AMENDMENT NO 183

CITY OF MANDURAH
DISTRICT ZONING SCHEME NO 1A

HARBOUR CITY CANAL ESTATE

WITH SUPPORTING

PLANNING AND ENVIRONMENTAL REPORTS

Prepared by: BSD Consultants Pty Ltd

Prepared for: Esplanade (Mandurah) Pty Ltd

MARCH 1992

INVITATION

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

The Consultative Environmental Review (CER) has been prepared in accordance with Western Australian Government procedures. The CER proposes to establish a residential canal development resort and tourist commercial centre just south of the Mandurah Bypass Road Bridge. The report will be available for comment until 18 May 1992.

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.

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 CER 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.

When making comments on specific proposals in the CER:

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

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CITY OF MANDURAH
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TABLE OF CONTENTS

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 CER;
- if you discuss different sections of the CER, 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; and
- date.

The closing date for submissions is 18 May 1992.

Submissions should be addressed to:

The Chairman,
Environmental Protection Authority,
8th Floor, Westralia Square,
38 Mounts Bay Road
Perth 6000

Attention: Ms Eve Bunbury.

LIST OF FIGURES

LIST OF APPENDICES

PART 1

INTRODUCTION

AMENDMENT NO 183
HARBOUR CITY CANAL ESTATE
PLANNING AND ENVIRONMENTAL REPORT AND TEXT

PART 1 - INTRODUCTION

1 INTRODUCTION

1.1 Purpose of Document

The purpose of this document is to present a combined comprehensive planning and environmental assessment report on the proposed Harbour City canal estate development at Mandurah in order to obtain the necessary planning and environmental approvals from the relevant Government agencies. Presenting the document in this manner will enable the planning and environmental approval processes to proceed concurrently whilst avoiding the need for two separate documents which would contain much of the same information.

1.2 The Proponent

The Proponent for the Harbour City development is Esplanade (Mandurah) Pty Ltd (E(M)PL). The Harbour City project is 100% owned by E(M)PL who are a wholly owned subsidiary of Cedar Woods Limited. Cedar Woods Limited was established in July 1987 as a property development company specifically geared as a land subdivision specialist. The company currently has major landholdings in Helena Valley (proposed residential estate), Rockingham (District Shopping Centre Site and Retirement Village Site) and Mandurah (Port Mandurah Canal Subdivision). In its first four years of trading, the company has successfully established itself as one of the major land developers in the Perth Metropolitan Region.

1.3 Background

Proposals to construct a canal estate on the subject land date back to the early 1980's when the previous owner of the site, John Holland Constructions Pty Ltd (JHC), proposed to construct the Waterside Mandurah canal estate. The land became divided into Stages 1 and 2 as a result of the Main Roads Department proposal to construct the Mandurah Bypass Road with Stage 1 occurring north of the road and Stage 2 on the subject land. An Environmental Review and Management Programme (ERMP) document was prepared for the entire Waterside Mandurah Project (Stages 1 and 2) in 1982 (JHC 1982). The ERMP included a conceptual plan for the Stage 1 and Stage 2 development and provided a detailed and comprehensive environmental assessment of the whole project.

The ERMP was assessed by the Environmental Protection Authority (EPA) in 1982 (Bulletin 126) and environmental approval granted to the whole project (Stages 1 and 2) although it was acknowledged that the Stage 2 design and layout was conceptual only and would be subject to further detailed design (Department of Conservation and Environment (DCE 1982). Bulletin 126 therefore specifically recognised that the Stage 2 concept plan would be subject to future adjustment.

The Stage 1 area gained rezoning approval for canals development. The Stage 2 area is currently zoned "Rural".

Stage 1 of the Waterside Mandurah canal estate has subsequently been constructed. It is important to note that no sunset clauses were specified in Bulletin 126 of 1982 and therefore the EPA approval for the Stage 2 component of the project is still operative providing the project as generally presented in the ERMP forms the basis of the current proposal.

In 1987, JHC sought to develop the subject land with a revised and significantly modified canal estate design. This proposal was abandoned before the application and environmental assessment documents were lodged with the relevant decision making authorities.

E(M)PL purchased the subject land from JHC in 1991 with the intention of constructing a canal development on the land relying upon existing approvals and the existing development guidelines that were previously supported by the whole of Government. This project will be known as Harbour City. E(M)PL have recently completed a high quality canal development in the Mandurah area known as Port Mandurah which is located on the western side of the Mandurah Channel opposite the Mandurah townsite. It is intended that Harbour City be developed to an equally high standard utilising the same design criteria and construction specifications. Water quality monitoring has confirmed the acceptability of the Port Mandurah project in terms of environmental performance.

1.4 The Study Team

This document has been produced by BSD Consultants on behalf of E(M)PL. A number of consultants contributed to the study as outlined below:

- BSD Consultants: town planning, civil engineering and environmental assessment;
- Soil & Rock Engineering Pty Ltd: geotechnical investigation;
- Dames & Moore: groundwater characteristics and use;
- Kinhill Reidel & Byrne: tidal and floodplain characteristics, shoreline stability, water quality and flushing aspects of canals and implications of Greenhouse Effect and Dawesville Cut;
- Landscan Pty Ltd: landscape planning and design;
- AR & MJ Bamford Consulting Ecologists: waterbird survey and review; and
- EM Goble-Garratt: botanical survey and vegetation mapping.

PART 2

PLANNING CONSIDERATIONS

PART 2 - PLANNING CONSIDERATIONS

2 THE SUBJECT LAND

2.1 Location

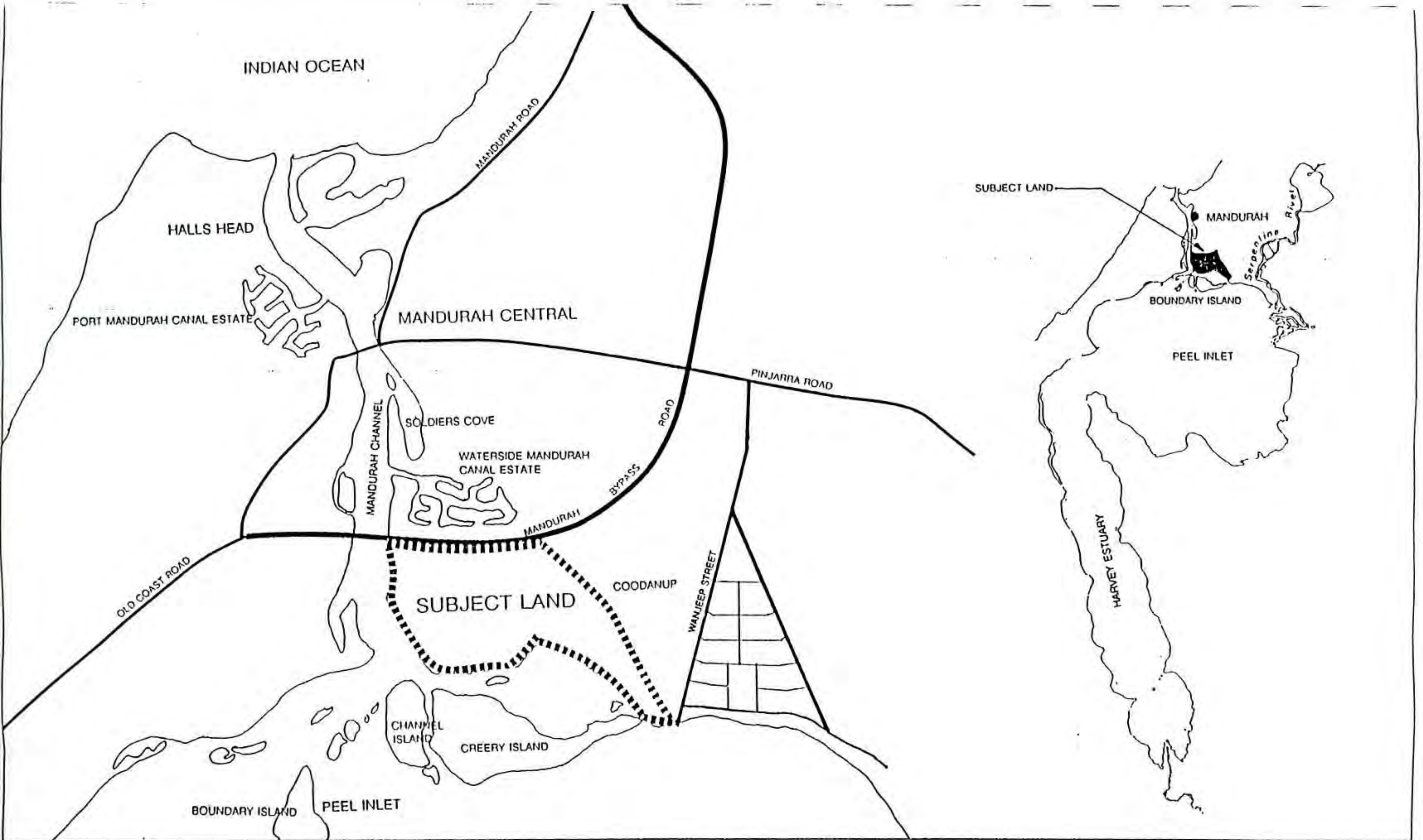
The subject land is situated approximately 2km south of the Mandurah city centre on the shoreline of the Peel-Harvey estuarine system (Figure 1).

The subject land is located on the south-eastern end of the Mandurah Channel at its confluence with the Peel Inlet. The subject land is bounded to the west by the Mandurah Channel, to the north by the Mandurah Bypass road, to the east by the Dudley Park residential estate and Wanjeep Road, and to the south by the northern reaches of the Peel Inlet. A small area of shallows separates the subject land from Creery and Channel Islands to the south which have formed in the Mandurah Channel Delta.

2.2 Site Description

The subject land is 197ha in area. With the exception of a small line of dunes along the eastern boundary, the subject land is virtually flat rising from a height of approximately 0.0m above Australian Height Datum (AHD) along the shoreline of Peel Inlet and the Mandurah Channel to a height of approximately 1.0m above AHD along the inland boundary of the subject land. The dunes along the eastern boundary vary in height from approximately 3.0m above AHD in the south-eastern corner to 6.0m above AHD in the north-eastern corner of the subject land.

The low lying areas of the subject land adjacent to the shoreline are covered in samphire flats with she-oak (*Casuarina* sp.) and paperbark (*Melaleuca* sp.) on the higher ground further inland. The dunes along the eastern boundary support a *Banksia* woodland with some Marri and Tuart (Figure 2).



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TITLE

FIGURE 1 LOCATION PLAN

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PLAN No.

2.3 Land Ownership

The land subject of this proposal is legally described as being Cockburn Sound Location 16 on Plan 2413, Volume 1682 Folio 35.

This land is currently owned by Esplanade (Mandurah) Pty Ltd who purchased the property from Haughton Holdings Pty Ltd.

2.4 Existing Zoning

2.4.1 Metropolitan Region Scheme

The City of Mandurah is not located within the Perth Metropolitan Region as defined by the Metropolitan Region Scheme. Development in this area therefore is not subject to the provisions of the Metropolitan Region Scheme.

2.4.2 City of Mandurah Town Planning Scheme No. 1A

Development within the municipality of Mandurah is controlled by the provisions detailed in the City of Mandurah Town Planning Scheme No. 1A.

Scheme 1A is a District Zoning Scheme and was gazetted on the 30th December 1983. Under the provisions of that Scheme the land is zoned 'Rural'.

Within the Rural Zone a number of uses can be permitted, however rezoning is required to facilitate Canal and residential development as proposed.

2.5 Existing Landuse

The land subject of this report was previously extensively used for the grazing and agistment of livestock. For the past ten years or so the land has remained vacant and unused.

Land within the immediate vicinity is used for a variety of purposes including canal development and residential purposes.

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FIGURE 2 SITE PLAN

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SCALE

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2.6 Constraints to Development

There are a number of constraints to development on the subject land. These can be overcome and are noted as;

- provision of a conservation area;
- requirement to fill the site above flood levels (fill supplied from canal excavation);
- disposal and/or treatment of spoil not suitable for development;
- long term management of the canal waterways;
- rezoning to Canal and Residential zones; and
- control of access to Mandurah Bypass Road.

3 PLANNING FRAMEWORK

3.1 Peel Region Plan

With respect to the subject land the Peel Region Plan proposes a zone (Rural C) for the conservation of flora and fauna and for passive recreation purposes which is up to approximately 500m wide along the southern shore of the subject land and approximately 100-150m wide adjacent to the Mandurah Inlet Channel.

The Draft Peel Region Plan acknowledges the subject land as suitable for urban development as follows:

> "A cell of future urban land between Peel Inlet (Creery wetlands) and Mandurah Bypass Road is also identified. Development of this land will depend on the resolution of a number of constraints including the amount of land to become a conservation reserve and the environmental impacts of the proposal" (DPUD 1990).

3.2 DPUD Draft Policy No. DC 1-8 - Canal Guidelines

Draft Policy DC 1-8 has been recently reviewed and is proposed to be gazetted as a 5AA Policy under the provisions of the Town Planning and Development Act 1928 (as amended). This policy outlines criteria for the design and management of artificial waterways in Western Australia. This policy also defines a 'Canal Zone' such that land proposed for artificial waterway developments must be zoned accordingly.

The proposed Harbour City development has been designed to comply with the design requirements stipulated by the policy including, canal depth/width, shore stability, flood mitigation etc. The issue of management is addressed in Section 11.7.3 of this report.

3.3 . City of Mandurah District Town Planning Scheme No. 1A

The City of Mandurah District Zoning Scheme was gazetted some 9 years ago and will in the immediate future be subject to review.

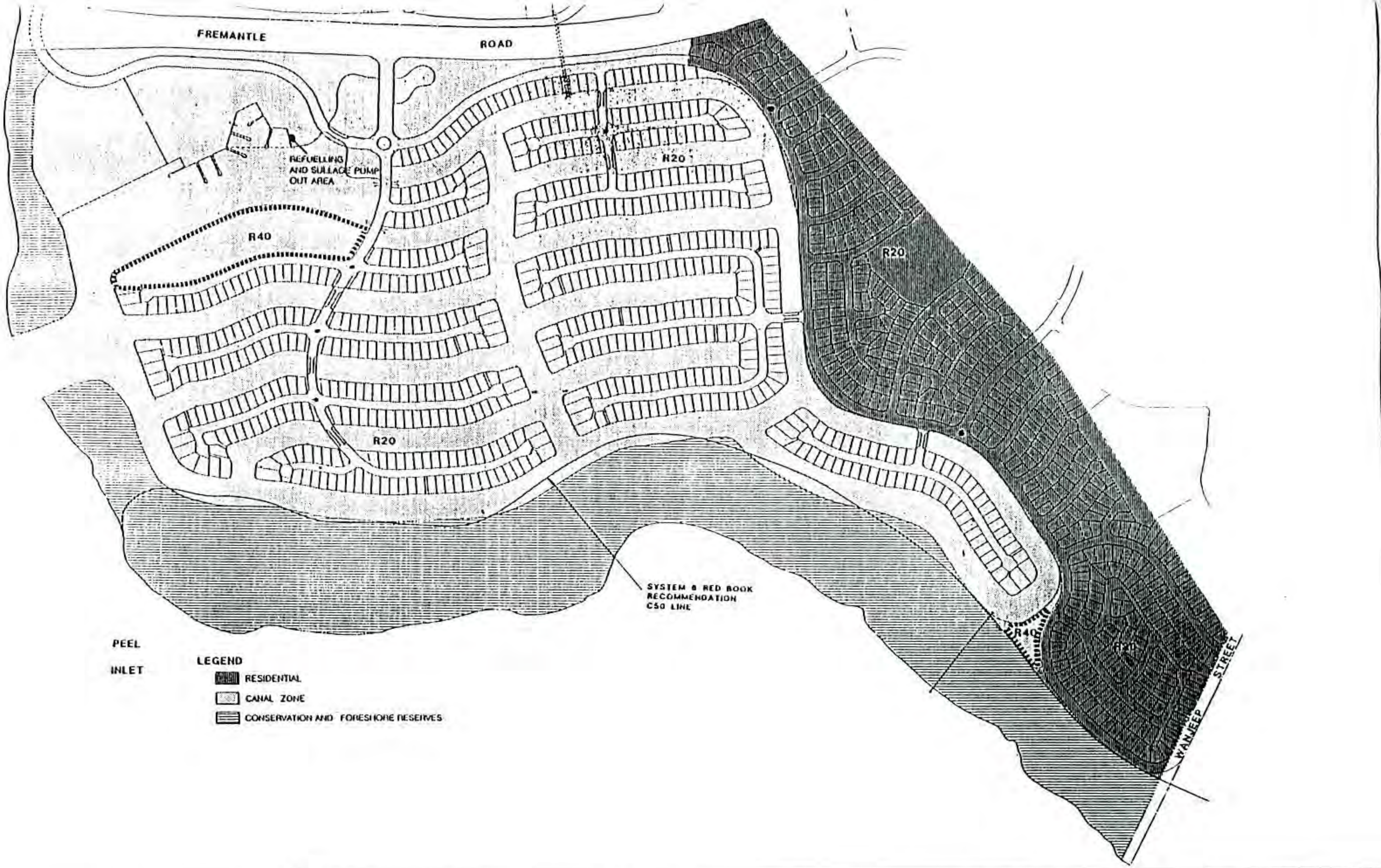
Similar canal development proposals have been permitted in the past subject to rezoning and scheme amendment. Given the likely time delays associated with the Scheme Review, this proposal recommends the adoption of the rezoning and amendment procedure forthwith.

3.4 Proposed Zoning

The development proposal recommends the rezoning of the subject land into primarily three distinct zones as shown on Figure 3. The dry development area will be zoned 'Residential' and assigned an 'R20' density coding.

The proposed canals area will be zoned 'Canal Zone'. A schedule of added uses will be attached to the canal zone permitting the provision of restaurant, boating and administrative facilities, retail and resort hotel facilities.

A 'Conservation and Foreshore Reserve' will be created over the proposed conservation and foreshore reserves. This land will be transferred to the Crown and vested with the City of Mandurah.



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TITLE

FIGURE 3

PROPOSED ZONING

PROJECT

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4 THE PROPOSAL

4.1 Approach/Design Philosophy

The Harbour City development proposal represents the culmination of an intensive investigation of conservation, design and development considerations.

Harbour City project provides a residential canal waterway development with a wide range of residential and tourist accommodation and commercial facilities set behind a substantial samphire flat conservation area. A series of islands and finger canals are proposed to maximise the number of waterfront properties. The canal and road layout has been carefully chosen to maximise wind driven water circulation and also provide a pleasing outlook over the canal waterways for dry lots further inland.

Opportunities will be provided for water based activities with a functional layout of commercial facilities to enable easy access to both visitors and estate residents. The canal waterways have been aligned to maximise flushing and promote water exchange in order to maintain water at an acceptable quality.

4.2 Scope of Development

The details provided in this document address the proposed development of the 197 ha subject land. The proposed development comprises canal waterways and associated residential and commercial development, dry lot subdivision and substantial foreshore and conservation reserves (Figure 4 in the attached pocket).

This document outlines the development concepts by providing planning, engineering and environmental justification for the Harbour City proposal.

4.3 Components

4.3.1 Canal Waterways

4.3.1.1 Overall and Navigable Widths

A typical waterway cross section is shown on Figure 5. Waterway widths between canal walls will be maintained at a minimum width of 40m for short waterways, increasing to 45m for waterways servicing more than 20 residential units. Main

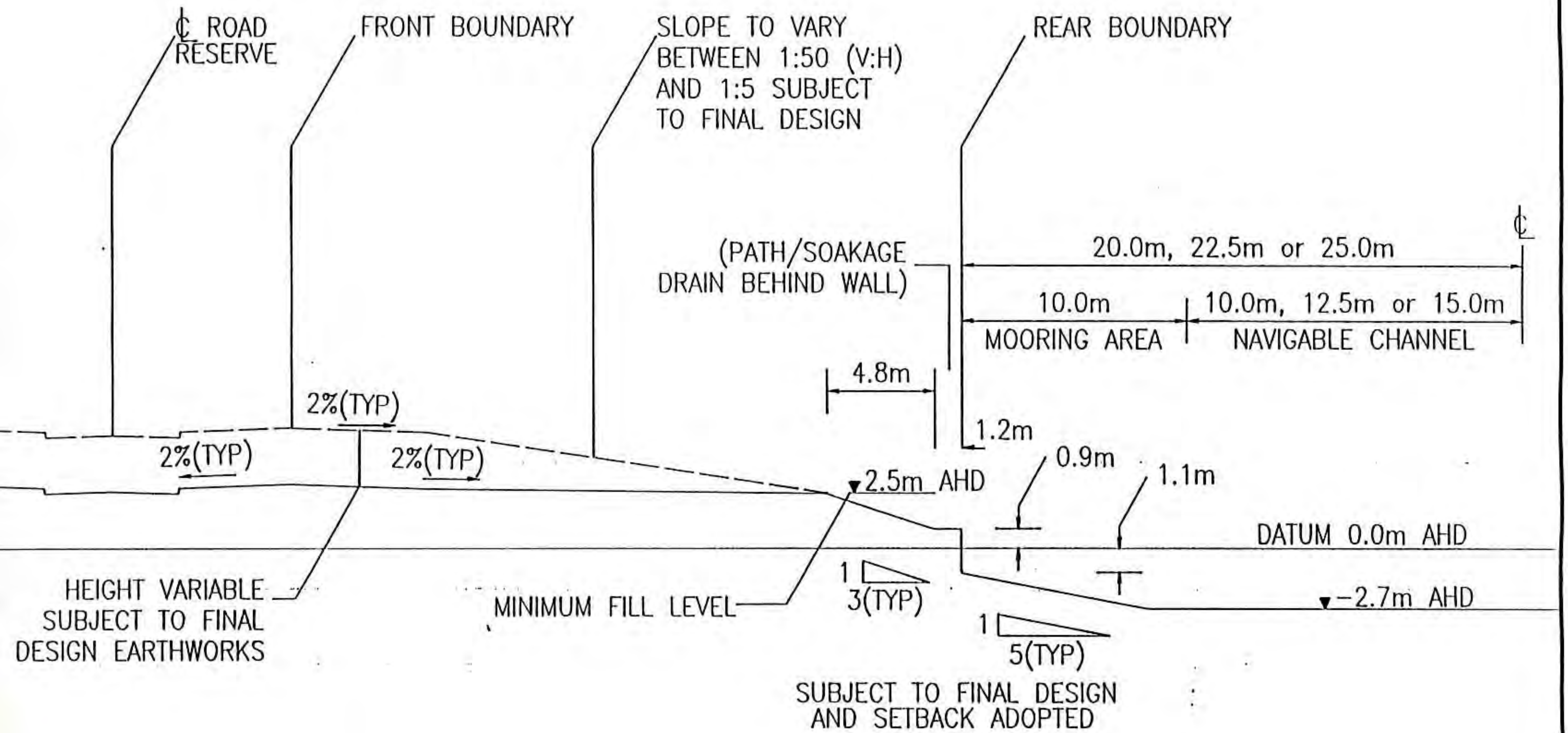

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FIGURE 5 TYPICAL ELEVATION THROUGH WATERWAY AND LOTS

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JOB No.	P9186
SCALE	1:250
PLAN No.	

waterways shall have a minimum width of 50m. These widths equate to navigable widths of 20m, 25m and 30m; which correspond to 2, 2.5 and 3 times the design vessel length of 10m.

Waterway width opposite the Resort and the R40 complex has been increased to 150m generally to provide additional space for higher volumes of boat traffic, Marina activity as well as providing a more enhanced aspect from these sites.

A batter slope of 1:5 has been used on the waterway edge adjacent the canal wall (Figure 5). Preliminary analysis suggests that this slope will be stable, under normal safety factors, based on preliminary soil investigations carried out. The need for scour protection to this slope will be investigated and analysed in detail during the design phase of the project with appropriate measures or modifications to be incorporated as necessary.

4.3.1.2 Design Vessel

The design boat adopted will have the following dimensions:

- design length: 10m;
- design beam: 4.0m (cruisers); and
- design draft: 1.8m (yacht).

These have been selected by the proponent to satisfy the greatest proportion of boat owners likely to be attracted to the Estate.

4.3.1.3 Depth of Waterways

The depth of the canal waterway is proposed at -2.7m AHD. This is based on using the 98% confidence limits for tidal levels, along with suitable under keel clearances, and wave height allowances. A summary is as follows:

Low tide (98% confidence)	-0.4m AHD (rounded)
Draft of 10m design vessel	1.8
Under keel clearance and siltation allowance	0.5
	-2.70m AHD

The depth of -2.70m AHD will render available an effective depth of 2.3m below normal low tide level of -0.4m AHD for at least 98% of the time.

4.3.1.4 Wall Types

Wall types within the estate can be grouped into two main categories which are described in turn.

a) "L" Shaped Reinforced Concrete Walls

These walls would either be precast or cast in situ. It is presently envisaged that the walls would be precast, with a precast capping placed on top to improve stability and provide an aesthetically pleasing finish.

It is proposed to use these walls to all residential canal lots, including the R40 and retail/resort hotel sites. The top of the walls will be set at 0.9m AHD. The overall effective height of the walls will be 2.0m (-1.10m AHD at Canal Bed Slope) at canal lots including the R40 site. The base of the wall will be constructed below the canal bed slope to provide structural stability and to prevent scour. A typical wall elevation is shown in Figure 8.

b) Sloping Rock Pitched Walls

These walls will consist of limestone spalling of varying slopes up to 1 (v) to 1.5 (H). Spalls will be no less than an average diameter of 300mm to ensure that they are not easily moved by humans, and be laid on a geotechnical filter cloth to prevent "wash out" of fines as well as providing a stable foundation.

It is proposed to locate this type of wall at the canal wall abutting the conservation reserve, at the canal entrance to the Mandurah Channel and along the edge of the boulevard style road fronting the dry lot subdivision. Final slopes, wall heights and thickness will be determined at the detailed design stage.

The height of the wall will generally be designed to match existing levels to minimise disturbance to the conservation area. A typical elevation is outlined in Figures 6 & 7.

4.3.2 Lots

Harbour City will, when ultimately developed, yield approximately 639 single residential canal lots and 172 group dwellings. An additional 443 single residential dry lots will be provided as part of the development.

In total the proposal will create approximately 1,254 residences, being comprised of single and group dwellings.

4.3.3 Roads and Traffic

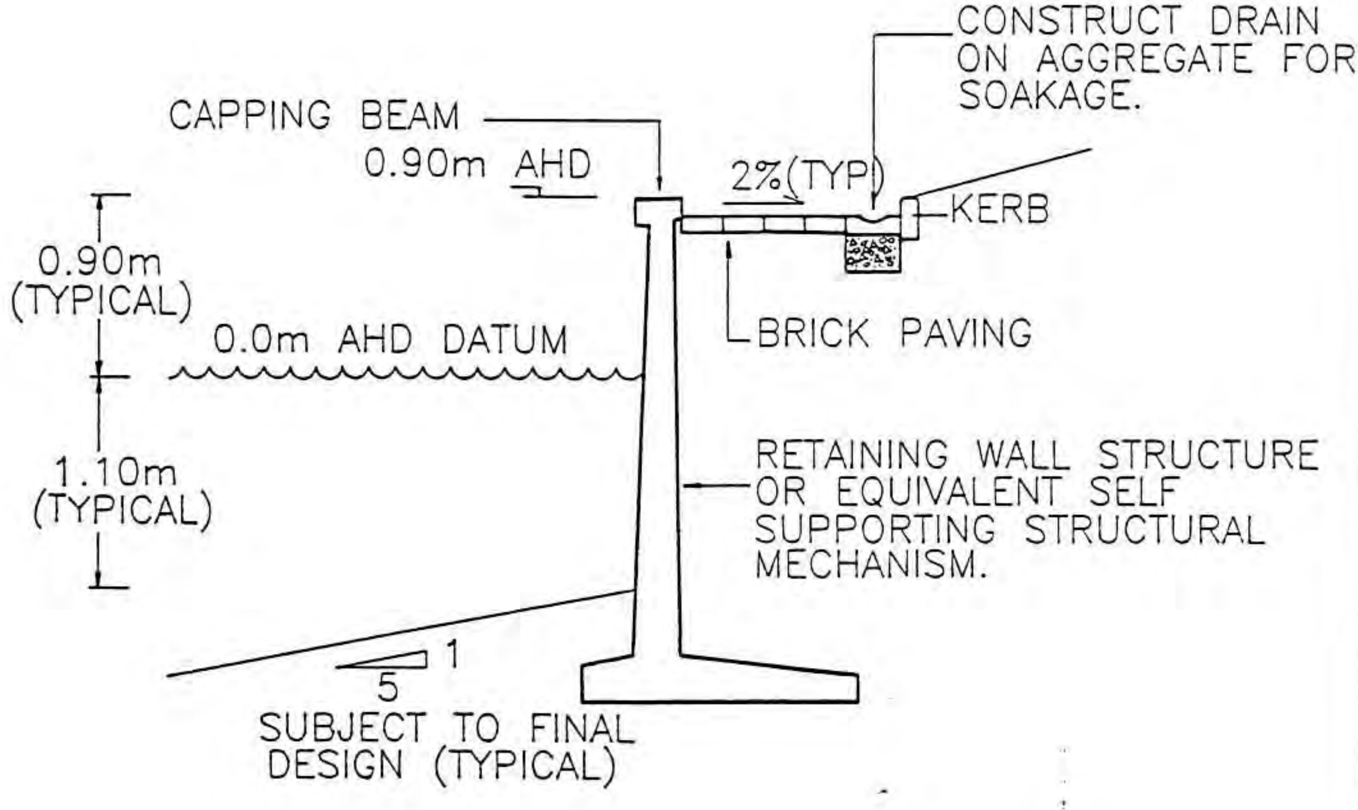
Roads within the development have been designed so as to promote a hierarchy based on function. Wherever possible residential and canal lots have frontage to local cul-de-sac roads and not collector roads. Local roads will be designed within 15m road reserves. The collector road reserves will vary in width between 18m and 20m.

In total eight roundabouts are proposed, some of which provide an entry statement, vehicular control and offer motorists an opportunity to turnaround without having to use the culs-de-sac of the residential streets.

Existing traffic volumes in this area are available only for Mandurah Bypass. These volumes are presented as annual average weekday traffic for the 1990/91 financial year.

- Pinjarra Road, south of Pinjarra Road 9,440 vpd
- Pinjarra Road, at Mandurah Estuary Bridge 10,440 vpd

Analysis of the traffic distribution of the Development Concept Plan has been undertaken and the resultant daily traffic volumes within this subdivision are shown on Figure 8A.



PROJECT **HARBOUR CITY**	TITLE **FIGURE 8 TYPICAL CANAL WALL ELEVATION**
PRINCIPAL **ESPLANADE(MANDURAH) PTY.LTD.**	**BSD CONSULTANTS** CONSULTING ENGINEERS, TOWN PLANNERS & PROJECT MANAGERS BSD HOUSE, 1 SLEAT ROAD, APPLECROSS. PHONE No 316 2988 DATE 10.3.92 JOB No. P9186 SCALE N.T.S. PLAN No.

The Development Concept Plan shows four entry points to the subdivision. These are located at:

- New connection to the Mandurah Bypass (between Leslie Street and the Mandurah Estuary Bridge);
- Ravendale Drive;
- Newport Drive; and
- Wanjeep Street.

The traffic volumes at the first of these will be in excess of 6,000 vpd and no residential lots are located along this high volume section between the Mandurah Bypass and the entry statement roundabout of the subdivision.

Traffic volumes at the remaining three entry points will be below 3,000 vpd.

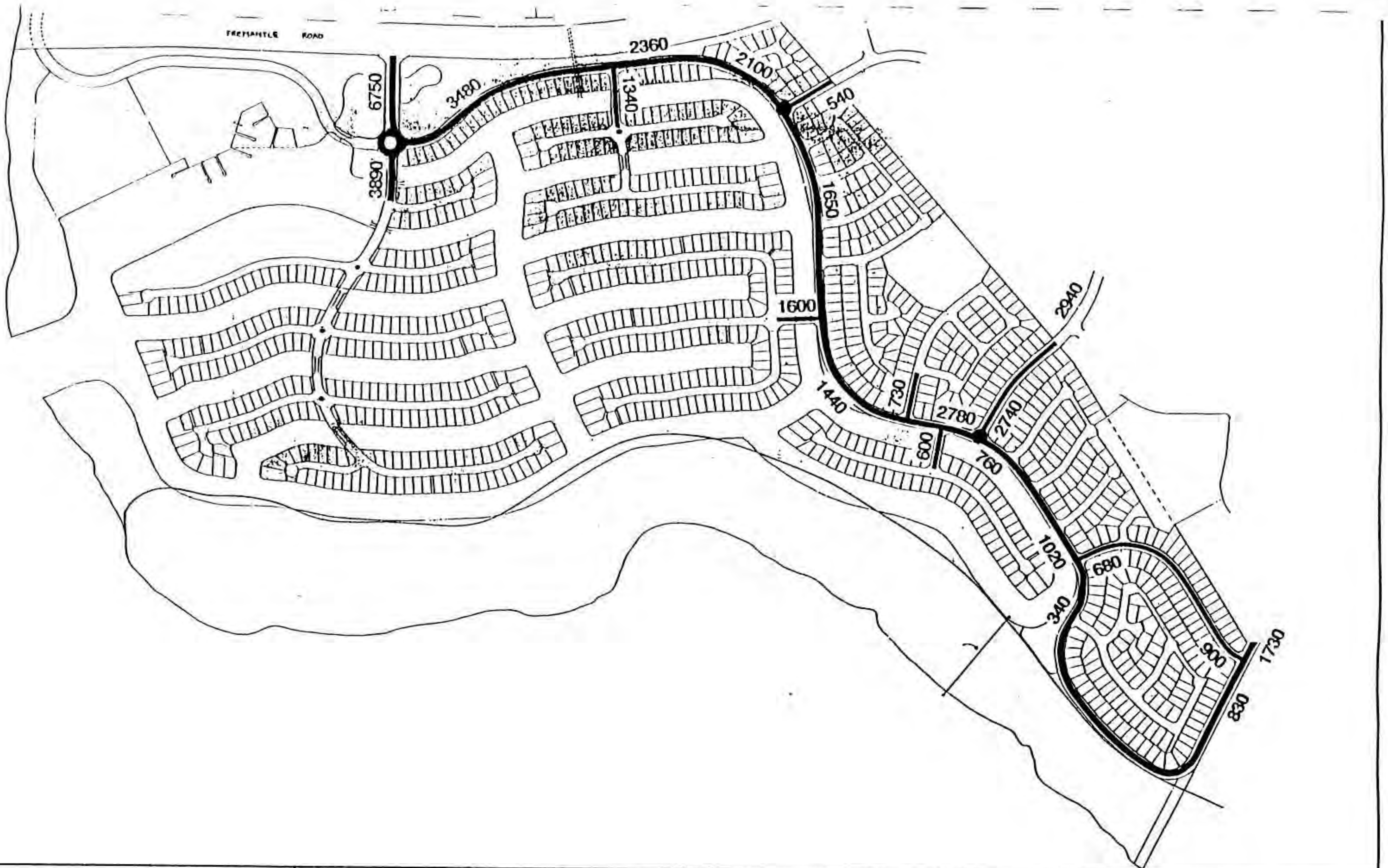
Traffic volumes on the subdivisional road running south from the entry statement roundabout will be approximately 3,900 vpd but no residential lots will have frontage access to this section of road.

Traffic volumes on the boulevard road immediately to the east of the entry statement roundabout are calculated to be up to 3,480 vpd on the first sector from the entry statement but as this road is of a curvilinear alignment with roundabouts located along its length to control vehicle speeds and residential lots access only one side of this road it is considered that this traffic volume can be satisfactorily accommodated with frontage access.

All other subdivisional roads will have volumes less than 3,000 vpd and therefore residential access concurs with DPUD policy.

4.3.4 Bridges and Culverts

It is proposed to construct 7 bridges and 2 culverts to provide access between various islands within the canal estate. These structures will facilitate water circulation and flushing within the canal estate as well as to provide attractive views and vistas of the



PRINCIPAL

CEDAR WOODS LIMITED

TITLE

FORECAST DAILY TRAFFIC VOLUMES

PROJECT

FIGURE 8A
HARBOUR CITY

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JOB No. P9186
SCALE
PLAN No.

canals. Adequate height will be provided between the base of bridges and culverts and water surface to maximise wind driven water circulation within the canal waterways. These structures will extend to the full depth of the canals to ensure unimpeded water circulation (eg. density currents).

4.3.5 Public Open Space

Substantial areas of the development site contribute to public open space. The conservation and foreshore reserves, and canal waterway areas combined account for approximately 94ha or 54% of the subject land. Whilst these areas do not strictly conform with the definition of public open space, they do contribute to the openness of the estate and in themselves have recreational and conservation value.

In addition a further 10% of the net developable site area (ie. developable land excluding canal waterways) has been proposed as formal open space. These areas comply with DPUD standards and offer passive and active recreation opportunities.

4.3.6 Foreshore Reserve

A foreshore reserve of 5.4ha is proposed along the foreshore of the Mandurah Channel. This reserve varies in width from approximately 100 m to 130 m and is in accordance with DPUD and EPA requirements. The reserve will provide access to the Mandurah Channel for both residents of and visitors to Harbour City.

4.3.7 Conservation Reserve

The boundaries of the samphire flat conservation reserve have been determined based on ecological considerations as assessed in Section 10.6. The area of the conservation reserve is 1.1 ha greater in size than that of the EPA System 6 Red Book conservation reserve recommendation C50 area (Department of Conservation and Environment (DCE) 1983) and with the exception of minor adjustments, adheres to the boundaries of this area. The Reserve varies from 130 m to 250 m in width. Additional samphire habitat will be preserved in the foreshore reserve adjacent to the Mandurah Channel. The boundaries of the proposed conservation and foreshore reserves are shown in Figure 9.

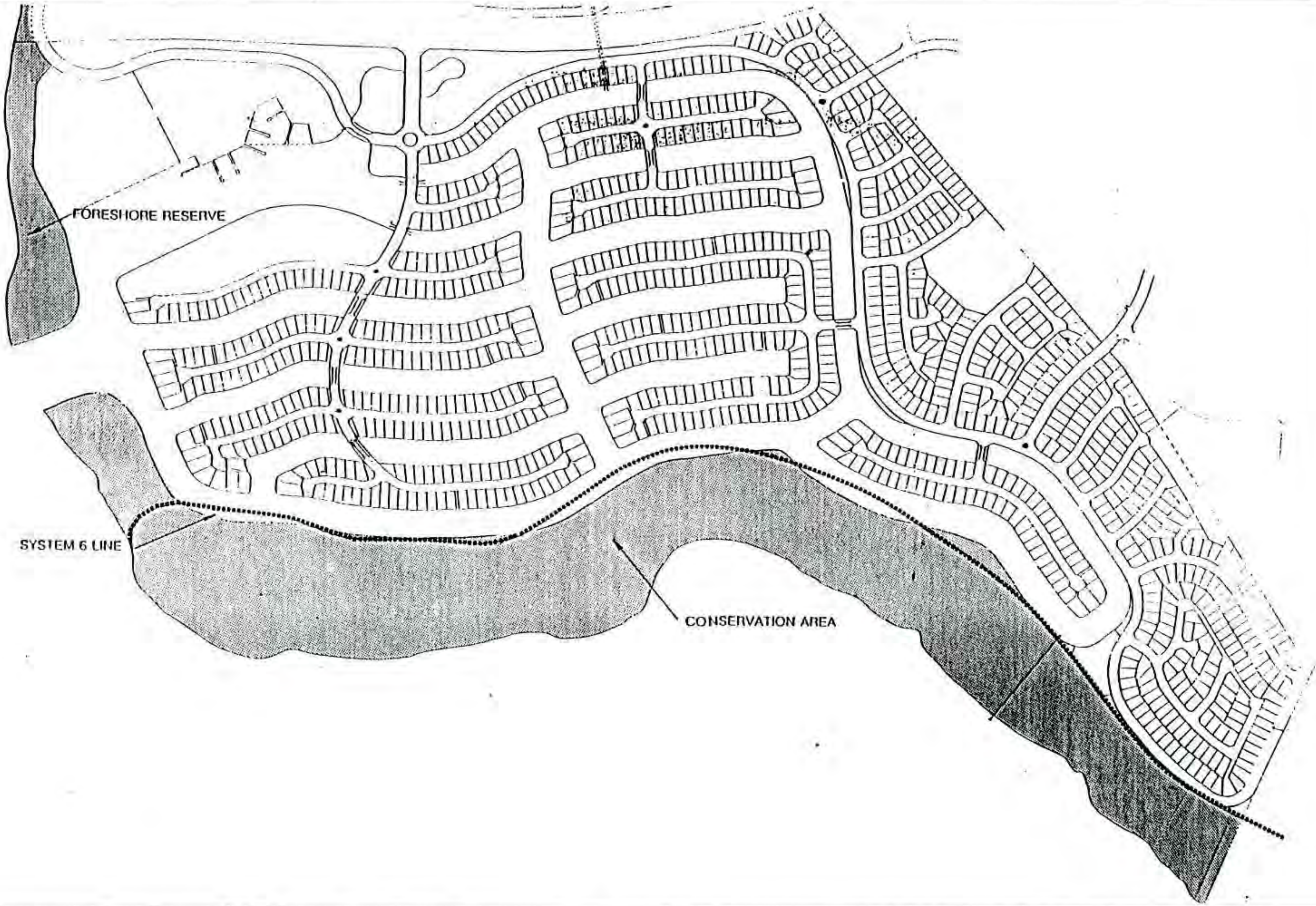

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FIGURE 9A CONSERVATION AND FORESHORE RESERVE AREAS

PROJECT

HARBOUR CITY

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DATE 10.3.92

JOB No. P9186

SCALE

PLAN No.

PRINCIPAL	TITLE				
ESPLANADE (MANDURAH) PTY LTD	AERIAL PHOTOGRAPHS OF SITE WITH DEVELOPMENT LINE SHOWN				
	PROJECT: HARBOUR CITY	BSD CONSULTANTS CONSULTING ENGINEERS, TOWN PLANNERS & PROJECT MANAGERS BSD HOUSE, 1 SLEAT ROAD, APPLECROSS. PHONE No 316 2988	DATE: 13.4.92 JOB No.: P9186 SCALE: NTS	PLAN No.: 9b	

Under the proposed Harbour City development design, the conservation reserve will be retained as a peninsula bounded by the Peel Inlet to the south, Mandurah Channel to the west and canal waterways to the north. Where the peninsula connects to the south-eastern corner of the subject land it is proposed to construct a vermin proof fence to prohibit public access and intrusion by feral animals. Details on the proposed management of the conservation reserve are provided in Section 11.6.

Figure 6 details in cross section the proposed treatment of the Conservation Reserve which will be constructed in stages reflecting the staged development of the canal estate. A hard inhospitable edge is proposed along the northern edge of the Conservation Reserve to control public access. Earthwork is also proposed to prevent water from the Peel Inlet entering the Canal Estate over the Conservation Reserve.

It is proposed to prepare a Management Programme for the Reserve which will include landscaping and planting of indigenous vegetation as necessary to generally improve the area.

4.3.8 Landscape Treatment

Landscaping will be given a high priority to ensure an attractive development that will improve the visual amenity of the area. The major landscape components within the development are streetscapes, public open space and buffer along the Mandurah Bypass Road which are discussed in turn.

The streetscape will consist of grass verges with street tree planting using indigenous trees that are naturally salt, wind and drought resistant such as Swamp she-oak (*Casuarina obesa*) and Salt-water paperbark (*Melaleuca raphiophylla*).

The public open space areas will generally be grassed with grouped plantings of the above indigenous trees. Feature trees including Coral Trees or Norfolk Island Pines will be used in key locations.

The buffer along the Mandurah Bypass Road will consist of dense tree planting in dry land grass, using trees such as *Casuarina obesa* and Tuart (*Eucalyptus gomphocephala*). The tree buffer will provide an attractive outlook from Mandurah Bypass Road, and will screen the residential canal development from the road, thereby reducing the visual impact when viewed from this road by the passing traffic.

4.3.9 Entrance Statement

The entrance statement (refer Figure 9A) will feature a large grassed open space with ornamental lakes, bisected by the main entry road. The road will be a dual carriageway lined with a formal avenue of Norfolk Island Pines with a colourful groundcover planting in the median strip and within the roundabout. The entrance statement has been designed to create a 'water based' development theme from first contact, with wide open space, views to the main canal waterways and high quality landscaping to enhance the quality of the estate. A tower in the form of a lighthouse is proposed in the entrance statement roundabout to reflect the water based nature of the Harbour City development.

4.3.10 Commercial Facilities

Approximately 9.4ha of the site will be developed into commercial facilities comprising:

- a four/five star tourist resort hotel; and
- tourist food and beverage retail complex modelled on the successful Pier 39 at Fishermans Wharf in San Francisco and the Fishing Boat Harbour in Fremantle. This complex will be known as 'Mariners Cove'.

An administration sales office site, which will later be used for residential development, will be located adjacent to the commercial complex.

4.3.11 Moorings and Jetties

Moorings have been designed to comply with the requirements stipulated in Draft DPUD Policy D.C. 1.8. The moorings are located to ensure adequate navigable water depth irrespective of tides. Sufficient space is provided to allow for the construction of jetties within the mooring envelope for all canal lots. Jetty design shall be pre-approved by PIMA for construction by individual lot owners.

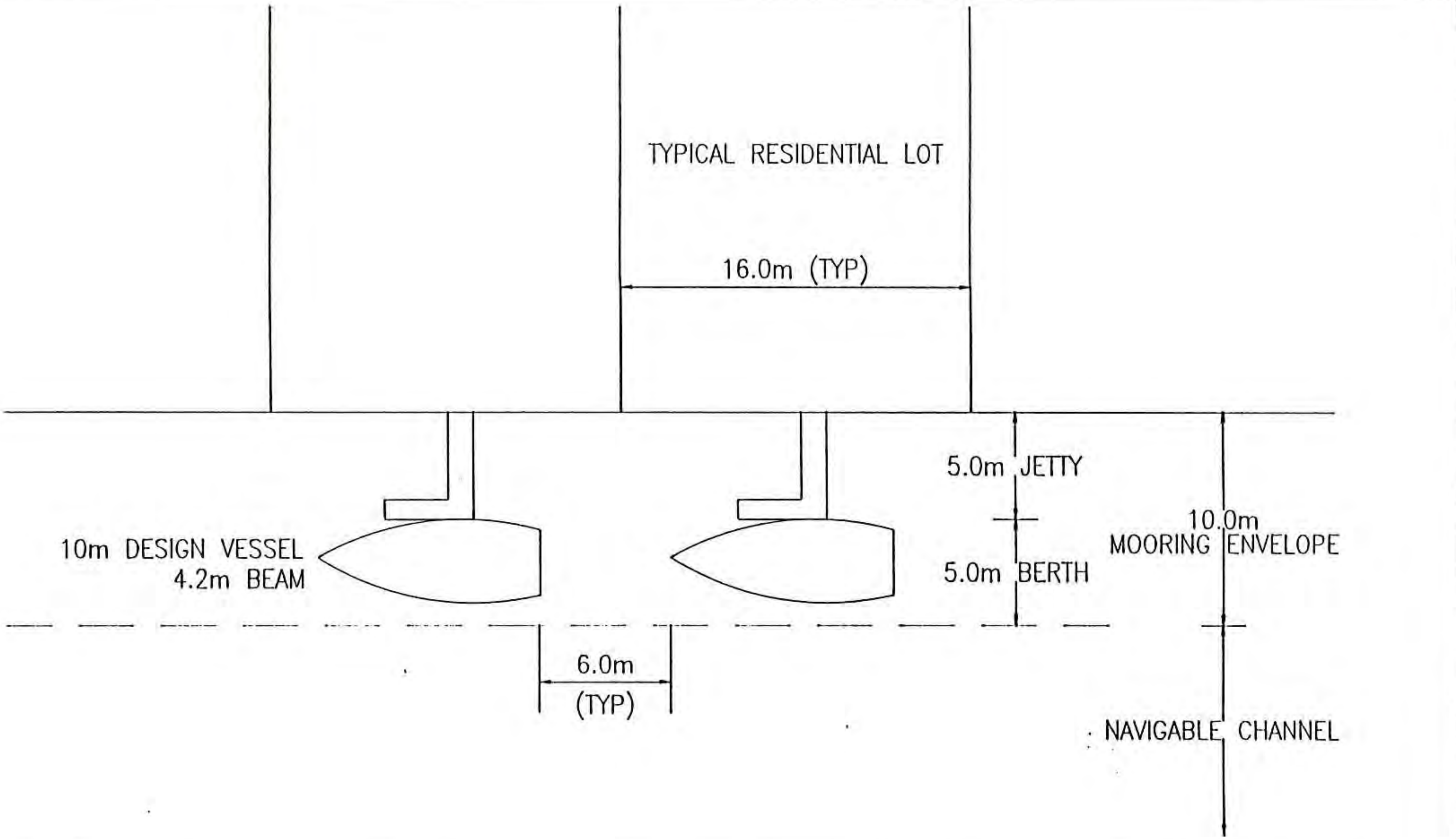
4.3.11.1 Mooring Depths and Widths

A minimum effective depth of 2.0m below low tide (-0.4m AHD, 98% confidence) has been adopted at boat moorings. This depth is summarised below and is in accordance with Australian Standard 3962-1991.

Design boat draft (Yacht)	1.8m
Allowance for negative tide	0.2
Total Effective Depth	2.0m

It is proposed to provide a total mooring envelope width of 10m, based on a proposed canal wall height of 2.0m (0.9 AHD down to -1.10 AHD) and a jetty length of 5.0m, which would leave a berthing width of 5.0m for single berths as recommended in the Australian Standard. Figures 10 & 11 outlines details of the proposed mooring envelope showing a jetty profile including dimensions.

The length of moorings will generally be based on the residential lot frontage width abutting the canals. The minimum residential canal lot frontage adopted will be 16m, giving a mooring length of similar dimension. At curves, mooring lengths will be greater. Based on a 10m design vessel, the minimum clearance between berthed vessels would be 6m. This clearance will provide more than adequate room for a design vessel of beam 4.0m to be able to manoeuvre into its berth. The likelihood of two adjacent design vessels berthing at any one time is considered extremely small and is therefore not catered for. This has been confirmed in previous discussions with the Department of Marine and Harbours (DMH). More common smaller vessels, if berthing together, would be readily catered for. A typical plan showing berth for 16m frontage lots is outlined in Figure 10.



PRINCIPAL

ESPLANADE (MANDURAH) PTY LTD

TITLE

FIGURE 10 TYPICAL PLAN OF BOAT MOORINGS

PROJECT

HARBOUR CITY

BSD CONSULTANTS
CONSULTING ENGINEERS, TOWN PLANNERS & PROJECT MANAGERS
BSD HOUSE, 1 SLEAT ROAD, APPLECROSS. PHONE No 316 2988

DATE 10.3.92
JOB No. P9186
SCALE 1:2500
PLAN No.

4.3.11.2 Jetties - Residential

It is proposed to use jetties based on standard designs already approved and adopted for the Port Mandurah project in the locality. These would typically consist generally of "L" shaped, or where circumstances require, shared "T" shaped jetties to allow mooring of boats and access to the residential lots.

Jetties would generally be based on designs already approved by PIMA, with modifications as necessary to suit the estate. Construction would typically consist of timber decking and chafers attached to steel stringers, all supported on steel piles driven into the canal bed to design requirements. Steel work shall be hot dip galvanised and piles to be coated with coal tar epoxy for corrosion protection. Single owner jetties shall be located at least 4.5m away from the projection of a lot side boundary, and out of the navigational channel.

It is proposed to construct marina style piers to provide boat mooring facilities for each grouped housing unit in the proposed R40 sites.

4.3.11.3 Jetties - Resort

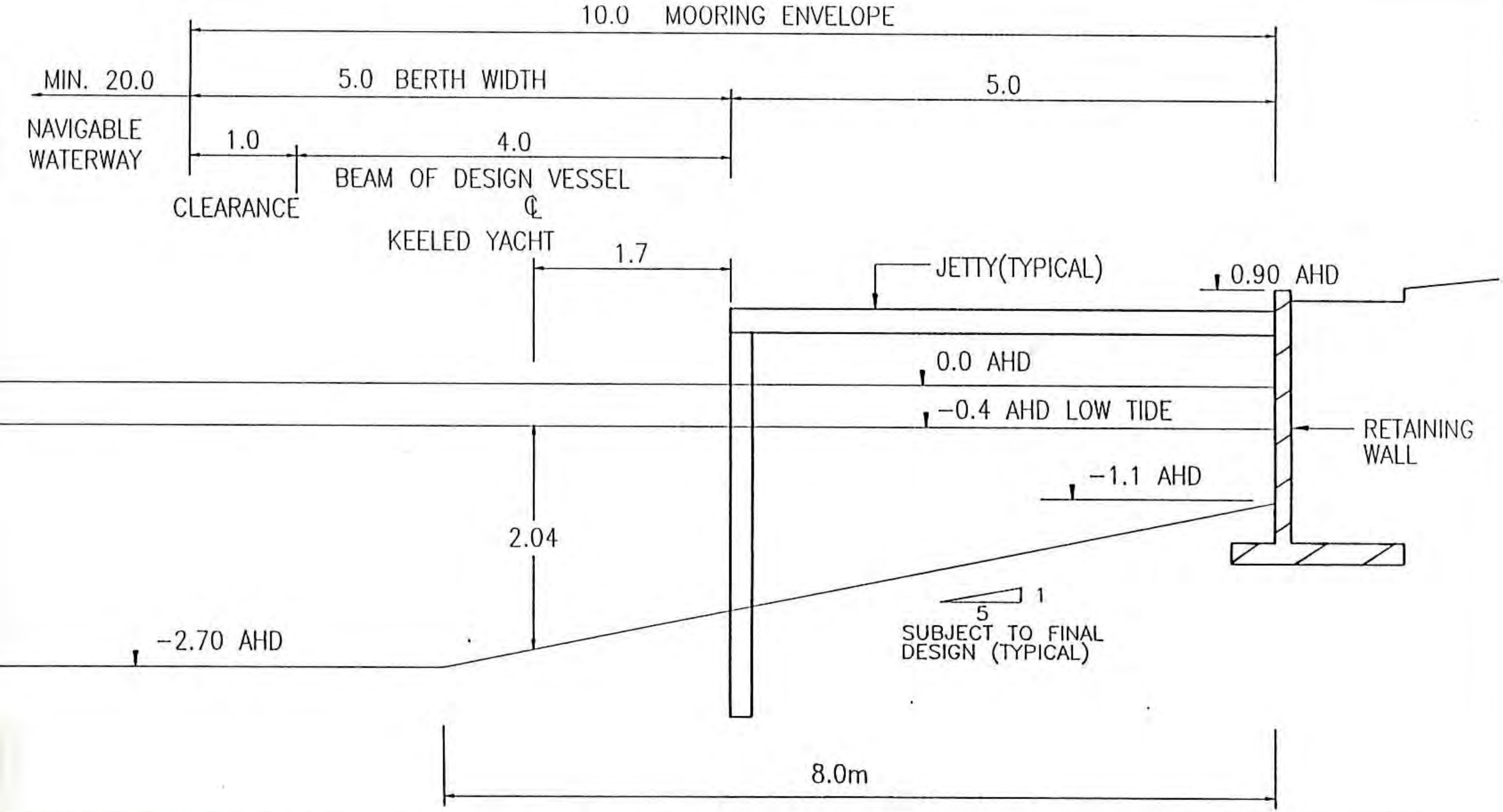
It is proposed to provide jetties for both public and commercial purposes. Jetties will be designed to be either of similar construction standards as for residential allotments, except on a larger scale compatible to their expected usage or new designs for floating jetties.

Final designs will be in accordance with PIMA and DMH requirements, and will be located to not interfere with navigable waterways.

4.4 Public Access and Facilities

4.4.1 Present Status

At present, informal public access to the site, including the foreshore, is unrestricted. It is evident that off road vehicles have been and are continuing to be used on the site for recreation purposes.



PRINCIPAL **ESPLANADE(MANDURAH) PTY.LTD.**	TITLE **FIGURE 11 TYPICAL ELEVATION AT MOORING ENVELOPE**
PROJECT **HARBOUR CITY**	**BSD CONSULTANTS** CONSULTING ENGINEERS, TOWN PLANNERS & PROJECT MANAGERS
DATE 10.3.92	JOB No. P9186
SCALE 1:50	PLAN No.

4.4.2. Access Within the Development

Approximately 10 hectares of open space will be provided within the development. This represents more than 10% of the net developable area excluding canal water area. A comprehensive system of roads and bridges will enable public access throughout the site.

Small areas of public open space have been located adjacent to canal waterways to maximise their visual amenity value to residents and visitors alike. These areas will serve a 'passive' role and will be landscaped accordingly.

Larger areas of public open space have been located away from the canal waterways in order to eliminate potential nutrient input into the waterways associated with fertiliser use on these areas and to provide active use spaces.

Over 44ha of land is to be transferred to the Crown and vested with the City of Mandurah for conservation and foreshore purposes. The foreshore reserve adjacent Mandurah Channel will provide public access to the estuary and allow for flood compensation. It is proposed to exclude public access from the conservation reserve which contains a valuable waterbird habitat samphire flat area by making it difficult to provide boat access. It should also be noted that the southern edge of the Conservation Reserve is virtually inaccessible due to very shallow depths in the Estuary.

4.4.3 External Access to Proposed Development

Access to the site will principally be from Mandurah Bypass Road with additional access from the Waterside Mandurah development under the Mandurah Bypass Road bridge, from Wanjeep Road in the south-east corner of the subject land and through the Dudley Park residential area to the east. The internal road system is designed as a hierarchy of cul-de-sacs.

Internal circulation is facilitated by a series of roundabouts and bridges across the canals. In total seven bridges are proposed.

All roads will be designed to Main Roads Department (MRD) and City of Mandurah standards as applicable.

Public parking areas will be provided at the boat ramp, within the commercial centre and tourist resort hotel.

Public boat access into the canal will be unrestricted. The canal has been purposely designed to allow yacht access to any part of the canal without a need to lower masts. The size of boats able to access the canals is likely to be determined by the height of the Mandurah Traffic Bridge and navigable depth of the Peel-Harvey Estuary rather than from the size of the proposed canals.

4.5 Construction Details

4.5.1 Development Stages and Timing

E(M)PL proposes a staged development for the Harbour City Project. In general, the company proposes to develop waterfront lots in the first stage and dry lots in the final stages of subdivision. The first stages of subdivision will commence with the construction of the entrance channel to the canal waterways system, the first series of canal waterfront lots to be developed at the western end of the landholding, thereafter moving in an easterly direction. The first stage of subdivision will also include construction of the access/egress road from the Mandurah By-pass Road, the main entry roundabout and the retail and tourist hotel area.

The company intends to develop approximately 100 lots per annum spanning over an 8-12 year period. It is expected that the first stage will commence directly following environmental and planning approvals being completed in 1992.

The reason for the proposed staged approach to construction of the Harbour City development is that it will not be economically viable to excavate the entire canal waterways and subdivide the whole site in one operation. The staged approach allows the development to be market driven. The proposed stages of development are shown in Figure 12 and discussed in more detail in Section 7.3. Although construction and development of the Harbour City project will proceed in stages, it is intended that the necessary planning and environmental approvals will be granted to the overall development proposal.

4.5.2 Construction Methods

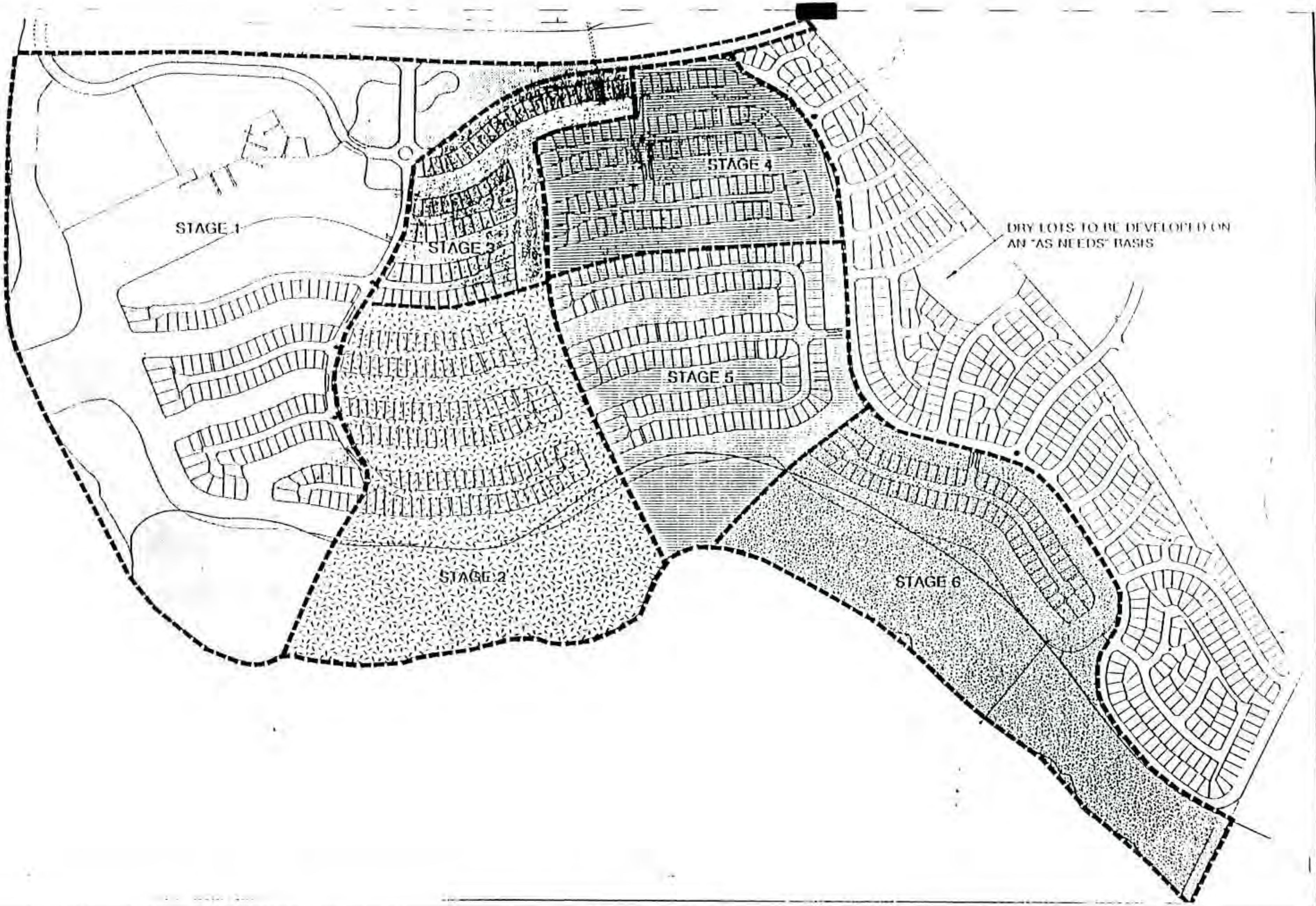
4.5.2.1 Earthworks, Dewatering and Dredging

It is proposed to excavate canal waterways to -2.7m AHD, and generally to fill low lying loss to a minimum level of 2.5m AHD. It is proposed as far as possible that excavation of the canal waterways and filling of lots will be carried out in sections by conventional earthmoving machinery, eg. bulldozers, excavators, scrapers, compaction rollers etc. as appropriate. In order to carry out excavations, it will be necessary to dewater the ground using conventional techniques (eg sludge pumps). Each stage of development will be broken up into several cells which will be progressively dewatered in sequence. The entire groundwater from dewatering operations will be discharged into settling ponds to settle fine particles before being discharged to the Estuary. The manner and timing of discharging waters will be carried out to the satisfaction of the EPA and PIMA.

Preliminary geotechnical investigations have identified soils as generally being of marine and estuarine in origin. These investigations have identified areas of soils containing a high proportion of fines, which will require mixing with good quality material before being used as structural fill to canal and dry lots. Any materials that are structurally unsuitable will be relocated to non structural areas (eg P.O.S. etc).

Preliminary geotechnical investigations have also identified areas which will require preloading to improve the soil structure at those areas to support building foundations.

In order to carry out preloading, it is envisaged that up to 5m high embankments of soil will need to be placed gradually in layers over a period of time to consolidate existing strata. Soil for preloading will either be won from the site or imported as



PRINCIPAL: ESPLANADE (MANDURAH) PTY. LTD.	TITLE: FIGURE 12 STAGING OF CANAL EARTHWORKS				
	PROJECT: HARBOUR CITY	BSD CONSULTANTS CONSULTING ENGINEERS, TOWN PLANNERS & PROJECT MANAGERS BSD HOUSE, 1 SLEAT ROAD, APPLECROSS. PHONE No 316 2988		DATE 10.3.92 JOB No. P9186 SCALE NTS	PLAN No.

appropriate. Stabilisation measures to prevent wind borne transport of surface soils will be used.

The suitability of spoil for filling, extent of preloading and the need to import fill will be the subject of a comprehensive and detailed geotechnical investigation before the commencement of any works.

The proposed sequence of operation for works would be to carry out pre-loading, undertake excavations and fill to allotments, construct walls and services. Areas not requiring preloading can be earthworked as required, subject to the dewatering sequence. Final designs of all earth works shall be in accordance with the requirements of the relevant statutory authorities.

Construction of the entrance canal to the Mandurah Channel will be carried out using conventional earthmoving equipment or a floating cutter suction dredge if required. This work will be carried out after the completion of canal waterways and walls.

4.5.2.2 Stabilisation for dust control

All due possible care will be taken to ensure that no nuisance from wind blown dust and sand is caused to neighbouring residences. The use of water carts as necessary during earthworks will ensure the suppression of wind borne dusts. Upon completion of sections of works, exposed soils will be sprayed with a mixture of grass seed and appropriate dust suppressing agents to ensure the establishment of adequate ground cover as soon as possible.

Any areas left temporarily open before the recommencement of earthworks will also be sprayed with short term dust suppressing agents to alleviate dust nuisances.

4.5.3 Materials Balance

The project earthworks will be designed on the basis of all materials won from excavations to be used as fill over the site, with any shortfalls to be obtained as necessary from approved sources within the region to the satisfaction of the City of

Mandurah and the EPA. Should any geotechnically unsuitable material need to be disposed of off site, a spoil area to the approval of the applicable authorities will be located and documented as appropriate.

Preliminary figures suggest that at least 1.5 million cubic metres of material will need to be cut and utilised for fill. This figure makes no allowance for pre loading earthworks or imported filling if necessary. Final volumes will be subject of a detailed geotechnical investigation and quantities calculations, and will be documented to the approval of the City of Mandurah and PIMA, and other authorities as appropriate.

Limestone armouring required for breakwaters, the internal boundary of the conservation area and the canal wall along the boulevard style road will be either taken from excavation, if suitable, or imported from approved sources.

4.5.4 Design Criteria - Engineering Risk Assessment

4.5.4.1 Storm surge

The Department of Marine and Harbours have estimated the 1 in 100 year storm surge level in the open ocean to be approximately 1.5m AHD. The impact of storm surge decreases with increasing distance along the Mandurah Channel from the coast and is estimated to be approximately 1.2m AHD in the Peel Inlet. The canal walls and other structures have been designed to accommodate this storm surge plus an additional allowance of 0.4m for set-up due to cyclonic winds.

4.5.4.2 Flood Control

The flood characteristics of the Mandurah Channel have been modelled by the Public Works Department (1984) which showed that the 1 in 100 year flood level within the Peel Inlet is 1.6m AHD. The development has been designed to accommodate this flood level plus an additional allowance of 0.1m for wind set-up.

4.5.4.3 Sea level Rise (Greenhouse)

A literature review conducted by Kinhill Riedel & Byrne on the implications of the Greenhouse Effect on coastal development in Australia (Appendix 1) concluded that the design of coastal structures should make a 30cm allowance for potential sea level rise over the next 60 years. The Harbour City development has been designed accordingly.

4.5.4.4 Project Levels

The design building level for the Harbour City development has been set at 2.5m AHD which provides for an additional 0.5m safety margin above that of the effects discussed previously taken in combination.

4.5.4.5 Jetties/Walls

Wall structures shall be designed for a minimum 30 year design life. For foreshore breakwater armouring at the main connecting channel, a 100 year design life will be adopted, in accordance with draft DPUD policy DC 1.8. All structures have been designed to accommodate storm surge and long term sea level rises associated with the Greenhouse Effect.

4.5.4.6 Storm Drainage

Storm drainage to roads shall generally be designed to a 1 in 5 year return period, in accordance with standard practice, with provision to accommodate up to 1 in 100 year events by providing flow paths and storage to prevent flooding to allotments.

4.5.4.7 Landform modification

The proposed development will modify the current landform by the excavation of canals generally to -2.7m AHD, and the spoil of this excavation, including importation of clean fill as necessary, to raise the existing flats, to provide storm and flood protection. Modifications will also involve final contouring of the site to facilitate road construction and to finish off landscaped and P.O.S. areas.

4.6 Operation Details

4.6.1 Projected Lifetime of Project

It is envisaged that the proposed residential and commercial uses of the Harbour City development subject land will continue indefinitely. In terms of engineering structures, the canal walls shall be designed for a minimum 30 year design life and the foreshore breakwaters of the entrance canal for a minimum 100 year design life.

4.6.2 Project Agreement and Management Programme

The Project Agreement as provided for in the Canal Development Guidelines DPUD Policy 1.8 is to be finalised between the proponent and City of Mandurah.

Long-term management of the Harbour City development including the artificial waterways outlined in the Management System Report attached in Appendix 2 and discussed in Section 11.8.3.

5 ALTERNATIVES CONSIDERED

5.1 Alternative Developments

Several alternative development options were considered prior to the finalisation of the preferred option including the 'no development' option.

5.1.1 No Development Option

The subject land is currently vacant and undeveloped and contains a samphire flat area. The area provides limited social amenity although it is used informally by off-road vehicles.

The samphire flats, whilst degraded, are an important feeding and breeding habitat for waterbirds. Under the 'no development' option the following considerations would continue to apply:

- further degradation of the samphire flat area;
- management of the samphire flat remains unresolved;
- public access to foreshore areas remains informal and results in increased degradation; and
- difficult to control mosquito breeding habitat.

The 'no development' option is therefore not a viable option because it does not resolve any of the above issues and will result in continued degradation of the subject land and long term retardation of the environmental productivity of the samphire flats area.

5.1.2 Rural Use

One option available is to use the land for Rural purposes in accordance with the current zoning of the land. This alternative is not considered acceptable given the proximity of the site to the Mandurah Townsite, the further degradation of samphire flat areas that would result, the increased nutrient loading to the estuarine system and because the proposal would not be economically viable.

5.1.3 Urban Subdivision and Conservation Area

This option envisages urban subdivision of most of the subject land with the balance retained as a samphire flat conservation area. This option would result in a number of problems, mostly associated with the management of the conservation area and was not considered acceptable because of the following:

- control of human access into the conservation area could not be guaranteed, unless the entire foreshore reserve was fenced which is an unacceptable solution;
- disturbance to waterbirds in the conservation area would occur as a result of noise and light spill in addition to human access;
- the likelihood of weed invasion of the conservation area from adjacent properties;
- the likelihood of illegal burning and littering of the conservation area due to ready public access to the boundary of the reserve;
- the considerable cost associated with importing sufficient fill material to raise the urban development above flood levels; and
- depending upon the definition of an acceptable conservation reserve, it is highly likely that a significantly greater number of residential lots could be created with a resultant increased population and impacts upon the Conservation Reserve.

5.1.4 Residential Canal Estate and Large Samphire Conservation Area

Development of the land as a residential canal estate up to the Waterways Protection Precinct as recommended by the Peel Inlet Management Authority (PIMA) in their Draft Peel Inlet Management Programme Review (Waterways Commission 1990), with the balance retained for conservation purposes was also investigated.

Although the provision of a canal waterway as a buffer between urban development and the conservation area would overcome many of the difficulties listed previously in Section 5.1.3, a number of financial and management difficulties would arise as follows:

- ceding the entire samphire flat area for conservation purposes plus a foreshore reserve (representing approximately 45% of the subject land) would mean the development of remaining developable area would not be economically viable; and
- there would not be sufficient funds generated by the resulting urban development to adequately manage the conservation area (eg. remove weed growth and rubbish, rehabilitate degraded areas, control mosquito breeding etc), thereby transferring this cost to the general community.

5.1.5 Waterside Mandurah Stage II Proposal

The Waterside Mandurah Stage II proposal by John Holland Constructions Pty Ltd (JHC 1982) has been approved and could be constructed subject to compliance with conditions established by the EPA and rezoning. The subsequent sale of the site to E(M)PL has introduced a new developer with specialised experience. Consequently the design has been altered which reflects the knowledge and experience E(M)PL has gained from the development of the Port Mandurah canal subdivision and other residential estates.

5.1.6 Proposed Harbour City Development

The proposed Harbour City development is virtually identical to the Stage II Waterside Mandurah proposal for which environmental approval has previously been granted with respect to proposed land usage and the areas proposed for canal waterways and conservation and foreshore reserves. The Harbour City development differs in terms of layout which represents a significant improvement in water circulation and improved design from a planning perspective to the Stage II Waterside Mandurah proposal.

5.2 Preferred Option

The preferred option is the proposed Harbour City development set out in Figure 4 which has been developed in recognition of the opportunities and constraints associated with the various development options. The preferred option recommends development to a line in keeping with that advocated by the EPA's System 6 Red

Book conservation reserve recommendations (Department of Conservation and Environment 1983), which will be upgraded and managed, and provide for the control of public access to foreshore and conservation areas.

5.3 Need for Development

There is an obvious desire for further canal estate development within the region. This is evidenced by the success and popularity of existing projects at Port Mandurah and Waterside Mandurah. The canal lifestyle offers a pleasant respite from conventional suburbia.

Development of the subject land will also facilitate the upgrading and conservation of the degraded samphire flats by the proponent and the transfer of approximately 44 hectares of land to the Crown on a free of cost basis which in turn is to be vested in the City of Mandurah to facilitate management by a specially created Management Entity. There is an obvious need for this work to be undertaken as is evidenced by the damage sustained through uncontrolled public access to this sensitive area.

6 SERVICING CONSIDERATIONS

6.1 Roads

The major point of access to the proposed Harbour City development will be from the Mandurah Bypass Road. Discussions with the District Engineer from the Bunbury office of the MRD have determined that this is satisfactory.

Additional road access will be provided beneath the Mandurah Bypass Road bridge over the Mandurah Channel to link the development with the Waterside Mandurah canal estate, to Wanjeep road in the south-eastern corner of the development and to the Dudley Park residential area currently under construction along the eastern boundary of the subject land.

6.2 Sewerage

A reticulated sewerage collection scheme will be established that will deliver effluent to permanent pumping station(s) within the development. Discharge from the pump station will outfall into main gravity sewers in the Dudley Park residential area and ultimately flow to the Gordon Road treatment plant. All infrastructure will be built to the specifications of the Water Authority of Western Australia (WAWA) and will become the management responsibility of the Authority when completed.

6.3 Drainage

Stormwater drainage infrastructure will be provided within the proposed development as required by WAWA and the City of Mandurah and will not require any extensions or modifications to existing stormwater disposal infrastructure in the adjacent residential areas. It is proposed that run-off from roads be collected into a pipe network via road gullies and passed through grease/silt traps before discharging into the canals.

6.4 Water

The proposed development can be served by existing mains water supply infrastructure within the region. However, it may be necessary to extend water mains to the site to provide scheme water to the development, subject to the timing and extent of the first stages of development. All mains shall be designed and built to the specifications of WAWA and will become the management responsibility of this authority when completed.

6.5 Electricity and Telecom

The proposed development will not require major electrical improvements or upgrading external to the subdivision as existing infrastructure in the vicinity of the subject land has the capacity to meet the expected demand. Underground power is proposed within the development and will be established according to normal subdivision practices.

The existing Telecom exchange has sufficient capacity to service the proposed development. However, new cabling may be required to the site subject to the timing of the development.

7 PROJECT MANAGEMENT AND MARKETING

7.1 Management Philosophy

In preparing the development concept plan for Harbour City, Cedar Woods Limited has adopted several principle objectives which reflect the Company's management philosophy. These include:

- total responsibility towards conservation and planning;
- having regard to important environmental information that is essential for a proper and sustainable development;
- ensuring maximum canal water quality and circulation is achieved and maintained;
- accommodating possible long term environmental changes such as the Greenhouse Effect; and
- establishing a functional and credible long-term management strategy for the canal waterways and public areas.

7.2 Management Strategy

Cedar Woods Limited on behalf of E(M)PL has spent considerable time in researching and developing a management system to satisfy both State Government departments and the Local Authority in providing a comprehensive system for the long term management of artificial waterways which is proposed for the Harbour City project. It is believed that a systematic approach for waterways management, based on a joint effort by various Government departments, land owners within the development and the project developer, all under the control and direction of the City of Mandurah represents the most satisfactory management solution. Details on the proposed management strategy are provided in Section 11.7.3 and in Appendix 2.

7.3 Staging

It will not be economically viable to construct the entire Harbour City canal waterways and lots in a single earthmoving operation and therefore a staged approach to development which will be market driven is proposed. The company intends to develop approximately 100 residential lots per annum. The development staging shall basically involve the subdivision and construction of all canal waterfront allotments in the preliminary stage on the western portion of the subject land thereafter followed by the successive development stages on the eastern portion of the landholding. A total of 6 stages of canal waterway and waterfront lot development are envisaged as depicted on Figure 12 which will be developed over a period of 8-12 years. It is proposed that dry lot subdivision will occur as required by demand either in conjunction with or independent of the canal lot subdivision.

In essence, the Stage 1 development shall include the access/egress from the Mandurah By-pass road including entry statement and public open space landscaped areas. The entry statement shall culminate in the major roundabout adjacent to the Mariners Cove precinct. Initial development in Stage 1 shall incorporate 111 single residential and 150 grouped housing canal allotments. Stage 1 development will also include the retail site and the tourist resort hotel site completing all earthworks, canal walls and siteworks.

Construction of the entrance channel shall include rock pitching and establishment of the foreshore reserve areas either side of the main entrance channel. Also included in Stage 1 construction shall be rock pitching of the first section of the conservation reserve to be established on the southern fringe of the subject land adjoining the Peel Inlet.

The ensuing stages will each comprise of approximately 100 canal lots. Each stage will include construction of the canal waterways adjacent to any lots created in that stage. As construction of adjoining stages commences, it will be necessary to close off the existing immediately adjacent canal with a temporary bund to enable construction of the canal walls in the next stage in the dry.

The successive stages have been selected so as to ensure that water circulation will be satisfactory in each in the event that the construction of subsequent stages incorporating additional channels and through flows are delayed or postponed.

Similarly, the successive stages represent viable units with respect to planning considerations.

The construction stage and canal water quality monitoring programmes have been designed to automatically extend to the successive stages as the development proceeds.

Although construction and development of the Harbour City project will proceed in stages, it is intended that the necessary planning and environmental approvals will be granted to the overall development proposal.

7.4 Marketing

The company shall directly control all marketing of the Harbour City Project and will engage a number of Mandurah based Real Estate Agents to assist in marketing and sales of the residential allotments. One of the major objectives of the marketing exercise shall be to boost the current image of Mandurah as a tourist destination whilst also promoting Mandurah's quality lifestyle environment for establishment of residential homes, catering for the mature consumer.

8 PLANNING GROUNDS FOR DEVELOPMENT

8.1 Overview of the Proposal

The Harbour City development site is located south of the Mandurah Bypass Road and has a total area of 197.4ha. Approximately 105ha of the site will be developed for residential and commercial uses with the balance of the land comprising canal waterways, and conservation and foreshore reserves. Incorporated into the development design which is set out in Figure 4 are distinct components as follows:

- canal waterways;
- canal lot subdivision;
- dry lot subdivision;
- Mariners Cove tourist resort hotel and commercial retail complex;
- public boat ramp and boat servicing facilities;
- hierarchal structure road pattern;
- samphire conservation reserve;
- foreshore reserve; and
- public open space for active and passive use.

The project land has previously been approved and accepted for a smaller canal development.

8.2 Statutory Planning Considerations

Development of the subject land in accordance with the concept plan will require an amendment to the existing City of Mandurah Town Planning Scheme No. 1A. The scheme will need to be modified to incorporate the appropriate 'Canal Zone' over the subject land and residential zoning over the balance of the land. Consideration will also need to be given to incorporating appropriate management controls and provisions into the Scheme text as part of the amendment. These Scheme amendment details are outlined in Section 15.

8.3 Planning Justification

Prior to the adoption of a preferred concept plan, a number of alternative development options were considered including the no development option, rural use, conventional urban subdivision adjacent to a conservation area, limited canal estate development with a large samphire flat conservation area and the original Waterside Mandurah Stage II concept. The proposed Harbour City development, being predominantly a canal estate which is a modification of the Waterside Mandurah Stage II concept, represents a logical development scenario which is in keeping with established subdivision patterns for the area and previous development approvals for the subject land.

The proposal provides an efficient use of valued resources near the Mandurah city centre and reflects market demand and expectations for the subject land. The proposal conforms with established planning criteria and policy for such development and complies with the objectives and requirements of:

- the Peel Region Plan;
- DPUD Draft Policy No. DC 1.8; and
- the City of Mandurah Town Planning Scheme No. 1A (subject to the proposed rezoning).

8.4 Description of Proposed Development

8.4.1 General

The preferred Concept Development Plan is depicted in Figure 4. The design of this plan gave cognisance to all the relevant policies and development criteria applicable to this form of development.

8.4.2 Canal Lot Development

The canal estate development has been designed to afford high quality lifestyle development which is supplemented by a variety of services and facilities. All canal lots have an area greater than $500m^2$ with the typical lot configuration being 16m x 32m. Notwithstanding this, 69 canal lots have an area of 800-$1000m^2$. The objective has been to promote a variety of lot sizes which can accommodate a broad spectrum of lifestyle requirements.

In total approximately 639 single residential canal lots are proposed but will be subject to further design refinement as the project proceeds.

8.4.3 Dry Lot Development

Approximately 443 lots is to be subdivided for dry lot purposes with no lot being less than $500m^2$ in area. These dry lots do not have direct frontage to the canals, however, they are within close proximity so that residents can enjoy the advantages of the development and utilise the canal facilities and services.

The dry lot development accommodates residents who prefer not to have immediate canal frontage and still wish to be within close proximity of the canals. The proposals have been framed so that the road system interacts directly to the boulevard distributor road thereby creating view opportunities directly to the canals.

A proper road hierarchy has been designed based on 18m, 16m and 15m road reserves as defined in DPUD Policy DC 2.6. Equal attention has been given to ensure that through routes connect with the planning that has occurred in the adjoining Dudley Park residential estate to the east of the subject land.

8.4.4 Public Open Space

Several areas of public open space have been incorporated in the design of the Harbour City project. The larger parcels have been located in the dry lot area because these offer the best opportunity to be used for active recreation purposes. These areas have been designed to be accessible and to link into the open space areas proposed in the Dudley Park residential area to the east. Smaller areas of public open space are proposed on the canal islands in order to provide areas for passive respite and to promote views over the canals. Substantial passive ornamental open space areas are proposed at the entry to the development. These areas provide a theme and focus for the development.

In total some 10ha of public open space is proposed which represents 10% of net developable area and complies with the requirements of DPUD Policy DC 2.3.

8.4.5 Conservation and Foreshore Reserves

The value and purpose of the conservation and foreshore reserves proposed is extensively detailed in Part 3 of this report. In summary these reserves are proposed to provide protection for the most significant samphire flat areas of the subject land and provide foreshore access where appropriate.

These reserves are proposed to be vested with the City of Mandurah. The ongoing management of these areas will however be the responsibility of the Management Entity which is to be established by provisions to be incorporated into the Mandurah Town Planning Scheme No. 1A as outlined in Section 11.7.3 and Appendix 2. The integrity of the conservation and foreshore reserve areas will be guaranteed by the proposed zoning of these areas as Landscape Protection Area.

The extent of the foreshore and conservation reserve is shown on the Concept Development Plan and has been justified in Section 10.6.

8.4.6 Tourist Resort Hotel and Retail Complex

A high quality resort hotel complex is proposed which will cater for local interstate and overseas visitors. The tourist resort hotel will have 260 rooms with an aspect focusing on the Mariners Cove component of the development.

A retail centre is proposed immediately to the east of the tourist hotel. This centre will provide a service for residents of the estate as well as visitors to the area. The retail centre is proposed to be developed in the style of Fishermans Wharf in San Francisco with a tavern, market, square, restaurants, boardwalk, marina and boat chandlery/refuelling facilities.

Substantial public parking areas will be provided to the rear of the development to ensure adequate on-site parking to cater for demand and to maintain uninterrupted views from the development to Mariners Cove.

8.4.7 Entrance Statement/Landscape Treatment

A significant entry statement incorporating large grassed open space with ornamental lakes will provide the main entry feature to the Harbour City development. The entrance has been designed to create a water based development theme with a proposed lighthouse located in the roundabout. Boulevard planting is proposed along this dual carriage way entry.

Landscaping of the public domain being the street verges, public open space and buffer planting along the Mandurah Bypass Road has been given considerable attention. Wherever possible salt, wind and drought resistant species (eg. *Casuarina*) will be used, with feature trees including Coral trees and Norfolk Island Pines located in key areas.

8.4.8 Staging

Development of Harbour City is proposed to be staged with the creation of approximately 100 new lots in each stage. The life of the project is expected to extend between 8 to 12 years. A preliminary staging plan has been prepared (Figure 12), however, it must be acknowledged that the configuration of the stages may change to reflect changing market demand.

The establishment of the conservation reserve will also be staged to reflect earthworks associated with the various development stages.

8.4.9 Employment Opportunities

The implementation of one development phase per year is expected to generate approximately 150 jobs associated with land development. A further 200 tradespeople per annum are expected to be employed for the construction of canal estate housing.

The tourist resort hotel and retail complex will create approximately 400 permanent new jobs. Consideration must also be given to the multiplier effect of employment opportunity increase throughout the Mandurah community. Whilst this is difficult to quantify, experience suggests a further increase of 25-30%. The benefits of development therefore not only extend to residents and visitors but to the broader community of Mandurah as a whole.

8.5 Zoning Justification

The existing City of Mandurah Town Planning Scheme already incorporates development standards and requirements for two similar proposals (Waterside Mandurah and Port Mandurah Stage 1). Reference is made to these projects in the Scheme text and the development standards and permitted uses are detailed in a schedule incorporated as part of the appendices to the Scheme (Appendix 10).

The advantage of adopting the same format is that all existing terminology and referencing is constant within the Scheme text. All that is required is to add additional provisions to Appendix 10. The schedule details the development standards and criteria specific to Harbour City, the establishment of the Management Entity, a new Reservation and is detailed in Section 15.

8.6 Residential Development

Residential development within the R20 dry land subdivision zone will be in accordance with the standards prescribed by the Residential Planning Codes.

Residential development in the Canal Zone shall be generally in accord with the R20 development standards prescribed by the Residential Planning Codes. There are however three notable exceptions being the front and rear setback requirement. Given lot configuration it is proposed to have a 6m front street setback requirement with 50% averaging permitted. The minimum rear setback shall be 4m with an average of 6m. The integrity of the canal wall is still protected whilst at the same time the intended owner retains considerable flexibility through variations of the various setback requirements.

It is proposed to vary the minimum open space requirement outlined in the Residential Planning Codes for residential development. Under the provisions of these Codes a minimum 50% open space requirement is to be provided for residential development in the R20 and R40 density codes.

For the purpose of this development the open space requirement is recommended to be reduced to 25%. The 25% open space provision will be primarily accommodated within the front and rear setback areas where it is most functional. The variation is justifiable given the smaller than conventional size of the lots proposed. The focus of the development on active recreation and water based activities associated with the canals and the extensive provision of open space throughout the estate is over 10% of net developable area.

8.7 Design Guidelines

Design guidelines are proposed to be developed to enable the Management Entity which is proposed to be established to manage the Estate to specifically control issues of development aesthetics.

The primary objective of these guidelines is to promote and protect the overall quality of development within the Canal Zone. Intended purchasers will be aware of the design guidelines by reference via covenants on title and conditions attached to the sale documents. Council officers and developers will be aware of the requirement by reference to the Scheme Provisions, namely Appendix 10 Development Standards Canal Zone Area 3 Harbour City. Specific design guidelines will be incorporated within a legal agreement and managed by the Management Entity.

The following design guidelines will apply:

<u>Setbacks</u>

Front: Minimum front setbacks for residential land within the Canal Zone will be 3m with an average of 6m.

Back: Minimum rear setback for residential land in the Canal Zone will be 4m with an average of 6m.

Orientation

Housing orientation should primarily be to the canal with main living and external living areas designed to optimise these views. The canal lots have been designed essentially to a north/south orientation to facilitate solar design.

Fencing

No Super Six fencing is permitted within the Canal Zone. Minimum standard fencing is considered masonry pillars with treated timberlap pine infills. No fences are permitted to be constructed beyond the rear setback requirement and front fences shall not exceed 900mm in height unless more than 75% of the fence is open with wrought iron or timber patch infill.

Boat/Caravan Parking

Boats and caravans may be parked in open areas however they are required to be screened from view from the street and canals. Landscaping and dense native tree planting may be used to screen these areas.

Materials

All houses must be constructed of brick or masonry materials. In some circumstances second storeys may be of cladding considered acceptable (eg. timberlap).

Clothes Drying Facilities

Clothes drying facilities are required to be screened from view and in no circumstances should they be located within the rear or front building setback areas.

PART 3

ENVIRONMENTAL CONSIDERATIONS

PART 3 - ENVIRONMENTAL CONSIDERATIONS

9 INTRODUCTION

9.1 Purpose, Scope and Level of Environmental Assessment

The purpose of Part 3 of this document is to undertake a detailed environmental assessment of the potential environmental impacts of the proposed Harbour City development and to present comprehensive management strategies and commitments to mitigate these impacts. Included in this assessment is an evaluation of the conservation significance of the samphire flats of the subject land.

This scope of the environmental assessment is to assess the potential environmental impacts and evaluate the conservation significance of the samphire flats on both a local (Mandurah Channel) and regional (Peel - Harvey Estuary) scale.

The level of assessment for this development proposal, as determined by the EPA, was set at a Consultative Environmental Review (CER).

9.2 Background

Proposals to construct a canal estate on the subject land date back to the early 1980's when the previous owner of the site, John Holland Constructions Pty Ltd (JHC), proposed to construct the Waterside Mandurah canal estate. The land became divided into Stages 1 and 2 as a result of the Main Roads Department proposal to construct the Mandurah Bypass Road with Stage 1 occurring north of the road and Stage 2 on the subject land. An Environmental Review and Management Programme (ERMP) document was prepared for the entire Waterside Mandurah Project (Stages 1 and 2) in 1982 (JHC 1982). The ERMP included a conceptual plan for the Stage 1 and Stage 2 development and provided an environmental assessment of the whole project.

The ERMP was assessed by the Environmental Protection Authority (EPA) in 1982 (Bulletin 126) and environmental approval granted to the whole project (Stages 1 and 2) although it was acknowledged that the Stage 2 design and layout was conceptual only and would be subject to further detailed design (Department of Conservation and Environment (DCE 1982). Bulletin 126 therefore specifically recognised that the Stage 2 concept plan would be subject to future adjustment.

The Stage 1 area was zoned for canals development. The Stage 2 area is currently zoned "Rural".

Stage 1 of the Waterside Mandurah canal estate has subsequently been constructed. It is important to note that no sunset clauses were specified in Bulletin 126 of 1982 and therefore the EPA approval for the Stage 2 component of the project is still operative providing the project as generally presented in the ERMP forms the basis of the current proposal.

In 1987, JHC sought to develop the subject land with a revised and significantly modified canal estate design. This proposal was abandoned before the application and environmental assessment documents were lodged with the relevant decision making authorities.

Cedar Woods purchased the subject land from JHC's management company Haughton Holdings Pty Ltd in 1991 with the intention of constructing a canal development on the land relying upon existing approvals and the existing development guidelines that were previously supported by the whole of Government. This project will be known as Harbour City. Cedar Woods have recently completed a high quality canal development in the Mandurah area known as Port Mandurah which is located on the western side of the Mandurah Channel opposite the Mandurah townsite. It is intended that the Harbour City development will be developed to an equally high standard utilising the same design criteria and construction specifications. Water quality monitoring has confirmed the acceptability of the Port Mandurah project in terms of environmental performance.

10 DESCRIPTION OF ENVIRONMENT

10.1 Introduction

This section of the report describes the salient physical, biological and social characteristics of the regional and local environment and includes an evaluation of the conservation significance of the samphire flats of the subject land.

10.2 Available Information, and Studies Conducted

Information on the environmental characteristics of the area was obtained from a review of literature pertaining to the Peel-Harvey Estuary and other regional studies and previous assessment reports for development proposals on the subject land. In addition a number of specialist consultants were engaged to undertake specific studies of the subject land. Soil & Rock Engineering Pty Ltd undertook a geotechnical investigation of the subject land, and Dames & Moore provided information on the groundwater characteristics and groundwater use in the vicinity of the site. The tidal and floodplain characteristics of the subject land, shoreline stability, flushing and exchange aspects of the canal waterways and implications of the Greenhouse Effect and proposed Dawesville Cut were detailed by Kinhill Riedel & Byrne. Wildlife surveys and a review of previous waterbird studies in the Peel Inlet and on the subject land were undertaken by AR & MJ Bamford Consulting Ecologists in conjunction with Ninox Wildlife Consulting. A botanical survey of the subject land was conducted by E. M. Goble-Garratt. A number of additional surveys were conducted for previous development proposals of the subject land which have been used in this report including a mosquito population survey by Mike Lindsay and an archaeological and ethnographic survey of the subject land by R. O'Connor, G. Quartermaine and C. Bodney.

10.3 Physical Environment

10.3.1 Climate

The climate of the Mandurah region is characterised by a Mediterranean climate with hot, dry summers and mild, wet winters.

The average daily temperature in the Mandurah region in summer months ranges from a maximum of 29.5°C to a minimum of 17.2°C and in winter months from a maximum of 17.2°C to a minimum of 8.5°C. Rainfall is moderate (*ca* 825 mm/year) and seasonal with the majority falling between May and October while evaporation is high (*ca* 1,980 mm/year).

The wind pattern in the region is dominated by two systems; cyclonic/anticyclonic winds and a landbreeze/seabreeze system. Cyclonic and anticyclonic winds are associated with the seasonal north-south migration of high and low pressure systems which traverse the southern parts of the Australian continent (Gentilli 1972). Winds affecting Mandurah associated with this system originate from the eastern sectors during summer months and from the north-west to southern sectors in winter months. Periodic storms are a feature of the winter climate, impinging upon the coast from the north-west to south-west, although predominantly from the north-west. In addition, the Peel-Harvey Estuary is potentially subject to minor storm surges, particularly if a tropical cyclone, originating from the far north of Western Australia during summer, crosses the coast.

The landbreeze/seabreeze system is superimposed over this large-scale pattern and is driven by temperature differences between the ocean and land masses. The system features moderate winds from the eastern sectors in the morning followed by strong south to south-westerly winds in the afternoon.

10.3.2 Geomorphology

10.3.2.1 Regional setting

The Peel Harvey estuarine system, which occupies some 300km^2 in area, is situated on the Swan Coastal Plain. The estuary comprises the area of confluence of three rivers (Murray, Serpentine and Harvey). The fluvial terrain is low, and marine flooding has resulted in the formation of the estuarine system (LeProvost Semeniuk and Chalmer (LSC) 1981). The system is composed of the circular Peel Inlet which is the receiving basin for the Murray and Serpentine rivers, the elongate Harvey Estuary which is the receiving basin for the Harvey River and the narrow Mandurah Channel which connects the estuary system with the ocean. The main geomorphic components forming the estuarine system are a barrier ridge of Spearwood Dunes to the west, aeolian and fluvial lowlands of Bassendean Dunes and Pinjarra Plain to the east, and riverine discharge points (Semeniuk and Semeniuk 1990). These units have influenced the development of coastal landforms and sediments along the estuary shore and the wetlands within the Peel Harvey system.

10.3.2.2 Local setting

The subject land comprises part of a relict tidal delta, approximately 1.5km x 100m in size, and its geomorphology has been described by Semeniuk and Semeniuk (1990, 1991). The relict tidal delta is an emergent strandplain complex that formed during an earlier period of higher sealevel. The complex is composed of a flat terrain with abandoned, infilled tidal channels, and emergent shoals, onlapped by sand and shelly sand and mud sheets which fill the depressions. Some of the depressions are seasonally inundated wetlands, while others are only seasonally water logged. The stratigraphy of the subject land is variable over short distances, with lensoid veneers of sand, shelly sand and mud disconformably overlying shelly muddy sand, medium to coarse quartz sand which in turn disconformably overlie calcarenite at variable depth. This complex stratigraphy reflects the origin of the terrain that formed by shifting fluvial and tidal channels, accompanied by erosion and filling, and shoal accretion.

10.3.3 Geology and Soils

The geology and soils of the subject land have been described by Dames & Moore (1991) and Soil & Rock Engineering (SRE) Pty Ltd (1987) respectively. The landforms and soils of the region have been mapped (scale 1:50,000) and described by the Department of Agriculture (Wells and Hesp 1989).

The subject land is underlain by silty claystones and silty sandstones of the Leederville Formation at a depth of approximately 10m. The Leederville Formation is unconformably overlain by superficial formations which consist of organic muds, organic clayey silty sands and sandy silts, silty sands, coarse grained sands with calcarenite gravel and siliceous calcarenite. The siliceous calcarenite consists of sandstone, which is generally friable, but contains some hard bands of limestone (Dames & Moore 1991). Investigations by SRE (1987) indicate that calcarenite occurs as a ridge trending north to south which is approximately 500m wide at the northern boundary and in excess of 750m wide at the southern boundary of the subject land. The surface of the ridge is uneven and is covered by an alluvium of sandy clays and clayey sands which varies in thickness from 1.6m to in excess of 3m. The calcarenite ridge is flanked by erosion channels in excess of 7m deep which are filled with very loose and highly compressible alluvium (SRE 1987).

With the exception of a band of dune sands of the Spearwood Dune and Plain system which occurs along the eastern boundary, the subject land occurs within the Vasse Estuarine and Lagoonal System as mapped and described by Wells and Hesp (1989). This is a system of low lying poorly drained terraces, flats and beach ridges fringing the Peel-Harvey Estuary. The soils show a general transition from saline flats in the south comprised of grey, black and brown foetid muds and humic sandy clays subject to frequent inundation to upper level sand flats, sandy terraces and gently undulating beach ridges with deep grey siliceous sands in the north (Wells and Hesp 1989). The sands are generally medium - grained and sub-rounded to rounded and contain shell fragments, as do the muds and sandy clays (Dames and Moore 1991).

The dunes along the eastern boundary of the subject land form part of a gently undulating sand plain with deep pale sands with yellow brown subsoils (Wells and Hesp 1989).

10.3.4 Groundwater

The groundwater characteristics of the subject land have been described by Dames & Moore (1991). Groundwater is present in aquifer horizons within both the shallow superficial formations and deeper Leederville Formation.

The calcarenite is the major aquifer unit in the superficial formations. It extends throughout the area including the samphire flats, and is thicker and more permeable in the eastern half of the subject land.

The water table in the superficial formations ranges from 2-4m below ground in the eastern boundary of the site to 0.5 -1m below ground on the west. On the samphire flats water levels are slightly higher with a depth to water of 0.2m - 0.5m. Infiltrating winter rainfall is the primary source of groundwater recharge to the aquifer. Consequently water levels are lowest at the end of summer (February - April) and highest at the end of winter (September - October) with a seasonal fluctuation of 0.6 - 1.0m.

Groundwater flow at the subject land is south westerly towards the samphire flats and the Mandurah Channel. The hydraulic gradient varies from 1:200 on the eastern boundary to 1:1000 in the west and reflects changes in the hydraulic conductivity between the permeable calcarenite and the siltier units in the east.

Groundwater quality in the superficial formations is saline in the western part of the site including the samphire flats, becoming fresh to brackish on the east. The saltwater-freshwater interface is a relatively broad transition zone dipping eastward with fresher groundwater overlying denser, more saline groundwater. The position of the interface varies in response to seasonal changes in groundwater levels, tides, aquifer recharge, evapotranspiration and bore abstraction. However the average long term position of the interface remains static.

The Leederville Formation is clayey and impermeable below most of the area except in the north eastern corner of the subject land, where an area of sand and silty sand is present.

The groundwater in the Leederville Formation is saline and upconing into the superficial formation may occur where the Leederville Formation is sandy and permeable.

10.3.5 Drainage

The samphire flats adjacent to the Peel Inlet and the Mandurah Channel are periodically flooded with saline water from the estuary during the winter months. The relatively flat nature of the area results in little or no surface runoff, and these areas drain once the estuary/channel levels have fallen and eventually completely dry up in summer (JHC 1982).

Further inland, the permeable nature of the soils of the subject land allows most of the rainfall to infiltrate to the superficial groundwater table. However, during winter, areas with a thicker layer of muds and clayey sands have a layer of rainwater perched on the surface which is unable to drain away (JHC 1982).

10.3.6 Tidal Features

10.3.6.1 Astronomical tides

Analysis of twelve months of tide records at Mandurah Jetty at the northern end of the Mandurah Channel (Riedel & Byrne 1981) indicate a tidal range (from +0.5m AHD to - 0.4m AHD) for normal conditions with average daily variations of 0.4m. In the year analysed, the highest level recorded was +0.9m AHD, and this appeared to be during a period of high river flows. The lowest recorded level was -0.5m AHD. For 98% of the time, the level was between +0.5m AHD and -0.35 m AHD. Long term water level variations not associated with astronomical tides are also evident. Records for the tidal gauge at "Chimneys" near the southern end of the Mandurah Channel show tidal variations of about 85% of those at the Mandurah Jetty. An average daily range of astronomical tide for the Harbour City site may be set at 0.35m.

10.3.6.2 Barometric tides

Long period water level variations are experienced along the coast of Western Australia. This variation can be as large as the tidal variation, but the change occurs over several days or weeks.

Variations at Fremantle after diurnal and semidiurnal tides have been filtered out show sea level variations with periods of 1-20 days and 20-365 days (Provis & Radok, 1979). Several factors contribute to these variations:

- the response to low and high pressure atmospheric conditions moving across Australia at intervals in the range of 3-10 days;
- shelf waves with deep ocean energy and wind shear effects trapped on the shallow continental shelf with periods from 5-20 days;
- wave set-up from storm systems moving across the coast with periods of 1-5 days; and
- large scale coastal currents and eddies.

These effects are significant to the Harbour City development in that the barometric tides serve to produce the higher high tides and the lower low tides with their longer period oscillations. But, unlike normal tides, the high highs and the low lows do not occur on the same day.

10.3.6.3 Wind set-up

Constant wind blowing over a confined body of water exerts horizontal forces on the surface of water through shear stresses and pressure differentials over waves. Currents are induced in this manner and in shallow areas such as Peel Inlet the combined effect of wind and currents is to increase water levels downwind and decrease them upwind.

Steedman & Associates (1982) analysed wind at Fremantle and concluded that sea breezes of duration 3 - 4 hours and wind speeds of 8 - 10 metres per second 1 km inland are part of the normal summer wind pattern.

Based on the normal summer pattern sea breeze from the southwest, Department of Marine and Harbours (1988) estimate a wind set-up in the order 0.14 m on the eastern shores of Inlet. Winds during summer are from the south and southwest sectors about 60% of the time. At the Harbour City development on the north-east shores of the Inlet, an allowance of 0.1m should be made for wind set-up.

10.3.6.4 Effect on samphire flats

Survey data on the samphire flats of the subject land has been obtained from the Public Works Department (PWD) (1984). The samphire flats have a level of at least 0.0m AHD in the vicinity of the shoreline, extending up to +0.7m AHD further inland. A tidal level of at least Mean Sea Level is required before inundation of the shoreline samphire area starts to occur. Statistically, the water level is below Mean Sea Level fifty percent of the time and consequently the inland samphire areas would only rarely be inundated by tidal events.

10.3.7 Floodplain Considerations

10.3.7.1 Floodplain management

The PWD (1984) modelled the flood characteristics of the Mandurah Channel. The results of this modelling were that the 1 in 100 year flood level within the Peel Inlet is +1.60m AHD. Adjacent to the Harbour City site the level is +1.54m AHD while at the border of the subject land with the Mandurah Bypass Bridge, the flood level is +1.54m AHD.

The proposed development falls within the Recommended Line of Development established by the PWD and as such will not contribute to flooding in the area. In fact, the canal development will provide some additional flood storage not allowed for in the PWD model, thus marginally reducing estimated flood levels.

An allowance for wind set-up of approximately 0.1m needs to be added to the flood level in establishing appropriate development levels.

10.3.7.2 Storm surge

The Department of Marine and Harbours have estimated the 1 in 100 year storm surge level in the open ocean to be approximately +1.5 AHD.

The impact of storm surge reduces with increasing distance (along the Mandurah Channel) from the coast and is estimated to be approximately +1.2 AHD in the Peel

Inlet. An additional allowance of 0.4m needs to be made for set-up due to cyclonic winds.

10.3.7.3 Effects on samphire flats

The effects discussed in this section are related to extreme event with return periods significantly longer than astronomical or barometric tides or greater. However, due to the level of the samphire flats on the subject land, inundation would occur during these events. The extent of the inundation will depend upon the severity of the event.

10.3.8 Water Quality Considerations

10.3.8.1 Peel-Harvey Estuary

The waters of the Peel-Harvey estuarine system are eutrophic (nutrient enriched) as a result of leaching of nutrients from fertilisers and other activities associated with agricultural and urban development within the estuarine catchment area. The eutrophic conditions provide a favourable environment for excessive algal blooms which threatens both the health of the natural estuarine ecosystem and the aesthetic qualities of the region.

Algal growth within the Peel-Harvey Estuary occurs in a cycle which has been found to be dependent on the availability of phosphorus. The algal bloom cycle has been described by Kinhill Engineers (1988) as follows:

- winter river inflow provides nutrient input to the estuarine system;
- the nutrients are taken up in macroalgal (diatom)blooms;
- bacterial decomposition of the diatom biomass results in the re-release of phosphorus to the water column;
- warmer water within the estuary during spring/early summer and the available phosphorus promote phytoplankton (*Nodularia*) blooms;
- hypersaline conditions in late summer cause the *Nodularia* blooms to collapse, releasing phosphorus to the water and promoting macroalgal blooms until early autumn; and

- decomposing plankton and macroalgae release phosphorus which may be bound into the sediments and later released into the water column under anaerobic conditions.

10.3.8.2 Mandurah Channel

Due to its connection with the ocean, the Mandurah Channel experiences relatively high water quality of a marine nature during inflowing tides. However, water and its associated algal blooms in the Harvey Estuary, Peel Inlet and tributary rivers are flushed into the ocean via the Mandurah Channel during ebb tides. Consequently water quality within the Mandurah Channel, during periods of severe algal blooms may be relatively poor. Recent dredging of the Mandurah Channel carried out by the Department of Marine and Harbours has created more favourable conditions for flushing, and has resulted in improved water quality within the northern Peel Inlet and the Mandurah Channel (EPA 1989).

10.3.8.3 Other artificial waterway developments

There are presently two existing canal developments along the Mandurah Channel. These are the Waterside Mandurah canal estate situated on the eastern shore immediately north of the subject land on the other side of the Mandurah Bypass Road, and the Port Mandurah Stage 1 development, located on the western shore of the Mandurah Channel to the north of the Mandurah traffic bridge opposite Mandurah city centre. Another artificial waterway project (in addition to the Harbour City proposal), the Mandurah Quay development which features a small marina has been proposed on the western side of the Mandurah Channel Delta opposite the subject land. The overall effect of these existing and proposed developments on the estuarine system is discussed in Section 11.5.5.6.

10.4 Biological Environment

10.4.1 Vegetation

10.4.1.1 Regional setting

The earliest comprehensive examination of the peripheral vegetation of the Peel - Harvey estuarine system was that of Backshall and Bridgewater (1981), who classified the vegetation types present and examined their relationship to soil and topographic variables. There have been numerous localised surveys conducted subsequently, usually related to development proposals, or to specific management problems such as rare flora conservation and mosquito control. A wider ranging study has been published by Semeniuk & Semeniuk (1990), which emphasises the variety of shore types found, all of which exhibit a degree of internal complexity in parent material and depositional/erosional history. This variety in basic habitat has led to a concomitant diversity of vegetation assemblages, although the limited number of wetland species in the region often results in a relatively simple floristic composition. The same suite of species recur throughout the wetland types, but in variable structural formations, alliances, abundance and luxuriance (Semeniuk and Semeniuk, 1990).

The succulent samphires occur on low lying land around the shoreline of the Peel-Harvey system, although in most places they form only a narrow band. They are also present along the lower reaches of the tributary of the estuary rivers (Ninox Wildlife Consulting, 1990). According to Rose and McComb (1980) they are most extensive along the eastern edge of the Peel Inlet between Fauntleroy and Greenlands drains, and at the southern end of the Harvey Estuary. However there are also large areas of samphire communities on the relic tidal delta at the northern end of the Inlet (ie. the subject land), on Creery and Channel Islands, and fringing the Sticks and Entrance Channels (LeProvost Semeniuk & Chalmer, 1985; Kirke, 1986).

Rushes (*Juncus* spp.) and sedges (*Bolboschoenus* spp.) and a small number of non-succulent, salt tolerant species are also common along the shorelines. The only tall (shrub or tree) members of this group are the Swamp she-oak (*Casuarina obesa*) and the Salt-water paperbark (*Melaleuca raphiophylla*).

The vegetation of the beach ridges along the eastern edge of the estuarine system, and of the hinterland is extremely diverse, and related to the major soil groups present, and to topography. The formations encountered include *Banksia* woodland/low forest, Marri (*Eucalyptus calophylla*) woodlands, wet closed heath communities, and low forests of *Casuarina* and *Melaleuca* species.

10.4.1.2 Local perspective

The southern portion of the site is vegetated by periodically inundated samphire communities. On these samphire flats the species mix may be fairly homogeneous over large areas, but there are marked dominance and density changes related to minor variations in the topography and thus to the duration of inundation. Some differences are secondary and result from fire and disturbance. Generally the areas closest to the shoreline are dominated by *Sarcocornia quinquiflora*, followed by a band of various *Halosarcia* species.

Halosarcia indica ssp. *bidens* is dominant along the south of the site. This community is bounded on the landward side by a community dominated by *Halosarcia pergranulata* which follows the contour round to the south-western areas. The remainder of the salt flats support an admixture of these species with the addition of *Halosarcia halocnemoides*, *Halosarcia syncarpa* and *Halosarcia* sp. Along the shoreline, a low beach ridge supports a different community which includes *Frankenia pauciflora*, *Atriplex hypoleuca*, *Suaeda australis* and *Cakile maritima*. There are also isolated occurrences of rushes (*Juncus krausii*) and sedges (*Isolepis nodosa*) and a few *Casuarina obesa* on this ridge.

Narrow bands of low relief on the eastern side of the site support communities of sedges. The main species present are *Bolboschoenus caldwellii*, *Isolepis nodosa*, *Lepidosperma longitudinale*, *Leptocarpus* sp. *Lepyrodia* sp. and *Juncus krausii*.

Woodland patches of *Melaleuca* and *Casuarina* occur on higher ground fringing the Samphire communities, and on banks along the eastern side of the site. The relative contribution of *Melaleuca raphiophylla* and *Casuarina obesa* varies, and has been influenced by fire. There are also isolated occurrences of *Eucalyptus rudis*.

Banksia woodland with some Marri (*Eucalyptus calophylla*) occurs along the eastern boundary of the site. At the northern end the canopy is more open, but Tuart (*Eucalyptus gomphocephala*) appears as an emergent above the *Banksia attenuata*. Closer to the shoreline *Acacia saligna* and *Jacksonia* species are significant components of the canopy as a result of disturbance and fire.

A map of the vegetation units of the subject land including cleared areas and tracks is shown on Figure 13. A comprehensive list of the vegetation species on the subject land is included in Appendix 3.

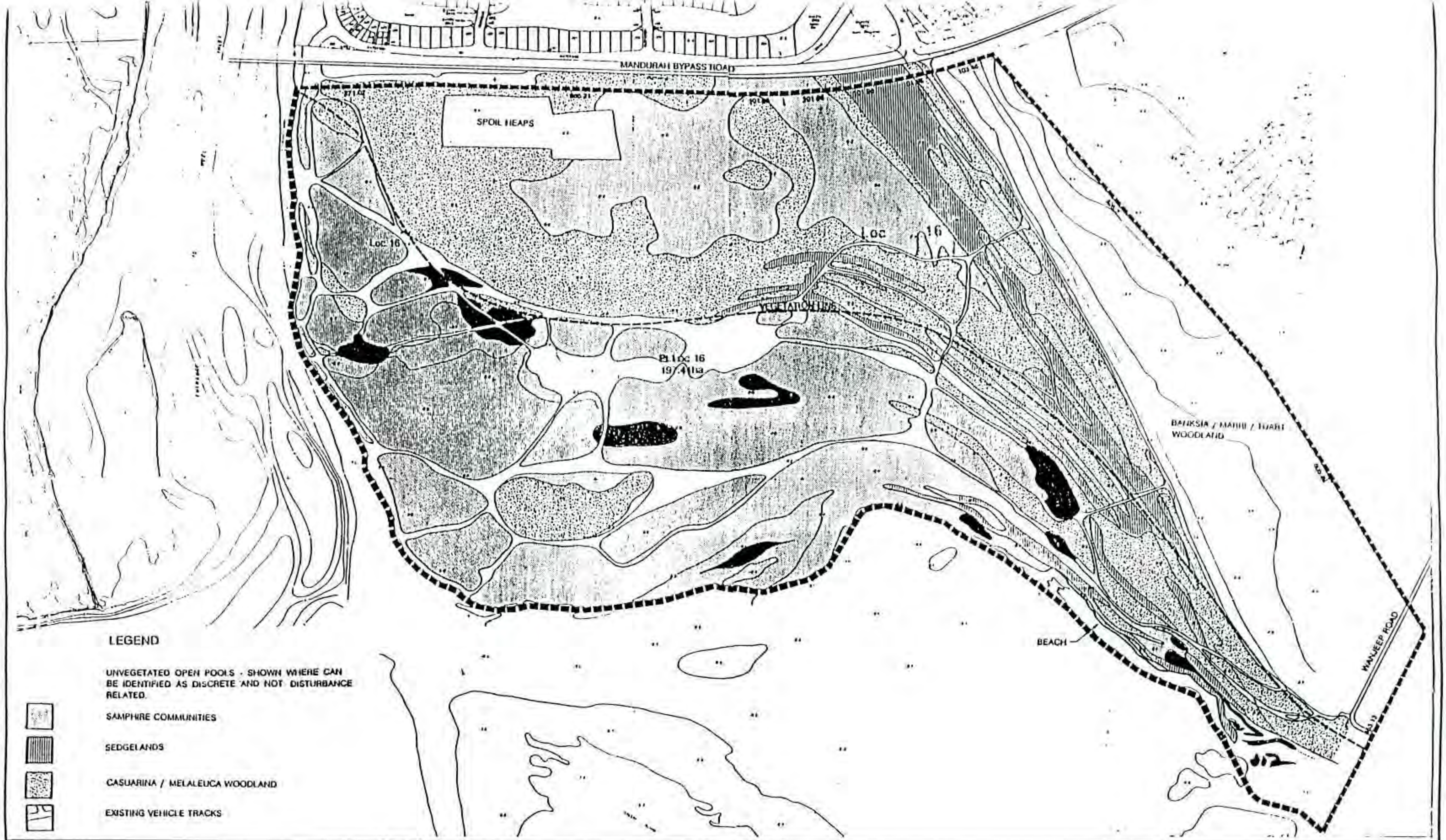
10.4.2 Waterbird Usage

10.4.2.1 Regional perspective

To assess the conservation significance of the samphire flats of the subject land for waterbirds requires that it be considered in a regional (Peel-Harvey Estuary) context.

The eastern side of the Mandurah Channel Delta, including the samphire flats of the subject land is known as the Creery Marshes. The Creery Marshes are identified by Hodgkin *et al.* (1980) as being one of the four most important areas for waterbirds in the Peel-Harvey system as a result of the extensive areas of the samphire habitat that occur there.

The Peel-Harvey Estuary is widely recognised as being of great importance for waterbirds in the South-west of Western Australia. Of 285 wetland areas surveyed by the Royal Australasian Ornithologists Union (RAOU) in the South-West between 1981 and 1985, Austin Bay Nature Reserve in the south-east portion of Peel Inlet had the highest single count of waterbirds (41,161) (Jaennsch *et al.* 1988). It also had the second highest number of waterbird species (67) of 197 wetland nature reserves surveyed. In more extensive surveys of Peel Inlet conducted by the Department of Conservation and Land Management (CALM) in 1976 and 1977, the highest single



PRINCIPAL	TITLE			
ESPLANADE (MANDURAH) PTY. LTD.	FIGURE 13 SIMPLIFIED VEGETATION TYPES			
	PROJECT HARBOUR CITY	BSD CONSULTANTS CONSULTING ENGINEERS, TOWN PLANNERS & PROJECT MANAGERS BSD HOUSE, 1 SLEAT ROAD, APPLECROSS. PHONE No. 316 2988	DATE 10.3.92 JOB No. P9186 SCALE NTS	PLAN No.

count was of 110,227 waterbirds (Lane unpub. data., cited by Ninox Wildlife Consulting 1990).

Despite these counts, additional counts conducted by the RAOU from 1985 to 1988 and counts conducted by Ninox Wildlife Consulting (for the Mosquito Control Review Committee of the Waterways Commission), most references to the importance of the Peel-Harvey system for waterbirds are imprecise. In particular, important sites and habitats within the system are inadequately identified, making if very difficult to assess the probable impact upon waterbirds of individual development projects around the estuarine system.

The three main programmes of waterbird counts conducted on Peel Inlet are: CALM, 6 surveys from August 1976 to June 1977; RAOU, 5-35 surveys on a range of sites from July 1981 to 1988 and; Ninox Wildlife Consulting, 9 surveys from November 1988 to December 1989 (Ninox Wildlife Consulting 1990). While none of these surveys was designed for assessing the importance of the subject land for waterbirds, they do provide some information on this topic.

According to Kirke (1986), 23% to 37% of individual waterbirds recorded in the CALM surveys of Peel Inlet were in the Mandurah Channel Delta. Total counts in the delta ranged from ca. 2,000 to 24,000 waterbirds. Over half of these would probably have been in the Creery Marshes. Highest counts in the Peel Inlet and the Mandurah Channel Delta were in summer. Fifty seven species of waterbirds were recorded in the delta area, compared with 66 for all of the Peel Inlet (Lane, unpub. data, in Ninox Wildlife Consulting 1990). The species included waterfowl (ducks, swans, coots and allies) and waders (stilts, plovers, sandpipers and allies).

Counts by the RAOU in Peel Inlet covered many of the major waterbird sites in the region and make it possible to compare Creery Marshes with other sites (Table 1 in Appendix 4). Overall, 22.8% of maximum waterbird counts recorded on Peel Inlet were on Creery Marshes, the area being particularly important for waders, many of them migratory species protected by international conservation treaties, such as:

Grey Plover, Lesser Golden Plover, Eastern Curlew, Greenshank, Marsh Sandpiper, Bar-tailed Godwit, Great Knot, Sharp-tailed Sandpiper, Red-necked Stint and Curlew Sandpiper. Highest single counts obtained annually for Creery marshes ranged from 792 (February 1982) to 17,189 (February 1987) individual waterbirds. As with the CALM data, highest counts were in summer. RAOU surveys recorded 80 waterbird species on the Peel Inlet; 58 of these being present on Creery Marshes.

Ninox surveys differed from CALM and RAOU surveys in that they concentrated on a selection of sites thought to be mosquito breeding habitat. They did not attempt to cover the entire Peel Inlet but do allow for comparison between Creery Marshes and a selection of similar sites in the northern Peel Inlet (Table 2 in Appendix 4). Overall, 21% of waterbirds counted were in the Creery Marshes, a value very similar to those of the CALM and RAOU data. As was found with the RAOU data, Creery Marshes were particularly important for wader species including some protected by international conservation treaties. Counts on Creery Marshes were highest in January 1989 (*ca.* 1050 waterbirds), April 1989 (*ca.* 1600 waterbirds) and December 1989 (1000 waterbirds) and lowest in the July to October 1989 period (50 to 200 waterbirds). The waterbird species responsible for this summer peak varied from transequatorial migratory waders in January to ducks in December and Black-winged and Banded Stilts in April. The two stilt species made up 65% of individual waterbirds on Creery Marshes in April and 78% of all stilts recorded on the Inlet in April were in Creery Marshes. Ninox surveys recorded a total of 60 waterbird species. The results of the RAOU and Ninox surveys for Peel Inlet as a whole and Creery Marshes are included in Tables 1 and 2 within Appendix 4.

10.4.2.2 Local perspective

Data collected by CALM and the RAOU treat Creery Marshes as a single site at best and therefore do not allow for variations in waterbird abundance within the marshes. The Ninox data allow for greater resolution as activity and habitat records were also collected. While not specifically designed to examine the importance of that part of the Creery Marshes which would be affected by the proposed Harbour City development, the Ninox data at least allows this question to be approached. The area that will be affected by the proposed Harbour City development is the inland samphire which is only occasionally inundated to form wet samphire and pools in winter and during exceptional spring tides.

Ninox recognised 9 habitat categories in their surveys: dry samphire (ie. areas of samphire that were dry at the time of survey); wet samphire (ie. inundated samphire areas at the time of survey); lagoons and pools; deep, open water; foreshore; tidal flats; sand-spits; perches and; other (mostly birds in flight). The break up of waterbird individuals and species across these habitats in the Creery Marshes are presented on Figures 1 a & b in Appendix 4. Most species and especially most individuals utilised lagoons and pools (particularly Creery Lagoon (defined as the open waterbody between the subject land and Creery Island) but also pools within wet samphire areas). Waders made up 50% of the birds using lagoons and pools. Dry and wet samphire supported few individuals. This pattern of usage, with greatest numbers of individuals and species on lagoons and pools, was consistent for all sites surveyed by Ninox.

Habitat data were dominated by summer records as that was when most birds were recorded, but it has been suggested that samphire areas may be of greater importance during flooding (after rain or high tides). This flooding would affect the development area, so the proportion of birds in samphire areas was compared between the periods April to November, when flooding occurred in the inland samphire flat area to some degree, and December to February, when the area was not flooded. In summer samples, only 0.4% of the 2957 records in the Creery Marshes were in samphire, compared with 12% of 2704 records in winter to spring. There is a shift of waterbirds into the inland samphire areas in autumn to spring. Records of birds in samphire in Creery Marshes in autumn to spring, some of which would have been in the inland area, represent 2.4% of all birds recorded in all sites during Ninox surveys in autumn to spring. The subject land contains a large portion of the samphire habitat of Creery Marshes. Therefore, it is estimated that up to approximately 2% of all birds recorded in the northern Peel Inlet as surveyed by Ninox Wildlife Consulting (1990) in autumn to spring would have occurred on the subject land.

In addition to habitat classifications, the Ninox data classified all birds according to activity. Activities were: feeding; roosting; loafing; aerial; breeding and; other. The distribution of activities of all waterbird records on Creery Marshes is compared with that of all Peel Inlet sites on Figure 2 in Appendix 4. Feeding was the major activity on the Creery Marshes whereas roosting was the major activity across all sites.

The distribution of activities across habitat types in Creery Marshes is presented on Figure 3 in Appendix 4. These can be summarised as follows:

- dry samphire: major activity was of birds passing overhead. Roosting the next most important activity, mainly by ducks and swans;
- wet samphire: roosting (mainly be Black-winged Stilts) followed by feeding (mainly by herons, egrets and ibis) were the main activities;
- lagoons and pools: most activity in this habitat was feeding. Waders, including a large proportion of transequatorial migrants, made up 46% of this category, followed by ducks and swans (41%);
- deeper water: most activity in this habitat was feeding, involving Black-winged and Banded Stilts (62%) and Grey Teal (17%);
- foreshore: feeding and roosting were of equal importance in this habitat, feeding being dominated by Silver Gulls (75%) and roosting by Grey Teal (49%);
- tidal flats: major activity was roosting, by Grey Teal (62%) and Silver Gulls (21%);
- sandspits: only roosting scored in this habitat, mainly by Grey Teal and Pacific Black Ducks;
- perches: only roosting scored in this habitat, mainly by Little Pied Cormorants (92%); and
- other: a small number of birds recorded flying over a range of habitats.

Analysis of CALM, RAOU and Ninox data clearly indicates that the Creery Marshes are important for waterbirds within Peel Inlet. More detailed analysis of Ninox data, however, indicates that usage within Creery Marshes is concentrated on Creery

Lagoon and in tidal pools adjacent to the Inlet. The drier inland samphire areas are used only when seasonally-flooded in the autumn to spring period and then only by a small proportion of birds. It should be noted that occasional inundation of the inland samphire areas may occur in summer. Such an event occurred recently at the subject land, which subsequently attracted considerable numbers of waterbirds to the inland samphire area as outlined in Appendix 4.

10.4.3 Mosquitoes

The mosquito breeding and activity characteristics of the subject land have been recorded by the Western Australian Health Department (Wright 1988) as part of a survey of mosquitoes in the Mandurah region. Two larval collection and adult trapping sites (No's 58 and 59) were located on the subject land in the south-east and north-west corners respectively.

A total of thirteen species of mosquitoes were collected on the subject land by Mike Lindsay during a year long survey of the mosquito breeding characteristics of the subject land which were dominated by two species *Aedes camptorhynchus* and *A. vigilax*. Both of these species bite viciously at any hour of day, disperse widely and are known vectors of Ross River Virus. Larval survey results indicate almost continuous breeding of both *Aedes camptorhynchus* and *A. vigilax* in response to the highest of high tides during the warmer months of the year (Wright 1988). During adult trapping *Aedes camptorhynchus* was collected at above nuisance levels (defined as >50 mosquitos/trap/night) during six months of the year and numbers were highest during September and October. *Aedes vigilax* was collected for eight months of the year and occurred above nuisance levels in February.

Wright (1988) determined that *Aedes camptorhynchus* breeding is widespread, but occurs at low to moderate densities throughout the samphire flats on the subject land during the cooler months of the year, and *Aedes camptorhynchus* and *A. vigilax* breeding occurs at high densities in only the most low lying of the open pools in the tidal zone during late spring, summer and early autumn. This is because mosquitos require pools of water for breeding that remain inundated for sufficient time for the eggs to develop into larvae, pupae and finally an adult mosquito (7-10 days in summer and up to 3 weeks in winter) (Chester and Klemm 1990). In winter the shoreline areas of the samphire flats are too frequently flushed and drained by tidal action for successful breeding to occur, while in summer the inland samphire areas dry out completely so that breeding can only take place in pools along the shoreline that occur within the tidal zone.

Wright (1988) concluded that mosquitoes occur on the subject land in sufficient number to cause a "very significant" to "severe" nuisance problem in the Coodanup area. In addition, mosquito populations originate from the tidal reaches of Creery Island and other mosquito sites adjacent to the subject land.

10.4.4 Present Condition of Project Site

10.4.4.1 Vegetation

The samphire area on the southern part of the site are, excepting the presence of a network of well used tracks, in relatively good condition. This is in stark contrast to the samphire communities at the northern end of the site, and to all the higher lying areas (including the present beach ridge and the two small islands in the samphires) which are heavily weed infested. An area to the north and north-east of the larger of the two islands is showing some effects of being partially smothered by algal mats. If the algal blooms can be limited, or the mats are successfully harvested in future, this area should not show any further deterioration.

10.4.4.2 Waterbirds

The inland area of samphire flats within the Creery Marshes is used by waterbirds for foraging and roosting mainly when inundated in the autumn to spring period. Approximately 2% of waterbirds recorded in the northern Peel Inlet by Ninox Wildlife Consulting (see section 10.4.2) in the autumn to spring period were present in this samphire flat area. This period is when waterbird numbers are lowest on Peel Inlet. Wading birds subject to international conservation treaties are generally absent or uncommon on Peel Inlet at this time.

10.4.4.3 Ecological functions and values

Rose and McComb (1980) speculated that the marsh systems (both sedge and samphire communities) may act as partial sinks for the increased nutrients resulting from the eutrophication of the Peel Harvey System. This was based on the fact that measurements of biomass for these communities were high compared to the very few other data available. Kirke (1986) quotes work which indicates that salt marshes, when inundated, also act as filters for sediments and organic material from the water column. Samphires along with other fringing vegetation are also important for providing shoreline stability (Hodgkin *et al.* 1980).

With respect to the *Banksia* and *Casuarina/Melaleuca* woodlands of the subject land, they play an important role in soil stabilisation and provide habitat for honey-eater birds and reptiles (snakes and lizards).

10.5 Human Environment

10.5.1 Regional Perspective

10.5.1.1 Demography

In 1986, the estimated resident population of the City of Mandurah was 19,196 and was projected to be 27,700 by 1991, 39,800 by 1996 and 51,300 by 2001 (DPUD 1990).

The Peel Region is identified as the third most popular tourist destination in Western Australia (Dames & Moore 1987). A large proportion of the tourist population are day trippers with day trips to the Mandurah/Pinjarra region in 1985/1986 numbering 1.6 million. Some 60,000 persons stayed in commercial accommodation in the region in 1985/1986 and during the 1986 census it was found that approximately 30% of houses in Mandurah are holiday homes (Australian Bureau of Statistics 1986).

10.5.1.2 Regional development - history

Prior to European settlement of the Peel Region, the area was inhabited by Aborigines of the Pindjarup dialect group of the Bibbulmun people. Aboriginal occupation was concentrated on the coastal plain in the vicinity of the Murray and

Serpentine Rivers with regular hunting and gathering expeditions into the Darling Plateau (DPUD 1990).

The mythological framework of the region mainly concerns the Waugal (also Wagal, Wagyl or Uocol) which is the Dreaming ancestor, usually manifested as a water serpent, who created the Murray and Serpentine River systems, and still retains a presence in some deep pools in the area. So far as could be ascertained, there are no Waugal beliefs associated with the subject land.

European settlement of the region occurred in 1830 when Peeltown (now Mandurah) was established. Agriculture soon developed as the main economic activity in the Region as people moved away from Mandurah in search of fertile land. Mandurah remained as a fishing village until the 1950's and 60's when tourist and retirement settlement developed. Mandurah has now grown to become a city and provides the regional service centre supporting the diverse range of activities in the Peel Region (DPUD 1990).

10.5.1.3 Economic profile

Mandurah is the centre for commercial fishing in the Peel Region supporting both an ocean and estuarine fishery. In 1985/1986 the total fishing catch was 1,126 tonnes, valued at $2.6 million. The estuarine catch is estimated to be worth $500,000/year (DPUD 1990). Tourism also plays an important role in the Peel region economy. Mandurah provides the regional centre for these and other industries including agriculture, mining, forestry as well as manufacturing, retailing and commercial development (DPUD 1990).

10.5.1.4 Recreation and boating facilities

The Peel-Harvey region has considerable recreational and leisure resources with the ocean, estuary, extensive foreshore areas and intermediate landforms encompassing a wide range of recreational pursuits. The estuary has six main public boat ramps and a further twenty-three minor public boat ramps (Kinhill Engineers 1988). During peak holiday periods, these public launching facilities experience severe congestion owing to the lack of sufficient vehicle and trailer parking.

10.5.1.5 Identified community needs

The community needs for the Mandurah region have been determined in a study of foreshore land use by Wilson Sayer Core (1988) and from recreational use surveys conducted by the Waterways Commission (1990). Identified community needs include:

- improved water quality in the estuary;
- improved access and enhancement of the foreshore regions for passive recreation;
- more foreshore reserves with picnic and toilet facilities, and places for people to socialise and relax;
- more boat launching, mooring and associated onshore facilities including overflow vehicle and trailer parking areas for use during busy periods;
- more typical residential dwellings, as opposed to holiday homes; and
- increased tourist accommodation.

10.5.1.6 Identified community values and concerns

Community values and concerns in the Mandurah region have been determined from two attitudinal studies which are evaluated in Skitmore and Bunbury (1985) and Kinhill Stearns (1985) and a recreation study conducted by the Waterways Commission (Thurlow and Chalmers 1990).

The identified community values were predominantly related to the proximity of the ocean or freshwater bodies including beaches, ocean, waterways and estuary and associated recreational opportunities such as fishing, prawning, crabbing and boating. Life style considerations relating to a quiet peaceful nature, country/rural atmosphere and the casual way of life were also highly valued.

The main community concerns were identified as mosquito nuisance, algae/weed growth and associated odours and poor water quality. Additional concerns related to changing lifestyle and conservation of the environment.

10.5.1.7 Peel-Harvey Estuary Management Strategy

Development of a management strategy for the Peel-Harvey Estuary was subject to a staged environmental assessment process. The preferred strategy is outlined in the Stage 2 ERMP (Kinhill Engineers 1988) which was subsequently approved by the EPA subject to various conditions and the commitments made in the ERMP (EPA, 1988). The principle management measures proposed by the strategy to improve water quality within the Peel-Harvey Estuary are:

- construction of the Dawesville Channel to enable marine flushing of the Harvey Estuary and to a lesser extent the Peel Inlet;
- dredging of the Mandurah Channel including the Sticks Channel in the Mandurah Channel Delta and the Fairbridge Bank at the ocean entrance to the Mandurah Channel to increase marine flushing of the Peel Inlet (completed in 1988);
- catchment monitoring and fertiliser management to reduce nutrient inputs to the estuarine system; and
- investigations into nutrient sources and land use within the catchment.

10.5.2 Local Perspective

10.5.2.1 Land use

Much of the land near the Mandurah Channel Delta is vacant, including the subject land, which was previously used for sheep and cattle grazing. To the north of the subject land is the Mandurah Bypass Road and a residential canal development, conservation and recreation reserves and other residential development. To the south-east of the subject land is the Coodanup residential area, while immediately to the east is cleared land that is currently being developed for the urban expansion of the Dudley Park residential area. The islands of the Mandurah Channel Delta are reserved for recreational and conservation purposes. A resort and residential development has been approved on the opposite bank of the Mandurah Channel (EPA 1990).

10.5.2.2 Groundwater use

Groundwater from the shallow superficial formations surrounding the subject land in utilised by local householders for small-scale garden reticulation using domestic and private bores. These bores are unlicensed and it is estimated there are in excess of 250 shallow bores within 1,000m of the site boundary.

Groundwater abstraction from the Leederville Formation is licensed by the Water Authority and the allocations are strictly enforced. Seventeen production bores are operational in the Mandurah district with a total allocation of 1,630,000 kL/annum. Groundwater can only be abstracted from the Leederville Formation for public or community purposes.

10.5.2.3 Beneficial uses of estuary waters

Bulletin 103 of the EPA (DCE 1981) outlines 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 identified and considered in Bulletin 103, those applicable to the Mandurah Channel and waters of the Peel Inlet adjacent to the subject land are identified below:

- 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 values;
- Beneficial Use 10 - Flushing water and water replenishment; and
- Beneficial Use 16 - Navigation and shipping.

10.5.2.4 Human use of subject land

Although within 2km of the Mandurah City Centre, the subject land has been relatively isolated from the surrounding urban areas by the Mandurah Bypass Road to the north, bushland to the east and the estuary and Mandurah Channel to the south and west. However in recent years urban expansion in the Dudley Park area has extended residential subdivision to the eastern part of the property.

As the subject land has been vacant and unused for some years there has been uncontrolled public access to the site. The samphire flats of the subject land are crossed with vehicle tracks, indicating the unrestricted use of trail bikes and other vehicles on the site. This has resulted in a degraded unattractive landscape when viewed from the Mandurah Bypass Road.

Due to the exposed nature of the site it is very difficult to control public access to the land given its attractive location for crabbers, campers and off road vehicle enthusiasts which has resulted in the areas heavily degraded condition. In excess of 30 wrecked motor vehicles occur on the subject land indication that it is a common dumping ground for old or wrecked vehicles. Such is the condition of the land, that it has significantly affected the natural ecology and habitat qualities for which the area has previously been noted.

The future redevelopment of the land will need to address the impact and control of human usage of the subject land.

10.5.2.5 Historical, archaeological and ethnographic sites

Archaeological and ethnographic surveys of the subject land were undertaken by R. O'Connor, G. Quartermaine and C. Bodney. The surveys recovered no previously unrecorded sites. There is one previously recorded archaeological site located on the south-east margin of the survey area. This site is in a disturbed situation and it has been recommended that development may proceed in this area. During project development, the proponent will comply with the provisions of the *Aboriginal Heritage Act 1972-1980.*

10.6 Conservation and Significance of Project Site

10.6.1 Identified Conservation Values

A number of studies and reports have identified the samphire flats of the subject land as having conservation value for various reasons. In these documents, the area of samphire flat recommended for conservation varies considerably as discussed in the following sections and depicted in Figure 14.

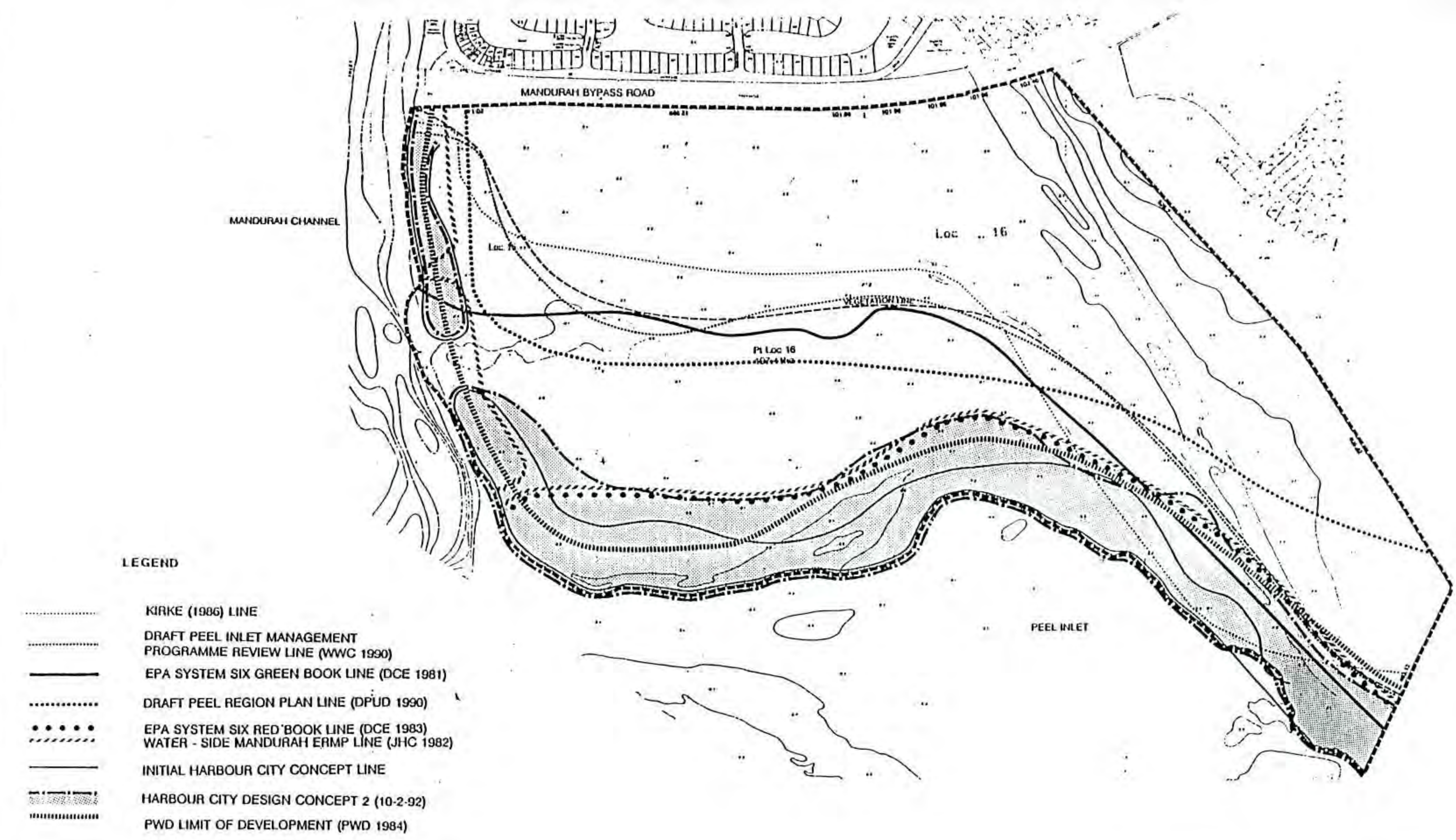
10.6.1.1 Geomorphology

The subject land comprises a relict tidal delta as discussed in Section 10.3.2 which was formed in the middle Holocene. Semeniuk and Semeniuk (1990) state that areas of elevated deposits such as this provide valuable resources of information about sealevel history, Holocene climate history and long-term estuarine dynamics useful for research purposes. Semeniuk and Semeniuk (1991) have used the results of radiocarbon dating on the subject land to determine the age and formation sequence of the relict tidal delta. This information has been used to provide a chronology of different shore types and to determine the sealevel history of the Peel-Harvey estuarine system. The landforms and geomorphology of the subject land are therefore identified as having conservation value for scientific purposes in relation to the study of estuary development and sealevel history.

10.6.1.2 EPA System Six Green Book

The System 6 Green Book was essentially a draft document which made a series of recommendations to the EPA for the establishment of conservation reserves within the Darling System (defined as the area from Moore River to the Blackwood River extending inland approximately 80km). The Green Book was prepared by the System 6 Committee and was made available for public comment (Department of Conservation and Environment (DCE) 1981).

Green Book Recommendation C50 proposed a foreshore reserve up to approximately 500m wide along the southern shoreline of the Harbour City site for the conservation of flora and fauna. The text accompanying the C50 recommendation identified the Peel-Harvey Estuary as probably the most important estuary in the south-west of WA



PRINCIPAL ESPLANADE (MANDURAH PTY. LTD.	TITLE FIGURE 14 VARIOUS CONSERVATION AREAS PROPOSED ON SUBJECT LAND
	PROJECT HARBOUR CITY

BSD CONSULTANTS
CONSULTING ENGINEERS, TOWN PLANNERS & PROJECT MANAGERS
BSD HOUSE, 1 SLEAT ROAD, APPLECROSS. PHONE No 316 2984

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as a conservation area for water birds. The tidal flats and shallows around Channel and Creery Islands and the adjacent shores (ie Creery Marshes) were identified as being important to many thousands of transequatorial migratory wading birds that use these areas in summer as well as small parties of little egrets which use the area throughout the year. The samphire flats and marshes were considered to represent important vegetation complexes in the area which have a restricted occurrence elsewhere and which are important for eastern curlews and whimbrels, being one of the few places in the south-west where these birds can always be seen (DCE 1981).

10.6.1.3 Waterside Mandurah Environmental Review and Management Programme

The Environmental Review and Management Programme (ERMP) document prepared for the Waterside Mandurah Estate (JHC 1982) addressed the entire John Holland landholding which includes the Harbour City site. The land became divided into Stages 1 and 2 as a result of the Main Roads Department proposal and subsequent construction of the Mandurah Bypass Road.

The ERMP proposed a conservation reserve approximately 150-200 m wide along the southern shore of the site, a 50-100m wide foreshore reserve adjacent to the Mandurah Channel for both Stage 1 north of the Mandurah Bypass Road (now constructed) and Stage 2 (Harbour City site) plus a conservation reserve around Soldiers Cove immediately north of the Stage 1 entrance channel. This proposal represented a significant modification of the System 6 Green Book C50 area. The rationale for this proposal was that the samphire flats are only fully inundated occasionally in the winter months when they provide a feeding opportunity for water birds. However migratory waterbirds visit the Peel-Harvey estuary in summer and are dependent on the moist tidal zone for feeding. Although some samphire areas were intended to be developed, the retention of the most significant samphire habitat (ie the wetter samphire community adjoining the tidal zone) would be maximised by inclusion of the samphire flats adjoining Soldiers Cove into a conservation reserve (JHC 1982).

10.6.1.4 EPA Assessment of Waterside Mandurah ERMP

The EPA assessment of the Waterside Mandurah ERMP (Bulletin 126) gave environmental approval to the whole project (Stages 1 and 2) as presented in the ERMP although acknowledging that the Stage 2 design and layout was conceptual only and would be subject to further detailed design. The proposed conservation areas around Soldiers Cove and along the southern shore of the project site were considered to:

> "represent a reasonable recognition by the proponent of the conservation values of the area" (DCE 1982).

However, in response to the ERMP's identification of the tidal zone being the most significant samphire habitat for waterbirds the EPA suggested a more significant section may be that subject to winter inundation and used as a winter feeding ground for ducks, swans and some wading species (DCE 1982). The analysis of bird count data (Section 10.4.2) does not support this view as bird usage in the wet and dry samphire areas was mainly confined to roosting activities.

10.6.1.5 EPA System Six Red Book

The System 6 Red Book presents the EPA's recommendations for conservation reserves in the Darling System following the public review period for the Green Book document. Red Book Recommendation C50 proposes a conservation reserve up to approximately 150-200m wide along the southern shore of the Harbour City site plus the area around Soldiers Cove. The accompanying text acknowledges that approval by the EPA of the Waterside Mandurah ERMP resulted in the amended reserve boundaries to that originally proposed in the Green Book. The C50 area is considered to be of regional significance because of its high conservation and recreation values and its proximity to the Perth and Bunbury region and neighbouring rural districts (DCE 1983).

10.6.1.6 Draft Peel Region Plan

The Draft Peel Region Plan is a planning document prepared by DPUD (1990) to guide future landuse, development and conservation in the Peel Region. With respect to the subject land, the draft plan proposes a zone (Rural C) for the conservation of flora and fauna which approximates that of the System 6 Green Book area with a 100-500m wide foreshore reserve adjacent to the Mandurah Channel. Table 13 of the plan indicated the locality of the Rural C zone is based upon occurrence of the Vasse Estuarine and Lagoonal land system adjacent to the estuary (DPUD 1990). However officers from DPUD have stated that it is not the role of Region Plan to precisely define the boundary of the conservation area and that this will require consideration of vegetation and overall conservation significance in addition to landform and soil characteristics (pers. comm. L Guise, DPUD 5-2-92).

The Draft Peel Region Plan acknowledges the subject land as suitable for urban development as follows:

> "A cell of future urban land between Peel Inlet and Mandurah Bypass Road (Creery wetlands) is also identified. Development of this land will depend on the resolution of a number of constraints including the amount of land to become a conservation reserve and the environmental impacts of the proposal" (DPUD 1990).

This document has been the subject of public consideration and comment and is now in the course of being finalised for presentation to Government.

10.6.1.7 Draft Peel Inlet Management Programme Review

The Draft Peel Inlet Management Programme Review was prepared by the Waterways Commission (1990) and establishes a series of management objectives and recommendations for the ongoing environmental management of the Peel-Harvey Estuary. With respect to conservation areas, Recommendation 22 supports the implementation of the System 6 (Red Book) recommendation relevant to the estuarine system which includes Recommendation C50.

Recommendation 23 of the Draft Management Programme Review proposes the establishment of a Waterways Protection Precinct in areas where the protection of waterways and adjacent foreshore margins is of high priority. The report states that the boundaries of the Waterways Protection Precinct were determined after considering:

> "the existence of fragile estuarine margins, natural and exotic vegetation, wildlife habitat, landscape values, the location of the WAWA floodway and floodplain and relevant contours " (Waterways Commission 1990).

The map that accompanies the report establishes a Waterways Protection Precinct up to approximately 600m wide along the southern boundary of the subject land extending northwards, adjacent to the Mandurah Channel, to the Mandurah Bypass Road (Waterways Commission 1990). There are no specific recommendations on the subject land in the "Area Recommendations" section of the report and there is no discussion on the rationale for the boundaries of this particular Waterways Protection Precinct. The Waterways Protection Precinct area on the Harbour City site equates to approximately 80ha of land and is not consistent with the intent of Recommendation 22.

Recent discussions between the Proponents and Mr Colin Chalmers of the Waterways Commission has indicated that the final Peel Inlet Management Programme Review report which is presently being finalised will reflect the need for the development line to be properly determined by assessment of the Harbour City project.

10.6.1.8 Kirke Report

In response to conflict between development and conservation of the estuary margins, the Peel-Harvey Conservation and Development Committee commissioned a study (Kirke 1986) to look at the conservation value and requirements of three foreshore areas of the Peel-Harvey estuarine system. The tidal delta at the confluence of the Mandurah Channel and Peel Inlet incorporating the subject land was one of the foreshore areas examined in the study. The conservation evaluation of the Mandurah Channel Delta was assessed using the following criteria; diversity, rarity, naturalness area, threat of human interference, representativeness, education value and special interest values. Each criteria was rated either high, medium or low and qualified with supportive evidence based on an extensive literature search, field observations and contact with relevant institutions, organisations and individuals (Kirke 1986).

Kirke (1986) identified five areas of significant conservation value in the Mandurah Channel Delta including the portion of samphire flats on the subject land corresponding to the original recommended area of conservation value in the System Six Green Book. The subject land area was considered to be of significant conservation value because it comprises a significant area of samphire (representing approximately 13% of the tidal area of salt marsh in the Peel-Harvey Estuary) and intertidal shallows which supports large numbers of waterbirds and in particular migratory wader species (Kirke 1986).

10.6.1.9 International Waterbird Treaties

The Peel Harvey estuarine system has been included on the Ramsar *Convention on Wetlands of International Importance Especially as Waterfowl Habitat* to which Australia is a signatory. This convention contracts countries to conserve to the best of their ability certain carefully specified wetlands within their boundaries designated as wetlands of international importance. However, it should be noted that the convention excludes land that is in private ownership and therefore does not directly apply to the subject land.

Australia has entered into agreements with Japan and China entitled respectively the *Agreement Between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment* which came into force in 1981 and the *Agreement between the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment* which came into force in 1988. Under these agreements Japan and Australia, and China and Australia are obliged to take special protective measures for the preservation of species of migratory birds and birds in danger of extinction and to encourage the formulation of joint research programmes on migratory birds and species of birds whose survival is threatened. Bird surveys on the samphire flats of the subject land between November 1988 and December 1989 recorded 9 species included in the Japan-Australia and/or China-Australia agreements (Ninox Wildlife Consulting 1990) and 28 of these species have been recorded in the overall Mandurah Channel Delta region (Kirke 1986) indicating the potential for an additional 19 protected species to utilise the subject land.

10.6.1.10 Ninox Wildlife Consulting Report

In 1990 Ninox Wildlife Consulting prepared a report on the significance of mosquito breeding areas to the waterbirds of Peel Inlet for the Mosquito Control Review Committee and the Waterways Commission. The report was based on waterbird surveys conducted by the consultants between November 1988 and December 1989 and a review of previous waterbird counts in the area. A total of 37 waterbird survey sites were located in wetlands and tidal shoreline areas between Falcon and Yunderup to the south and Lake Goegrup on the Serpentine River to the north which were visited for intensive sampling on nine occasions over the study period. Three of the survey sites were located within the samphire flats of the subject land; No. 25 in the south-eastern corner, No. 26 near the centre of the samphire flats and No. 27 in the north-western corner adjacent to the Mandurah Bypass Road bridge (Ninox Wildlife Consulting 1990).

During the survey 66 species and 45,969 individual waterbirds were recorded. At Sites 25-27, 38 species of waterbird representing 12% of the total count were recorded. To determine the conservation significance of each survey site a series of criteria were evaluated based on field data, physical attributes which control diversity and subjective or qualitative judgements based on previous experience. The criterion examined and scored for each site were species richness, number of individuals, presence of significant species (ie protected by international agreements), breeding potential, habitat quality, habitat representation, diversity of habitats and site area. Using this system Sites 25 and 26 were ranked as being of very high significance and Site 27 as intermediate significance (Ninox Wildlife Consulting 1990).

10.6.1.11 Evaluation by Specialist Consultants

AR & MJ Bamford Consulting Ecologists and EM Goble-Garratt (botanist) were commissioned in January 1992 to undertake an evaluation of the conservation values of the samphire flat of the subject land with reference to waterbirds and vegetation respectively. Their findings are outlined in the following sections.

Waterbird assessment

The conservation value of Creery Marshes as a whole is great and this needs to be recognised as the proposed project is immediately adjacent to the Marshes. Up to 25 waterbird species protected by international conservation treaties (between Australia and Japan and Australia and China) are known to regularly use the Marshes. At any one time, the Marshes may support approximately a quarter of the waterbirds on Peel Inlet.

The inland samphire flats of the subject land are of lower conservation value for waterbirds than the remainder of the Creery Marshes area. This area supports a low proportion of waterbirds present on Peel Inlet when numbers of waterbirds on Peel Inlet are low. This is in winter, when migratory species subject to international treaties are scarce or absent. Its importance may be underestimated, however, because of the nature of tides in Peel Inlet. Temporary flooding in spring when waterbird numbers increase on the Inlet may lead to short-term use by large numbers of birds, including transequatorial migrants, not detected by surveys. Such a spring peak in numbers has been observed on the Swan Estuary (M. Bamford, unpub. data) and summer usage of the subject land was observed following recent unseasonably high summer rainfall (Appendix 4).

Although of apparently low conservation value for waterbirds in itself, the inland samphire habitat does form a buffer between terrestrial environments and the high conservation value wet or shoreline samphire and lagoonal areas of the Creery Marshes.

Vegetation assessment

The significance of the samphire flat does not rest on its floristic composition. Of greater importance are its geomorphological formation and the ecological processes to which it contributes eg. as a nutrient sink, biological filter and faunal habitat. With the exception of its significance to avifauna, data on these processes are scanty and thus the effect of the loss of all or part of this community can not be gauged.

10.6.2 Significance of Samphire Flat

10.6.2.1 Waterbird Significance

The inland samphire areas of the subject land are in a degraded state, due mainly to the use of off-road vehicles. This probably has little relevance to its value for waterbirds, however. Open areas within samphire created by vehicles may even be used by birds as foraging areas, particularly when flooded, and the aesthetics of a site are of more significance to people than waterbirds. Most usage of the site by waterbirds is in winter when the area is flooded and direct disturbance of the birds by people would be low. Samphire recovers quickly when disturbance by off-road vehicles and other damaging uses are controlled.

Similar areas of samphire flat in the Mandurah Channel region are probably subject to similar levels of disturbance. Samphire flats in the south-eastern portion of Peel Inlet (Austin Bay Nature Reserve) have some degree of protection from disturbance, mainly due to isolation, but disturbance in this area will increase with the growth of Mandurah.

10.6.2.2 Vegetation

There does not appear to be any firm data on the area of samphire flats surrounding the Inlet and Estuary. Rose and McComb (1980) gave a figure of 12.8 km^2 for a combination of rush (*Juncus*), sedge (*Bolboschoenus*) and samphire communities. Kirke (1986) states that the subject land included 18% of the salt marsh in the Peel-Harvey System. It is not clear however, whether this figure refers to sedge and samphire areas, or to the samphires only.

Completion of Stage 1 of the Waterside Mandurah canal development and other developments along the Mandurah Channel mean that the percentage represented by the project site would now be considerably higher.

Extensive uncontrolled recreational use of the subject land has resulted in a network of tracks through the samphire communities. As the other major areas of samphire vegetation are less accessible to the general public they do not have this disturbance. With respect to weed invasion and general vigour however, the southern area of samphire on the project site is in good condition, as mentioned previously.

11 POTENTIAL ENVIRONMENTAL IMPACTS AND THEIR MANAGEMENT

11.1 Introduction and Objectives

This section assesses the potential environmental impacts identified to result from the Harbour City development and outlines proposed management actions to mitigate these potential impacts.

The objective for the environmental management of the Harbour City development is to minimise the impact of the project on the existing physical, biological and social environment. The proponent proposes to achieve this by the implementation of a management programme aimed at mitigating or avoiding potential adverse environmental impacts resulting from the proposal. This management programme will include monitoring programme to provide feedback on the effectiveness of the management programme, and determine the accuracy of predictions made regarding the potential environmental impacts of the project.

11.2 Available Information

In order to identify potential impacts and appropriate management strategies to address them for the Harbour City Project, a desk review of available information from existing canal developments in the region was undertaken in conjunction with specialist studies of the subject land as detailed in the Technical Appendices to this report.

Five residential canal estate developments presently exist within the Peel-Harvey Estuary system, two of which are located along the Mandurah Channel. Environmental assessment documentation of these developments and the results of construction and post-development monitoring, provide an information base from which to predict the potential environmental impacts of canal developments on the estuarine environment. Therefore, the potential issues with respect to the Harbour City proposal have been drawn from examination of this local knowledge.

It is important to note that an environmental assessment has previously been made for a canal development on the subject land in the Waterside Mandurah Stage II ERMP (JHC 1981) and EPA approval subject to various conditions was subsequently granted to the project (DCE 1982). The Harbour City development has many features identical to the Waterside Mandurah Stage II project and the recommendations made by the EPA have been incorporated into the concept design, and the proposed management and monitoring programmes, as documented in this section. In addition, the issues identified in the Canal Guidelines (DPUD Draft Policy No. DC 1.8) pertaining to functional design and administrative aspects of canal proposals have been addressed in the concept design and management strategies proposed for the Harbour City development.

11.3 Environmental Management and Monitoring Programme

The Environmental Management and Monitoring Programme for the Harbour City development comprises three integrated management plans which include monitoring of certain elements of the project with the potential to have an adverse impact on the existing environment. The three areas of management are:

- construction management;
- operational management; and
- conservation reserve management.

11.4 Construction Impacts and Management

11.4.1 Scope and Objectives

Construction of the Harbour City development will occur in stages in accordance with the development programme outlined in Section 4.5.1. In this context, the construction phase refers to the time when construction commences on each stage to the time when the newly created canal waterways are connected to the Mandurah Channel or adjoining canal waterways constructed during a previous stage. The objective of the construction management programme is to minimise inconvenience to nearby residents and impacts to the quality of estuary waters and on wildlife within the conservation reserve during construction of each stage of the project.

11.4.2 Physical Environment

11.4.2.1 Landform modification and spoil disposal

Impacts

The proposed development will modify the existing topography of the subject land by excavation to create the canals, filling to raise the level of estuarine flats within the development area and earthmoving and levelling across the development area. Detail on proposed development levels and estimates of the volume of spoil to be moved are outlined in Section 4.5.3.

Management

Further soil surveys will be carried out to determine localised variations in soil characteristics before details regarding the disposal of excavated material are finalised. Cut and fill operations for site earthworks will be monitored and an engineering construction programme relating to cut and fill operations and import and export of fill will be provided. Any waste material generated during construction (rubbish or waste construction material) will be disposed of at the Mandurah landfill site in accordance with standard City of Mandurah requirements.

All suitable excavated material will be re-used on site, and options for disposal of surplus material unsuitable for use on site will be documented to the satisfaction of the EPA. There will be no fill placed within the foreshore or conservation reserves (with the exception of filling along the canal edge of the latter) in order to maintain the flood relief characteristics of the subject land.

11.4.2.2 Shoreline and land stability

Impacts

The shoreline in the vicinity of the entrance to the canal system has not changed noticeably over the past 28 years and it is considered highly unlikely that the proposed development will directly adversely impact on shoreline stability in the region (Appendix 1).

Management

Foreshore stabilisation works will be carried out by the proponent if unacceptable erosion of the foreshore occurs.

The proposed construction techniques and canal design (Sections 4.3, 4.5) will ensure the overall stability of the site, including the conservation reserve, during canal construction. Following drainage and compaction of spoil to be used to create waterfront lots, reinforced concrete retaining walls will be constructed to provide stability. The sides of the entrance canal will be stabilised with limestone breakwaters. The canal wall abutting the conservation reserve and the boulevard style road separating the canal waterways in the eastern portion of the development from the dry lot subdivision will be stabilised with limestone rock pitching.

11.4.2.3 Groundwater

Impacts

Construction of the proposed canal waterways will result in a number of impacts on local groundwater resources (Appendix 5). These are as follows:

- landward migration of up to 600m of the saltwater/freshwater interface;
- landward migration of the existing groundwater outflow to the eastern edge of the canals; and
- a temporary reduction in groundwater levels of up to 3m in the southern portion of the Dudley Park residential area during construction.

The effect of the predicted modifications to the shallow aquifer on the adjacent community are detailed in Section 11.5.4.6.

The landward migration of the saltwater/freshwater interface will not affect the vegetation of the foreshore and conservation reserves as groundwater in these areas is naturally saline.

Management

The proponent will undertake a monitoring programme of groundwater levels and quality in local domestic bores during construction of the Harbour City development as outlined in Section 11.5.7.2.

11.4.2.4 Water quality

Impacts

Canal construction is not expected to cause a deterioration in water quality within the adjacent estuarine waters. Although localised turbidity will occur during construction, arising from disposal of impounded dewatering fluids and dredging of the entrance canal and disturbance at the mouth of the entrance canal associated with excavation and stabilisation works, this will be a short term event and is not expected to have an adverse effect on estuarine water quality or biota.

Management

Turbid dewatering fluids generated during construction activity will be impounded on site to allow particulates to settle prior to discharge to the Mandurah Channel. No dewatering fluids will be permitted to be discharged into the samphire flats of the conservation and foreshore reserves. Canal excavation will take place in a closed system and hence turbid water will be contained. Physical opening of the canal system to the Mandurah Channel will occur when the two water bodies are at the same level and assisted by flow controlled pipe links until water levels are equal. Final details will be agreed with the EPA and PIMA for licensing prior to construction commencing.

11.4.3 Biological Environment

11.4.3.1 Loss of vegetation

Impacts

The proposed development will result in the loss of the following areas of vegetation:

- approximately 50ha of relatively dry inland samphire habitat;
- approximately 67ha of *Casuarina/Melaleuca* woodland; and
- approximately 36ha of *Banksia*/Marri/Tuart woodland.

These areas are presently significantly degraded as a result of uncontrolled use of the subject land by off-road vehicles, weed invasion and frequent burning.

Management

Approximately 44ha of shoreline samphire habitat will be retained in the proposed conservation and foreshore reserves. This habitat is presently relatively undisturbed and largely free from weed invasion, and has been identified as being of significant value to waterbirds as discussed previously in Section 10.6.

During detailed design and construction of the land-based development the proponent will retain as many existing trees as possible which will be supplemented with landscape planting of indigenous vegetation and other species which are able to withstand the salt-laden conditions and poor soil conditions throughout the development.

11.4.3.2 Loss of waterbird habitat

Impacts

The proposed development will result in the loss of approximately 50ha of inland samphire habitat which is only intermittently inundated during seasonally wet periods and from the highest of high tides. As inundation of this area usually only occurs in winter when most waterbirds, particularly migratory species, are absent from the Peel-Harvey Estuary the drier inland samphire areas are not considered to represent an important habitat for wildlife and the impact of its loss is not considered to be significant.

The remainder of the site is currently in a degraded state and is not considered to be of significance to wildlife.

Management

The most valuable habitat for waterbirds identified on the subject land (i.e. the shoreline samphire areas) will be retained in a conservation reserve. Specific management actions for this reserve are detailed in Section 11.6. However, it is important to note that the conservation reserve area will be out of bounds when construction commences on the subject land in order to prevent disturbance or degradation by construction vehicles and workers from occurring. All construction workers on the Harbour City Project will be briefed on the importance of the conservation reserve and requested to assist in its preservation during the construction period. As each stage is completed, the vermin proof fence shall be established at an appropriate position to protect the newly created conservation area.

11.4.4 Human Environment

11.4.4.1 Traffic, noise, vibration and dust

Impacts

During the construction phase of the project, nearby residents in Coodanup and Dudley Park and earlier completed stages may be inconvenienced at times by noise and vibration impacts associated with traffic movements and earthmoving activities on the site. Dust is not expected to be a problem as most of the earthmoving activities will involve damp or wet soil excavated from the propose canals.

Management

The level of ground vibration in the vicinity of construction activity and in surrounding area will be monitored, particularly at the commencement of works, in order to set a parameters and modify work patterns and equipment types if necessary. It is proposed to access the site directly from the Mandurah Bypass Road in order to avoid potential noise impacts on local residents associated with construction vehicle movements to and from the site.

Working hours on the site will be restricted to between 7.00 am and 6.00 pm Monday to Saturday, in accordance with approvals to be granted by the City of Mandurah, to minimise disturbance to nearby residents.

If dust emissions from earthmoving activities or from cleared areas of the site subject to strong winds prove to be a problem to local residents, then water carts or other dust control methods such as mulching will be utilised.

The proponent will liaise with the City of Mandurah to ensure that construction noise, traffic, vibration and dust do not create excessive disturbance to local residents and alternative management techniques and work patterns will be adopted if necessary.

11.4.4.2 Public access

Impacts

Public access to the project site will be prohibited during construction for safety reasons.

Management

The access roads to the site will be fenced and appropriately worded signage erected during construction. Workers on the site will be instructed to deny access to members of the public during construction.

11.4.4.3 Landscape aesthetics

Impacts

The project will result in a modified landscape, particularly when viewed from the Mandurah Bypass Road, by transforming an area of semi-natural although severely degraded estuarine flats environment into a developed and managed environment, consisting of an artificial waterway system with residential and commercial development. The aesthetic acceptability of this change will vary with the perceptions of the individual. However, previous experience has shown that urban and commercial land near or adjacent to water is sought after as it is considered to have high landscape value and visual amenity.

The landscape of the subject land when viewed from boats in the Mandurah Channel and Peel Inlet will be modified but will not change significantly due to the retention of significant areas of samphire habitat in the conservation and foreshore reserves, thereby maintaining the existing natural appearance.

Management

High visual amenity will be provided in the Harbour City development by the creation of more than 50ha of carefully designed canal waterways, retention and rehabilitation of approximately 44ha of foreshore and conservation reserves, and landscaping of over 10ha of public open space areas, commercial areas and streetscapes. Areas of public open space will be landscaped in accordance with a Landscape Master Plan, and will be developed and implemented by the proponent for and operational period of twelve months until the land is vested with the City of Mandurah and the proposed Management Entity assumes control then full responsibility will be handed over to the City of Mandurah. The purpose of the landscaping treatment is to create an attractive development with a natural appearance. The landscape design will:

- retain significant stands of trees and fringing vegetation where possible;
- establish a dense buffer of tree planting along the Mandurah Bypass Road frontage;
- provide for street tree planting and landscaping of commercial facilities in addition to public open space areas; and
- maintain a natural character by planting of low maintenance tree and shrub species indigenous to the area and/or species capable of living in a severe salt-laden and poor soil environment.

Underground power reticulation will be provided for all electrical power and street lighting within the proposed development to avoid unsightly overhead wires.

11.5 Operational Impacts and Management

11.5.1 Scope and Objectives

The operational phase of the Harbour City project is defined as the time commencing at the practical completion of construction of each stage and continuing until all the lots in that stage are sold. During the operational phase, the proponent will be responsible for the management of the canal waterways, in conjunction with the Management Entity proposed to be established under the direct control of the City of Mandurah.

The objectives of the operational management programme are to:

- ensure the ongoing serviceability and integrity of all public infrastructure and facilities; and
- maintain acceptable water quality within the canal waterways, subject to the limitations imposed by the water quality of the Mandurah Channel, while not adversely affecting the water quality of the Peel-Harvey Estuary.

11.5.2 Physical Environment

11.5.2.1 Groundwater

The proposed Harbour City development will have a negligible long-term effect on the superficial fresh groundwater aquifer which occurs beneath the adjacent residential land to the east of the subject land. Monitoring results from the Waterside Mandurah canal development confirm that the impact of canal construction has been largely of short-term duration. Following five years of post-construction groundwater monitoring, Dames & Moore (1991) identified the following longer term effects on the local groundwater resource:

- the hydrogeological regime has restabilised;
- the saltwater interface has become re-established about 50m inland from the eastern margin of the canals. The saltwater interface is closer to the canals than originally predicted in the ERMP (JHC 1982) as a result of enhanced recharge caused by urbanisation;
- the saltwater interface migrates seasonally in response to changes in recharge, but the average long-term position of the interface remains static; and
- water table levels have continued to rise slowly since completion of the canals, over too long a period to be attributed to recovery from dewatering during construction, which is attributed to enhanced recharge as result of urbanisation. The rise is expected to continue for several years before water levels are stabilised as a result of increased evapotranspiration as the vegetation cover is re-established on cleared areas, increased groundwater discharge from direct evaporation from the water table and increased groundwater seepage losses to the canals and waterways.

It is predicted that the same changes to the groundwater regime will be experienced at the Harbour City development area.

Management

Household groundwater bores will not be permitted within the Harbour City canal lots as the saltwater interface will be relocated to the east of the canals following their excavation and therefore water from the superficial formations will be too salty for garden reticulation.

With respect to public open space areas, streetscapes and entrance statement, it is presently envisaged that only limited use of groundwater from the Leederville Formation for reticulation will be required as low maintenance grass and tree species will be planted. The proponent will further consult with WAWA and the City of Mandurah to determine the requirements for groundwater usage within the development.

A programme to monitor groundwater in the vicinity of the subject land following construction of the Harbour City canal waterways is described in Section 11.5.7.2.

11.5.2.2 Drainage

Impacts

The natural drainage characteristics of the subject land will be modified by the construction of the canal development. Paving of cleared surfaces will require the installation of an artificial drainage system.

The development proposed will generate minimal nutrient discharge to the Mandurah Channel and Peel Inlet as a result of management strategies proposed, and will generate far less nutrient discharge than if the area were developed into a conventional residential estate.

Management

Drainage from all road and other paved surfaces will be passed through suitable grease/silt traps to remove possible contaminants prior to discharge into the canal waterways. All private and public boat ramps within the development will be designed to include a drainage system to the satisfaction of PIMA. Drainage from the boat servicing area will be passed through sumps to prevent silt, grease, oil and other contaminants from entering the waterways. The drainage system will be maintained on a regular basis by the proponent for the operational period or until the lots are sold to ensure effective trapping of contaminants.

Residential lots with canal frontage will be gently graded to slope downwards to the canals where a porous spoon drain adjacent to the canal wall walkway will be provided adjacent to the canal wall of each lot. Generally water from roofs will be directed through a separate drainage (piped) system directly into the canals except for those lots located in good draining sandy soils, whereby roof drainage will be discharged into on-site soakwells. These areas will be identified during the detailed investigation and design phase of the project. Direct drainage connections to the canals will be via preformed holes in the canal wall located below the low tide level.

Additional drainage from residential lots including paved areas or irrigation will be discharged to the soil via standard soak wells or surface infiltration or will naturally drain to the front of each lot where it will be collected in spoon drains and infiltrate the soil. Solids will be removed by traps which would be regularly cleaned through normal maintenance operations. This method of stormwater disposal provides for the direct discharge of stormwater from roofs into the canal system and discharge of any possible nutrient loaded water via soakwells into appropriate drainage traps. This system has been successfully utilised in the Waterside Mandurah development.

A strong commitment is made by the proponent to educate all landowners in landscaping with native (low nutrient requiring) plants, the use of slow-release fertilisers and efficient water usage in order to minimise nutrient input to the local environment. Education will be achieved by means of suitably worded information being distributed to all purchasers of land within the development. Building guidelines under the direct control of the company will also be geared to supervise correct drainage installation and provide educational instruction. It is anticipated that landowners will be receptive to this management responsibility as they will be aware of the disbenefits to themselves resulting from pollution of the canal waterways.

The water quality monitoring programme (Section 11.5.7) will be designed to ensure early detection of any adverse impacts resulting from the drainage system.

11.5.2.3 Canal and estuary water quality

Water quality monitoring for the Waterside Mandurah (LeProvost Environmental Consultants (LEC) 1991a) and Port Mandurah (LEC 1991b) canal estates, indicates that water quality within the proposed Harbour City canals will be determined almost exclusively by the quality of the source (Mandurah Channel) water. During periods of reduced water quality in the Mandurah Channel resulting from phytoplankton and macroalgal blooms in the estuary, the canals experienced a similar decline in water quality. During periods of *Nodularia* bloom in the Peel Inlet, reduced water quality was recorded in the canals. This was found to be a short-term phenomenon, lasting only as long as the bloom survived. Low-level blooms have been evident for an extended period within the Waterside Mandurah canals during years of *Nodularia* blooms, resulting in colouration of canal waters. However, there was no evidence to indicate that the slightly reduced water quality in the canals had any adverse effect on the water quality in the Mandurah Channel (LEC 1991a).

Monitoring of the two canal estates has shown no evidence of persistent bacterial contamination of the canals, and the waterways have been deemed safe for occasional human immersion (LEC 1991a, 1991b).

Kinhill Riedel & Byrne (Appendix 1) have investigated the flushing characteristics of the proposed Harbour City canal waterways and have shown that there are three likely mechanisms for the flushing of the canals as follows:

- tidal exchange, which consists of astronomical tides (at least once a day) and longer term barometric tides (5-20 days);
- wind-induced currents and mixing within the canals; and
- density currents due to salinity and temperature gradients.

It is estimated that during calm wind periods, tide and density driven currents would produce around 50% exchange per day. During periods of stronger winds, the density currents would be broken down by vertical mixing of the water. Flushing during these periods would be due to tide and wind producing at least 30% exchange per day. The combined effects of tidal flushing, wind induced circulation and mixing and gravitational flushing due to salinity and temperature gradients should ensure that the water quality in the Harbour City canals will closely reflect that of the source water in the Mandurah Channel at all times, the quality of which has been shown to be adequate for the purposes to which the canal waters will be subjected.

Management

The Harbour City canals will be maintained such that the water quality within the canals meets the criteria stipulated in Schedules 1, 2, 5, 7, 8 and 16 of Bulletin 103 (DCE 1981) which allows for the following Beneficial Uses:

- harvesting of aquatic life for food;
- passage of fish and other aquatic life;
- maintenance and preservation of the aquatic ecosystem;
- maintenance of foreshores and banks; and
- navigation.

Maintenance of canal water quality for these Beneficial Uses will mean that the uses stipulated in the Canal Guidelines (DPUD Policy No. DC 1.8) for canal waterways will not be adversely affected (i.e. occasional human immersion and wading, boating, adjacent development and passive recreation).

Long term accommodation on vessels within the development will not be permitted, and discharge from boat holding tanks will be strictly prohibited. A boat sullage pump-out facility will be provided in the commercial centre of the Harbour City development. This pump-out will be directly connected to the sewerage system.

The canal waterways will be inspected regularly by the proponent in addition to the water quality monitoring programme outlined in Section 11.5.7) and any corrective action required to maintain water quality and aesthetics to the high standard required by the proponent and Government agencies will be implemented immediately. Adequate clearance between culvert and bridge soffits and the water surface is provided in the design to allow any wind blown debris to pass through and minimise restriction of wind driven water circulation. The sides of the culverts and bridges will extend to the full depth of the canals to avoid restriction of density driven currents which will provide significant mixing and flushing of canal waters.

11.5.2.4 Nutrients and heavy metal accumulation in sediments

Impacts

Nutrient and heavy metal accumulations in the bottom sediments of waterways are site specific, and thus monitoring data obtained for the Waterside Mandurah and Port Mandurah canal waterways cannot be directly related to the Harbour City canals. However, the monitoring results of sediment nutrient levels in the Waterside Mandurah canals indicate that the trend in sediment nutrient levels in the canals follows that observed in monitoring sites in the Mandurah Channel and Peel Inlet (LEC 1991a). This would indicate that with effective management of nutrient discharge to the Harbour City canals, the sediments will not act as a nutrient sink.

It is possible that heavy metals such as copper, zinc, cadmium, tin, lead and chromium may enter the canals and accumulate in the sediments over time. The results of sediment monitoring in the Waterside Mandurah canals has revealed evidence of copper and lead accumulation over the past five years. These heavy metals are concentrated along the main channel, indicating that the passage of boats from the public boat launching ramp to the Mandurah Channel is the main source of heavy metals (LEC 1991a). It should be noted that although the heavy metal concentrations recorded in the Waterside Mandurah canals are notably higher than natural background levels, the present concentrations do not pose a threat to biota or to humans eating fish caught within the canals. However, in order to avoid a similar situation occurring within the Harbour City canals, the public boat launching ramp has been located at the entrance to the waterway system where the effects of flushing will be greatest and hence the potential for accumulation of heavy metals from this source is reduced.

Management

Drainage management as described in Section 11.5.2.2 is anticipated to aid in reducing the likelihood of nutrient and heavy metal accumulation in the canal sediments. Monitoring of sediments is proposed as discussed in Section 11.5.7.

11.5.2.5 Navigable waterways

Impacts

Sedimentation of the canal waterways could occur due to the expansion of flow lines, slowing the velocities and allowing suspended particles to deposit. However, investigations by Kinhill Riedel & Byrne (Appendix 1) concluded that this is unlikely to occur because:

- the entrance canal is small in comparison to the Mandurah Channel cross section and expansion of flow lines into it would be minimal; and
- alignment of the entrance as in the Waterside Mandurah development and gentle batter slopes will allow smooth transition of flow.

The most likely cause of sedimentation in the canal waterways is from suspended material during flood events which is often caused by interaction with the saline front. Monitoring for the Waterside Mandurah development has shown that this occurs in the Peel Inlet and therefore the bulk of the suspended sediment load is deposited before it reaches the Mandurah Channel. The following conclusions are made for the Harbour City development:

- the cross-section of the canals is much smaller than that of the Mandurah Channel, and calculated velocities are an order of magnitude lower with small tidal flows. The impact of the proposed canals on the channel will therefore be minimal; and
- low sediment loads in the Mandurah Channel and relatively low velocities will result in minimal sedimentation of the entrance or canals, except perhaps during an unusual flood event.

Management

The canals will be surveyed upon completion to ensure that they conform to the design depth. Additional surveys will be conducted after the first, third and fifth years of operation of each stage to determine whether sedimentation of the canals has occurred. As the Harbour City canals are not expected to experience siltation to the extent that navigation is adversely affected during the period in which the proponent will be responsible for canal maintenance, dredging will be the responsibility of the long-term Waterways Manager. However, in the unlikely event that management action is required within the operational period, the proponent will undertake any necessary dredging works to the satisfaction of DMH and EPA.

11.5.2.6 Maintenance and stability of canal walls and entrance canal

Impacts

The Harbour City canal walls and entrance canal breakwaters have been designed with expected 30 and 100 year lifespans respectively and include scour protection. As such they are not expected to require any maintenance works within the operational period of the project.

Management

A programme to monitor the stability and condition of the canal walls and entrance canal is presented in Section 11.5.7.

11.5.3 Biological Environment

11.5.3.1 Increased pressure on estuarine fishery

Impacts

The potential impact of the Waterside Mandurah canal development on the estuarine fishery was identified as an issue of concern in the EPA's assessment of the ERMP for the project (DCE 1982). The EPA considered that the project may interrupt or alter the migration of fish and crustaceans between the ocean and the estuary. Monitoring was subsequently undertaken in the Waterside Mandurah canals which demonstrated that the canals did not adversely affect the recruitment of juvenile fish and crustaceans to Peel Inlet. The canals were in fact found to form a preferred nursery area for juvenile yellow-eye mullet and king prawns which occurred there in large numbers before moving into the Mandurah Channel (LEC 1991a).

An additional concern with respect to the estuarine fishery and biota is the increased human pressure that may result from the proposed development owing to an increase in local recreational fishing. However, no adverse impact on fish stocks can be expected to be caused solely as a result of the Harbour City development, rather this increased fishing pressure is likely to occur as a result of natural population growth whether or not this particular project proceeds.

It should be noted that the canal waterways will provide additional fish and crustacean nursery areas which will compensate in part for increased fishing pressure in the area.

Management

Fisheries management is the responsibility of the Department of Fisheries which has the authority to regulate the exploitation of fish resources. However, the proponent will erect signs at the public boat ramp outlining minimum catchable fish and crustacean sizes, net requirements and bag limits.

11.5.3.2 Disturbance to waterbirds

Impacts

Ninox Wildlife Consulting (1988) have identified a number of potential sources of impact on the abundance and diversity of waterbirds utilising areas adjacent to developments as follows:

- noise from boats, cars and other sources within the development;
- illumination of the area adjacent to the development;
- physical disturbance of birds by residents intruding on feeding, breeding and refuge areas;
- harassment and predation by domestic pets (cats and dogs); and
- effects of mosquito control measures on waterbird habitat and food sources.

Ninox Wildlife Consulting (1988) concluded that while there is no evidence from researchers to suggest that waterbird populations in the Perth metropolitan wetlands would be greater without the surrounding urban development, locations such as Alfred Cove, Lake Monger and Herdsman Lake are relatively highly disturbed areas (and would certainly receive more disturbance than that anticipated by the proposed Harbour City development), but still maintain large, diverse populations of waterbirds. Similarly the Sticks Channel in the Mandurah Channel Delta supports a large number of waterbirds even during the extremely heavy boat and vehicle traffic of a long-weekend.

Management

Although some physical disturbance to waterbirds is unavoidable, the proposed development creates the opportunity to manage access to the conservation reserve whereas the site at present is unmanaged and is degraded as a result of uncontrolled access and use of the site. Disturbance to waterbirds will be minimised by the following management actions:

- separation of the conservation reserve from residential development by a canal waterway with a limestone rock pitched treatment along the reserve edge which creates a hostile berthing situation and will assist to prevent boat landings;

- vermin proof fencing of the conservation reserve to prevent access from the land;
- provision of a buffer of trees along the edge of the conservation reserve to screen the conservation reserve from the development (see Section 11.6.1) which will reduce night-time light spill into the reserve; and
- education of all residents as to the importance of protecting the conservation reserve area.

With respect to mosquito control measures, it is proposed to mechanically dig shallow channels extending inland from the Peel Inlet to increase tidal inundation of the samphire flats and improve the flushing and drainage characteristics of pools and seasonally wet areas which are currently significant mosquito breeding areas. This approach to mosquito control is considered to have less impact on waterbirds than chemical application and may actually benefit waterbirds by improving the value of the site to waterbirds during summer months when the samphire flats are usually dry. All mosquito control measures undertaken at the subject land will be implemented in consultation with PIMA and the Mosquito Control Review Committee.

11.5.4 Human Environment

11.5.4.1 Community services and facilities

The Harbour City development will not adversely affect existing community services and facilities as the existing headworks can be expanded to adequately cater for the development. Existing external sewage pump stations and treatment plants have sufficient capacity to accommodate waste water from the development.

The proposed development will increase the recreational and boating facilities available to the local community. The demand for improved recreational opportunities on the foreshore of the Peel-Harvey Estuary has previously been noted and therefore the proposed development is perceived to have a beneficial impact on the local and tourist communities alike with respect to available facilities.

11.5.4.2 Workforce

Impacts

The proposed development will have a positive impact on the workforce in the region by increasing employment opportunities in both the short and long term.

Management

The majority of the construction and operational workforce will be drawn from the Mandurah region.

11.5.4.3 Traffic

Discussions with the Main Roads Department have indicated that there will be no problems associated with providing access to the development from the existing and proposed road system. The calculated traffic volumes generated by the development are presented in Section 4.3.3. Under the proposed staging of construction, the development will contribute to a gradual increase in traffic volumes along the Mandurah Bypass Road, Wanjeep Road and through the Dudley Park area. This is not considered to pose any problems as the road system can easily accommodate the extra traffic. It should be noted that the traffic generated by the proposed development would be considerably smaller than if conventional urban subdivision was created on the subject land, owing to a decreased lot yield.

11.5.4.4 Recreational facilities

Impacts

The recreational boating public will benefit from the proposed canal development by the provision of new public boating facilities, which is an identified need in the Mandurah region (Section 10.1.5.1). Boat servicing facilities within the development will accommodate the needs of resident boat owners.

The canal lots will each be able to have a mooring or jetty. Boat owners within the dry lot subdivision will be able to access the public boat launching facility within the development. Therefore boat owners within the development will not create significant pressure upon existing boating facilities in Mandurah.

The canal waterways, commercial facilities, foreshore reserve and public open space area will provide additional recreation opportunities for water-orientated activities such as boating and fishing and for passive recreation.

Management

All facilities provided in the development will be managed and maintained by the proponent to maximise public amenity. Navigation aids will be provided to the satisfaction of the Department of Marine and Harbours within and adjacent to the canal waterways to ensure the safe movement of boats in this area.

11.5.4.5 Land use

Impacts

The subject land is presently undeveloped and therefore the change in land use from vacant grazing land to residential and commercial development will be an obvious local impact. The continued uncontrolled use of the subject land by off road vehicles will not be permitted following development of the site. Although providing for private residential subdivision, the development will provide a range of public facilities discussed previously which is seen as a beneficial impact of development.

Approval of the proposed Harbour City development will define the boundary between conservation and development areas, currently not accurately defined within the System 6 Red Book recommendations for the site (DCE, 1983). The conservation reserve, as defined in this report (Figure 9) protects the most valuable areas of waterbird habitat while providing the necessary land to make the project viable.

Management

The proponent will maintain all facilities created in the development to maximise the land use potential of the project to both private landowners and the public.

The conservation reserve will be ceded to the Crown as an added benefit of the project, to be managed as a reserve for the conservation of waterbirds and samphire habitat. Consultation will be undertaken with CALM and PIMA to determine appropriate management strategies to ensure the long term protection of the reserve is achieved. This will be done at the time a Management Plan is prepared.

11.5.4.6 Groundwater use

Impacts

Preliminary calculations by Dames & Moore (Appendix 5) indicate that water levels in domestic bores in Dudley Park in the vicinity of Blythwood Street will decline by up to 0.5m in the short term, and bores south of Coolibah Street can expect temporary water level declines of 2-3m.

The results of groundwater monitoring from the Waterside Mandurah project indicate that the Harbour City development will not adversely affect present users of this resource in the long term. It was concluded that the Waterside Mandurah canals appear to have had little, if any deleterious impact on domestic bores (Dames & Moore 1991).

Management

The groundwater in adjacent residential areas will be monitored in accordance with the monitoring programme outlined in Section 11.5.7.2. The final details of the monitoring programme will be determined in consultation with WAWA.

11.5.4.7 Foreshore use

Impacts

The proposed development will result in increased use of the foreshore areas of the subject land compared to the existing uncontrolled use of the site. The waterway frontage provided to a large proportion of the development may result in less pressure on the foreshore areas than that which would occur within a conventional residential subdivision.

Management

A system of dual-use pathways will be routed along the foreshore reserve and through the development to link various components of the development. The pathways in conjunction with the proposed landscaping works and fencing or signage as required will ensure that the foreshore areas are not degraded from increased and uncontrolled use. Adequate public parking areas will be available for public access.

11.5.4.8 Archaeological and ethnographic sites

Impacts

An archaeological and ethnographic survey of the subject land concluded that the development of the site would not adversely impact upon archaeological or ethnographic values.

Management

The proponent will comply with the provisions of the *Aboriginal Heritage Act 1972-1980.*

11.5.4.9 Cumulative Effects

Impacts

Canal development alongside the Mandurah Channel is a relatively new landuse addressing the increased demand for water based residential developments.

In the proximity of the Mandurah Bypass Road Bridge are a number of existing (Waterside, Mandurah Quays, Port Mandurah Stage 1) and proposed (Harbour City Port Mandurah Stage 2 and 3) canal developments which collectively may cause visual impacts.

Management

The proponent, through the provision of amenity landscaping and functional buffer zone establishment, will endeavour to reduce the visual impacts of the Harbour City development to a minimum. Particular attention to blending the development into the existing environment will be given along the Mandurah Bypass Road.

Landscaping employed as part of the aesthetic appeal and marketability of existing and proposed canal developments will become more apparent in the future as established vegetation grows.

The Mandurah Channel has been recognised for potential canal developments by various government authorities (DPUD, EPA (System 6), and City of Mandurah) since 1982.

With respect to the Harbour City development site the environmental impacts, including visual impacts has previously been assessed (JHC 1982) and given environmental approval (DCE 1982).

The fact that an environmental approval for a similar canal development presently exists over the land, the community has to realise that the opportunity to consider alternative landuse for the land is limited, given that an expectation has existed since 1982 that the land would be developed for canal and related development. Furthermore, the proponents could act upon the present approvals and develop the land as a canals estate in accordance with the original John Holland plan. The current proposals are similar in that the extent of the principal landuse elements are almost exactly the same. The only other possible landuse alternative would be single residential development which would have a more significant visual and environmental impact.

11.5.4.10 Public education programme

The proponent will prepare a public education pamphlet to be distributed to all landowners which will outline their responsibilities with regard to environmental management. The pamphlet will focus on the importance of nutrient and waterways management and preservation of the conservation and foreshore reserves. The pamphlet will actively promote the following:

- planting of native trees and shrubs in private gardens which have low nutrient and watering requirements;
- use of slow-release and low phosphorus content fertilisers;

- avoiding littering or pollution of canal waterways;
- boat use and safety techniques to avoid accidents and fuel spills; and
- the importance of the conservation reserve to waterbirds with a direction not to enter the reserve.

In addition the proponent is committed to assisting in the provision of appropriately worded signage regarding fishing requirements.

11.5.5 Impact of Environment on Development

11.5.5.1 Mosquitoes

Impacts

The mosquito survey undertaken for the subject land by Mike Lindsay concluded that prospective residents of the Harbour City development can expect a similar level of mosquito nuisance to that experienced by residents of nearby Coodanup, and other waterside suburbs of Mandurah. While the adult population of *Aedes camptorhynchus* breeding on the subject land will be reduced as a result of the development due to alteration or destruction of breeding sites, mosquito numbers will not be significantly reduced at the subject land because of the dispersal range of mosquitos which originate from other breeding sites in the Mandurah region.

Management

Most of the mosquito control measures for the Harbour City development will need to be directed at breeding areas within the conservation and foreshore reserves. Management techniques proposed for these areas are outlined in Section 11.6.1.4. Within the development area, site filling will remove existing breeding sites and the proposed land contouring and drainage system outlined previously in Section 11.5.2.2 will ensure that new breeding sites are not created within the development.

Information regarding mosquito populations within the Mandurah region and the health implications with respect to Ross River Virus will be provided to landowners and prospective buyers in the form of a pamphlet which has been developed by the Health Department.

11.5.5.2 Algal blooms

Impacts

Water quality in the Harbour City canals is expected to be determined by the quality of the source (Mandurah Channel) water as discussed in Section 11.5.2.3. Therefore the canal waterways will occasionally be subjected to the passage of *Nodularia* and macroalgal blooms, and residents and boat users within the development will experience the associated reduced water quality associated with these events such as colouration, odour and the presence of fine suspended matter in the water column.

Management

The entrance canal breakwaters have been designed to trap floating algae to enable harvesting and removal before algae enters the canal system. The proponent is currently investigating a series of barrier systems to prevent algal blooms entering the canal waterways including the feasibility of an air jet barrier system.

Actions proposed to reduce nutrient input and accumulation within the canals are outlined in Sections 11.5.2.3 and 11.5.2.4.

11.5.5.3 Greenhouse effect

Impacts

Kinhill Riedel & Byrne have conducted a literature review on the implications of the Greenhouse Effect (Appendix 1) on sea and estuary levels in the Mandurah region. The conclusion from this review is that an allowance should be made for a rise in sea level of 30cm.

Management

The residential and commercial components of the Harbour City development have been designed to accommodate the predicted sea level rise in calculating building design height (set at 2.5m AHD).

11.5.5.4 Flood risk

Impacts

The existing flood relief characteristics of the Mandurah Channel will not be adversely affected by the Harbour City development. In its previous assessment of the Stage II Waterside Mandurah development on the subject land, the EPA concluded that development of the site would not exacerbate the flood hazard, provided adequate block levels and suitable floodways were retained along the Mandurah Channel (DCE 1982).

The Harbour City development falls within the Recommended Line of Development established by the PWD (1984) and as such will not contribute to flooding in the area. In fact, the canal development will provide some additional flood storage not allowed for in the PWD model, thus marginally reducing estimated flood levels.

Management

The design building level for residential and commercial development within the canal estate will be set at 2.5m AHD, which accounts for water levels from either storm surge or flooding, with allowance made for wind set up and potential Greenhouse Effects.

11.5.5.5 Peel-Harvey Estuary Management Strategy

A number of changes to the estuarine system are predicted to arise from the implementation of the Peel-Harvey Estuary Management Strategy discussed previously in Section 10.5.1.7. The main changes which will have implications for the proposed development include the following (Kinhill Engineers 1988):

- improved flushing of the estuary via the Mandurah Channel due to dredging of the channel and ocean entrance;
- a 30% increase in Peel Inlet tidal amplitudes;
- a reduction in peak flood levels from 1.6m AHD to 1.2m AHD;
- an increase in the 1 in 100 year storm surge from 1.2m AHD to 1.35m AHD as a result of the Dawesville Channel, and an increase in the tidal range from 0.1m to 0.3m; and

- expected long term water quality improvements in the estuary.

The EPA (1989) report that water flows through the Mandurah Channel have increased more than was predicted to occur following dredging of the channel by the Department of Marine and Harbours in 1988 and a notable increase in the quality of the waters of the Mandurah Channel has been recorded in water quality monitoring for the Waterside Mandurah development (LEC 1991a). As the quality of the estuary waters continues to improve in response to the Peel-Harvey Estuary Management Strategy, water quality in the proposed canals will also improve.

While decreased flood levels can be expected as a result of the Dawesville Channel, an increase in the effect of storm surge will mean that peak water levels will remain much the same as at present for the proposed Harbour City development.

11.5.5.6 Effect of proposed adjacent waterway developments

Water quality monitoring data from the Waterside Mandurah and Port Mandurah Stage 1 canal developments indicate that these canal developments are not adversely affecting the water quality of the Mandurah Channel (LEC 1991a, 1991b). Based on this previous experience, predictions of flushing and the proposed management strategies for the Harbour City development, it is predicted that the canals will not adversely affect the water quality of the Mandurah Channel and will generally be determined by the quality of the source water.

An additional artificial waterway development has been proposed in the Mandurah Channel Delta featuring a small marina (Mandurah Quay development) and environmental approval has been granted to this proposal (EPA 1990). Stage II of Port Mandurah on the western side of the Mandurah Channel opposite Mandurah city centre is also proposed for development in the future.

The flushing characteristics of the Mandurah Channel make this environment a prime location for artificial waterway developments. Based on the monitoring results from the two existing canal developments in the Mandurah Channel, it is concluded that the proposed additional artificial waterway developments in the region will not impact on the proposed Harbour City development.

11.5.6 Contingency Plans

11.5.6.1 Maintenance of acceptable water quality

In the event large quantities of algal wrack enter the canal waterways which subsequently cause odour and water quality problems the proponent or the Management Entity will be responsible for manually removing the wrack for disposal off-site.

A contingency plan for the management of any major fuel or oil spill, either at the boat servicing centre or anywhere else within the canal waterways, will involve notification of WWC, PIMA and the Police Department. Assessment and implementation of procedures for control of the spillage and the eventual recovery will be undertaken as necessary.

All details relevant to the management of unexpected events which may potentially affect the environment will be documented in an Emergency Procedures Manual.

11.5.6.2 Navigable entrance and canals

In the event of unforeseen siltation of the canal waterways to the extent that navigation is adversely affected, the proponent will undertake the necessary measures to restore the canals to the designed depth during the agreed maintenance period with responsibility transferring to the Management Entity thereafter.

11.5.6.3 Storm and flood damage

In the event of a severe storm or extreme flood event, contingency measures will be implemented to ensure that any damage to supporting structures, public and commercial facilities, and the foreshore and conservation reserves is rectified as soon as possible and that the long-term integrity of these is assured.

11.5.6.4 Stormwater drainage

The road drainage system will be the responsibility of the City of Mandurah upon completion of the development and the proposed spoon drains and soakwells on individual lots will be the responsibility of landowners. However, in the event that a major problem arises with the proposed stormwater drainage system during the operational period of the project, then the proponent will take the necessary steps to rectify the situation.

11.5.6.5 Sewerage system

The sewerage system will be the responsibility of the WAWA. However, to accommodate potential system failure, the system will have integrated emergency storage to prevent any discharge from the sewerage system from entering the canals until WAWA has rectified the fault.

11.5.7 Monitoring Programme

11.5.7.1 Objectives

The objectives of the proposed monitoring programme for the Harbour City development are as follows:

- to provide an indication of the environmental performance of selected aspects of the proposed development and provide adequate warning of the occurrence of any undesirable impacts on the environment to enable an appropriate management response to be initiated;
- to detect trends in main water quality parameters;
- to provide feedback on the effectiveness of the environmental management programme so that it can be modified if necessary; and
- to confirm predictions made in this document.

11.5.7.2 Groundwater characteristics

The proposed programme of groundwater monitoring is designed to provide data on groundwater quality and levels, including the location of the saltwater/freshwater interface, before, during and after construction of each stage of the Harbour City development. The programme will therefore determine both the short-term impacts associated with construction activities and the longer-term impacts of the canals on local groundwater characteristics.

Prior to construction commencing, groundwater monitoring will be undertaken to provide information on baseline conditions. The baseline monitoring programme will include:

- an initial survey of local domestic bores and any WAWA or City of Mandurah bores in the vicinity of the subject land;
- establishment of observation bores as required to supplement areas where existing groundwater bores are not available;
- quarterly monitoring of salinity and water levels within observation and domestic bores for a period of 12 months prior to construction where practical; and
- observation of the position of the saltwater/freshwater interface.

During construction activity (ie. dewatering operations), groundwater monitoring data will be obtained and assessed according to WAWA and EPA requirements and a report prepared for submission to these authorities.

Following construction of each stage groundwater monitoring in the vicinity will include:

- observation of the new position of the saltwater/freshwater interface; and
- quarterly monitoring of salinity and water levels within observation and domestic bores.

After an initial 12 month monitoring period, the programme will be reviewed and the monitoring reduced from quarterly to biannually for a further two years, subject to stabilisation of the saltwater/freshwater interface. Groundwater monitoring results will be reported on an annual basis and the programme for each stage of development will be reviewed after three years.

11.5.7.3 Canal water quality

It is important to ensure that the water quality is similar to that of the source water. Consequently at the conclusion of each stage of construction, a concentrated measuring programme will be conducted to determine the flushing characteristics of the newly created canal waterways.

Based on the conclusions of water quality monitoring at the Waterside Mandurah (LEC 1991a) and Port Mandurah (LEC 1991b) canal developments and the extensive baseline information on the water quality characteristics and performance of canal developments in the region, it is proposed that ongoing water quality monitoring within the Harbour City canals be conducted on a less frequent basis than has previously occurred at other canal developments. The proposed monitoring programme will focus on the time of year most prone to poor water quality (spring-summer) and will be sufficiently sensitive to detect adverse water quality in the canals should such an event occur.

It is proposed to undertake daily monitoring for one working week in summer each year. Water quality monitoring will be undertaken at two sites within the first stage and at one site in each successive stage at the locations shown on Figure 15. These sites have been selected as being the ones least susceptible to mixing and flushing and therefore most prone to adverse water quality should this occur in the canals. Following five years of monitoring, the programme will be subject to review. Water quality monitoring will commence in each stage at the time the canals are permanently connected to the Mandurah Channel or adjoining previously constructed stage. The parameters to be monitored are as follows:

- chlorophyll 'a' (surface and 0.5m from bottom of water);
- dissolved oxygen (surface and 0.5m from bottom of water);
- orthophosphate (surface and 0.5m from bottom of water); and
- inorganic nitrogen (surface and 0.5m from bottom of water);

Water quality monitoring will be undertaken in conjunction with the programme for Port Mandurah Stage 1 in order to assess the results in relation to other similar developments, and against conditions within the regional environment of the Mandurah Channel and Peel Inlet.

11.5.7.4 Canal sediments

Canal sediments will be monitored at the water quality monitoring sites identified on Figure 15. Canal sediment monitoring will target the following pollutants:

- pesticides (associated with domestic garden applications) to be monitored annually in the vicinity of stormwater drainage discharge pipes following the first winter rains;
- petroleum hydrocarbons to be monitored annually in the vicinity of the boat ramp and boat servicing facilities in summer when boat usage is at a maximum; and
- heavy metals (associated with anti-fouling paints on boats) to be monitored every three years in the Mariners Cove complex where boat usage will be most concentrated. The heavy metals to be monitored will include copper, zinc, cadmium, tin, lead and chromium.

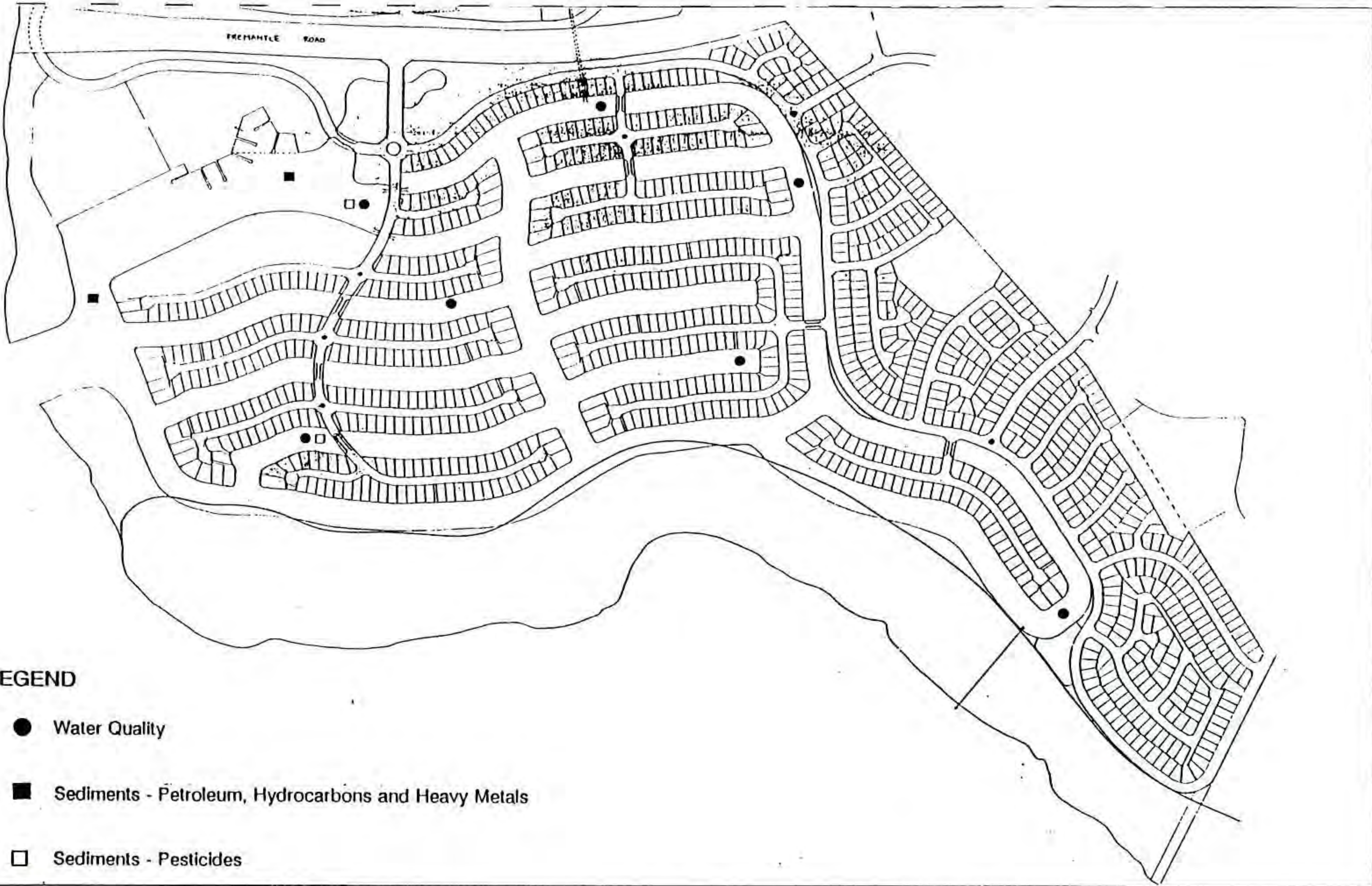
These parameters will be measured initially immediately following completion of the first stage of the canals to provide baseline information. The programme will be subject to review following three years of operation although it is acknowledged that heavy metal monitoring may need to extend over a greater period of time to detect rates of accumulation.

11.5.7.5 Entrance channel stability

The stability of the foreshore and entrance canal at the confluence of the canal waterways with the Mandurah Channel will be monitored by site inspection on an annual basis for five years, commencing within one month of practical completion of the first stage of the development.

11.5.7.6 Condition of canal walls

The condition of the canal walls including the rock pitched treatment along the boundary of the conservation reserve and the entrance canal breakwaters will be



LEGEND

- ● Water Quality
- ■ Sediments - Petroleum, Hydrocarbons and Heavy Metals
- □ Sediments - Pesticides

PRINCIPAL	TITLE				
ESPLANADE (MANDURAH) PTY. LTD.	FIGURE 15 LOCATION OF MONITORING SITES				
	PROJECT: HARBOUR CITY	BSD CONSULTANTS CONSULTING ENGINEERS, TOWN PLANNERS & PROJECT MANAGERS BSD HOUSE, 1 SLEAT ROAD, APPLECROSS. PHONE No 318 2988	DATE 10.3.92 JOB No. P9186 SCALE NTS	PLAN No	

monitored on an annual basis for five years, commencing within one month of practical completion of each stage. A monitoring procedure will be developed to confirm that the design and construction of the walls and scour protection measures are satisfactory. Monitoring will include an assessment of any scour occurring at the base of the entrance canal breakwaters or canal walls.

11.6 Conservation Reserve Impacts and Management

11.6.1 Scope and Objectives

The scope of the conservation reserve management programme will extend to the foreshore reserve proposed in the Harbour City development. The objective of the conservation reserve management programme is to maintain and enhance the conservation values of the samphire flats on the subject land while maintaining the flood management requirements of the site and providing for effective low impact mosquito control.

The development boundaries to a large extent follows the old shorelines and the EPA System Six Red Book C50 conservation line. The Reserve boundary also forms the division between areas of high and low conservation value for waterbirds. The Harbour City development is limited to rarely inundated samphire which is of lower importance to waterbirds than the high importance of Creery Lagoon.

A detailed management plan for the proposed conservation and foreshore reserves will be prepared once the boundaries and approvals for development have been finalised. The plan will be prepared in consultation with the EPA, PIMA and CALM.

11.6.2 Increased pressure on Waterbirds

<u>Impacts</u>

The potential impacts on waterbirds arising from locating residential and commercial development adjacent to waterbird habitat were previously discussed in Section 11.5.3.2.

Management

The proposed Harbour City development offers the opportunity to effectively manage the samphire flat conservation reserve so as to minimise disturbance to waterbirds compared to the existing uncontrolled use of the subject land. In addition to the management actions outlined in Section 11.5.3.2, proposed strategies for the management of the conservation reserve, many of which will have direct benefits to waterbirds, are discussed in Sections 11.6.3 - 11.6.7 following.

11.6.3 Public Access

Under the proposed Harbour City development design, the conservation reserve will be retained as a peninsula bounded by the Peel Inlet to the south, Mandurah Channel to the west and canal waterways to the north. Where the peninsula connects to the south-eastern corner of the subject land it is proposed to construct a fence to prohibit public access. Appropriate signage explaining the purpose of the conservation reserve would also be erected at this point. The fence would be of sufficient standard to prohibit the access of domestic pets or vermin which may otherwise enter the reserve from nearby residential properties and disturb or attack waterbirds. Public access to the foreshore reserve from boats will be discouraged by providing a limestone rock pitched edge along the canal waterway on the north side. Appropriate signage prohibiting access will be erected along this edge. Public access from the Mandurah Channel or Peel Inlet is unlikely to occur as the surrounding water is very shallow which effectively prevents boat access. During marketing of the estate, the developer will ensure that all land owners are advised of the importance of the conservation reserve and its 'sanctuary' type environment, and their consequent responsibility to ensure its protection.

11.6.4 Rehabilitation

In comparison to the area of the samphire flats proposed for development, only a small area of the samphire habitat to be incorporated in the conservation reserve is presently degraded. Much of this area occurs at the boundary with the development area and will be affected by construction of the abutting canal wall. Kirke (1986) reports that samphire has high regenerative capabilities and with no public access to the conservation reserve, the remaining degraded areas in the conservation reserve are expected to recover within a few years. Several species of *Halosarcia* including *H. pergranulata* and *H. halocnemoides* are known to grow readily from seed (P. G. Wilson, WA Herbarium, pers. comm.) and other samphires possibly do the same. The tracks could be expected to be recolonised over time. This would compensate, though only to a small degree, for the loss of biomass resulting from the clearing of the rest of the site.

It is proposed to remove any weed growth from the conservation reserve in order to improve the natural regeneration of the samphire communities. Most weed growth occurs adjacent to the existing shoreline, along the proposed northern boundary of the conservation reserve and on the raised 'island' of *Casuarina/Melaleuca* woodland.

Planting of clumps of *Casuarina obesa* and *Melaleuca raphiophylla* is proposed along the internal rock-pitched edge of the conservation zone to provide visual amenity and shelter, screening and perches for waterbirds. This area will not be suitable for samphire vegetation as the canal wall will be raised to prevent overtopping of water during tidal flooding of the conservation reserve.

Development of the Harbour City Project will require partial clearing of *Casuarina* trees from the subject land. It is proposed that the trunks and main branches of several of the trees be placed in the conservation reserve to provide perching places for waterbirds. Currently there are very few perching sites in the conservation reserve area.

11.6.5 Mosquitoes

All rubbish will be removed from the conservation area and wheel ruts will be filled and levelled. In order to reduce the mosquito breeding characteristics of the conservation reserve and to improve the value of the site to waterbirds during the summer months, it is proposed to dig shallow channels extending inland from the Peel Inlet shoreline. The channels would increase tidal inundation of the samphire flats which will improve the flushing and drainage characteristics of pools and seasonally inundated flats which are currently significant mosquito breeding areas. As the site is currently dry during the summer months, the increased tidal zone area created by the channels would improve the value of the site to waterbirds, particularly the migratory species which visit the Peel-Harvey estuary in summer. Any such channels or other physical modifications to the conservation reserve would be in accordance with the mosquito control option techniques advocated by the Mosquito Control Review Committee (Chester and Klemm 1990) and will be undertaken according to the requirements of PIMA and the EPA.

11.6.6 Contingency plan for extreme events

In the event that extreme storm or flood events cause damage to the foreshore and conservation reserves, the proponent during the project maintenance period and the Management Entity thereafter will undertake to repair any damage incurred during the operational period.

11.7 Administrative Considerations

11.7.1 Environmental Management and Monitoring Reporting Schedule

11.7.1.1 Items to be reported

The following components of the proposed environmental management and monitoring programme will be reported upon:

- water quality in the canals and adjacent waterways;
- nutrient and heavy metal concentration in canal sediments;
- groundwater quality and levels prior to, during and following construction;
- entrance canal and foreshore stability;
- condition of canal walls and entrance canal breakwaters;
- sedimentation and navigability of canals; and
- waterbird use of the conservation reserve.

11.7.1.2 Reporting frequency

Reporting will be undertaken on an annual basis with the results and analyses of each year's monitoring being incorporated into a single report. After five years of operation of each stage, a Triennial Review will be prepared which will analyse all monitoring data to date. A final report will be submitted at the end of the operational period prior to handover of management responsibility to the appropriate authorities. In each monitoring report prepared, the analysis of results will provide the basis for recommendations regarding the future management and monitoring of the development.

11.7.1.3 Reporting authorities

The monitoring reports will be made available to the City of Mandurah and relevant government departments with responsibilities and interests in the development, including the EPA, PIMA and the Department of Marine and Harbours.

11.7.2 Authorities responsible for management

11.7.2.1 The proponent

The proponent will be responsible for the establishment of a Management Entity under the control of the City of Mandurah which will assume responsibility for the management of all aspects of the development as described in this report. Refer to Section 11.7.3 for details on management proposals.

The proponent will be responsible for land transfering land to the Crown and seeking vestings as necessary to the appropriate authorities.

11.7.2.2 Waterways Manager

The Waterways Manager will be responsible for the day to day management of the canal waterways and for the maintenance and monitoring programme encompassing these areas. A discussion on the issue of the long-term waterways management is presented in Section 11.7.3.

11.7.2.3 State Government

Management of the sewerage system and other services will be the responsibility of the relevant government agencies upon completion.

11.7.2.4 City of Mandurah

Under the proposed management structure described in Appendix 2, management of the canal waterways and the conservation reserve will be the responsibility of the City of Mandurah. The City of Mandurah will also be responsible for the management of public roads and drainage as well as normal ratepayer services. Public open space management will become the responsibility of the City of Mandurah once these areas are established.

11.7.3 Long Term Management of Artificial Waterways

Cedar Woods Limited on behalf of E(M)PL has spent considerable time in researching and developing a management system to satisfy both State Government departments and the Local Authority in providing a comprehensive management system which addresses the critical management issues of management structure, funding and management duties, for the long term management of artificial waterway developments. A detailed discussion paper on the proposed management system is provided in Appendix 2. In summary the system is outlined as follows:

- Management Structure based on joint State Government departments and Local Authority input with overall control being retained by Mandurah City Council.

- Funding based on seed capital being provided by the Developer plus specific area rates being levied by Council against canal estate land owners.

- Management Entity structure to include two Council Representatives, Department of Marine & Harbours Representative, PIMA Representative, Land Owners Representative and Developer Representative (until last lot sold).

- Waterways Management responsibilities to include:
  a) Water quality
  b) Silting of canals and/or entrance channels

c) Canal walls and sea wall

d) Foreshore management

e) Groundwater quality

f) Conservation area

g) Public open space and landscaped areas.

- Management Entity to prepare budgets for authorisation by Council, to plan and schedule the works, send invoices (within approved budget) to Council for final approval and payment.

- Management Entity to work very closely with Council and associated Government Agencies.

- Reserve Fund to be established to ensure long term funding available for any substantial maintenance task that may arise in the future life span of the Canal Waterways Estate.

- A separate report on Management Expenditure and Systems utilised by Gold Coast City Council is also attached in Appendix 2. This report delineates current costs incurred for upkeep of "beachfront" canal lots, which are substantially different from the wall panel systems proposed to be utilised at Harbour City.

12 ENVIRONMENTAL COMMITMENTS

The proponent will undertake to abide by all commitments made in this document for the management of the proposed Harbour City development. With respect to environmental performance, the project will be operated and maintained in accordance with the guidelines established in the three management programmes detailed in Section 11 of this report. The proponent seeks environmental approval for the whole Harbour City Project and it is intendedm, as outlined in Construction Details (Section 4.5.1), to follow a staged development approach designed to address environmental, economic and market driven factors. The environmental commitments listed below apply progressively to each stage of the project and will be incorporated into the Project Agreement to be established between the proponent, State and the City of Mandurah.

The commitments have been categorised into:

Pre-construction

During construction

Post-construction

and are numbered individually for easy reference and auditing purposes.

12.1 Pre-Construction

(1) Final details of canal construction methods and timing will be agreed with the EPA and PIMA for licencing prior to implementation.

(2) Further soil surveys will be carried out prior to construction. Cut and fill operations for site earthworks will be monitored and an engineering construction programme relating to cut and fill operations and import and export of fill will be provided to the satisfaction of the City of Mandurah and EPA.

(3) The proponent will further consult with WAWA and the City of Mandurah to determine groundwater usage (to be drawn from the Leederville Formation) within the development.

(4) Prior to construction commencing on each stage, baseline monitoring of groundwater will include:

- an initial survey of local domestic bores and any WAWA or City of Mandurah bores in the vicinity of the subject land;
- establishment of a series of observation bores to supplement areas where existing groundwater bores are not available;
- quarterly monitoring of salinity and water levels within observation and domestic bores for up to 12 months prior to construction; and
- observation of the position of the saltwater/freshwater interface.

(5) The detailed design and construction of the drainage system will be carried out to the satisfaction of the City of Mandurah.

(6) The construction and operational workforce will be drawn from the Mandurah region.

(7) The proponent will comply with the provisions of the *Aboriginal Heritage Act 1972-1980.*

(8) High visual amenity will be provided in the design of the development.(11)All residential and commercial land within the proposed development will be filled to a minimum floor level of 2.5m AHD.

(9) Currently the proponent is investigating a series of barrier systems to prevent algal blooms entering the canal waterways. This research will include investigation of the feasibility of an air jet barrier system.

(10) The design building level for residential and commercial development within the canal estate will be set at 2.5m AHD to accommodate high water levels associated with the potential Greenhouse Effect and flood events.

12.2 During Construction

(11) Throughout the During Construction phase in each Stage, the proponent will submit a report every 3 months to the EPA identifying those environmental commitments adhered to during this period.

(12) All residential and commercial land within the proposed development will be filled to a minimum floor level of 2.5m AHD.

(14) The canal waterways will be excavated to a depth of -2.7m AHD.

(15) Excavation and dredging of the canal waterways will be undertaken in a closed system to prevent turbid water from entering the Mandurah Channel.

(16) Excavation of the canal waterways will be accomplished using conventional land-based earthmoving equipment wherever possible. Bank slopes will be placed at gradients of 1:4 to ensure stability of the adjacent land areas. The entrance will be excavated using standard earthworking equipment and if necessary a floating cutter-suction dredge or an approved equivalent.

Dewatering

(16) Dewatering fluids will be pumped to settling ponds to remove suspended solids prior to discharge to the Mandurah Channel via controlled drainage lines. Dewatering fluids will not be discharge into the samphire flats of the conservation and foreshore reserves.

(17) Domestic groundwater bores in the vicinity will be monitored during dewatering operations to determine whether any lowering of groundwater levels occurs. Should domestic bores run dry as a result of the dewatering on the subject land, the proponent will fund excess water bills for the irrigation of affected gardens from the Mains supply until such time as the aquifer is restored.

(18) Reinforced concrete retaining walls will be constructed to provide stability for waterfront lots.

(19) The sides of the entrance canal will be stabilised with limestone breakwaters.

(20) The canal wall abutting the conservation reserve and boulevard style road will be stabilised with limestone rock pitching.

(21) The proponent will undertake any dredging or other works necessary to maintain navigable depth in the canal waterways during the operational period.

(22) The level of ground vibration in the vicintiy of construction activity and in adjacent residential areas will be monitored, particularly at the commencement of works, to set parameters and modify work patterns and equipment types if necessary.

(23) Construction traffic will access the subject land from Mandurah Bypass Road.

(24) Working hours will be restricted to between 7.00 am and 6.00 pm Monday to Saturday in accordance with approvals to be granted by the City of Mandurah in order to minimise disturbance to residents.

(25) Dust emissions will be monitored. If a dust nuisance is detected, then the necessary watering or mulching of exposed surfaces will be undertaken to alleviate the problem.

(26) Liaison with the City of Mandurah will ensure that construction noise, traffic, vibration and dust emissions do not create excessive disturbance to local residents. Management techniques and modified work patterns will be adopted if necessary.

(27) The development will be provided with reticulated scheme water.

(28) All drainage discharging into the canal waterways (from roads and other paved surfaces, boat ramps and boat servicing area) will be passed through suitable grease/silt traps to remove any contaminants. The drainage traps will be regularly serviced to ensure effective trapping of contaminants.

(29) Canal lots will be graded downwards towards the waterways with a porous spoon drain provided above an agricultural drain adjacent to a walkway parallel to the canal walls to prevent direct discharge to the canal waterways and provide for groundwater infiltration.

(30) In private lots, provision shall be made for a drainage trap with an overflow pipe directly to the canal waterway to provide for individual owners piping roof water direct to canals. This will be a closed system for roof water only. Other runoff from lots, ie paths, lawns and gardens, shall be drained into soakwells onsite.

(31) Adequate clearance between culvert and bridge soffits and the water surface will be provided to allow any wind blown debris to pass through and minimise restriction of wind driven water circulation.

(32) The sides of the culverts and bridges will extend to the full depth of the canals to avoid restriction of density driven currents which will provide significant mixing and flushing of canal waters.

(33) The development will be provided with a reticulated sewerage system which will be designed and constructed in accordance with WAWA requirements, including inbuilt safeguards to prevent the input of sewage effluent to the waterways in the event of system failure.

(34) The access points to the subject land will be fenced and appropriately signposted during construction.

(35) All roads and pathways created within the development will be designed and constructed to Main Roads Department standards.

(36) The detailed design of the land based components of the development will retain as many existing trees as possible.

(37) The minimal channelling techniques recommended by the Mosquito Control Review Committee (Chester and Klemm 1990) will be utilised in the conservation reserve to minimise disturbance to samphire whilst creating greater areas of tidally inundated samphire habitat.

(38) Landscaping of the development will utilise indigenous and/or salt tolerant vegetation wherever practical to reduce the impact of habitat loss.

(39) Stands of existing trees will be retained within the development wherever possible.

(40) Public open space areas and streetscapes will be landscaped with indigenous flora and/or salt tolerant species.

(41) The Mandurah Bypass Road frontage will be landscaped with a dense buffer of native trees.

(42) The conservation reserve will be separated from residential development by a canal waterway with a limestone rock pitched treatment along the reserve edge to prevent boat landings.

(43) Planted groups of indigenous trees will be provided along the edge of the conservation reserve to screen the conservation reserve from the development to reduce night-time light spill into the reserve.

Excavation and Dredging

(44) A fence to prohibit public access and domestic pets or vermin will be constructed across the peninsula connecting the conservation reserve to the south-eastern corner of the subject land.

(45) Appropriate signage explaining the purpose of the conservation reserve would also be erected at this point.

(46) Public access to the foreshore reserve from boats will be discouraged by providing a limestone rock pitched edge along the canal waterway on the north side.

(47) Weed growth will be removed from the conservation reserve to enable recolonisation of affected areas by samphire.

(48) Clumps of *Casuarina obesa* and *Melaleuca raphiophylla* will be planted along the wall edge of the conservation reserve to provide visual amenity and shelter, screening and perches for waterbirds.

(49) The trunks and main branches of several of the trees to be cleared from the canal estate development area will be placed in the conservation reserve to provide perching places for waterbirds.

(50) All rubbish will be removed from the conservation area and wheel ruts will be filled and levelled.

(51) It is proposed to dig shallow channels extending inland from the Peel Inlet shoreline into the conservation reserve to increase tidal inundation and drainage of the samphire flats in order to reduce the mosquito breeding characteristics of the conservation reserve and improve the value of the site to waterbirds, particularly during the summer months. Any such channels would be undertaken to the requirements of the Mosquito Control Review Committee, PIMA and the EPA.

(52) The following mosquito management options are proposed within the development area of the subject land:

- site filling to remove existing breeding sites; and
- land contouring and drainage system design to ensure that new breeding sites are not created within the development.

(53) The limestone breakwaters at the entrance to the Mandurah Channel will be aligned to collect any floating algal wrack that may enter the canals. Algae accumulating along the foreshore, on the entrance canal breakwaters or within the canals will be manually removed and disposed of off site.

(54) During construction, groundwater monitoring data will be obtained and assessed according to WAWA and EPA requirements and a report prepared for submission to these authorities.

(55) Measurement of flushing will be conducted for each stage of the canals following construction.

(56) Dual-use pathways will be provided along the foreshore reserve and through the development to link various components of the development.

(57) Public parking areas will be provided to enable public access to the foreshore, public open space areas and boating and commercial facilities.

(58) Navigation aids will be provided to the satisfaction of the Department of Marine and Harbours within and adjacent to the canal waterways.

(59) A two lane public boat ramp and parking facilities for car and trailer parking will be provided.

(60) Public parking areas will be provided at the boat ramp and within the commercial centre, shopping area and resort hotel complex.

(61) Boating facilities will include:

- pens within Mariners Cove adjacent to the commercial centre for temporary and permanent mooring of boats plus associated boat servicing requirements;
- boat chandlery and servicing area; and
- boat fuelling facilities.

(62) The proponent will install a boat sullage pump-out facility within the boat servicing component of the Harbour City development.

(63) Signs will be provided at the public boat ramp and at the boat servicing area, providing information about minimum size of catchable fish and crustacean sizes, bag limits and net requirements.

(64) Any waste material generated during construction will be disposed of at the Mandurah landfill site in accordance with standard City of Mandurah requirements.

(65) Physical opening of the canal system to the Mandurah Channel will occur when the two water bodies are at the same level and assisted by flow controlled pipe links until water levels are equal.

(66) A Landscape Master Plan for the Project land will be developed and implemented by the proponent for an operational period of one year, following which responsibility will be with the Management Entity proposed to manage the entire development (Appendix 2). Maintenance of landscaping during this time will include mowing, weed removal, irrigation and replacement of dead plants.

12.3 Post-Construction

(67) During the first 5 years of the Post-Construction phase, the Management Entity will submit annual reports to the EPA outlining adherence to environmental commitments. After this 5 year period, triennial reports compiled by the Management Entity will be submitted to the EPA in order to assess on-going compliance with environmental commitments.

(68) Groundwater bores will be prohibited in both canal and dry lots of the development.

(69) With respect to the constraints imposed by the quality of the source water (Mandurah Channel), water quality within the canals will be maintained to meet the criteria set down in Schedules 2,5,7,8, and 1 of Bulletin 103 (DCE 1981).

(70) The canal waterways will be inspected regularly by the Waterways Manager and any corrective action required to maintain water quality and aesthetics to the high standard required by the proponent and Government agencies will be implemented immediately.

(71) The canals will be surveyed upon completion to ensure that they conform to the design depth. Additional surveys will be conducted after the first, third and fifth years of operation of each stage to determine whether sedimentation of the canals has occurred.

(72) An educational brochure will be distributed to all landowners containing information about landscaping and fertiliser usage as well as drainage management with the aim of minimising nutrient input to individual lots and therefore the waterways.

(73) Information regarding mosquito populations within the Mandurah region and the health implications with respect to Ross River Virus will be provided to landowners and prospective buyers in the form of a pamphlet which has been developed by the Health Department.

(74) During marketing of the estate, the developer will ensure that all land owners are advised of the importance of the conservation reserve and their consequent responsibility to ensure its protection.

(75) Water quality within each stage of the canals will be monitored for three years in accordance with the programme described in Section 11.5.7.3, commencing at the time the canals are permanently connected to the Mandurah Channel or adjoining stage. Following three years of monitoring, the programme will be subject to review. The parameters to be monitored include:

- chlorophyll 'a' (surface and 0.5m from bottom of water);
- dissolved oxygen (surface and 0.5m from bottom of water);
- orthophosphate (surface and 0.5m from bottom of water);
- inorganic nitrogen (surface and 0.5m from bottom of water);

(76) Water quality monitoring will be undertaken in conjunction with the existing programme for Port Mandurah Stage 1.

(77) Following construction of each stage, groundwater monitoring in the vicinity will include:

- quarterly monitoring of salinity and water levels within observation and domestic bores for one year;
- biannual monitoring of salinity and water levels within observation and domestic bores for a further two years; and
- observation of the new position of the saltwater/freshwater interface.

(78) Groundwater monitoring results will be reported on an annual basis and the programme for each stage will be subject to review following three years of operation.

(79) Canal sediments will be monitored on an annual basis for three years prior to review. The parameters to be monitored are as follows:

- pesticides in the vicinity of stormwater drainage discharge pipes following the first winter rains;
- petroleum hydrocarbons in the vicinity of the boat ramp and boat servicing facilities in summer when boat usage is at a maximum; and
- heavy metals (copper, zinc, cadmium, tin, lead and chromium) in the Mariners Cove complex where boat usage will be most concentrated.

(80) The stability of the foreshore and entrance canal at the confluence of the canal waterways with the Mandurah Channel will be monitored by site inspection on an annual basis.

(81) The condition of the canal walls including the rock pitched treatment along the boundary of the conservation reserve and the entrance canal breakwaters will be monitored by site inspection on an annual basis.

(82) Canal wall and channel stability monitoring programmes will be developed and will commence within one month of practical completion of each stage and continue for five years.

(83) Contingency plans for potential water quality problems associated with fuel and oil spills or algal blooms, maintenance of navigable waterways, restoration of storm or flood damage and operation of the stormwater drainage and sewerage systems will be documented in an Emergency Procedures Manual.

(84) In the event that extreme storm or flood events cause damage to the foreshore and conservation reserves, funds will be available via the Management Entity/Waterways Manager to ensure repairs and maintenance can be undertaken if required.

13 ENVIRONMENTAL ASSESSMENT PROCESS

13.1 Environmental Protection Act 1986

Environmental impact assessment of development proposals in Western Australia is undertaken by the EPA under the provisions of the *Environmental Protection Act 1986.* Development proposals that may have a significant effect on the environment are referred to the EPA who make a decision on the level of assessment. Environmental impact assessment may be conducted on either a formal or informal basis.

Under the formal process there are three levels of assessment (Consultative Environmental Review (CER), Public Environmental Report (PER) or Environmental Review and Management Plan (ERMP). These documents differ in terms of the length of the public review period and the scope of the proposal (ie. a CER usually relates to local scale projects while an ERMP usually relates to regional or state-wide scale projects). The proponent is required to prepare the required assessment document according to EPA prepared guidelines. This document is subsequently reviewed by the EPA who determine whether the proposal as described is considered environmentally acceptable, and accordingly make recommendations for the approval and management of the project by the Minister. The Minister for the Environment then sets conditions and procedures for implementation of the project which are legally binding and are usually based on EPA recommendations.

Under the informal environmental impact assessment process, the EPA advises other decision making authorities of its environmental concerns. Appropriate development controls and conditions can be then established by authorities (eg. DPUD planning conditions established for rezoning or subdivision and other).

Having regard to this process, the EPA has determined a level of assessment of CER for the Harbour City Project and has issued guidelines which are included in Appendix 6.

13.2 Planning Process

The State Government through the auspices of DPUD have established a policy for the processing and consideration of canal developments titled "Procedures for Approval of Artificial Waterways and Canal Estates - Policy 1.8". This policy will shortly become a 5AA policy which will make it obligatory on Local Authorities to have regard to the policy in the preparation of Town Planning Scheme and Scheme Amendments where ever applicable.

To facilitate the approval of a canal development where an existing Town Planning Scheme is in operation a Local Authority must initially resolve to amend the Scheme and to adopt amendment documentation which have to be prepared in accordance with Town Planning Regulations.

The amendment documents are submitted by the Council to DPUD which refers the amendment proposals to all relevant Government Agencies including the EPA for assessment and comment. DPUD staff prepare a report on the proposal which is considered by the Statutory Procedures Committee along with advice given and comments made by the agencies.

Subject to the amendment proposals being considered acceptable a decision is made consenting to the advertisement of the Amendment for public comment. This is usually for a 42 day period. Every attempt is made by DPUD and the EPA to co-ordinate the submission period for both the planning and environmental process.

At the completion of the public submission phase for the planning process, the Local Authority reviews, comments and makes recommendations on all submissions received and has to resolve whether to proceed with the amendment or not. This advice along with the submissions are forwarded to the Hon. Minister for Planning via DPUD and the Statutory Procedures Committee who must then decide whether the Amendment should be approved. This decision cannot be made until the environmental process has been completed and where formal assessment has been followed, the proposal has been deemed to be environmentally acceptable and environmental conditions have been set by the Hon. Minister for the Environment. The environmental conditions, where these are set, are legally enforceable.

13.3 Proposed Participation and Consultation

During the Public Review period for the Harbour City Consultative Environmental Review (CER) the proponent will:

- forward copies of the CER upon request (for a $5 fee) to any member of the public;

- automatically send copies to special interest groups involved with, or affected by, the development proposal as directed by the Environmental Protection authority, and

- make available company representatives and consultants as necessary to talk with any interested party about the development proposal or information contained in the CER.

PART 4

CONCLUSIONS

PART 4 CONCLUSIONS

14 CONCLUSIONS

In preparing the environmental assessment report and amendment documentation considerable liaison and consultation has occurred with the staff of all relevant agencies and their respective Ministers along with the Local Authority. Generally, all responses have been extremely positive with a prevailing view that the development will be of significant value to the Mandurah Community.

Considerable attention has been given to properly assess the extent of development and establishing the extent of the land to be conserved to protect the conservation values of the samphire habitat on the subject land. The Concept Development Plan (Figure 4) details the extent of the land required to be protected which closely resembles the line established by the EPA in Bulletin 126 (DCE 1982) and finally reflected in Recommendation C50 in the System Six Red Book report. Confirmation of the appropriateness of the line was only reached after detailed evaluation of the botanical, wildlife, tidal, topographic, historical shoreline assessment and other essential elements. These matters have been fully canvassed in the report along with summaries of detailed relevant research which is applicable being either site specific or relative to the tidal delta of the Mandurah Channel.

It is important to highlight that the EPA has previously approved an ERMP for an earlier similar canal development which coincidently has similar land use components whilst being essentially differing proposals. It is strongly argued that given the historical significance of earlier reports and studies, that it is appropriate for the EPA to agree to an informal assessment process, as the proponents are simply exchanging one plan for another plan. The Harbour City design also represents a more environmentally sensitive and sustainable design than the original Waterside Mandurah Stage II proposal.

The report also contains Amendment proposals to the City of Mandurah District Planning Scheme set out in Section 15 which follows.

In order to recognise the changes to the Environmental Protection Act since Bulletin 126 was issued on the Waterside Mandurah project, particularly the extent of Ministerial involvement in condition setting which can now only occur when a proposal is formally assessed, it is proposed to protect the specific commitments and conditions by the introduction of specific town planning scheme provisions which will result in a similar level of protection being achieved. The whole question of what level of assessment that will be applied to the Harbour City project has yet to be determined by the EPA, however, the approach taken in preparing the Scheme Amendment proposal assumes that the project will be informally assessed and that the conditions will be protected by way of Scheme provisions. No attempt has yet been made to fully detail these conditions as they have yet to be determined by the EPA, however, scope exists in the draft amendment format to accommodate these when they are known.

In conclusion, significant justification exists for Government to support the Harbour City development as described in this report in environmental and planning terms as well as well as providing a major economic impetus to the development of the Mandurah District which is adversely affected by high numbers of unemployed people. The Harbour City project is therefore commended to the approval authorities for their urgent support and approval.

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PART 5

PROPOSED AMENDMENT TO THE CITY OF MANDURAH TOWN PLANNING SCHEME NO 1

TOWN PLANNING AND DEVELOPMENT ACT 1928 (AS AMENDED)

RESOLUTION DECIDING TO AMEND A TOWN PLANNING SCHEME

CITY OF MANDURAH

DISTRICT PLANNING SCHEME NO 1A

AMENDMENT NO 183

RESOLVED that the Council, in pursuance of Section 7 of the Town Planning and Development Act, 1928 (as amended) amend the above Town Planning Scheme by:

A) ADDING TO APPENDIX 10 OF THE SCHEME TEXT AS FOLLOWS:

Appendix 10 - Canal Zone : Area 3 Harbour City

(See overleaf).

(B) Amending Clause 2.5 of the Scheme - "Classification into Reserves" by adding to the list of Reserves in sub-clause 2.5.1 after "Local Recreation Reserve" the following:
"Conservation and Foreshore Reserve".

(C) By deleting Clause 2.5.4 and replacing it with a new Clause 2.5.4 as follows:

"2.5.4 The notations on the Reserve Development Table and Schedule 2 - Area 3 - Harbour City set out in Appendix 10 - Special Requirements, Canal Zone have the same meanings as those in the Zoning and Development Table which are specified in Clause 2.4.2 and Clauses 2.4.3 to 2.4.12 inclusive, shall apply as if the term "Zoning and Development Table" in those clauses was substituted for Reserve Development Table or Schedule 2 - Area 3 - Harbour City set out in Appendix 10 to the Scheme".

(D) Amending the Scheme Map and legend as appropriate by rezoning and reserving Cockburn Sound Location 16 depicted on LTO Plan 2413 Volume 1682 Folio 35 from "Rural" to "Canal Zone", "Residential R20" and "Conservation and Foreshore Reserve". The Canal zone shall generally have a Residential R20 Density Code except for two sites depicted on the Concept Development Plan which are proposed to be coded R40.

TOWN PLANNING AND DEVELOPMENT ACT 1928 (AS AMENDED)

CITY OF MANDURAH

DISTRICT PLANNING SCHEME NO 1A

AMENDMENT NO 183

The City of Mandurah Council, under and by virtue of the powers conferred upon it in that behalf by the Town Planning Development Act 1928 (as amended) hereby amends the above Town Planning Scheme by:

a) Rezoning and reserving portion of Cockburn Sound Location 16 depicted on Plan 2413 Volume 1682 Folio 35 and bounded by Wanjeep Road, Mandurah Bypass Road, the "Dudley Park" residential estate to the east and the Mandurah Estuary from "Rural" to "Canal Zone", "Residential R20" and "Conservation and Foreshore Reserve" as shown on the amending plan.

b) Modifying the Scheme Maps and legend to reflect the zoning and reservation changes detailed in a) above.

c) Adding a new Schedule of development conditions and permitted uses titled "Canal Zone Area 3 : Harbour City" to Appendix 10 of the existing Scheme.

d) Incorporating provisions in Appendix 10 for the creation of a Management Entity which will manage and maintain the artificial waterways and other aspects of the development under the guidance of the Council along with environmental commitments and conditions agreed to by the Hon Minister for the Environment.

e) Amending Clause 2.5 - Classification into Reserves to create the "Conservation and Foreshore Reserve".

Dated the day of 1992

2.0 DRY LOT RESIDENTIAL DEVELOPMENT

The balance of the project land as depicted on the Concept Development Plan shall be zoned "Residential" and coded with an R20 Residential Density Code.

3.0 MANAGEMENT OF ARTIFICIAL WATERWAYS AND THE PROJECT LAND

3.1 All artificial waterways and the project land defined above shall be managed by the Management Entity to be established by the proponent, at the proponents cost, to the satisfaction of the Council and the State Government.

3.2 The management of the artificial waterways shall be based on a joint State Government and Local Authority basis with overall control being retained by the Council who shall have power to direct the Management Entity as necessary and who shall establish a Reserve Account from which the activities of the Management Entity can be funded.

The Management Entity shall work closely with the Council and associated Government Agencies to ensure that the artificial waterways and the conservation and foreshore land is properly managed.

3.3 It is proposed that an Advisory Committee, known as the Management Entity for Harbour City Canal Estate be established by the proponent. The Management Entity shall comprise of a group of representatives as follows:

- Two representatives from the City of Mandurah;
- One representative from Department of Marine and Harbours;
- One representative from the Peel Inlet Management Authority;
- One representative from Development Company (until last lot sold);
- Two representatives from Canal Estate Land Owners.

The Management Entity shall be responsible for preparation of annual budgets to cover all anticipated management duties for artificial waterways. Budgets shall be approved by the Council on an annual basis.

The Management Entity shall ensure all management duties are carried out efficiently, within required time, that appropriate long term planning for maintenance of the artificial waterway is carried out annually, that management duties are kept within the costs defined in the approved budget, that actual costs incurred are authorised by the Management Entity and forwarded to Council for approval and payment.

The Management Entity shall be established as an Incorporated Body. Standing Orders for the operation of the Management Entity shall be prepared by the proponents and approved by the Council prior to the "clearance" of the first stage of the development:

3.4 Management duties of the Management Entity shall apply to all canal and dry lots within the Estate and shall include but not be limited to:

a) Water quality monitoring and protection
b) Monitoring silting of canals and entrance channel. Dredging of canals as required
c) Sea wall monitoring, maintenance and reconstruction if necessary
d) Foreshore management and maintenance including dual use paths etc
e) Groundwater monitoring
f) Other general management and maintenance including jetties, signage, etc
g) Conservation area management, maintenance and protection
h) Public open space areas and landscape feature areas
i) The review of all applications for development, building applications etc proposed for land within the Estate prior to them being submitted formally to Council
j) Those other matters which from time to time may be assigned to it by the Council.

3.5 It is proposed that funding of the Management Entity be as follows:

a) The proponent shall contribute a sum of $200 per lot into a Reserve Fund established by the Council specifically for the maintenance of the estate. Funds to be paid to the Council as each lot is sold and settled or 6 months after issue of titles whichever is the earlier.
b) Specific area rating shall be applied by the Council on each canal lot annually by Council, a proportion of which shall be (as determined annually by the Council) be transferred to the Reserve Account.

It shall be the responsibility of the proponent to ensure that all lot owners are advised prior to purchase of their allotment that a Specific Area rating shall be imposed over each individual lot by Council at a rate subject to review and adjustment annually.

3.6 The Conservation and Foreshore Reserves shall be transferred by the proponent to the Crown on a free of cost basis and shall be vested in the City of Mandurah with a view to the ongoing management of the Reserves being undertaken by the Management Entity under the supervision and direction of the Council.

3.7 The Management Entity shall come into effect at the time the first lot in Stage 1 of the project is sold and settled and shall continue to operate in perpetuity.

3.8 The proponents propose to subdivide the project land in stages. The proponent shall ensure that the role and responsibility of the Management Entity is automatically extended to all land in the Harbour City project as it is subdivided and developed.

3.9 After the completion of subdivision, all following development of land within the Estate shall comply with development guidelines to be approved by the

Council and which will be the subject of a separate legal agreement that will place the responsibility ensuring compliance with the Management Entity.

3.10 No development or building application for land in the Harbour City project shall be determined by the Council unless extenuating circumstances exist, until Council has received advice from the Management Entity that the proposal complies with the design criteria adopted (from time to time) for the project land.

3.11 With the approval of the Council, the Management Entity may employ staff to undertake project, remedial and maintenance work in the Harbour City project but will be encouraged as far as practically possible to employ cost effective contract services.

4.0 ENVIRONMENTAL COMMITMENTS AND CONDITIONS SET BY THE EPA

4.1 The proponent shall, to the satisfaction of the Council and EPA, comply with all undertakings and commitments made in the Environmental Assessment Report (March 1992) for the management of the Harbour City project.

4.2 *(Incorporate all specific conditions/provisions as required by the Hon Minister for the Environment. This will occur after the amendment has been advertised for public comment and the Environmental Process has reached a point where these conditions are known).*

APPENDIX 10 - SPECIAL REQUIREMENTS - CANAL ZONE

AREA 3 - HARBOUR CITY - AREA CONTAINED WITHIN COCKBURN SOUND LOC 16 ON PLAN 2413 VOLUME 1682 FOLIO 133 BEING THE LAND BOUNDED E WANJEEP STREET, MANDURAH BYPASS ROAD, MANDURAH ESTUARY AND WEST OF THE DUDLEY PARK ESTATE

Explanation of Symbols:
(See Clause 2.4.2)

P = Use permitted subject to compliance with Development Standards
PS = Use not permitted unless special approval given by Council and conditions complied with
AP = Not permitted unless special approval given by Council after advertising
IP = Use not permitted unless it is incidental to a predominant use as determined by Council.

PERMITTED USES AND DEVELOPMENT STANDARDS

	DEVELOPMENT STANDARDS								
	Minimum lot area	Minimum effective frontage	Minimum plot ratio	MINIMUM BOUNDARY SETBACKS			Minimum car parking spaces	Minimum Landscaping	Other Requirements
				Front	Rear	Sides			
1 Canal Zone Development Standards (Schedule 1 of Area 3)	As per R20 and R40 Codes as defined on the Concept Development Plan	15m	As per R20/40	A minimum front setback of 3m will be permitted provided a 6m average is maintained	As per the defined Codes however where the boundary abuts a canal the setback shall be not less than 4m with an average 6m	As per the appropriate Code except where the boundary abuts a canal the setback can be reduced to 0.6m	As per the R20 and R40 Codes as appropriate	As per the R20 and R40 Codes as appropriate	1. Subdivision and development within the Canal Zone Area No 3 shall be generally in accordance with the Concept Development Plan as endorsed by the Mayor and Town Clerk or any variation to that plan as approved by the DPUD. Subdivision and development shall also comply with the guidelines set down in the Harbour City Environmental Assessment Report dated March 1992 and the Environmental Protection Authority Bulletin No * dated *. 2. No retaining wall or fence shall be erected along the canal frontage or within 0.6m of the outer edge (canal side) of a canal wall. 3. Where a boundary abuts water the setback requirements shall be measured from the outer or canal side of the canal wall. 4. All development shall comply with the criteria set out in an agreement between Council, the Management Entity and the proponent and will be enforced by the Management Entity to the satisfaction of Council.

PERMITTED USES AND DEVELOPMENT STANDARDS

		DEVELOPMENT STANDARDS								
		Minimum lot area	Minimum effective frontage	Minimum plot ratio	MINIMUM BOUNDARY SETBACKS			Minimum car parking spaces	Minimum Landscaping	Other Requirements
					Front	Rear	Sides			
PERMITTED USES		NOTE - UNLESS OTHERWISE SPECIFIED AGAINST A PARTICULAR USE BELOW, THE STANDARDS ABOVE WILL APPLY TO THIS ZONE								
1 Group housing	P							As per R40 Codes	As per R40 Codes	The minimum total % of a site to be set aside as open space as defined in R Codes shall be 25%.
2 Multiple dwelling	IP									
3 Dwelling house	P	500m²	15m	As per R20	A minimum front setback of 3m will be permitted provided a 6m average is maintained	As per the defined Codes however where the boundary abuts a canal the setback shall be not less than 4m with an average of 6m	As per the appropriate Code except where boundary abuts a canal the setback can be reduced to 0.6m	As per R20 Code	As per R20 Code	1. No retaining wall situated more than 0.6m but less than 6m from a canal frontage shall exceed 1.0m above the original stabilised surface. 2. No fence shall exceed 1.8m above the stabilised surface. 3. No retaining wall shall be constructed more than 1.0m above the stabilised surface.
4 Canal Waterways	PS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
5 Canal walls, retaining walls and fences	PS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
6 Recreation and community facilities	PS							N/A	N/A	
7 Sewer pumping station	PS	N/A	N/A		N/A			N/A	N/A	
8 Boat toilet pump out facility	PS	N/A	N/A		N/A			N/A	N/A	
9 Car Park	PS				2m	1m	1m		N/A	
10 Caretakers house	IP									
11 Aged Persons Village	PS									

PERMITTED USES AND DEVELOPMENT STANDARDS

		DEVELOPMENT STANDARDS								
		Minimum lot area	Minimum effective frontage	Minimum plot ratio	MINIMUM BOUNDARY SETBACKS			Minimum car parking spaces	Minimum Landscaping	Other Requirements
					Front	Rear	Sides			
12 Shop & tourist retailing	PS	1,000m²	20m	1.0		Nil	Nil	1 per 20m² of GLA		1. The size and location of developments involving uses 12 to 25 shall be in accordance with the Concept Development Plan for the area as adopted by Council. 2. Minimum landscaping 10% of site.
13 Residential building	PS							1 per bed		
14 Hotel	PS	5,000m²	20m					1 per unit		
15 Motel	PS	4,000m²								
16 Tavern	PS	4,000m²								
17 Chalets,holiday flats & caravan park	P									
18 Private recreation (inc squash court)	P									
19 Public amusement	AP									
20 Club premises	P									
21 Licensed and un-licensed restaurants & fast food outlet	P							1 per 4 seats		
22 Place of amuse-ment (being part of tourist building)	IP									
23 Marina, boat repairs and assoc chandlery operation	PS									
24 Marina filling station	PS									
25 Service station	PS									

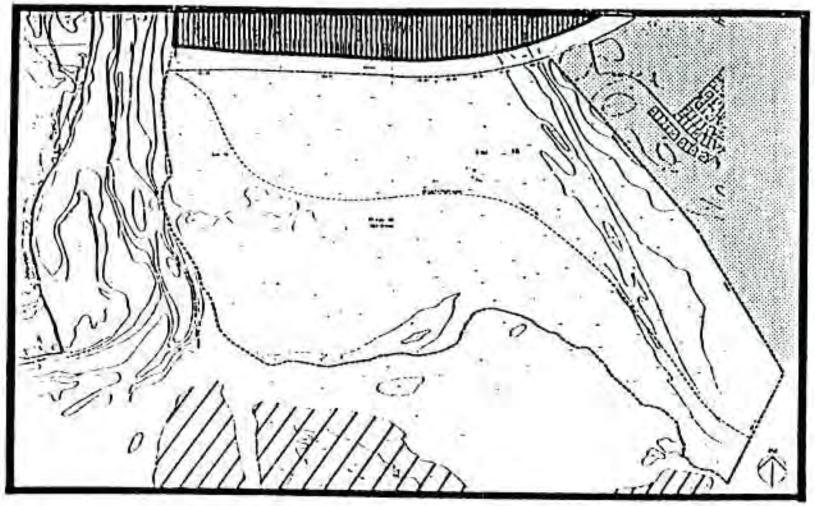
2. CONSERVATION AND FORESHORE RESERVE DEVELOPMENT STANDARDS
(Schedule of 2 of Area 3)

PERMITTED USES AND DEVELOPMENT STANDARDS

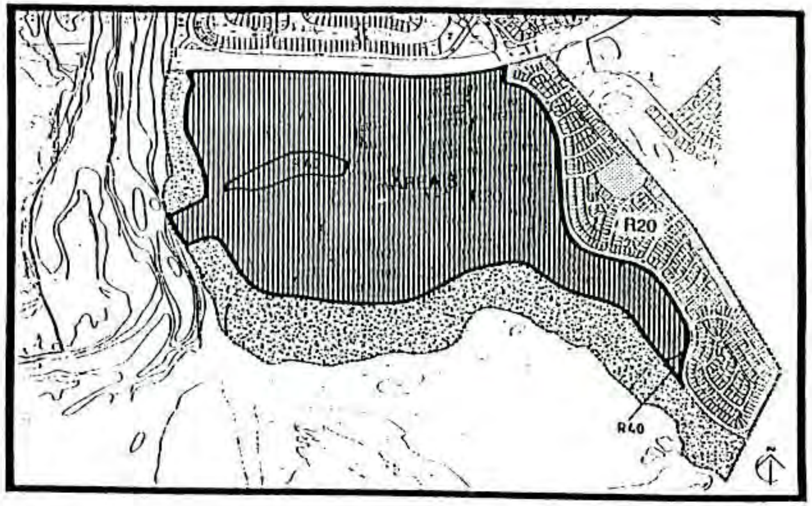
		DEVELOPMENT STANDARDS								
		Minimum lot area	Minimum effective frontage	Minimum plot ratio	MINIMUM BOUNDARY SETBACKS			Minimum car parking spaces	Minimum Landscaping	Other Requirements
					Front	Rear	Sides			
1 Conservation reserve	P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1. The size and location of the Conservation and Foreshore Reserves shall be in accordance with the Concept Development Plan for the area as adopted by Council. 2. These areas will be transferred to the Crown and vested in the Council to facilitate the management role to be exercised by the Management Entity. 3. Management of these areas shall be the responsibility of the Management Entity created by the Scheme. 4. The proponent shall prepare a management plan for the conservation and foreshore reserve areas to the satisfaction of Council and the EPA which is to be implemented by the proponent in accordance with the planned stages of the canal lot subdivision.
2 Foreshore reserve	P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

CITY OF MANDURAH

TOWN PLANNING SCHEME NO. 1A AMENDMENT NO. 183



EXISTING ZONING
SCALE 1: 20000



PROPOSED ZONING
SCALE 1: 20000

LEGEND

ZONES

- CANAL ZONE
- RESIDENTIAL
- CONSERVATION AND FORESHORE RESERVE
- RURAL
- R20 APPLICABLE RESIDENTIAL CODING
- LANDSCAPE PROTECTION AREA

ADOPTION (REGULATION 13 (1))
Adopted by Resolution of the Council of the City of Mandurah at the meeting of the Council held on the ..... day of .... 19...

.... Mayor .... Date

.... Town Clerk .... Date

FINAL APPROVAL (Regulation 21(2), 22(1) and (2))
1. Adopted by the resolution of the Council of the City of Mandurah at the .... meeting of the Council held on the .... day of .... 19...... and the seal of the Municipality was pursuant to that resolution hereunto affixed in the presence of

.... Mayor .... Date

.... Town Clerk .... Date

2. Recommended for final approval by the State Planning Commission

(SEAL)

.... Chairman .... Date

3. Final approval granted

.... Minister for Planning .... Date

Adoption Regulation 13 (1)

Adoption by Resolution of the Council of the City of Mandurah at the Ordinary Meeting of the Council held on the day of 19

Mayor

Town Clerk

Final Approval Regulation 21 (2), 22 (1) and (2)

Adopted for Final Approval by Resolution of the City of Mandurah at the Ordinary Meeting of the Council held on the day of 19 and the Seal of the Municipality was, pursuant to that Resolution, hereunto affixed in the presence of

Mayor

Town Clerk

Recommended/submitted for Final Approval

for Chairman
State Planning Commission

Date ______________

Final Approval Granted

Minister for Planning

APPENDICES

APPENDIX 1
ESPLANADE (MANDURAH) PTY LTD
HARBOUR CITY CANAL ESTATE
MANDURAH, WESTERN AUSTRALIA

MARINE AND WATER QUALITY ASPECTS

(by Kinhill Riedel and Byrne)

ESPLANADE (MANDURAH) PTY LTD

HARBOUR CITY CANAL ESTATE
MANDURAH, WESTERN AUSTRALIA

MARINE AND WATER QUALITY ASPECTS

Prepared by:

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April 1992
PE2004/RP511

Client	Esplanade (Mandurah) Pty Ltd
Project	Harbour City
Location	Mandurah, Western Australia
Job no.	PE2004
Document	**Report**
Subject	**Marine and Water Quality Aspects**

Document no. **PE2004/RP511** **First issue date:** **6/03/92**

This title page is a record of the issue and revisions of the document. Each time the document is changed, only the new or revised pages are issued. For convenience, the nature of the revision is briefly noted under remarks, but these remarks are not a part of the document

Rev.	Date	By	Approval	Pages	Client approval	Remarks
A	06/03/92	DJT		All		Draft
B	10/03/92	DJT		All		Draft for EPA Submission
0	06/04/92	DJT		All		Final issue for EIS Document, incorporating editorial changes and LEC 1991 reference data.

CONTENTS

1 INTRODUCTION

It is proposed to construct a residential canal estate at Mandurah, to the east of the Mandurah Channel and south of the Mandurah Bypass Road. The Harbour City Canal Estate would comprise a mixture of residential lots (approximately 1,150 in total), parklands, retail areas, a marina, and a wetland conservation reserve with an area of around 197 ha.

The proposed Harbour City development would connect into the Mandurah Channel, which runs between the Peel–Harvey estuarine system and the ocean. The location and canal layout are shown in Figures 1.1 and 1.2.

This report has been prepared for inclusion in a Environmental Impact Assessment Document and discusses the environmental issues associated with canal development, with particular reference to its marine and hydraulic aspects.

The following issues are addressed:

- Water quality—in particular, the impact that tide, wind, and salinity/temperature differences have on canal flushing.
- Greenhouse effects—how current estimates affect development levels.
- Entrance stability and siltation—the impact of entrance discharge and potential sedimentation of the channel.
- Shoreline erosion—analysis of historical aerial photography to establish shoreline stability.
- Impact of changes to the Peel–Harvey estuarine system, the effect on water quality, water levels, etc. of proposed changes to the system.
- Floodplain management—the effect of the proposed development on flooding, and recommended development levels.

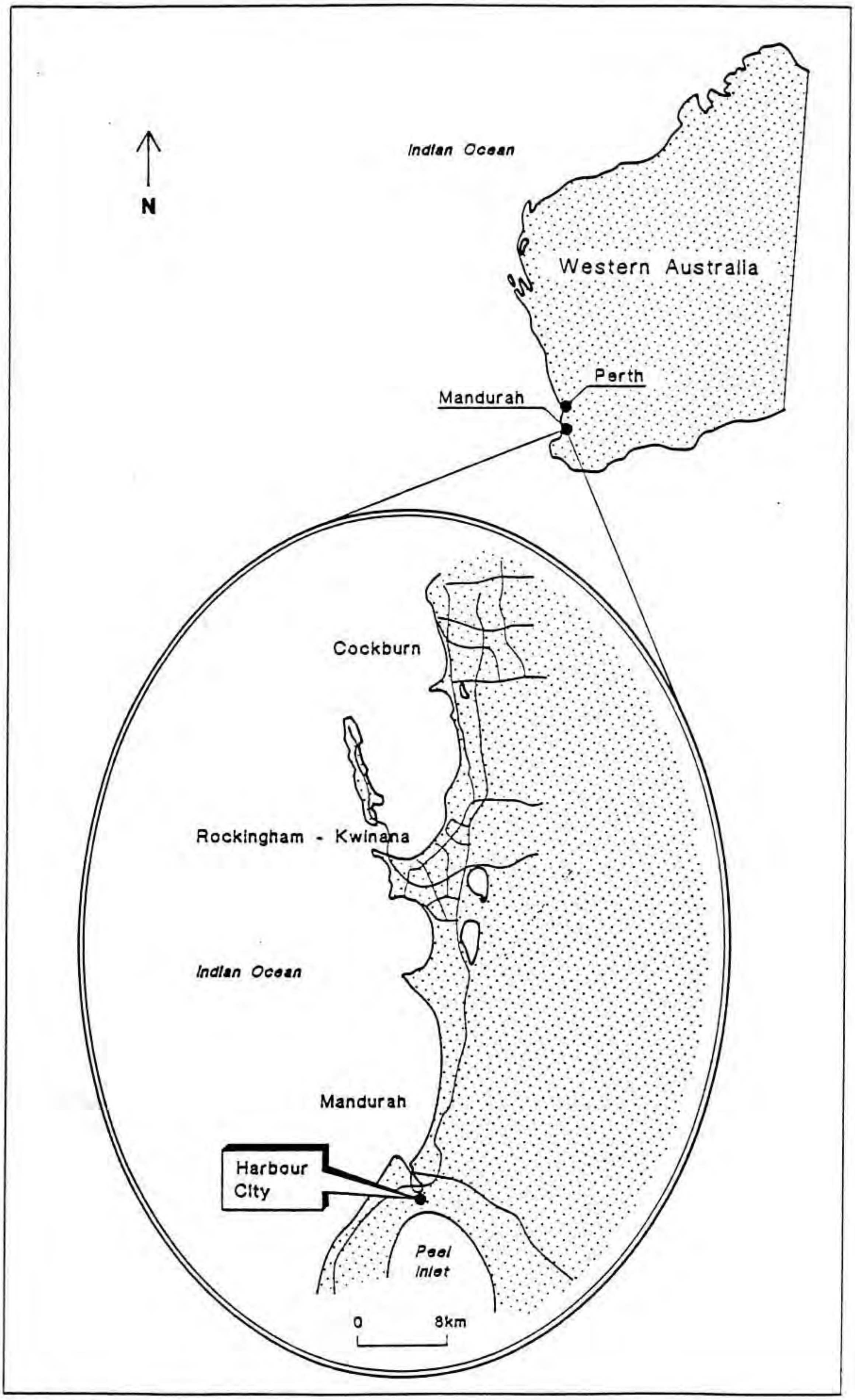


Figure 1.1

LOCALITY PLAN

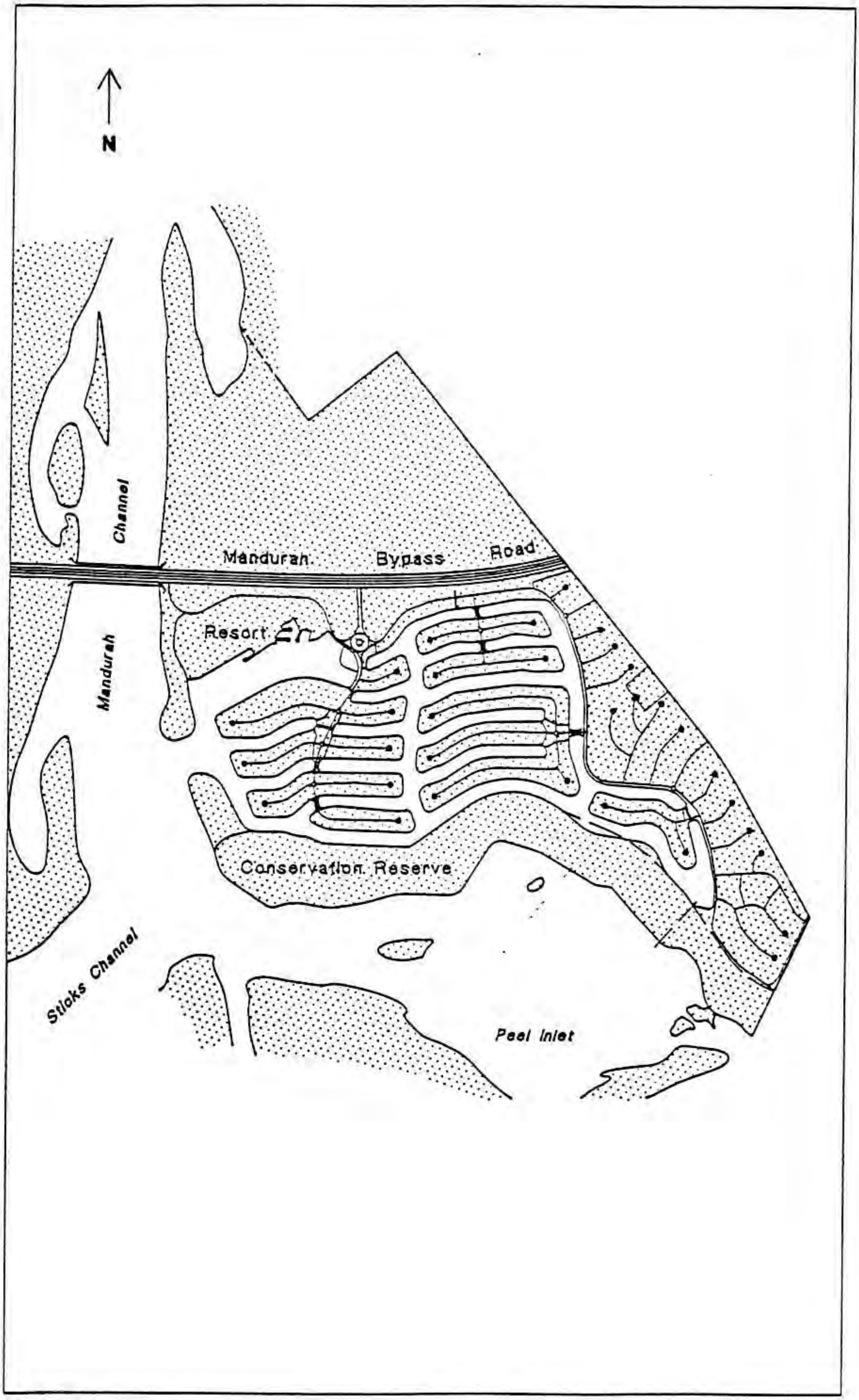


Figure 1.2
PROPOSED CANALS

2 DESCRIPTION OF ENVIRONMENT

2.1 LOCAL CLIMATE

Mandurah's climate is similar to Perth's, being mediterranean in nature with hot, dry summers and mild, wet winters.

2.1.1 WIND

Results of analysis of wind records from the Port Mandurah development site for the period August 1986 to September 1987 (Riedel & Byrne Consulting Engineers Pty Ltd 1990) show wind predominantly from the south-south-easterly sector (Figure 2.1). The records also indicate that the wind is quite strong, between 10 km/h and 30 km/h for over 50% of the time. Seasonally, the 50% occurrence winds are shown in Table 2.1.

Table 2.1 **Seasonal 50% occurrence wind speeds at Port Mandurah**

Season	50% occurrence wind speed
Winter	>8.6 km/h
Spring	>11.5 km/h
Summer	>14.4 km/h
Autumn	>10.0 km/h

The Port Mandurah anemometer half hourly records were compared with Mandurah Post Office twice daily records. A higher occurrence of south-west winds was evident from the latter. The Port Mandurah site is shielded by higher ground to the south-west, which may account for the records showing winds predominantly from the south parallel to the Mandurah Channel. The proposed Harbour City site, due to its position adjacent to Peel Inlet, would experience a higher occurrence of winds from the south-west. The more detailed Port Mandurah data were adopted for calculations of exchange.

Calm periods (below 1.5 m/s) occur mainly in winter. Steedman and Associates (1979) showed that for Cockburn Sound a calm period of over 16 hours would occur only once a year, while a calm period of over 24 hours would occur only once every 10 years. For all practical purposes, this analysis is indicative of conditions likely at Mandurah.

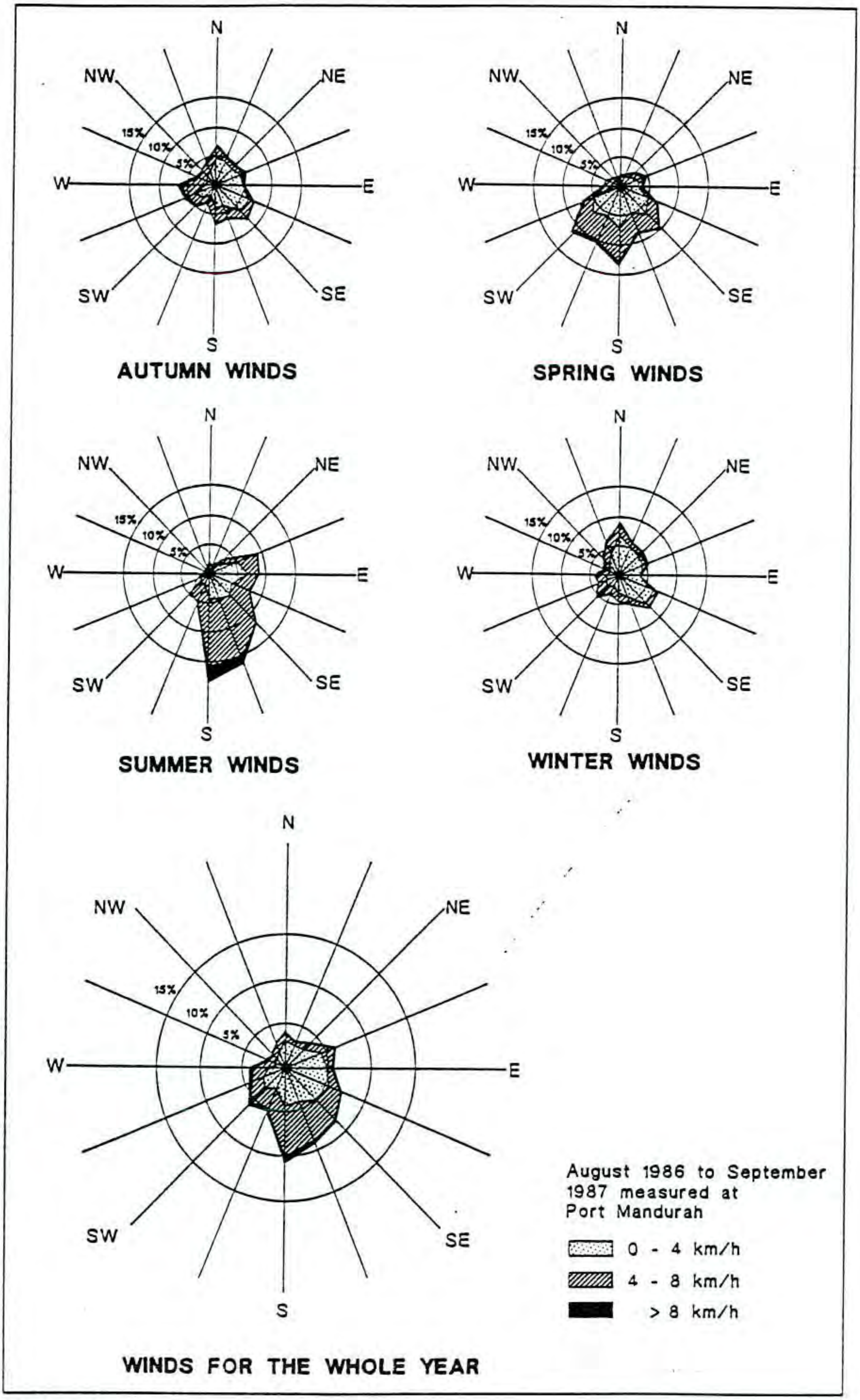


Figure 2.1

PORT MANDURAH WIND ROSES

These wind records are dealt with further in Section 3.3.2 in order to calculate wind induced flushing of the development.

2.1.2 TEMPERATURE

The mean maximum temperature during summer at Mandurah is 29°C and the mean minimum temperature during winter is 9.8°C. Table 2.2 has been prepared from Bureau of Meteorology data for the station at Mandurah.

Table 2.2 **Mandurah monthly temperature**

Temperature (°C)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov	Dec.	Year (av.)
Daily max. temp. (mean)	29.6	30.2	27.8	24.1	21.0	18.6	17.8	18.1	19.5	21.9	24.3	27.3	23.4
Daily min. temp. (mean)	17.8	18.3	16.5	14.1	11.8	10.4	9.6	9.4	10.2	12.0	14.0	16.2	13.4

Source: Bureau of Meteorology 1987.

2.1.3 RAINFALL

Mandurah has an annual average rainfall of 886 mm, with 70% of the annual rainfall occurring between May and August, inclusive. Table 2.3 has been prepared from Bureau of Meteorology data for the station at Mandurah.

Table 2.3 **Mandurah monthly rainfall**

Rainfall (mm)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year (total)
Mean	10	12	19	43	129	194	176	127	89	53	22	12	886
Rain days	2	2	4	7	14	18	20	17	14	11	6	3	118

Source: Bureau of Meteorology 1987.

2.2 TIDAL FEATURES

2.2.1 ASTRONOMICAL TIDES

Analysis of 12 months of tidal records at Mandurah Jetty at the northern end of the Mandurah Channel (Riedel & Byrne 1981) indicate a tidal range (from +0.5 m Australian Height Datum [AHD] to –0.41 m AHD) for normal conditions with average daily variations of 0.4 m. In the year analysed, the highest level recorded was +0.88 m AHD, and this appeared to be during a period of high river flows. The lowest recorded level was –0.5 m AHD. For 98% of the time, the level was between +0.5 m AHD and –0.35 m AHD. Long period water level variations not associated with astronomical tides are also evident. Records for the Chimneys in the Peel Inlet near the southern end of the Mandurah Channel show tidal variations of about 85% of those at the Mandurah Jetty. An average daily range of 0.35 m has been selected for the astronomical tide for the Harbour City site.

2.2.2 BAROMETRIC TIDES

Long period water level variations are experienced along the coast of Western Australia. This variation can be as large as the tidal variation, but the change occurs over several days or weeks.

Tidal records at Fremantle show, after diurnal and semi-diurnal tides have been filtered out, sea level variations with periods of 1–20 days and 20–365 days (Provis and Radok 1979).

These variations are the result of:

- the response to low pressure and high pressure atmospheric conditions moving across Australia at intervals in the range of 3–10 days;
- shelf waves with deep ocean energy and winds shear effects trapped on the shallow continental shelf with periods of 5–20 days;
- wave set-up from storm systems moving across the coast with periods of 1–5 days;
- large scale coastal currents and eddies.

These effects are significant to the proposed Harbour City development in that the barometric tides serve to produce the higher high tides and the lower low tides with their longer period oscillations. But, unlike normal tides, the high highs and the low lows do not occur on the same day.

2.2.3 WIND SET-UP

Constant wind blowing over a confined body of water exerts horizontal forces on the surface of water through shear stresses and pressure differentials over waves. Currents are induced in this manner, and in shallow areas such as Peel Inlet the combined effect of wind and currents is to increase water levels downwind and decrease them upwind.

Steedman and Associates (1982) analysed wind at Fremantle and concluded that sea breezes of a 3–4 hour duration and wind speeds of 8–10 m/s 1 km inland are part of the normal summer wind pattern.

Based on the normal summer sea breeze pattern from the south-west, the Department of Marine and Harbours (1987) estimates a wind set-up in the order of 0.14 m on the eastern shores of Peel Inlet. Winds during summer are from the south and south-west sectors about 60% of the time. An allowance of 0.1 m should be made for wind set-up at the Harbour City development on the north-east shores of the inlet.

2.2.4 EFFECT ON SAMPHIRE FLATS

Survey data on the Samphire Flats area have been obtained from the Public Works Department of Western Australia (PWD) Plan No. 52725–6–2, 'Flood investigations—Peel Inlet entrance channel—Plan showing limit of development and flood prone area'.

Because Samphire Flats has a surface level of at least 0.0 m AHD, and up to +0.7 m AHD, a tidal level of at least Mean Sea Level is required before inundation starts to occur. Statistically, the water level is below Mean Sea Level 50% of the time. Indeed, some areas would only rarely be inundated by tidal events.

2.3 FLOODPLAIN CONSIDERATIONS

Owing to the location of the site—between the ocean and Peel Inlet—consideration must be given to both flood and storm induced high water level events.

2.3.1 FLOODPLAIN MANAGEMENT

In 1984, the Water Authority of Western Australia (Water Authority) modelled the Mandurah Channel flood characteristics for the Peel Inlet entrance channel flood investigation (PWD Plan No. 52725–6–2). This modelling indicated that the 1 in 100 year flood level within Peel Inlet is likely to be 1.6 m AHD. Adjacent to the Harbour City site the flood level is 1.54 m AHD, while on the development's border with the Mandurah Bypass Bridge the flood level is 1.45 m AHD.

The proposed development falls within the limits set by Water Authority and, as such, would not contribute to flooding in the area. In fact, the canal development would provide some additional flood storage not allowed for in the Water Authority model, thus marginally reducing estimated flood levels.

An allowance for wind set-up of approximately 0.1 m needs to be added to the flood level in establishing appropriate development levels.

2.3.2 STORM SURGE

The Department of Marine and Harbours (1987) has estimated the 1 in 100 year storm surge level in the open ocean to be approximately +1.5 m AHD.

The impact of storm surge reduces with increasing distance (along the Mandurah Channel) from the coast and is estimated to be approximately +1.2 m AHD in Peel Inlet. An allowance of 0.4 m, in addition to this, needs to be made for set-up resulting from cyclonic winds.

2.3.3 EFFECTS ON SAMPHIRE FLATS

The effects discussed in Section 2.3 are related to extreme events with return periods significantly longer than astronomical or barometric tides. However, because of the surface level of Samphire Flats, inundation would occur during these events. The extent of inundation would depend upon the severity of the event.

2.4 WATER QUALITY CONSIDERATIONS

Care should be taken in developments such as the residential canals at Mandurah to ensure that water quality in the canals does not deteriorate.

The Steering Committee on Canal Development (1984) recommended that water quality in the canals should not adversely affect the following beneficial uses:

- occasional immersion and wading
- boating
- adjacent development
- passive recreation

In addition, the canal estate should not measurably reduce water quality in its source waterbody.

Water quality criteria for estuarine waters have also been set by the Environmental Protection Authority (formerly the Department of Conservation and Environment) such that aquatic ecosystems are maintained and any changes can readily be assimilated (Department of Conservation and Environment 1981).

According to these criteria and general aesthetic criteria, the water should be free from:

- substances that would settle to form putrescent or objectionable sludge;
- floating debris, oils, etc. in objectionable amounts;
- materials that would produce colour, odour, or turbidity, which may be objectionable;
- dangerous pollutants at unacceptable levels.

These criteria can be met if there is good quality source water, if nutrient and contaminant loadings are minimised, and if there is adequate circulation and exchange.

2.4.1 GENERAL

A large number of developments of the type proposed for the Harbour City Canal Estate have been built successfully both overseas and interstate. Many developments, such as those on the south coast of France, experience virtually no tidal action yet maintain adequate water quality throughout the year. In developments that have suffered deterioration in water quality, causes have been isolated and the situation has been satisfactorily rectified.

The main sources of contaminants that cause deterioration in the water quality associated with similar developments have been identified as:

- nutrient inflow from inadequate sewerage (whether residential or accommodated boats), farm runoff, and indiscriminate rubbish dumping;
- stormwater-carried silt and pollutants;
- antifouling coatings;
- oil, fuel and grease spillages or bilge discharges.

For the most part, these can be controlled by a strict management policy. The algal problems associated with the nutrient enriched waters of Peel Inlet are of concern, and the canals in this area must exchange quickly to ensure algal blooms do not occur.

An Environmental Monitoring Programme has been undertaken for the Waterside Mandurah development, which has been in operation for over 5 years. Monitoring of fish and crustaceans, water quality parameters and sediment—conducted by LeProvost Environmental Consultants (LEC)—is detailed in LEC's Fifth Annual Report and Quinquennial Review (LEC 1991). The findings of the report on the water quality in the canals and their effect on the Mandurah Channel may be summarised as follows:

- Water quality within the canals is determined by the water quality of the Mandurah Channel, which can fluctuate from year to year, depending upon winter rainfall.
- There is no evidence that the water quality in the canals is less than that in the Mandurah Channel, nor that the canals are adversely affecting water quality in the Mandurah Channel.
- Bacteria levels in the canals are suitable for Direct Contact recreation.
- There is no evidence of long term siltation.
- The accumulations of heavy metals appear to be levelling off and previously high values of lead concentration have been reduced following re-analysis.

The Environmental Monitoring Programme for Waterside Mandurah provides useful data on water quality criteria essential for the assessment of the Harbour City canals and is currently the most detailed information available (LEC 1991).

2.4.2 PEEL–HARVEY ESTUARINE SYSTEM AND MANDURAH CHANNEL

The source water for the Harbour City development canal would be the Mandurah Channel connecting the Peel–Harvey estuarine system with the ocean. The higher than normal nutrient levels in this system are well documented and are the subject of major estuary management measures to improve the existing situation. Management strategies have been formulated to reduce nutrient loading in the system, including improvements associated with the proposed Dawesville Channel. Elements of these strategies, such as Mandurah Channel dredging and algal harvesting, are already in place.

The Environmental Monitoring Programme for Waterside Mandurah has highlighted a number of issues associated with source water for canals connected to the Mandurah Channel (LSC 1990 and LEC 1991). Among the most important is that canal water quality is determined almost exclusively by the source water in the channel. Furthermore, changes in channel water quality are reflected in the canals within 7 days, indicating that total exchange takes place within this time.

Water quality in the Mandurah Channel is dominated by runoff in the winter and algal blooms in the summer. Winter runoff increases nutrient levels in the Peel–Harvey estuarine system and the following *Nodularia* blooms are a significant result of this. Water quality is aesthetically reduced as a result of these blooms, resuspended sediment, changes in water colour, and the accumulation of seagrass wrack.

Desirable water quality and aesthetic values are generally maintained as recommended by the Environmental Protection Authority (Department of Conservation and Environment 1981) except during periods of algal blooms over the summer.

Changes to the estuarine system proposed in the Peel Inlet and Harvey Estuary Management Strategy (Kinhill Engineers Pty Ltd 1988) are predicted to improve Mandurah Channel water quality in the long term. Improvements associated with Sticks Channel dredging have already been documented and are due to increased flushing of the Peel–Harvey estuarine system. Together with the proposed Dawesville Channel, these alterations should result in the system becoming more marine, and in the long term the algal nuisance should diminish.

Except for periods of algal blooms when water quality is aesthetically reduced, the source waters are generally to be acceptable for the beneficial uses proposed.

2.4.3 NUTRIENT INFLOW

In canal estates, nutrient input derives primarily from the source water, septic tank systems, fertilisers in localised stormwater runoff, boat discharge, and rubbish dumping.

As the proposed Harbour City development would be deep sewered, nutrient input from that source would not be a problem.

Encouraging native planting and the reduced use of artificial fertilisers would limit input from groundwater and stormwater runoff.

Experience elsewhere in Australia indicates that rubbish dumping in this type of residential development is unlikely because residents are concerned at maintaining water quality within their waterway.

Effluent loading from boats should be minimal, as long term accommodation on board vessels within the development would not be permitted and the discharge from holding tanks would be strictly prohibited.

As no commercial activity would be permitted that would add other pollutants to the canal water, canal nutrient levels should not be significantly different from those of the source water.

Monitoring of Waterside Mandurah development has found that nutrient levels in the sediments have not accumulated and the development is not a 'sink' for nutrients (LEC 1991). Higher nutrient levels in these canals have been recorded on occasion, but these have been associated with higher nutrient levels in the Mandurah Channel itself, and have reduced as the water quality in the Mandurah Channel has improved.

2.4.4 ANTIFOULING COATINGS

The principal chemicals currently used for antifouling coatings in Australia are:

- Copper: This element has been used in antifouling paints and coatings for more than a century and its toxicology to marine organisms at low concentrations is well known. Hart (1982) recommended < 5 µg/L for protection of marine organisms.

- Tributyl Tin Oxide (TBTO): In recent times, studies carried out by the French Oyster Industry and the New South Wales Fishing Industry have brought into question the use of TBTO as an antifoulant, and legislation against future use of TBTO in Australia is being progressively introduced. Since August 1991, legislation within Western Australia has prohibited the use of TBTO paints on small pleasure craft.

Work undertaken for the proposed canal development at Port Geographe (Riedel & Byrne 1987) has shown that, for canals similar to those in the Harbour City Canal Estate, the build-up of copper concentrations in the water is unlikely to reach unacceptable levels unless water exchange is very poor (i.e. exchange rates of 30–40 days). These calculations were based on an assumed berth occupancy rate of 80%, whereas experience from Waterside Mandurah would indicate occupancies of less than 30%.

2.4.5 HEAVY METALS

Levels of heavy metals in the sediments have been monitored as part of the programme for the Waterside Mandurah canals (LeProvost, Semeniuk & Chalmer 1990; LEC 1991).

Table 2.4 provides a comparison of the results of that monitoring with the Peel Inlet and at the Mandurah Ocean Marina.

Table 2.4 **Sediment heavy metals**

Location	Pb	Cr	Cu	Zn	Cd
			µg/g (dry weight)		
Ocean Marina	17.9	23.7	10.1	31.8	1.1
Mandurah Channel	4.7	1.4	1.8	1.3	0.3
Waterside Mandurah – Centre of Main Canal	18.9	19.4	5.9	17.1	0.5
Waterside Mandurah – End of Main Canal	20.0	20.1	10.5	23.5	0.4
Peel Inlet	13.1	2.8	4.9	10.1	0.4

Source: LEC (1991).

The data shows that, in general, the concentrations in the Waterside Mandurah canals are between those of Ocean Marina and the Peel Inlet. Slightly higher concentrations of some of the metals was attributed to presence of the public boat launching ramp at the end of the main canal, although other terrestrial and domestic sources exist.

For the Harvour City develoment, the public boat launching ramp has been positioned close to the entrance of the canal estate.

2.4.6 OILS, FUELS AND GREASES

The effect of oils in seawater is variable because of the complex mixture of a large number of hydrocarbons.

Hydrocarbons spilled into the water are affected by evaporation and solution. Aromatic hydrocarbons evaporate at 1,200 times the rate of solution, whereas for alkanes the rate is up to 100 times. McAuliffe (1977) reports that lower hydrocarbons were completely lost from spilled oils within 8 hours.

Petrol is considered to be highly toxic because of its high concentration of aromatics and other soluble hydrocarbons. Diesel is moderately toxic because the aromatics are of higher molecular weight and less soluble. Oils and grease are of low toxicity but may have an aesthetic impact.

No data are available for the release of hydrocarbons from owners servicing craft in residential canals. However, during normal marina fuelling operations, spillage would be negligible, and the provision of a waste oil storage and handling facilities would minimise dumping of small quantities into the canals. Monitoring at Hillarys Boat Harbour by the Department of Marine and Harbours has shown only very slight build-up of petrogenic hydrocarbons in sediments, even given its high level of boat traffic. Therefore, negligible impact on the Harbour City development or source water is expected from oils, fuels and greases.

2.4.7 BILGE WATER DISCHARGES

The Public Works Department of New South Wales (1987) analysed discharge from bilges as part of the Environmental Impact Statement for the Rozelle Bay Marina. It found that steel-hulled vessels contributed the majority of lower quality water, with elevated levels of suspended solids, greases and oils, phosphate, zinc, lead, copper and phosphorus. Elevated levels of all these parameters are indicative of the use of corrosion-preventative coatings typically used on steel-hulled vessels. Vessels using the proposed Harbour City development are expected to be almost exclusively of fibreglass or aluminium construction (87%), as shown by the Department of Marine and Harbours' 1990/91 private boat registrations. Riedel & Byrne (1987) has shown that, based on the Rozelle Bay data, there would be an insignificant contribution of pollutants from bilge water discharges.

3 POTENTIAL ENVIRONMENTAL IMPACTS AND THEIR MANAGEMENT

3.1 SHORELINE AND LAND STABILITY

Inspection of the proposed Harbour City development site and analysis of aerial photography have identified minor shoreline erosion along the development boundary to Peel Inlet.

Analysis of aerial photography between 1960 and 1988 shows retreat in the area facing the Sticks Channel and minor realignment of shorelines over the previous 28 years, as shown in Figure 3.1. The rate of these changes is quite small on this time-scale. Site inspection indicated that the retreat is due to wave attack, probably in part from wind blowing along the Sticks Channel and in part from boating activity.

If the erosion identified becomes a problem, a form of bank protection may be required some time in the future.

3.2 SILTATION AND ENTRANCE STABILITY

In considering the design of the Harbour City canals and entrance channel, there are a number of factors that need to be considered:

- siltation within the canal system
- stability of the entrance channel
- impacts of the construction on the Mandurah Channel.

For all of these factors, the most reliable guide is an analysis of the results from the monitoring programme for the Waterside Mandurah development (LSC 1990 and LEC 1991).

Waterside Mandurah has been in operation for over 5 years, and measurements show that there has been insignificant siltation, no significant change to the entrance channel alignment or depth, and no impact on the Mandurah Channel itself.

3.2.1 MONITORING OF WATERSIDE MANDURAH

Monitoring of the Waterside Mandurah canals has consisted of cross-sectional measurements through the internal and entrance canals and along the Mandurah Channel adjacent to the entrance canal.

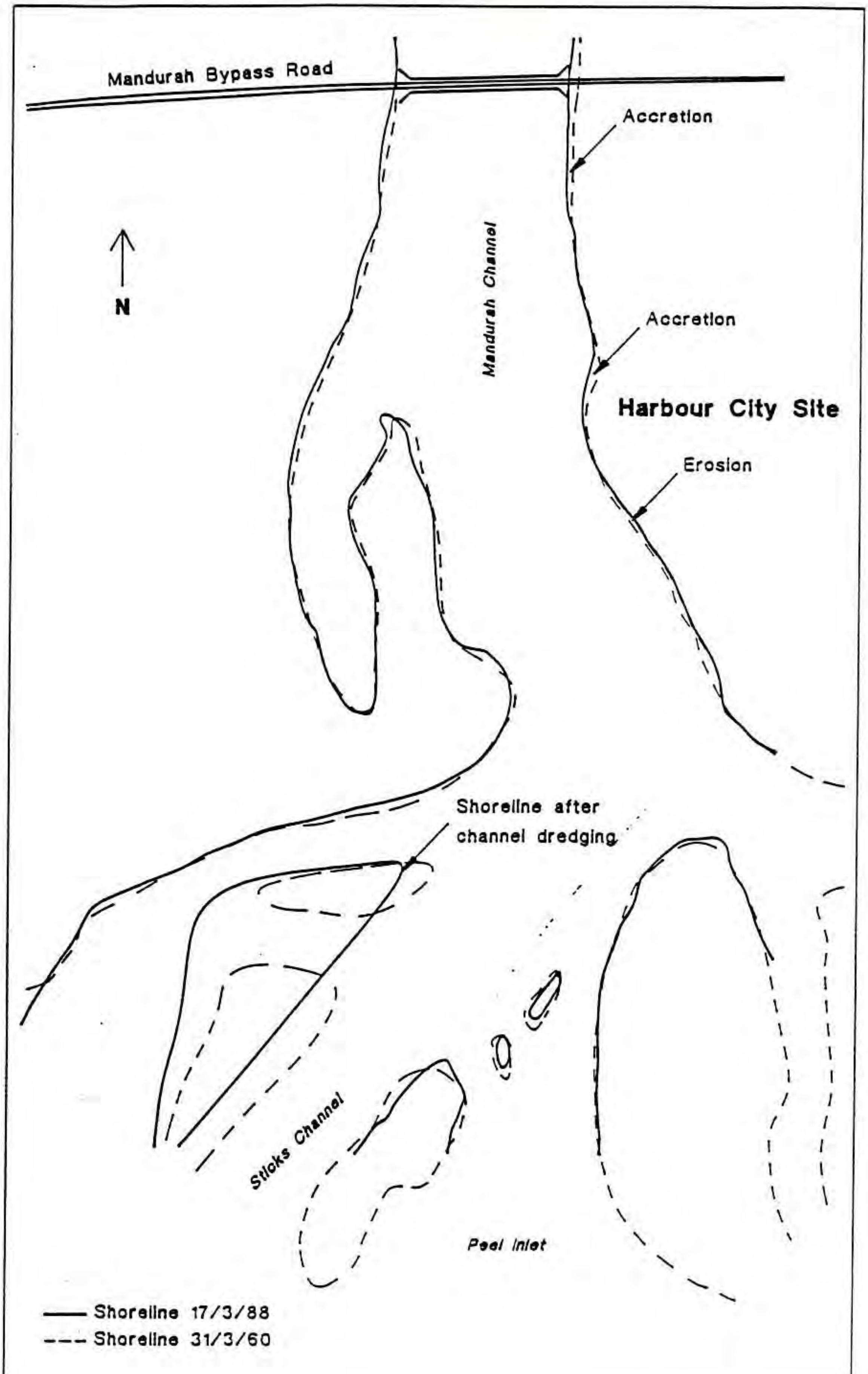


Figure 3.1

SHORELINE EROSION 1960 - 1988

The results of this monitoring are discussed as follows.

Entrance canal

Transects taken through the channel bank and along the entrance canal showed that the entrance long section has remained stable after some minor initial alteration to the channel bank. Soundings further into the channel have also remained the same.

A transect across the entrance channel also showed some early readjustment of the dredged profile, followed by stable behaviour in the ensuing years. This was also indicated in adjacent transects.

Internal canals

Similar readjustment was evident within the internal canals; however, form and navigable depths were maintained with no evidence of an accumulation of sediments. A long section through the development from the Mandurah Channel along the main canal to the interior of the waterways showed some evidence of redistribution of material. However, there was no sign of accumulation of sediment, with inner sections showing very little change.

Effect on Mandurah Channel

It is to be expected that a canal development of the type proposed with small tidal amplitudes would experience very low entrance velocities. These are estimated to be in the order of 0.1 m/s, which are too low to initiate sediment transport of any scale or to influence channel flows significantly.

Analysis of aerial photographs of the Waterside Mandurah canals showed no evidence of any impact on the behaviour of the Mandurah Channel. The sand bank opposite the entrance has shown no sign of alteration since construction, and the areas of weed fringing it have remained unaffected. The channel bank through which the entrance cuts shows no tendency to sediment, and the construction formation has remained stable after initial readjustment. It is expected that the same behaviour would be exhibited at the Harbour City entrance, with no discernible effect on the Mandurah Channel in alignment or section.

3.2.2 PROPOSED HARBOUR CITY DEVELOPMENT

From the study of historical aerial photography of the area, the Mandurah Channel is shown to have been stable over the past 20 years. There is no indication of significant erosion or accretion in the area adjacent to the proposed Harbour City Canal Estate.

Sedimentation can occur due to the widening of flow paths, which reduces water velocity and allows suspended particles to deposit. This is unlikely to occur at the proposed development because:

- the canal entrance would be small in comparison to the total cross-section of the four east–west oriented canals feeding into it, and widening of flow paths would be minimal;

- alignment of the entrance like that of Waterside Mandurah and gentle batter slopes would allow smooth transition of flow.

The most likely cause of sedimentation is flocculation during flood events. This is often caused by interaction with the saline front. The monitoring programme for Waterside Mandurah has shown that this occurs in Peel Inlet and therefore the bulk of the suspended sediment load is deposited before it reaches the Mandurah Channel (LSC 1990). As shown by Waterside Mandurah canal monitoring, maintenance dredging would not be a significant economic or management problem for the Harbour City development.

The following conclusions can be made for the canal development at Harbour City:

- The cross-section of the Harbour City canals would be much smaller than that of the Mandurah Channel, and calculated velocities are an order of magnitude lower, with small tidal flows. The impact of the canals on the main channel would therefore be minimal.

- Low sediment loads in the Mandurah Channel and relatively low velocities would indicate little sedimentation of the entrance or canals, except perhaps when an unusual flood event occurred.

3.3 WATER EXCHANGE

There are three likely mechanisms for the flushing of the residential canals at Harbour City (Figure 3.2), resulting in the exchange of water between the enclosed canals, the Mandurah Channel, and the ocean:

- tidal exchange, consisting of astronomical tides that occur at least once a day and longer term barometric tides that have periods of 5–20 days;

- wind induced currents and mixing within the canals;

- density currents resulting from salinity and temperature gradients.

Van de Kreeke et al. (1977) showed that exchange rates of canals are largely dependent on density, wind induced flows and thermal convection. Variations in tide levels provide a dividing mechanism that enhances these flows, resulting in significant water exchange. More recently Hinwood and Pollock (1989) have shown the importance of density and wind driven flows in canal exchange in a canal subject to a combination of mechanisms. The difficulty of separating the mechanisms in practice was highlighted and it was shown that the simple one dimensional models invariably overestimate the flushing time of a canal. Schwartz and Imberger (1988) showed the importance of these effects in a coastal marina, where density currents resulted in exchange rate significantly greater than that predicted by tidal exchange alone.

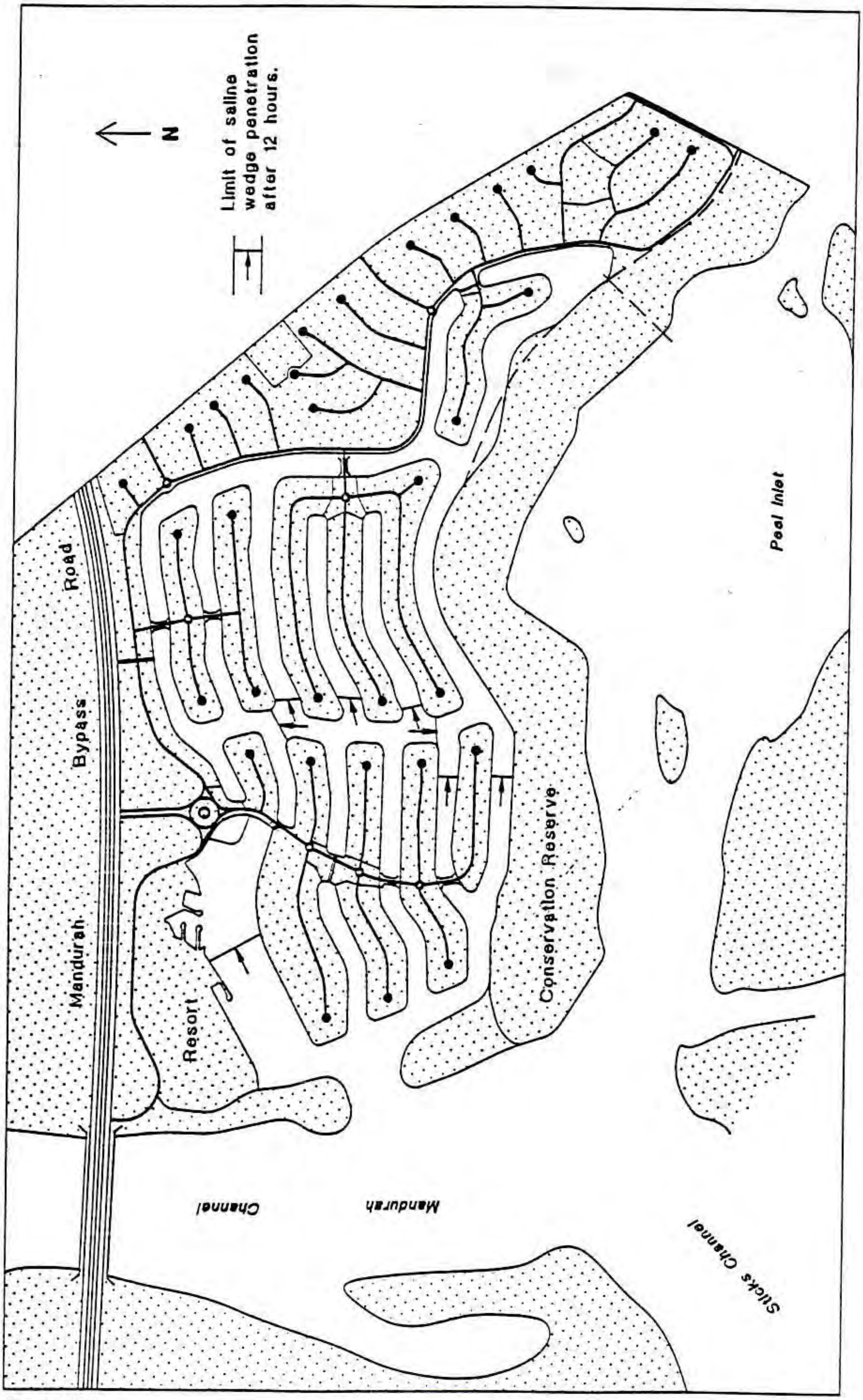


Figure 3.2

PROPOSED CANAL LAYOUT

As part of the Environmental Monitoring Programme for Waterside Mandurah, salinity and temperature in Peel Inlet, Mandurah Channel and the canals have been monitored. Monitoring of the Port Mandurah canal estate, over an intensive period, has been undertaken by Riedel & Byrne (1990). Analysis of data from these sources, in combination with tidal influences and wind circulation and exchange, has used to estimate total exchange for the Harbour City Canal Estate.

3.3.1 TIDAL EXCHANGE

The tidal features at the proposed development site are detailed in Section 2.2. The exchange occurring as a result of those features is discussed as follows.

The influence that variations in tidal level have on water exchange depends to a large extent on the patterns of water flow that are set up. Falconer et al. (1976) discussed how the shape of a harbour could be changed to set up a single gyre circulation and thus increase the efficiency of water exchange.

Where there are differences in density within the water column caused by variations in temperature or salinity, stratified flow occurs, with water flowing out at the top/bottom and being replaced with water flowing in along the bottom/top of the canal. Under these circumstances, changes in tidal levels can provide an additional head of water significantly enhancing that flow and resulting in considerably greater water exchange.

Astronomical tides

With an average daily range for astronomical tides at the Harbour City development site of 0.35 m, the development should exchange between 10% and 15% of total canal water (based upon canal depth at –2.7 m AHD) with the Mandurah Channel each day under the influence of average daily tides.

Barometric tides

The rise in water level that would be periodically produced by barometric tides would provide additional volume within the canals, thus increasing water exchange. They would provide about 6-7% exchange each time they occurred.

Wind set-up

The rise in water level due to wind set-up would provide an average daily contribution to water exchange of about 2% during the summer period.

3.3.2 WIND INDUCED EXCHANGE

Surface currents mobilised by shear stress induced by wind passing across the water surface are known to be important in the mixing and exchange of waters within canals and boat harbours.

A number of researchers have examined the relationship between wind and surface currents (Wu 1973; Bishop,1979; Shemdin 1972) and generally agree that the surface current is between 2% and 5% of the wind speed. Bishop suggests the most appropriate value is 3.5%. The magnitude of the currents decreases rapidly with depth, and in a closed-end waterbody a reverse current of equal mass flow forms to re-establish equilibrium. The surface flow is theoretically limited to the top one third of the water column. McKeehan (1975) presents the following formula to relate the current magnitude and direction to depth below the water surface:

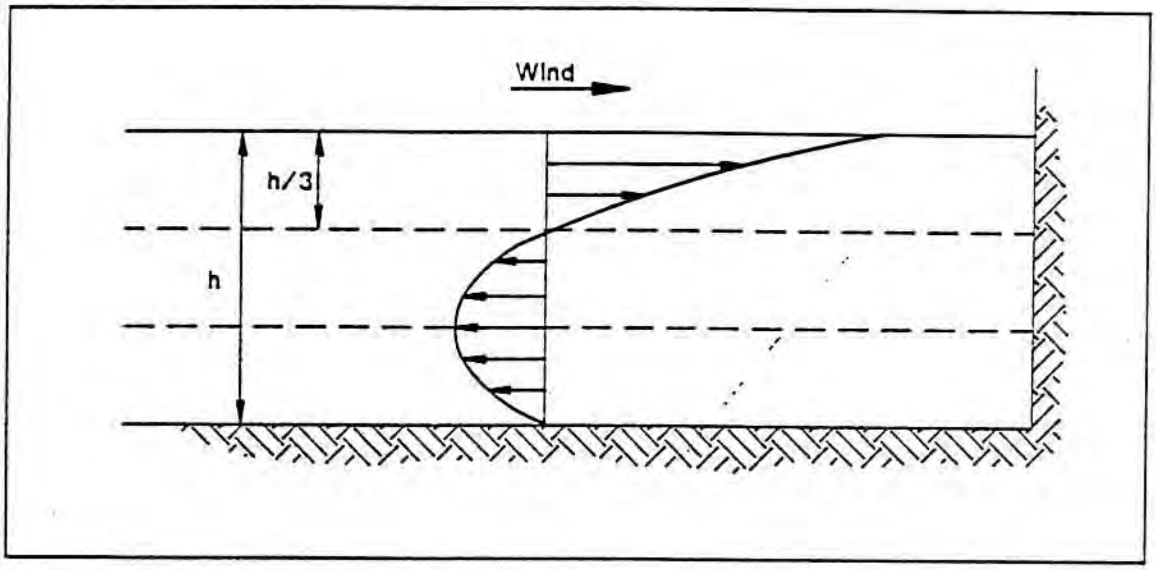
$$U(z) = Us\,(1 - 4z/h + 3\{z/h\}^2)$$

where:

U(z)	=	water velocity at depth z
Us	=	water velocity at the surface = 0.035 x wind speed
z	=	distance below the surface
h	=	total depth of water flow

The velocity profile corresponding to the above equation is shown in Figure 3.3.

Figure 3.3
WIND INDUCED VELOCITY PROFILE



In a residential canal, the flow is not truly two-dimensional. Some sheltering near the banks occurs where the resistance to flow is also higher. Surface flows in the direction of the wind are strongest at the centre of the canal. Return flows occur in sheltered areas at the surface, such as the canal sides, as well as along the canal bed. The velocity profile is also affected by depth, with shallower waterbodies exhibiting flows entirely in the direction of the wind. Superimposed tidal velocities also alter the current profile. Finger canals exhibit a return flow at the dead end associated with wind stress induced currents at the surface and elevated water levels due to wind set-up.

The results of analysis of wind records relevant to the proposed development site are discussed in detail in Section 2.1.1.

In order to calculate wind induced exchange, the more detailed (but sheltered) Port Mandurah data have been used; the exchange estimates thus derived are slightly conservative. The additional data analysed for Cockburn Sound also indicate only occasional occurrences of extended calm periods (Steedman and Associates 1979). This means that the wind may be relied upon to contribute to circulation of the canal waters on an almost daily basis. The orientation of the Harbour City canals is such that most canals are aligned in an east–west orientation. Calculations of wind driven canal flushing have been undertaken for this alignment of canal channels. For the purposes of conservatism, flushing was calculated at the two times (December/January and June/July) when salinity differences between the ocean and Peel Inlet are small and thus density currents are at their lowest (see also Section 3.3.3).

The detailed Port Mandurah wind records were analysed to identify calm periods for the determination of maximum possible flushing times under the calmest conditions.

Based on the methods of Bishop (1979) and McKeehan (1975), the flushing has been calculated at between 14% and 20% per day, depending upon the location within the canal estate.

Thus, in approximately 3 days, 50% of the Harbour City canal waters would be exchanged under this mechanism alone. At other times of the year and with stronger winds, the exchange rate would be very much greater.

3.3.3 DENSITY CURRENTS

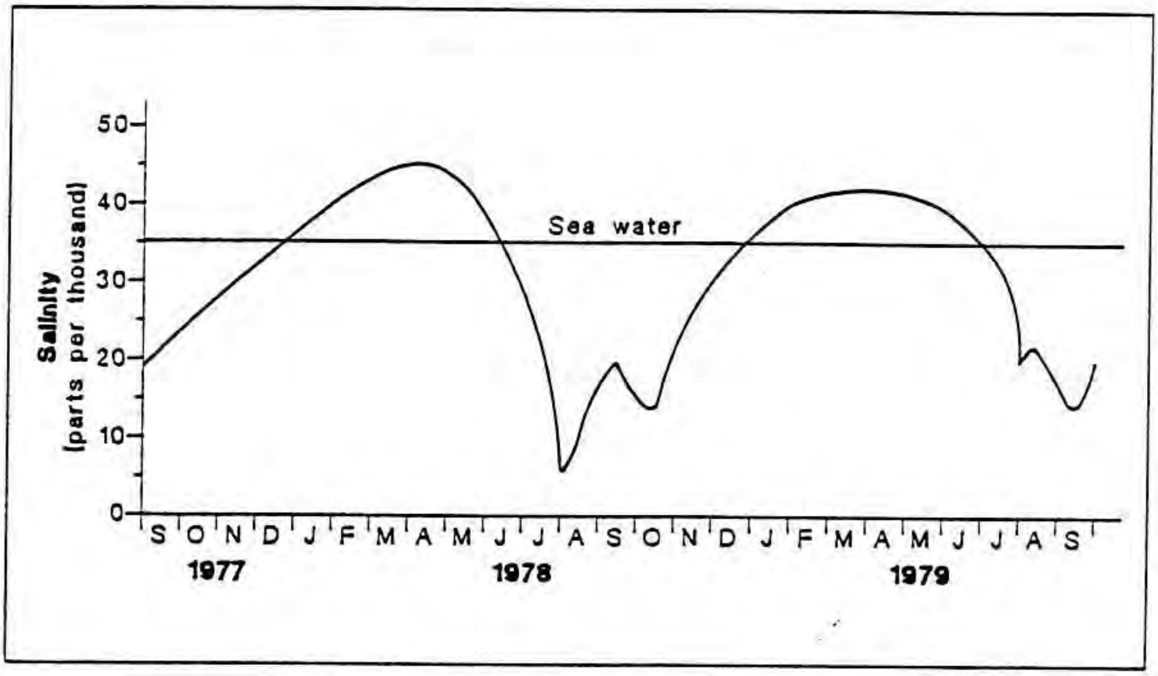
Stratification has been observed in the Mandurah Channel with waters of different salinities and temperature. The resulting difference in density at different levels and tidal flows can drive density currents and significantly assist water exchange and circulation. The experience at Hillarys Boat Harbour highlights the importance of considering the contribution to exchange by this mechanism (Schwartz and Imberger 1988).

Measurements of salinity and temperature profiles in the Waterside Mandurah canals undertaken for the post-construction Environmental Monitoring Programme (LeProvost, Semeniuk & Chalmer 1990) have provided information on the seasonal movement of waters of different salinities, first measured by Black and Beer (1979). However, those measurements were taken at one instance on selected days throughout the year.

More recent work involving intensive measurements of the flushing characteristics of the Port Mandurah canal estate (Riedel & Byrne 1990) and the proposed East Perth redevelopment—Claisebrook Inlet (Kinhill Riedel & Byrne 1992) has revealed further information on density stratification within tidal channels and rivers. This has allowed more accurate calculation of the contribution of this phenomenon to the flushing of canal estates.

Within the Mandurah Channel, the incoming and outflowing tidal action can produce stratified conditions, with ocean water being introduced into the channel during flood tides and Peel Inlet water displacing it during ebb tides. The actual nature of the stratification depends upon the relative salinities of the ocean and Peel Inlet waters. During winter, fresh water inflow into the Peel Inlet causes the water to become lighter than the seawater. In summer, evaporation raises the salt concentration, and thus density, of the inlet water above that of seawater. Figure 3.4 shows a plot of average salinity levels in Peel Inlet indicating this cyclic behaviour.

Figure 3.4
SALINITY IN PEEL INLET



Source: Peel - Harvey Study Group 1985a

This difference in density could drive currents within the Harbour City Canal Estate until the conditions within the Mandurah Channel and the canal estate were equalised. This would significantly assist in water exchange and circulation.

Measurements of the flushing characteristics at the proposed East Perth redevelopment—Claisebrook Inlet revealed the presence of a saline wedge within the Swan River that travels upstream along the bottom of the river under a flood tide (Kinhill Riedel & Byrne 1992).

However, further analysis of the measurements of the flushing characteristics at the Port Mandurah canal estate (Riedel & Byrne 1990) has shown that in the Mandurah Channel the saline wedge takes on the form of a saline 'wall', as the incoming ocean water totally reverses the flow direction and empties into Peel Inlet. Figure 3.5 shows this behaviour at a measurement site adjacent to the Port Mandurah canal estate. The measurements were taken during winter and thus the salinities oscillate between seawater and fresh water. It is expected that, during summer, the salinities would oscillate between seawater and hypersaline water. Figure 3.6 shows the assumed model for behaviour of the density currents within the Mandurah Channel and the Harbour City Canal Estate.

Turner (1973) suggested that flow velocities may be estimated from density intrusions using the following formula:

$$U = 0.5 \left(\frac{\Delta\rho}{\rho} gd\right)^{0.5}$$

where:

ρ	=	density of layer
g	=	acceleration due to gravity
d	=	depth of waterbody.

By taking into account the driving forces as shown in Figure 3.5, friction, a canal entrance width of 80 m at Mean Sea Level, and a canal estate volume of 1,000,000 m^3, it has been determined that around 36% exchange per day could be derived from density currents.

It has been calculated that the saline wedge would enter the development site through the entrance canal at around 0.04–0.08 m/s. Once inside the canal estate, its ingress velocity would adjust as a result of the additional flow paths available into the four east–west oriented canals (Figure 3.2).

To ensure effective penetration of these saline wedges, it is proposed to use free-flowing culvert-type structures at all locations where north–south running roads cross east–west oriented canals.

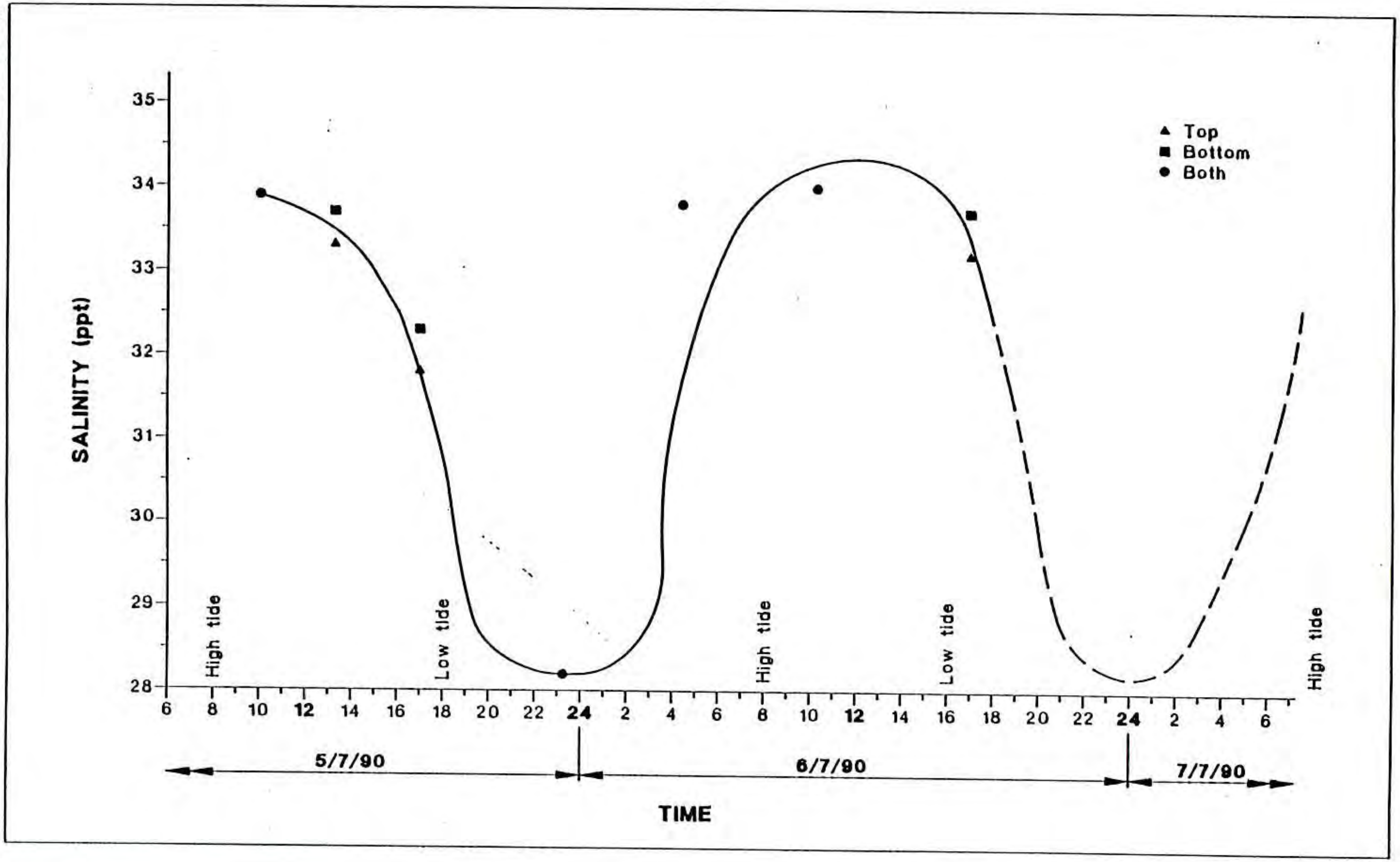
Over the available tidal cycle time of 12 hours, the saline wedges would travel eastwards to the approximate locations shown in Figure 3.2. The saline wedges may continue to penetrate the canals after the end of the tidal cycle; if they did, this cyclic penetration of wedges along the top and bottom of the canals would assist in providing a density driven contribution to flushing at the far ends of the canal estate.

If the saline wedges reversed direction after the change in tide after a 12 hour cycle, then the exchange of water at the ends of the canals would depend upon wind driven exchange. Section 3.3.2 shows that this mechanism would provide 50% exchange in approximately 3 days.

3.3.4 TOTAL EXCHANGE

The effects of tidal flushing, wind induced circulation and mixing, and gravitational flushing due to salinity and temperature gradients should ensure that the water quality in the Harbour City canals would closely reflect that of the source water in the Mandurah Channel.

Figure 3.5
SALINITY IN MANDURAH CHANNEL



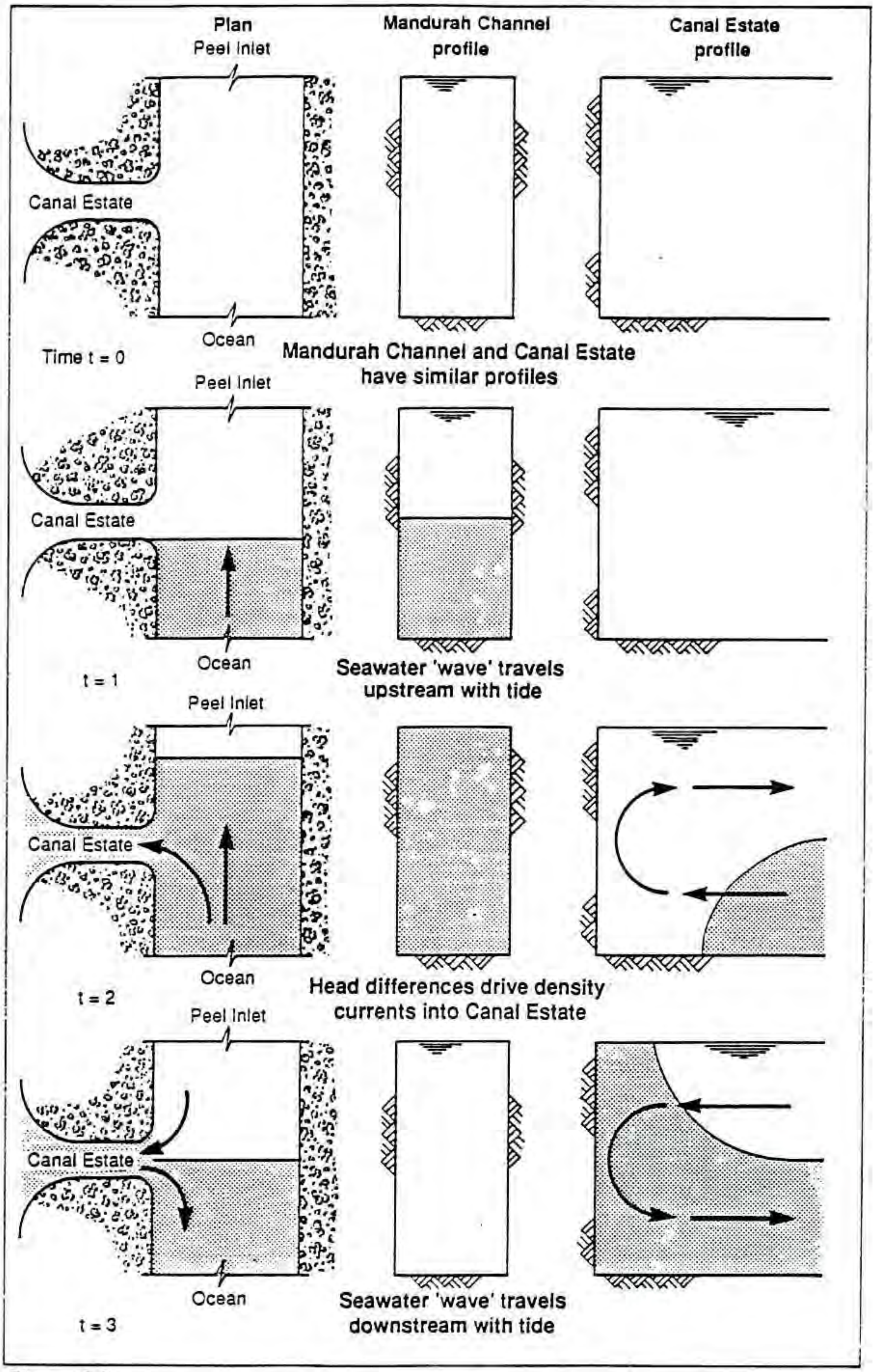


Figure 3.6

DENSITY CURRENTS

The expected minimum contributions to flushing are summarised in Table 3.1.

Table 3.1 **Expected minimum contributions to flushing**

Mechanism		% Flushing/day of total water
Tides:		
• Astronomical	10–15%	
• Barometric	1%	
• Wind set-up	2%	say 15
Wind		15–20
Density		35

Table 3.1 shows that quite reasonable contributions to flushing are available from the three separate mechanisms. During calm wind periods, flushing would be obtained from tide and density driven currents, thus producing around 50% exchange per day. During periods of stronger winds, the density currents would be broken down by vertical mixing of the water.

This has been confirmed by a study of the relationships between wind and density currents at Hillarys Boat Harbour. Schwartz and Imberger (1988) found that density current structures were capable of being disrupted through vertical mixing caused by wind.

The flushing during these periods of stronger winds would be due to tide and wind, thus producing at least 30% exchange per day.

3.4 GREENHOUSE EFFECT

All new coastal and estuarine developments should be designed to allow for the possibility of future changes as a result of the Greenhouse Effect.

The possibility of global warming as a result of the build-up of greenhouse gases in the atmosphere is attracting increasing attention in both technical and popular circles. In particular, the possibility of a rise in sea level must be considered in planning for coastal and estuarine engineering works. However, questions exist as to whether sea levels have in fact been rising and about predictions for the immediate future.

3.4.1 EXISTING TIDAL GAUGES

A number of studies have been carried out to assess global trends in Relative Sea Level (RSL) over the past century. These studies have concluded that there has been a rise of at least 10 cm over this period.

Nevertheless, convincing evidence of RSL rising on a global scale does not exist because data from tidal gauges are not adequately distributed and doubts exist about the reliability of many records.

The problems associated with the use of existing records include:

- the concentration of reliable records on continental margins in the northern hemisphere. The study by Pirazzoli (1986) indicated that only 2.6% of reliable records were located in the southern hemisphere;

- the location of most gauges in bays and harbours where engineering works affect the RSL;

- unreliability of instruments;

- gaps in records.

3.4.2 OTHER FACTORS

A major problem in attempting to assess whether sea levels are actually rising is the fact that the RSL is affected by a combination of tectonic, oceanographic and meteorological factors, which may be operating either locally, regionally or globally.

For example, the study by Wallace (1988) indicated that there may be evidence to show an uplift of the south-west of Western Australia which has been offsetting any possibly global sea level rise. Meteorological phenomena such as the Southern Oscillation changes in ocean currents, earthquake activity and changes in ocean topography are also factors affecting the RSL.

3.4.3 TEMPERATURE AND SEA LEVEL RISE

There have been many studies that have attempted to estimate the contribution of the warming over the past century to sea level rise and to estimate the rise in eustatic sea level that could result from the projected global warming. The studies suggest that three factors may cause eustatic rise in sea level:

- the expansion of ocean water
- the melting of Alpine and other small glaciers
- the melting of the Greenland and Antarctic glaciers.

Similar to the problems associated with tidal records, the assessment of global temperature trends is hindered by poor spatial coverage and unreliability of data. It should be noted that a recent study by the National Oceanic and Atmospheric Administration (1989) indicated no statistically significant trends in the United States of America from 1985 to the present.

In addition, it has been suggested that oceanographic theory is not sufficiently well developed to give a clear understanding of the response to temperature change of lower ocean levels or of patterns of water circulation (Robin de Q. 1986).

The response of the Greenland and Antarctic ice sheets to temperature change is not clear. It is possible that warming may cause increased snowfall and therefore net ice growth. The study by Meier (1984) of the contribution that the melting of the small glaciers would make to sea level rise forecast a rise from ice melt of 8–25 cm over the next 100 years. However, the study also showed that, from 1960 to 1975, the small glaciers were in balance despite increased concentration of greenhouse gases.

There are also problems associated with the climatic modelling that has been used to assess future results of the Greenhouse Effect. These problems relate to uncertainties in terms of:

- future pattern of greenhouse gas emissions
- climatic response to given levels of greenhouse gas emissions
- hydrological processes.

Although global sea level rise is possible, conclusive evidence is not available to prove it. There is certainly no evidence to suggest a dramatic increase in global sea level within the life span of most engineering structures.

The scientific community is at present engaged in extensive research in order to determine more precisely the effects of the accumulation of greenhouse gases. Until confident predictions of sea level and climatic changes are available, Kinhill Riedel & Byrne believes it is appropriate to design coastal structures that allow for a sea level rise of approximately 30 cm within the next 60 years. This is in agreement with the recommendations of the Intergovernmental Panel on Climate Change (IPCC 1990) and the CSIRO.

A more detailed discussion of the influence of the Greenhouse Effect on sea level and climate is included in this report as Appendix B.

3.5 DESIGN WATER LEVELS

Floodplain considerations for flood and storm events are detailed in Section 2.3; a summary of those considerations is presented as follows.

3.5.1 FLOOD EVENTS AND STORM SURGE

The modelling of a 1 in 100 year flood event by the Water Authority has been done, based upon the Authority's estuary management plan for the Peel Inlet and Harvey Estuary. The channel flows were modelled as shown in Figure 3.7. The modelling has resulted in a flood level at the proposed development site of +1.6 m AHD.

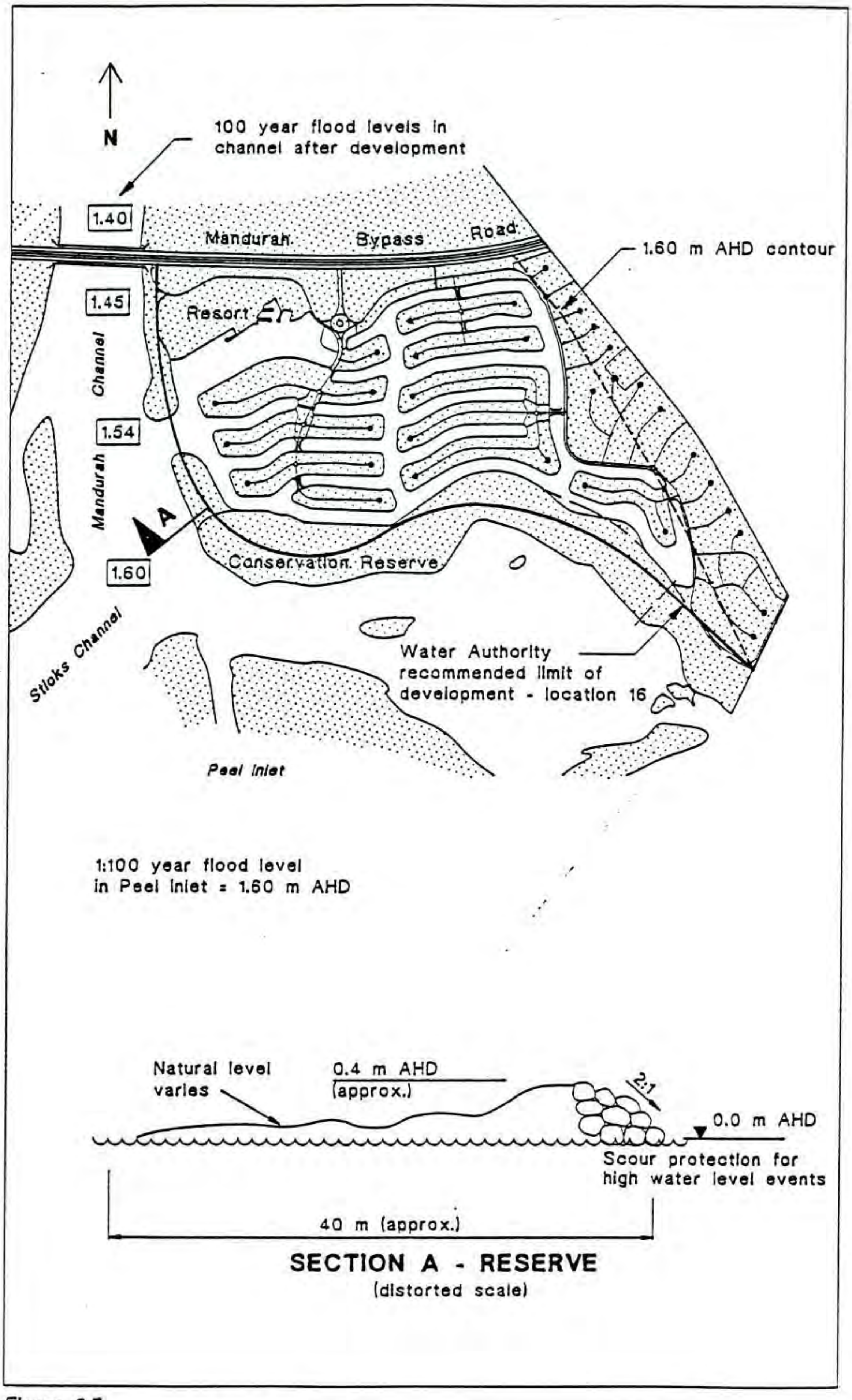


Figure 3.7

100 YEAR FLOOD LEVELS

As the conservation reserve is mostly below 0.4 m AHD, there is the opportunity for the Peel Inlet water to enter the outermost canal over the conservation reserve during high water level events. Because scour of the canal bank in the lee of the flow is likely, some form of protection would be provided, as shown in Figure 3.7. This would also serve to protect the reserve from erosion caused by boat wash in the canals.

The 1 in 100 year storm surge level has been estimated by the Department of Marine and Harbours and, after adjustment for the development's set-back from the open ocean, it is +1.2 m AHD. An allowance of 0.4 m also needs to be made to account for cyclonic winds.

3.5.2 RECOMMENDED DEVELOPMENT LEVELS

In establishing appropriate development levels, account needs to be taken of extreme water levels from either storm surge or flooding, together with an allowance for wind set-up and potential greenhouse effects.

The estimated water levels are summarised in Table 3.2.

Table 3.2 **Recommended development levels**

Event	1 in 100 year flood (m AHD)	1 in 100 year storm surge (m AHD)
Still water level	1.6	1.2
Wind set-up	0.1	0.4
Greenhouse effects	0.3	0.3
Safety margin	0.5	0.4
Total	2.5	2.3

A slightly lower safety margin is applied to the storm surge because of its significantly lower duration.

It is therefore recommended that the design building level for residential development within the proposed Harbour City Canal Estate be set at 2.5 m AHD.

3.6 IMPACT OF THE PEEL INLET AND HARVEY ESTUARY MANAGEMENT STRATEGY

The Peel-Harvey Study Group (1985a) recommended a number of strategies aimed at improving water quality within the Peel–Harvey estuarine system by increasing water exchange and reducing nutrients available for algal growth.

Dredging of the existing Mandurah Channel has been proposed to increase its efficiency (Peel-Harvey Study Group 1985b), and much of that work has already been completed.

The construction of an additional ocean entrance at Dawesville has commenced (Figure 3.8). It is understood that this work will be completed within approximately 2 years.

The increase in water exchange resulting from these improvements would not only affect water quality but would also have some influence on flood dissipation and extreme water levels associated with storm surge.

3.6.1 ASTRONOMICAL TIDES

Analysis of water level records by Riedel & Byrne (1981) shows a maximum astronomical tidal range of 0.6 m at Mandurah Jetty, 0.4 m at the Sticks Channel and semi-diurnal constituents low upstream of this point with maximum ranges of up to 0.1 m.

The Peel-Harvey Study Group (1985b) presents results of the Centre for Water Research modelling of dredging the ocean entrance and Sticks Channel. Higher flow rates in the Mandurah Channel are predicted at the entrance and give an indication of improved flushing to the Peel–Harvey estuarine system. A 30% increase in the tidal amplitudes in Peel Inlet is also predicted.

3.6.2 FLOODING

The Murray River Flood Study gives results of estuary modelling that produced a 1 in 100 year flood level of 1.6 m AHD (Public Works Department of Western Australia 1984). Proposed dredging and flow training options have been analysed by the Public Works Department of Western Australia (1983). It was estimated that a reduction in peak flood levels from 1.6 m AHD to 1.2 m AHD would occur as a result of Mandurah Channel flow improvements effected through dredging.

3.6.3 STORM SURGE

The Department of Marine and Harbours (1987) estimates that the 1 in 100 year storm surge water level in the Peel Inlet is 1.2 m AHD. With the Dawesville Channel in place, this is expected to rise by approximately 0.15 m to 1.35 m AHD.

For the Peel–Harvey estuarine system, Kinhill (1988) cites an expected improvement in water quality and an increase in tidal range from the existing 0.1 m to about 0.3 m, once the Dawesville Channel is constructed.

3.6.4 WATER QUALITY

Expected long term water quality improvements in the Peel–Harvey estuarine system as a result of the Dawesville Channel construction and Mandurah Channel dredging would provide a similar improvement to the water quality of the Harbour City development. Increased flushing of Peel Inlet would reduce Mandurah Channel algal loads and nutrient levels, which would be reflected in the canal waters. All aesthetic parameters should improve with time. LeProvost, Semeniuk & Chalmer (1990) has already measured water quality improvements in the Mandurah Channel associated with Sticks Channel dredging.

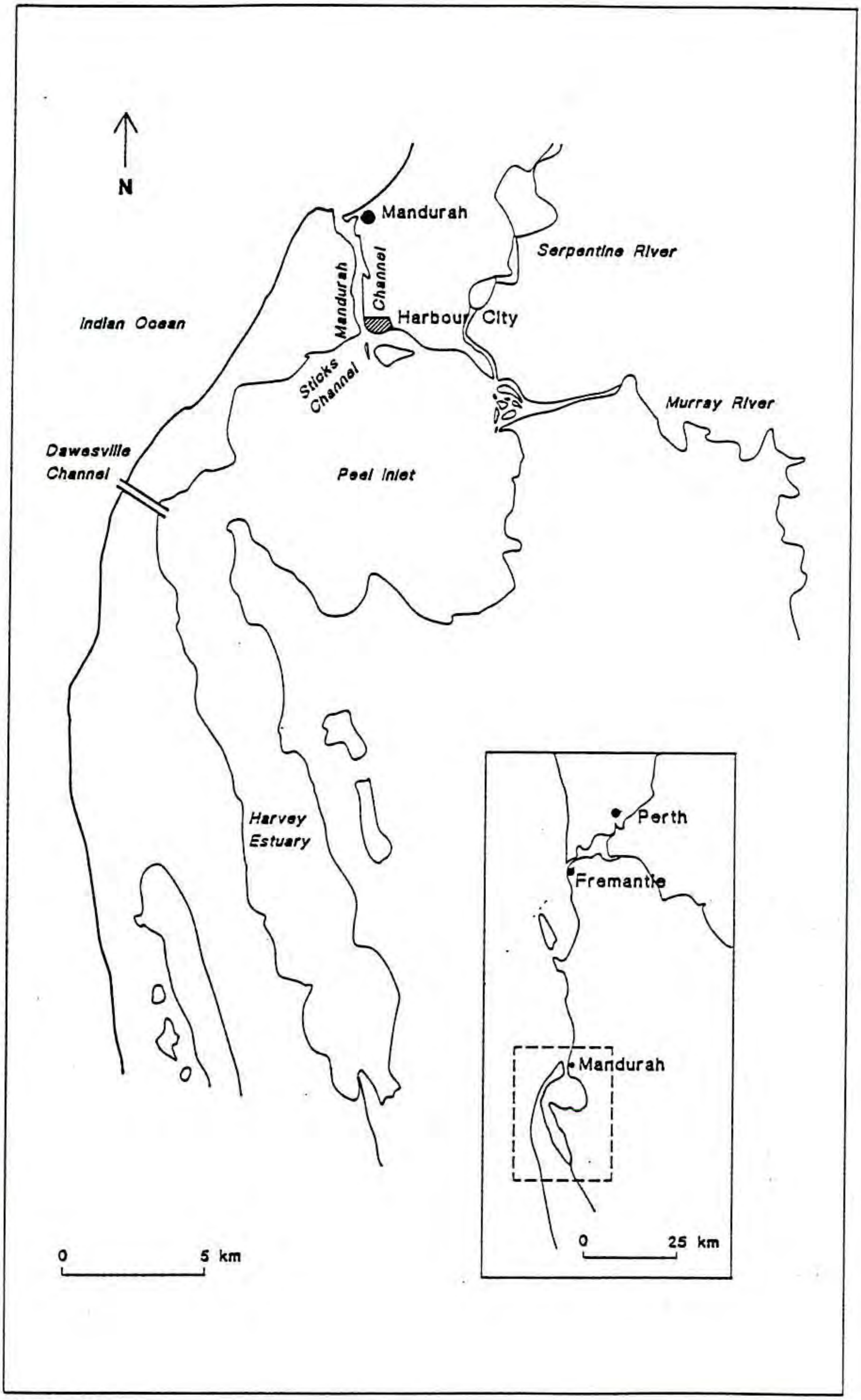


Figure 3.8

LOCATION OF DAWESVILLE CHANNEL

3.6.5 MAXIMUM WATER LEVELS

While decreased flood levels can be expected as a result of the Dawesville Channel, an increase in the effect of storm surge would mean that peak water levels would remain much the same as those presently predicted for the Harbour City development.

3.7 ADJACENT WATERWAY DEVELOPMENTS

The monitoring of the recent Port Mandurah and Waterside Mandurah developments has shown no adverse effects on the Mandurah Channel. This is principally due to the developments' small total volumes compared with the total tidal volume carried by the Mandurah Channel into the Peel Inlet and Harvey Estuary.

Similarly, it is not expected that other proposed developments (Mandurah Quay, Port Mandurah Stage II, Sticks Marina) would have any detrimental effects on the Mandurah Channel or on the Harbour City Canal Estate.

3.8 CONTINGENCY PLANS

Although a monitoring and management programme would be established for the Harbour City development, it would still be necessary to have contingency plans for unexpected events.

3.8.1 MAINTENANCE OF WATER QUALITY

Unexpected events that could lead to a decrease in water quality are the ingress of algal wrack into the canals and petrol or oil spills from vessels.

The contingency plan for cleaning up seagrass or algal wrack should involve the use of manual collection of wrack from the areas that it accumulates in, such as canal ends and other downwind locations. This could be done from a boat/barge or from the shore. The wrack would require disposal in an approved area. Similar techniques are periodically used at Mindarie Keys Marina.

Petrol or oil spills are expected to be minimal in nature; however, a contingency plan for larger spills could include the provision of some containment and removal equipment on site at the marina.

3.8.2 NAVIGABLE ENTRANCE AND CANALS

It is difficult to imagine an event that would affect channel navigation depths or widths that would not be detected by a monitoring programme. However, should this occur, a contingency plan would include the re-establishment of the original conditions by either land-based or dredge-based excavation methods, the posting of signs at the canal entrance, the issuing of a notice to mariners, and advising all residents within the canal estate.

3.8.3 STORM AND FLOOD DAMAGE

Should extremely severe storms and flooding occur, damage to the Harbour City development would be less than the damage to other housing estates in low lying areas in the Mandurah area.

The contingency plan would also need to take into account possible damage to the development's revetments, canal wall structures and boat mooring structures.

3.9 MONITORING PROGRAMME

A monitoring programme would be undertaken to check water quality, sediment quality and entrance channel stability. The monitoring programme would be designed to match the staging of the Harbour City development, especially for water quality, as this would provide useful information on the flushing performance of the canal system.

3.9.1 CANAL WATER QUALITY

It would be important to ensure that the water quality of the canals was similar to that of the source water—the Mandurah Channel. At the conclusion of each stage of construction, a concentrated measurement programme could be conducted to determine the flushing mechanisms at work. The stages of construction past the limit of saline wedge penetration (Figure 3.2) would be the most critical. From previous experience at Port Mandurah and East Perth (Riedel & Byrne 1990; Kinhill, Riedel & Byrne 1992), the most beneficial monitoring programmes are those over a 24 hour period (or longer) rather than monthly measurements at random stages of the tidal cycles.

3.9.2 CANAL SEDIMENTS

The canal system should be sampled at several locations, evenly distributed throughout the estate, for concentrations of heavy metals.

3.9.3 ENTRANCE CHANNEL AND LAND STABILITY

A set of survey locations along the eastern shore of the Mandurah Channel and within the Harbour City Canal Estate should be established. Transects should be periodically surveyed to determine the stability, and identify siltation, of the entrance channel and internal canals.

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Appendix A

HARBOUR CITY LAYOUT

Figure A1.1 Subdivision Layout
BSD Drawing SP9154-2

Appendix B
GREENHOUSE EFFECT

GREENHOUSE EFFECT AND SEA LEVEL CHANGE

TABLE OF CONTENTS

1. INTRODUCTION

The possibility of a global climatic change as a result of the anticipated significant increase in "greenhouse" gases in the atmosphere is attracting increasing attention in both technical literature and the public press. In particular, the possibility of a rise in sea level must be considered in the planning of coastal engineering works.

There is ample evidence of major rises and falls in Relative Sea Level (RSL) during the late Pleistocene and early Holocene periods. These culminated in a rise of approximately 120 m in the period from 18000 to 6000 B.P. Since then levels have remained relatively constant except for possible minor fluctuations (Bird 1984, Hopley 1982).

However the question arises as to whether the sea level has been undergoing a rise over the past century and what will occur in the immediate future.

This discussion considers a number of studies based on tidal records which have assessed global changes to sea level over the past century. The difficulty of determining whether changes have occurred globally or only on a local or regional level is indicated by an outline of the tectonic, oceanographic and meteorological factors which operate to affect RSL.

The influence of the Greenhouse Effect on sea levels is considered by a discussion of the link between temperature increase, climatic change and a rise in RSL. Models developed to determine past and future ice melting and thermal expansion of the oceans are discussed. Uncertainties concerning assessment of future sea level rises are also identified.

2. RECENT CHANGES IN SEA LEVEL

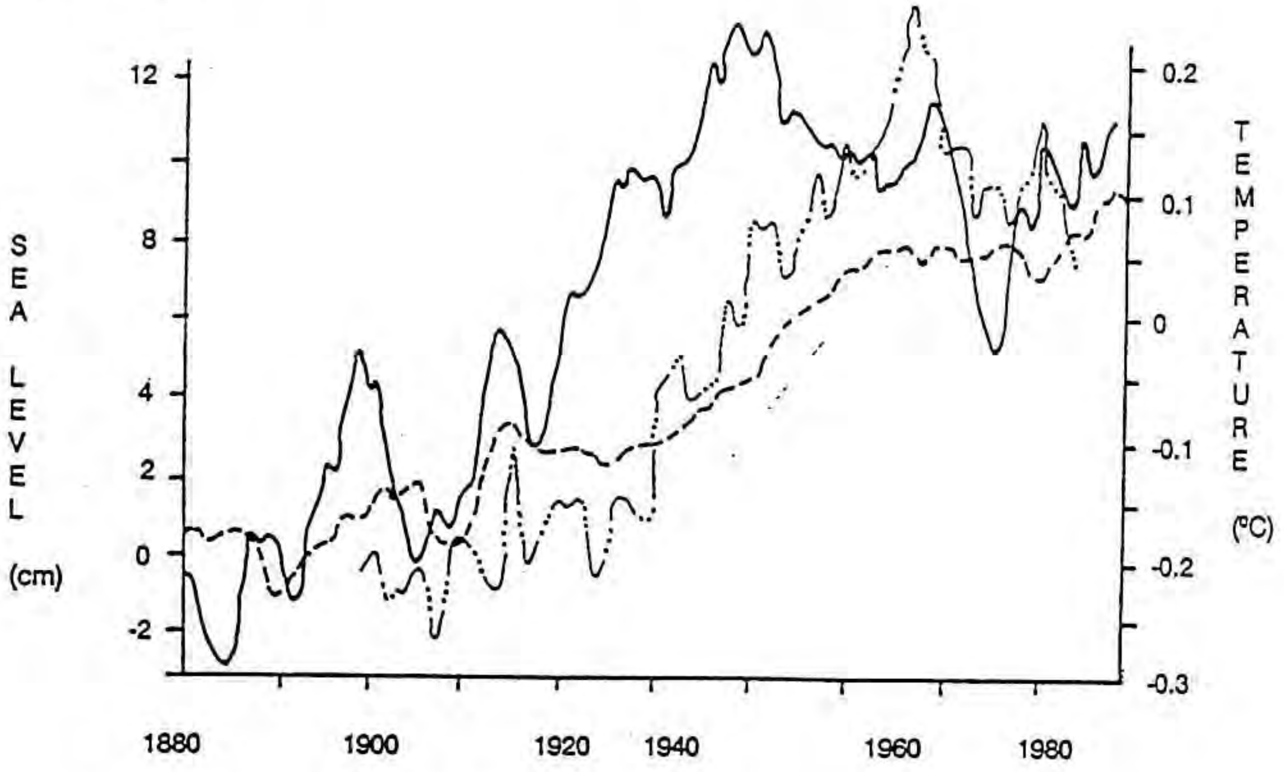
In order to assess global trends in RSL over the past century several studies have been made of mean values of sea level from tidal gauges. Table 1 summarises the conclusions of a number of these studies.

Table 1 Estimates of Mean Global Sea Level Increase

Authors	Magnitude and Period
Fairbridge and Krebs (1962)	+ 12 cm (1860-1960)
Gornitz et al (1982)	+ 10 cm (1880-1980)
Klige (1982)	+ 15 cm (1900-1975)
Barnett (1984)	+ 14.3 cm (1881-1980)
	+ 22.7 cm (1930-1980)

Gornitz et al (1982) took data from 700 stations and excluded those with records of less than 20 years and those in seismically active areas. The remaining 193 stations were divided into 14 regions and a mean sea level curve was produced for each region. A global curve was obtained by averaging these regional curves. A rise of 10 cm was arrived at after subtraction of 2 cm for the longterm isostatic rebound. This study and that of Klige (1982) suggest a possible relationship between global temperature and global mean sea level. The data indicate a lag of approximately 20 years between temperature change and sea level response (see Figure 1). The significance of this relationship is further discussed in the section on the Greenhouse Effect.

Fairbridge and Krebs (1962) selected tidal stations which they considered to be in areas that were tectonically stable and to give the broadest geographical coverage (however a concentration in the North Atlantic was admitted). A rise of 6 cm (1.2 mm per year) was identified for the period 1900 to 1950. In the total period 1860 to 1960 however, both falls in sea level and a faster rate of rise from 1946 to 1956 (5.5 mm per year) were identified. Since no subtraction was made for the long term isostatic rebound the global figure of 12 cm is the same as that of Gornitz et al.



——————— Global mean temperature, 5 year running mean from Hansen et al, 1981.

- - - - - - - Gornitz S.L. Sea level. Global mean - from Gornitz et al, (1982 - 5) year mean.

—··· —··· Klige S.L. Sea level. Global mean - from Klige, 1982, annual values.

Temperature and Sea Level Change **Figure 1**

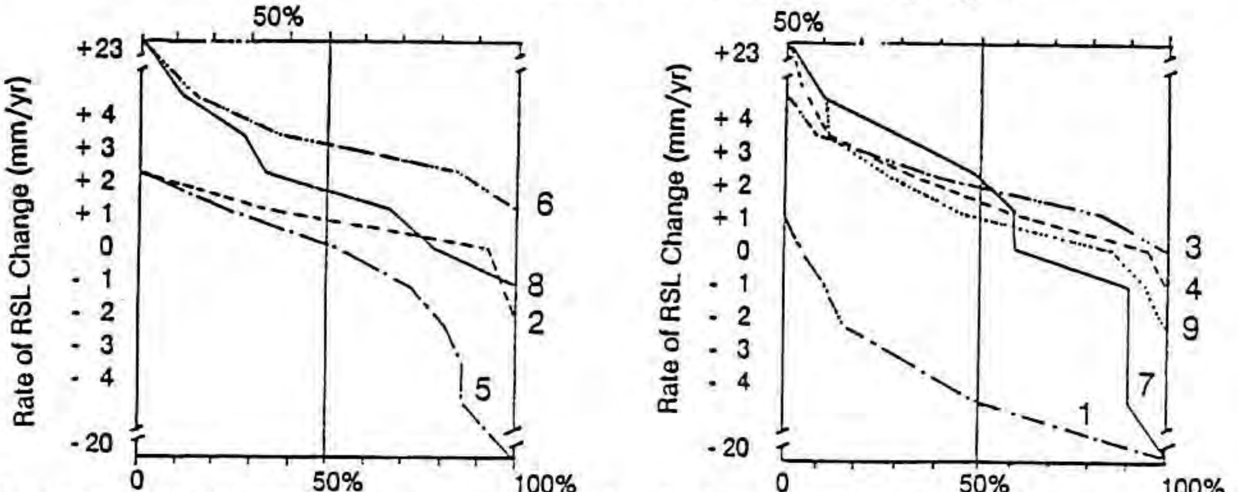
Source: Robin de Q., 1986.

Barnett (1984) developed regional averages of sea level change for many of the world's continental margins by using 155 stations. These were reduced to 82 usable data series by averaging over the high station density regions. His results indicated coherent changes over many of the regions with sea level rises in all regions except Scandinavia, Alaska and S.E. Asia. However he concluded that it was not possible to determine a global rate of change or even an average rate of change (Refer Section 3).

Another study by Pirazzoli (1986) was based on the records of 1178 stations. In order to identify long term trends only records of more than 30 years were used. Of the 229 stations which were considered to have reliable records 28.5% indicated a drop in RSL, 20.5% a rise of 0.1 to 1.0 mm per year, 22.5% a 2.0 mm rise and 28.5% more than 2.0 mm per year. Pirazzoli divided the 229 stations into 9 groups:

1. Norway, Sweden and Finland
2. South Baltic coasts and Denmark
3. Atlantic Europe
4. Mediterranean and Black Sea coasts
5. Pacific coasts of North America
6. Gulf and East Coasts of USA
7. North and East coasts of Canada and Greenland
8. Stations in highly tectonic areas: Japan, Phillipines, Pakistan, Burma, Adaman Islands, Taiwan, Panama, Aden
9. Azores Islands, Canary Islands, Ghana, India, Thailand, Australia, Hawaii, Argentina, Bermuda.

A great variety of trends appear inside each group indicating that there is no uniform trend even on a regional scale (Figure 2). For example, on the Pacific coasts of North America (Group 5) 50% of the stations indicated almost no change. However 10% show a fall in RSL of more than 15 mm per year and 10% show a rise of 1 to 2 mm per year.



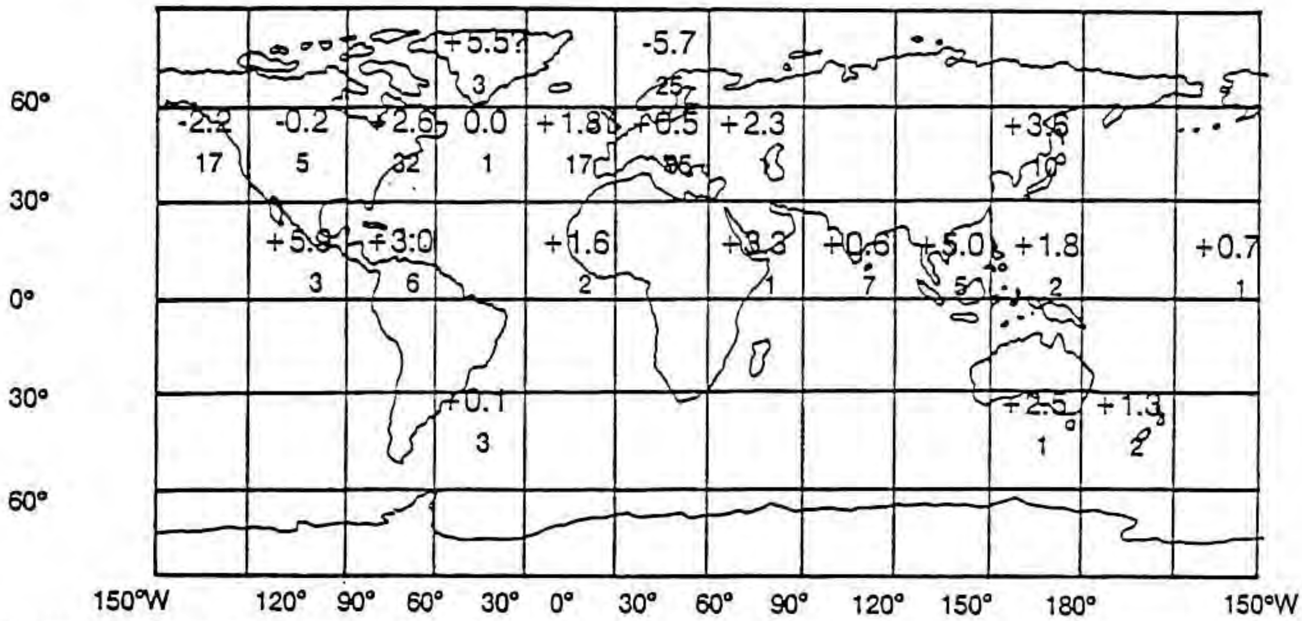
Percentage distribution of long-term rates of RSL change in nine groups of tide-gauge stations

Figure 2

Source: Pirazzoli, 1986.

3. PROBLEMS WITH THE USE OF RECORDS FROM TIDAL GAUGES

Both Barnett (1984) and Pirazzoli (1986) conclude that the unevenness of the distribution of reliable tidal records means that it is not possible to determine a global rate of sea level change. Of the 229 stations used in Pirazzoli's study only 2.6% of the records were in the Southern hemisphere and 89.5% of the records were located north of the Tropic of Cancer. There is also significant concentration of the records on continental shores and there are almost no records available in high latitudes (Figure 3).



Note: The larger upper numbers indicate long-term linear trends of RSL change.

The smaller numbers indicate the number of stations in each compartment.

Distribution and Trends of 229 Reliable Tide Gauge Stations **Figure 3**

Source: Pirazzoli, 1986

A majority of tidal gauges are located in bays rather than on open coasts. Studies by Mehta and Philip (1986) and Hicks (1984) concluded that gauges inside bays will underestimate sea level rise when compared with gauges outside bays. Location in harbours also means that levels may be affected by engineering works such as the deepening of channels, land reclamation, and by the construction of jetties and seawalls (Bird and Koike, 1986).

Tidal gauges are frequently located in estuaries of rivers where freshwater flows may cause changes in water density and sediment compaction may result in subsidence at the site of the gauge.

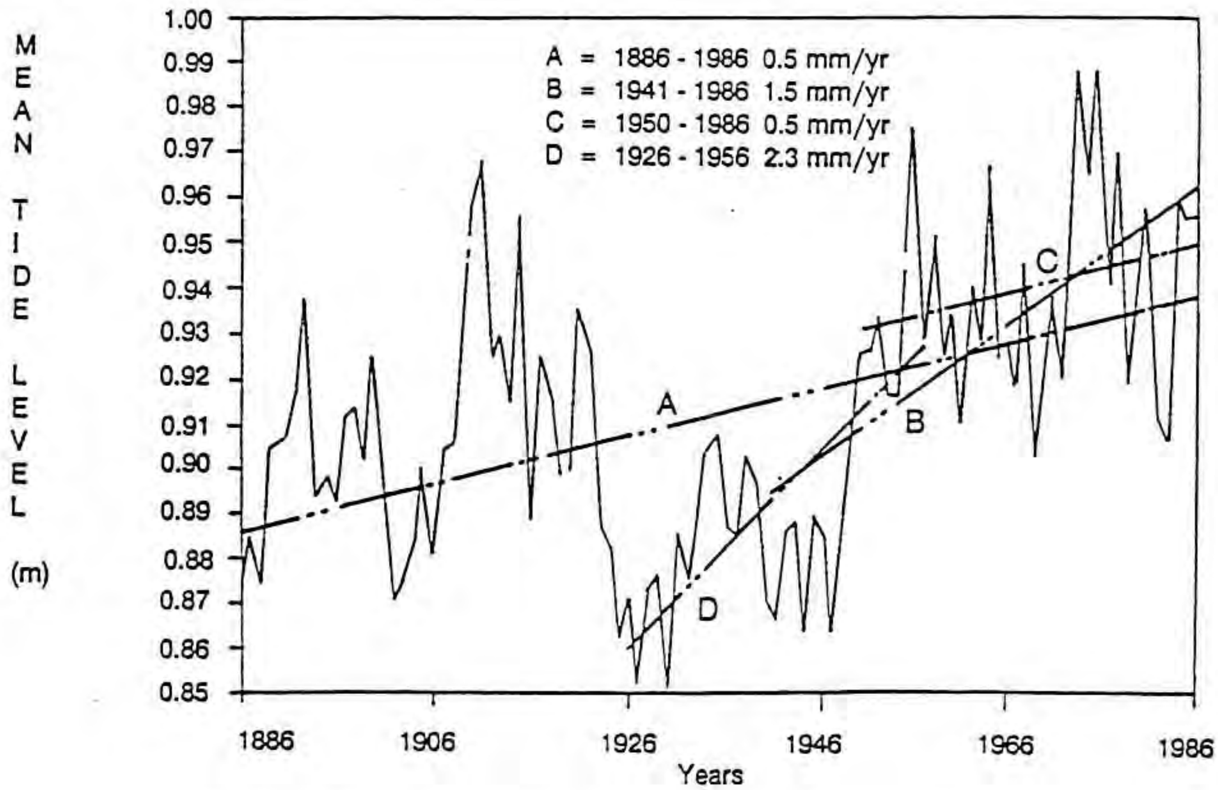
There is a tendency for continental margins to be subsiding because of:

- Sediment transfer from the continents to the oceans;
- The weight of post glacial water depressing the ocean floor and continental margins;
- Cooling and subsidence of the ocean floor away from the mid ocean ridges;
- Withdrawal of water, oil and gas from the coastal margins.

As a result of these factors, tidal gauges are more likely to indicate a rise in RSL even if there is no increase in global water volume (Pirazzoli, 1986).

The existence of long period sea level fluctuations, for example those caused by the Southern Oscillation and the North Atlantic Oscillation (Fairbridge and Krebs, 1962), make it difficult to assess long term changes (eg over the last century). Pirazzoli (1986) identified oscillations lasting up to 20 to 30 years, so that the length of data series is obviously significant.

The importance of the length of the data series when assessing long term changes is indicated in the study of trends at Sydney (Gordon, 1987). Using the records for Fort Denison 1886 to 1986 different rates of change can be determined according to the length of the data. (See Figure 4.) Pirazzoli (1986) provides the example of tidal records at Bombay to indicate that over a period of a century, 10 years of additional data can significantly alter the long term trend. In this case the last 10 years of data indicate a drop in RSL which counterbalances the rise of the previous 30 years.



Sea Level Behaviour NSW (Fort Denison tide gauge) **Figure 4**

Source: Gordon, 1987

The method of computing the long term trends will significantly affect the results. Barnett, (1984) developed an objective method of estimating regional averages of sea level change but concluded that variations of up to 50% could be obtained with the same data simply by the use of different averaging methodology.

The reliability of tidal records is examined in Hamon's study (1987) of the Fort Denison records from 1886 to 1986. He identifies errors in tidal records associated with factors such as mechanical and hydraulic friction in the recording instruments, inaccurate chart rulings and changes to the mechanical equipment. However it should be noted that he concluded that the data are suitable for mean sea level studies on a wide range of time scales.

Further problems associated with tidal records are indicated by the limitations of the records from Port Adelaide since 1882 (South Australian Coast Protection Board, 1984). These include large gaps in the records, uncertainty about early datum changes, and a possible lack of precision because the gauges have been maintained primarily for port operations.

It is evident that there are significant problems associated with the use of the available tidal data in order to assess whether changes are occurring in RSL. In the future, the proposed Global Sea Level Observing System should provide data which are more reliable and more adequately distributed on a global basis.

4. OTHER FACTORS CAUSING CHANGES IN RELATIVE SEA LEVEL

There are a number of tectonic, oceanographic and meteorological factors which may operate to cause changes in RSL on a local or regional level.

The U.S. National Research Council (1987) discusses the major categories of tectonic movement which may result in change to RSL. These are:

- Subsidence of former glacio-isostatic marginal uplift belts (eg the eastern United States)
- Cooling crustal belts following rifting (eg parts of the Gulf of California)
- Subsidence in regions of sediment loading (eg Mississippi Delta)
- Uplift in regions of active crustal subduction (eg Puget Sound)
- Subsidence due to loading by volcanic eruptions (eg Hawaii).

Wallace (1988) indicates that there may be evidence to show an uplift of the south-west of Western Australia which has been offsetting any possible sea level rise.

Subsidence or uplift may also result from earthquake activity. Japan's tidal records indicate the interruption to long term trends by sudden vertical movements at the time of earthquakes

(Pirazzoli, 1986). Compaction or consolidation of soft underlying sediments will also cause subsidence. The fall in RSL in Canada and Scandinavia appears to be the result of isostatic rebound following the melting of the ice caps. This melting also appears to have caused sinking of the ocean basins with a resulting effect on RSL.

Changes in ocean topography have been identified by the examination of satellite imagery, with differences in ocean levels of up to 180 m (Pirazzoli, 1985). These irregularities correspond to changes in the density of the earth's core material.

A shift or change in speed of ocean currents may also cause changes in RSL. For example, the Kuroshio current causes differences of up to 2.5 m in the ocean's topography (Pirazzoli, 1986). There may be planetary spin rate effects on RSL and the U.S. National Research Council (1987) notes that the spin rate has decreased slightly. This would have resulted in decreases in RSL at low latitudes and increases at high latitudes.

Meteorological phenomena have been identified as causing changes to RSL. Fairbridge and Krebs (1962) indicate that the average effect of an increase in air pressure by 1 mb is a fall in sea level of 1 cm. They report a distinct 2 to 3 year oscillation of 1 cm to 3 cm as a result of the Southern Oscillation. The 1982-83 El Nino event apparently caused the sea level along the west coast of North America to be raised 20 to 30 cm above its normal level (Barnett, 1985).

The piling up of water in shallow shelf regions under continued wind stress was identified in the study of Easton & Radok (1970). This study of 3 years of hourly height records for 39 Australian tide gauges indicated the significance of winds in determining sea levels within the South Australia gulfs. It also indicated the strong influence of low pressure systems which caused surges of up to 90 cm.

Variations in temperature and rainfall will affect sea density and therefore sea level. In addition sea density is influenced by changes in salinity. These result from variable discharges from rivers and melting ice, and from salt rejection during sea ice formation (Robin de Q., 1986).

Manmade changes may also result in variations in RSL. Bird and Koike (1986) discuss the effects of changes to the configuration of enclosed and semi-enclosed areas. The Gippsland Lakes, the Venice Lagoon and Tokyo Bay are given as examples where the tidal range has been modified as a result of activities such as reclamation, dredging, breakwater and seawall construction. The extraction of water, oil and gas have already been discussed as activities resulting in subsidence of coastal margins.

Thus a significant number of factors other than a change in the volume of sea water may result in changes to RSL. Figure 3 indicates a concentration of the reliable tidal records in regions such as northern Europe and eastern North America which are known to be subject to tectonic change and also to manmade changes which are likely to result in variations to RSL. Therefore it is difficult to use this data to develop global trends.

5. THE GREENHOUSE EFFECT

There has been an increase in atmospheric CO_2 from 280-300 ppm in 1880 to 340 ppm in 1980 (Hansen et al, 1981). This is largely due to the combustion of fossil fuels although deforestation and cement production have also contributed to the increase. In addition, there has been an increase in trace gases including methane, nitrous oxide and chlorofluorocarbons. The atmospheric carbon dioxide and other gases absorb outgoing infrared radiation thus warming the earth's surface and the lower atmosphere. The warmer atmosphere is able to retain more moisture and the water vapour also absorbs the infrared radiation, resulting in increased warming. It has also been suggested that a further warming would result from the albedo effect with the melting of snow reducing reflection of sunlight (Hansen et al, 1981).

Some recent studies indicate an increase in global air temperatures of approximately 0.5°C between 1861 and 1984, with the 3 warmest years being 1980, 1981 and 1983 (Jones et al, 1986). Within this trend of increasing temperature there were fluctuations, in particular a slight cooling from 1940 to 1970. This suggests that factors other than an increase in carbon dioxide affect global temperatures. For example, solar luminosity variations and the effects of large volcanic eruptions may result in temperature changes (Hansen et al, 1981). Similar to the problems associated with tidal records, the assessment of global temperature trends is hindered by poor spatial coverage and unreliability of the data (Barnett, 1985). It should be noted that a recent study by the National Oceanic and Atmospheric Administration indicated no statistically significant trends in average temperature in the U.S. from 1895 to the present (New Scientist 4.4.89).

There are serious problems associated with climatic modelling and therefore with the prediction of temperature change. The 1987 Villach and Bellagio Workshops concluded that uncertainty resulted from:

- *'future patterns of fossil fuel use, rates of deforestation and other activities leading to GHG emissions;*
- *the response of the climate system to a given level of GHG emissions.'*

Stephen Schneider (1988) from the National Center for Atmospheric Research stressed the uncertainty of models attempting to predict local or regional climatic responses. *'The principal reasons for the uncertainty are two-fold: the crude treatment in climatic models of hydrological processes and the neglect of the effects of the deep oceans.'*

Even if the use of fossil fuels slows, it is possible that levels of carbon dioxide in the atmosphere will double over the next century, resulting in a temperature increase of 1.5°C to 4.5°C (Hansen et al, 1981). The joint UNEP/WMO/ICSU Conference at Villach (1985) suggested that this temperature range was most likely with the expected increase in the levels of carbon dioxide and other greenhouse gases.

5.1 Sea Level Changes

There have been many studies which have attempted to estimate the contribution of the warming over the past century to sea level rise and to estimate the rise in eustatic sea level which could result from the projected global warming. The studies suggest that three factors may cause a eustatic rise in sea levels:

- The expansion of ocean water;
- The melting of alpine and other small glaciers;
- The melting of the Greenland and Antarctic glaciers.

Wigley & Raper (1987) investigated the relationship between global mean temperature change as a result of the Greenhouse Effect and sea level rise due to thermal expansion of the oceans using upwelling diffusion and pure diffusion models. The study concluded that the contribution to sea level rise by thermal expansion of the oceans was 2 to 5 cm from 1880 to 1984. The forecast for the period 1985 to 2025 was 4 to 8 cm which was based on a predicted temperature rise of 0.6°C to 1.0°C. Gornitz et al (1982) had concluded that about half of their observed sea level change of approx. 10 cm from 1880 to 1980 was due to thermal expansion. It has been suggested however that oceanographic theory is not sufficiently well developed to give a clear understanding of the responses to temperature change of lower ocean levels or of patterns of water circulation (Robin de Q., 1986).

In addition to the thermal expansion of the oceans, the global warming may be causing a rise in RSL as a result of the melting of glaciers. Meier (1984) used data from 25 glaciers (all in the Northern hemisphere) and developed a model to suggest that the melting of all small glaciers and ice caps (excluding Antarctica and Greenland) contributed approximately one third to one half of the observed sea level rise since 1884 (2 to 7 cm). Meier forecast a sea level rise from ice melt of 8 to 25 cm in the next 100 years with an increase in temperatures from 1.5°C to 4.5°C. However the study suggests that there is no direct evidence that the melting which has occurred has been caused by the increased concentration of "greenhouse" gases. For example, the period from 1960 to 1975 was a period of significant increase in carbon dioxide levels but was also a period when the small glaciers were in balance.

The glaciers in temperate regions are thinning and receding more quickly than those in polar regions and the shrinkage is much less in areas of large ice cover (Meier, 1984). At least partly for this reason, the response of the Greenland and Antarctic ice sheets to temperature increase is not clear. It may even be that the warming may cause increased snowfall and therefore net ice sheet growth. For example it has been suggested that a global warming of 3.5°C could increase Antarctic accumulation by 10% to 25% above the present level. The Greenland ice sheet appears to be thickening in the centre and thinning on the margins although poor distribution of data make any estimate of change in mass difficult (Robin de Q., 1986).

It is also likely that the melting of a major ice sheet would not produce a uniform rise in sea level over the whole globe. The changed gravitational field due to the removal of the ice from land and the increased loading on the ocean basins would result in the viscous flow of material below the earth's crust and hence cause changes to the ocean's topography (Clarke et al, 1978).

These problems associated with the assessment of future sea level rises were identified at the workshop on sea level change and the Australian coastline (2-3 October 1989). The news release (CSIRO Division of Atmospheric Research, 1989) outlined a number of major uncertainties. These included:

- Future rates of emission of greenhouse gases since these are dependent on human decision making, population growth and economic growth.
- The amount of surface warming likely to result from increase in greenhouse gases. This is because the effects of changes in cloud cover are uncertain. It appears that an increase in low and middle level cloud would decrease warming but an increase in high level cirrus cloud would add to the warming.
- The mass balance of the Antarctic and Greenland ice sheets.

The above discussion indicates some of the difficulties in attempting to forecast the response of sea level to temperature increase. However it is interesting to note that if the projections of rise due to thermal expansion (Wigley and Rapier, 1987) and ice melt (Meier, 1984) are combined, the result is an approximate rise of 7.2 to 18 cms from 1985 to 2025, or 18 to 45 cms over the next century.

Some earlier studies suggested rises of a much greater magnitude over the next century. For example, Hoffmann et al (1983) predicted a rise of 13 to 55 cm by the year 2025 and 38 to 212 cms by 2075 by using models of global warming and thermal expansion. However accurate projections were not able to be made of the contributions of snow and ice melting to sea level. Titus et al (1984) note that Hoffmann concluded that the mid-range low scenario of 91.2 cm by 2075 was more likely than his mid-range high scenario. These predictions were revised in Hoffmann et al (1986) with the availability of glacial process models and new information on atmospheric concentrations. The revised estimates were for a rise of 10 to 21 cm by 2025, and 36 to 191 cm by 2075.

5.2 Climatic Change

As indicated above, there is considerable uncertainty associated with forecasts of global climatic change because of problems associated with climatic modelling.

However any increase in the earth's surface temperature as a result of the Greenhouse Effect would not necessarily be uniform and greater warming would be likely to occur at high latitudes and in the winter. The result of warming would be a change in atmospheric circulation and therefore a change in the distribution of climatic zones (Gordon, 1988).

It is possible that with an increase in sea surface temperature there will be a shift of tropical cyclones 200 to 400 km south (Hille, 1988). Buchan (1988) suggests that there is likely to be an increase in the areal extent of cyclones and in the duration of the season, but there may be a drecrease in the frequency of occurrence. However the trend of cyclone intensity cannot be predicted. If there is increased cyclone or storm activity in the south-west of Western Australia this will have implications for flooding because of increased storm surge and wave setup. However at present it does not appear possible to reliably predict local or regional climatic responses to the Greenhouse Effect. This is because available climatic models are not sufficiently complex (Schneider, 1988).

6. CONCLUSIONS

One of the major problems in attempting to assess whether sea level is rising is the fact that Relative Sea Level is affected by a combination of tectonic, oceanographic and meteorological factors which may be operating locally, regionally or globally.

There is no convincing evidence that RSL is rising on a global scale. The data obtained from tidal gauges are not adequately distributed and there are doubts associated with the reliability of most records. Similarly models developed to assess the relationship between temperature and sea level rise are dependent on poorly distributed land-based data. Knowledge of the dynamics of ice melting and of ocean circulation and heat uptake is incomplete and therefore it is not possible to use the models to determine conclusively changes over the past century or to forecast future changes.

Pirazzoli's (1986) study shows that of the reliable tidal data approximately 70% indicates some rise in RSL. The model developed by Meier (1984) indicated that the melting of the small glaciers contributed 2 to 7 cm to the rise in RSL over the past century. The models used by Wigley and Raper (1987) indicated a rise of 2 to 5 cm as a result of thermal expansion of the oceans over approximately the same period. The combination of these 2 sets of results gives a rise of 4 to 12 cm. Since this total does not include any contribution from the Greenland or

Antarctic ice sheets and does not allow the 2 cm per century which Gornitz et al (1982) take into account for long term isostatic rebound it is generally consistent with the results of the studies based on tidal records.

It is possible that sea level is rising globally, however the available evidence is not sufficient to prove this conclusively. There is certainly no evidence to suggest a dramatic increase in global sea level within the time frame of most engineering structures.

The world scientific community is at present engaged in extensive research in order to determine more precisely the effects of the accumulation of greenhouse gases. Until confident predictions of sea level and climatic change are available we believe it is appropriate to design coastal structures which allow for a sea level rise of approximately 30 cms.

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APPENDIX 2
LONG TERM MANAGEMENT OF ARTIFICIAL WATERWAYS
(by Cedar Woods Limited)

INTRODUCTION

Following careful examination of a Position Paper on Artificial Waterways Management adopted by Mandurah City Council on Tuesday 11th February 1992, Cedar Woods Limited have formulated a Management Strategy which we believe can be universally applied to all artificial waterways and canal estates currently under construction or proposed in the City of Mandurah.

Our development proposal for our Harbour City Project requires a clear management solution before rezoning can be implemented. We see our responsibility as a Developer to refine the Management Strategy, ensure that it is legally and administratively sound and most importantly that it fits in with Council's requirements for a solution to the current issues raised between the State Government and the Local Authority regarding management of artificial waterways.

EXECUTIVE SUMMARY

*** Management Structure based on joint State Government and Local Authority input with overall control being retained by Mandurah City Council.

*** Funding based on seed capital being provided by Developer, Specified Area Rates being levied against canal estate land owners.

*** Management Entity structure to include two Council Representatives, Department of Marine & Harbours Representative, PIMA Representative, Land Owners Representatives and Developer Representative.

*** Waterways Management responsibilities to include:

a) Water quality.
b) Silting of canals and/or entrance channels.
c) Canal walls and sea wall.
d) Foreshore management.
e) Groundwater quality.
f) Conservation area.
g) Public open space and landscaping areas.

*** Management Entity to prepare budgets for authorisation by Council, to plan and schedule the works, send invoices to Council for final approval and payment.

*** Management Entity to work very closely with Council and associated Government Agencies.

*** Reserve Fund to be established to ensure long term funding available for any substantial maintenance task that may arise in the future life span of the Canal Waterways Estate.

BACKGROUND

Cedar Woods Limited has conducted preliminary investigation into effective management plans conducted by the Gold Coast Shire Council and the Albert Shire Council; both located in Queensland; who currently have approximately 11,000 canal lots under their management. Further investigation has been made into canal estates in USA where long term management of canal waterways has been undertaken for more than 20 years.

Cedar Woods believe a systematic approach for waterways management, based on a joint effort by Government Departments, Land Owners and the Developer, all under the control and direction of the City of Mandurah is a satisfactory management solution which substantially conforms with the Position Paper adopted by Council.

Cedar Woods intends sending a representative to Gold Coast Shire Council and Albert Shire Council to further examine the working budgets prepared annually for waterways management; to further research their management system; to report back to the Company (and to Council) with a comprehensive report on waterways management. This will ensure a streamlined system is adopted here in Western Australia.

MANAGEMENT ENTITY

It is proposed that an advisory committee, known as the Management Entity for Harbour City Canal Subdivision be established. The Management Entity shall comprise of a group of representatives as follows:

- Two representatives from the City of Mandurah.
- One representative from Department of Marine & Harbours.
- One representative from the Peel Inlet Management Authority.
- One representative from Developer (until last lot sold).
- Two representatives from Canal Estate Land Owners.

The Management Entity shall be responsible for preparation of annual budgets to cover all anticipated management duties for artificial waterways. Budgets to be presented to the Finance Committee of Mandurah City Council for approval and subsequent endorsement by Full Council. The Management Entity to work in an advisory capacity to Council.

The Management Entity to ensure all management duties are carried out efficiently, within required time, that appropriate long term planning for maintenance of the artificial waterway is carried out annually, that management duties are kept within the costs defined in the approved budget, that actual costs incurred are authorised by the Management Entity and forwarded to Council for approval and payment.

MANAGEMENT ROLE & RESPONSIBILITY

Management duties shall include but not be limited to:

a) Water quality monitoring and protection.
b) Monitoring silting of canals and entrance channel. Dredging of canals as required.
c) Sea wall monitoring, maintenance and reconstruction if necessary.
d) Foreshore management and maintenance including dual use paths etc.
e) Groundwater monitoring.
f) Other general management and maintenance including jetties, signage, speed limits etc.
g) Conservation Area management, maintenance and protection.
h) Public Open Space areas and landscape feature areas maintenance and protection.

FUNDING

It is proposed that funding by provided by two methods:

1.a) Developer to contribute a sum of $200.00 per lot into a Reserve Fund established by Council specifically designated to each individual canal estate. Funds to be provided as each lot is sold and settled.

2.a) Specified Area Rating to be imposed on each canal waterfront lot annually by Council in the approximate sum of $200.00. Of this specific area rating amount, $100.00 (50%) to be allocated directly to the Reserve Fund.

b) The balance of Specified Area Rate, $100.00 (50%) to be applied directly to costs associated with performance of management duties.

It shall be the responsibility of Cedar Woods Limited (Developer) to ensure that all lot owners are advised prior to purchase of their allotment that a Specified Area Rate shall be imposed over each individual lot by Council annually at a rate subject to review and adjustment annually.

Attached to this report is an Indicative Cashflow Chart which relates to the growth of the Reserve Fund for the Harbour City Project. It comprises of contributions of $200.00 per lot by the Developer and $100.00 per lot annually extracted from Specific Area rates.

It is clear that as sales and development at Harbour City are completed the Reserve Fund will contain approximately $1.2M after 12 years. The Reserve Fund shall contain in excess of $4.6M after 25 years, which shall be specifically tied to Harbour City only. When Council considers the Reserve Fund has grown large enough, they may elect to stop levying or reduce the Specific Area Rate.

Cedar Woods Limited in conjunction with the City of Mandurah are currently obtaining legal advice on the exact process by which Specified Area Rates can be levied and those funds applied partially to ongoing management and the balance to the Reserve Fund linked to a particular Canal Estate. To ensure that the fundraising methods fall within the constraints of the Local Government Act; advice as to the exact system will shortly be obtained from each parties lawyers and a final management funding structure will then be adopted.

MANAGEMENT ENTITY BUDGETS AND APPROVALS

It is proposed that the Management Entity shall prepare budgets and management plans for the estate on an annual basis.

These budgets and management plans to be presented to the Finance Committee of Mandurah City Council for approval and subsequent endorsement by Full Council.

Following approval by Full Council, the Management Entity shall proceed to ensure that all management duties are carried out efficiently and on time. Any variation to the management plan in any one year shall be re-presented to the Finance Committee for approval prior to any expenditure being occurred.

The Management Entity shall act as an advisory committee to Mandurah Council and request all works to be undertaken in order that Council can issue work orders. This system provides for Council having total control over expenditure of funds not only through approval of budgets but also through final payments being approved by Council and directed to service subcontractors.

Annual costs of maintenance shall be covered by balance of differential rates of $100.00 (50%) to be raised each year from individual land owners. Funds available for maintenance annually are as follows:

i)	Year 1	$ 3,850
ii)	Year 2	$13,250
iii)	Year 3	$24,850
iv)	Year 4	$36,950
v)	Year 5	$49,050
vi)	Year 12	$83,600
vii)	Year 25	$83,600

{Note: these figures make no allowance for CPI escalation.}

It should be noted that during the first 12 years of the Harbour City development, Cedar Woods Limited (Developer) shall regularly engage contractors on site as each stage of the subdivision is constructed. This will ensure that management costs are kept to a minimum by utilizing the existing construction contractors and personnel already on site.

LEGAL POSITION

Underpinning this management system is an opinion from Northmore Hale Davy & Leake, a well qualified firm of lawyers who act for a number of Local Authorities throughout Western Australia. Their report demonstrates that funding of this management proposal is able to be accommodated within the requirements of the Local Government Act. In summary the opinion states:

Council has the power to collect:

(i) Specified Area Rates under Section 548(4)(c) of the Local Government Act.

(ii) Monies collected through Specified Area Rates must be paid into a separate and specific reserve fund to be used only for the purpose for which they are collected.

CANAL WALLS ADJACENT TO PRIVATE LOTS

It is extremely important to note that canal walls adjacent to private lots are contained within the boundary of each private lot. Therefore the maintenance requirement (after completion of defects liability periods by the construction contractor for developer) shall be the ongoing responsibility of individual lot owners.

CANAL ESTATE DEVELOPMENT GUIDELINES - DPUD

The Company is aware that DPUD has recently produced a new policy on canal estate developments. That policy requires Deeds of Agreement to be executed between the Developer and Council for a period of 5 years following practical completion of development stages.

The implementation of an effective management structure for each canal estate, as soon as practical completion is finalized and lots are beginning to be sold, will ensure the requirements of the Deed of Agreement between the Developer and Council are being dutifully carried out on a regular basis.

In fact; an effective permanent Management Strategy will facilitate the Deeds of Agreement between the Developer and Council are kept to a minimum in their complexity and that the funding required by the Developer by way of Bank Guarantees to ensure ongoing management performance will also be kept to a minimum. In this way the Developer will be in a position to provide cash payments of seed capital direct to the Reserve Fund.

CONCLUSIONS

This management system is universal, it can be equally applied to other artificial waterway developments. Stage I of Port Mandurah can be brought under the system in the meantime by Council commencing to apply Specified Area Rates in 1992/93. All residents were advised of the application of Differential Rates in the restrictive covenants at the time of purchase.

This is a comprehensive management solution. It is simple in its application and provides a solution in line with Council requirements.

1. The Developers will advise every purchaser from the outset that Specified Area Rates will apply to their land.
2. There is a strong commitment for seed capital from the Developer.
3. Council has overall control of the Management Entity and its expenditure without suffering any undue strain on existing staff resources.
4. Input of expertise from State Government Departments is included.

(END OF DOCUMENT)

ATTACHED: Appendix 1 - Indicative Cashflow Chart

HARBOUR CITY MANAGEMENT RESERVE FUND

Indicative Cashflow Chart

MANAGEMENT STRATEGY FOR ARTIFICIAL WATERWAYS

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Estimated Lot Selling Program		77	111	121	121	121	121	121	43	0	0	0	0
Cedar Woods Ltd contribution	$200	$15,400	$22,200	$24,200	$24,200	$24,200	$24,200	$24,200	$8,600	$0	$0	$0	$0
Rate contribution	$100	$3,850	$13,250	$24,850	$36,950	$49,050	$61,150	$73,250	$81,450	$83,600	$83,600	$83,600	$83,600
Total Contributions		$19,250	$35,450	$49,050	$61,150	$73,250	$85,350	$97,450	$90,050	$83,600	$83,600	$83,600	$83,600
RESERVE FUND													
Opening balance			$19,924	$58,009	$112,837	$184,025	$272,721	$380,149	$507,620	$636,355	$767,426	$907,672	$1,057,735
Contributions		$19,250	$35,450	$49,050	$61,150	$73,250	$85,350	$97,450	$90,050	$83,600	$83,600	$83,600	$83,600
Interest	7.00%	$674	$2,635	$5,777	$10,039	$15,446	$22,078	$30,021	$38,685	$47,471	$56,646	$66,463	$76,967
Closing Balance		$19,924	$58,009	$112,837	$184,025	$272,721	$380,149	$507,620	$636,355	$767,426	$907,672	$1,057,735	$1,218,302

		Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
Rate contribution	$100	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600
RESERVE FUND														
Opening balance		$1,218,302	$1,390,109	$1,573,943	$1,770,645	$1,981,116	$2,206,320	$2,447,288	$2,705,125	$2,981,009	$3,276,206	$3,592,066	$3,930,037	$4,291,666
Contributions		$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600	$83,600
Interest	7.00%	$88,207	$100,234	$113,102	$126,871	$141,604	$157,368	$174,236	$192,285	$211,597	$232,260	$254,371	$278,029	$303,343
Closing Balance		$1,390,109	$1,573,943	$1,770,645	$1,981,116	$2,206,320	$2,447,288	$2,705,125	$2,981,009	$3,276,206	$3,592,066	$3,930,037	$4,291,666	$4,678,608

Notes - Main Assumptions

1. The specific area rate of $200 per annum has been allocated equally between ongoing maintenance and accumulating reserve fund. For the calculation of the contribution to the reserve fund it has been assumed that 50% of the rates will be received in the first year the property is sold.

2. Interest has been charged on contributions assuming that the funds will be contributed equally during the year.

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 12	Year 25
Funds available for annual maintenance	100.00%	$3,850	$13,250	$24,850	$36,950	$49,050	$83,600	$83,600

GOLD COAST CITY COUNCIL - CANAL WATERWAYS MAINTENANCE

The Gold Coast City Council has a budget of $380m per annum for the entire City. In terms of the Engineering Department costs were allocated as follows:

- general maintenance works $45m per annum
- capital improvement works $32m per annum.

Gold Coast City Council has 5,000 canal lots allocated approximately as follows:

- sandy beach front lots	3,500
- rocky beach front lots	700
- canal wall panel lots	800

	5,000

Canal wall panel lots currently exist at Runaway Bay Development and Sovereign Island. Sovereign Island has approximately 300 waterfront lots. Runaway Bay has approximately 500 waterfront lots.

Significant problems with canal wall panel construction has been experienced over the last 10 years, Mr Peter Hill has written a thesis for his Masters in Engineering on canal wall panel lots. A summary of that thesis is attached to this report.

The Gold Coast City Council has resolved that every 3-4 years beach replenishment to every canal waterfront lot with a sandy beach frontage shall be carried out.

The Canals Act promulgated by Queensland Parliament deems that Gold Coast City Council is entitled to levy Special Area Ratings over the canal waterfront lots but this has never been implemented by Council.

Maintenance programs are directed by the Senior Engineer operating in the Foreshore Protection Department and are always based on field investigation reports which include hydrographic surveys to ensure that navigation channels are always maintained and the scouring adjacent to canal walls is identified early to be included in a priority sand replenishment program. Hydrographic surveys are carried out by utilising a geodometer reflector on a wetbike mounted with an echo sounder. A surveyor operating the geodometer from the shoreline correctly fixes the position of the bike/echo sounder and the depth of the canal is then plotted on an echo sounding chart. A colour photocopy of the wetbike set up is attached to this report.

Beach replenishment programs which generally involve the replacement of sand in front of all canal waterfront lots by dredging sand out of the canal channel itself and replacing approximately a 500mm cover at a 1"-7" slope over a distance of 3-5m in front of each canal lot. This work is carried out by a 6" intake 4" discharge dredge utilising a cyclone to deliver the sand on the shoreline. It is a two man operation carried by contractors at a cost $53.00 per hour. A full report on the dredge set up and operation is detailed in a separate section.

It should be noted that with beach replenishment carried out on a 3 year cycle a dredge operating at a cost of $53.00 per hour is able to comfortably complete sand replacement in front of 4 lots per day operating for 8 hours. This produces a cost of approximately $120 per lot (with overheads). It must be noted that this cost is only incurred on a 3-4 yearly cycle for each lot. However where retrievable sand supply is scarce these costs per lot will increase marginally.

Rubbish and debris collection is carried out by a contractor from an aluminium dinghy using scoop nets. After heavy seasonal rains is the busiest period for rubbish removal. Contractors are on a charge out rate of $25.00 per hour and work approximately 20 hours per week for the year.

GOLD COAST CITY COUNCIL MAINTENANCE PROGRAM

Annual maintenance programs cover the following areas:

1. beach replenishment (sand replacement)

2. siltation removal from canals

3. desilting stormwater outlets (apron in front of pipe outlet into canal)

4. reed and weed growth removal

5. litter and debris removal.

Item 2, siltation removal includes mooring envelopes around jetties and pontoons and also maintaining navigation channels including the entrance to each canal estate.

Gold Coast City Council spends $400,000 per annum on canal maintenance to complete the five above listed maintenance tasks, the following expenditure is incurred:

1. navigation channel dredging $80,000 per annum
2. rock work replacement $80,000 per annum
3. reed and weed removal $30,000 per annum
4. litter removal $20,000 per annum
4. dredging and beach sand replenishment $170,000 per annum
5. stormwater drain apron clearoff $10,000 per annum.

Of a total of 5,000 canal lots in Gold Coast City this equates to an average cost of $80.00 per lot per annum.

Currently, Gold Coast developers creating canal lot subdivisions are required to sign a 2 year maintenance responsibility agreement with the Council. Council has recently moved to increase the maintenance responsibility agreement to a 5 year period. Peter Hill advises the most critical factor in ensuring that canal wall panels have no maintenance problems is to be absolutely certain that the geotextile fabric positioned behind the canal wall panel is placed in the correct position and does not move during compaction. Hydrostatic pressure following heavy rain puts pressure on the rear of walls, if the filter cloth is not correctly in position the opportunity for piping to occur is significant (refer thesis summary).

Hill advises that sand movement occurring throughout the canal waterways is generally associated with wave action. Wave action hitting the beaches stirs up the sand putting it into suspension from which it is then transported throughout the canal waterways.

A current project under construction on the Gold Coast is the Hope Island Project which has utilised canal wall panels and will not have sandy beach fronts. The developers of Hope Island are expending the sum of $1,600 per lineal metre for wall panel, this does not include ancillary works for compaction behind the walls.

The consulting engineers to the Hope Island project are Burchill, Stone, Buntine and Partners. The project is being handled by Graham Buntine and John Bate who is the Senior Project Engineer. Phone number on the Gold Coast is 075-383 411. Burchill and Partners are also the consulting engineers to the Sovereign Islands Project.

It should be noted that Hope Island is using a new canal wall panel system which involves key and slot joints between canal wall panels and geotextile fabric silicone sealed either side of the wall panel joint with sufficient allowance for expansion and contraction of the wall panel joints. It should be noted that on Sovereign Island where poor soil conditions were experienced some wall panels were piled with timber poles. A poured concrete footing over the top of the timber poles and wall panel standing on top of the footings.

In all instances on the Gold Coast the lot boundary includes the actual wall panel which is not therefore part of council's maintenance program. 90% of the projects have a lot boundary being the water face front of the canal wall panels. Two developments, the older style with beach fronts; includes ownership of 1.8m of the beach front.

In keeping with the critical factor of geotextile placement, the highest maintenance difficulties experienced occur after very heavy rain where hydrostatic pressure behind the walls builds up significantly and wall failure occurs during an excessive surcharge on the rear of the wall and transport of sand either through the weep holes or joints where geotextile fabric is not in place or piping of sand occurs underneath the footing and out below the base of the wall causing scouring and wall failure.

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Date: 7th April 1992
reference: 737/1/1
reference:
Contact: Mr P Hill
Telephone: 319 263

For the Attention of N. J. Perrignon

Dear sir

CANAL MAINTENANCE - GOLD COAST CITY COUNCIL

Further to your letter of the 2nd April, 1992 I advise that I am in agreement with your report which satisfactorily outlines Gold Coast City Council's Annual Canal Maintenance programme.

The facts and figures contained within reflect a reasonable assessment of the basic expenditure currently being experienced by this Council.

Yours faithfully

P. Hill

for (R.H. Brown)
TOWN CLERK

PH/CG

APPENDIX 3
CHECKLIST OF THE VASCULAR FLORA
HARBOUR CITY PROJECT SITE
(by E.M. Goble-Garratt)

CHECKLIST OF THE VASCULAR FLORA HARBOUR CITY PROJECT SITE.

(by E.M. Goble - Garratt)

Note: Nomenclature follows Green (1985) or Marchant et al (1987). The checklist is the result of opportunistic survey, with effort concentrated on the Samphire flats and on the areas supporting the sedge or Melaleuca/Casuarina communities. A total of 92 species were identified from the site of which 31 were introduced exotics. The 25 (15 native and 10 exotic) species indicated by "S" are found on the Samphire flats, along the present shoreline, or on the two small islands of higher ground on the west and south-west of the Samphire area.

* = introduced taxon.

FAMILY ZAMIACEAE.

Macrozamia riedlei

FAMILY JUNCAGINACEAE.

Triglochin striata

FAMILY POACEAE.

*Avena barbata	S
*Briza maxima	
*Briza minima	
*Cynodon dactylon	
*Eragrostis curvula	
*Ehrharta calycina	
*Lagurus ovatus	S
*Polypogon monspeliensis	S
*Rhynchelytrum repens	
Sporobolus virginicus	S

FAMILY CYPERACEAE.

Bolboschoenus caldwellii	
Gahnia trifida	
Isolepis cernua	
Isolepis nodosa	S
Lepidosperma longitudinale	

FAMILY RESTIONACEAE.

Leptocarpus sp.
Lepyrodia sp.
Loxocarya cinerea

FAMILY JUNCACEAE.

Juncus krausii	S
Juncus pallidus	

FAMILY XANTHORRHOEACEAE.

Xanthorrhoea preisii

FAMILY PHORMIACEAE.

Dianella revoluta

FAMILY ANTHERICACEAE.

Arthropodium capillipes
Tricoryne elatior

FAMILY IRIDACEAE.

*Romulea sp.	S
*Watsonia bulbillifera	

FAMILY CASUARINACEAE.

Allocasuarina fraseriana	
Casuarina obesa	S

FAMILY PROTEACEAE.

Banksia attenuata
Banksia grandis

FAMILY LORANTHACEAE.

Nuytsia floribunda

FAMILY POLYGONACEAE.

Muehlenbeckia adpressa		
*Polygonum aviculare	S	
*Rumex acetosella		
*Rumex pulcher		S

FAMILY CHENOPODIACEAE.

Atriplex hypoleuca		
Atriplex prostrata	S	
Halosarcia halocnemoides	S	
Halosarcia indica ssp. bidens	S	
Halosarcia pergranulata	S	
Halosarcia syncarpa		S
Halosarcia sp.(undescribed species)	S	
Rhagodia baccata		
Sarcocornia blackiana	S	
Sarcocornia quinqueflora	S	
Suaeda australis	S	

FAMILY AIZOACEAE.

*Carpobrotus edulis		S
*Tetragonia decumbens	S	

FAMILY BRASSICACEAE.

*Cakile maritima	S	

FAMILY MIMOSACEAE.

Acacia cyclops
Acacia pulchella
Acacia saligna

FAMILY PAPILIONACEAE.

*Cytisus proliferus
Hardenbergia comptoniana
Jacksonia furcellata
Jacksonia sterbergiana
*Lupinus sp.

*Trifolium arvense
Viminaria juncea

FAMILY GERANIACEAE.

*Pelargonium capitatum

FAMILY TREMANDRACEAE.

Tetratheca sp.

FAMILY EUPHORBIACEAE.

*Euphorbia terracina

FAMILY MALVACEAE.

Lawrencia spicata S

FAMILY DILLENIACEAE.

Hibbertia hypericoides
Hibbertia racemosa

FAMILY FRANKENIACEAE.

Frankenia pauciflora S

FAMILY THYMELAEACEAE.

Pimelea sp.

FAMILY MYRTACEAE.

Eucalyptus calophylla
Eucalyptus gomphocephala
Eucalyptus rudis
Kunzea ericifolia
Melaleuca cuticularis
Melaleuca hamulosa
Melaleuca raphiophylla

FAMILY APIACEAE.

*Hydrocotyle bonariensis
Trachymene coerulea

FAMILY EPACRIDACEAE.

Leucopogon propinquus

FAMILY PRIMULACEAE.

Samolus repens

FAMILY SOLANACEAE.

*Solanum nigrum
*Solanum sodomaeum

FAMILY OROBANCHACEAE.

*Orobanche minor

FAMILY LOBELIACEAE.

Lobelia alata

FAMILY GOODENIACEAE.

Scaevola thesioides

FAMILY ASTERACEAE.

*Aster subulatus S
*Centaurea melitensis
*Conyza sp.
Cotula coronopifolia
*Hypochaerus glabra
Olearia axillaris

APPENDIX 4
WATERBIRD SURVEY DATA
(by AR & MJ Bamford Consulting Ecologists)

Table 1. Waterbird records from RAOU data, presenting the sum of maximum counts for all Peel Inlet sites (including Creery Marshes) and Creery Marshes separately, obtained in the period 1981-1988. The maximum counts on Creery Marshes are also expressed as the percentage of the maximum total count for Peel Inlet for each species (in parenthesis). Species subject to international conservation treaties are marked with an asterisk.

Species	Peel Inlet	Creery Marshes	
Great Crested Grebe	40	-	
Hoary-headed Grebe	975	-	
Australasian Grebe	6	2	(33.3)
Australian Pelican	919	100	(10.9)
Darter	70	8	(11.4)
Great Cormorant	209	12	(5.7)
Pied Cormorant	1198	258	(21.5)
Little Black Cormorant	1422	100	(7.0
Little Pied Cormorant	1647	405	(24.6)
Pacific Heron	1	-	
White-faced Heron	258	52	(20.2)
Great Egret*	218	30	(13.8)
Cattle Egret*	1	-	
Little Egret	33	21	(63.6)
Rufous Night Heron	1	-	
Glossy Ibis	4	1	(25.0)
Australian White Ibis	51	17	(33.3)
Straw-necked Ibis	290	9	(3.1)
Royal Spoonbill	9	1	(11.1)
Yellow-billed Spoonbill	117	52	(44.4)
Black Swan	2559	120	(4.7)
Australian Shelduck	6767	500	(7.4)
Pacific Black Duck	3450	200	(5.8)
Grey Teal	10408	951	(9.1)
Chestnut Teal	4	-	
Australasian Shoveler	1510	10	(0.7)
Pink-eared Duck	200	-	
Hardhead	11	-	
Maned Duck	4	-	
Blue-billed Duck	1200	-	
Musk Duck	150	-	
Osprey	5	2	(40.0)
White-bellied Sea-Eagle	3	1	(33.3)
Marsh Harrier	3	1	(33.3)
Australasian Crake	1	1	(100.0)
Spotless Crake	2	-	
Eurasian Coot	118	-	
Pied Oystercatcher	65	60	(92.3)
Grey Plover*	657	600	(91.3)
Lesser Golden Plover*	85	85	(100.0)
Hooded Plover	1	-	
Mongolian Plover*	4	4	(100.0)

Table 1 (cont.).

Species	Peel Inlet	Creery Marshes	
Large Sand Plover*	30	15	(50.0)
Red-capped Plover	1445	223	(15.4)
Black-fronted Plover	6	1	(16.7)
Black-winged Stilt	3693	340	(9.2)
Banded Stilt	20481	9000	(43.9)
Red-necked Avocet	3077	101	(3.2)
Ruddy Turnstone*	13	-	
Eastern Curlew*	25	11	(44.0)
Whimbrel*	12	7	(58.3)
Grey-tailed Tattler*	15	5	(33.3)
Common Sandpiper*	32	2	(6.2)
Greenshank*	528	200	(37.9)
Terek Sandpiper*	13	7	(53.8)
Marsh Sandpiper*	289	284	(98.3)
Redshank	1	1	(100.0)
Bar-tailed Godwit*	2078	500	(24.1)
Black-tailed Godwit*	1	1	(100.0)
Red Knot*	654	100	(15.3)
Great Knot*	986	850	(86.2
Sharp-tailed Sandpiper*	4517	2381	(52.7)
Pectoral Sandpiper*	5	2	(40.0)
Red-necked Stint*	11371	3246	(28.5)
Long-toed Stint*	8	-	
Sanderling*	12	10	(83.3)
Curlew Sandpiper*	4808	2000	(41.6)
Broad-billed Sandpiper*	1	1	(100.0)
Ruff*	2	1	(50.0)
Silver Gull	5545	1000	(18.0)
Whiskered Tern	1107	200	(18.1)
White-winged Tern*	5	-	
Gull-billed Tern	14	6	(42.9)
Caspian Tern*	106	7	(6.6)
Common Tern*	9	-	
Roseate Tern	20	-	
Fairy Tern	94	15	(16.0)
Crested Tern	129	22	(17.1)
Little Grassbird	22	18	(81.8)
Clamorous Reed-Warbler	3	-	
Unidentified grebes	313	200	(63.9)
Unidentified ducks	17000	2000	(11.8)
Unidentied stilts	3000	-	
Unidentified terns	400	-	
Unidentified waders	3470	1000	(28.8)
TOTAL	120016	27360	(22.8)

Table 2. Waterbird records from Ninox data, presenting the sum of all counts for all Peel Inlet sites (including Creery Marshes) and Creery Marshes separately, obtained in the period November 1988 to December 1989. The counts on Creery Marshes are also expressed as the percentage of the total count for Peel Inlet for each species (in parenthesis). Species subject to international conservation treaties are marked with an asterisk.

Species	Peel Inlet	Creery Marshes	
Great Crested Grebe	3	-	
Hoary-headed Grebe	80	-	
Australasian Grebe	142	-	
Australian Pelican	718	88	(12.3)
Darter	171	1	(0.6)
Great Cormorant	133	5	(3.8)
Pied Cormorant	41	5	(12.2)
Little Black Cormorant	1686	13	(0.1)
Little Pied Cormorant	2098	371	(17.7)
White-faced Heron	722	115	(15.9)
Great Egret*	340	57	(16.8)
Little Egret	78	22	(28.2)
Rufous Night Heron	1	-	
Australian White Ibis	119	23	(19.3)
Straw-necked Ibis	3	-	
Royal Spoonbill	4	2	(50.0)
Yellow-billed Spoonbill	244	46	(18.9)
Black Swan	489	193	(39.5)
Australian Shelduck	3113	460	(14.8)
Pacific Black Duck	1920	253	(13.2)
Mallard (domestic duck)	8	-	
Grey Teal	4238	1146	(27.0)
Chestnut Teal	2	-	
Australasian Shoveler	21	-	
Pink-eared Duck	112	-	
Hardhead	43	-	
Maned Duck	11	-	
Blue-billed Duck	5	-	
Musk Duck	215	-	
Osprey	13	3	(23.1)
Marsh Harrier	8	1	(12.5)
Australasian Crake	1	-	
Spotless Crake	4	-	
Dusky Moorhen	1	-	
Eurasian Coot	1536	-	
Pied Oystercatcher	11	5	(45.5)
Grey Plover*	82	66	(80.5)
Red-capped Plover	297	26	(8.8)
Black-fronted Plover	20	-	
Black-winged Stilt	1503	862	(57.4)
Banded Stilt	722	722	(100.0)

Table 2 (cont.).

Species	Peel Inlet	Creery Marshes	
Red-necked Avocet	1400	11	(0.1)
Eastern Curlew*	6	6	(100.0)
Whimbrel*	6	-	
Ruddy Turnstone*	1	1	(100.0)
Common Sandpiper*	16	-	
Greenshank*	987	246	(24.9)
Marsh Sandpiper*	8	-	
Terek Sandpiper*	3	-	
Bar-tailed Godwit*	251	247	(98.4)
Great Knot*	35	-	
Sharp-tailed Sandpiper*	257	41	(16.0)
Red-necked Stint*	261	58	(22.2)
Curlew Sandpiper*	165	6	(3.6)
Silver Gull	2304	464	(20.1)
Whiskered Tern	1	-	
Caspian Tern*	101	-	
Fairy Tern	9	9	(100.0)
Crested Tern	22	-	
Little Grassbird	117	8	(6.8)
White-fronted Chat	74	38	(51.4)
Unidentified grebe	3	-	
Unidentified duck	23	-	
TOTAL	26729	5620	(21.0)

44

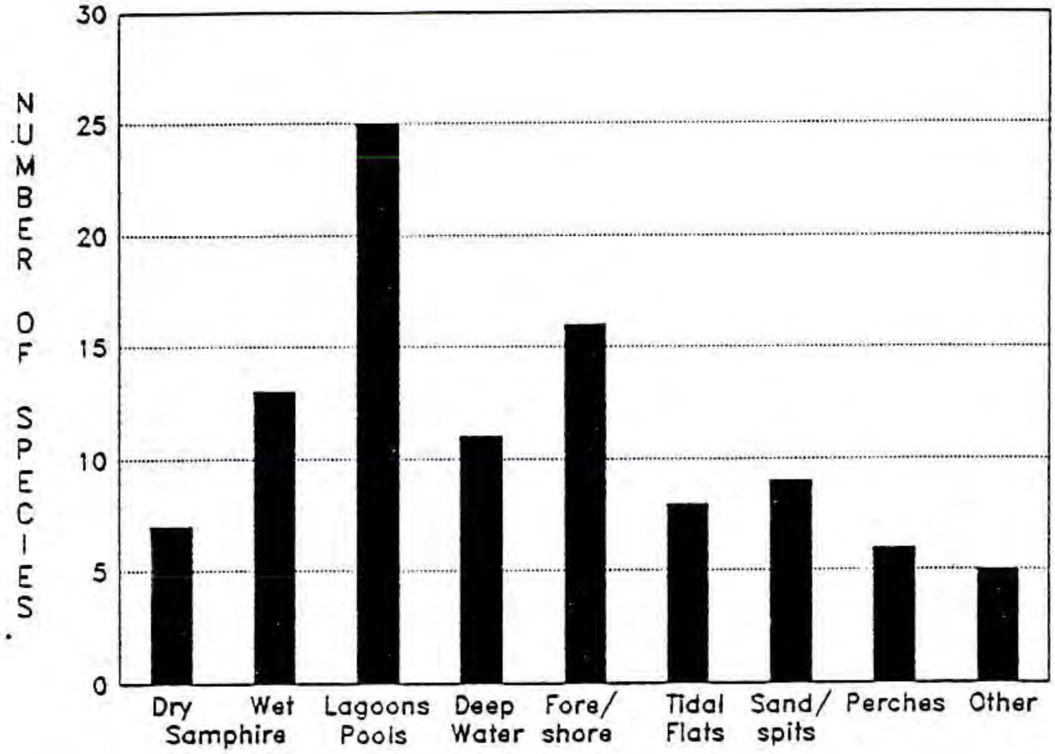


Figure 1a. Number of waterbird species recorded in each habitat type in the Creery Marshes (Ninox Wildlife Consulting unpub. data).

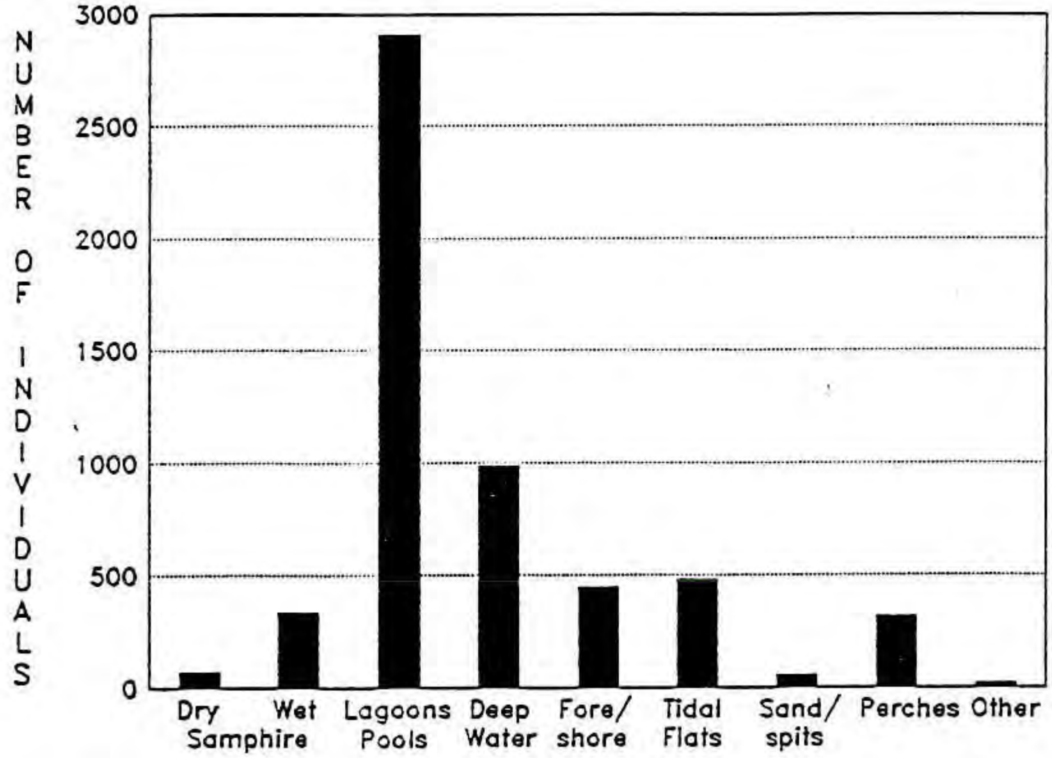


Figure 1b. Number of waterbirds recorded in each habitat type in the Creery Marshes (Ninox Wildlife Consulting unpub. data).

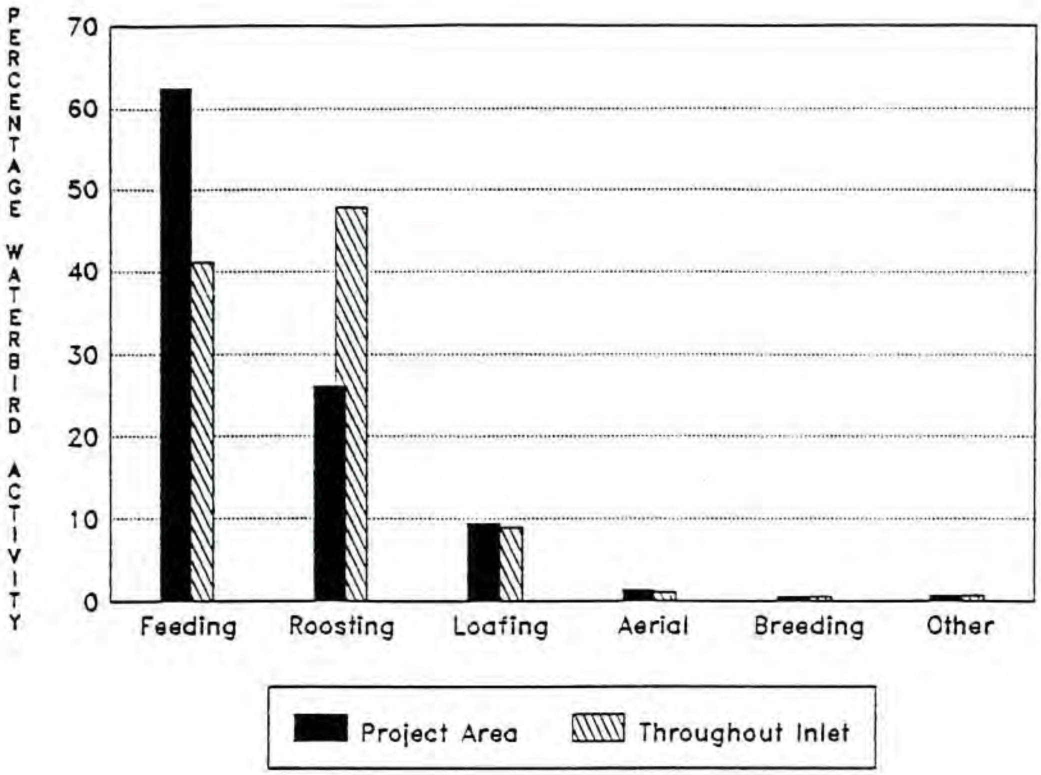


Figure 2. Waterbird activity patterns in Creery Marshes and throughout the northern Peel Inlet (Ninox Wildlife Consulting unpub. data).

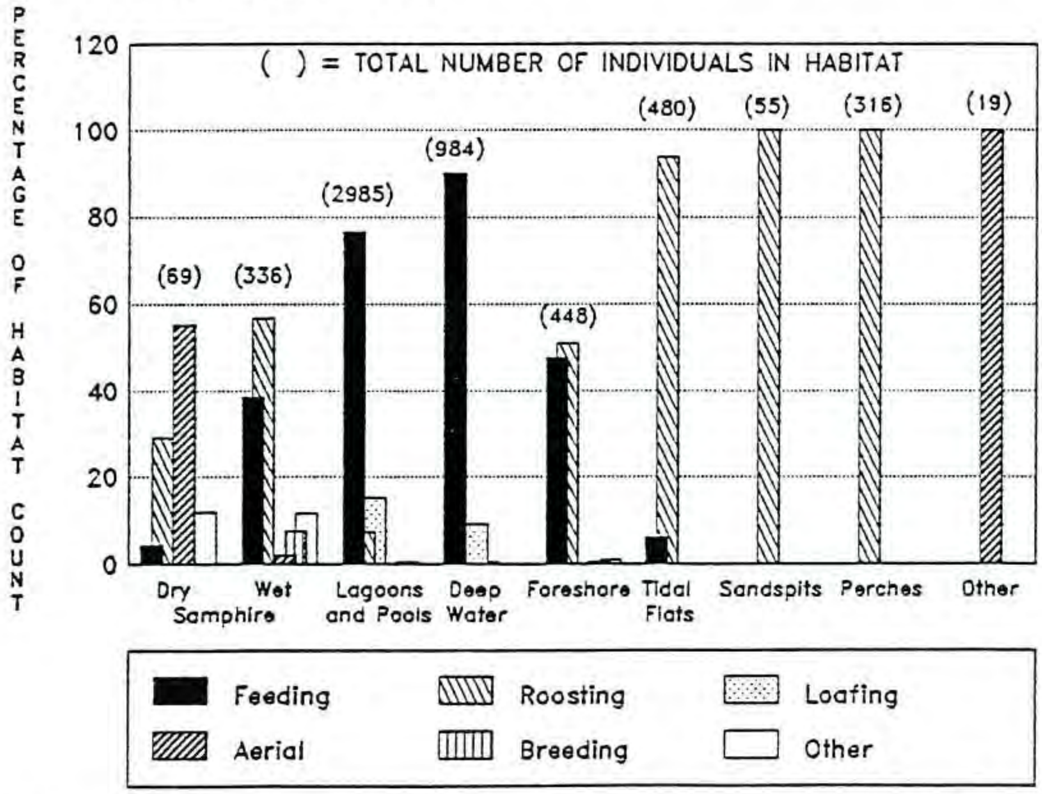


Figure 3. Waterbird activities in each habitat type in the Creery Marshes (Ninox Wildlife Consulting unpub. data).

SITE VISIT TO CREERY MARSHES 10/02/92
(by AR & MJ Bamford Consulting Ecologists)

Although the assessment of the significance of the project areas for waterbirds was based on available data and the consultant was familiar with the site, a visit was made to the area on February 10. As a result of record rainfall several days before and a high tide, the samphire flat was completely inundated and was utilised by waterbirds to an extent not previously recorded (see Table A). Most of the birds were loafing ducks which were present at greater densities than on the adjacent Creery Lagoon. Waders subject to international conservation treaties occurred mainly on Creery Lagoon.

It was noted in Section 4.4 (above) that the samphire flat might be used by waterbirds whenever it became inundated and could be significant for waterbirds if regularly flooded in summer. Therefore, the large numbers of birds observed on this visit were not unexpected. What is not clear is the significance of this result. The data from Ninox Wildlife Consulting were collected on 9 visits spread over more than a year. It may be a matter of chance that large numbers of waterbirds were not observed on the samphire flat during these surveys. RAOU data were not sufficiently specific to determine if some of the very large counts (up to 17,000 waterbirds) included large numbers of birds on the samphire flat. Waterbirds move very quickly in response to changing conditions and water levels can change very quickly on low-lying sites such as the samphire flat of the project area.

If detailed tidal records are available, it might be possible to predict the frequency of inundation of the samphire flat and thereby determine the frequency of significant waterbird usage of it. For example, in the last three summers, heavy rains occurred in February 1990 and February 1992. If summer flooding of the site regularly occurs at this frequency the waterbird usage as observed on February 10, 1992 is normal during such events, then the value of the site for waterbirds may be greater than was suggested by previously existing data. Factors such as the duration of the flooding and associated waterbird usage are also important.

Table A Waterbird counts on Creery Lagoon and the samphire flat within the development area on February 10, 1992. Numbers were conservatively estimated only and it is unlikely that all species were recorded. Species subject to international conservation treaties are marked with an askerisk.

Species	Creery Lagoon	Samphire Flat
Little Egret	3	-
Australian White Ibis	-	50
Straw-necked Isis	-	1
Australian Shelduck	400	30
Pacific Black Duck	300	100
Grey Teal	1500	650
Spotless Crake	4	-
Grey Plover *	10	1
Red-capped Plover	200	-
Black-winged Stilt	200	100
Greenshank *	50	10
Sharp-tailed Sandpiper	500	50
Red-necked Stint *	800	-
Curlew Sandpiper *	100	50
Little Grassbird	10	-
White-fronted Chat	20	-
TOTAL	4097	1042

APPENDIX 5
HYDROGEOLOGICAL ASSESSMENT OF PROPOSED HARBOUR CITY CANAL ESTATE
(by Dames & Moore)

HYDROGEOLOGICAL ASSESSMENT OF
PROPOSED HARBOUR CITY CANAL ESTATE

for

Cedar Woods Limited

Dames & Moore Job No. 23917-001-074

March 1992

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

HYDROGEOLOGICAL ASSESSMENT OF PROPOSED HARBOUR CITY CANAL ESTATE

1.0 INTRODUCTION

1.1 BACKGROUND

Esplanade Mandurah Pty Ltd propose to develop the Harbour City canal estate on the eastern side of the Mandurah Channel (Figure 1). The project involves the development of single residential canal and dry allotments fronting onto a network of canals including a tourist development and village centre. The proposed development is located on the same site as Stage II "Waterside Mandurah" originally proposed by John Holland Construction.

Dames & Moore were commissioned in December 1991 to address the hydrogeological aspects of the Harbour City development as part of the Planning and Environmental Report.

The aims of this report are:

- to characterise the hydrogeological environment prior to canal construction;
- to define the position of the saltwater interface and assess the available monitoring data to determine seasonal groundwater level fluctuations due to variations in recharge either from rainfall or progressive urbanisation;
- to identify potential environmental impacts during the construction and operational phase of the development;
- to recommend strategies that will minimise these impacts during the construction and post-construction phases;
- to identify areas where further work is required; and
- to prepare guidelines for ongoing management of the groundwater resource including design of a monitoring network.

Figure 1 shows the location of all investigation and observation bores in the existing Waterside Mandurah and proposed Harbour City developments.

1.2 PREVIOUS REPORTS AND STUDIES

Twelve exploratory bores (Nos. M1-M12) were drilled in September-October 1981, to investigate the stratigraphy of and groundwater quality in the superficial formations in the vicinity of the then-proposed Waterside Mandurah canals project. An inventory of private bores in the adjacent Dudley Park residential area was also compiled from Geological Survey of Western Australia (GSWA) records.

Five observation bores (Nos. OB1-OB5) were construction in November 1981, on the inland side of the Waterside Mandurah site. Another six observation bores (Nos. OB6-OB11) were installed in April 1985, but only two of them (Nos. OB6 and OB8) remain, the others being destroyed during construction. Another four observation bores (Nos. OB12-OB15) were installed in mid-1986. Several of the original bores have been replaced at various times, following damage or destruction due to vandalism or building construction. These replacement bores are designated A (first replacement) or B (second replacement).

Monthly monitoring of groundwater levels and electrical conductivity commenced in selected domestic bores in Dudley Park in December 1981, and the Waterside Mandurah observation bores were included in this programme from January 1985.

Monitoring frequency was increased to weekly measurements between October 1985 and September 1986, covering the period of canal construction and dewatering for the Waterside Mandurah development.

Nine observation bores (Nos. OB20-OB28) were constructed in April 1987 to investigate the stratigraphy and groundwater quality of the superficial formations in the vicinity of Harbour City. This site is the same as the former Stage II Waterside Mandurah project area.

Monitoring of domestic bores was discontinued in June 1988 and monitoring frequency in the observations bores for both Waterside Mandurah and Harbour City was decreased to quarterly measurements from September 1988.

Relevant reports on hydrogeological investigations at the Waterside Mandurah and Harbour City sites and previous annual aquifer reviews are listed below:

Waterside Mandurah

1. Reconnaissance Hydrogeological Investigation, Waterside Canal Project, Mandurah, for John Holland (Construction) Pty Ltd. (October 1981)

2. Waterside Mandurah, Proposals for Waterfront Living, Vols. 1 and 2, Environmental Review and Management Programme by John Holland (Constructions) Pty Ltd. (January 1982)

3. A General Summary of the Hydrogeology of the Waterside Development, Mandurah for John Holland Construction Pty Ltd. (June 1986)

4. Groundwater Annual Performance Review of the Waterside Mandurah Development for John Holland Construction Pty Ltd, June 1987. (July 1987)

5. Groundwater Annual Performance Review of the Waterside Mandurah Development for John Holland Construction Pty Ltd, June 1987 to June 1988. (July 1988)

6. Groundwater Annual Performance Review of the Waterside Mandurah Development for John Holland Construction Pty Ltd, June 1988 to June 1989. (August 1989)

7. Review of Groundwater Monitoring at Waterside Mandurah to June 1990 for John Holland Pty Ltd. (August 1989)

8. Review of Groundwater Monitoring for the Stage I development at Waterside Mandurah to June 1991 for John Holland Pty Ltd. (July 1991)

Harbour City

1. Preliminary Geotechnical Investigation, Waterside Mandurah Stage II by Soil and Rock Engineering Pty Ltd. (May 1987)

2. Hydrogeological Investigation of the Stage II Waterside Mandurah Development for John Holland Pty Ltd. (November 1988)

3. Review of Groundwater Monitoring at Waterside Mandurah to June 1990 for John Holland Pty Ltd. (August 1990)

4. Review of Groundwater Monitoring for Stage II Development at Waterside Mandurah to June 1991 for John Holland Pty Ltd. (July 1991)

2.0 PHYSICAL ENVIRONMENT

2.1 RAINFALL AND EVAPORATION

Rainfall and evaporation figures were obtained from the Bureau of Meteorology for comparison with observed fluctuations in groundwater levels. The nearest recording stations are Mandurah for rainfall and Perth for evaporation.

Annual rainfall totals are tabulated in Table 1 together with winter rainfall surplus. Approximately 90% of the rain occurs between April and October, but rainfall only exceeds evaporation (when direct aquifer recharge can occur) between May and August. The winter rainfall surplus is the aggregate excess of rainfall over evaporation for the winter months May to August or June to August (excluding May in those years in which May evaporation exceeds rainfall). Monthly totals for rainfall and evaporation from 1983 onwards are appended as graphs (Appendix A).

TABLE 1

RAINFALL AND WINTER RAINFALL SURPLUS

Year	*Total Rainfall (mm)*	*Winter Rainfall Surplus (mm)*
1984	934	355
1985	857	328
1986	796	324
1987	703	224
1988	919	252
1989	953	362
1990	807	215
1991	1,057	463
Annual Average	878	316

Annual rainfall totals for 1991 were significantly above average with a corresponding 50 percent increase in winter rainfall surplus over the same period.

2.2 GEOLOGY

The area is underlain by superficial formations, which are generally about 10m thick and consist of sand, calcarenite and clay. The superficial formations unconformably overlie the Leederville Formation, which is composed of silty claystone and silty sandstone.

From northwest to southeast along the eastern boundary, the superficial formations show a general transition from calcarenite to sand and then to sandy clays and clayey sands (Figure 2). There is an abrupt lithological change in the vicinity of M9/OB2 which may relate to post-depositional erosion of the calcarenite and subsequent infilling with sand.

From west to east the superficial formations grade from calcarenite to sand to sandy clay (Figure 3). The sand is laterally extensive under most of the eastern position of the site east of bore OB22. This is confirmed by detailed drilling undertaken by Soil and Rock Engineering in 1987. The sands and sandy clay are overlain by a sequence of dune sands which thin towards the west. The distribution of the calcarenite and sands are an important factor to be considered in the design of the dewatering system.

The calcarenite consists of calcite-cemented quartz sandstone, which is generally friable, but contains some hard bands of limestone. The sands are generally medium-grained, subrounded to rounded, and contain shell fragments in places, as do the clayey sands and sandy clays.

The unconformity between the superficial formations and the Leederville Formation slopes to the west, from about 0m AHD at bore OB25 to -10m AHD at bore OB21. The contact is difficult to define in some bores, as the upper part of the Leederville Formation is probably reworked in places. It appears to be fairly regular, however, with a local basement high in the vicinity of bore M12 and a local depression or channel in the vicinity of bore M7/OB5 (Figure 2).

Over most of the area the Leederville Formation consists of dark grey micaceous silty claystone, which weathers to a variegated micaceous clay. In the central and eastern part of the area the Leederville Formation is composed of silty sandstone (bores M8, M9, OB20 and OB23). This may represent a channel feature within the Leederville Formation or a reworked deposit.

2.3 HYDROGEOLOGY

2.3.1 Aquifer Systems

Groundwater is present in two aquifer systems namely:

- the calcarenite, sands and clayey sands of the unconfined superficial formations; and
- the silty sandstone of the underlying confined Leederville Formation.

The upper part of the Leederville Formation comprises thick micaceous siltstones with occasional sandstone units. Generally, this sequence has a low vertical permeability and separates the saline groundwater of the Leederville Formation from the saline/fresh groundwater of the superficial formations.

Because of the generally impermeable nature of the upper Leederville Formation over much of the study area, the effect of the canal development on groundwater flow or quality will be primarily limited to aquifer units within the superficial formations. In the central and eastern part of the site where sands and silty sands are present at the top of the Leederville Formation, the design of the dewatering system may need to extend to the base of the superficial formations.

The principal source of recharge to the superficial formations is from infiltrating rainfall. Where the potentiometric surface in the confined Leederville Formation is higher than the water table in the superficial formations additional recharge (in the form of vertical upward leakage) may occur, especially if the upper part of the Leederville Formation is sandy and relatively permeable.

2.3.2 Groundwater Flow

Fresh groundwater moving through the superficial formations tends to overlie denser more saline groundwater near the coast. This relatively diffuse broad transition zone is referred to as the saltwater interface, with the denser saline groundwater forming a saltwater wedge dipping landward along the base of the superficial formations. The interface is dynamic, migrating laterally in response to seasonal changes in water level, tides and recharge.

The water table in the superficial formations ranges from 2-4m below ground surface (eastern boundary) to 0.5-1m below ground surface (western boundary). Groundwater flow is towards the southwest (Figure 4) discharging into Samphire Flats on the edge of Peel Inlet. Hydrographs for Harbour City monitoring bores (OB20-OB28) are included in Appendix B. The water table fluctuates seasonally by 0.6-1.0m with minimum values in February to April and maximum values in September to October in response to winter recharge from rainfall.

Fluctuations tend to be largest in the eastern part of the site. The seasonal rainfall recharge causes the 0m AHD groundwater level contour to migrate approximately 1,000m to the west at the end of the winter before receding again during the summer.

The long-term groundwater level trend for all bores, with the exception of OB25 since June 1987, has remained static. Over the same period minimum groundwater levels in OB25 have risen from 1.8m AHD in June 1987 to 3m AHD in June 1991. This rise is attributed to enhanced recharge as a result of the clearing of land for development to the east of the Harbour City site.

2.3.3 Aquifer Characteristics

The hydraulic conductivity of the superficial formations varies with lithology, being significantly greater for the calcarenite and sands. The subsurface distribution of these lithologies is therefore the main hydrogeological consideration in determining dewatering requirements and the effects of dewatering in the superficial formations, namely the lowering of groundwater levels and the migration of the saltwater interface.

Table 2 shows the results of falling head tests (FHT) completed at Harbour City in March 1987.

TABLE 2

FALLING HEAD TEST ANALYSES

Bore No.	*Mean Permeability (m / day)*	*Aquifer Material*
20	3.25	Calcarenite/Sands
21	0.3	Calcarenite/Sandy Clay
22	0.9	Calcarenite/Sandy Clay
23	1.40	Calcarenite
24	0.2	Silty Sand
25	1.0	Sand and Silty Clay
26	Inaccessible	-
27	0.2	Silty Sand
28	0.005	Sandy Clay/Clay

The permeability results range from 3.2m/day for the permeable calcarenite and sands to 0.005m/day for the relatively impermeable basal sandy clay/clay sequence. These results should be regarded as being conservative as FHT tend to underestimate the true aquifer values.

The calcarenites and sands are well developed in the northeastern and eastern portions of the site and are extensively used as aquifers for domestic bores in Dudley Park and Coodanup. Given the social implications of major dewatering of these aquifers, more extensive hydraulic testing is warranted to calculate representative aquifer parameters.

2.3.4 Groundwater Quality

Downhole conductivity measurements have been recorded on a monthly and quarterly basis in all Harbour City monitoring bores since June 1987. The profiles for all bores covering the 12 months to December 1991 are included as Appendix C.

Groundwater quality in the superficial formations is saline in the western part of the site and fresh to brackish in the east. The freshwater is derived from infiltrating rainfall and where it mixes with seawater a broad brackish or transitional zone develops. On the basis of GSWA borehole records, most of the groundwater abstracted from domestic bores in Dudley Park and Coodanup is fresh with salinity in the range 500 to 1,000mg/L.

Groundwater quality in the upper part of the Leederville Formation is saline. These high groundwater salinities are derived from the downward migration of estuarine and seawater from the Peel Inlet. This groundwater is a potential source of salinity contamination into superficial formations where the upper Leederville Formation is sandy and permeable.

2.3.4.1 Position of the Saltwater Interface

The saltwater interface generally extends between the water table and the impermeable top of the Leederville Formation. Where the upper surface is sandy and relatively permeable, the interface extends into the Leederville Formation. The interface is a relatively broad transition zone sloping landward with fresher groundwater (1,000-1,500 micromhos/cm) overlying denser more saline groundwater (15,000-50,000 micromhos/cm).

The interface is dynamic, migrating laterally in response to seasonal variations in groundwater levels, tides, recharge, evapotranspiration and domestic abstraction.

The saltwater interface is currently located between OB22 and OB23 approximately 400 metres west of the eastern boundary of the project. It is aligned parallel to this boundary, curving eastward to the south between bores OB27 and OB28 where there is an embayment in the Peel Inlet.

Two cross-sections (Figures 5 and 6) show the distribution of groundwater conductivity across the site for mid-winter June 1991 and mid-summer December 1991.

As a result of above-average winter rainfall in 1991 and increased throughflow of fresh groundwater derived from infiltrating rain, the saltwater interface was pushed seaward. At the same time the transition zone (5,000 to 30,000micromhos/cm) broadened substantially. Between June and December 1991 the interface progressively receded 400m landward with a corresponding contraction of the transition zone.

2.4 DRAINAGE

Due to the permeable nature of the superficial formations, especially in the eastern and northern parts of the site, most precipitation percolates into the sands with minimal surface runoff. Where there are thicker layers of organic mud at the surface there is some perching/ponding of fresh rainwater which is unable to drain away and tends to gradually evaporate.

The Samphire Flats, adjacent to the Peel Inlet and the Mandurah Channel, are periodically flooded with saline water from the estuary during the winter months. The relatively flat nature of the area results in little or no surface runoff. These areas drain once the estuary/channel levels have fallen and are generally dry in summer.

3.0 GROUNDWATER USERS

3.1 SUPERFICIAL FORMATIONS

The shallow calcarenite and sand aquifers are extensively used by local householders for domestic reticulation. The majority of these bores are less than 6m deep with a depth to static groundwater level of 2 to 4m. The majority of the domestic bores are constructed with well spears or concrete liners and equipped with small electric submersible or centrifugal pumps. Reported salinities range between 200 and 6,000mg/L TDS (Total Dissolved Salts).

On the basis of the GSWA well records, a total of 60 domestic bores exist at Coodanup with an additional 50 domestic bore in the southern part of Dudley Park. However, the GSWA records have not been updated since 1980 and it is probable that the total number of domestic bores now exceeds 250.

3.2 LEEDERVILLE FORMATION

Abstraction of groundwater from the Leederville Formation is strictly regulated by the Water Authority of Western Australia. This groundwater resource is reserved for public water supply and community purposes. The construction of the canals will not directly affect the resource. However, there is a proposal to use groundwater from the Leederville Formation to reticulate the proposed public open space and foreshore areas of the Harbour City development.

Table 3 details licensed groundwater abstractions from the Leederville Formation within Mandurah.

TABLE 3

LICENSED GROUNDWATER ALLOCATIONS
MANDURAH

Description of Land	*Total Depth*	*Allocation (kL/annum)*	*Eastings (m)*	*Northings (m)*
Bortello Oval Reserve	180	115,000	382840	6399940
Western Foreshore Reserve	*200	100,000	379100	6399285
Peelwood Recreation Reserve	195	75,000	377830	6397550
Rushton Park Reserve	213	96,000	381000	6399600
Falcon Sports Oval	190	30,000	374225	6394340
Eastern Foreshore Reserve	192	75,000	379800	6400340
Meadow Springs Golf Course	149	368,500	382500	6403500
Mandurah Country Club	213	360,000	378000	6399000
Glencoe Primary School	81	19,000	378200	6398600
Mandurah High School	120	82,500	381400	6401600
Coodanup High School	*120	30,000	382400	6398200
Falcon Primary School	156	19,000	372480	6392890
Erskine No. 1	167	*	378000	6397000
Port Mandurah - Shire	200	85,000	378420	6400060
East Mandurah Golf Course	136	*	Not located	
Murray Lakes - Sunland	131	150,000	388500	6393700
Miami Caravan Park	117	25,000	374300	6394150
TOTAL		1,630,000kL		

Note: * - Allocation unknown.

Preliminary discussions with the Water Authority of Western Australia indicate that sufficient groundwater resources are available to meet the demand for open space reticulation and would be allocated provided it is for public or community purposes.

4.0 POTENTIAL HYDROGEOLOGICAL IMPACTS

Canal construction and urbanisation of the site will impact on the hydrogeological environment, both during the short-term construction and long-term operational phases of the development.

4.1 CONSTRUCTION IMPACTS

The canals will primarily be constructed using bulldozers and scrapers, with some excavation of the entrance canal near the Mandurah Channel using a dredger. Canal construction will be staged and is expected to take approximately 3 months per stage. Excavation is required to RL -3m AHD, permitting the construction of the canal floor to -2.7m AHD.

4.1.1 Groundwater Levels

Assuming the Harbour City canals are constructed in the same manner as Waterside Mandurah, i.e. using a dredger for the main entrance and earth moving equipment for the canals, extensive dewatering will be necessary. This dewatering will be achieved using high capacity pumps, operating in sumps, to maintain dry working conditions.

The permeable calcarenite is well developed in the northern part of the site near bores OB20, OB21, OB22 and OB23. The unit correlates with the high permeability zone recognised in the southeastern corner of the Waterside Mandurah development. Dewatering of this zone was responsible for the significant drop in domestic water levels in Dudley Park during the summer of 1985/86.

The calcarenite and channel sand in the area is better developed and laterally more extensive than in Waterside Mandurah. The combination of a steeper hydraulic gradient, extended seepage face and well developed permeable calcarenite will result in high aquifer throughflow which will necessitate extensive dewatering to maintain dry working conditions. The dewatering will significantly effect groundwater levels in the southern portion of the Dudley Park Estate and possibly Coodanup.

At present there are insufficient data to accurately predict the project dewatering requirements or the extent of the drawdown cone associated with dewatering. Preliminary calculations indicate that groundwater levels in domestic bores in the vicinity of Kookerbrook Street will decline by up to 0.5m and bores in the newer subdivisions south of Coolabah Avenue could have temporary groundwater level declines of two to three metres. This may be sufficient to draw the water table below the suction level of the pumps in these bores and cause pump failure and a lack of reticulation supply. Groundwater levels will progressively rise for two or three years after canal construction and are expected to recover to within one metre of pre-construction levels.

4.1.2 Groundwater Quality

During canal construction, and dependent on the location of the sumps used for dewatering, initial dewatering will remove the fresh to saline groundwater which presently underlies the site. This will encourage the movement of water towards the excavation from three sources namely:

- westward movement of fresh groundwater from Dudley Park and Coodanup;
- eastward movement of saline groundwater/seawater from the Mandurah Channel and Peel Inlet; and
- possible upward migration of saline groundwater from the Leederville Formation into the superficial formations in areas where the upper sediments are permeable and there is a positive upward hydraulic head.

During canal construction, seepage is expected to be a blend of brackish/saline groundwater with a bulk salinity in the range 10,000 to 30,000micromhos/cm while dewatering operations are taking place. The dewatering itself will not cause an increase in the salinity of groundwater discharged from domestic bores. However, if householders either deepen their bores, or set their pumps lower, this may induce up-coning of the brackish groundwater which exists below the fresh groundwater in the superficial formations.

4.1.3 Disposal of Dewatering Discharge

If sumps, using high capacity pumps, are used to dewater the canals, the resultant discharge is expected to be brackish to saline with a significant proportion of fine suspended material. Prior to disposal of this groundwater into the Mandurah Channel it will be necessary to remove a large proportion of these solids. Alternative options to minimise or remove fines are discussed in Section 5.2.2.

4.2 OPERATIONAL IMPACTS

After construction of the canals and their subsequent infilling with seawater, there will be long-term impacts of the development on the hydrogeological setting of the area, these include:

- o readjustment of groundwater levels;
- o migration of the saltwater interface;
- o accumulation of nutrients in the soil; and
- o availability of groundwater for domestic use.

4.2.1 Groundwater Levels

Groundwater flow is currently southwesterly to a discharge point at sea level along the eastern bank of the Mandurah Channel. After canal construction, the discharge point will migrate approximately 1,500m inland to be re-established at the eastern end of the canals, 50 metres west of OB23. Groundwater levels will drop over most of the site and the water table will tend to steepen on the landward side of OB23. This will induce an initial increase in groundwater throughflow towards the canals. After a new flow regime is established as a result of the variation in hydraulic gradient, the water table in the southern part of Dudley Park and the area east of Harbour City is calculated to drop 0.5 to 1m. However, initially groundwater levels east of Harbour City are expected to continue to rise for several years before water levels are stabilised. The rise is attributed to enhanced recharge as a result of urbanisation with increased runoff from pavements, roads and roofed areas.

4.2.2 Migration of the Saltwater Interface

The existing interface is located between OB22 and OB23 and is aligned northwest southeast with a slope to the east. The interface migrates seasonally in response to changes in recharge, but the average long-term position of the interface remains static. After canal construction, the saltwater interface is calculated to migrate further inland and re-establish itself in the vicinity of OB23 and OB24. Migration of the saltwater interface will not cause any deterioration in the groundwater quality in existing domestic bores in Dudley Park due to the large distance and the fact the domestic bores only draw groundwater from the upper part of the superficial formations. However, if existing bores are deepened or pumps set lower, up coning of brackish groundwater, already present in the lower part of the superficial formations, may occur.

4.2.3 Nutrient and Heavy Metal Accumulation

In their native state, the soils of the project area are extremely infertile and although some soil will be imported, the soil will generally have a low organic content. Applications of phosphorus, sulphur, potassium and the trace elements copper and zinc are required for successful garden development. Phosphorus in particular is essential on the sandy soils. Application rates of elemental phosphorus (usually applied as superphosphate and superphosphate/potassium chloride mixes) are commonly 30kg P/ha at initial development and 10-20kg P/ha annually thereafter.

Phosphorus applied to very sandy soils in the Peel-Harvey catchment (in which the development is located) has been shown to be the major cause of eutrophication of the estuary. Phosphorus lost from these soils is rapidly carried by drainage water into the estuarine system or other wetlands, where it acts to fertilise massive blooms of algal growth. This situation developed after construction of the Waterside Mandurah development.

Sandy soils with clay subsoils may also contribute significant amounts of phosphorus fertiliser to drainage water (and storm runoff). This is caused by lateral waterflow into drainage lines rather than vertical movement to the clay subsoil which would "strip" (absorb) phosphorus from solution. Although heavier soils strongly absorb phosphorus and leaching is generally negligible compared to loss from the sandy soils, erosion and transport of particulate-bound phosphate from heavy soils can occur.

Despite large phosphorus leaching losses from sandy soils, small amounts retained in the soil from repeated applications build soil levels sufficiently to allow subsequent applications of fertiliser to be reduced or ceased temporarily.

As gardens are established on both the canal and dry lots the rates of application required will reduce compared with those necessary at the time of initial planting. For the sandy soils, maintenance application requirements of superphosphate are estimated to be about 9kg/ha per annum.

All of the residential lots will be deep sewered and septic tanks will not be permitted. Accordingly there is not expected to be an accumulation of septic effluent contaminants in the soil which may subsequently seep into the canals or affect existing domestic bores surrounding the site.

4.2.4 Availability of Groundwater for Domestic Use

On the basis of available data, any new domestic bores drilled either within the development or in the area bounded by Harbour City in the west, Castella Drive in the north and Wanjeep Street in the east will encourage further landward migration of the saltwater interface and may induce up-coning of saline groundwater. The resultant change in hydrogeological conditions will cause these bores to pump brackish groundwater within the first five years of operation.

5.0 RECOMMENDED MANAGEMENT STRATEGY

5.1 FURTHER INVESTIGATIONS

Additional information is required to define critical aspects of the groundwater regime which remain poorly understood. Proposed works include:

- A survey of all domestic and private bores within 500m of the proposed Harbour City canals, to include details of groundwater level and electrical conductivity. Twelve of these bores will be selected for inclusion in the Harbour City monitoring programme. The census and monitoring data will establish baseline data against which the effects of dewatering and canal construction on domestic and private users can be measured. The baseline monitoring data will be required to deal with claims from householders.

- o Additional shallow investigative drilling to define critical aspects of the hydrogeology, particularly the distribution of calcarenite limestone in the superficial formations in the northern and eastern parts of the site and of sandy horizons in the Leederville Formation, as well as the precise position of the saltwater interface throughout the development area. The bores will be located in optimum long-term positions.

- o Implementation of a monitoring programme for groundwater levels and electrical conductivity profiles, to determine baseline parameters for the groundwater regime, including location of the saltwater interface, distribution of groundwater salinity, local water table variations, groundwater flow directions, and seasonal changes in groundwater regime.

5.2 CONSTRUCTION MANAGEMENT

The existing groundwater observation bores, along with proposed new bores, should be incorporated into a comprehensive groundwater observation bore network. While the project environmental assessment document is being reviewed by the EPA, the bore network should be monitored on a quarterly basis. Twelve months prior to canal construction, where practical, or for a minimum of six months, groundwater level measurements and conductivity profiling should be undertaken monthly. During the dewatering phase of each canal stage fortnightly monitoring will be necessary. Based on the ongoing monitoring results, two progress reports will be prepared for the Water Authority advising on temporary impacts on other groundwater users and on the position of the saline interface.

5.2.1 Dewatering Strategy

Dewatering for canal construction for Harbour City will result in lowering of groundwater levels in the vicinity, at least in the short-term, and the possible eastward migration of the saltwater interface.

The magnitude of these effects will be largely determined by the subsurface distribution of calcarenite, which is the most permeable sediment in the superficial formations. Where the Leederville Formation is sandy and permeable, saline upconing into the superficial formations may also occur.

Additional investigative drilling is proposed to delineate the extent and thickness of the calcarenite in the northern and eastern part of the area.

The design of the proposed dewatering system will form part of the earthwork contractor's brief. This design will be validated using an acceptable groundwater flow model, e.g. TARGET-2DU or MODFLOW, and the results critically reviewed by the nominated groundwater consultant, to ensure the design complies with EPA/Water Authority criteria.

Alternative options to sump dewatering include the installation of interceptor bores on the landward side of the development, progressive canal construction from west to east, interceptor trenches or well points.

5.2.2 Disposal of Dewatering Discharge

Assuming the canals will be constructed in a similar manner to Waterside Mandurah, the dewatering discharge from the sumps will contain a significant proportion of clay and silt particles. Prior to discharge into the Peel Inlet this water will need to be filtered or pumped into a series of temporary settling ponds. After there has been sufficient removal of fines, the discharge (which will be primarily saline to brackish water) will be pumped into the Peel Inlet in accordance with any disposal conditions imposed by the EPA, Water Authority or Waterways Commission.

5.3 OPERATIONAL MANAGEMENT

After construction of each canal stage it will be necessary to impose a project management and monitoring programme to determine short-term and long-term effects of the development and minimise any deleterious impacts which may initially occur.

5.3.1 Monitoring of the Saltwater Interface

For the initial 12 months after canal construction, monitoring of groundwater levels and conductivity profiling should be undertaken quarterly at observation points around each canal stage and in the 12 domestic bores.

After the initial 12 month monitoring period, the programme for each stage would be reviewed and where appropriate reduced from quarterly to biannually, subject to stabilisation of the saltwater interface.

5.3.2 Construction of Domestic Bores

Because of the sensitive nature of the aquifers within the superficial formations, no domestic bores would be permitted within the Harbour City Canal Estate and a recommendation would be made to the City of Mandurah and the Water Authority that no new domestic bores should be permitted within the area bounded by Coolibah Avenue in the northwest, Coodanup Drive in the northeast and Wanjeep Street in the east.

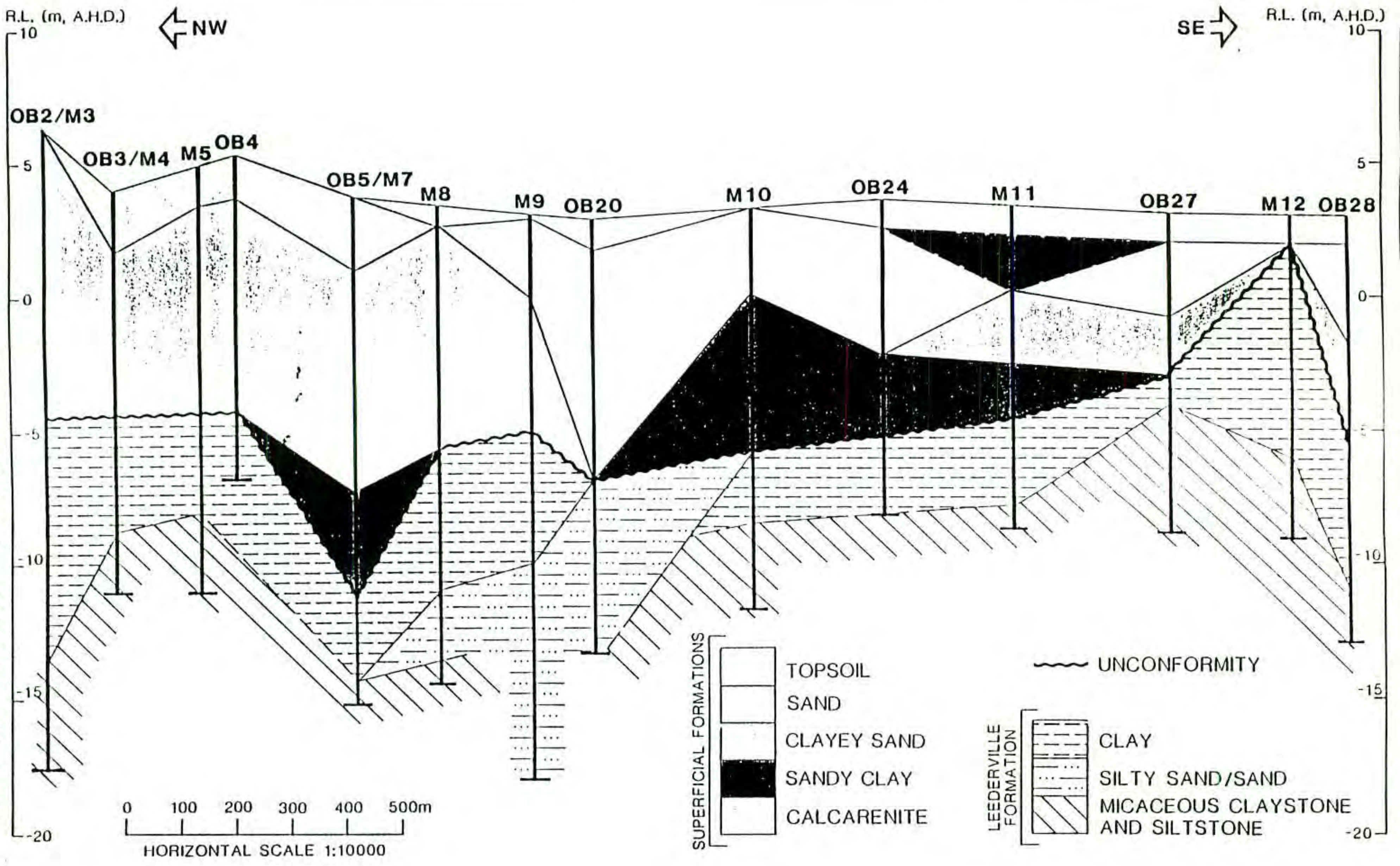
* * *

Respectfully submitted
DAMES & MOORE

Marcus S. Chandler

M.S. Chandler
Senior Hydrogeologist

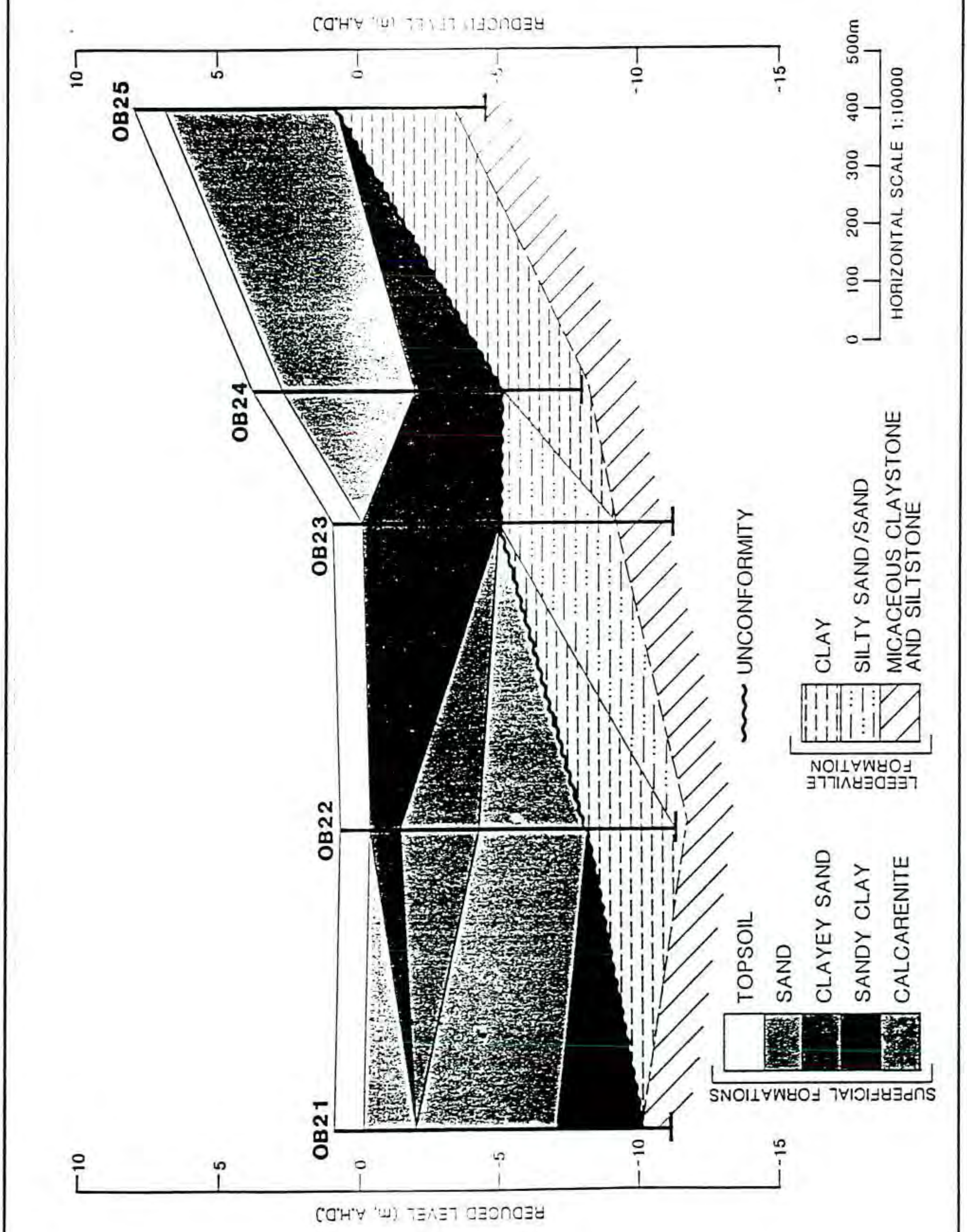
Figures



JOB No.	23917-001-071
PREPARED BY	MSC
APPROVED BY	
DATE	25/02/92

CEDAR WOODS LTD - HARBOUR CITY CANAL ESTATE
GEOLOGICAL CROSS SECTION
ALONG EASTERN BOUNDARY

FIGURE 2
DAMES & MOORE



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APPROVED BY		

CEDAR WOODS LTD - HARBOUR CITY CANAL ESTATE

GEOLOGICAL CROSS SECTION
WEST TO EAST

FIGURE 3
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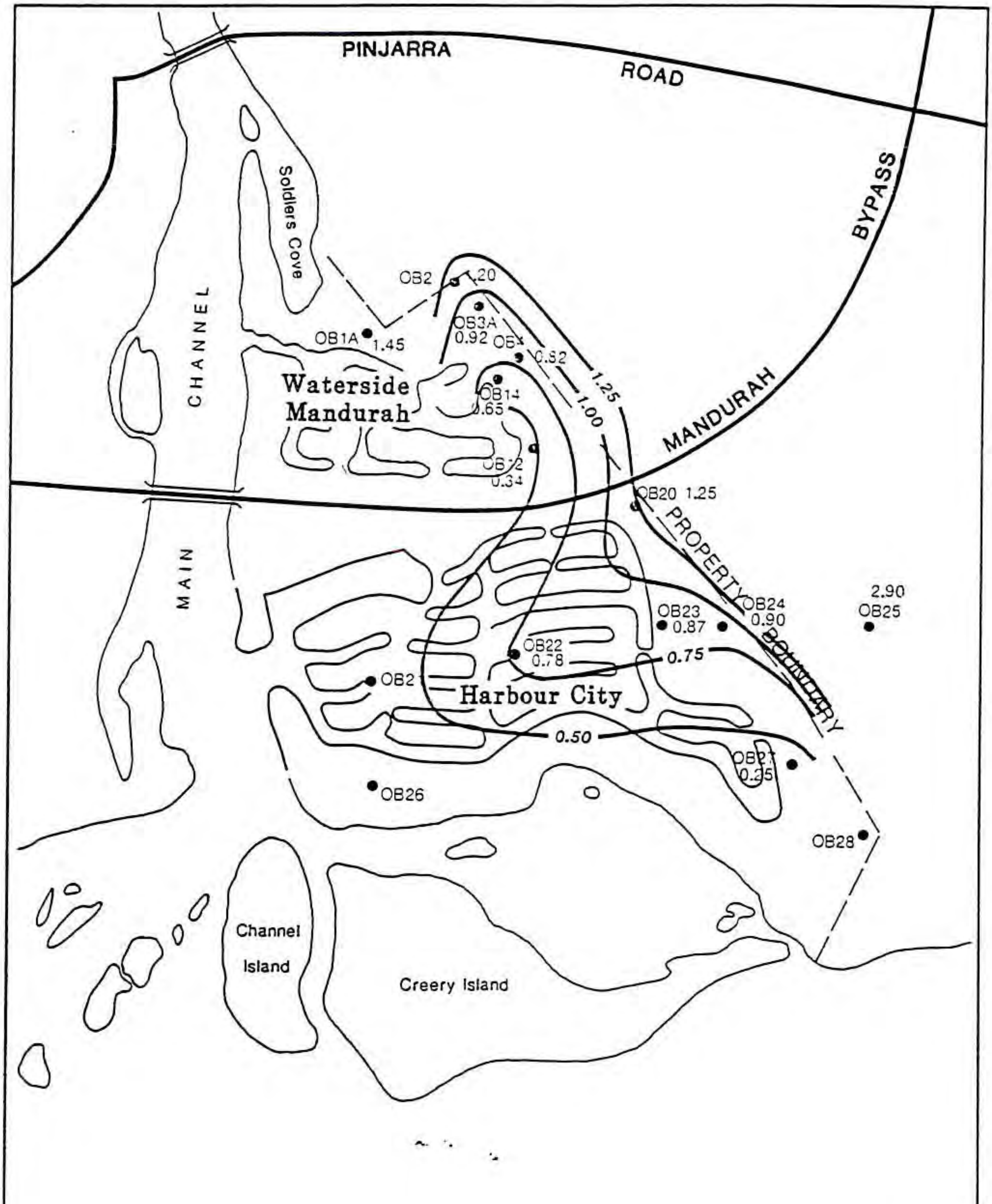

- CURRENT MONITORING BORE

1.25 WATER LEVEL (m, AHD)

WATER LEVEL CONTOUR (m, AHD)

0 0.5 1.0km

SCALE 1 : 20 000

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CEDAR WOODS LTD - HARBOUR CITY CANAL ESTATE

WATER LEVEL CONTOURS - JUNE 1991

FIGURE 4
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CEDAR WOODS LTD - HARBOUR CITY CANAL ESTATE
ELECTRICAL CONDUCTIVITY
OF GROUNDWATER - JUNE 1991

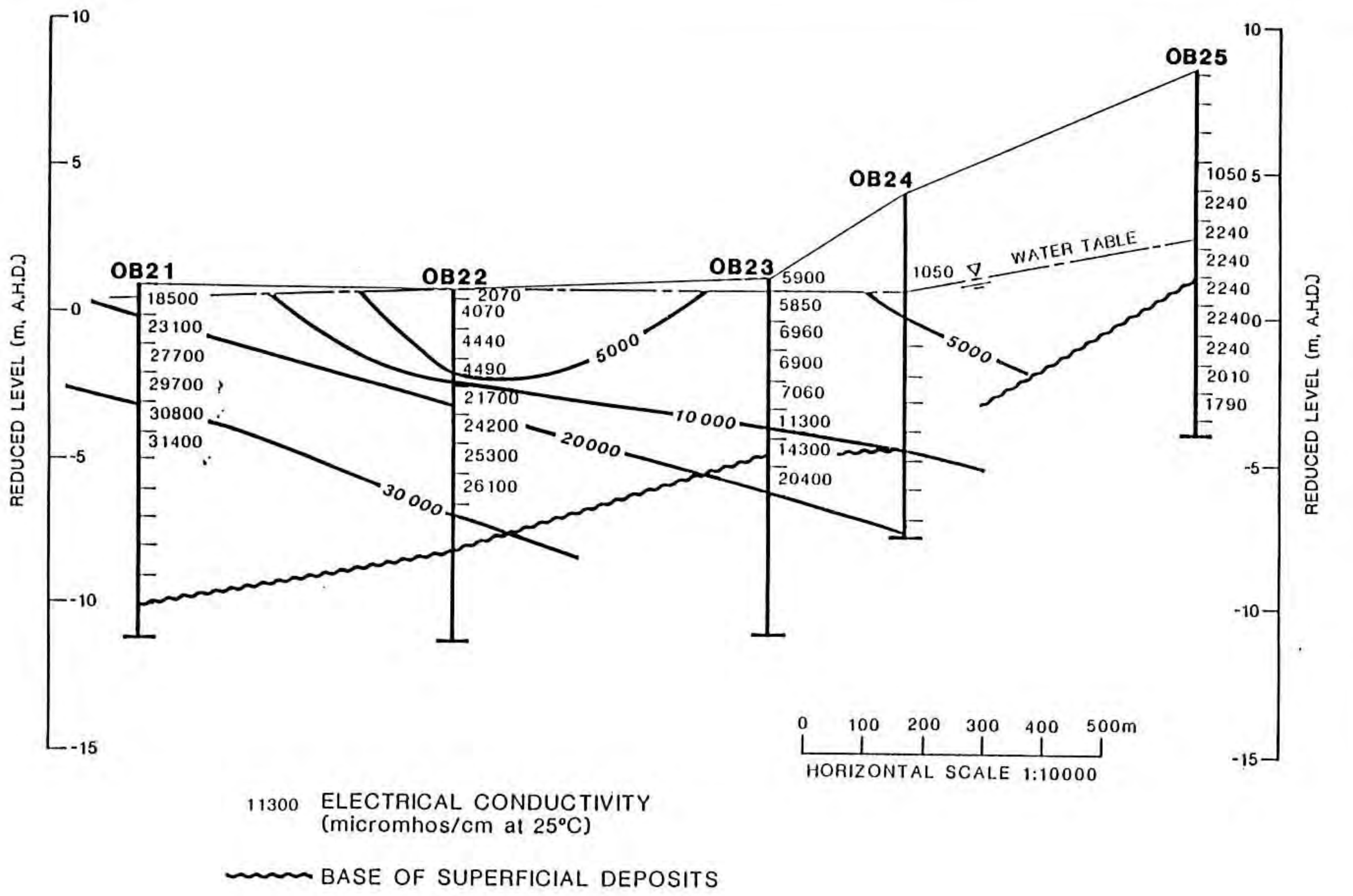

FIGURE 5
DAMES & MOORE

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APPROVED BY		

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ELECTRICAL CONDUCTIVITY
OF GROUNDWATER - DECEMBER 1991

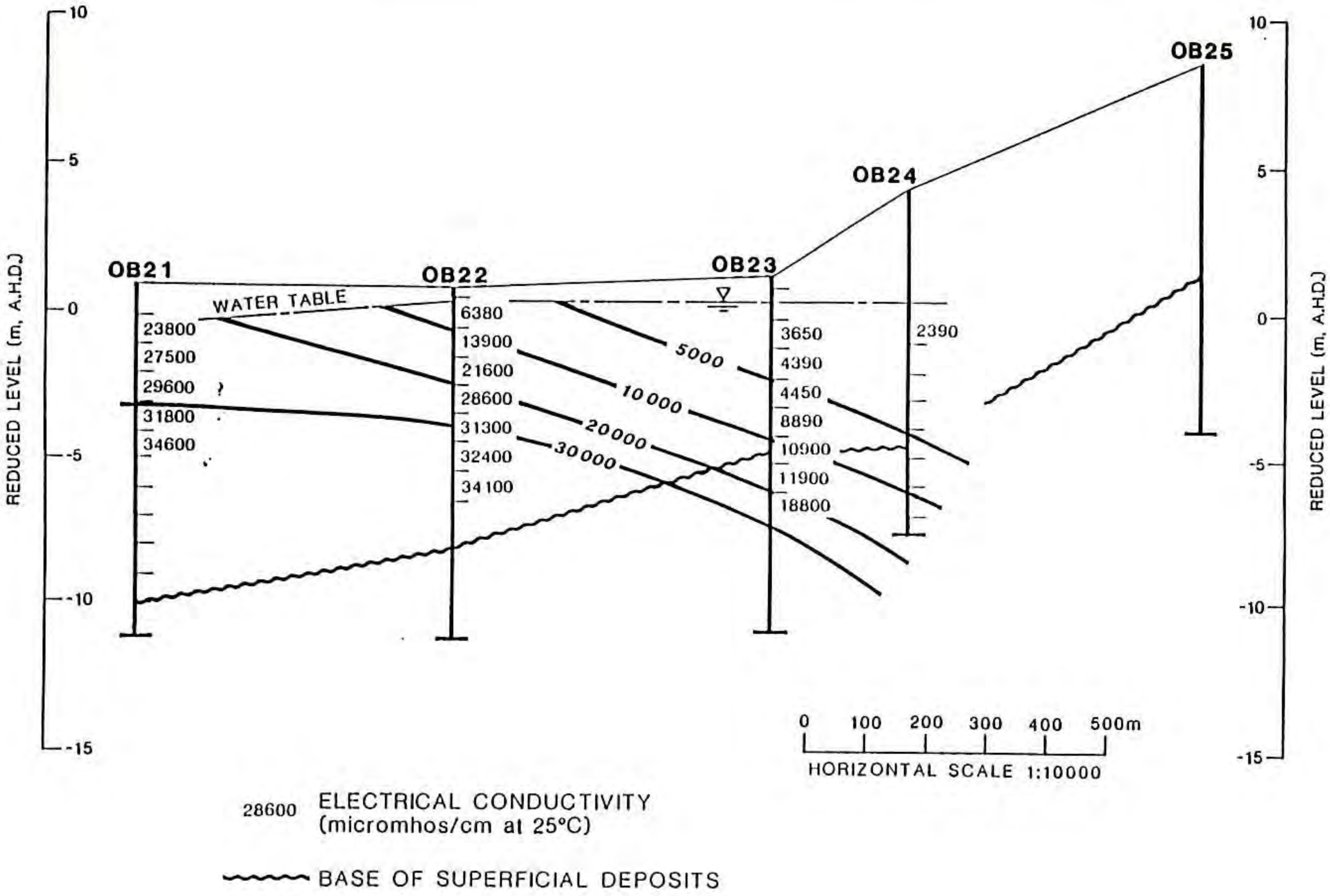

FIGURE 6
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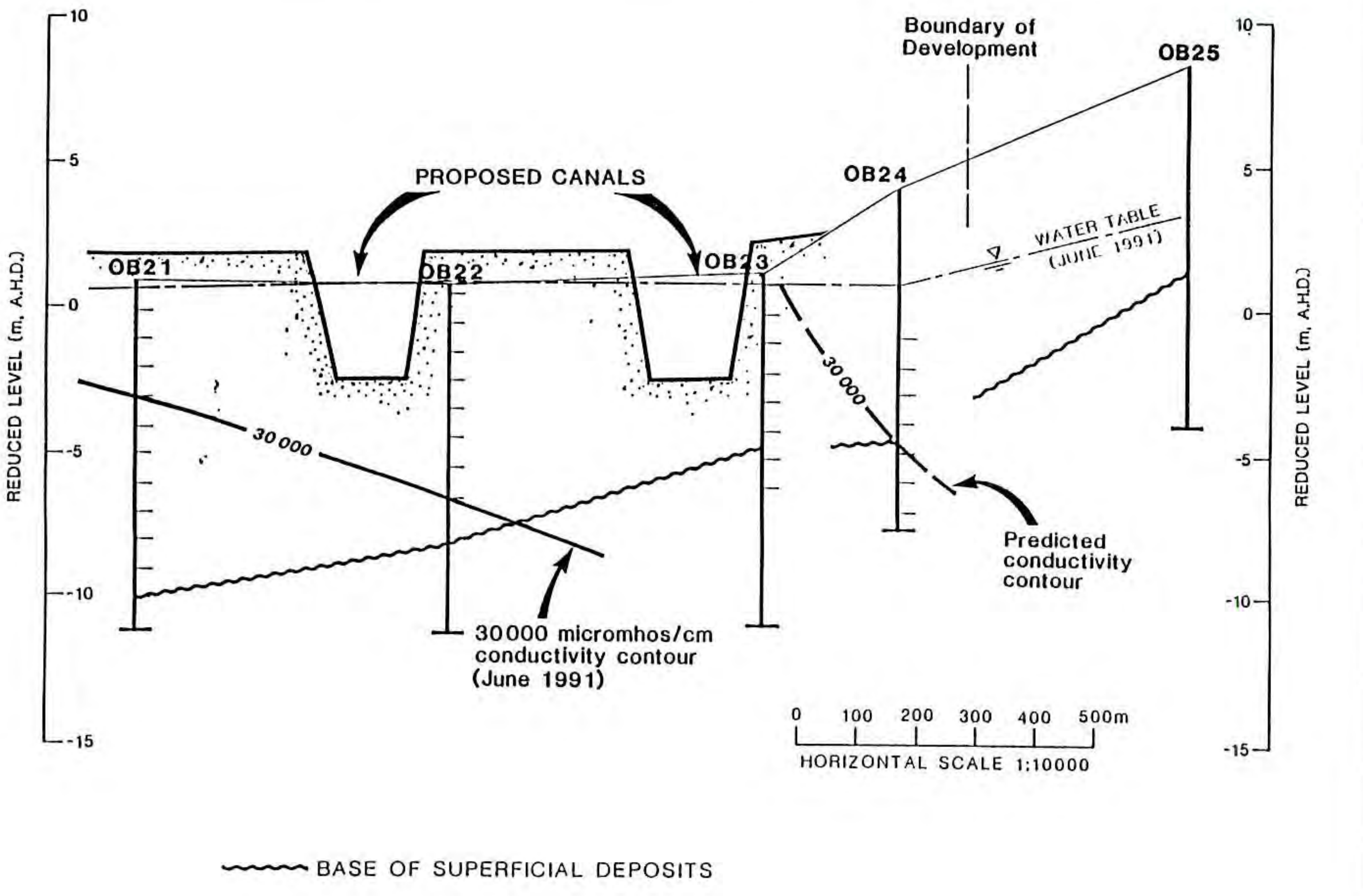
APPROVED BY	



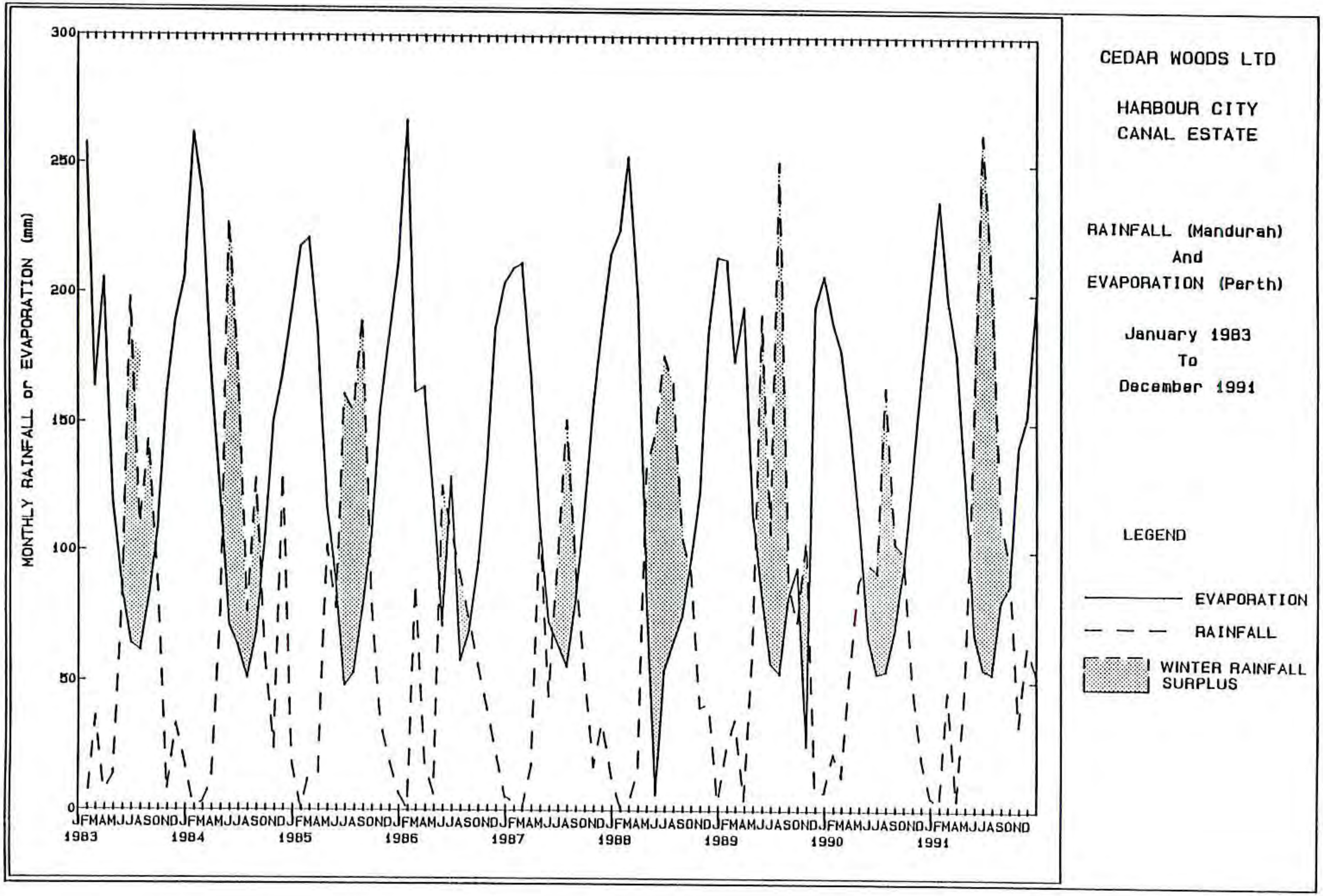
CEDAR WOODS LTD - HARBOUR CITY CANAL ESTATE
PREDICTED POSITION OF SALTWATER INTERFACE AFTER CANAL CONSTRUCTION

FIGURE 7
DAMES & MOORE

Appendix A

APPENDIX A

RAINFALL AND EVAPORATION 1983-1991

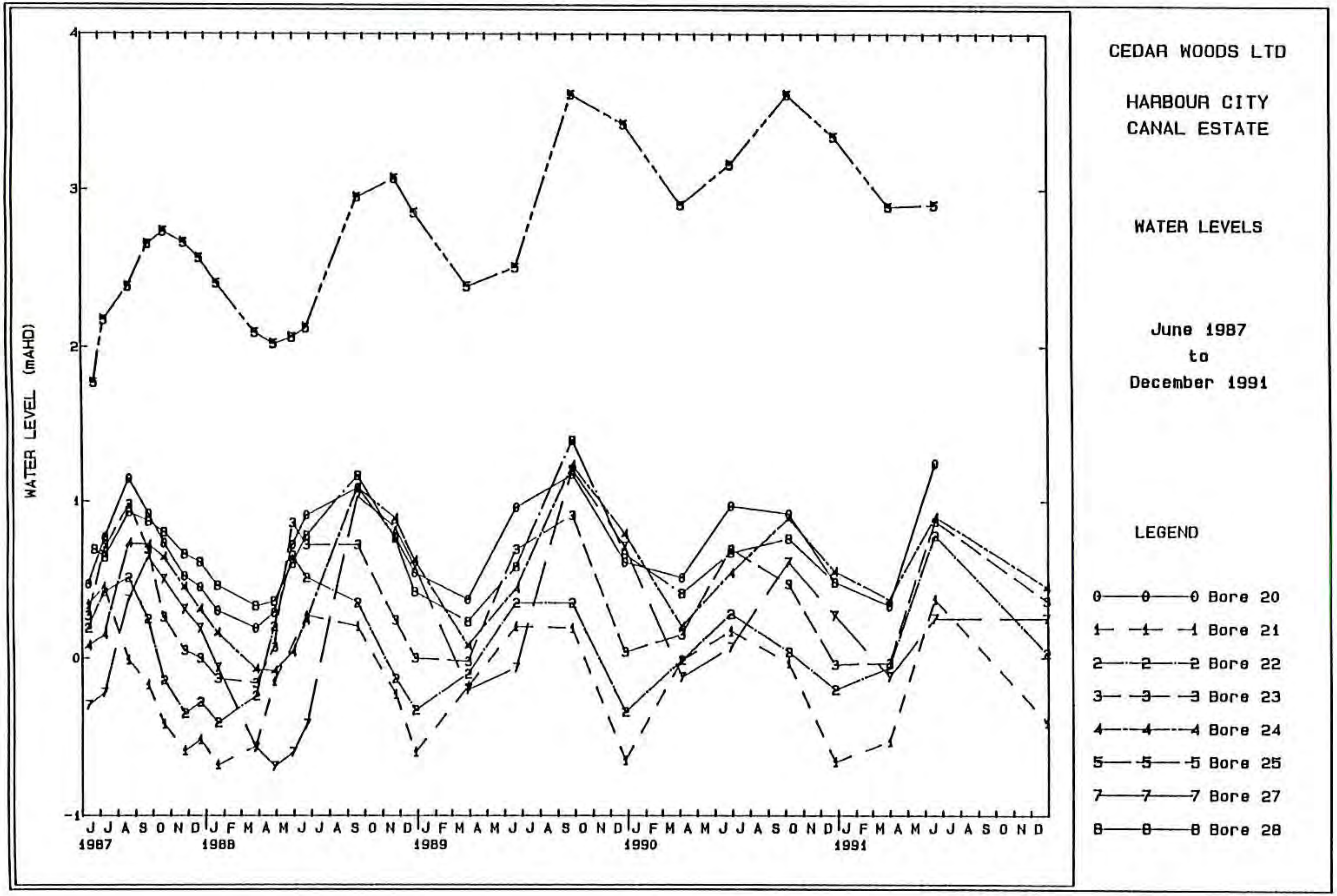


MONTHLY RAINFALL or EVAPORATION (mm)
300
250
200
150
100
50
0
JFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASOND
1983
1984
1985
1986
1987
1988
1989
1990
1991
CEDAR WOODS LTD
HARBOUR CITY
CANAL ESTATE
RAINFALL (Mandurah)
And
EVAPORATION (Perth)
January 1983
To
December 1991
LEGEND
EVAPORATION
RAINFALL
WINTER RAINFALL SURPLUS

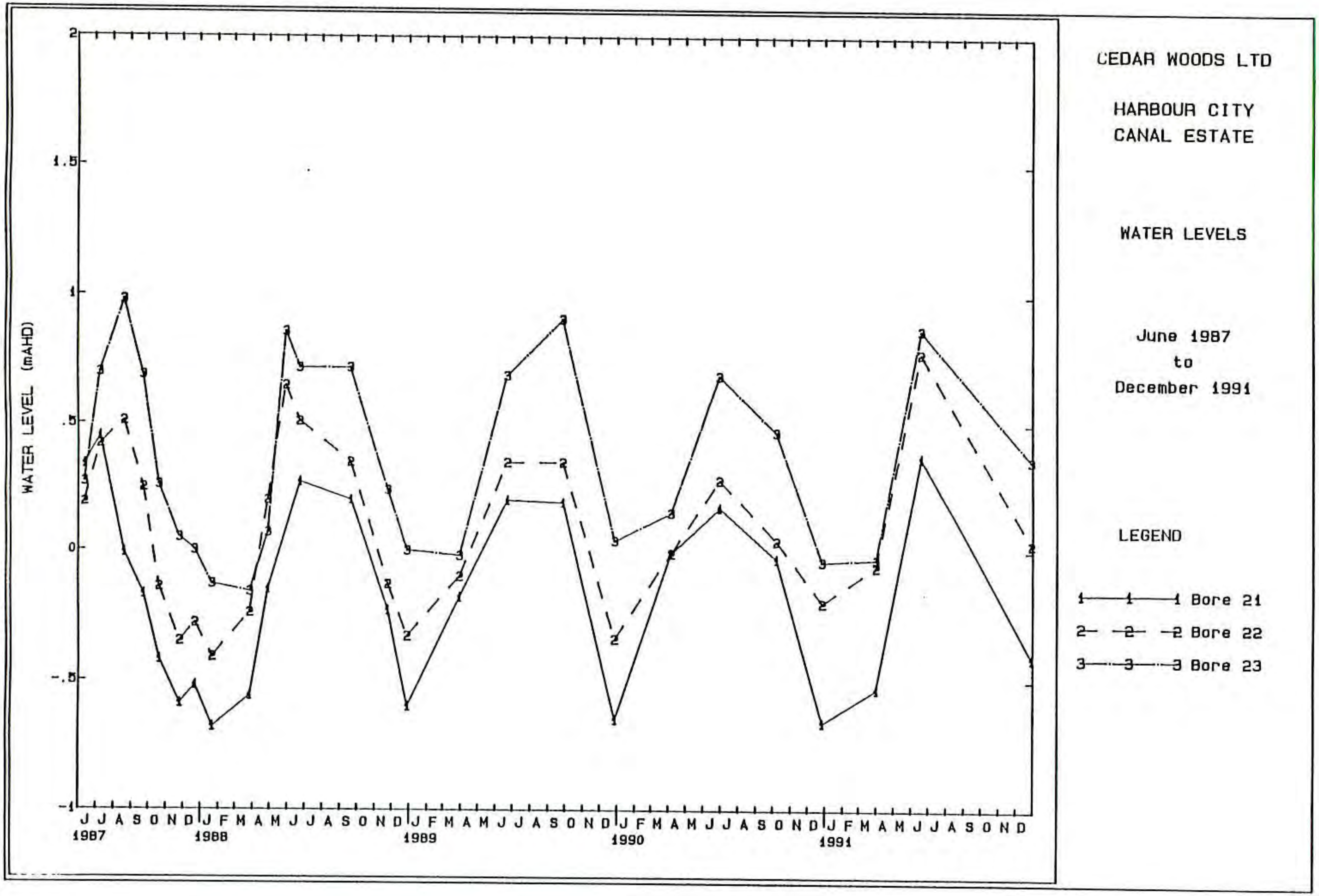
Appendix B

APPENDIX B

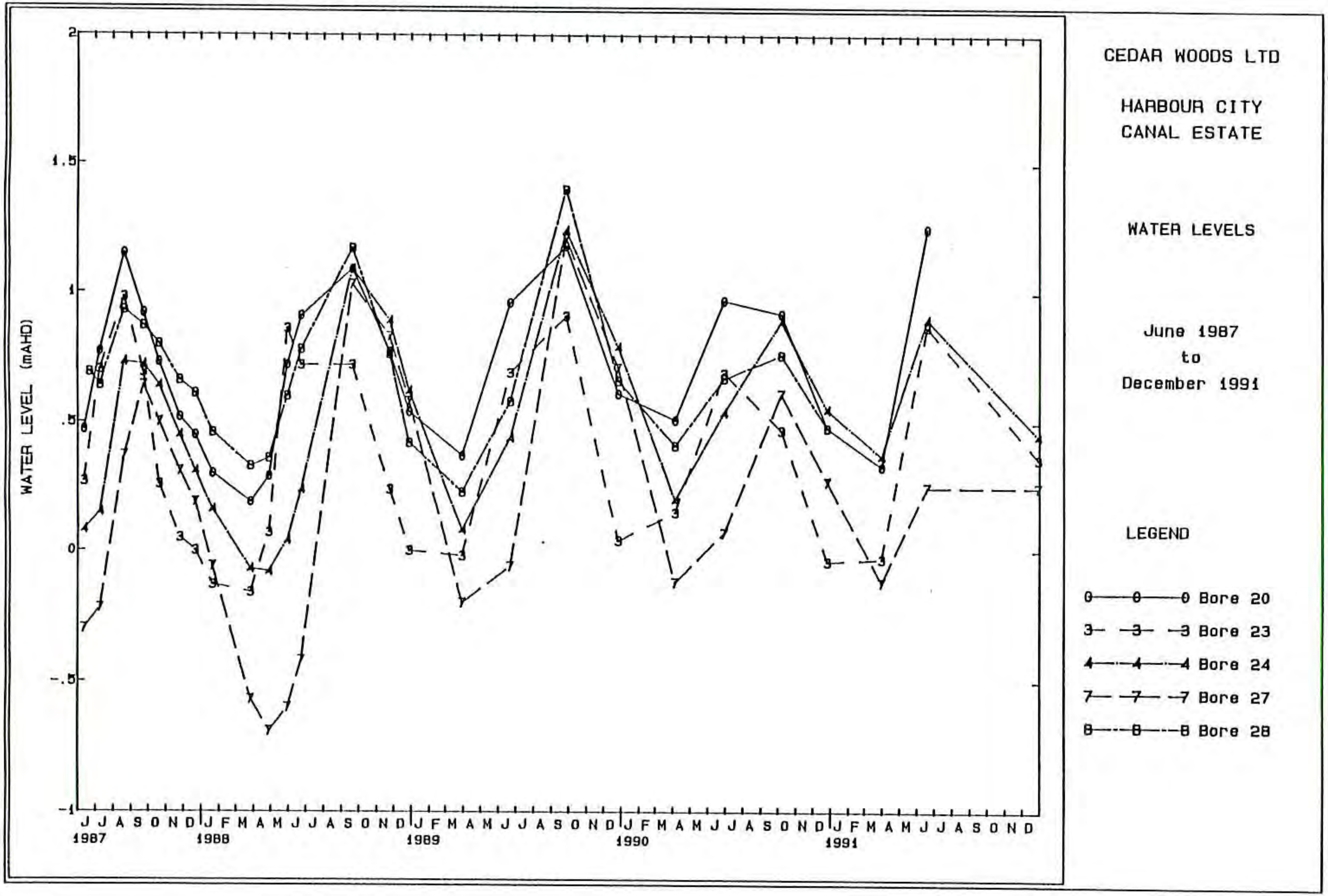
BORE HYDROGRAPHS



CEDAR WOODS LTD
HARBOUR CITY
CANAL ESTATE
WATER LEVELS
June 1987
to
December 1991
WATER LEVEL (mAHD)
4
3
2
1
0
-1
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1987
1988
1989
1990
1991
LEGEND
0 Bore 20
1 Bore 21
2 Bore 22
3 Bore 23
4 Bore 24
5 Bore 25
7 Bore 27
8 Bore 28



CEDAR WOODS LTD
HARBOUR CITY
CANAL ESTATE
WATER LEVELS
June 1987
to
December 1991
LEGEND
1 Bore 21
2 Bore 22
3 Bore 23
WATER LEVEL (mAHD)
2
1.5
1
.5
0
-.5
-1
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1987
1988
1989
1990
1991

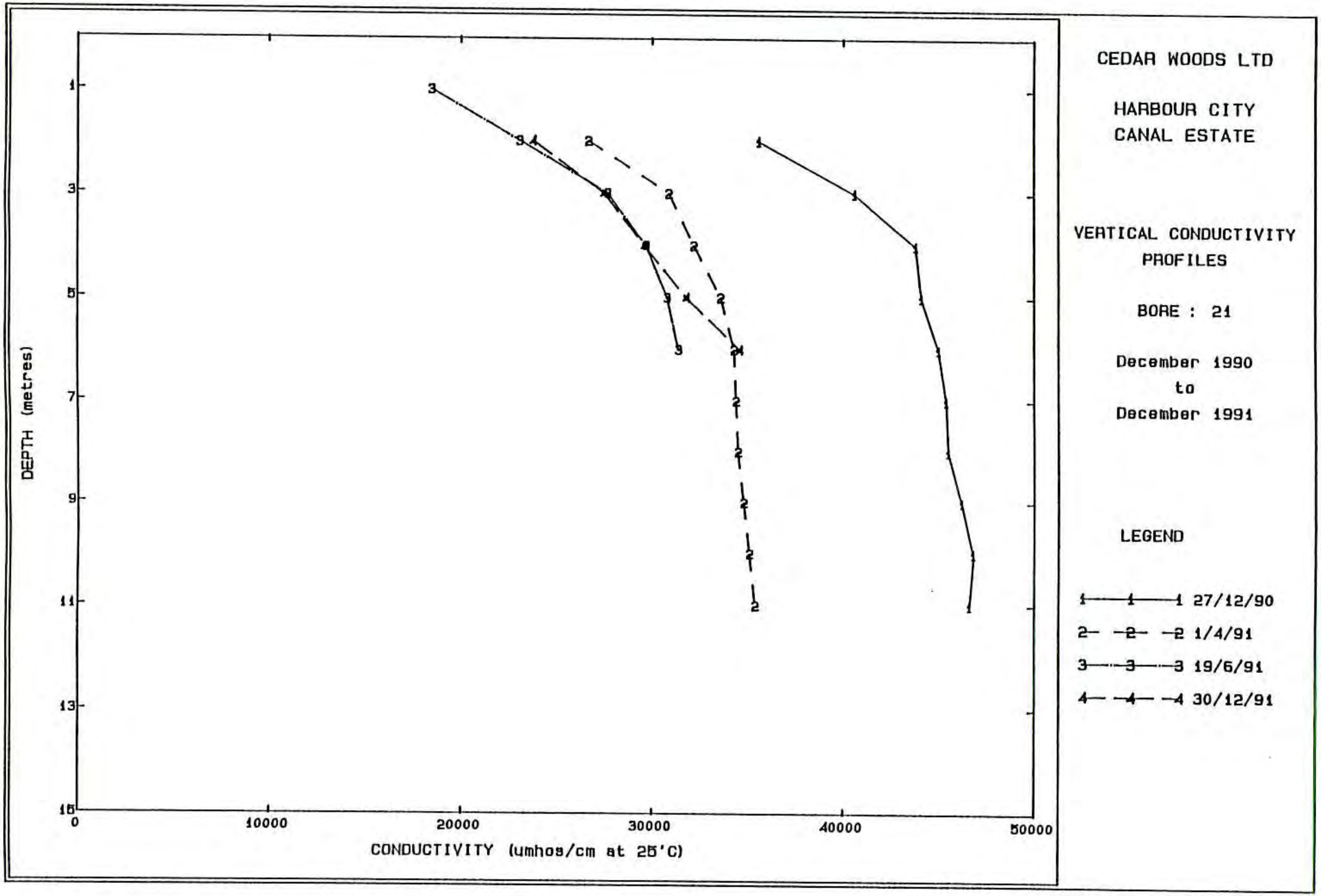


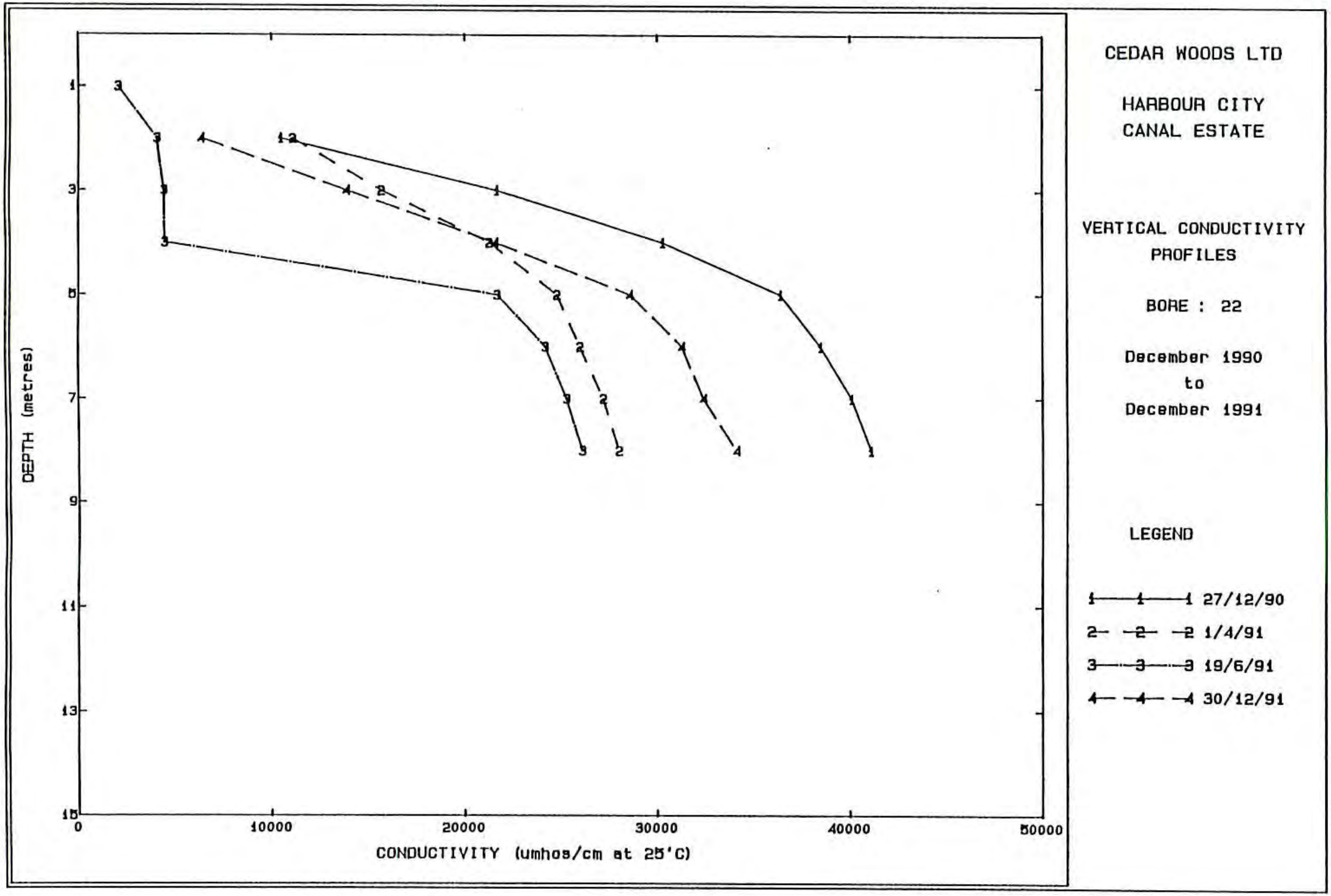
CEDAR WOODS LTD
HARBOUR CITY
CANAL ESTATE
WATER LEVELS
June 1987
to
December 1991
LEGEND
0 Bore 20
3 Bore 23
4 Bore 24
7 Bore 27
8 Bore 28
WATER LEVEL (mAHD)
2
1.5
1
.5
0
-.5
-1
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1987
1988
1989
1990
1991

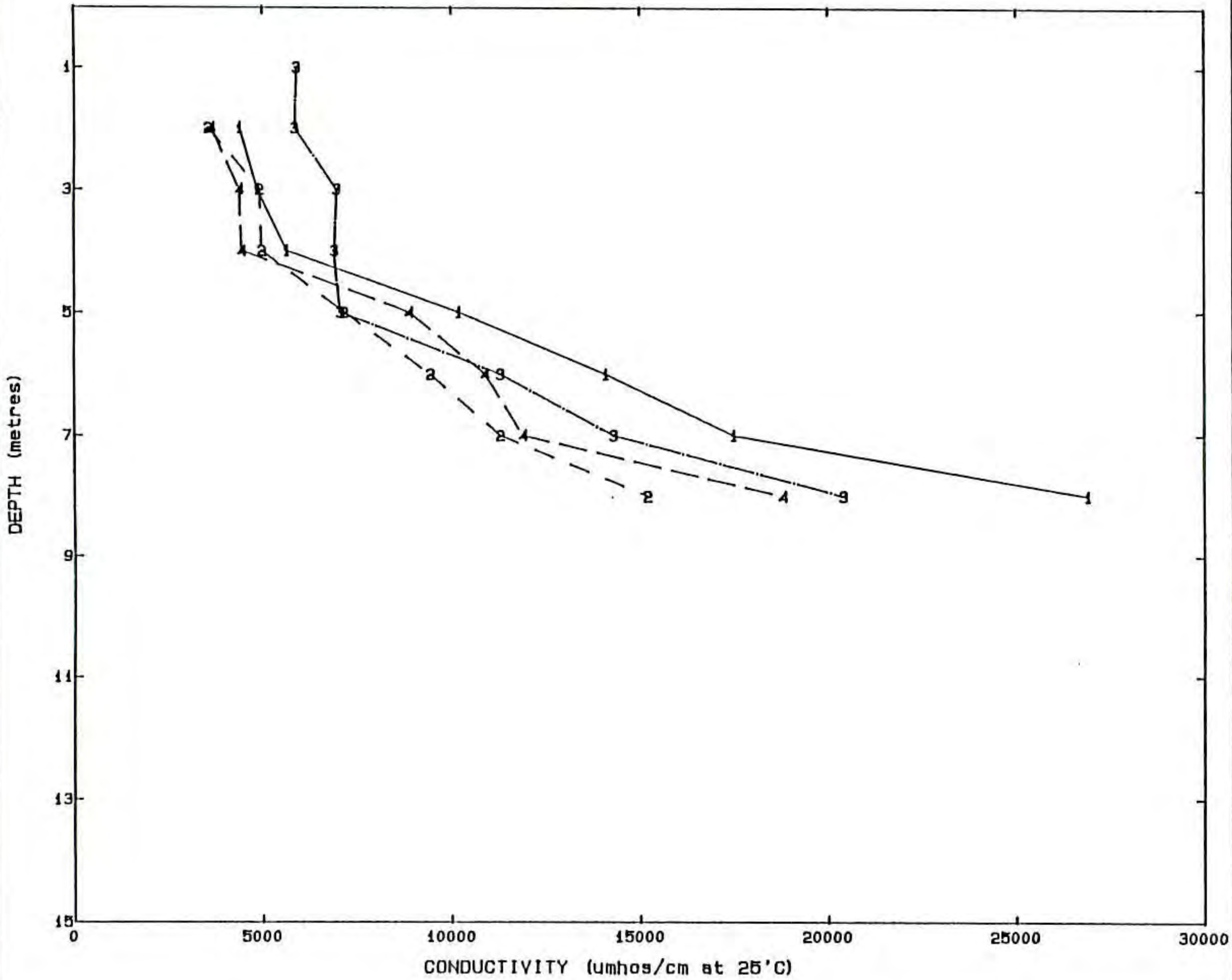
Appendix C

APPENDIX C

CONDUCTIVITY PROFILES


CEDAR WOODS LTD
HARBOUR CITY
CANAL ESTATE
VERTICAL CONDUCTIVITY
PROFILES
BORE : 21
December 1990
to
December 1991
LEGEND
1 27/12/90
2 1/4/91
3 19/6/91
4 30/12/91
DEPTH (metres)
1
3
5
7
9
11
13
15
0
10000
20000
30000
40000
50000
CONDUCTIVITY (umhos/cm at 25'C)


CEDAR WOODS LTD
HARBOUR CITY
CANAL ESTATE
VERTICAL CONDUCTIVITY
PROFILES
BORE : 22
December 1990
to
December 1991
LEGEND
1 27/12/90
2 1/4/91
3 19/6/91
4 30/12/91
DEPTH (metres)
1
3
5
7
9
11
13
15
0
10000
20000
30000
40000
50000
CONDUCTIVITY (umhos/cm at 25'C)



CEDAR WOODS LTD

HARBOUR CITY
CANAL ESTATE

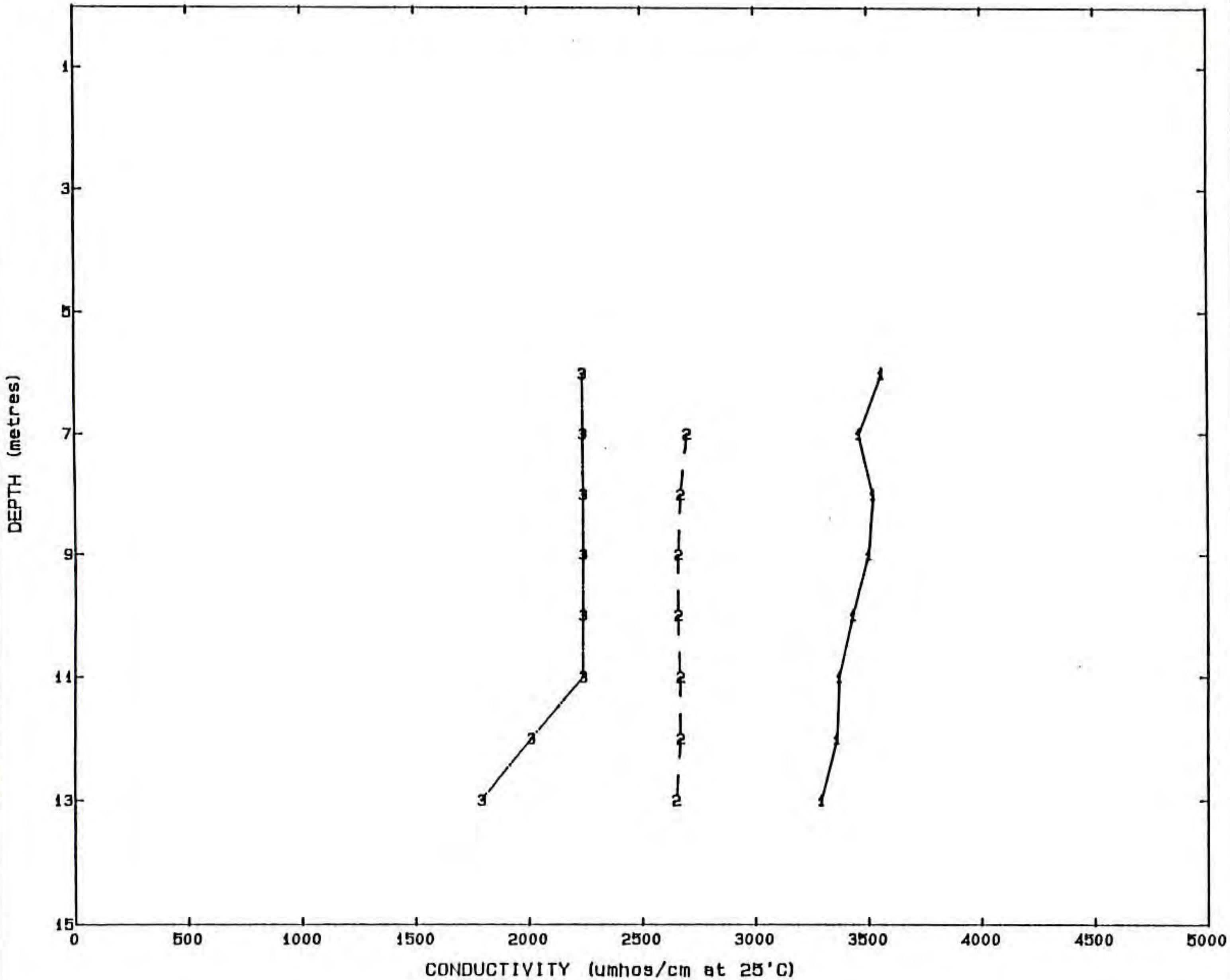
VERTICAL CONDUCTIVITY
PROFILES

BORE : 23

December 1990
to
December 1991

LEGEND

1——1——1 27/12/90
2– –2– –2 1/4/91
3—·—3—·—3 19/6/91
4– –4– –4 30/12/91



CEDAR WOODS LTD

HARBOUR CITY
CANAL ESTATE

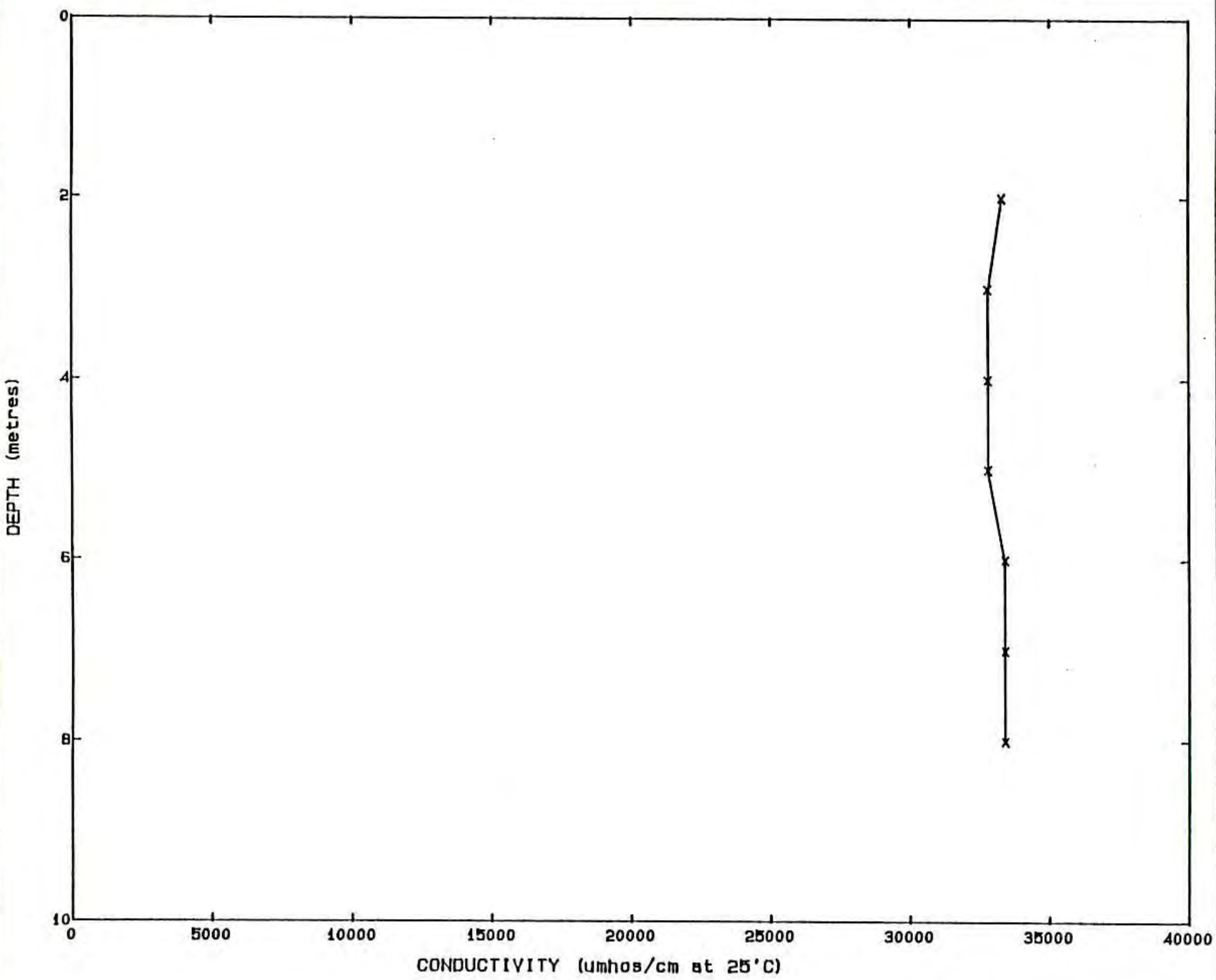
VERTICAL CONDUCTIVITY
PROFILES

BORE : 25

December 1990
to
June 1991

LEGEND

1——1——1 27/12/90
2– –2– –2 1/4/91
3—·—3—·—3 19/6/91



CEDAR WOODS LTD

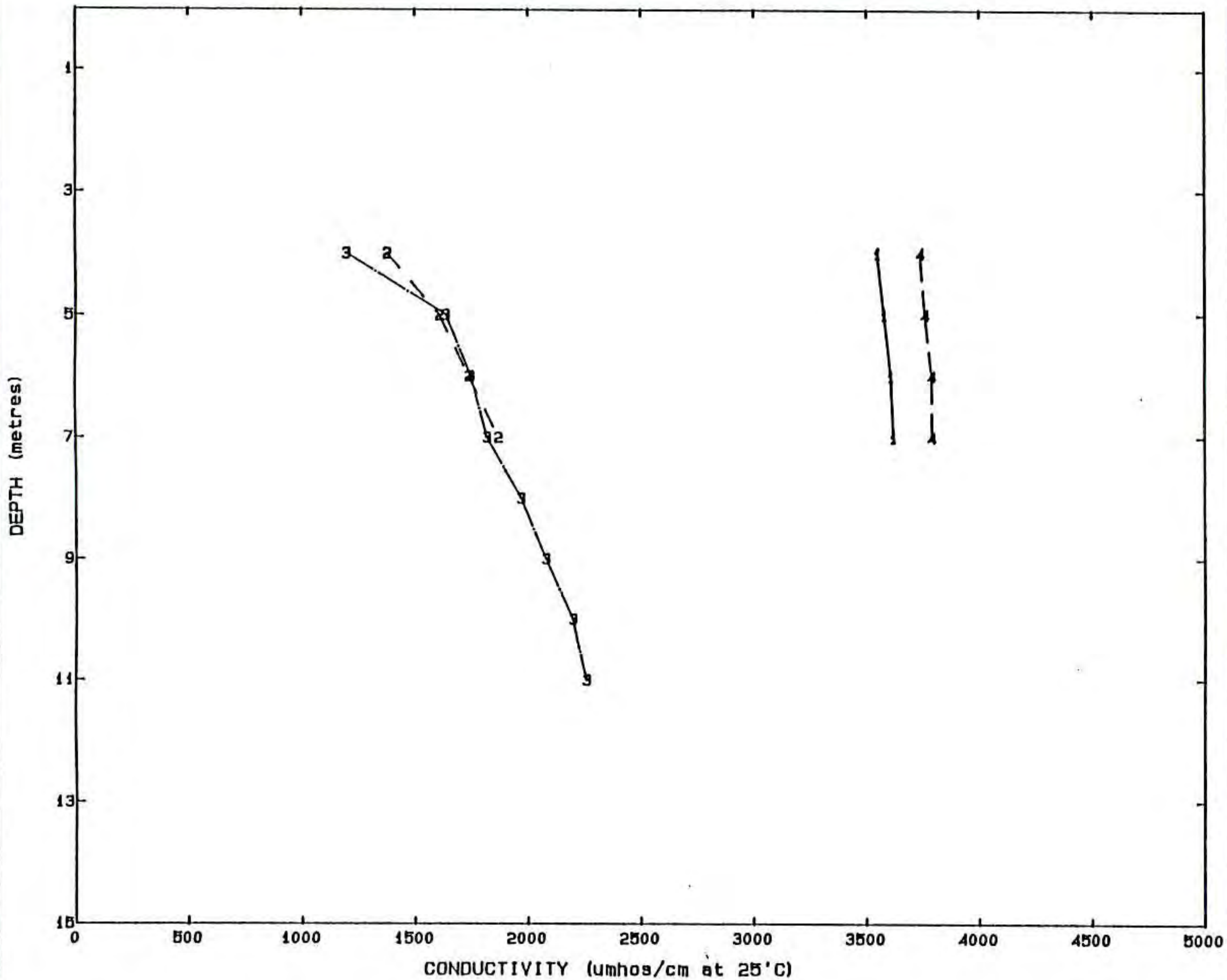
HARBOUR CITY
CANAL ESTATE

VERTICAL CONDUCTIVITY
PROFILES

BORE : 26

December 1991

LEGEND



CEDAR WOODS LTD

HARBOUR CITY
CANAL ESTATE

VERTICAL CONDUCTIVITY
PROFILES

BORE : 27

December 1990
to
December 1991

LEGEND

1——1——1 27/12/90
2– –2– –2 1/4/91
3—·–3—·–3 19/6/91
4– –4– –4 30/12/91

APPENDIX 6

EPA GUIDELINES FOR THE CONSULTATIVE ENVIRONMENTAL REVIEW FOR THE PROPOSED HARBOUR CITY CANAL ESTATE, MANDURAH

GUIDELINES FOR THE CONSULTATIVE ENVIRONMENTAL REVIEW FOR THE PROPOSED HARBOUR CITY CANAL ESTATE, MANDURAH

Overview

In Western Australia, all environmental reviews are about protecting the environment, which for this proposal means that the environmental values associated with the land south east of the new Mandurah traffic bridge adjoining the Mandurah Inlet Channel and Peel Inlet is protected.

These Guidelines have been prepared in response to a proposal forwarded to the Authority by Esplanade (Mandurah) Pty Ltd to construct a new canal estate in the City of Mandurah, adjacent to the Peel Inlet and Mandurah Inlet Channel. The primary purpose of the Consultative Environmental Review (CER) is to provide information on the proposal to the Environmental Protection Authority within a local framework. The Authority will assess this information and then provide advice to the Government on protecting the environment. An additional function is to communicate clearly with the public so that the Authority can obtain informed public comment. As such, environmental impact assessment is quite deliberately a public process. It also seeks to inform decision makers, to identify risks and minimise adverse environmental impacts, to achieve environmentally sound proposals through research, management and monitoring, and to manage conflict through the provision of the means for effective public participation.

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

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

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

Objectives of the CER

The CER should have the following objectives :

- to place this proposal in the context of the local environment;
- to explain the issues and decisions which led to the choice of this proposal at this place at this time;
- to set out the environmental impacts that the proposal may have; and
- for each impact, to describe any environmental management steps the proponent believes would avoid, mitigate or ameliorate that impact.

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

Key Issues

Key issues include :

1. Justification

• an evaluation of alternative locations and scales, including discussion alternative options, and constraints associated with other potential sites;
• justification of preferred site, including scale; and
• anticipated use of site and perceived need for a development proposal of this type at this location.

2. Proposal

This should include a discussion of the following points:

• background of proposal (i.e.previously proposed Waterside Mandurah Stage 2 Canal Development);
• precise location;
• size / area of canal estate and associated components (i.e. waterways, foreshore reserve, urban subdivision, marina);
• details of proposed services (roads, sewage disposal, boat servicing and refuelling facilities);
• source of fill for proposed reclamation of any low lying land;
• construction method of canals (such as use of bund walls to provide barrier between estuary and excavation of canals);
• anticipated construction timetable, including details of proposed staging of development; and
• final proposed land use layout and when this is expected to be achieved in view of proposed staging of development.

3. Existing Environment

• Soils;
• geology;
• groundwater;
• hydrological characteristics of adjacent water body;
• estuarine flora / fauna ;
• land use, including past land uses and current reservation ;
• local and regional significance of the land, including recreation, landscape and visual amenity. The proposal needs to be viewed in the context of other similar existing and approved proposed developments in the near vicinity; and
• historical, archaeological and ethnographic sites;

4. Environmental Impacts and Management

The following impacts should be addressed :

• impact of development on estuary foreshore;
• impact on System 6 Recommendation area C. 50 and proposed management of potential impacts associated with adjacent urban development;