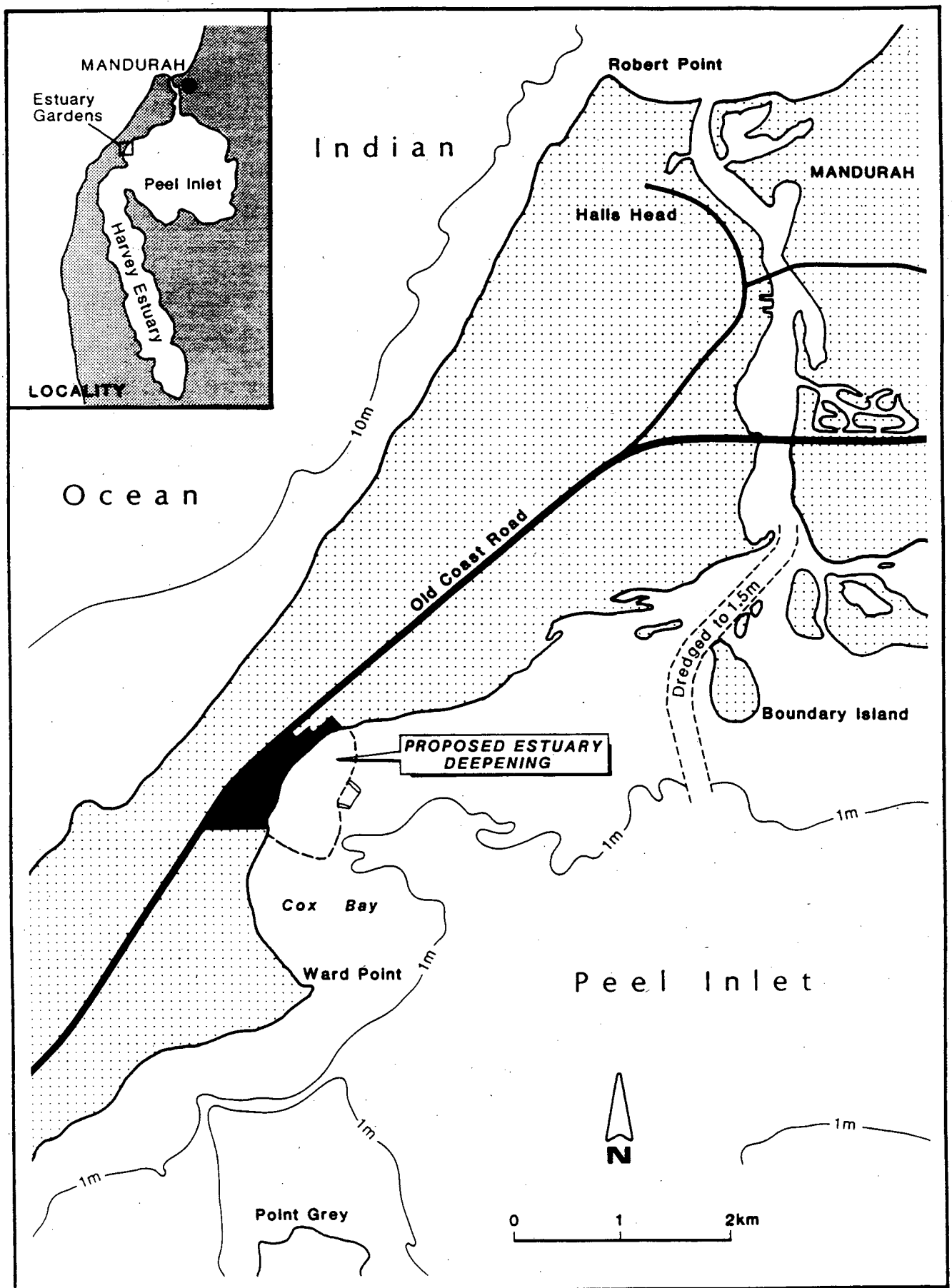
Jaensch, R.P., Vervest, R.M. & Hewish, M.J. (1988). Waterbirds in Nature Reserves of South-Western Australia 1981-1985: Reserve Accounts. Royal Australian Ornithologists Union. Report No. 30.

Ninox Wildlife Consulting (1989). The significance of mosquito breeding areas to the waterbirds of Leschenault estuary, Western Australia. Waterways Commission, Report No. 14.

Ninox Wildlife Consulting (1990). The significance of mosquito breeding areas to the waterbirds of Peel Inlet, Western Australia. Waterways Commission, Report No. 20.

Wright, A.E. (1986). Survey of mosquitoes in the Bunbury region, W.A. Health Dept. of West. Aust.

Wright, A.E. (1988). Survey of mosquitoes in the Mandurah region, W.A. Health Dept. of West. Aust.



COX BAY, FALCON

LOCALITY PLAN

Figure **1**

Auth : PC | Date : 9/90

Environmental Drafting

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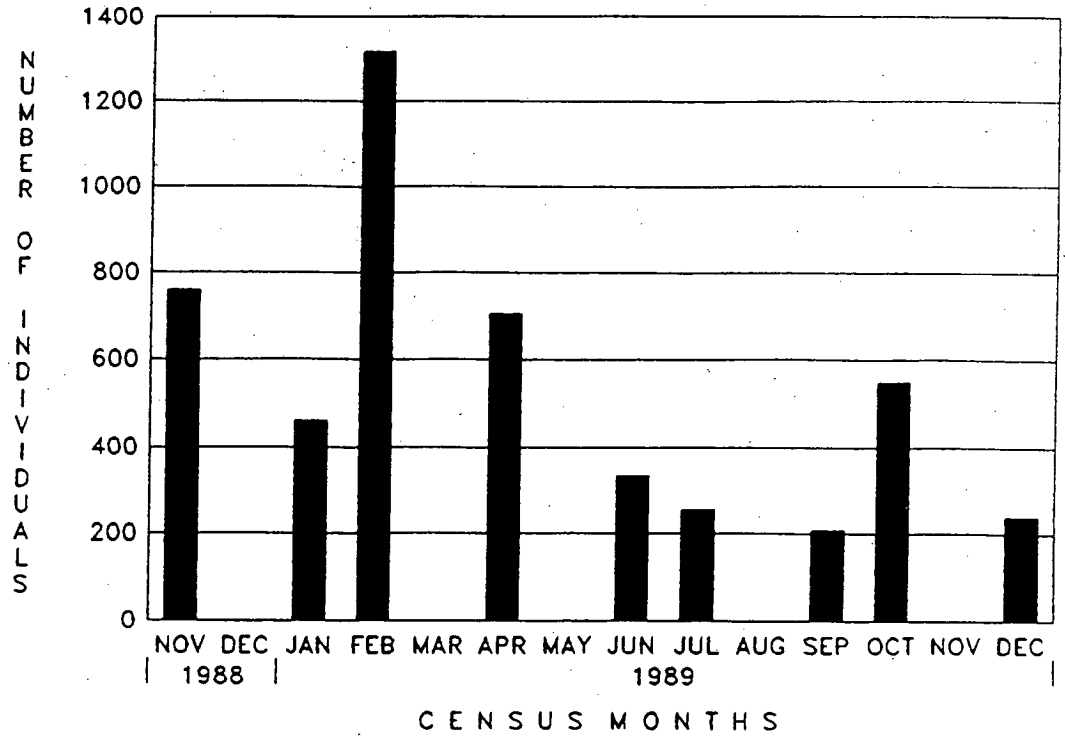

Figure 2: Seasonal fluctuations of waterbird populations in the vicinity of Falcon between November 1988 and December 1989.

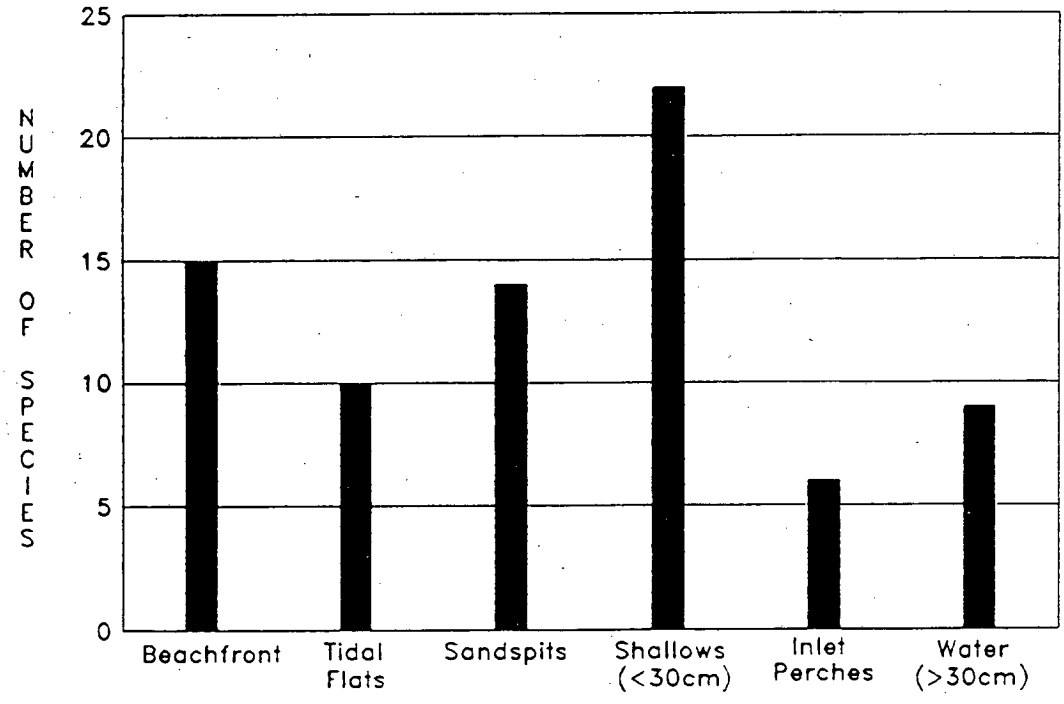

Figure 3: Number of waterbird species recorded in habitat sub-units in and adjacent to Cox Bay between November 1988 and December 1989.

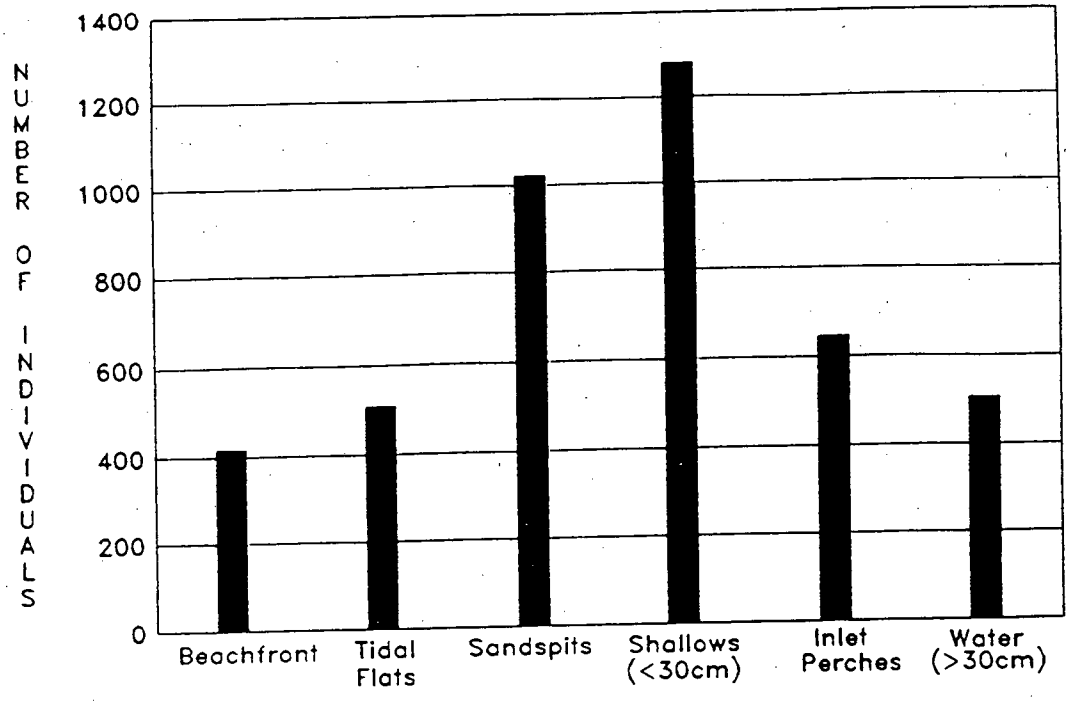

Figure 4: Number of waterbird individuals recorded in habitat sub-units in and adjacent to Cox Bay between November 1988 and December 1989.

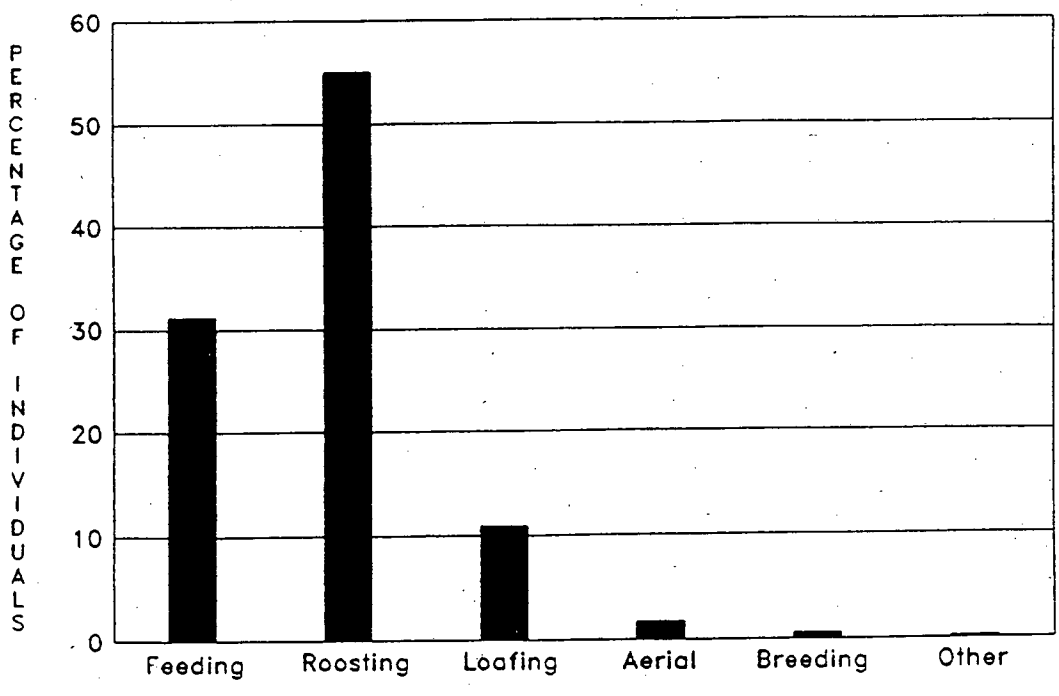

Figure 5: Diagram showing overall habitat activity patterns in the project area. Activity is expressed as a percentage of all individuals recorded.

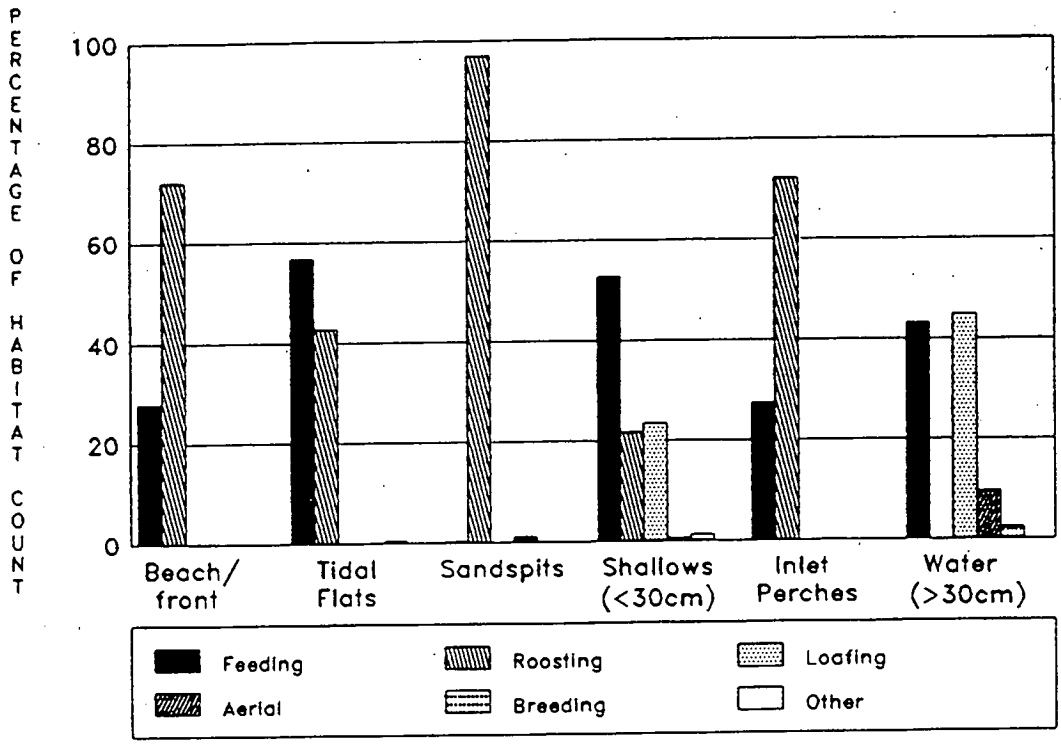

Figure 6: Diagram showing the relationship between habitat sub-units and waterbird activity patterns. Activity is expressed as a percentage of all records logged in a particular zone.

Meiyu Australia Pty Ltd

Estuary Deepening

Cox Bay, Falcon

Public Environmental Review

APPENDIX 6

REPORT ON A SURVEY FOR ABORIGINAL SITES

LEC REF: J192/R328

REPORT ON A SURVEY FOR

ABORIGINAL SITES

ESTUARY GARDENS PROJECT

Prepared for LeProvost Environmental Consultants

by

R.O'Connor and G. Quartermaine

October 1990

PART ONE

ETHNOGRAPHY

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Figure 1: Location of Survey Area

1.0 INTRODUCTION

1.1 Background

This report, which is based on a period of field research carried out in April, 1990, was commissioned by LeProvost Environmental Consultants. The aim of the research was to consult with Aboriginal people who retain traditional and current links with the Mandurah region, to ensure that development of the proposed Estuary Gardens Project does not impact any areas of Aboriginal significance (see Figure One for location of survey are). At the same time, and in recognition of the possible archaeological significance of the areas to be impacted by the proposed development, an archaeological survey was conducted by Gary Quartermaine. Part Two of this report details the results of that survey.

1.2 Acknowledgements

The research was conducted by R.O'Connor, who gratefully acknowledges the assistance and advice given by Mr. F. Nannup and the Windjan Progress Association.

1.3 Research Brief

The research brief required the researchers to ascertain whether any areas of Aboriginal significance, within the meaning of Section 5 of the W.A. *Aboriginal Heritage Act*, 1972-1980, are located within the area of the proposed development. If such exist, they are to be reported in sufficient detail and in a format suitable for submission to the Western Australian Museum's Department of Aboriginal Sites, together with recommendations for their protection and management.

2.0 ABORIGINAL SITES IN SOUTH - WESTERN AUSTRALIA

2.1 Anthropological Considerations

The Aboriginal political geography of South-Western Australia has been described in O'Connor (1984 and 1985) and O'Connor and Quartermaine (1986 and 1987). The following summarised points are relevant to the present exercise.

2.1.1 South-Western Aborigines were a distinct sociocultural group in pre-contact times.

2.1.2 Dialectal variation occurred within a single South-Western language family.

2.1.3 A regional system of land tenure, based on either kinship or dialectal units existed.

2.1.4 As contemporary accounts of these systems are internally inconsistent and sometimes contradictory, it is now impossible to reconstruct the pre-contact political geography of the region.

2.1.5 Territorial separateness disappeared soon after European settlement, due to population movements, deaths and the development of the fringe camps (and later settlements and "missions").

2.1.6 The development of a widely-scattered population of mixed - ethnic background, who live in the South-West of this State, see themselves as sharing a common identity and refer to themselves as "Nyungars" occurred during the nineteenth century.

2.1.7 Continuity with the traditional past, knowledge of regional mythology and knowledge of areas of religious significance were passed to the present senior adult generation of Nyungars by a pivotal generation of culture transmitters. Among these, in the Metropolitan Region were Maitland Sandy, Chitty Hedland, Daglish Granny, Sam Broomhall, Herbert Dyson, Bulyil, Wandi,

Nyinda Bropho, Lottie Harris and Ollie Worrell; and in the Murray River region were George Windjan, who settled in Mandurah, and Kitty, who settled in Pinjarra. The two last-named were survivors of the Battle of Pinjarra.

2.1.8 There is now a determination among the present senior adult generation to protect remaining areas of significance from development.

2.2 "Significance"

"Significance", in the survey area is attributed by Aboriginal people on the basis of former or current domestic usage, or on the basis of relevance to traditional ritual or mythology. Broadly speaking, this distinction can be viewed as a series of dichotomies between historical and mythological, human and supernatural, or mundane and sacred areas. Thus, one area may be viewed as significant from a historical/human/mundane viewpoint, and another from a mythological/supernatural/sacred viewpoint.

As noted by O'Connor and Quartermaine (1989) in a recent report to the Water Authority of Western Australia (Aboriginal Site Survey of Proposed Jandakot Mound Borefield), a substantial number of Aboriginal sites are mentioned in Hammond (1933), Moore (1885), Bates (numerous dates) and other historical sources. Any sites not known to contemporary Aborigines cannot reasonably be classified as "sites of significance to living Aborigines." However, rediscovery or realization of the existence of such sites, could lead to an attribution of significance. The history of Western Australian Museum (archaeological) site number S0999 is a clear example of this: in that case, a 40,000 year old archaeological site, which was discovered by chance, has become an area of importance and significance to Aboriginal people from the Swan Valley (see Pearce and Barbetti [1981] for a description of this site). Therefore, the neat compartmentalization resulting from European academic disciplines may not fit absolutely the Aboriginal models; any archaeological or

historical site in the survey region could also be potentially significant to Aboriginal people.

2.3 Regional Framework

Waugal (also Wagal, Wagyl or Uocol) is the Dreaming Ancestor who, according to local tradition, created the Swan, Canning, Murray and Serpentine River systems, and retains a presence in some of the deep pools in the area. Waugal beliefs, widespread throughout the south-west, refer to a water-creative spiritual force with a serpentine physical manifestation. In some cases, the Waugal is seen as ubiquitous (described by one person as "a bit like God", i.e. the Christian Deity) or, at least, multi locational; in others, as purely local and associated with a particular creek or spring. This religious philosophy is not unique to the south-west; Maddock (1982:114-115) describes a similar system in Arnhem Land.

Apart from Waugal beliefs, however, a number of other myths, fragments of which have continued to the present day, are associated with the coastal plain and its hinterland (see, for example, O'Connor, *et al*, 1985). Under the mythological/supernatural/sacred rubric could also be grouped rainmaking sites, which generally occurred in relationship with Waugal sites, and ritual grounds (colloquially known as "corroboree grounds"), generally located in proximity to large camping areas.

3.0 THE SURVEY

3.1 Methodology

Four separate phases were involved in the survey;

(i) examination of the existing ethnographic data base;
(ii) consultation and discussions with relevant Aboriginal persons;
(iii) site visit in company of Aboriginal spokespersons;
(iv) report preparation

3.2 Previously Recorded Sites

No sites of significance to living Aboriginal people have been recorded previously within the area to be impacted by the proposed development.

3.3 Newly Recorded Sites

The conclusion reached as a result of the survey is that no sites of significance to Aboriginal people will be affected by the proposed development.

4.0 RECOMMENDATIONS

Human interference with Aboriginal sites in Western Australia is an offence under the Aboriginal Heritage Act, unless authorised as outlined in Section 17 of that Act.

As no Aboriginal sites were recorded in the course of the survey, no recommendations are incorporated into this report.

5.0 REFERENCES

Hammond, J. 1983. *Winjan's People*. Perth: Imperial Printing.

Maddock, K. 1982. *The Australian Aboriginals*. Penguin Books, Ringwood.

O'Connor, R. 1984. Report on the Anthropological Survey of the Proposed Power Station Site, Collie, South-Western Australia. Prepared for SEC.

O'Connor, R. 1987. Report on the Ethnographic Survey of Four Alternative Water Supply Sources, Prepared for WAWA.

O'Connor, R. Bodney, C. and Little, L. 1985. Report on the survey of Aboriginal Areas of Significance in the Perth Metropolitan and Murray River Regions. Prepared for the Australian Heritage Commission.

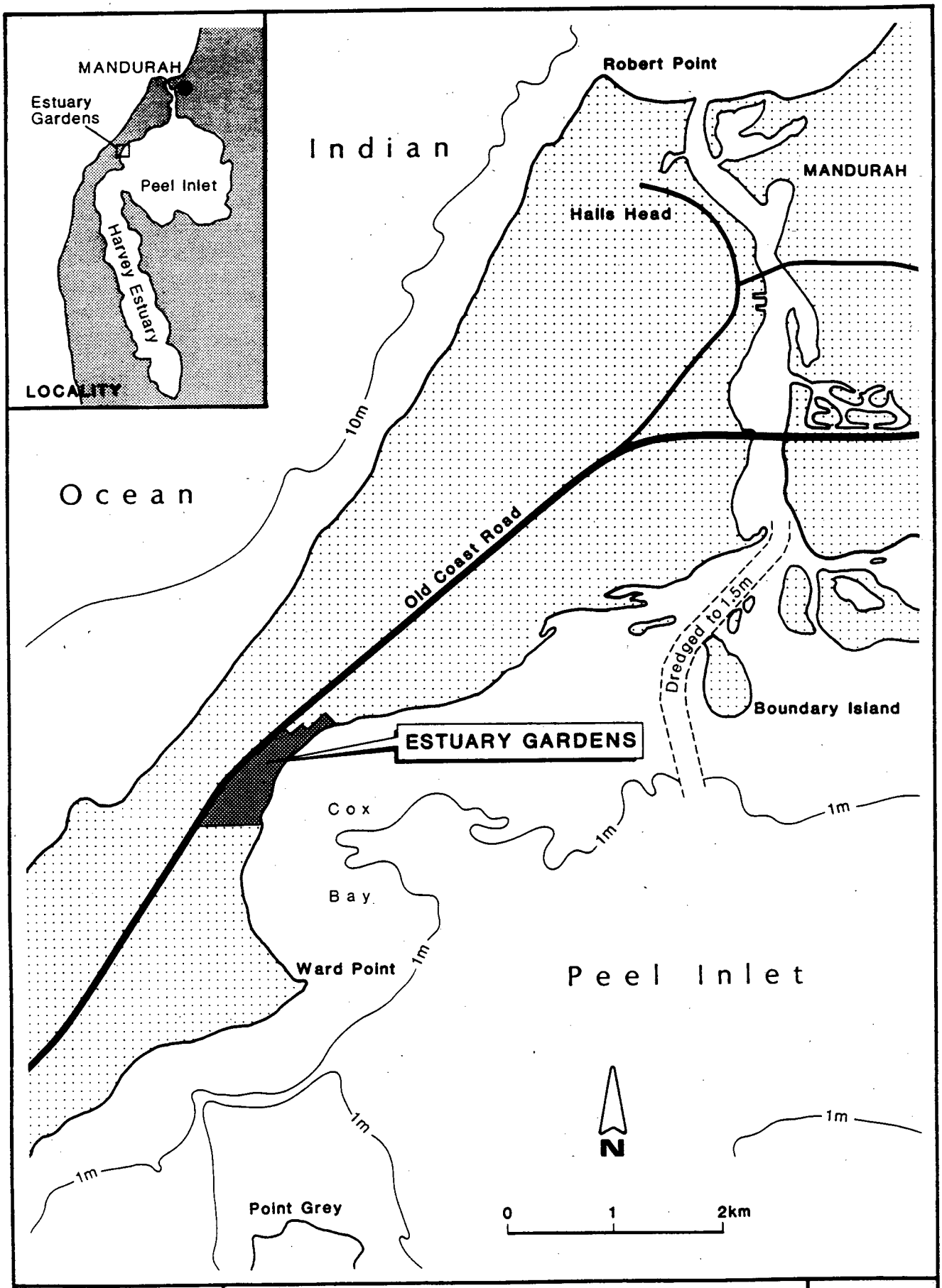
O'Connor, R. and Quartermaine, G. 1986. Aboriginal Site Survey - Mandurah to Pinjarra. Prepared for MRD.

O'Connor, R. and Quartermaine, G. 1987a. Report on the Survey for Aboriginal Sites in the Cooljarloo Mineral Sands Project. Copy lodged at DAS.

O'Connor, R. and Quartermaine, G. 1987b. Report on the Survey for Aboriginal Sites in the Vicinity of the Proposed Kwinana Freeway Southern Extension. Thomas Road to MRS Boundary. Report to MRD.

O'Connor, R. and Quartermaine, G. 1987c. Report on the Survey for Aboriginal Sites in the Vicinity of the Proposed Kemerton to Kwinana 300kV Powerline Route. Report to Dames and Moore.

Pearce, R. & Barbetti, M. 1981. "A 38,000 year old archaeological site at Upper Swan, Western Australia". *Archaeology in Oceania,* 16 : 173-178.



Environmental Drafting

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ESTUARY GARDENS

LOCALITY DIAGRAM

Figure 1

J192 R293

PART TWO

ARCHAEOLOGY

PART TWO - ARCHAEOLOGY

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1.0 INTRODUCTION

1.1 Background to Survey

An Aboriginal site survey of the Proposed Estuary Gardens Project at Falcon, six kilometres south of Mandurah, was commissioned by LeProvost Environmental Consultants and executed in October, 1990. The archaeological investigation was undertaken by Gary Quartermaine with Caroline Heine as field and research assistant and Marney Quartermaine and Atlanta Veld as field assistants.

The objectives of the archaeological survey were as follows:

1. The assembly of data from previous work in the region, including information from W.A. Museum Aboriginal site files, previous survey reports, maps and environmental data.

2. A sample survey of the project area.

3. The location and recording of archaeological sites within the designated survey area.

1.2 Location

The proposed development is situated on the foreshore of Peel Inlet on the Swan Coastal Plain. It is bounded by the Old Coast Road on the west side, Miami Caravan Park on the south, Karanga Street and Flinders Street on the north, and the Peel Inlet to the west (see Figure 1 for location). Maximum dimensions are 1.1 by 0.4 kilometres encompassing approximately 40 hectares of land. The area is heavily vegetated in some parts and disturbed in others. Tracks, firebreaks and the foreshore provided the only areas of reasonable surface visibility.

1.3 Environment

The proposed development is situated at Falcon, between Dawesville and Mandurah, on the shore of the Peel Inlet on the Swan Coastal Plain.

The climate of the area is Mediterranean, which is characterised by a warm summer and winter rainfall. Average annual rainfall is 800 mm and temperatures are moderate (Beard, 1979).

The coastal plain is part of the Perth Basin geological formation. The Perth Basin is a deep trough filled with Phanerozoic sedimentary rock and with a surface mantle of Quaternary deposits (Playford, et al, 1975).

The Swan Coastal Plain is a narrow (20-30 km wide) strip which is generally of low relief. It is composed of Quaternary alluvium and aeolian sediments. The study area is within the Spearwood Dune System landform. This is mostly a low hilly landscape with a grey brown sandy surface. Some areas of yellow sand occur over limestone, which outcrops in several places. The shoreline of the Peel Inlet and Harvey estuary includes sandy terraces and beach ridges and some areas of saline flats (McArthur and Bettenay, 1980).

The vegetation of the area appears in three units:

(i) Jarrah (*Eucalyptus marginata*), Marri (*E. calophylla*) and Tuart (*E. gomphocephala*) with *Banksia attenuata* and *B. ilicifolia*, and where not cleared, a shrub layer including *Xanthorrhoea* spp., *Macrozamia riedlei*, *Daviesia* spp., plus others.

(ii) Shoreline vegetation includes *Melaleuca* spp., some scattered Banksia and Eucalypts plus *Carpobrotus* spp. and other ground cover, backed by thickets of *Kunzia ericifolia*.

(iii) Melaleuca thickets surround swampy areas that contain dense sedges and rushes (McArthur and Bartle, 1980).

1.4 Previous Archaeological Research

As a result of previous surveys, a number of Aboriginal sites have been registered with the WA Museum in the vicinity of the proposed development (Novak, 1975; O'Connor, et al, 1985; O'Connor, Quartermaine and Bodney, 1990a,b&c; Quartermaine, 1986; and Strawbridge, 1989).

The archaeological sites are mostly small (less that 30 pieces) quartz artefact scatters. They are situated on either watercourse or swamp margins, or in areas where vegetation has been removed by sand quarrying, grading or natural blowouts.

Flakes and chips make up a major component of the artefact assemblages, where figures are available. Other artefacts recorded, all in low or single quantities, are scrapers, cores and core fragments.

The earliest evidence for prehistoric occupation of the south-west of Australia is dated at 38,000 years ago, for a stratified site on the Upper Swan (Pearce & Barbetti, 1981). A number of holocene sequences have yielded data on possible cultural/environmental changes during, and after, the recent transgression of the sea, about 5,000 years ago (Hallam, 1974; Clark & Dortch, 1977 and Pearce, 1978). This work postulates increased populations on the coastal plain, rising to a peak just before European contact. As part of a regional survey of the metropolitan area, Hallam (1986:5) concludes that the majority of sites lie around the lakes and swamp of the coastal plain, and that site number double in the last few hundred years.

Prehistoric stone industries, in the south-west, have been classified into earlier and later phases (Dortch, 1977). The early phase includes small, thick flake-scrapers, bipolar cores, notch denticulated pieces, flakes from discoidal cores, and single and multi-platform cores. These artefacts were made on a variety of lithic materials, including a distinctive Eocene fossiliferous chart. It appears that access to this chart was lost after the last marine transgression (Glover, 19875; Dortch, 1977).

Later phase industries, generally found in archaeological contexts dating from 4,000 years ago, include the addition of geometric microliths, backed blades and a variety of adze flakes, to the existing assemblage (Dortch, 1977).

Aboriginal burials have been recorded in the coastal dunes systems along the Western Australian coast at various locations. The closest registered burials to this area are at Mandurah (S0177 and S0473), and Halls Head (S1387). These are usually discovered as a result of development.

From the existing information, it is possible to make the following conclusions:

1. Small, low density surface artefact scatters are the most numerous archaeological sites.
2. Quartz is the dominant lithic material used for the manufacture of artefacts.
3. Flakes and chips form the major class of artefact types in the artefact assemblages.
4. River margins, swamp margins, and areas of devegetated sand are the main site locations.

TABLE 1: PREVIOUSLY RECORDED ABORIGINAL SITES IN THE VICINITY OF THE PROPOSED DEVELOPMENT

WA MUSEUM SITE NO.	S1 50-2 1:250,000 Map Ref.	SITE TYPE	SITE NAME
S0172	362.965	Archaeological	Dawesville
S0305	362.966	Artefacts	Sea View 1 S6
S0306	362.966	Artefacts	Sea View 2 S7
S0309	363.969	Artefacts	Brian's Site S10
S2535	363.969	Artefacts	Estuary Road
S0302	365.973	Archaeological	Miami S3
S0301	367.974	Archaeological	Paddock S2
S0307	360.964	Artefacts	Village S8
S0358	360.964	Archaeological	Old Coast Road S59
S0310	363.962	Artefacts	Slope Site S11
S0315	363.963	Archaeological	Estuary site S16
S0311	363.964	Archaeological	Crossroads S12
S0312	364.959	Archaeological	Harvey Estuary S13
S0225	364.961	Cave	Moffitt's Cave
S0173	364.962	Artefacts	Harvey Estuary
S0304	364.964	Archaeological	Tuart Site S5
S0316	365.956	Archaeological	Yellow Sand S17
S0317	365.956	Archaeological	Tank Site S18
S0313	365.958	Archaeological	Toussaint's Property
S0314	365.958	Archaeological	Phillip's Property
S0174	365.959	Archaeological	Harvey Estuary
S0321	365.959	Archaeological	Truck Bay Site S22
S0324	366.951	Archaeological	Bridge Site 1 S25
S0325	366.951	Archaeological	Bridge Site 2 S26
S0318	366.954	Archaeological	Sundowner S19
S0320	367.952	Archaeological	Dam Site S21
S0175	367.953	Archaeological	Harvey Estuary
S0319	367.953	Archaeological	Building Site S20
S0323	368.948	Archaeological	Swamp Site S24
S0322	368.949	Archaeological	Farmer's Site S23
S0327	370.945	Archaeological	Pine Site S28

The two closest sites to the development area are S0301 and S0302. The archaeological material has been previously collected from these sites and is held at the W.A. Museum. Details of the sites are as follows. Both are small surface artefact scatters. Information is taken from W.A. Museum Aboriginal site files.

S0301 is a quartz flake situated in a grey sand firebreak well north of the survey area and is sufficiently clear of the proposed development. S0302 is six quartz flakes and chips situated between Olive Road and the Miami Caravan Park. It is also outside the present project area.

2.0 METHODS

2.1 Obligations Under the Act

The Western Australian *Aboriginal Heritage Act*, 1972-1980, makes provision for the recording and preservation of places and objects customarily used by, or traditional to, the original settlers of Australia. The Act defines the obligations of the community relating to sites (Sections 15-18).

The archaeological survey should identify the effects of the proposed disturbance of the physical environment on any Aboriginal archaeological sites.

The consultant is obliged to submit site documentation for any newly recorded sites on appropriate forms for registration with the W.A. Museum.

2.2 Survey Design

The survey design involved the following stages of operation.

i) Background research - this involved familiarisation with W.A. Museum site files, survey reports, plus maps and environmental information for the area to be surveyed. Previously recorded Aboriginal sites, registered with the W.A. Museum, are listed in Table 1.

ii) Survey strategy - this consisted of a systematic sample survey of the proposed proposed development area.

The field survey was completed using 1:20,000, 1:100,000 and 1:250,000 topographic maps of the area plus a 1:5,000 plan of the area.

The systematic sample was based on a series of transects, at 25 metres intervals, conducted from the various tracks through the survey area. Compass bearings were used for direction while conducting the transects. At least 50 percent of the area was covered in this way, positioned so that a cross-section of the environment was inspected. Any clear areas of ground encountered were closely inspected.

Access was possible to all sections of the survey area by vehicle and on foot. Visibility was restricted by the ground cover vegetation in most parts particularly on the east side where heavy growth of reeds and paperbark were present. Disturbance was in the form of a sand-pit, previous agricultural activity, tracks and firebreaks.

2.3 Site Definitions

Aboriginal material culture is based, to a large extent, on non-durable materials, such as wood, bark, fibre and skins, that have a limited life in the archaeological record. Stone tools, conversely, remain as often the only evidence of prehistoric activity. Bone, either as a tool, as refuse, or as a burial, falls somewhere between these extremes. Lofgren (1975:7) describes spears, spear-throwers and clubs for men, and digging sticks, wooden carrying dishes and grindstones for women, as the basic implements of Aboriginal life.

Therefore, stone artefact sites reflect only one aspect of Aboriginal material culture which utilised a wide range of materials from the natural environment.

For the purpose of this survey, a site was defined as any material evidence of prehistoric Aboriginal activity. This is manifested in a number of different site components which may occur singularly or with one or more of the others to form an archaeological site. The most common of these are surface artefact scatters, quarries, art sites, stone arrangements, rockshelters with evidence of occupation, grinding patches, burials, and marked trees. An artefact scatter will be recorded as a site if it contains two or more artefacts in association. Solitary artefacts will be recorded as Isolated Finds but will not be registered as sites.

3.0 RESULTS

No newly recorded archaeological sites were located as a result of a systematic sample survey of the area of the project area. No previously recorded sites are within the project area. It is considered that any major archaeological sites would have been discovered by the survey strategy employed, given the size and the environment of the survey area.

4.0 CONCLUSIONS

4.1 Discussion

The Proposed Estuary Gardens Project is situated at Falcon, six kilometres south of Mandurah. It is situated on the foreshore of Peel Inlet and involves an area of 40 hectares.

The archaeological survey involved an investigation of previous research in the area, a systematic field survey of the project area, and the recording of any archaeological material located.

Access was possible to all parts of the survey area by vehicle and on foot. Surface visibility varied due to the groundcover vegetation plus the disturbance due to firebreaks and tracks. However, it is considered that a satisfactory cross-section was sampled.

A number of archaeological sites have been previously recorded in the area of the proposed development but none are on the present project area. All are small, low density artefact scatters that have been subject to a total assemblage collection. No newly recorded sites were located as a result of the systematic survey of the project area.

4.2 Recommendations

The recommendations which follow are based on field observations and knowledge of previously recorded sites in area.

1. Based on the results of the archaeological survey and the small size of the project area, it is considered that no further archaeological work is warranted. It is recommended that development may proceed in the designated area.

2. It is pointed out that human interference to Aboriginal sites is an offence, unless authorised under the Act, as outlined in Section 17 of the W.A. *Aboriginal Heritage Act*, 1972 - 1980. Therefore, it is recommended that the Developers take adequate measures to inform any project personnel of this requirement.

Acknowledgements

The information and assistance provided by Peter Collins, Caroline Heine, Marney Quartermaine and Atlanta Veld is gratefully acknowledged.

5.0 REFERENCES

Beard, J.S. (1979) *The Vegetation of the Pinjarra Area*. Vegmap Publications, Perth.

Clarke, J. and C.E.Dortch. (1977) "A 10,000 year BP radio carbon date for archaeological finds in a soil of the Spearwood Dune system, Mosman Park, W.A." *Search*, 8:36-38.

Dortch, C.E. (1977) "Early and late stone industrial phases in Western Australia" in Wright, R.V.S. (ed.) *Stone Tools as Cultural Markers*. A.I.A.S. Canberra: 104 - 132.

Glover, J E. (1975) "The petrology and probable stratigraphic significance of Aboriginal Artefacts from part of south-west Australia". *Journal of the Royal Society of Western Australia*, 58:75-85.

Hallam, S.J. (1974) "Excavations at the Orchestra Shell Cave, Wanneroo, Western Australia". *Archaeology and Physical Anthropology in Oceania*, 9: 66 - 84.

Hallam S.J. (1986) Prehistoric Aboriginal Populations on the Swan Coastal Plain, Western Australia. Final Report on the project: Australian Research Grants Scheme.

Lofgren, M. (1975) *Patterns of Life*. W.A. Museum Information Series No. 6.

McArthur, W.M. & Bartle, G.A. (1980) Soils and Land Use Planning in the Mandurah-Bunbury Coastal Zone, Western Australia. Land Resources Management Series, No. 6, CSIRO.

Mulvaney, D.J. (1975) *The Prehistory of Australia*. Penguin, Melbourne.

Novak, V. (1975) Report on Aboriginal sites of the Lake Peel-Preston Lakelands. W.A. Museum Report.

O'Connor, R., Bodney, C. and Little, L.(1985) Preliminary Report of the Survey of Aboriginal Areas of Significance in the Perth Metropolitan and Murray River Regions. Report to the Centre for Prehistory, UWA, Perth.

O'Connor, R., Quartermaine, G. and Bodney, C. (1990a) Report on the Survey for Aboriginal Sites, John Holland Stage II Development, Mandurah. Report to LeProvost, Semeniuk and Chalmer.

O'Connor, R., Quartermaine, G. and Bodney, C. (1990b) Report on the Survey for Aboriginal Sites, Mandurah Quay Development. Report to LeProvost, Semeniuk and Chalmer.

O'Connor, R., Quartermaine, G. and Bodney, C. (1990c) Report on the Survey for Aboriginal Sites on the Proposed Optic Fibre Cable Route, Dawesville to Lake Clifton. Report to Telecom Australia.

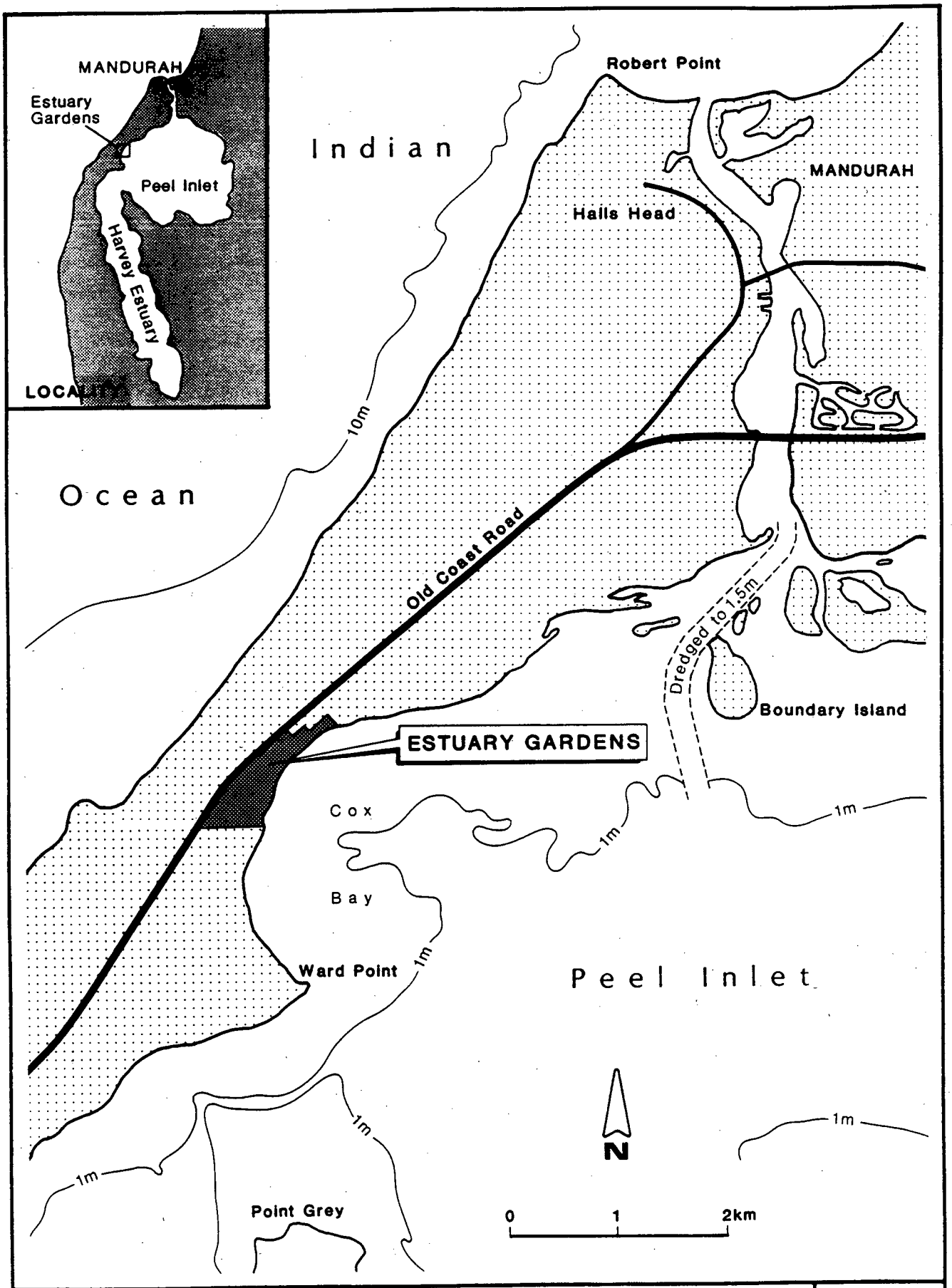
Pearce, R.H. (1978) "A dated sequence from Walyunga. Western Australia." *Journal of the Royal Society of Western Australia*, 61: 1 - 10.

Pearce, R.H. & M. Barbetti. (1981) "A 38,000 year old archaeological site at Upper Swan, Western Australia". *Archaeology in Oceania*, 16: 173-178.

Playford, P.E., Cope, R.N. & Cockbain,A.E. (1975) Phanerozoic, in *The Geology of Western Australia*. Geological Survey of Western Australia, Memoir 2: 451-460.

Quartermaine, G. (1986) Report on the Archaeological Survey of the Point Grey Development Study Area. Report to Dames and Moore.

Strawbridge, L. (1989) An Archaeological and Ethnographic Survey for Aboriginal Sites in the area of the Dawesville Channel Project. Report at W.A Museum.



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ESTUARY GARDENS

LOCALITY DIAGRAM

Figure **1**

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APPENDICES

APPENDIX 1

OBLIGATIONS RELATING TO SITES UNDER THE ABORIGINAL HERITAGE ACT, 1972-1980

Report of Findings

"15. Any person who has knowledge of the existance of anything in the nature of Aboriginal burial grounds, symbols or objects of sacred, ritual of ceremonial significance, cave or rock paintings or engravings, stone structures or arranged stones, carved trees, or of any other place or thing to which this Act applies or to which this Act might reasonably be suspected to apply shall report its existance to the Trustees, or to a police officer, unless he has reasonable cause to believe the existance of the thing or place in question to be already known to the Trustees."

Excavation of Aboriginal Sites

"16. (1) Subject to Section 18, the right to excavate or to remove any thing from an Aboriginal site is reserved to the Trustees.

(2) The Trustees may authorise the entry upon and excavating of an Aboriginal site and the and the examination or removal of any thing on or under the site in such manner and subject to such conditions as they may direct."

Offences Relating to Aboriginal Sites

"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 authorisation of the Trustees under Section 16 or the consent of the Minister under Section 18."

Consent to Certain Uses

"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 in 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 recommendations 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) When 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 the 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 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 the rules of court, appeal from the decision of the Minister to the Supreme Court which may hear and determine an 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 has been made or quash the 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 the 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 constitute an offence against the Act."

APPENDIX 2

Notes on the Recognition of Aboriginal Sites

There are various types of Aboriginal Sites, and these notes have been prepared as a guide to the recognition of those types likely to be located in the survey area.

An Aboriginal Site is defined in the Aboriginal Heritage Act, 1972-1980, in Section 5 as:

"(a) Any place of importance and significance where persons of Aboriginal descent have, or appear to have, left any object, natural or artificial, used for, or made for or adapted for use for, any purpose connected with the traditional cultural life of the Aboriginal people, past or present;

(b) Any sacred, ritual or ceremonial site, which is of importance and special significance to persons of Aboriginal descent;

(c) Any place which, in the opinion of the Trustees is or was associated with the Aboriginal people and which is of historical, anthropological, archaeological or ethnographical interest and should be preserved because of its importance and significance to the cultural heritage of the state;

(d) Any place where objects to this Act applies are traditionally stored, or to which, under the provisions of this Act, such objects have been taken or removed."

Habitation Sites

These are commonly found throughout Western Australia and usually contain evidence of tool-making, seed grinding and other food processing, cooking, painting, engraving or numerous other activities. The archaeological evidence for some of these activities is discussed in details under the appropriate heading below.

Habitation sites are usually found near an existing or former water source such as a gnamma hole, rock pool, spring or soak. They are generally in the open, but they sometimes occur in shallow rock shelters or caves. It is particularly important that none of these sites be disturbed as the stratified deposits which may be found at such sites can yield valuable information about the inhabitants when excavated by archaeologists.

Seed Grinding

Polished or smoothed areas are sometimes noticed on/near horizontal rock surfaces. The smooth areas are usually 25cm wide and 40 or 50cm long. They are the result of seed grinding by the Aboriginal women and indicate aspects of past economy.

Habitation Structures

Aboriginal people sheltered in simple ephemeral structures, generally made of branches and sometimes of grass. These sites are rarely preserved for more than one occupation period. Occasionally rocks were pushed aside or used to stabilise other building materials. When these rocks patterns are located they provide evidence for former habitation sites.

Middens

When a localised source of shellfish and other foods has been exploited from a favoured camping place, the accumulated ashes, hearth stones, shells, bones and other refuse can form mounds at times several metres high and many metres in diameter. Occasionally these refuse mounds or middens contain stone, shell or bone tools. These are most common near the coast, but examples on inland lake and river banks are not unknown.

Stone Artefact Factory Sites

Pieces of rock from which artefacts could be made were often carried to camp sites or other places for final production. Such sites are usually easily recognisable because the manufacturing process produces quantities of flakes and waste material which are clearly out of context when compared with the surrounding rocks. All rocks found on the sandy coastal plain , for example, must have been transported by human agencies. These sites are widely distributed throughout the State.

Quarries

When outcrops of rock suitable for the manufacture of stone tools were quarried by the Aborigines, evidence of the flaking and chipping of the source material can usually be seen in situ and nearby. Ochre and other mineral pigments used in painting rock surfaces, artefacts and in body decoration are mined from naturally occurring seams, bands and other deposits. This activity can sometimes be recognised by the presence of wooden digging sticks or the marks made by these implements.

Marked Trees

Occasionally trees are located that have designs in the bark which have been incised by Aborigines. Toeholds, to assist the climber, were sometimes cut into the bark and sapwood of trees in the hollow limbs of which possums and other arboreal animals sheltered. Some tree trunks bear scars where section of bark or wood have been removed and which would have been used to make dishes, shield, spearthrowers and other wooden artefacts. In some parts of the state wooden platforms were built in trees to accommodate a corpse during complex rituals following death.

Burials

In the north of the state it was formerly the custom to place the bones of the dead on a ledge in a cave after certain rituals were completed. The bones were wrapped in sheets of bark and the skull placed beside this. In other parts of Western Australia the dead were buried, the burial position varying according to the customs of the particular area and time. Natural erosion, or mechanical earthmoving equipment occasionally exposes these burial sites.

Stone Structures

If one or more stone are found partly buried or wedged into a position which is not likely to be the result of natural forces, then it is probable that the place is an Aboriginal site and that possibly there are other important sites nearby. There are several different types of stone arrangements ranging simple cairns or piles of stones to more elaborate designs. Low weirs which detain fish when tides fall are found in coastal ares. Some rivers contain similar structures that trap fish against the current. It seems likely that low stone slab structures in the south west jarrah forests were built to provide suitable environments in which to trap some small animals. Low walls or pits were sometimes made to provide a hide or shelter for a hunter.

Elongated rock fragments are occasionally erected as a sign or warning that a special area is being approached. Heaps or alignments of stones may be naturalistic or symbolic representations of animals, people or mythological figures.

Paintings

These usually occur in rock shelters, caves or other sheltered situations which offer a certain degree of protection from the weather. The best known examples in Western Australia occur in the Kimberley region but paintings are also found through most of the states. One of several coloured ochres as well as other coloured pigments may have been used at a site. Stencilling was a common painting technique used throughout the state. The negative image of an object was created by spraying pigment over the object which was held against the wall.

Engravings

This term described designs which have been carved, pecked or pounded into a rock surface. They form the predominant art form of the Pilbara region but are known to occur in the Kimberleys in the north to about Toodyay in the south. Most engravings occur in the open, but some are situated in rock shelters.

Caches

It was the custom to hide ceremonial objects in niches and other secluded places. The removal of objects from these places, or photography of the places or objects or any other interference with these places is not permitted.

Ceremonial Grounds

At some sites the ground has been modified in some way by the removal of surface pebbles, or the modeling of the soil, or the digging of pits and trenches. In other places there is not noticeable alteration of the ground surface and Aborigines familiar with the site must be consulted concerning its location.

Mythological Sites

Most sites already described have a place in Aboriginal mythology. In addition there are many Aboriginal sites with no man-made features which enable them to be recognised. They are often natural features in the landscape linked to the Aboriginal Account of the formation of the world during the creative "Dreaming" period in the distant past. Many such sites are located at focal points in the creative journeys of mythological spirit beings of the Dreaming. Such sites can only be identified by the Aboriginal people who are familiar with the associated traditions.

Meiyu Australia Pty Ltd

Estuary Deepening

Cox Bay, Falcon

Public Environmental Review

APPENDIX 7

IMPACT OF A TRIAL EXCAVATION AND BUND WALL CONSTRUCTION TECHNIQUE ON WATER QUALITY, COX BAY, FALCON

LEC REF: J192/R328

IMPACT OF A TRIAL EXCAVATION AND BUND WALL CONSTRUCTION TECHNIQUE ON WATER QUALITY, COX BAY, FALCON

Report to: Meiyu Australia Pty Ltd,
26 Riverside Road,
EAST FREMANTLE WA 6158.

by: LeProvost Environmental Consultants,
Suite 2, 1st Floor,
175 Labouchere Road,
COMO WA 6152.

10 December 1990

LEC Ref: J192

IMPACT OF A TRIAL EXCAVATION AND BUND WALL CONSTRUCTION TECHNIQUE ON WATER QUALITY, COX BAY, FALCON

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IMPACT OF A TRIAL EXCAVATION AND BUND WALL CONSTRUCTION TECHNIQUE ON WATER QUALITY, COX BAY, FALCON.

1 INTRODUCTION

Meiyu Australia Pty Ltd have initiated a proposal to deepen part of Cox Bay in Peel Inlet (Fig. 1, p.10) in order to facilitate management of the periodic algal problem and to provide increased aquatic recreational opportunities in this part of Peel Inlet.

The proponent's ability to deepen the comparatively large area envisaged however, depends on establishing an engineeringly-sound, and cost effective construction technique.

As part of the feasibility studies necessary to establish the viability of the proposal the proponent had previously undertaken a sediment sampling programme in Cox Bay, involving the collection of 20 sediment cores on a 200 m grid pattern (Fig. 2, p.11).

These cores were analysed by the Engineering Research Station of the Water Authority of Western Australia (WAWA) to determine the particle size distribution and organic matter content of the sediments. A representative core, from Site 9 at the centre of the survey area (Fig. 2, p.11), was also analysed for Total Phosphorus, Kjeldahl Nitrogen, calcium carbonate and organic content in two strata, by the Nutrient Analysis Laboratory of the Centre for Water Research, Murdoch University (Table 1, p.8).

These investigations produced the following conclusions with respect to the sediments of Cox Bay:

(i) There are two major sediment units within Cox Bay:

- a shallow nearshore sand shelf unit which extends outward from the shoreline for a distance of up to 400 m; and
- an offshore clayey silty sand basin unit, which commences at the outer margin of the sand shelf and extends into the main basin of Peel Inlet (Fig. 3, p.12).

The boundary between the two units is abrupt and marked by a drop-off between the sand shelf and the basin. The difference between the two sediment units is shown diagrammatically in Figures 4 (p.13) and 5 (p.14), which show the core analysis data from Site 9, a typical shelf site (Fig. 4) and Site 11, a typical basin site (Fig. 5).

(ii) The results of these physical analyses indicated that excavation using terrestrial excavation equipment was feasible if constrained to the sand shelf located between the shoreline and the edge of the basin.

(iii) Chemical analysis of sediments from two intervals within a typical shelf unit core (Site 9) (Table 1) show that the shelf sands are typically low in organic matter and carbonate content, both at the surface and at depth. The consistency of the sediment throughout the column, in terms of particle size and nutrient levels as well as organic matter and carbonate content, indicates that excavation to the depth proposed would not expose sediments of a type inconsistent with the present substrate.

Based on these investigations, construction using conventional land-based tracked excavators to excavate, and at the same time progressively construct, a bund wall which would provide a working platform from which the machine could operate, was identified as theoretically the most prospective construction technique.

However, to determine whether this technique would prove to be feasible at Cox Bay required on-site testing to confirm that it was practical under the substrate conditions found at the site, and that the level of impact on the estuarine environment arising from the use of this technique would be acceptable.

It was initially proposed to test the construction method at a central location within the proposed deepening area, however, during early investigations it had been identified that the channel leading from the boat ramp at Novara (Fig. 6, p.15) was inadequate as:

(i) the channel did not progress far enough into the Inlet and the propellers of small boats were bottoming as they crossed the shelf to the deeper water of the main inlet basin; and

(ii) the existing channel, which was barred at the outer end, was becoming infilled with silt and organic matter.

It was therefore considered that the reconstruction of the boat channel would provide a suitable site to test the construction technique and approval was given by the relevant authorities to construct a new boat channel. The construction was undertaken by the proponent at his expense for the following purposes:

- to allow the construction method to be tested under actual field conditions;
- to provide the opportunity for the impact of the construction method on water quality to be tested; and
- allow the stability of the bund wall to be tested.

This proposal was reviewed informally by the Environmental Protection Authority (EPA), the Waterways Commission and the Peel Inlet Management Authority (PIMA) and approval to undertake the work granted.

Approval to undertake the work was however subject to the removal of the temporary bund wall immediately upon completion of the excavation of the channel, and consequently only an initial estimate of bund wall stability could be obtained.

2 OBJECTIVES

The objectives of the trial excavation and bund wall construction programme were therefore as follows:

(i) Creation of a facility of lasting benefit to the public by:

- providing a clear boat channel from the shoreline to the basin of Peel Inlet which would be useable at all times by small craft; and
- renourishing eroded beaches along the Novara shoreline using sand excavated from the channel.

(ii) Assist the proponent to collect technical data for the Public Environmental Review (PER) by:

- providing a field test of the construction technique;
- testing the impact of the construction on water quality; and
- assessing construction time and costs for the proposed excavation of the wider area of Cox Bay.

3 METHODS

3.1 CONSTRUCTION

Construction was undertaken using a 22 tonne tracked excavator with a 2 m^3 capacity bucket.

Excavation commenced at the shoreline on Monday 11 June 1990 and was completed to the full channel length of 325 m on Thursday 14 June 1990, after which the second phase of channel excavation and removal of the bund wall was undertaken. This phase of the project was also undertaken by the excavator, this time loading into dump trucks for placement along the foreshore to renourish the eroded beaches.

3.2 WATER QUALITY INVESTIGATION

The water quality investigation was undertaken during the second day of excavation and bund wall construction, when the channel was between 170 m and 200 m in length. Sampling was undertaken between the hours of 1.00 pm and 6.00 pm when it was assessed that maximum development of the plume for that day would have occurred.

During construction the following testing was undertaken:

(i) establishment of control sites by which to determine background water quality at the time of the survey; and

(ii) determination of the visual extent of the plume and water quality parameters within the plume and comparison of these results with background conditions to determine the effects.

The following parameters were measured at each station:

Total Suspended Solids (TSS);
Biochemical Oxygen Demand (BOD);
Dissolved Oxygen (DO);
pH;
Ammonia Nitrogen;
Nitrate/Nitrite Nitrogen;
Organic Nitrogen;
Total Nitrogen;
Orthophosphate Phosphorus;
Organic Phosphorus;
Total Phosphorus; and
Secchi Depth.

4 RESULTS

4.1 CONSTRUCTION PROGRAMME

The proposed bund wall and the first stage of channel excavation was completed to a distance of 325 m offshore over a period of three days and subsequently completed to the designed width and depth, as shown in the survey diagram (Fig. 7, p.16).

4.2 WATER QUALITY SURVEY

The results of the analyses of the water samples collected at the 15 stations shown on Figure 8 (p.17) are presented in Table 2 (p. 9) and shown graphically in Figures 9a to 9d (pp.18-21).

In the graphical presentation, the value for each parameter at each station is shown against the mean and standard deviation for that parameter for the seven sites taken to represent background for the period of the survey.

The seven sites taken as representing background water quality (Stations 1-6, and 11) were selected on the basis of consistency with values at the most distant sites, particularly with respect to suspended solid levels. Values for all parameters at these Stations were however generally consistent.

5 DISCUSSION

5.1 CONSTRUCTION SURVEY RESULTS

The sand bund wall proved to satisfactorily support the weight of the excavator and subsequently of the dump trucks used to transport the sediment back to the foreshore. No difficulty was experienced in excavating the sediment or occasional limestone pinnacles which were encountered along the channel.

Comparison of the post construction survey (Fig. 7) to the proposed as constructed channel width of 17 m toe to toe and minimum depth of -0.5 m CD (Chart Datum, which is equal to an average water depth of approximately 0.95 m).

5.2 WATER QUALITY SURVEY RESULTS

Weather conditions during the period of survey were heavily overcast with periods of rainfall accompanied by squalls which made visual recognition of the full extent of the plume difficult. However, the north to north-westerly winds determined that the plume would be pushed offshore in a south to south-westerly direction and this was confirmed by observations made close to the excavation area.

In order to determine average background water quality during the survey, samples were taken at distances of up to 500 m upwind of the construction area (Fig. 8).

Upon analysis it was found that samples taken within 50 m upwind, 50 m offshore and 75 m downwind of the construction point produced values that were consistent with those recorded from the most distant sites (Table 2).

It was therefore possible to select seven sites representing background conditions and from these to determine average conditions at the time of survey. The mean and standard deviation of the background samples for each parameter is presented on the relevant graph (Figures 9a to 9d).

From reference to the data it can be seen that the impact of the excavation under the conditions prevailing at that time, i.e. offshore winds gusting to 15 kn, that the maximum extent of detectable impact on water quality was less than 100 m from

the excavator operation point and the effects were only clearly shown at distances of less than 50 m from the construction point.

As would be expected the principal effects were observed in the immediate vicinity of the excavator. Samples taken 6 m upwind and downwind (Stations 9 and 13) of the excavator, showed elevated levels of TSS, BOD, ammonia and organic nitrogen and both orthophosphate and organic phosphorus. Dissolved oxygen, pH and nitrate/nitrite nitrogen levels, however, remained within the standard deviation of the background samples.

At stations located 30-35 m downwind of the excavator (Stations 8 and 14) TSS levels were markedly less than those closer to the excavator. Biochemical Oxygen Demand, NH_3-N, organic N and organic P were reduced as compared to Station 9, while orthophosphate and NO_3/NO_2-N increased.

Similar patterns were observed at the two sites adjacent to the constructed bund (Stations 10 and 15). At Station 10, located 6 m from the downwind side of the bund, TSS and BOD levels were similar to those recorded at Station 9, but nutrient levels were lower.

At Station 15, located 5 m upwind of the bund, TSS, organic N and phosphorus levels were reduced, but pH and ammonia levels were similar to those at Station 9.

The measured impacts are considered typical of the conditions under which the programme was carried out. Under calmer conditions the detected nutrient and suspended solid levels could be greater but, with the reduced mixing typical of calms, would be expected to be confined to a still smaller area around the point of construction. Under higher wind conditions elevated suspended solid levels would be expected to be detectable over a greater area, but the concentrations reduced due to more effective turbulent mixing.

While the conditions imposed over bund wall construction and removal precluded testing of the stability and longevity of the bund wall, indications from the testing carried out adjacent to the older parts of the wall suggest that over a more extensive period nutrients and TSS would further decrease as fines were winnowed from the surface material and the bund walls would develop the characteristics of a sloping beach.

6 CONCLUSIONS

The technique of using conventional land-based excavation equipment has proven successful in the geotechnical conditions found on the sand shelf.

The area of impact on water quality has been found to be more restricted than is the case with conventional dredging equipment used under similar conditions, based on personal observations at other sites.

The low levels of organic materials present in the shelf sediments suggest that adoption of this excavation technique over a wider area would result in minimal adverse impact on the waters of Peel Inlet as long as it was conducted on sediments having similar characteristics.

Land-based excavation equipment is able to operate with the necessary accuracy in respect to positioning and final depth of cut to ensure that bottom profiles meet the specified design parameters.

TABLE 1

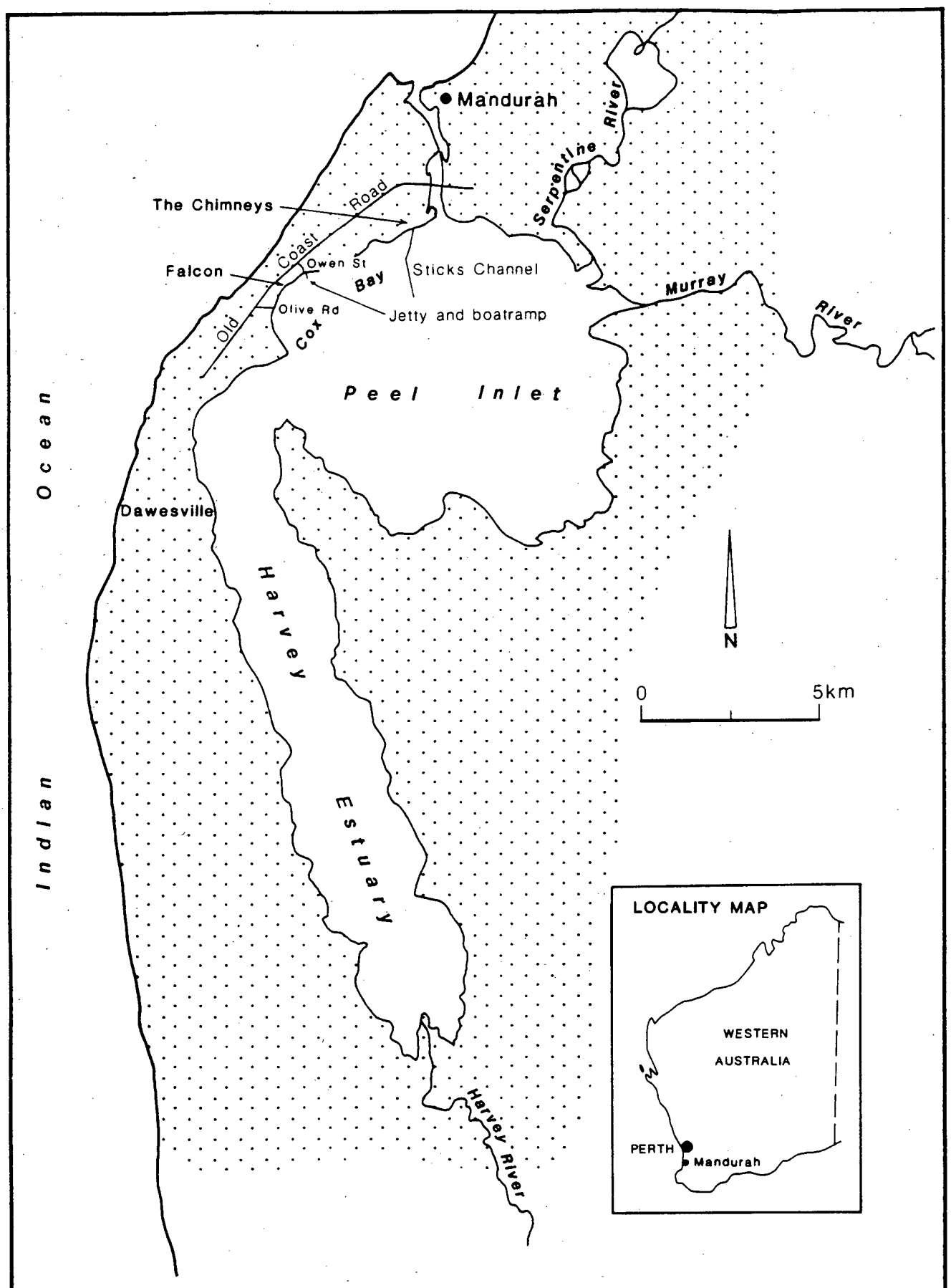
SEDIMENT CHARACTERISTICS - CORE SITE 9

SEDIMENT INTERVAL	SOIL CLASSIFICATION	ORGANIC CONTENT %	CALCIUM CARBONATE %	TOTAL PHOSPHORUS ug/g	KJELDAHL NITROGEN ug/g
0-0.3 m	Sand	0.72	3.1	15.2	345
1-1.3 m	Sand	0.61	2.7	16.8	141

TABLE 2

RESULTS OF WATER QUALITY MONITORING IN COX BAY, MANDURAH

STATION	DEPTH	mg/L			pH	NUTRIENTS (ug/L)							SECCHI DISC (m)
		BOD	DO	SS		NH_3	NO_2/NO_3	Org N	Total N	Ortho P	Org P	Total P	
1	1.0	18	8.7	3.7	8.11	26	115	638	779	21	39	60	Bottom
2	1.0	7	9.1	3.3	8.12	23	110	568	701	20	35	55	Bottom
3	1.0	26	9.6	2.6	8.17	15	80	584	679	22	39	61	Bottom
4	1.5	22	9.6	3.0	8.16	13	100	667	780	24	39	63	1.0
5	1.0	20	10.1	2.3	8.23	10	105	702	817	22	45	67	Bottom
6	1.0	24	10.2	2.3	8.22	12	100	652	764	19	34	53	Bottom
7	1.0	19	9.9	2.9	8.20	18	205	702	925	19	34	53	Bottom
8	0.9	26	9.5	35.8	8.20	37	120	675	832	47	18	65	0.5
9	0.6	38	9.0	110.6	8.17	50	83	969	1102	34	100	134	0.3
10	1.0	52	9.0	60.2	8.18	50	80	775	905	32	49	81	0.4
11	2.0	22	10.0	3.3	8.20	18	83	630	731	23	28	51	Bottom
12	0.8	24	9.9	3.5	8.21	19	90	661	770	18	36	54	Bottom
13	1.3	39	9.0	89.7	8.20	52	88	741	881	31	74	105	0.4
14	0.9	42	9.5	5.6	8.20	18	83	605	706	25	33	58	Bottom
15	2.3	40	9.4	6.8	8.16	60	90	604	754	22	35	57	0.8



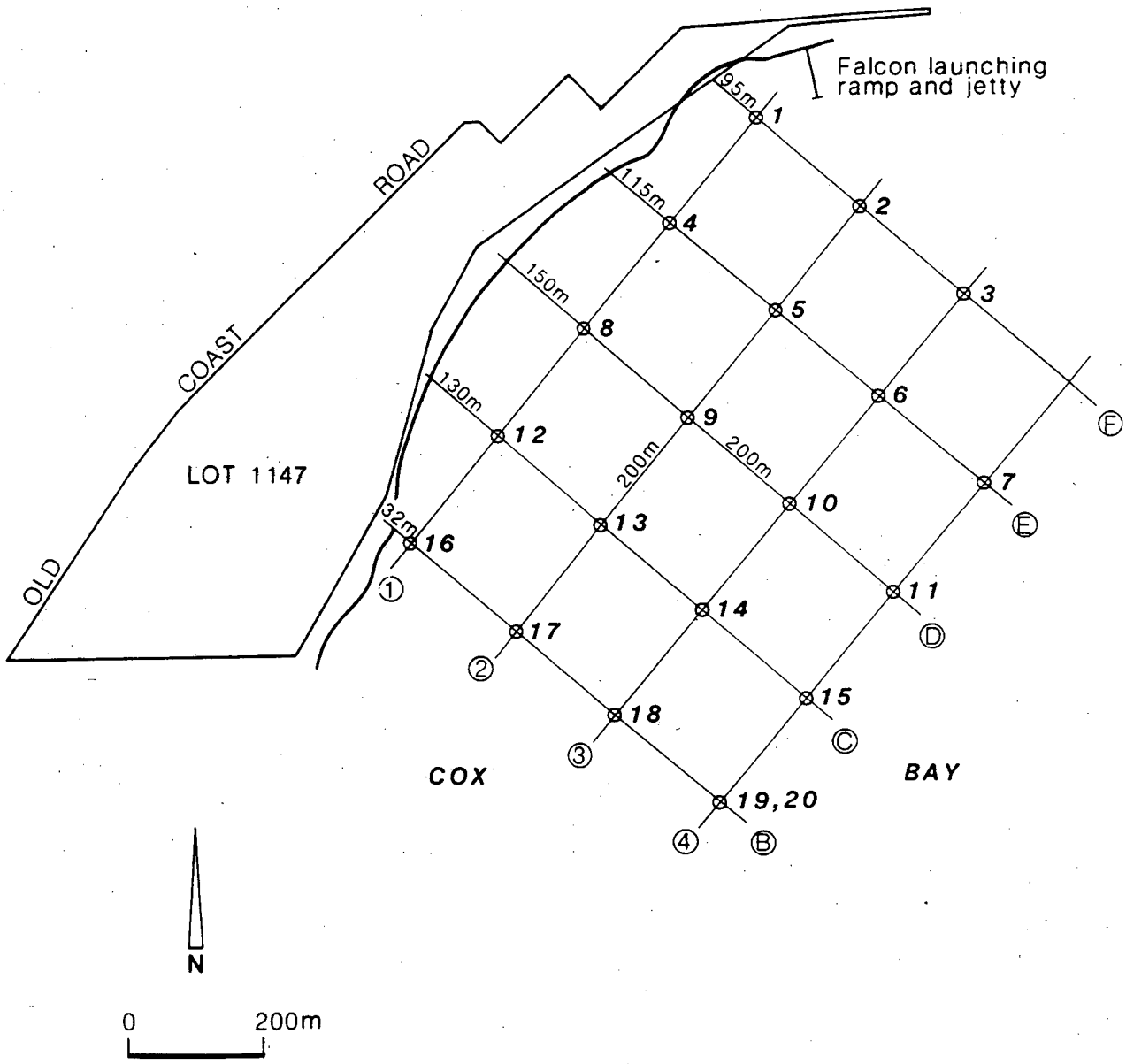
MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

LOCATION PLAN

Figure **1**

Geodraft
Auth : RWH | Date : 9/90

J192 R293



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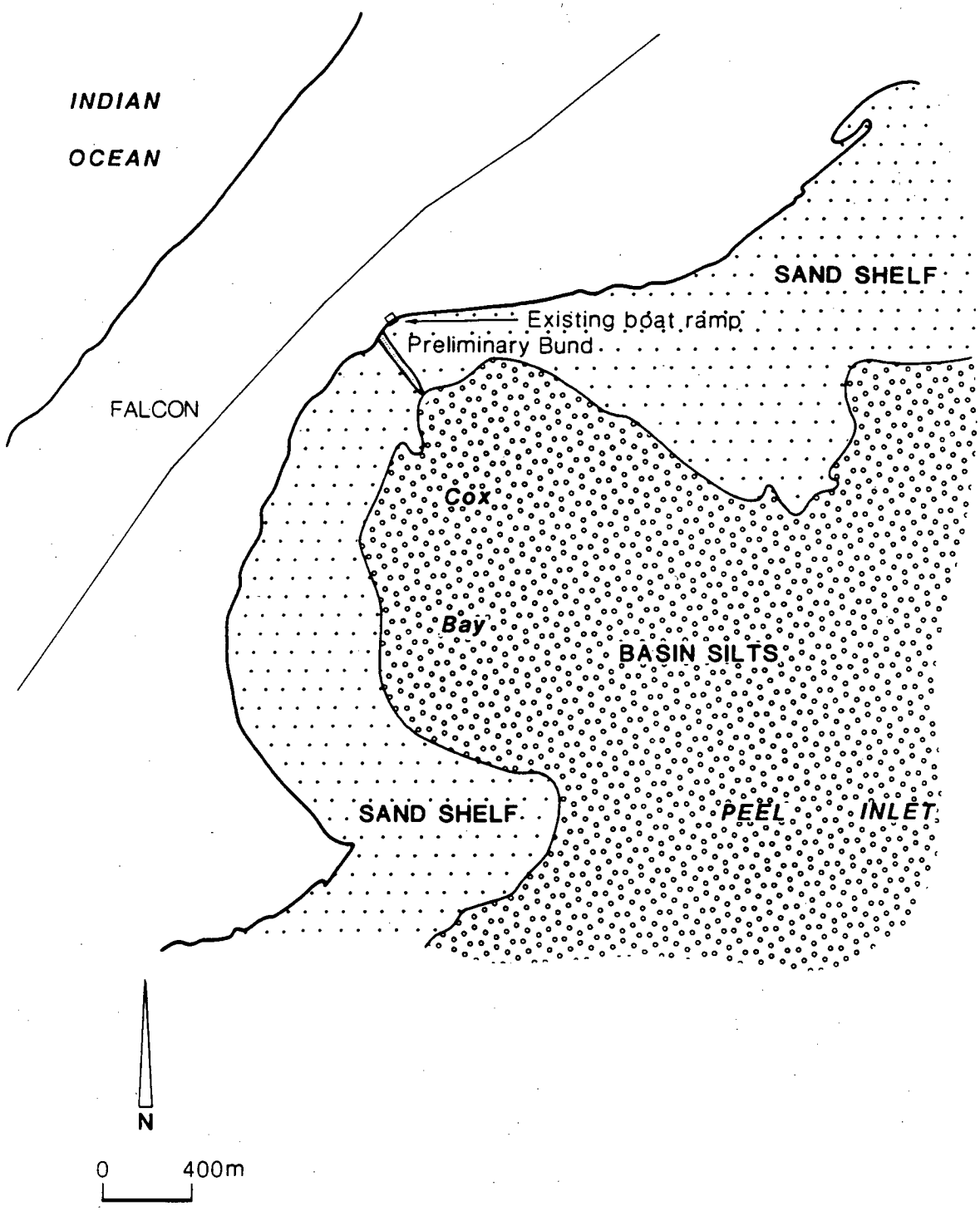
SEDIMENT CORE SITES

Figure **2**

Auth : PC | Date : 9/90

Geodraft



MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

SEDIMENT DISTRIBUTION

Figure **3**

Auth : PC | Date : 9/90

Geodraft

MANDURAH
Peel Estuary Study
RECORD OF TEST HOLE (PVC)

HOLE No S9 SHEET 1 OF 1
CO-ORDS E - N -
G.L. -1.23m W.R.L. -

GROUNDWATER	GEOLOGICAL DESCRIPTION	SOIL/CORE DESCRIPTION	GRAPHIC LOG	USC CLASSIFICATION	DEPTH (m)	REL DENSITY CONSISTENCY	MOISTURE CONTENT	SAMPLES	SOIL / CORE LOSS (%)	ADDITIONAL OBSERVATIONS
↓		SAND Light grey into dark grey. Reasonably well graded. -Slightly organic. Contains minor shell fragments towards bottom.		SP*	1					LAB TESTED S4769/90 0.00 0.30m LAB TESTED S4710/90 1.00-1.30m
		END OF HOLE 1.62m.								

* ESTIMATED

TERMINATION
↓ Can continue
✕ Too hard to continue
GROUNDWATER
▼ Water first encount'd
▽ Water rest level (W.R.L.)

WEATHERING
FR Fresh
FRST Fresh with stained joints
SW Slightly weathered
MW Moderately weathered
HW Highly weathered
CW Completely weathered
GEOLOGICAL DESCRIP'N
T Topsoil
R Residual

SAMPLES
U70 Undisturbed sample 70mm dia.
U50 Undisturbed sample 50mm dia.
D Disturbed sample
W Water sample
FIELD TESTS
Ip Permeability
N Std penet'n test

RELATIVE DENSITY
VL Very loose
L Loose
MD Medium dense
D Dense
VD Very dense
MOISTURE CONTENT
D Dry
M Moist
W Wet
S Saturated

CONSISTENCY
VS Very soft
S Soft
F Firm
St Stiff
VSt Very stiff
H Hard
Fb Friable

EQUIPMENT
Start
Finish

LOGGING
Logged T M
Date 12.04.90
Drawn 19.04.90
Checked

FIG

WATER AUTHORITY OF WESTERN AUSTRALIA

Auth : PC | Date : 9/90

MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

SEDIMENT CORE ANALYSIS

Figure 4

MANDURAH
Peel Estuary Study
RECORD OF TEST HOLE (PVC)

HOLE No S11 . SHEET 1 OF 1
CO-ORDS E - N -
G.L. -1.84m W.R.L. -

GROUNDWATER	GEOLOGICAL DESCRIPTION	SOIL/CORE DESCRIPTION	GRAPHIC LOG	USC CLASSIFICATION	DEPTH (m)	REL. DENSITY/ CONSISTENCY	MOISTURE CONTENT	SAMPLES	SOIL / CORE LOSS (%)	ADDITIONAL OBSERVATIONS
		SAND SP* Fine to medium grained. Slightly organic.		OL OH*						
		Clayey SILT Black. Organic mud. Medium plasticity. Contains shell fragments.								
		NO RECOVERY								
		END OF HOLE 1.98m.								

* ESTIMATED

TERMINATION
Can continue
Too hard to continue
GROUNDWATER
Water first encount'd
Water rest level (W.R.L.)

WEATHERING
FR Fresh
FRST Fresh with stained joints
SW Slightly weathered
MW Moderately weathered
HW Highly weathered
CW Completely weathered
GEOLOGICAL DESCRIP'N
T Topsoil
R Residual

SAMPLES
U70 Undisturbed sample 70mm dia.
U50 Undisturbed sample 50mm dia.
D Disturbed sample
W Water sample
FIELD TESTS
Ip Permeability
N Std penet'n test

RELATIVE DENSITY
VL Very loose
L Loose
MD Medium dense
D Dense
VD Very dense
MOISTURE CONTENT
D Dry
M Moist
W Wet
S Saturated

CONSISTENCY
VS Very soft
S Soft
F Firm
St Stiff
VSt Very stiff
H Hard
Fb Friable

EQUIPMENT
Start
Finish

LOGGING
Logged I.M.
Date 12.04.90
Drawn 19.04.90
Checked

WATER AUTHORITY OF WESTERN AUSTRALIA

FIG

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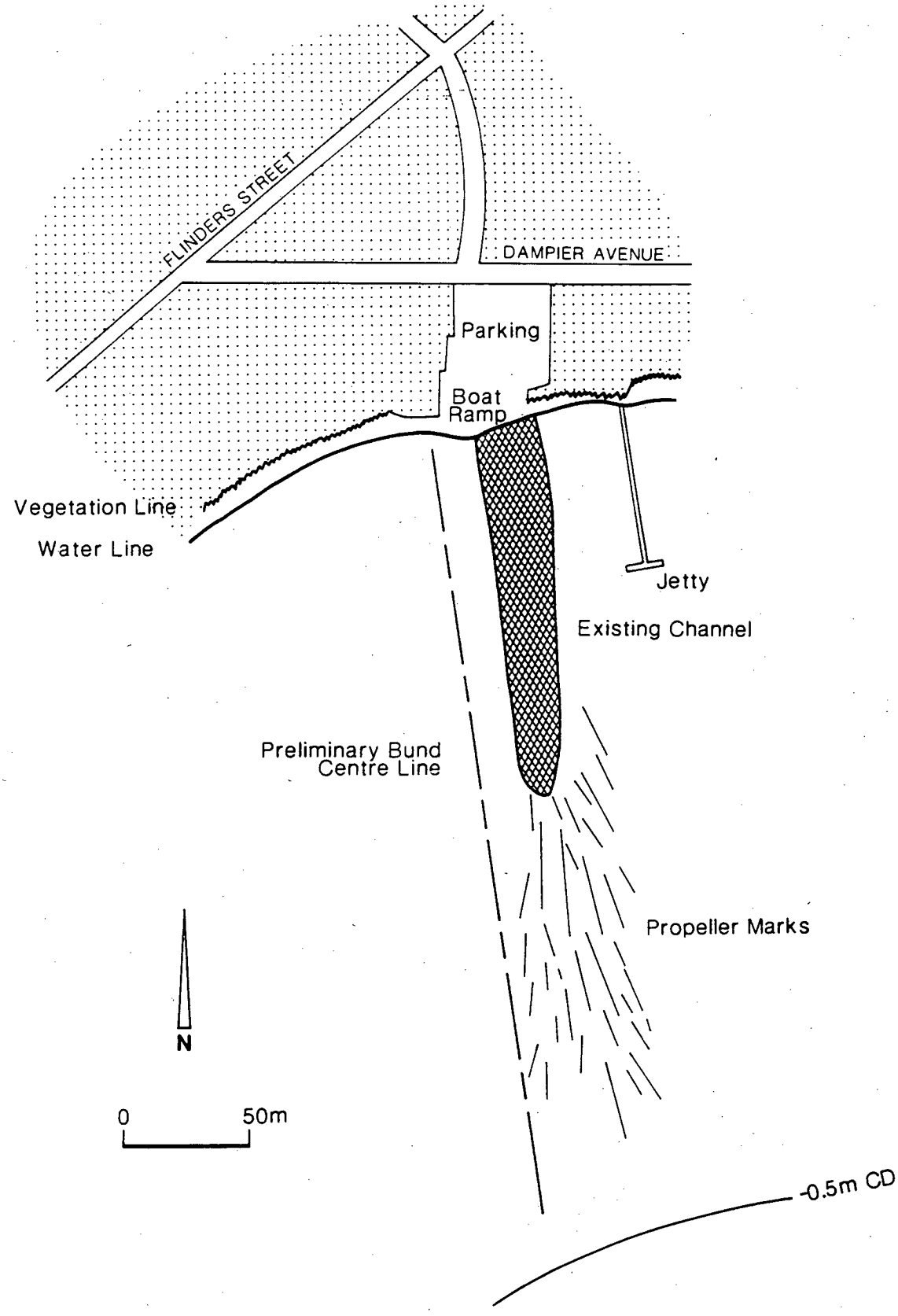
MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

SEDIMENT CORE ANALYSIS

Figure 5



MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

FALCON BOAT RAMP

Figure 6

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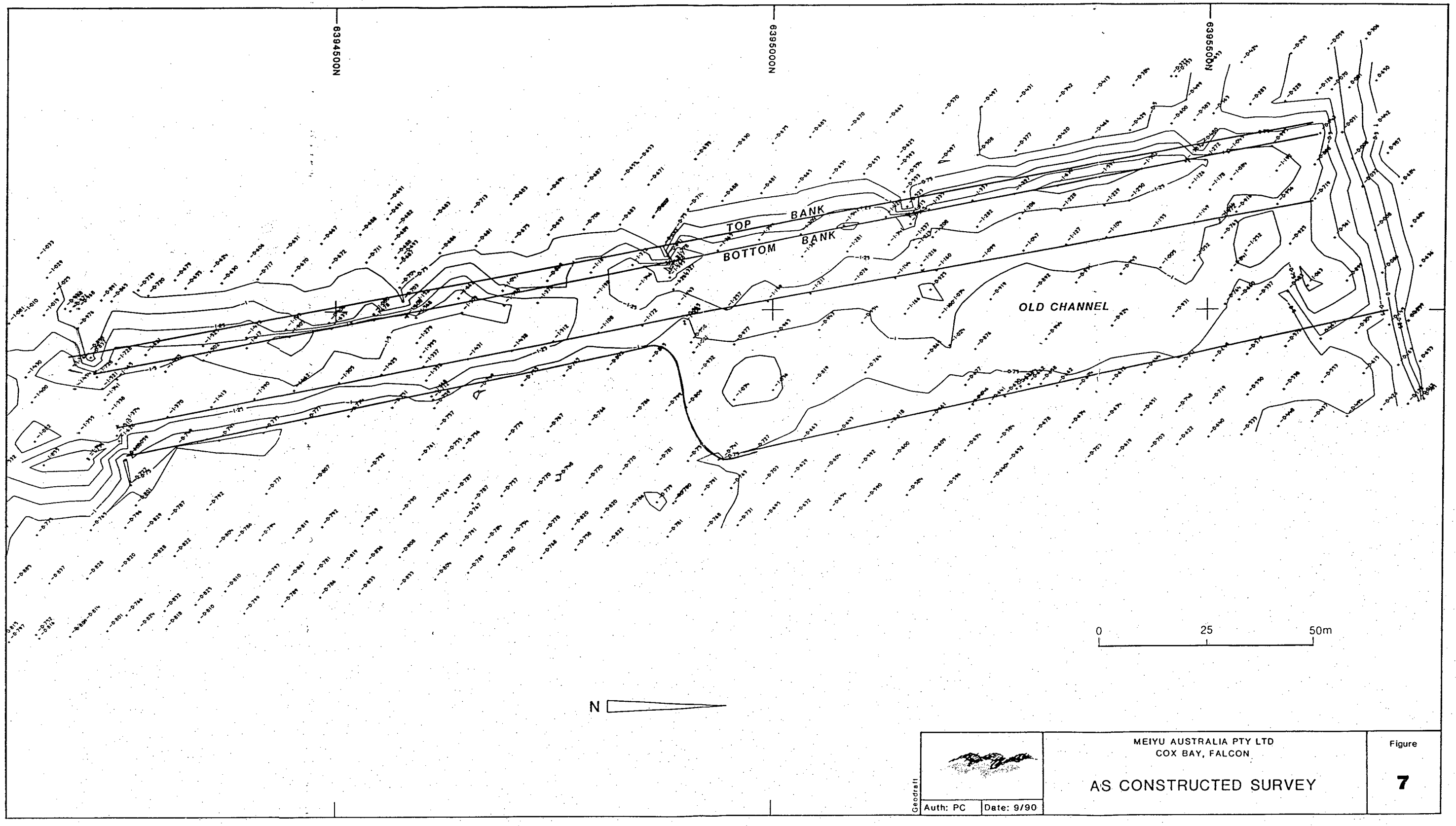

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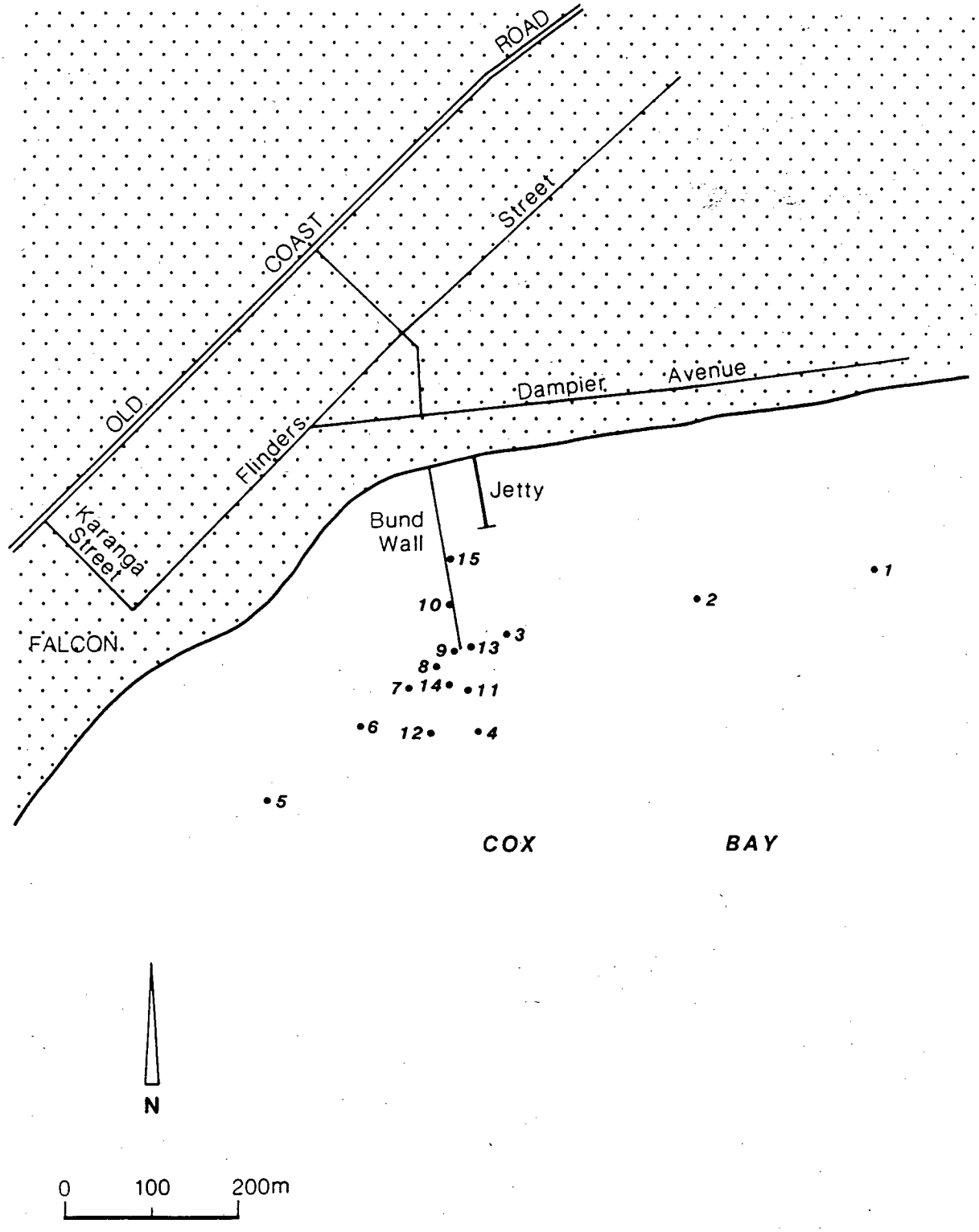
MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

AS CONSTRUCTED SURVEY

Figure 7



MEIYU AUSTRALIA PTY LTD
COX BAY, FALCON

WATER QUALITY SAMPLING SITES

Figure **8**

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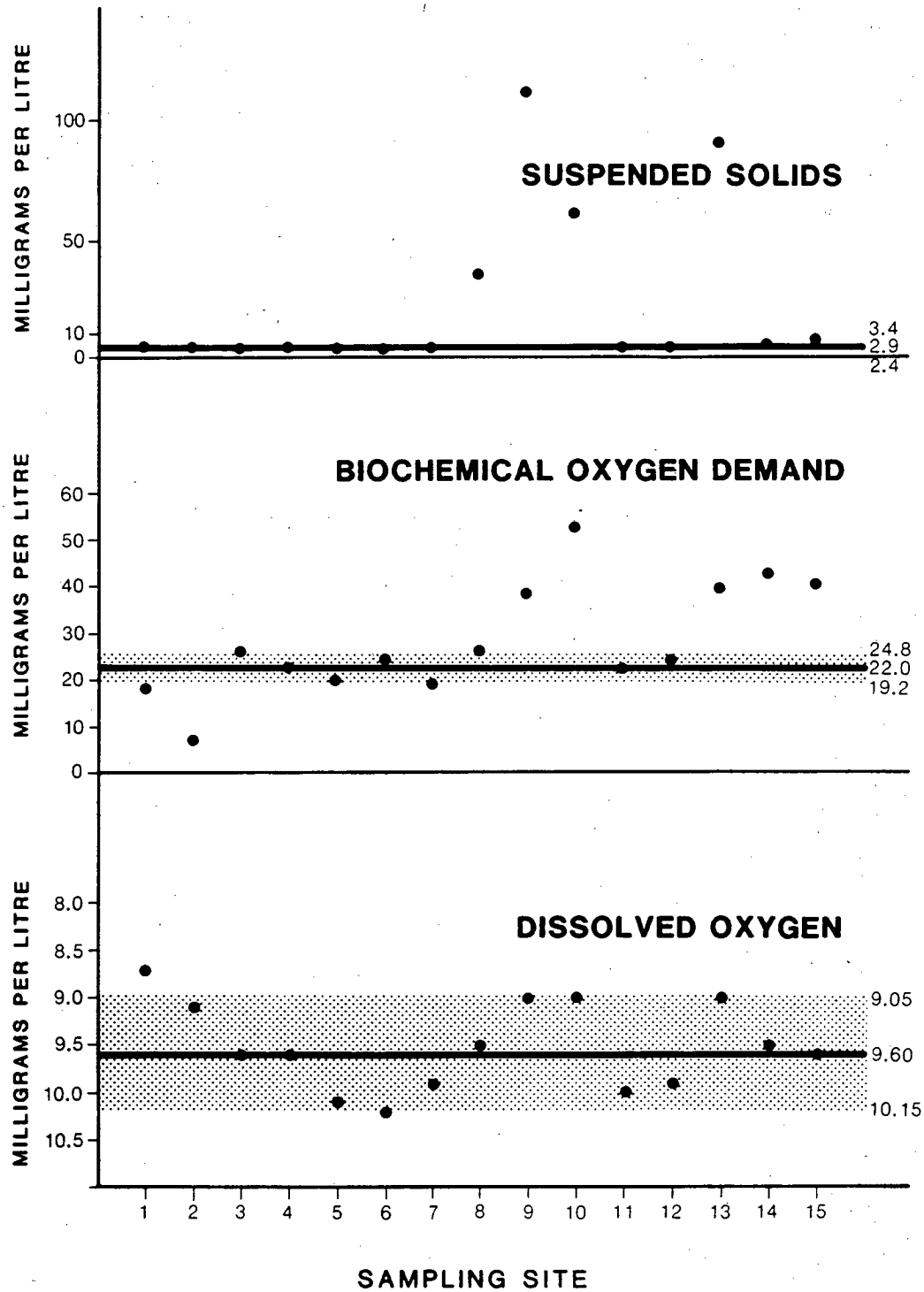

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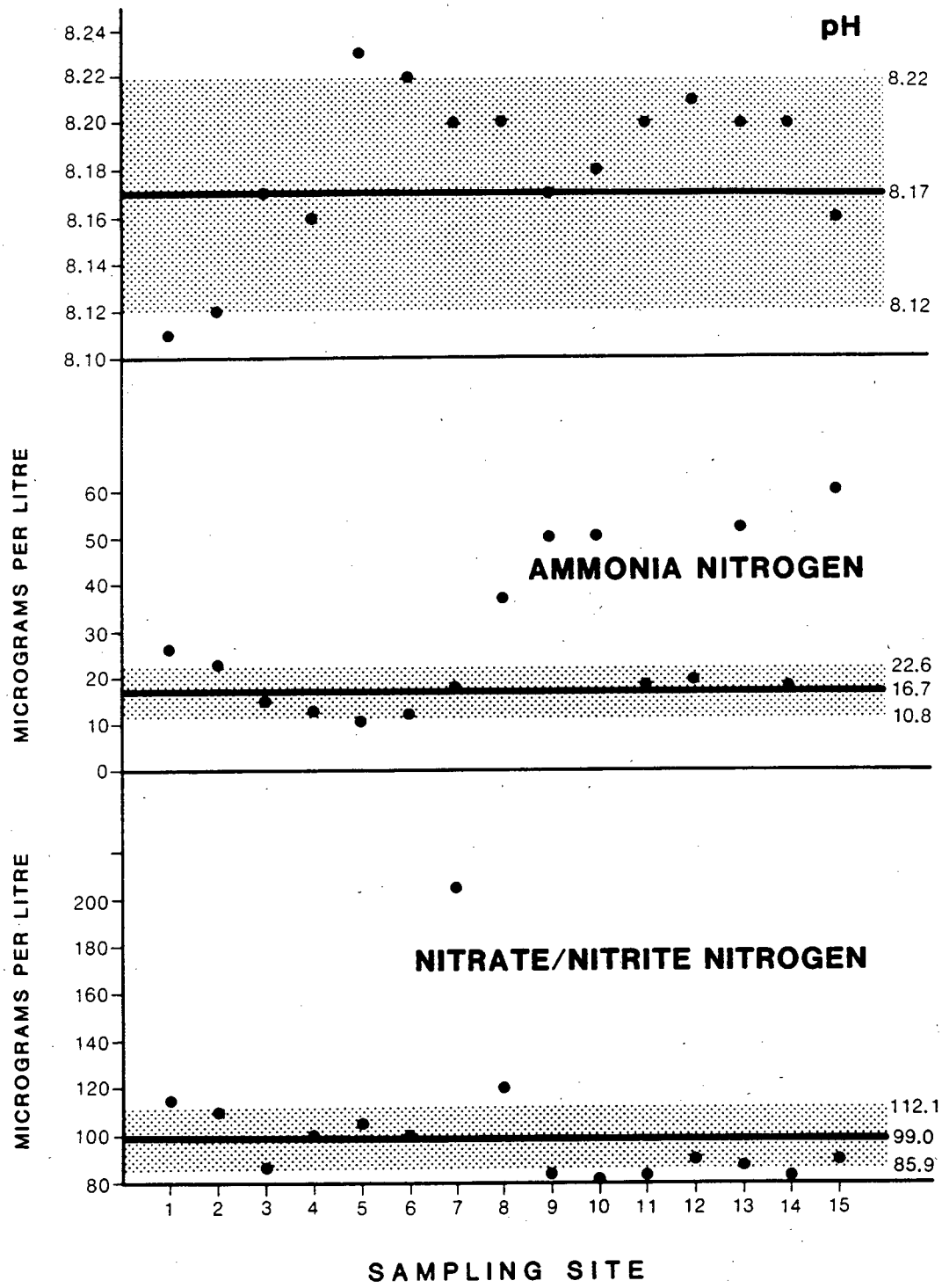
TRIAL EXCAVATION
COX BAY - FALCON

WATER QUALITY

Figure **9A**

J192 R293



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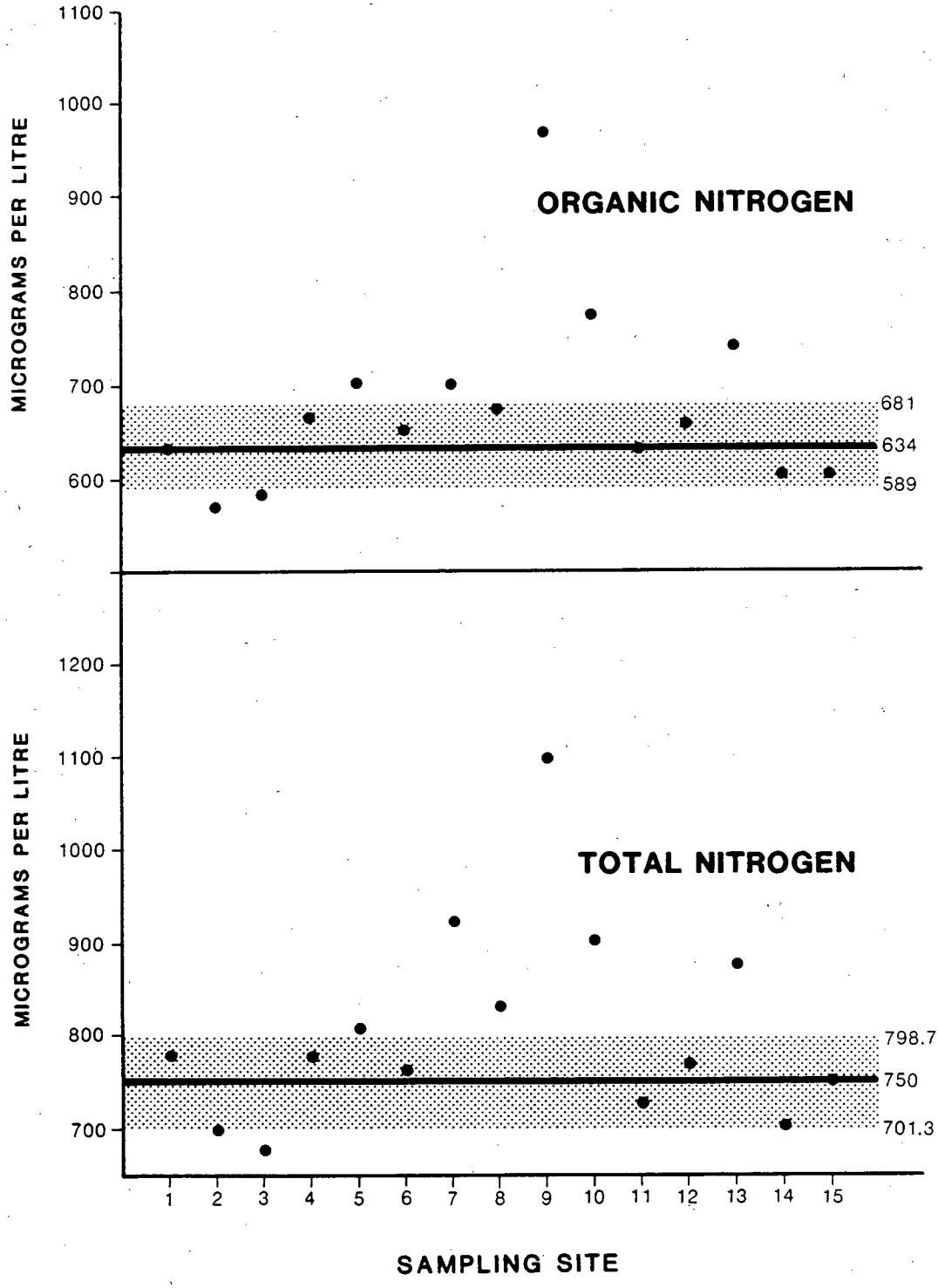
TRIAL EXCAVATION
COX BAY - FALCON

WATER QUALITY

Figure

9B

J192 R293



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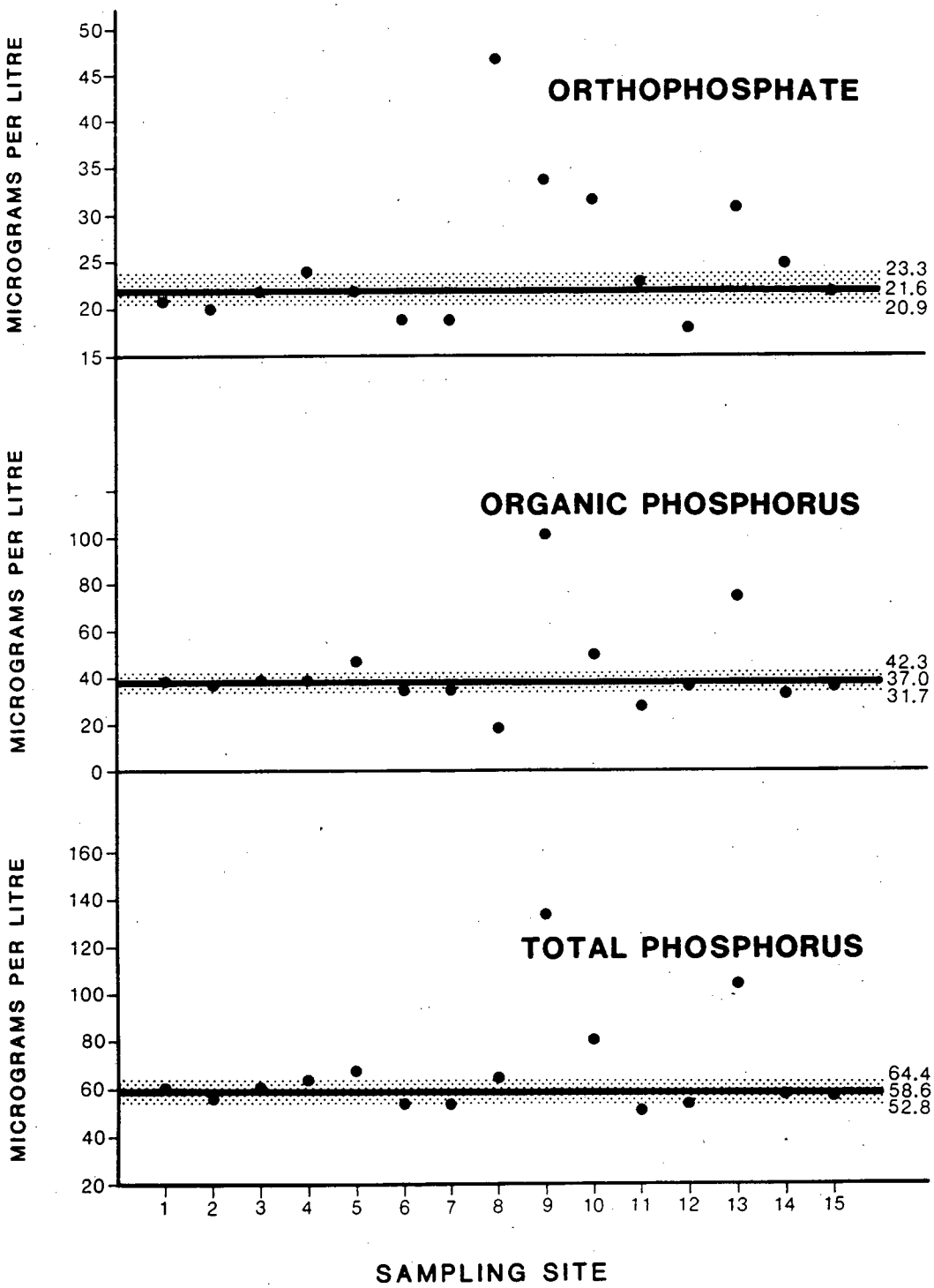
TRIAL EXCAVATION
COX BAY - FALCON

WATER QUALITY

Figure

9C



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TRIAL EXCAVATION
COX BAY - FALCON

WATER QUALITY

Figure

9D

Meiyu Australia Pty Ltd

Estuary Deepening

Cox Bay, Falcon

Public Environmental Review

APPENDIX 8

DRAFT FORESHORE MANAGEMENT PLAN

LEC REF: J192/R293

ESTUARY GARDENS

FALCON

DRAFT FORESHORE MANAGEMENT PLAN

Report to: Meiyu Australia Pty Ltd,
26 Riverside Road,
EAST FREMANTLE WA 6158.

by: LeProvost Environmental Consultants,
Suite 2, 1st Floor,
175 Labouchere Road,
COMO WA 6152.

10 December 1990

LEC Ref: J192

ESTUARY GARDENS

FALCON

DRAFT FORESHORE MANAGEMENT PLAN

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ESTUARY GARDENS

FALCON

DRAFT FORESHORE MANAGEMENT PLAN

1 INTRODUCTION

Meiyu Australia Pty Ltd (Meiyu) proposes to develop a resort and residential estate on Part Murray Location 1147, Falcon (Fig. 1, p.11). The development is to be called Estuary Gardens and this name for the locality has been adopted in this report in referring to the estuary foreshore adjacent to, and including parts of, Location 1147.

Development of the Estuary Gardens estate will lead to increased usage of this section of the estuary foreshore and consequently to a need for improved management to cater for this level of usage. The development also provides the opportunity to upgrade facilities provided in the area and to assist in the conservation of significant foreshore vegetation.

At present the foreshore to the west of Location 1147 is unvested Crown Land which has no active management plan in place. Originally 30 m in width the Crown Land now varies in width between 0 and 50 m in width due to the effects of erosion and accretion, at least partly human caused through the process of weed harvesting along the foreshore. As part of its commitments under the rezoning application, Meiyu has agreed to cede additional land adjoining the Crown Land to form a foreshore reserve which has a minimum width of 50 m and an average width in the order of 70 m (Fig. 2, p.12). In order to define a management strategy for the proposed total foreshore area Meiyu commissioned LeProvost Environmental Consultants (LEC) to develop a foreshore management plan for the area and has also undertaken to fund the implementation of the foreshore management plan, and to maintain the foreshore until such time as a community association is formed to undertake the responsibility for ongoing management.

This draft management plan sets out the proponent's preferred management strategy, which combines retention of parts of the existing habitats (Fig. 3, p.13) with more active recreational uses, has been prepared after consultation with officers of the Environmental Protection Authority (EPA) and Waterways Commission. As the foreshore is as yet unvested, the draft plan is being submitted to the City of Mandurah, Peel Inlet Management Authority (PIMA), EPA and Waterways Commission for further comment through the Public Environmental Review (PER) process for the proposed estuary deepening in Cox Bay, prior to finalisation and implementation. The locations of proposed facilities and the alignment of the dual use path (Fig. 4, p.14) are approximate and will be ultimately be defined on the basis of site considerations.

The area, which is the subject of this management plan, extends from the southern side of the Falcon boat-launching ramp to the southern boundary of Pt Loc. 1147 and west from the high water mark to the western boundary of the land proposed to be ceded to the Crown under the rezoning proposal.

2 NATURAL CHARACTERISTICS

2.1 LANDFORM

The land falls from west to east across the foreshore with a maximum elevation of between 2 m and 3 m on the proposed landward (western) boundary. A low beach ridge is present along parts of the shoreline and relict ridges are also present further inland in the central section of the foreshore.

The higher ground represents the edge of a sand plain which locally rises to heights of 4-5 m above sea level. The low land which fringes the estuary results from localised erosion and redeposition of the margins of this sand plain to form beaches, sand ridges and cut-off depressions or wetlands.

The process of shoreline modification is ongoing and has resulted in both erosion and accretion at various points on the shoreline (Fig. 3).

2.2 VEGETATION

The vegetation of the foreshore reflects the influences of elevation and groundwater salinity. The elevated sand plain which fringes the foreshore to the west supports a Tuart-Marri woodland. Much of this area has previously been parkland cleared and is now covered by regrowth, particularly of introduced grasses (Fig. 3).

The foreshore margins are vegetated with a variable band of paperbark woodlands, the species varying with the salinity of the groundwater. In the southern part of the area, the ground is low-lying and the groundwater saline. The dominant tree in this area is the saltwater paperbark, *Melaleuca cuticularis*. The associated understorey includes salt-tolerant samphire species.

In the more elevated central and northern parts, the dominant tree is the freshwater paperbark, *Melaleuca rhaphiophylla*, with an understorey of rushes and herbs.

The sheoak, *Casuarina obesa*, is found on the higher beach ridges, notably in the area adjacent to Karanga Street. From Karanga Street south, the foreshore is more disturbed and in places there is a dense growth of *Jacksonia furcellata*, scattered Melaleuca and a variable understorey of sedges, samphires and grasses.

2.3 WATERBIRD USAGE

The waterbird usage of the study area has been reviewed by Ninox (1990) as part of a study on the significance of mosquito breeding areas to the waterbirds of Peel Inlet. This study concluded that the northern wetland was of 'intermediate significance to waterbirds', primarily because of the presence of the dense fringing Melaleuca which would act as a refuge area for secretive birds such as crakes and rails. No survey reports have been prepared for the remainder of the foreshore area, however, it is proposed that this would be initiated prior to any action to modify the foreshore being undertaken.

3 HUMAN IMPACT

Past and continuing impacts include clearing, dumping of rubbish, weed incursion and creation of vehicle tracks. These impacts have resulted in the loss or degradation of native vegetation and the creation of mosquito breeding sites.

The major requirements of the management plan are therefore directed to the management of access to the foreshore, and the maintenance and enhancement of the more valuable parts of the existing vegetation, while catering for recreational uses associated with the estuary, e.g. fishing, crabbing and boating, and for associated passive recreational requirements.

4 EXISTING USAGE

The foreshore at present is primarily used to obtain access to the waters of Peel Inlet for crabbing and fishing. The foreshore provides access for wading parties and beach-launching sites for small dinghies.

Four wheel drive and trail bike usage is common and there is an ongoing problem with rubbish dumping in the area.

The major access points to the estuary are located at the eastern end of the site at the Novara boat launching ramp and car park and at a site immediately to the east of Karanga Street where a well-used but informal car parking area has developed. In addition there are a number of tracks through the property which allow access to the foreshore at other points.

5 NATURAL CONSTRAINTS TO RECREATIONAL DEVELOPMENT

Constraints to the recreational use of the Estuary Gardens foreshore occur as a result of the characteristics of the adjacent embayment as well as the site itself. The principal constraints include the depth of water in the bay and the associated algal problem, the lack of foreshore facilities and mosquito nuisance.

5.1 WATER DEPTH

The major constraint is the shallowness of the broad expanse of water which extends from the shoreline some 350-400 m into Peel Inlet. There are periodic accumulations of micro and macro algae within the bay and these either decay to form a black malodorous organic 'mat' which either becomes trapped to decay within the deep estuary basin or temporarily blankets the sandy floor of the nearshore shelf before being washed up onto the shore, where decay also takes place.

The shallowness of the bay restricts its use for swimming and fishing, while the periodic algal accumulations at times prevent the use of the bay for fishing, crabbing and prawning. During very low tides the water depth up to 200 m from shore may be too shallow for crabbing as these animals move offshore into cooler and deeper water.

5.2 FORESHORE FACILITIES

Constraints to the use of the foreshore for recreational purposes include the lack of public facilities, particularly parking, the eroded state of the beaches and the degraded nature of much of the vegetation which reduces the aesthetic value of the area.

Erosion along parts of the shoreline has given rise to recommendations which affect the shape of the recommended open space boundary, and constrains the location of facilities, such as the proposed dual use path, to ensure that ongoing maintenance costs are minimised.

5.3 MOSQUITOES

Ephemeral pools within the foreshore area commonly form sites for mosquito breeding, reducing the appeal of the area to recreational users and posing a hazard to nearby residents. In a report on a survey of mosquitoes in the Mandurah region Wright (1988) identified presence of mosquito breeding sites which occur intermittently along the length of the proposed Estuary Gardens foreshore. To control mosquito breeding generally in this area the application of larvicide was recommended. However, in the wetland between Karanga Street and the Falcon

boat ramp, which had been identified as a significant breeding area, physical control measures were recommended (Wright, 1988).

The recommended control measure was the construction of three channels to permanently link the wetland to the inlet and thereby permit access to predators (Fig. 5, p.15). The spoil dug from the channels was proposed to be used to fill wheel ruts occurring at the landward side of the wetland.

This recommendation was subsequently adopted under the Interim Strategy for Mosquito Control in the Peel and Leschenault Estuary Regions (Government of Western Australia, 1989), however, this recommendation has not been acted upon.

6 RECREATIONAL OPPORTUNITIES

Identification of the present recreational use pattern and the constraints imposed by the area indicate that the principal uses of the site should be for the provision of access to the estuary and uses incidental thereto and for passive recreation.

Enhancement of these opportunities will require improvement to and management of access to the foreshore, the creation, following filling and regrading, of areas of grassed and landscaped parkland suitable for low intensity recreational use, and the rehabilitation of the shoreline and wetland vegetation.

7 MANAGEMENT PROPOSALS

7.1 GENERAL CONCEPT

It is proposed to provide for a mixture of passive recreational activities interspersed with landscaped conservation zones within the foreshore area.

Four areas of conservation value have been identified within the foreshore area. These areas, which are shown in Figure 3, are:

- the saltwater paperbark wetland at the southern end of the site;
- the freshwater paperbark/Regelia thicket and seasonal wetland located in the middle part of the foreshore;
- the freshwater paperbark thickets surrounding the seasonal lake at the northern end of the site near the launching ramp; and

- parts of the shoreline with remnant shade trees, particularly the Casuarinas and the larger Melaleucas, which can be integrated into a more highly developed landscape.

The most significant area is regarded as the Saltwater paperbark, *Melaleuca cuticularis,* wetland at the southern end of the site. Although past clearing has resulted in the loss of almost all of the mature trees from the northern part of this area, it is proposed that it be rehabilitated, with supplementary planting where required, to return it to the condition of the adjacent uncleared area to the south. This area will be partially filled, as shown in Section 4 on Figure 7 of the PER (p.74), in order to ensure that the area drains freely to the estuary, eliminating the tidal pools which form mosquito breeding sites.

The central and northern wetlands have also been affected by human activity. In addition, the northern wetland generates odour problems and becomes a major mosquito breeding site as it dries out over the summer months. It is, however, proposed that these two areas be retained as landscaped features, by clearing the weed growth and further developing the tree canopy. Although a final decision depends on the results of an evaluation of waterbird usage of the foreshore area it is proposed to fill and landscape the central depression of the northern wetland as shown in Section 1 on Figure 6 of the PER (p.73) as it is not considered feasible to maintain adequate water quality within this water body.

It is proposed to retain the basin of the central wetland in its present form, however, some filling around the periphery is proposed to separate the wetland from the adjacent development and on the estuary side to provide a raised area for the dual use path (refer to Section 3 on Figure 7, p.74 of the PER).

It is also intended to widen the beaches along this section of the foreshore using fill generated during the proposed estuary deepening programme.

The foreshore vegetation will be separated from landscaped areas as described in Section 7.2. Enrichment planting with local tree species, i.e. *Melaleuca cuticularis, M. raphiophylla* and *Casuarina obesa* will be undertaken in appropriate locations.

The remainder of the site will be filled, regraded and grassed, and additional tree planting will be undertaken. The general fill level adopted is a height of approximately 0.7 m AHD, to prevent the formation of temporary pools which would form sites for mosquito breeding, and in winter make recreational use of the area difficult.

Elsewhere on the site, careful attention will be given to ensuring that natural drainage is not impeded and, where necessary, ephemeral pools will be drained.

7.2 LOCATION OF OPEN SPACE BOUNDARY

The proposed Open Space/development boundary has been determined on the basis of:

(i) natural processes, i.e. erosion affecting the shoreline;

(ii) the desire to protect the wetland features of the foreshore; and

(iii) the need to provide additional land for more intensive recreational uses at the northern end of the site.

The alignment selected provides additional buffering capacity at identified erosion sites and incorporates the wetlands into the proposed foreshore reserve. Recreational use at the northern end of the site is provided for by incorporating all of the land between Flinders Street and the Crown Land into the proposed foreshore reserve.

7.3 SEPARATION BETWEEN RESERVE COMPONENTS

As a result of the need to fill parts of the site to the west of the boundary of the proposed reserve which will be used for private development, the proponent proposes to construct a retaining wall along the boundary between public and private land. The presence of this wall will also assist in providing clear definition between public and privately-owned land. The wall would be constructed to a level of 2.0 m AHD and would have an effective average height of 1 m above the adjacent foreshore.

It is also proposed to construct a second wall within the foreshore area. This wall, which will have a finished height of 1 m AHD and an average effective height of 0.5 m, will be used to provide separation between landscaped and naturally-vegetated areas. Its alignment will approximately follow that of the dual use path (Fig. 4).

It is proposed to construct the retaining walls from pre-cast concrete units which can be placed and fixed with minimal disturbance to adjacent vegetation.

7.4 PUBLIC FACILITIES

7.4.1 Vehicular Access

It is proposed to exclude vehicles from the foreshore generally. However, allowance is made for future extension of parking to cater for increased demand at the Falcon boat-launching ramp as shown in Figure 4. It is also proposed to provide two additional parking areas on the proponents land, providing access to

the foreshore at Karanga Street and in the southern part of the property as shown in Figure 4.

7.4.2 Pedestrian/Cycle Access

It is proposed to provide access to pedestrians and cyclists along the length of the foreshore by means of a dual use pathway. This pathway will link into adjacent parkland to the north at the Falcon boat ramp. At the southern end, investigations are continuing as to the best way of joining the pathway into the Open Space at Olive Road.

Two options are presently being examined. The first is to locate the path on the landward side of the wetland using concrete construction. The second is to locate it closer to the foreshore on a boardwalk which would be elevated to avoid interference with the natural drainage of the wetland.

7.4.3 Public Recreational Jetties

As part of the concept of providing water oriented low-key public recreational facilities on the foreshore, Meiyu is also prepared, subject to approval from the authorities, to construct one or two small public jetties. These would be used for fishing and temporary mooring only and would not incorporate any commercial facilities.

The suggested location for the jetties is shown in Figure 4.

Riedel & Byrne (Appendix 2 of the PER) have examined the impact of jetty construction on the stability of the foreshore and have concluded that either solid core or open pile jetties could be constructed with minimal ongoing impact on the shoreline.

8 COMMITMENTS

Subject to approval by the relevant authorities, the proponent, Meiyu Australia Pty Ltd, undertakes to carry out the following works.

(i) Construction of the boundary retaining wall between the development and the foreshore reserve.

(ii) Construction of a low retaining wall within the reserve to separate passive recreation areas from conservation zones.

(iii) Filling of low-lying parts of the foreshore and widening of the existing beaches subject to approval by the relevant authorities.

(iv) Construction of a dual use path along the foreshore length of the proponents land.

(v) Enrichment planting with *Melaleuca cuticularis* of the southern wetlands.

(vi) Rehabilitation of the wetland in the central section of the reserve.

(vii) Landscaping of those sections of the reserve set aside for passive recreation.

(viii) Provision of additional parking at the northern end of the reserve, adjoining the Falcon boat ramp.

(ix) Provision of public parking and two additional public access points to the foreshore, one at Karanga Street and one in the southern part of the proponent's land.

Meiyu also undertakes to accept responsibility for the maintenance of the foreshore until such time as the community association is established.

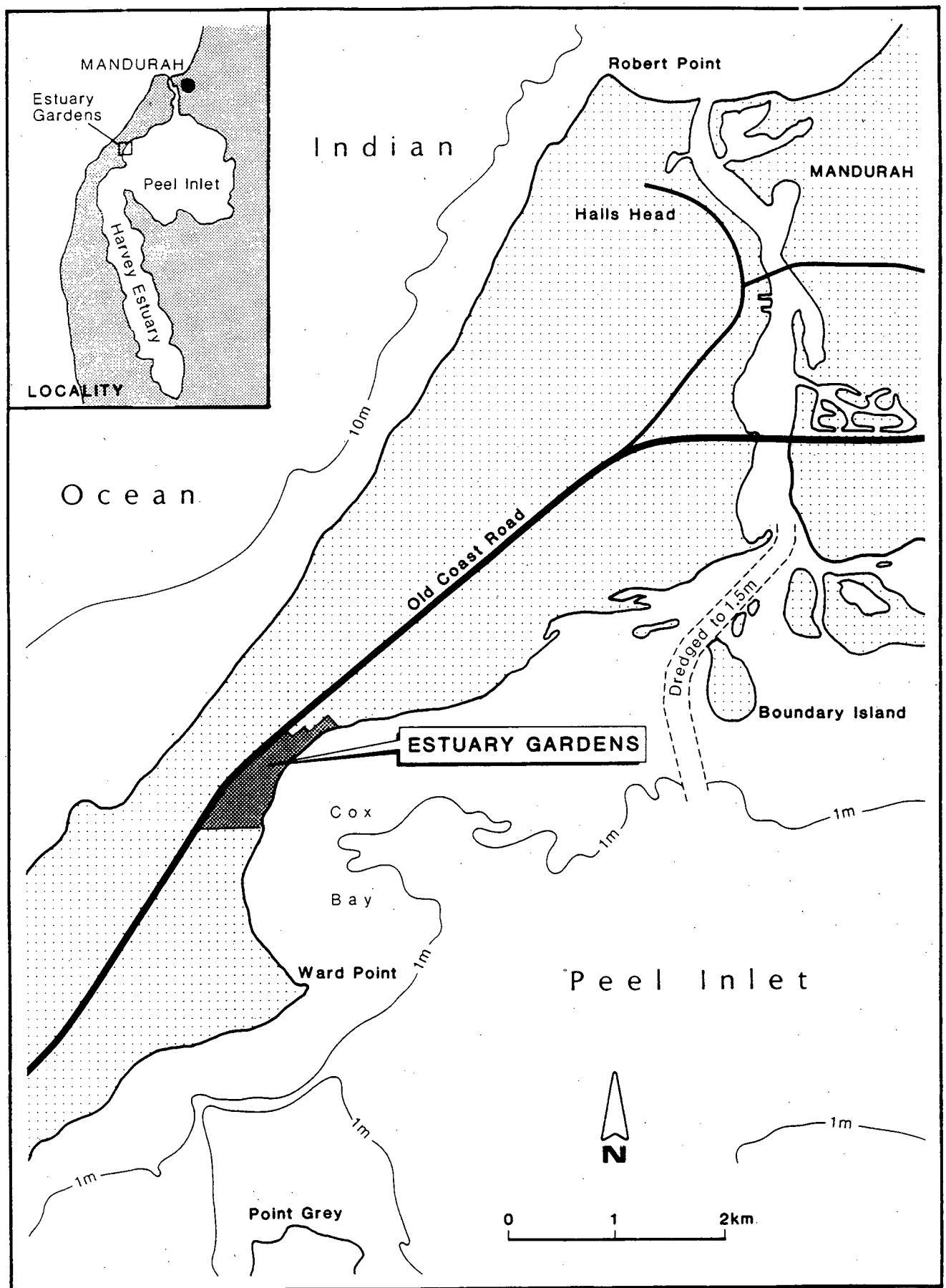
9 REFERENCES

Government of Western Australia, 1989: *Interim Strategy for Mosquito Control in the Peel Inlet and Harvey Estuary Regions.*

Ninox Wildlife Consulting, 1990: *The Significance of Mosquito Breeding Areas to the Waterbirds of Peel Inlet, Western Australia.* Report to the Mosquito Control Review Committee, Waterways Commission. Waterways Commission Report No. 20.

Riedel & Byrne Consulting Engineers Pty Ltd, 1990: *Estuary Deepening - Cox Bay. Preliminary Bund Construction.* Report No. R387. Riedel & Byrne Consulting Engineers, Perth, Western Australia.

Wright, A.E., 1988: *Report on the Mosquito Eradication Campaign Survey of Mosquitos in the Mandurah Region of Western Australia.* Health Department of Western Australia.



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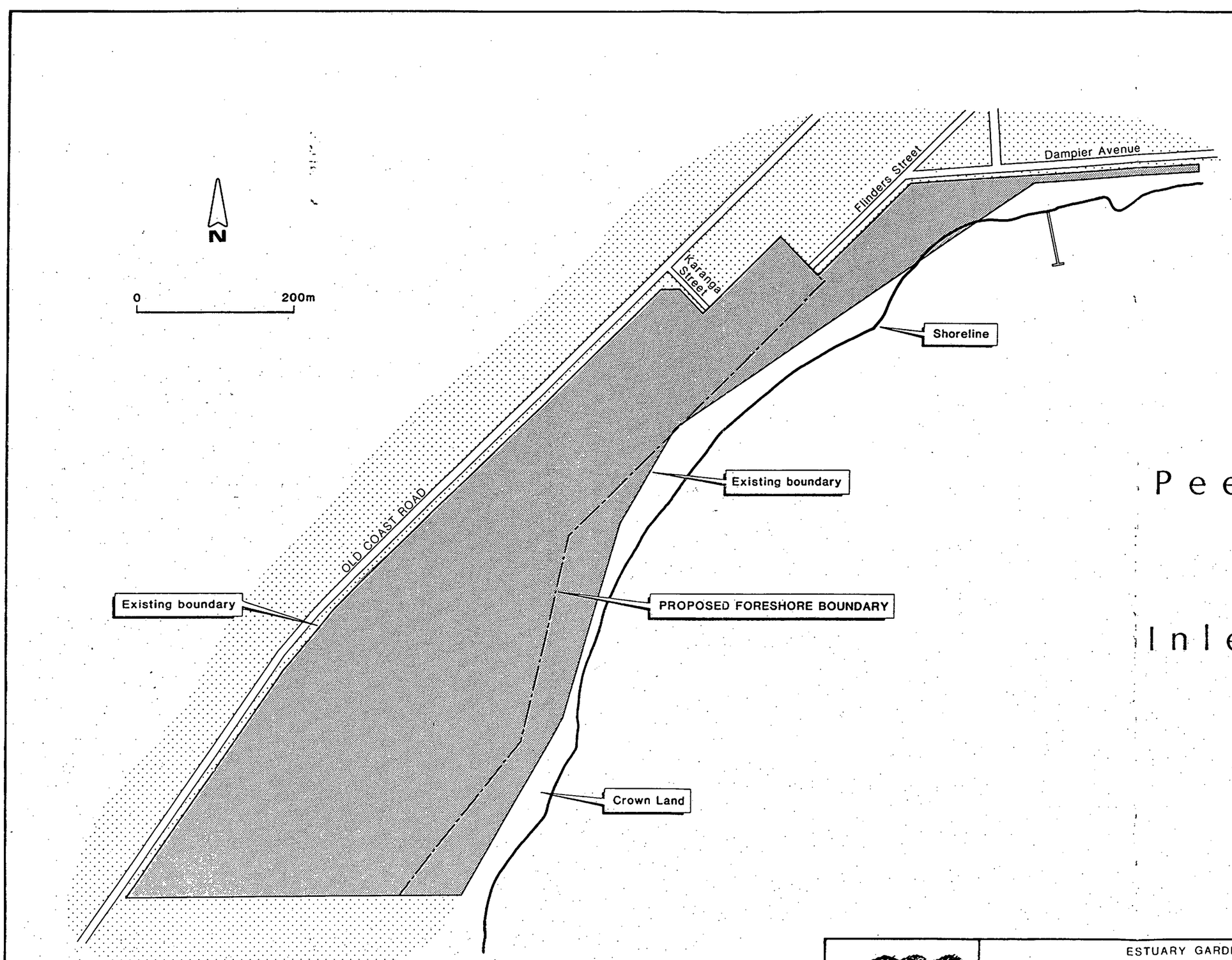

ESTUARY GARDENS

PROPOSED FORESHORE BOUNDARY

Figure 2

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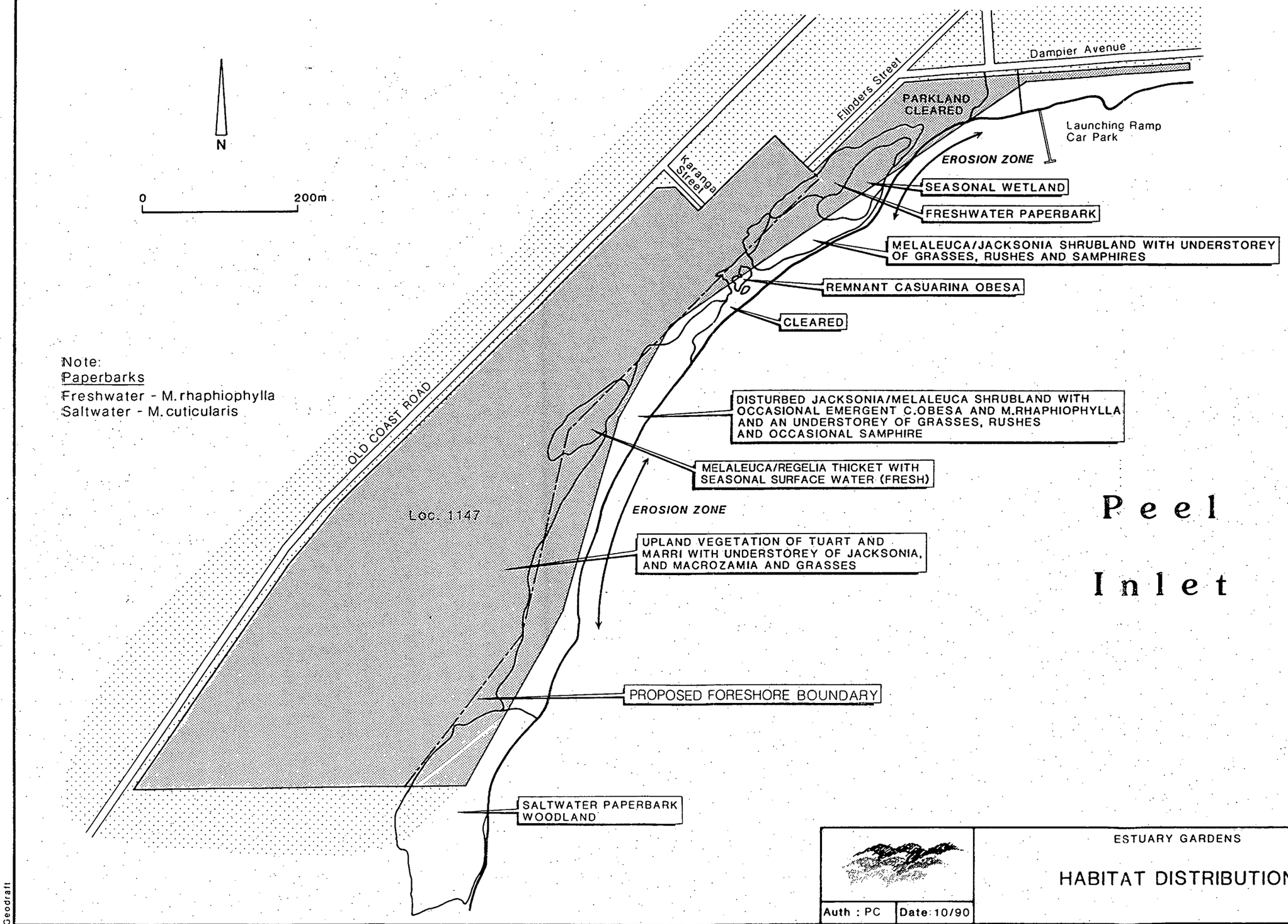
Environmental Drafting

J192 R293



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ESTUARY GARDENS

HABITAT DISTRIBUTION

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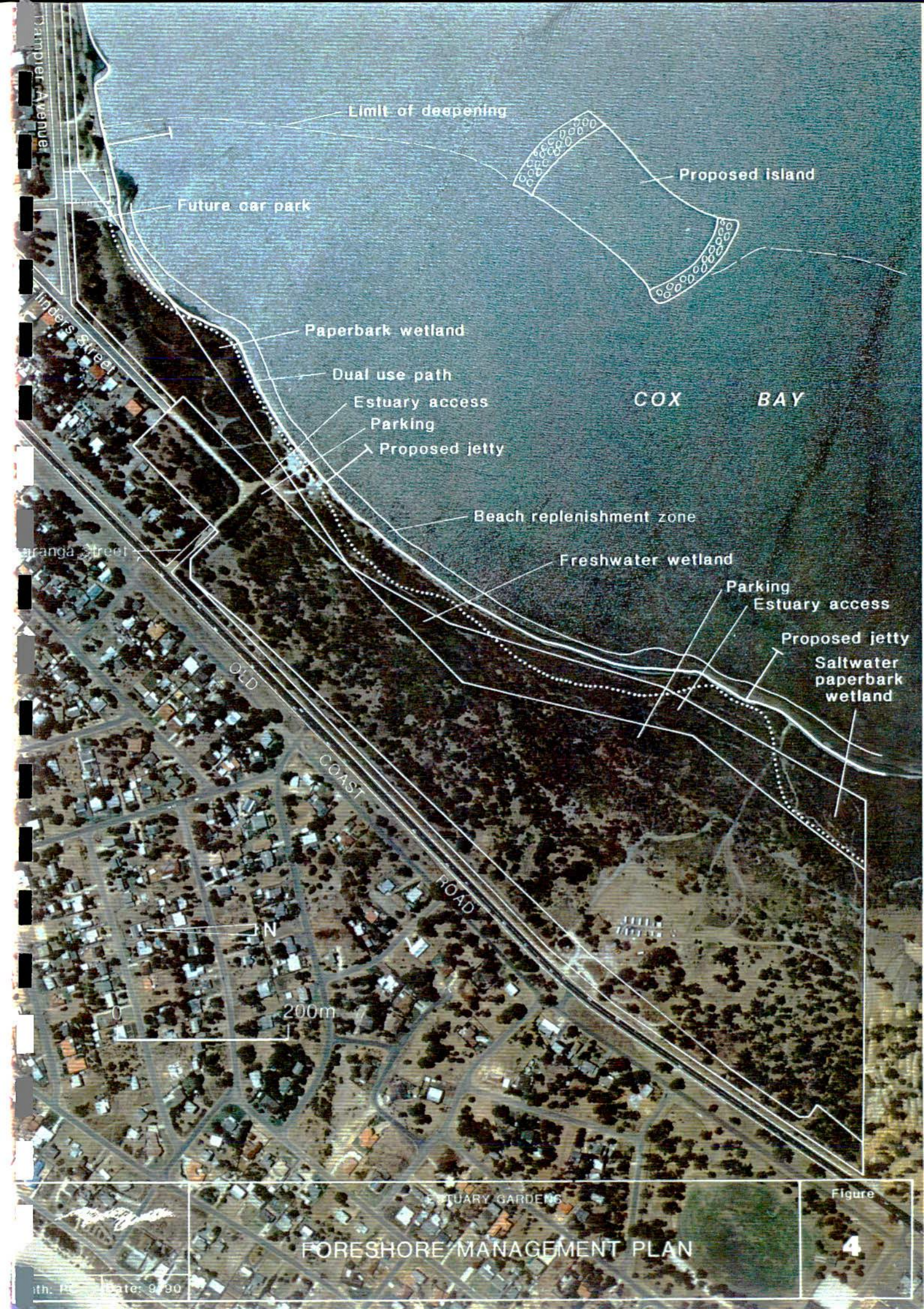
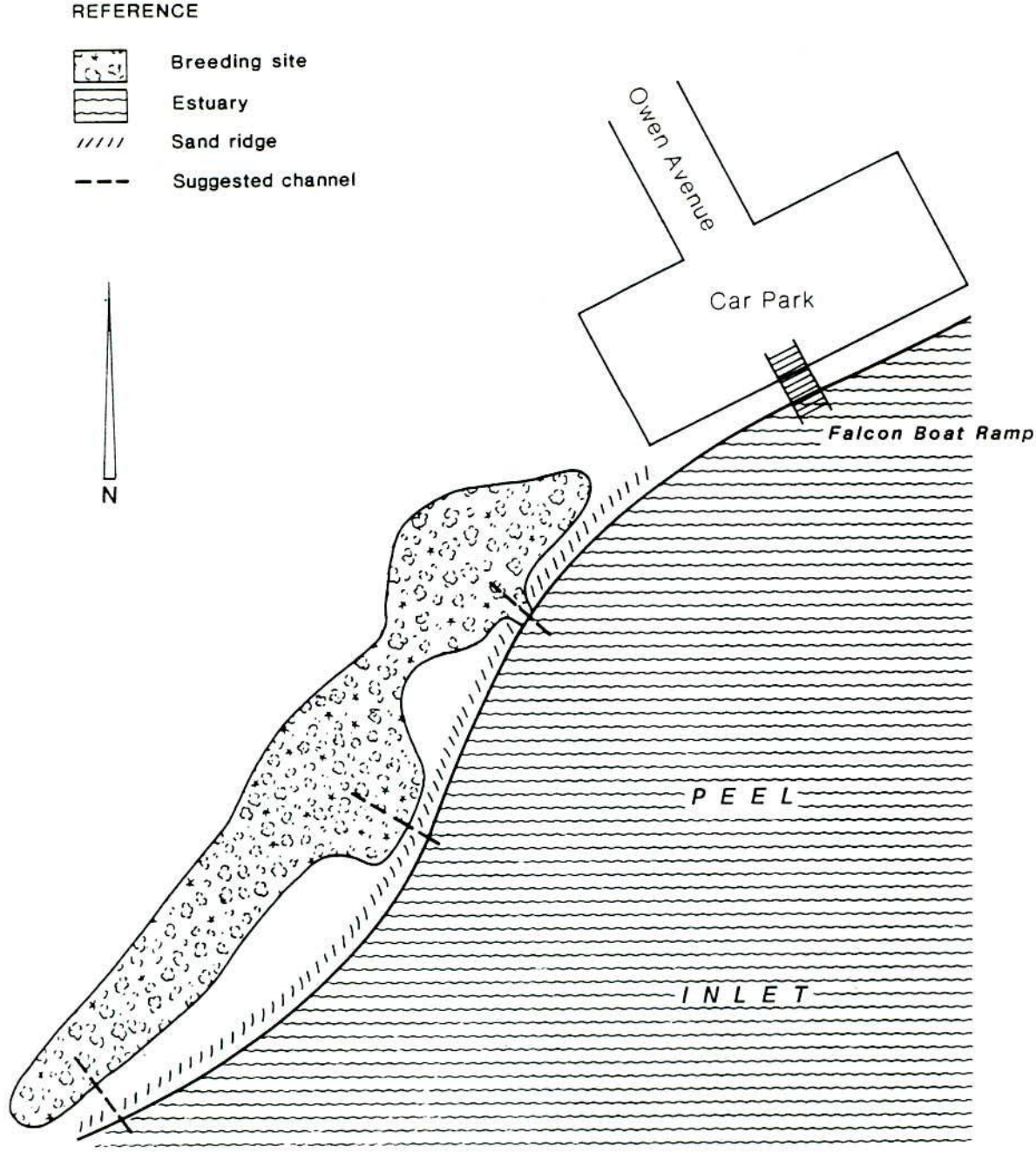
Figure 3


Limit of deepening
Proposed island
Future car park
Paperbark wetland
Dual use path
Estuary access
Parking
Proposed jetty
COX BAY
Beach replenishment zone
Freshwater wetland
Parking
Estuary access
Proposed jetty
Saltwater paperbark wetland
OLD COAST ROAD
N
0
200m
ESTUARY GARDENS
FORESHORE MANAGEMENT PLAN
Figure
4



ESTUARY GARDENS

PROPOSED MOSQUITO CONTROL MEASURES

after Wright, 1988

Figure **5**

Auth : | Date : 12/90

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WESTRALIA SQUARE
38 MOUNTS BAY ROAD, PERTH