PELICAN POINT PTY LTD

PELICAN POINT, BUNBURY

PUBLIC ENVIRONMENTAL REVIEW

VOLUME 2 OF 2

TECHNICAL APPENDICES

AUGUST 1991

LeProvost Environmental Consultants

PELICAN POINT, BUNBURY

PUBLIC ENVIRONMENTAL REVIEW

VOLUME 2 OF 2

TECHNICAL APPENDICES

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Pelican Point Pty Ltd

Pelican Point, Bunbury

Public Environmental Review

APPENDIX 1

CORRESPONDENCE

LEC Ref: J186/R320

J186

Mr Peter Collins
Le Provost Environmental Consultants
Suite 2, Preston Centre
75 LabouchereRoad
COMO 6152

Your ref: J186
Our ref: 72/86
Enquiries: Ms Corbett

Dear Mr Collins

PELICAN POINT PUBLIC ENVIRONMENTAL REVIEW

Thank you for your letter of 15th March, concerning the issues to be addressed in the Pelican Point Public Environmental Review.

The Environmental Protection Authority considers that the principal issue to be addressed in the documentation at this stage is the potential impacts on the existing wetlands. The Authority considers that unless it can be clearly established that the wetlands to be created are of equivalent environmental value or better than the existing wetlands, then it is unlikely that the project would be found environmentally acceptable.

The following steps are a guide to demonstrating the wetlands' environmental value:

(1) Define each wetland in terms of area, functions and its EPA Bulletin 374 category;

(2) Demonstrate very clearly that the proposed wetlands are equal to or greater than existing values, e.g. if a reduction in wetland area is proposed, then an increase in function must be provided;

(3) Make a commitment to monitor as appropriate and manage the wetlands for the project's life.

The importance of the wetlands issue is reinforced by the recent release of the Draft Environmental Protection (Swan Coastal Plains Wetlands) Policy.

In addition, the Authority believes that it is not the proponent's responsibility to raise the issue of risks and hazards created by both the proposed expansion of port facilities and the proposed residential areas at Pelican Point. At this stage this is seen as a planning issue, and should be pursued through the planning process. The Authority will draw this issue to the attention of the relevant authorities during the assessment process.

Environmental
Protection Authority

1 Mount Street Perth
Western Australia 6000
Telephone (09) 222 7000
Facsimile (09) 322 1598

Other issues may required more attention prior to the release of the PER, but until the wetland issue has been resolved, the Authority sees it as premature to proceed with them.

Yours sincerely

R.A.D.Sippe
DIRECTOR
EVALUATION DIVISION

3 April 1991

LeProvost, Environmental Consultants
Suite 2
Preston Centre
COMO WA 6152

Your ref:
Our ref: 72/86 Vol III
Enquiries:

Dear Sir

THE SANCTUARY - PELICAN POINT, BUNBURY

Please find enclosed draft guidelines for the proposed Sanctuary development, at Pelican point, Bunbury.

Though guidelines for a PER have previously been provided for earlier proposals, the proponent has recently requested updated guidelines prior to the completion of the draft PER.

I would be grateful if you could peruse the attached, and telephone any comments you have direct to Jim Singleton of the Evaluation Division on tel: 2227084.

Yours faithfully

R A D Sippe

R A D Sippe.
DIRECTOR
EVALUATION DIVISION

6 August, 1990

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Enc

Environmental Protection Authority

1 Mount Street Perth
Western Australia 6000
Telephone (09) 222 7000
Facsimile (09) 322 1598

DRAFT.

GUIDELINES FOR THE PROPOSED SANCTUARY, PELICAN POINT, BUNBURY

The following guidelines have been prepared for a Public Environmental Report (PER) on the development of a major tourist development featuring resort centre, golf course, lakeside villas and a residential canal, at a site at the mouth of the Collie River.

These guidelines are issued as a checklist of matters which the Environmental Protection Authority considers should be addressed in the PER. They are not exhaustive and other relevant issues may arise during the preparation of the document: these should also be included in the)PER. Much of the information required has already been prepared and included in earlier documentation but will need to be collated in the PER. The relevance and requirements of EPA Bulletin 267 and subsequent EPA advice provided to the proponent in correspondence dated 23 May 1988 and 25 January 1990, should be appropriately discussed and referenced.

It should be noted that the guidelines are not intended to convey the Authority's wishes with respect to the format of the document. The format is a matter for the proponent and his consultant.

A copy of these guidelines should appear in the PER.

1. Summary

The PER should contain a brief summary of:

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

2. Introduction

The PER should include an explanation of the following:

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

3. Need for the development

The PER should examine the justification for the project and projected costs and benefits (in the broad sense) at local and regional levels. Specific reference should be made to other relevant existing and proposed tourism developments in Australind/Bunbury.

4. Evaluation of alternatives

The evaluation of alternatives is an important part of a PER. A discussion of alternatives to the proposal, including alternative sites as well as the "do nothing" option should be given. A comparison of these in the context of the stated objectives should be included as well as costs and benefits at both construction and operational stages. This discussion should also briefly consider various components of the project (eg the golf course, lakes and wetlands, residential canal), and their implications. In this way the rationale for not choosing certain alternatives should be clear as would the basis for choosing the preferred option.

5. Description of proposal

The PER should include details of:

- overall concept;
- location and layout;
- proposed land uses, land tenures and a clear indication between boundaries of private and public land;

- infrastructure including any boating support facilities;
- number of employees;
- access;
- auxiliary services (eg power, water, sewerage);
- control and staging of project;
- operation during and after construction, including management of any boat facilities;
- projected life of the project;
- translocation and reinstatement of wetland bird habitat areas in terms of precise habitat value and management provision; and
- all statutory requirements required for the project to proceed.

6. Existing environment

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

It should then concentrate on the significant aspects of the environment likely to be impacted by the development (ie in particular, the processes sustaining the system). Only the processes, habitats, resources and potential resources which could be influenced should be defined. Detailed inventories should be placed in appendices to the PER.

Wherever possible in the discussion of physical and biological processes that are essential determinants in the maintenance of habitats and resources, conceptual models or diagrams should be used to illustrate and synthesize the interactions between the processes.

The following matters should be addressed:

6.1 Physical

- meteorology;
- oceanography of Leschenault Inlet/Collie River;
- geology and geomorphology;
- drainage;
- onshore hydrology and hydrogeology, including water quality;
- near shore water quality;
- wetlands.

6.2 Biological

- offshore and onshore biota (including wetlands) ecosystems;
- mosquitoes.

6.3 Human

- land use, including past land uses, land tenure, zoning and reservation, conservation recreational aspects;
- road systems and traffic;
- landscape;
- public access;
- adjacent sites affected by System 6 "Red Book" recommendations;
- historical, archaeological and ethnographic sites;
- adjacent urban developments;
- use of waters in vicinity of proposal;
- use of adjacent wetlands.

These issues need to be discussed in both a local and regional context. In addition, the PER should, where appropriate, take cognisance of any other similar developments proposed for the general area.

7. Environmental Impacts

This is the most important part of the PER and the result should show the overall effect on the total ecosystem and social surroundings of the location during and after construction.

This is the most important part of the PER and the result should show the overall effect on the total ecosystem and social surroundings of the location during and after construction.

The objective is to take an overview of the elements of the system involved and the external factors with which they interact and to present them as a synthesis or conceptual model which can be used to predict system behaviour under these stresses likely to be encountered. This should include an assessment of the resilience of the systems identified in 6 to natural and man-induced pressures. Impacts should be quantified where possible. Criteria for making assessments of their significance should be outlined. Compliance with relevant standards should be demonstrated. In some cases there will be advantage in discussing construction and operational impacts separately.

It will be necessary to determine impacts on individual components of the environment before a final overall synthesis of potential impacts is made.

The following potential environmental impacts should be included:

- oceanography of Leschenault Inlet and Collie River;
- offshore and onshore biota (in particular wetlands ecosystems);
- risk analysis of storm events eg floods;
- contingency planning and safety;
- drainage;
- water quality (within the newly created, and modified wetlands and within the residential canal portion) and groundwater;
- land stability (with particular reference to all areas disturbed during construction, especially the batters of significantly filled areas, and the peripheral areas of wetlands);
- landscape;
- local and regional significance of foreshores;
- any historical, archaeological and ethnographic sites;
- the adjacent System 6 areas;
- emissions (air, water, waste disposal, noise);
- land use including conservation and recreation aspects;
- access road systems and transport;
- effect on existing community and facilities;
- services (power, water, sewerage);
- use of adjacent offshore waters;
- construction and operational workforce;
- use of wetlands by waterfowl;
- impacts of the environment of the project eg mosquitoes; and
- the possible long-term impacts of Bunbury Port facility activities on the proposed tourism, residential uses of the development.

The final synthesis should include an assessment of the significance and timing of the various potential impacts identified.

8. Environmental management

An environmental management programme should be described on the basis of (land cross-referenced to) the synthesis of potential environmental impacts.

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

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

Elements of monitoring and the environmental management programme should include the impacts identified in 7.

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

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

It is important that specific commitments are given to all components and procedures of the management programme.

9. Summary of commitments by proponent

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

10. Conclusion

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

11. References

GLOSSARY (definitions of technical terms, abbreviations)

PER GUIDELINES

APPENDICES

AN ENVIRONMENT WORTH PROTECTION

J186

LeProvost, Semeniuk and Chalmer
Suite 2
Preston Centre
COMO WA 6152

ATTENTION: PETER COLLINS

Your Ref: J186
Our Ref: 72/86 Vol VII
Enquiries: Mr J Singleton

Dear Sir

PELICAN POINT

Further to your letter of 20 February 1990 in which you indicate in the sketch plan proposed amendments to the waterway and wetlands, I wish to inform you that based on the information received the assessment will remain at Consultative Environmental Review level, but that one month's limited public review in the Bunbury/Australind locality will be required.

As this advice is based on a sketch plan showing only notional layout, you should forward for confirmation the final details of the amendment prior to preparation of the CER.

If you have any further queries, please contact Jim Singleton of the Evaluation Division on 222 7084.

Yours faithfully

R A D Sippe
DIRECTOR
EVALUATION DIVISION

19 March 1990

78JSPELICAN:clb

Environmental Protection Authority
1 Mount Street Perth
Western Australia 6000
Telephone (09) 222 7000
Facsimile (09) 322 1598

AN ENVIRONMENT WORTH PROTECTION

Le Provost, Semeniuk
and Chalmer
Suite 2
Preston Centre
COMO WA 6152

Your Ref: J186
Our Ref: 72/86 VOL VII
Enquiries: Mr J Singleton

Dear Sir

PELICAN POINT - BUNBURY

Further to my letter of 18 January 1990, I include the following advice as to those matters of particular environmental significance that should be addressed in the CER.

I reiterate that the EPA's recommendations and findings contained within Bulletin 267 as they relate to the current proposal, together with subsequent advice provided in the Authority's letter dated 23 May 1988 to Zurdeveld Bennett (see attached), still apply to the proposal.

In summary, the issues are:

- appropriate mosquito control
- flood control provisions affecting the site
- public access to foreshores
- set back from the Collie River foreshore
- appropriate buffer (as modified) to adjacent industrial land
- hydrogeology of the site and adequate water supply
- treatment of existing wetlands and water quality matters
- appropriate re-establishment of wetland waterbird habitats
- adequate commitments and undertakings

Informal discussions with the Waterways Commission to date have clarified that any connection of the existing wetlands to the Collie River would only be for the purpose of maintaining water levels. This will be important in assisting in mosquito management of the existing wetland bodies on Part Lot 26.

The Authority will be particularly concerned with the final treatment of all wetlands within the development site, both existing and those to be created. You are advised to have discussions with Rob Atkins and Verity Klem of the Waterways Commission before finalising design details to be included in the CER.

A further matter of concern is the existing disposal of urban drainage from the Eaton subdivision onto the ILDA land. An appropriate solution is obviously required.

Finally, I should point out that if there is any significant revision of the existing proposal to include more complex components, such as a canal style development, the Environmental Protection Authority may wish to reconsider the level of assessment set and revise it upwards accordingly.

Environmental
Protection Authority
1 Mount Street Perth
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Telephone (09) 222 7000
Facsimile (09) 322 1598

If you have any further queries, please contact Jim Singleton of the Evaluation Division.

Yours faithfully

R A D Sippe
DIRECTOR
EVALUATION DIVISION

25 January 1990

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cc R Taylor and W Burrell

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ENVIRONMENTAL PROTECTION AUTHORITY
1 MOUNT STREET, PERTH, WESTERN AUSTRALIA 6000
Telephone (09) 222 7000

Manager
Le Provost Semeniuk and
Chalmer
Suit 2
Preston Centre
COMO WA 6151

Your Ref:
Our Ref: 72/86 VOL III
Enquiries: Mr J Singleton

Dear Sir

PELICAN POINT - BUNBURY

The letter is to advise you that the Environmental Protection Authority has decided that the Pelican Point proposal as currently submitted shall be assessed at CER level.

Due to the length of time that has elapsed since the first guidelines were provided, and since the publication of Bulletin No 267, you shortly will be provided with a summary statement of those environmental aspects of the project that the Authority considers of most significance. If you have any further queries in the meantime, please contact Jim Singleton of the Evaluation Division of the Authority.

Yours faithfully

R A D SIPPE
DIRECTOR
EVALUATION DIVISION

18 January 1990

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(17) 22
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ENVIRONMENTAL PROTECTION AUTHORITY
1 MOUNT STREET, PERTH, WESTERN AUSTRALIA 6000
Telephone (09) 222 7000

Zuideveld Bennett
Consulting Land Surveyors
PO Box 18
VICTORIA PARK WA 6100

Your Ref
Our Ref 76/86 Vol III
Enquiries Mr J Singleton

Dear Sir

RE: THE SANCTUARY - PELICAN POINT, BUNBURY

I refer to your recent meetings with Jim Singleton of the Evaluations Division, and confirm the following advice.

A draft Notice of Intent should be prepared which addresses all recommendations contained in Bulletin 267, as well as all aspects of the proposal. The draft Notice of Intent should demonstrate the positive trade-offs being proposed to resolve all areas of conflict with those recommendations, and should demonstrate that the essential environmental and other functions of the overall site are to be maintained. These include:

- the amount of available wetland habitat and feeding grounds for water fowl and wading birds, as determined by LIMA and the Department of Conservation and Land Management;
- the flood capacity of the site, as determined by the WA Water Authority;
- the essential drainage and hydrological functions of the site;
- the continued existence of mosquitoes, controlled to a level and by techniques that will not degrade the Leschenault Inlet environment, or estuarine habitats external to the site in question;
- full public access to the inlet and Collie River foreshore areas; and
- the buffer to adjacent industrial development provided by the ILDA land parcel.

Undertakings as to how these will be achieved should be given.

It is considered that a draft Notice of Intent will allow flexibility for referral to key government agencies, and for advice to be given and any necessary changes to be made, prior to final submission to the EPA.

The proponent is reminded that in view of the high level of public concern on the previous design proposal, the possibility of the EPA deciding that the proposal should be made available for further public review should not be discounted.

The Steering Group referred to in Recommendation 9 (Bulletin 267) will be convened to assist in the implementation of the proposals and undertakings provided in the Notice of Intent after the assessment process is completed, conditional upon EPA approval for the proposal being granted. This approach is taken on the grounds that the current proposal is considered to be fundamentally different from that addressed in Bulletin 267, that the assessment process is now at a different (earlier) stage, and that the EPA is dealing with a new proponent.

Finally, I would remind you that the existing land use zoning over Part Loc 26 prohibits development of the type proposed (re residential subdivision). This matter must be resolved with the City of Bunbury and the State Planning Commission as soon as possible.

As requested I include a copy of suggested sample headings and structure for a Notice of Intent. This advice is not absolute or exhaustive and there may be additional issues that the proponent considers warrant inclusion.

Yours faithfully

P Skitmore
A/DIRECTOR
EVALUATION DIVISION

23 May 1988

0140JSSAN:lp

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ALL CORRESPONDENCE TO BE ADDRESSED TO CHIEF EXECUTIVE

IN REPLY PLEASE QUOTE 853-6-2-9 Vol 3
YOUR REF WHB/AP 89/31
OUR REF Miss H Aitken:CS

DEPARTMENT OF
PLANNING AND URBAN DEVELOPMENT

November 22, 1989

Messrs Russell Taylor & William Burrell
PO Box 503
WEST PERTH WA 6005

Dear Sirs

PROPOSED RESORT DEVELOPMENT
PELICAN POINT
USE OF PART OF LOT 60 OLD COAST ROAD

I refer to your letter dated September 6, 1989 relating to the above matter.

The Committee for Statutory Procedures acting on behalf of the Commission under delegated power, resolved, at its meeting of November 20, 1989, to advise that:

(1) the Department generally supports the proposed golf course and golf estate uses on the subject land;

(2) comprehensive details will need to be provided in the Notice of Intent for the project showing the physical separation and buffer area between the golf estate and the port area;

(3) the City of Bunbury Council will need to initiate an appropriate amendment to Town Planning Scheme No 6 which permits and controls the developments; and

(4) the Industrial Lands Development Authority and the Bunbury Port Authority must be consulted in the preliminary stages of any proposal to amend Town Planning Scheme No 6.

Yours faithfully

G Smith
GORDON G SMITH
SECRETARY

Copies to: Ansaan
: Le Provost
: S. Thompson

To Mr Balan Nair
FROM Peter Dowding

DEPUTY PREMIER
MINISTER FOR FINANCE AND ECONOMIC DEVELOPMENT; THE GOLDFIELDS

JH12390NAIR

Mr Balan Nair
Managing Director
Ausean Consultants Pty Ltd
442 Murray Street
PERTH WA 6000

26 MAR 1990

Dear Mr Nair

PELICAN POINT RESORT DEVELOPMENT
PART LOT 60 - OLD COAST ROAD, BUNBURY

I refer to your meeting with my ministerial predecessor on 22 December, 1989 when concerns regarding the introduction of residential units into the Pelican Point development were discussed. My ministerial colleagues have conferred on the matter, and I am prepared to agree that residential development on the portion of Lot 60 to be purchased from the Industrial Lands Development Authority is acceptable upon the following terms and conditions:

1. A new formal agreement be entered into by you with Government agencies, including ILDA, for the purchase of portion of Lot 60 and its development in conjunction with the adjacent Pelican Point land.

2. Overall development plans for the project to be reviewed with the object of pushing the housing development as far north as possible on portion of Lot 60 and thereby extending the distance between the housing development and the proposed Preston River diversion, maximising the distance from the Port and Port industrial area.

   Final layout plans for the housing development to be submitted to Department of Planning and Urban Development for approval.

3. The number of residential units is not to be increased beyond the 60 units currently proposed for Part Lot 60.

4. Comprehensive details to be provided showing the nature and effectiveness of the buffer between housing and the Port industrial area.

5. The City of Bunbury Town Planning Scheme No 6 to be amended to include appropriate development control provisions as well as an appropriate zoning to permit the development. The Scheme amendement to be finalised when development is assured of proceeding and agreements have been entered into.

6. The total development to be reviewed by the Environmental Protection Authority with particular reference to Bulletin No 267. (Pelican Point Country Club and resort development).

7. The sale price of Part Lot 60 to be reviewed to reflect the current value of the land.

8. Evidence to be submitted that funds are available for the purchase of the ILDA land and the completion of the total project development.

I believe that these conditions will satisfy Government requirements related to the acquisition and use of the ILDA land, and I look forward to your advice that they are acceptable to you. Upon receipt of this confirmation, ILDA will proceed, in consultation with Department of Planning and Urban Development, to prepare the Agreement.

Yours sincerely

IAN TAYLOR M.L.A.

Industrial Lands Development Authority

14th FLOOR,
26 ST. GEORGE'S TERRACE, PERTH 6000
TELEPHONE 325 4266
FAX: 325 1306

Our Ref: 71/86 vol 3

Mr Balan Nair
Managing Director
Ausean Consultants Pty Ltd
442 Murray Street
PERTH WA 6000

Dear Mr Nair

PT LOT 60 OLD COAST ROAD, BUNBURY

I refer to our meeting on 8 May, at which Messrs Frewer, Klem, Ong and Burrell were also present, and at which your latest proposals for proceeding with your Pelican Point project were discussed, including the future use and development of Pt Lot 60, owned by the Authority.

In accordance with our discussion at that meeting, I confirm that I shall recommend to the Board of the Authority that it enter into an agreement with your company for the purchase of Pt Lot 60, on the following terms and conditions:

. The selling price of the land will be in accordance with current valuation, taking into account its proposed use and development. The valuation will assume that the development will take place in 2 years' time.

. The purchase price will be paid in full on execution of the Agreement for Sale.

. The Agreement for Sale will contain the following conditions, which will have to be satisfied within 2 years:

  - all necessary approvals for the development to be obtained by Ausean, including EPA, DPUD (including appropriate rezoning) and Bunbury City Council approvals.

  - Ausean to carry out bulk earthworks for the first 9 holes of the golf course, the 100 residential units, the commercial centre and the saltwater lake.

. Upon Ausean fulfilling its obligations under the contract, title to the land will be transferred, and a further payment will be made to ILDA to reflect an assumed increase in the value of the land, which will be measured by the increase in the Consumer Price Index between the date of execution of the Agreement for Sale and the date of transfer.

The matter will be considered by the Authority's Board on 24 May, and I shall inform you of the outcome immediately thereafter.

Yours faithfully

F B N Hodges
GENERAL MANAGER

10 May 1990

nh:510ausean

853/6/2/9 Pt 126
JAT/BC/Amendment 126
Miss H Aitken/MR

June 20, 1991

Town Clerk
City of Bunbury
P O Box 21
BUNBURY WA 6230

Dear Sir

TOWN PLANNING SCHEME NO 6
AMENDMENT NO 126

I refer to your letter of May 8, 1991 and advise that the Committee for Statutory Procedures acting on behalf of the Commission under delegated power has given its consent for the above Amendment to be advertised for public inspection subject to the following modifications being effected prior to advertising:

1. Delete the commercial B zoned site at the junction of the Estuary Drive and Old Coast Road and include internally within the development a site for a minor local centre to serve the needs only of the permanent residence and the resident tourist within the Pelican Point Development.

2. Correct the alignment of the boundary between the City of Bunbury and the Shire of Dardanup as shown on the documentation maps in the section north of Hamilton Road, to be consistent with the existing Town Planning Scheme maps.

3. Indicate by appropriate cross hatching the portion of Taylor Road to be closed on the proposed zoning map.

4. Include the Existing Zoning map with the amending text document by placing it prior to the Proposed Zoning map.

5. Include a copy of the Pelican Point Development Plan No 89/31/1, as amended in accordance with point 1. above, endorsed by the Mayor and the Town Clerk within the amending text documents.

6. Modifying item 2 of the amending text to read as follows:

   2 Rezoning Lot 100 from "Parks, Recreation and Drainage Reserve" and "Communication" Reserve, (controlled access highway) to "Parks, Recreation and Drainage, Restrictive" reserve, "Residential R20 and R40", "Communication" reserve, (sub-arterial road and controlled access highway) as depicted on the Scheme Amendment map.

7. Modifying the amending text, item 6 by adding to Clause 5.3.8(a) the words "The Mayor and" prior to the words "the Town Clerk".

In making the required modifications, Council is reminded of the need to ensure that the amending maps accurately reflect the intention of the amendment as detailed in the amending text.

Upon return of the amending documents to the Department modified in accordance with the above requirements, the Amendment will be advertised for a period of 42 days subject to:

1. Three signs to the satisfaction of Council, describing the proposal, being placed on-site within 14 days of the commencement of advertising and remaining on-site for the duration of the advertising period. Those three signs should be located as follows:

   (i) At the south-east corner of Lot 100 facing towards the intersection of Old Coast Road and the Australind By-pass Road.

   (ii) At the junction of Estuary Drive and Old Coast Road.

   (iii) At the junction of Taylor Road and Old Coast Road.

2. Adjoining/nearby owners to be notified in writing of the proposal and invited to make submissions.

Council is further advised that prior to seeking final approval to the development the following matters need to be addressed by Council:

(i) Liaise with the Shire of Dardanup to co-ordinate the positioning, design and programming for construction of a dual use pathway linking the Eaton residential area across the Old Coast Road, through the Pelican Point Development to the Leschenault Inlet.

(ii) Liaise with the Shire of Dardanup and the Water Authority of Western Australia to ensure that other development and filling works carried out within the proposed relief floodway do not preclude that floodway from functioning effectively for its intended purpose.

(iii) Council entering into a legal agreement, satisfactory to the Commission, with the proponent to cover special issues including:

   (a) Proposed land exchange.

   (b) Care and management of Public Open Space and waterways.

   (c) The balance between short stay and long stay residential units.

One set of amending documents is returned herewith.

Yours faithfully

SARAH ARTHUR
SECRETARY
COMMITTEE FOR STATUTORY PROCEDURES

Pelican Point Pty Ltd

Pelican Point, Bunbury

Public Environmental Review

APPENDIX 2

RECOMMENDATIONS OF THE ENVIRONMENTAL PROTECTION AUTHORITY AND THE LESCHENAULT INLET MANAGEMENT AUTHORITY FOR THE 1986 PELICAN POINT PROPOSAL

LEC Ref: J186/R320

RECOMMENDATIONS OF THE ENVIRONMENTAL PROTECTION AUTHORITY AND THE LESCHENAULT INLET MANAGEMENT AUTHORITY FOR THE 1986 PELICAN POINT PROPOSAL

RECOMMENDATION 1

EPA/LIMA recommend that all structures should be located outside the recommended limit of floodplain encroachment as shown on the WA Water Authority Plan PWD WA 52387-14-1 (see Figure 5) and that in all other respects the development should comply with the flood strategy for the Collie River.

RECOMMENDATION 2

EPA/LIMA recommend that the proponent be legally required to establish a 50-metre wide area of open space for the public along the foreshore, consistent with the intent of the Leschenault Inlet Management Programme, on Vittoria Bay and the Collie River.

The alignment of the foreshore area along Vittoria Bay should be consistent with the alignment of the foreshore area already pegged on Pt Loc 26.

The alignment of the foreshore area along the Collie River should be the "Recommended Limit of Floodplain Encroachment" shown in the Collie River Flood Strategy.

RECOMMENDATION 3

EPA/LIMA recommend that:

(i) continuous and ready public access should be made available throughout all foreshore areas; and

(ii) a defined public accessway, linking the public car and trailer parking facilities on the Collie River foreshore with the Vittoria Bay foreshore area, should be retained across the project site.

RECOMMENDATION 4

EPA/LIMA recommend that, in designing a golf course as part of the project, Pt Loc 26 and the adjacent ILDA site should be treated as a single land unit to accommodate the following objectives:

(i) provision of an 18-hole golf course; and

(ii) retention of the wetlands of the land unit to incorporate the natural conservation values of the whole area, in consultation with LIMA and CALM.

RECOMMENDATION 5

Recognising that the retention of the wetland areas on Pt Loc 26 is a matter of the highest priority, the EPA/LIMA recommend that any modification to that land, including provision of the 250-metre wide relief floodway, should be undertaken in such a way that its functions as waterbird/wading bird habitat and feeding grounds are maintained or enhanced.

RECOMMENDATION 6

EPA/LIMA recommend that any mosquito control programme or activities prepared or undertaken for this proposal should be environmentally acceptable to the satisfaction of both Authorities. They should also be complementary to the regional mosquito control strategy.

RECOMMENDATION 7

EPA/LIMA recommend that the legal agreement proposed by the proponent should include the commitments made by the proponent in the PER, provision for the management and monitoring programmes, and any additional requirements identified in this Assessment Report.

RECOMMENDATION 8

EPA/LIMA conclude that:

(i) subject to modifications sought in this report, the resort development on Pelican Point is environmentally acceptable, and could be commenced; and

(ii) development of a golf course on the combined Pt Loc 26 and ILDA site is presently not environmentally acceptable but could become acceptable with modifications to the satisfaction of EPA/LIMA.

RECOMMENDATION 9

EPA/LIMA recommend that a Steering Group should be established to advise and provide guidance in relation to:

(i) the design of the golf course part of the project on the combined Pt Loc 26 and ILDA site; and

(ii) ensuring that the relief floodway is designed and constructed in an environmentally acceptable manner.

EPA/LIMA are prepared to convene this group which should include, among others, the City of bunbury, the Water Authority of WA and the Department of Conservation and Land Management.

Pelican Point Pty Ltd

Pelican Point, Bunbury

Public Environmental Review

APPENDIX 3

ASSESSMENT OF WETLANDS AND TERRESTRIAL LAND UNITS

LEC Ref: J186/R320

ASSESSMENT OF WETLAND AND TERRESTRIAL LAND UNITS

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FIGURE

ASSESSMENT OF WETLAND AND TERRESTRIAL LAND UNITS

1 INTRODUCTION

The recent release of the Draft Environmental Protection (Swan Coastal Plain Wetlands) Policy (EPA, 1991) states the Environmental Protection Authority's (EPA) position regarding wetland use and modifications in the Swan Coastal Plain region. Since the proposed Pelican Point project will be constructed within an area containing a number a wetlands, it is important to clearly demonstrate that the wetlands to be created are of equivalent or greater environmental value than the existing wetlands which are to be modified.

At the suggestion of the EPA, the environmental values of both the existing and proposed wetlands of the project area have been assessed using the numerical approach described in EPA Bulletin No. 374, A Guide to Wetland Management in Perth (EPA, 1990). While this Bulletin was specifically designed for application to the Perth Metropolitan Region, with appropriate and minor amendment it can also be applied to other wetlands on the Swan Coastal Plain. The numerical approach seeks to determine a score for various wetland attributes which, when totalled for each particular wetland, enables its classification into one of the following categories:

(i) H: high conservation;
(ii) C: conservation;
(iii) O: conservation and recreation;
(iv) R: resource enhancement; and
(v) M: multiple use.

For the purpose of simplifying the assessment the study area has been divided into five land units which are distinguished on the basis of both natural characteristics and the type and extent of development which is proposed within each unit. The five units are as follows (Fig. 1):

(i) Upland/terrestrial unit on Lot 100;
(ii) Lowland/wetland unit on Lot 100;
(iii) Collie River foreshore;
(iv) Leschenault Inlet foreshore; and
(v) Pelican Point terrestrial and ephemeral wetland complex.

In the following text a description and assessment of each unit as it presently occurs is followed by a description of the unit as it would be, if developed according to the development scheme presented in the Public Environmental Review (PER). A discussion of the relative habitat value of the unit at both pre-development and post-development stages concludes the analysis of each unit.

2 UPLAND/TERRESTRIAL UNIT (LOT 100)

2.1 SITE DESCRIPTION AND ASSESSMENT - PRESENT STATUS

The upland unit on Lot 100 is a terrestrial unit comprising the sand ridge at the southern extremity of the Lot, together with the central lowland plain, an area of approximately 65 ha. The land is bounded to the north by Old Coast Road, to the south by the Australind Bypass and the railway reserve, and to the west by the proposed Preston River diversion. To the north the land adjoins the lowland/wetland unit which also occurs on Lot 100.

The land falls away from the southern boundary before levelling out at an elevation of approximately 1.0 m AHD. The soils are Cottesloe sands of the Spearwood dune system.

The land is parkland-cleared and the vegetation now consists of pasture species with retained trees, which include mature Tuart, Marri and paperbarks.

The faunal complement of the unit is believed to be relictual and depauperate. Some value is ascribed to the mature trees which provide a range of nesting and roosting sites for avifauna, bats and lizards.

The land, which is under contract of sale to Pelican Point Pty Ltd, is leased by the present owner, the Industrial Lands Development Authority (ILDA), for grazing purposes. The site is fully fenced and contains a number of farm buildings, yards, tracks, etc. Power transmission lines run through two SECWA easements in the southern part of the property.

Numerical Assessment

This unit currently contains no wetland features and therefore cannot be numerically assessed.

2.2 SITE DESCRIPTION AND ASSESSMENT - POST DEVELOPMENT

Following construction of the project, as described in Section 4 of the PER, this unit will be modified by the construction of:

- approximately 75% of the 18-hole golf course;
- a 5.6 ha saline lake which will incorporate a golf driving range and two islands naturally vegetated with rushes and mature paperbarks;
- four freshwater lakes with a combined water area of 2.5 ha, distributed around the golf course;
- a golf clubhouse; and

- 40 golf course units for short-stay accommodation.

The golf clubhouse and residential development will occupy approximately 5 ha of the 65 ha area of this unit. The remainder of the land will be developed to form the golf course, lakes and associated landscaping.

The golf course will be designed such that as many of the mature trees as possible will be retained in the areas between the fairways. In addition, further local native trees and flowering shrub species will be planted in the 'rough' areas between the fairways to provide additional food resources for the resident fauna and to attract other species of bushbirds.

The saline lakes will provide a mixture of active recreational space in the form of the golf driving range, and conservation space in the form of a shallow water lake with emergent vegetation, designed for use by wading birds. The lake will be isolated from the Leschenault Inlet and the proposed course of the Preston River by a vegetated bank. There will be no physical separation between recreation and conservation zones. The driving range portion of the lake is anticipated to attract less use by waterfowl during daylight, however, this portion of the lake will contribute to the overall productivity of the lake system, providing a habitat for invertebrates and amphibians, and is likely to be utilised between dusk and dawn.

The freshwater lakes, which will be sealed to prevent contamination by saline groundwater, will serve the dual function of providing the pressure balance system necessary for the irrigation of the golf course, while at the same time providing a permanent source of freshwater for avifauna. The latter is regarded as an important function of the freshwater lakes as this area is frequently dry in summer when usage of Leschenault Inlet by birds is at its highest. In recognition of this value, landscaping of the lake edges will be designed to provide shelter and access for birds using the lakes and some of the lake edges will be well separated from residential areas. Water quality within the lakes will be maintained by the regular pumping required for irrigation purposes, and replacement by groundwater drawn from the Leederville and shallow aquifers.

Numerical Assessment

Natural attributes - The wetlands to be created would be defined as permanent wetlands with well defined boundaries (Part 1A, EPA Bulletin No. 374).

ATTRIBUTE	COMMENT	SCORE
Environmental geology classification	The scores applied under this classification are not appropriate to wetlands outside of the Perth Metropolitan Area [refer to note under Section 2.2.1 Part A (i) of Bulletin No. 374].	Not scored
Adjacent wetlands	Other than within the development, there will not be similar (i.e. permanent freshwater) wetlands within a 2 km radius	3
Habitat diversity		Not scored
Drought refuge	Due to limited area, the lakes will not be a major drought refuge, but will provide a valuable source of freshwater for birds using the estuary for drought refuge.	2
Area of wetland	The area of artificial wetland will be less than 10 ha.	1
Habitat type	The proposed wetlands will provide the following habitat types: islands; permanent shallow water; permanent deep water; scattered paperbarks; and scattered rushes.	4
Emergent vegetation	Emergent vegetation will be primarily found in the saline lake. The percentage of all of the lakes to be covered by emergent wetland vegetation will, however, be less than 10%.	1
Adverse water quality	As a consequence of proposed management commitments, the Proponent (or subsequently approved management body) will be responsible for the maintenance of adequate water quality within the lake system.	5
Drainage	The wetlands will be designed to harvest rainfall runoff for re-use through the irrigation system. Water quality within the lakes will be maintained by the input of groundwater (of low nutrient content) from the Leederville aquifer and constant turnover achieved by regular pumping from the lakes for irrigation purposes.	3
Adjacent nutrient sources	The golf course will be a potential nutrient source to the saline lake, but will have negligible impact on the freshwater lakes, which will have their water regularly exchanged through drawdown for irrigation.	2
Area of wetland modified	The wetlands will be artificial and therefore totally modified.	1
Reserve area	The proposed wetlands will not be located within a reserve.	0
Native vegetation buffer	The margins of the lakes will be fringed by vegetation, however, due to area constraints these buffers will generally be less than 50 m in width.	1
TOTAL		**23**

HUMAN USE QUESTIONNAIRE		
ATTRIBUTE	**COMMENT**	**SCORE**
Aesthetics	There is a relatively steep ridge present which will provide views over the lakes.	3
Historical and archaeological features	There are no archaeological or historic features associated with the proposed lakes.	0
Security of wetland	The land is privately owned.	1
Protection groups	The lakes will be actively protected through the proposed golf course management body.	5
Passive recreation	The wetlands will be used for the conservation of fauna and will form part of a recognised tourist venue.	2
Active recreation	The wetlands will form part of a golf course.	1
Other human uses	The wetlands will be used for irrigation of the golf course.	1
TOTAL		**13**
CATEGORY		**R**

2.3 DISCUSSION

The existing terrestrial habitat of Lot 100 is of limited value to wildlife due to the extent of modification of the pre-existing habitats. The principal habitat of value being the remnant mature trees which provide nesting and roosting sites for birds and a seasonal source of food in the form of nectar and seeds.

Under the proposed development plan it is intended to retain the majority of these trees, and to supplement these with additional plantings of similar tree species and indigenous flowering shrubs. Habitat variability will also be increased by the construction of 10.1 ha of freshwater and saline lakes which will provide a permanent source of fresh water for wildlife and additional feeding and loafing areas for waterfowl (particularly the heron, egret, ibis, spoonbill group).

Overall it is considered that the loss of approximately 7.5% of the area to a built environment is more than offset by the proposed enhancement of the remaining terrestrial habitat. The creation of new permanent wetland habitat will not only replace part of the existing seasonal wetland which is will be lost elsewhere within the development, but will enhance the value of that habitat.

3 LOWLAND/WETLAND UNIT (LOT 100)

3.1 SITE DESCRIPTION AND ASSESSMENT - PRESENT STATUS

The lowland unit comprises part of the river floodplain/delta complex, the landward margin of which is taken as the 1.0 m AHD contour, which also corresponds with the 0.0 m AHD water table contour. The land slopes toward a central depression at approximately 0.0 m AHD.

The landform in which this unit is located is defined as estuarine/river floodplain. Natural drainage patterns have been modified by the construction of drains to the estuary or to Pelican Point, and road embankments.

The vegetation of the unit consists of a mixture of 'dry' and 'wet' samphire and rush beds covering a total area of 18.1 ha, with scattered paperbarks on higher ground at the margins of the wetland. Pasture fringes the rush beds to the north-east and to the south. The land has been extensively modified by clearing, grazing, stock trampling and soil compaction. There are no known records of the original vegetation. However, based on relict vegetation, it may be assumed that the extent of fringing samphire was once much greater, while that of the dry samphire, which is favoured by the clearing and modified drainage pattern, occupied a smaller area.

Ninox (1990) describe the main wetland value of this unit as the central depression (i.e. that part below the 1.0 m contour) which is a feeding area for members of the heron/egret/spoonbill group.

The drains and temporary pools within this unit are also recognised as significant mosquito breeding sites, which have been allocated a high priority mosquito control rating (Site 106; Wright, 1986).

Lot 100, in which this unit is located, is currently used for grazing and the lowland portion is used as a summer pasture.

Numerical Assessment

Natural attributes - This unit is defined as a seasonal wetland with poorly defined boundaries (Part 1B; EPA Bulletin No. 374).

ATTRIBUTE	COMMENT	SCORE
Environmental geology classification	The scores applied under this classification are not appropriate to wetlands outside of the Perth Metropolitan Area [refer to note under Section 2.2.1 Part A (i) of Bulletin No. 374].	Not scored
Adjacent wetlands	There are similar wetlands within a 2 km radius.	Not scored
Habitat diversity	The composition and structure of the vegetation are similar to that found at nearby wetlands.	1
Habitat type	The following habitat types are represented within the wetland: samphire; rush beds; and scattered paperbarks.	2.5
Drainage	There are drains directing water out of the wetland.	0
Area of wetland modified	In excess of 50% of the wetland has been modified by drainage and land use practices.	1
Native vegetation buffer	The wetland is not buffered by native vegetation of 50 m in width.	0
TOTAL		**4.5**
HUMAN USE QUESTIONNAIRE		
ATTRIBUTE	**COMMENT**	**SCORE**
Aesthetics	The ridge to the south provides views of this wetland.	1
Historical and archaeological features	There are no known archaeological or historic sites associated with this unit.	0
Security of wetland	The wetland is privately owned.	1
Protection groups	The wetland has no active protection groups.	0
Passive recreation	The wetland is not a recognised passive recreational area.	0
Active recreation	The wetland is not a recognised active recreational area.	0
Other human uses	The land is currently used for grazing, but forms part of an area proposed to be used for wetland conservation, recreation (golf), housing and commerce.	2
TOTAL		**4**
CATEGORY		**M**

3.2 SITE DESCRIPTION AND ASSESSMENT - POST DEVELOPMENT

The proposed development would result in the modification of the majority of the land within this land unit. The proposed land uses include:

- golf course and associated landscaping (approximately 25% of the course would be located within this unit);
- 1.1 ha of freshwater lake; and
- a saline lake with an area of 1.4 ha..

The residential and commercial development would be totally modified environments, although it can be expected that some bushbirds would be attracted to the landscaping within and fringing the development.

The freshwater lake would be designed and would function in the same way as those described in the previous section.

The saline lake and adjacent landscaping would be developed as replacement habitat for the central depression, which would be filled for the proposed residential development. The lake landscape would include both open water and emergent rush bed areas, with fringing rushes extending into the rough areas between adjacent fairways. The line of mature paperbarks which is present in this location would be retained along one side of the lake. The shallow open water and rush beds would provide suitable habitat for the prey species favoured by egrets and spoonbills, i.e. amphibians and aquatic invertebrates and molluscs.

Numerical Assessment

Natural attributes - Although the proposed wetlands will be permanent and have defined boundaries, the Part 1B assessment is used here to maintain the comparability of the pre- and post-development assessments.

ATTRIBUTE	COMMENT	SCORE
Environmental geology classification	The scores applied under this classification are not appropriate to wetlands outside of the Perth Metropolitan Area [refer to note under Section 2.2.1 Part A (i) of Bulletin No. 374].	Not scored
Adjacent wetlands	There will be similar wetlands within a 2 km radius.	Not scored
Habitat diversity	The composition and structure of the vegetation will be similar to that found at nearby wetlands.	1
Habitat type	The following habitat types are represented within the proposed wetland: islands; permanent shallow water; permanent deep water; scattered rushes; and scattered paperbarks.	4
Drainage	There will be no are drains directing water to or from the wetland.	5
Area of wetland modified	The lakes, being man-made, will be a totally modified environment.	1
Native vegetation buffer	The part of the lake not used for active recreation will include native vegetation buffers, however due to area constraints these will be less than 50 m in width.	0
TOTAL		**11**
HUMAN USE QUESTIONNAIRE		
ATTRIBUTE	**COMMENT**	**SCORE**
Aesthetics	There is a ridge present which will give a view of the open water of the lakes.	3
Historical and archaeological features	There are no archaeological or historic features associated with this part of the site.	0
Security of wetland	The proposed wetlands will remain within private ownership.	1
Protection groups	The wetland will be protected by the golf course management in accordance with an approved management plan.	5
Passive recreation	As part of a golf course, the area will not primarily be used for passive recreation, but will be used for the conservation of fauna, and will form part of a tourist venue.	2
Active recreation	The wetlands will form part of a golf course.	1
Other human uses	There will be no other use of the wetlands, once created.	0
TOTAL		**12**

CATEGORY		TRANSITION
SUPPLEMENTARY QUESTIONNAIRE		
ATTRIBUTE	**COMMENT**	**SCORE**
Species rarity	The wetlands are not anticipated to form the habitat of rare species.	
Effect on land values	As part of the overall golf course development the proposed lakes are expected to increase land values.	
Human use	The lakes will be visited by more than 100 people each week.	
MODIFIED CATEGORY		**O**

3.3 DISCUSSION

Reference to the numerical assessment indicates that the value of this unit will increase in terms of both natural attributes and human use following development. The principal reasons for this change are the proposed increase in diversity of habitats, the improved management of drainage which will be achieved, and, through the establishment of a permanent management body, which will oversee the management of the wetlands. Human use of the site will also increase following development.

It is predicted that, if developed following the guidelines presented by Ninox (1990), the proposed lake and its surrounds would provide a satisfactory replacement for the existing wetland and at the same time allow for effective control of the mosquito problem.

4 COLLIE RIVER FORESHORE

4.1 SITE DESCRIPTION AND ASSESSMENT - PRESENT STATUS

The Collie River foreshore comprises a narrow, occasionally steeply sloped bank backed by a level floodplain. From the water's edge the water deepens quickly as the bank slopes into the main river channel, which has a depth of approximately 2.3 m.

Erosion, both natural and human induced as a result of boating activity and the imposition of structures such as the Collie River bridge, has resulted in parts of the shoreline being washed away to the extent that it has been necessary to construct erosion control structures, in the form of log walling, along the eastern section of the river bank. Some evidence of continued erosion is noted along the central part of the foreshore which is the site of the most intense human activity. Spoil from dredging undertaken to maintain the navigable depth of the river mouth has been dumped on an area toward the tip of Pelican Point.

The typical foreshore vegetation of the river bank comprises a rush fringe at the waters edge, backed by overhanging *Casuarina* with Flooded Gums and paperbarks at the top of the bank. The understorey is generally degraded, comprising a mixture of weeds and grasses, of which couch is the dominant species. Toward the tip of Pelican Point the vegetation is denser, with a more age-structured growth of Flooded Gum, supported by an understorey of *Jacksonia*. Elsewhere on the foreshore there is no juvenile tree growth and consequently trees presently being lost to erosion are not being replaced.

Ninox (1990) has identified the trees growing along the Collie River foreshore as comprising the main habitat of this land unit, providing both roosting sites for waterbirds (cormorants, darters) and breeding sites for bushbird species. The denser vegetation along the banks of the river may also provide habitat for the Southern Brown Bandicoot and the water-rat.

The Collie River foreshore also provides for the most intense recreational use within the project area, principally because it provides a means of access to the Collie River and the Leschenault Inlet beyond. Limited recreational facilities, in the form of a public boat launching ramp, tourist ferry landing and toilets, are to be found in this area. Parking, however, is poorly defined and this has contributed to the decline of the vegetation on the river bank.

The presence of the old boat shed and landing provide evidence of the long history of this part of the river bank for boating purposes.

Numerical Assessment

As the section of wetland under consideration refers only to the Collie River bank and proposed foreshore reserve, numerical assessment is not considered appropriate (refer EPA Bulletin No. 374, Section 1.5).

4.2 SITE DESCRIPTION AND ASSESSMENT - POST DEVELOPMENT

Under the proposed development scheme the following changes would be made to the Collie River foreshore:

- public parking within the foreshore area will be formalised to prevent further damage to the vegetation;
- the existing launching ramp will be replaced with an upgraded launching ramp to be constructed to the east of the present site;
- a kiosk and public amenities block will be constructed in the vicinity of the new boat ramp;
- the shoreline adjacent to the launching ramp will be protected by erosion control measures designed to allow the regrowth of fringing rushes along the shoreline in a series of pocket beaches;
- additional planting of *Casuarina* and Flooded Gum will be undertaken to supplement, and eventually replace, the existing trees as they are lost through natural attrition;
- improvement of the existing rough grassed areas to provide for greater public use;
- creation of a public park on the northern extremity of Pelican Point;
- construction of a dual use path along the river foreshore to link through the development to a similar path on the Leschenault Inlet foreshore;
- the canal entrance; and
- tennis courts associated with the hotel facilities.

The above works, which are designed primarily as public facilities, will allow for the expected increase in human use of the river bank.

The proposal to maintain existing trees and to carry out additional planting of the same species will provide for continued use of the riverbank by the same range of bushbirds as currently use this area.

4.3 DISCUSSION

As shown by a comparison between the current and post-construction descriptions of the foreshore, the proposed changes to the river foreshore primarily affect human use of the area. The effect of the increased proximity of development will be offset by the improved access and facilities provided for the public.

The effects on the natural values of the area will be generally of a short-term nature, and associated with the reconstruction of the public facilities along the foreshore. In the longer term there will be no net loss of habitat and it will be the ability of the species currently using the area to habituate to increased human presence, rather than a loss of habitat, which will determine the future avifaunal use of this unit. As the bushbird species under consideration are already occupying an area subject to regular human presence, the development proposed should not preclude their continued occupation of the river foreshore.

5 LESCHENAULT INLET FORESHORE

5.1 SITE DESCRIPTION AND ASSESSMENT - PRESENT STATUS

The Leschenault Inlet foreshore comprises a gently sloping intertidal sandy beach backed by a vegetated sandy slope, recognisable in places as a beach berm. Offshore the estuary floor continues to slope gently, giving rise to a broad expanse of shallow water which may dry on extreme low tides.

The vegetation of the foreshore is comprised of a variety of the Common Couch, *Cnodon dactylon,* and an introduced species, *Trachyandra divaricata*, commonly known as strap weed or onion weed. The inland margin of the foreshore is marked by the presence of a few stunted specimens of the shrub species, *Jacksonia.*

The sandy beach and adjacent shallows provide a feeding and roosting habitat for a variety of wading birds and shoreline feeders, including a number protected under international treaty (Ninox, 1990).

Human use of the area includes crabbing, walking, horse riding and trail bike riding. There are no recreational facilities of any form within the foreshore area.

Numerical Assessment

Due to the recognised importance of Leschenault Inlet to waterbirds, and specifically the sandy shoreline and shallows to migratory wading birds recognised under the JAMBA and CAMBA agreements, the Vittoria Bay foreshore of Pelican Point has been classified as a Category H wetland. Management of this area to ensure the retention of migratory shorebird habitat is accorded the highest priority.

5.2 SITE DESCRIPTION AND ASSESSMENT - POST DEVELOPMENT

In recognition of the habitat value of the Leschenault Inlet foreshore, modification would be restricted to redevelopment of the vegetated bank for passive recreational purposes. The important sandy beach and shallows area would not be modified by the development and consequently there would be no loss of valuable intertidal feeding habitat. Development within the vegetated zone would be confined to smoothing surface hollows to allow the grass to be regularly mown, the planting of trees (*Casuarina obesa* and *Eucalyptus rudis*) and the construction of a dual use path toward the inland edge of the foreshore. A small retaining wall along parts of the foreshore boundary would differentiate between the public foreshore reserve and open space and the private development on the inland side.

Human use would be facilitated by increased access, and traditional pastimes, such as crabbing, would continue as at present. However horse riding and trail bike riding would no longer be permitted to occur.

5.3 DISCUSSION

Due to the recognised habitat value of the Leschenault Inlet foreshore, proposed changes within this area have been minimised. The proposed foreshore reserve will be extended to a 50 m wide reserve running the full length of the Pelican Point foreshore, and the most significant habitat associated with the site, the intertidal zone, will be retained in its present state. On the tip of Pelican Point, the reserve will be expanded to provide for a public park. This park will provide additional buffer between the development and the extensive tidal flats near the river mouth.

The main effects on the environment which are expected to occur, and will be addressed in the Foreshore Management Plan to be prepared by the Proponent, are those pertaining to increased human presence which will result both from the increased level of adjacent development and the greater accessibility of the foreshore to the general public. This increased level of use is expected to lead to greater emphasis on passive recreational pursuits and less emphasis on active recreational activities such as horse and trail bike riding, which presently take place on the foreshore. The change from active to passive recreation will tend to reduce the disturbance to wading birds and thereby lessen the impact associated with increased human use. Traditional pastimes such as crabbing will be facilitated by the increased accessibility of the area once development has been completed.

6 PELICAN POINT

6.1 SITE DESCRIPTION AND ASSESSMENT - PRESENT STATUS

Pelican Point comprises a mixture of generally modified land units arising from a history of human disturbance over many years.

The land comprises a series of relict river channels within a deltaic plain. The channels are now isolated from the main river channel and many are infilled or contain water on a seasonal basis only. The soils comprise riverine muds and sands with a complex vertical and horizontal distribution.

The vegetation pattern reflects the small scale changes in elevation within the site, and ranges from eucalypt (*Eucalyptus rudis*) woodland on the higher ground, to *Casuarina*/paperbark fringes on the margins of the wetlands, samphire on the seasonally inundated wetland and aquatic vegetation in the deeper portions of the old river channels.

Impacts on the land include interference to natural drainage through road construction and infilling, landform modification through the deposition of dredge spoil and other fill material, and vegetation modification through clearing, fires, and as a result of landform and drainage changes and the introduction of pasture grasses and other introduced species.

Previously used for pastoral purposes and for holiday chalets, the land is presently unused.

The faunal value of the site has been discussed by Ninox (1990) who conclude that while there is a moderate diversity of vertebrate species using the area the number of individuals, when compared to other parts of the estuary, is low. The main habitats of value are regarded as the inundated samphires and shallow pools, and the fringing paperbarks. The shallow water and inundated areas favoured by members of the heron/egret/spoonbill group and a range of duck species. The area also provides shelter for foreshore waders when adverse weather conditions, such as high winds, make the foreshore inhospitable.

Ninox (1989) rated these wetlands as having intermediate conservation significance on the basis of their use by waterfowl. The same wetlands are also recognised as major mosquito breeding areas and have been allocated a high priority control rating (Sites 101, 102, 104, 105 & 107; Wright, 1986). In addition, the old river channel which runs parallel to the Old Coast Road is the source of a severe odour problem during early summer.

Numerical Assessment

Natural attributes - This unit is defined as a seasonal wetland with well defined boundaries (Part 1A).

ATTRIBUTE	COMMENT	SCORE
Environmental geology classification	The scores applied under this classification are not appropriate to wetlands outside of the Perth Metropolitan Area [refer to note under Section 2.2.1 Part A (i) of Bulletin No. 374].	Not scored
Adjacent wetlands	There are similar wetlands within a 2 km radius.	Not scored
Habitat diversity	The composition and structure of the vegetation are similar to that found at nearby wetlands.	1
Drought refuge	The wetland is a drought refuge of minor importance to birds.	2
Area of wetland	The area under consideration contains a wetland of 13.6 ha including 4 ha of seasonal open water course and 9.6 ha of peripheral samphire and rush beds.	2
Habitat type	The following habitat types are represented within the wetland: fringing paperbark; fringing rushes and sedges; samphire; and permanent shallow water (dependent on summer conditions).	4
Emergent vegetation	The percentage of the wetland covered with emergent wetland vegetation is greater than 50%.	5
Adverse water quality	Adverse water quality, in the form of algal blooms and odour, is reported regularly, particularly during the summer months.	2
Drainage	There are both road and agricultural drains entering the wetland, the catchment slope, of which, exceeds 3.5:1.	1
Adjacent nutrient sources	Agricultural land adjacent to the site may provide a source of nutrients.	2
Area of wetland modified	Greater than 40% of the wetland is modified.	1
Reserve area	Although wetland areas will be set aside within the development, the land will remain in private ownership.	1
Native vegetation buffer	The native vegetation surrounding the wetlands is minimal due to past clearing, and buffers are less than 50 m in width.	1
TOTAL		**22**

HUMAN USE QUESTIONNAIRE		
ATTRIBUTE	**COMMENT**	**SCORE**
Aesthetics	Part of the wetlands contain open water and there are parts of the wetland which have few human visitors.	2
Historical and archaeological features	There are no recognised archaeological or historic features.	0
Security of wetland	The wetland is located on private land.	1
Protection groups	There is no active protection group.	0
Passive recreation	There is currently no use of the land for passive recreation.	0
Active recreation	The land is not used for active recreation.	0
Other human uses	There is a previous history of use of the site for grazing, and a small chalet development occupied part of the land, but there is no current usage. It is proposed to use the land for resort and residential development.	1
TOTAL		**4**
CATEGORY		**TRANSITION**
SUPPLEMENTARY QUESTIONNAIRE		
ATTRIBUTE	**COMMENT**	**SCORE**
Species rarity	The wetlands are not known to form the habitat of any rare species.	
Effect on land values	The mosquito and odour problems currently associated with the wetlands have a negative effect on land values.	
Human use	The wetlands are visited by few people.	
MODIFIED CATEGORY		**M**

6.2 SITE DESCRIPTION AND ASSESSMENT - POST DEVELOPMENT

The post-construction environment of Pelican Point will comprise the following elements: residential and tourist housing, hotel and infrastructure, canal, residential lake, tidal wetland and parklands. The built environment will take up approximately 60% of the total land area. The remainder will be subject to varying levels of human usage, but will provide a range of habitats colonised by a range of species as follows.

The tidal wetland and associated parkland (wetland reserve/floodway) will reconstruct a single ended cut-off tidal distributary channel with an area of 6.3 ha, which with the associated parklands will occupy approximately 25% of the land to the north of Old Coast Road. Existing vegetation will be retained where possible, and augmented on the re-shaped shorelines by transplanting appropriate species from parts of the site to be developed. Mosquito and odour control will be achieved through strict control over grades to prevent the formation of stagnant pools, and through regular tidal flushing. Although the design is

to a minor extent constrained by the necessity to provide for flood relief and to control mosquito breeding, the ultimate wetland design will improve over the present situation by providing permanent water, improving water quality during the summer months and providing tidal variability which will provide increased feeding area for intertidal and wading birds. The design will incorporate island sanctuaries and boardwalks to guide visitors through the area.

The canal will provide approximately 4 ha of sheltered habitat for fish, particularly for juvenile species. A number of species of bird, including cormorants, silver gulls and the Nankeen night heron, will also use the canal opportunistically as a feeding area.

The 2 ha residential lake will be less accessible to birds due to the greater proximity of proposed development. It is anticipated, however, that the area will be used by a similar range of species, although probably to a lesser extent.

Numerical Assessment

Natural attributes - Re-connection to the Collie River will result in the wetlands becoming permanent, and with well defined boundaries (Part 1A).

ATTRIBUTE	COMMENT	SCORE
Environmental geology classification	The scores applied under this classification are not appropriate to wetlands outside of the Perth Metropolitan Area [refer to note under Section 2.2.1 Part A (i) of Bulletin No. 374].	Not scored
Adjacent wetlands	There will be wetlands with similar characteristics within a 2 km radius.	Not scored
Habitat diversity	The composition and structure of the vegetation within the proposed wetlands will be similar to that found at nearby wetlands.	1
Drought refuge	The wetland will continue to provide a minor drought refuge for waterbirds, however this aspect will be enhanced by the provision of permanent, tidally flushed, open water within the wetlands.	2
Area of wetland	The area of permanently inundated wetland under the proposed development scheme, excluding the canal and the residentially fringed section of the tidal waterway, will be approximately 6 ha.	1
Habitat type	The habitat types represented within the wetland will include: fringing paperbark; fringing rushes and sedges; samphire; islands; and permanent shallow water.	5
Emergent vegetation	The percentage of the wetland covered with emergent wetland vegetation will be between 30% and 40%.	4
Adverse water quality	Adverse water quality will be prevented by the improved tidal flushing and will be subject to the management commitments given by the Proponent.	5
Drainage	Due to the proximity of adjacent development there will be some controlled drainage to the wetlands from a catchment area of similar size to that presently drained.	1
Adjacent nutrient sources	Potential sources of nutrient to the wetlands include the landscaped areas within the development and the adjacent golf course, however, these will be managed to minimise adverse effects on the wetland.	2
Area of wetland modified	The proposed wetlands will be a modified environment.	1
Reserve area	The ratio of potential reserve area to water area will be in the order of 1:1 in the wetland reserve/floodway area.	1
Native vegetation buffer	Buffers of native vegetation will surround the waterbodies, however given the area available, it is unlikely that the vegetation buffers will exceed 50 m in width.	1
TOTAL		**24**

HUMAN USE QUESTIONNAIRE		
ATTRIBUTE	**COMMENT**	**SCORE**
Aesthetics	Proposed boardwalks will provide views over the wetlands, while the islands will provide sanctuary for the more sensitive waterbird species.	2
Historical and archaeological features	There are no archaeological or historic sites.	0
Security of wetland	The principal wetland area will be located within a protected floodway and the canal will revert to the Crown, as a condition of the development.	2
Protection groups	The canal and tidal waterway will be managed in perpetuity, initially by the developer and subsequently by the residents, however, the long-term responsibility for the floodway/wetland reserve has yet to be determined.	0
Passive recreation	Passive recreational activities which will be promoted will include bird watching and the conservation of avifauna. The wetlands are regarded as an integral feature of the tourist facility being proposed.	3
Active recreation	Active recreation within this area will be restricted to walking.	1
Other human uses	No other uses are proposed within the wetland precinct.	0
TOTAL		**8**
CATEGORY		**R**

6.3 DISCUSSION

As shown by the result of the numerical assessment the value of the wetland will increase as a result of the proposed development. In respect to natural attributes this is brought about by the increased diversity of habitat proposed, in addition to improving existing water quality. The human use attributes will also be improved through the increased accessibility of the area and the increased security given to the wetlands either though acquisition by the State or by active management of the development through approved management schemes.

7 SYNTHESIS

The results of the assessments undertaken indicate that both natural attributes and human use of the five Pelican Point land units will increase if development proceeds as described in the PER. The principal benefits provided by the project are seen as increased habitat diversity, improvements to the current pattern of drainage of the wetlands and the adoption of positive wetland management practices. Human usage will be improved through the provision of increased access to the wetlands, much of which are currently on private property and inaccessible.

All of the wetland units, with the exception of the intertidal zone of the Leschenault Inlet foreshore, are highly modified and have limited conservation value. The main value of the wetlands is in the provision of habitat for various species of waterbird.

The inclusion of permanent fresh and saline waterbodies within the terrestrial unit will result in the area of defined open water within the development area increasing from 4 ha to 16.4 ha (excluding the 6.1 ha of canal and residential waterway). This mixture of fresh and saline waterbodies will compensate for wetland habitat lost or altered by the proposed development, most of which will be confined to the periphery of the wetlands. The area of seasonally inundated land modified through the development will be compensated through the management plans proposed for the golf course and wetland reserve areas. The numerical assessments indicate that loss of wetland habitat will be compensated by the increased habitat diversity, which will be achieved through the development, confirming the assessment by Ninox (1990).

To ensure that both natural and human use values are maintained the Proponent is committed to:

- The development of management plans for the golf course and residential wetlands, the wetland reserve and the affected sections of the Collie River and Leschenault Inlet foreshores.

- The implementation of the management recommendations contained within the management plans for each of the wetlands.

- The maintenance of the wetlands within the development site in perpetuity, and the maintenance of the publicly-owned foreshores for agreed periods.

  In the case of the golf course wetlands, both freshwater and saline, the residential wetlands and the canal, long-term management will be placed in the hands of an owners association for maintenance according to the approved management plan.

  In the case of the river and estuary foreshores, the Proponent will construct the proposed public facilities and maintain the foreshores for a period of three years, after which management will become the responsibility of the City of Bunbury. In the case of the wetland reserve/floodway, the Proponent will comply with the flood control requirements and establish and maintain the wetland reserve for a

period of three years, after which on-going maintenance will become the responsibility of the appropriate management authority. In the event that the floodway remains in private ownership, on-going maintenance will remain with the Proponent.

Due to the proximity of the various wetlands and the potential overlap in management responsibilities, the adoption of a differential rating scheme to cover the long-term maintenance of all of the wetlands has been discussed with the City of Bunbury as a means of generating on-going maintenance funding.

8 REFERENCES

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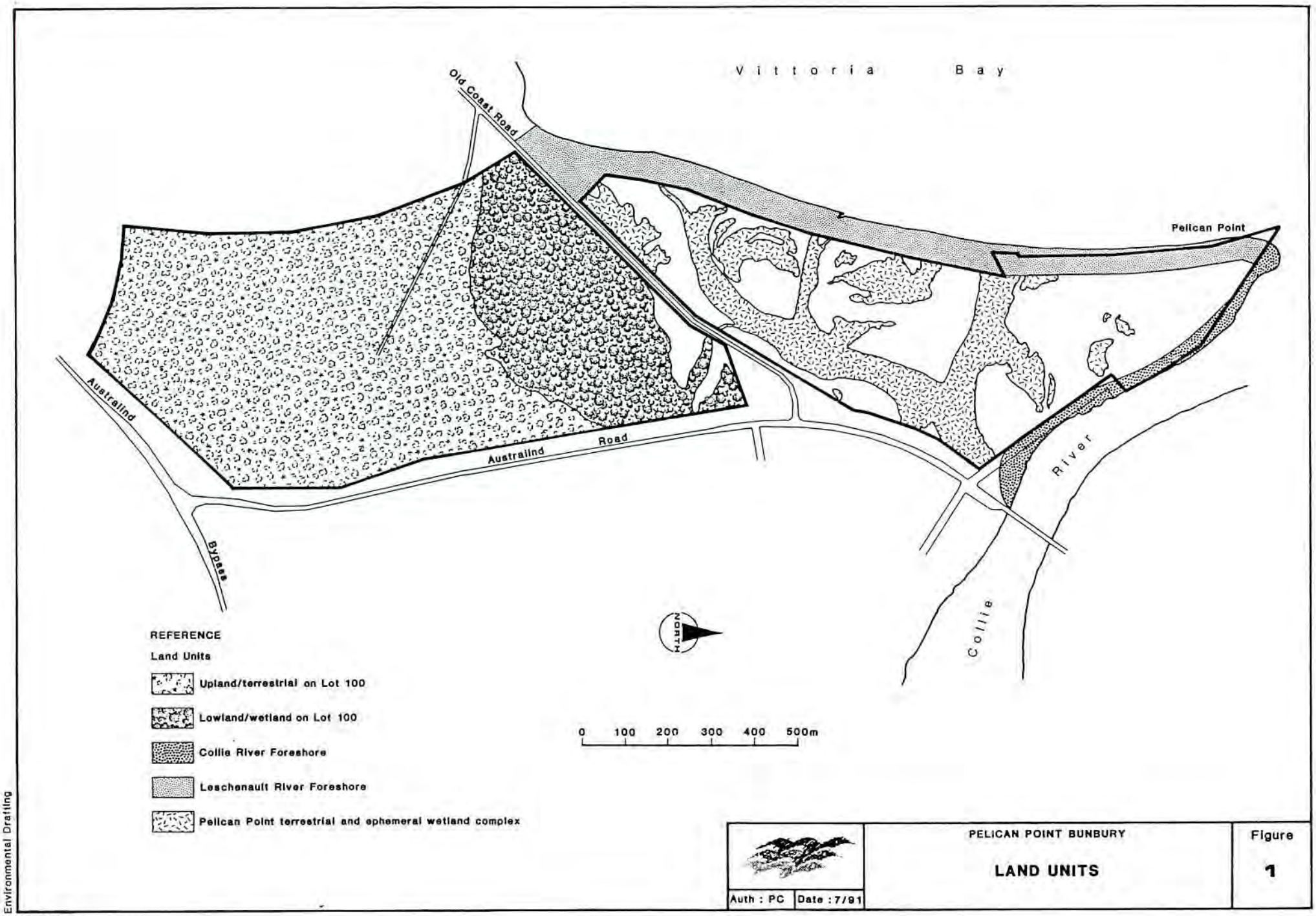

Environmental Drafting

J186 R320

Pelican Point Pty Ltd

Pelican Point, Bunbury

Public Environmental Review

APPENDIX 4

WATERBIRDS AND TERRESTRIAL VERTEBRATES OF THE PROPOSED PELICAN POINT RESORT DEVELOPMENT

LEC Ref: J186/R320

WATERBIRDS AND TERRESTRIAL VERTEBRATES

OF THE PROPOSED PELICAN POINT RESORT DEVELOPMENT

Prepared for: LeProvost Environmental Consultants

By: Ninox Wildlife Consulting

July 1990

SUMMARY

In 1987 the Mosquito Control Review Committee of the Waterways Commission contracted a study of Leschenault Estuary in order to define the significance of mosquito breeding areas to waterbirds. Forty waterbird sampling sites were established, six of which lay within or adjacent to the proposed development area. All sites, including the six Pelican Point locations were monitored for waterbirds and shorebirds on nine occasions from November 1988 to December 1989.

Sixty-two species of waterbird and 23,470 individuals were recorded throughout Leschenault Estuary and its fringing wetlands during the above survey, with accessory habitat and activity data also noted for each record. Forty-one species were recorded in the proposed development area and adjacent estuary. The number of species for both areas were similar with 32 and 29 species respectively, but the number of individuals for the proposed development area (928) and the adjacent estuary (4036) differed markedly. Breaking these results down to reflect actual usage of the landward development area where most physical disturbance will occur, rather than the adjacent portion of Vittoria Bay which will be subjected to minor, secondary impact, showed that 53% of all recorded species and a low 4% of all individuals censused at Leschenault Estuary were observed within the landward boundaries of the project area. Waterbirds were therefore concentrated within the adjacent estuary rather than the proposed development area. Eighteen species covered by international agreements have been recorded at Leschenault Estuary. Seven of these were recorded in the proposed development area and 13 were observed in the adjacent estuary.

The results of the surveys of the proposed development area and the adjacent estuary therefore indicate that:

- for the most part the landward habitats of the proposed development area show a high level of degradation, support relict populations of terrestrial species such as mammals, amphibians and reptiles and include five locations classified as high priority mosquito control sites and two classified as moderate control (Wright 1986):

- apart from certain species of conservation significance such as the Great Egret And Yellow-billed Spoonbill, the proposed development area landward habitats are relatively poorly used by waterbirds, and on the few occasions when trans-equatorial migratory shorebirds congregate on the site, this is a result of event-related circumstances such as unusually high tides and winds;

- isolated pools, inundated samphire and the foreshore are the most significant habitats in the proposed development area, particularly for birds such as herons, egrets and spoonbills, while tidal flats in the adjacent estuary, where a similar area of habitat was sampled, showed much larger concentrations of waterbirds including a high proportion of trans-equatorial migratory shorebirds covered by international treaties;

- roosting is the main activity which takes place in the proposed development area, while feeding is the primary activity in the adjacent estuary:

- the proposed development area and the adjacent estuary cannot be considered in isolation in that any impact in one will inevitably flow on to the other. The main impacts of the project are judged to be habitat loss, human disturbance, harassment by domestic pets, predation by introduced species such as foxes and feral cats and some deaths as a result of road casualties;

- the establishment of a series of permanent, freshwater and saline wetlands, removal of stock animals and the presence of a golf course in the proposed development area will more than offset any waterbird habitat loss by providing a greater range of wetland and bushland niches than now occur. The permanent, freshwater wetlands with various types of island will also operate as valuable drought refuges in summer and the number of waterbird and bushland species currently using the area is expected to rise;

- the creation of buffer zones along the foreshore, strict controls over domestic pets, minimum clearing of vegetation, a replanting and rehabilitation programme, informed management of wetland and bushland areas, introduced predator control and a public education programme will all substantially contribute to reducing the impact of the project.

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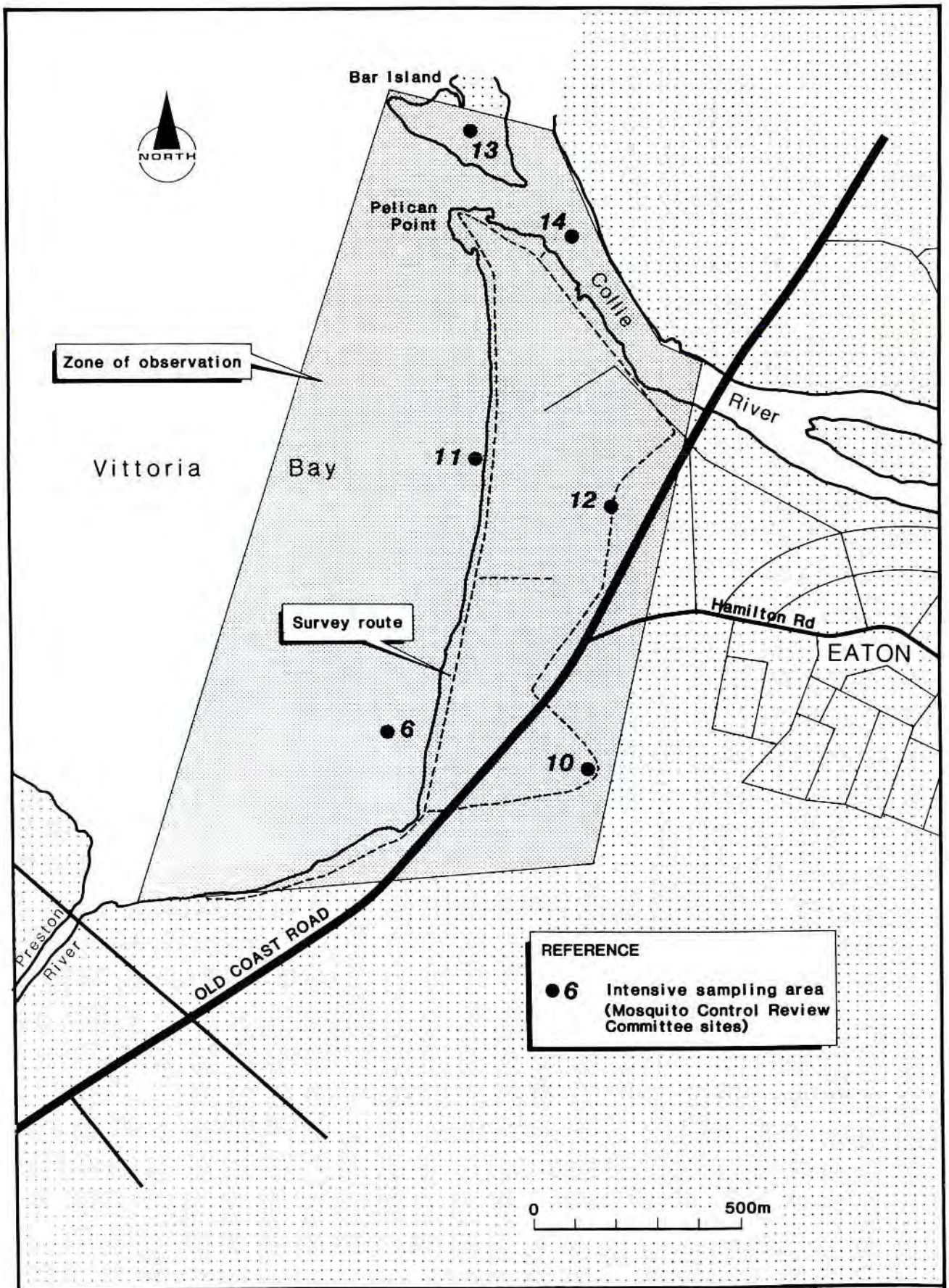

PELICAN POINT BUNBURY

PELICAN POINT OBSERVATION AREA AND SAMPLING AREAS

Figure **1**

Auth : KY | Date : 6/91

Environmental Drafting

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1.0 INTRODUCTION

The Pelican Point resort development consists of two main elements: a waterways estate and associated facilities on the peninsula north of the Old Coast Road; a golf course and estate on the southern side of the road. This latter portion is currently used as pasture land. The Environmental Protection Authority recommendations for the development are directed towards retaining the maximum wetland function of the area, therefore conceptual design plans by the proponent include a series of freshwater and saline wetland areas integrated with the golf course, housing estate and resort.

The following report assesses the current conservation status of the proposed development and, based on the information thus gained, provides advice on how future use of the area by native fauna, particularly waterbirds, might be maintained, possibly improved, and integrated with increased human presence in the area.

1.1 Study Objectives

The major objectives of this study are to:

- assess the current usage of the proposed development area and the adjacent estuary by waterbirds, bushbirds, amphibians, reptiles and mammals;
- define any locations, habitats or species within the project area of special conservation status;
- based on the above discuss the regional and local conservation significance of the proposed development area;
- advise on wetland and planting design to maintain or encourage waterbirds and other native fauna;

2.0 METHODS

2.1 Waterbirds

In 1987 the Mosquito Control Review Committee (MCRC) of the Waterways Commission contracted Ninox Wildlife Consulting, the authors of this current report, to carry out a study of Leschenault Estuary in order to define the significance of mosquito breeding areas to waterbirds. The study also required that where such areas were adjacent to, or inland from, the shoreline of the estuary, nearby offshore locations and fringing wetlands such as occur in the proposed development area were to be assessed. Forty waterbird

sampling sites were established, six of which lay within or very close to the proposed development area (Figure 1). On arrival at a sampling site the observer picked a vantage point and stayed in position until confident that all visible birds had been identified, counted, allocated to habitats and their activity defined. Telescopes and binoculars were used to assist in identification and to minimise disturbance of birds. Foot or vehicle transects were conducted between each station and spot-checks made along the way to ensure that all birds were, as far as possible, recorded. The data collected at each site included species lists, number of individuals, habitat sub-unit utilisation and the type of waterbird activity which took place within them.

All sites, including the six Pelican Point locations (Figure 1) were monitored for waterbirds and shorebirds on nine occasions from November 1988 to December 1989; survey dates are given below:

Table 1 Survey periods conducted at Leschenault Estuary between September 1987 and October 1988.

SURVEY	DATE		
1	September	3	1987
2	October	29	"
3	December	15	"
4	February	4	1988
5	March	23	"
6	May	11	"
7	June	29	"
8	August	4	"
9	October	20	"

A total of 62 species of waterbird and 23,470 individuals were recorded throughout Leschenault Estuary and its fringing wetlands during the MCRC survey, with accessory habitat and activity data also noted for each record. This information was stored on computer for later retrieval by a database programme. The MCRC has generously allowed access to the relevant sections of this database which was synthesised by Ninox Wildlife Consulting (1989a) and published by the Waterways Commission of Western Australia.

In 1985 the authors were commissioned by LeProvost Environmental Consultants to carry out a bird survey of Pelican Point. Three days were spent conducting this survey and 30 species of waterbirds were recorded. The survey area included the portion of the proposed development area north-west of the Old Coast Road and covered the

adjacent sections of Vittoria Bay. Data from the survey have been integrated with this report.

2.2 Other Fauna

During the 1985 survey of Pelican Point, data on other vertebrates were collected, particularly for bushbirds. Sampling for terrestrial species such frogs, reptiles and mammals is time consuming, labour intensive and in a highly disturbed area such as this, ultimately unproductive. Apart from opportunistic sampling of diurnally active species little terrestrial vertebrate sampling has been conducted. To remedy this, a list of provisional species expected to be present in the relict habitats of the area has been constructed (Annex 2) and has been drawn from Western Australian Museum records, known distribution patterns and published or unpublished data sources. Typical among these sources are: Blakers *et al.* (1984); Strahan (1983); Storr *et al.* (1981, 1983, 1986, 1990); Tyler *et al.* (1984); Ninox Wildlife Consulting (1985a); Bamford and Watkins (1983) and Nichols (1980).

3.0 RESULTS AND DISCUSSION

3.1 Waterbirds

Since a development such as this cannot be considered in isolation, for the purposes of this report all waterbirds recorded within the habitats of the adjacent estuary were considered to be associated with the development and within its predicted zone of impact. Increased activity along and near shorelines has the potential to disturb waterbirds. The size of the areas sampled within and beyond the proposed development site were similar (Figure 1).

3.1.1 Species Richness and Abundance

Sixty-two species of waterbird and 23,470 individuals were recorded throughout Leschenault Estuary and its fringing wetlands during the MCRC project. The nine waterbird surveys of the proposed development area and adjacent estuary resulted in 41 species of waterbirds and 4965 individuals being recorded. This represents 66% of all species and 21% of all individuals censused throughout the estuary and its surrounds. Breaking these results down to reflect actual usage of the landward development area where most physical disturbance will occur, rather than the adjacent portion of Vittoria Bay which will be subjected to minor, secondary impact, indicates that 53% of all recorded species and a low 4% of all individuals censused at

Leschenault Estuary were observed within the landward boundaries of the project area. In other words the proposed development area has a relatively high species richness and very low numbers of waterbirds per unit area. In comparison, an area of land of smaller size at the mouth of the Preston River diversion supported over twice as many individuals.

This is graphically illustrated on a smaller scale by comparing the relative number of species and individuals recorded in the proposed development area with the adjacent estuary sites (Annex 1). The number of species are similar with 32 and 29 species respectively, but the number of individuals for the proposed development area (928) and the adjacent estuary (4036) differ markedly.

The reasons for these differences are evident in Annex 1 when species composition in the two sampling locations is compared. The proposed development area was poor in trans-equatorial shorebirds and other wading birds with nine species and 198 individuals, while the adjacent estuary had 14 species and 3155 individual birds from this group, reflecting their preference for productive intertidal zones. However, the proposed development area was rich in the heron/egret/ibis group in terms of abundance with 97 individuals recorded, while the adjacent estuary supported only 18 during the sampling periods. Shallow tidal or brackish pools and periodically inundated tracts of samphire flats account for this discrepancy. Similarly the number of ducks attracted to these habitats was also higher than that recorded in the adjacent estuary (Annex 1).

3.1.2 Seasonality

Figures 2a and 2b show how waterbirds used the proposed development area and the adjacent estuary at different times of the year. In Figure 2a it can be seen that the number of species tended to be higher in the proposed development area in winter and spring while the adjacent estuary supported more species in summer due to the seasonal influx of trans-equatorial migratory shorebirds. The winter rise in species within the proposed development area reflects the arrival of numbers of breeding pairs of ducks, large numbers of cormorants and seasonally higher numbers of herons and egrets. Yellow-billed Spoonbills only occurred during this period in fairly large numbers for this species.

Figure 2b graphically illustrates the discrepancy in the seasonal presence of individuals between the two areas. Apart from June and October 1988, the adjacent estuary showed a consistently higher number of individuals than the proposed development area. The estuary sites were particularly productive in October 1987 due to

the presence of large numbers of trans-equatorial migratory shorebirds, which gradually decreased in numbers until all had left for the Northern Hemisphere by March.

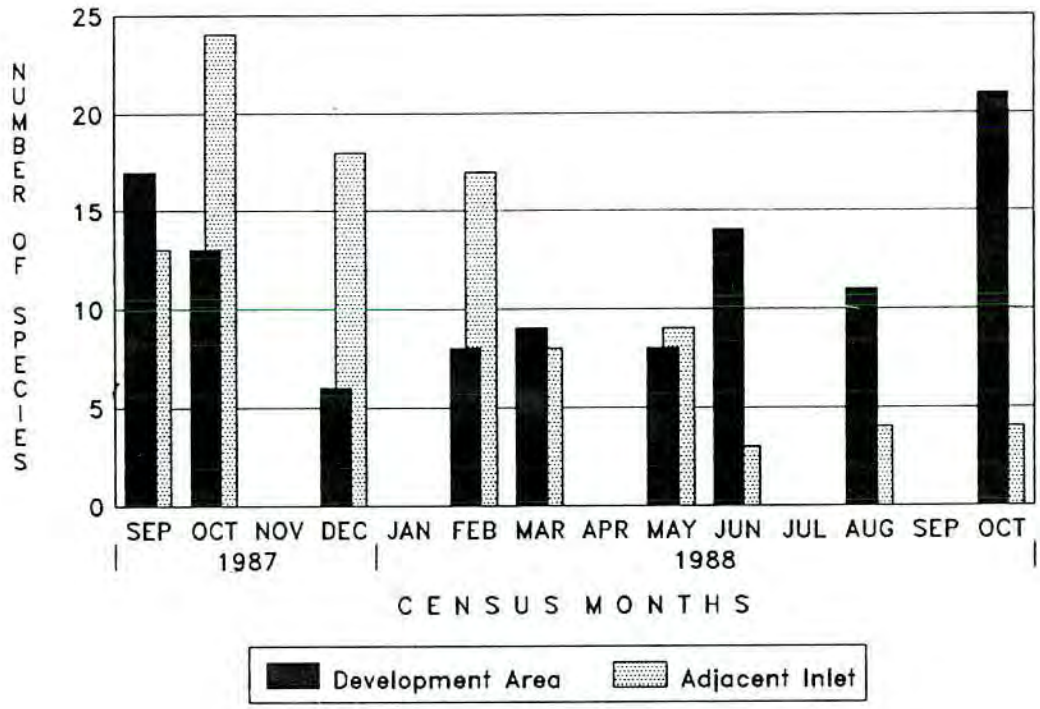

Figure 2a Number of species recorded in the proposed development area and adjacent estuary between September 1987 and October 1988.

In June, when numbers were higher in the proposed development area, Herons, Egrets and Spoonbills made up some 30% of the individuals present and were attracted to the numerous rainwater pools in the area. The October 1988 peak is an event-related occurrence because this census period coincided with the highest tide experienced during the survey; this and attendant strong winds forced birds away from the estuary and into the proposed development area, an effect that was apparent throughout the estuary. The primary activity in the proposed development area was normally feeding; on this occasion it was roosting in order to avoid the blustery conditions and high tides which excluded birds from their preferred feeding areas. This was also the only occasion when trans-equatorial migratory shorebirds appeared on the site in relatively large numbers for the reasons given above rather than any food source to which they were particularly attracted.

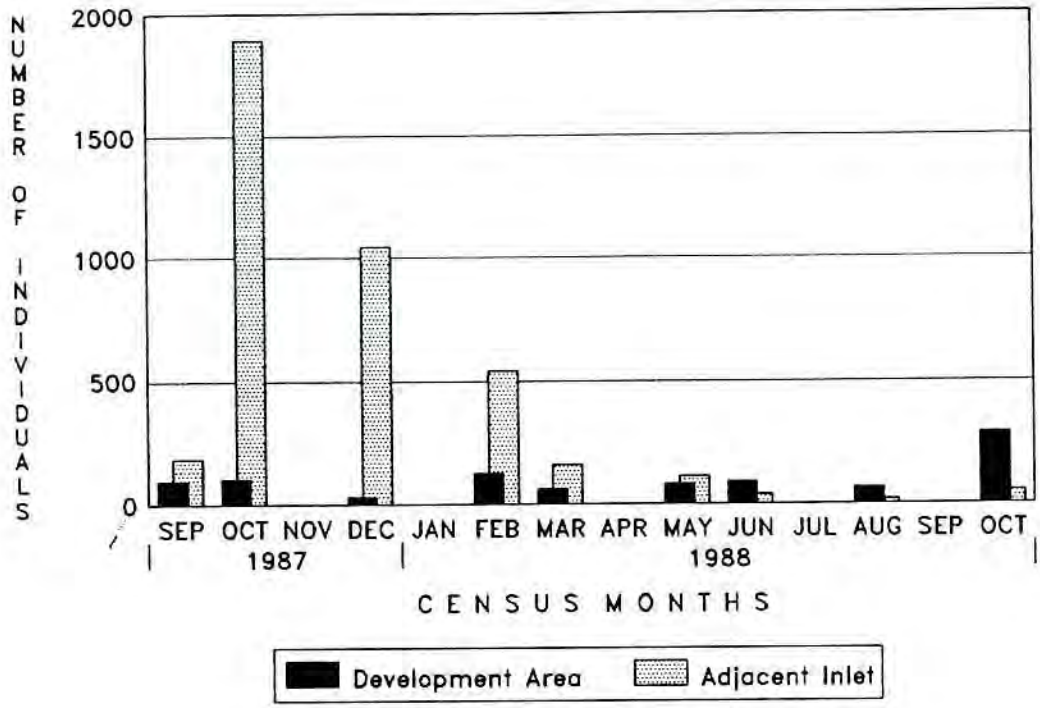

Figure 2b Number of individuals recorded in the proposed development area and adjacent estuary between September 1987 and October 1988.

3.1.3 Habitat utilisation

Twelve habitat sub-units in the proposed development area and the adjacent estuary have been chosen for analysis and cover all the major niches available. The category "other" in the proposed development area represents areas such as grassed lawns in the caravan park or cleared land, but mainly refers to birds rapidly flying over a series of habitats. The same category in the estuary habitats represents temporary elements such as moored boats or flying birds not associated with any particular habitat.

Species: Figure 3a shows that all locations immediately associated with water (i.e. inundated samphire, isolated tidal or rainwater pools and the foreshore) are used extensively by waterbirds. These three sub-units by themselves supported 31 of the 32 species which were recorded in the proposed development area, thus stressing their significance to waterbirds. The major activity in pools and flooded samphire was feeding while the foreshore was mainly used for

roosting. Dry samphire was poorly used by most species, while perches such as trees were important to waterbirds such as the various species of cormorant. "Other" refers to flying birds.

Usage of habitat sub-units in the adjacent estuary is very high inshore, particularly on tidal flats, buts drops markedly offshore from the proposed development area in habitat sub-units such as open, deeper water.

Individuals: in Figure 3b the relative usage by individual birds of habitat sub-units is clearly shown. Waterbirds were concentrated within the adjacent estuary rather than the proposed development area. Tidal flats were the most important habitat sub-unit with 42% of all individual birds recorded in the sampling area occurring in this single sub-unit alone. By way of comparison, the combined total of all habitat sub-units in the proposed development area represented 19% of all observations. Within the proposed development area inundated samphire, isolated pools and the foreshore are once again seen to be the most significant habitats.

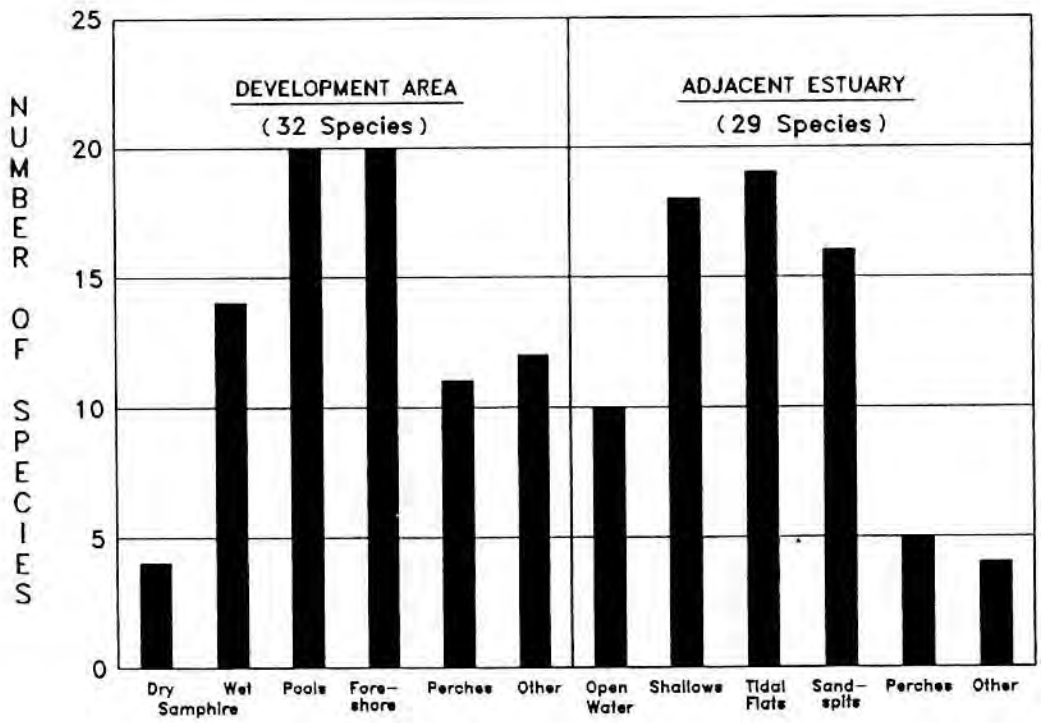

Figure 3a Habitat sub-unit utilisation by waterbird species in the proposed development area and the adjacent estuary.

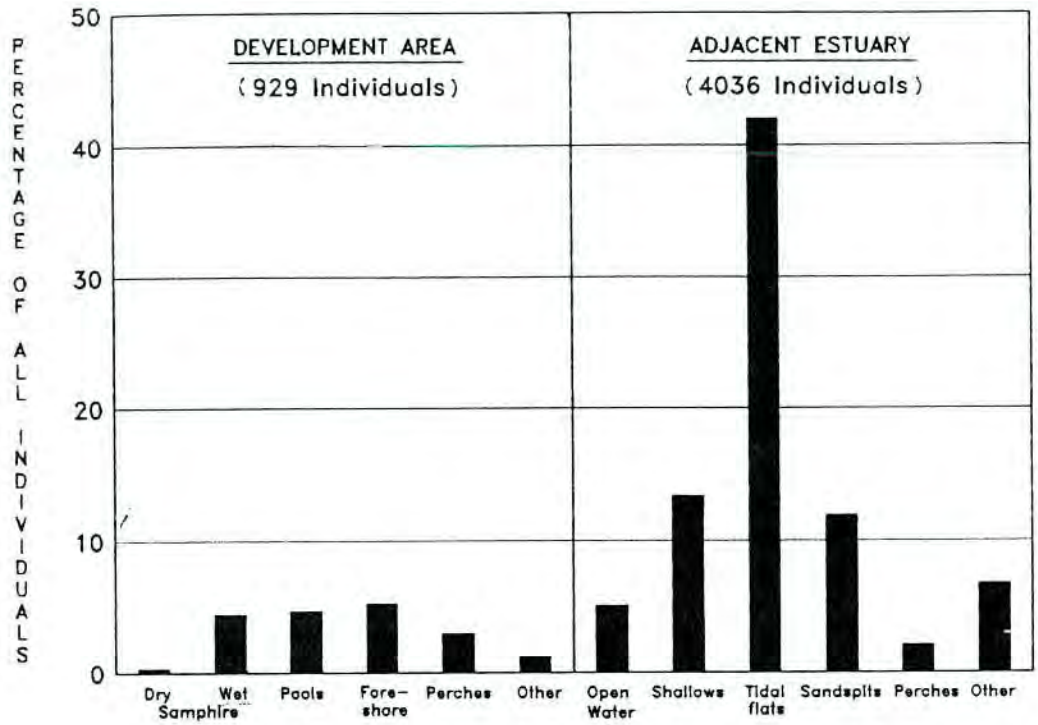

Figure 3b Habitat sub-unit utilisation by waterbird individuals in the proposed development area and the adjacent estuary.

3.1.4 Waterbird Activity

The waterbird activities assessed during the MCRC surveys were: feeding, roosting, loafing (directionless drifting or resting on water), flying, breeding and "other". The last category mainly refers to birds which were flushed before their activity could be recorded or when a bird was heard calling but not seen. Each individual record was accompanied by these data.

Waterbird activity patterns have been plotted in Figure 4. Because the adjacent estuary feeding category dominated all other activities, the proposed development area activities appeared insignificant. Therefore the the activity categories for the proposed development area and the adjacent estuary have been dealt with separately and expressed as a percentage of their individual waterbird totals.

It can be seen from the graph that the major activities which took place in the proposed development area were roosting and feeding.

Fifty percent of all roosting birds were recorded on the foreshore and of the 265 feeding observations collected, 254 (96%) were recorded in flooded samphire or isolated pools, the latter habitat categories accounting for 54% of all records. Feeding was by far the most important activity within the adjacent estuary making up 77% of all recorded behaviour (3126 records). Tidal flats and shallows were the most important habitat sub-units where this activity took place, with 81% of all feeding being recorded in these areas alone.

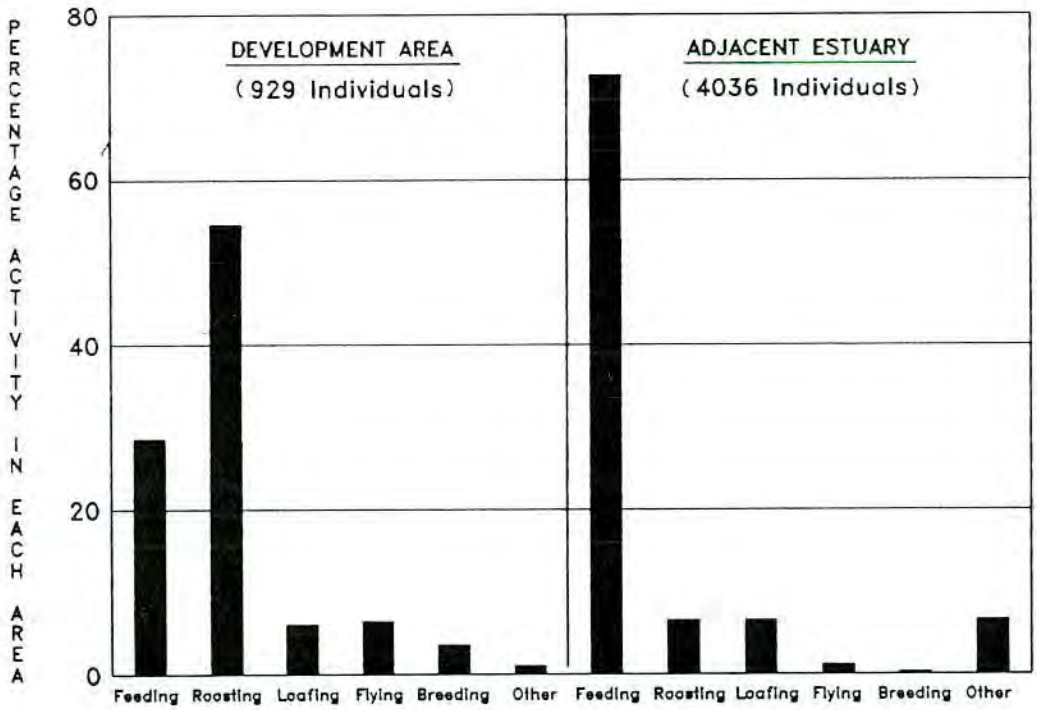

Figure 4 Waterbird activity patterns expressed as a percentage of all activities. The proposed development area and the adjacent estuary totals are treated separately.

3.1.5 November 1985 Survey

A further four species of waterbird have been added to the proposed development area and the adjacent estuary species list from the 1985 survey: Rufous Night Heron, Marsh Harrier, Large Sand Plover, Whimbrel (Annex 1). This brings the total number of waterbirds known from the area to 45. In the 1985 report it was concluded that there were two main areas of significance to waterbirds within Point Pelican itself: the central wetlands and surrounding samphire flats;

the western foreshore, specifically the small, tidal deltas formed by run-off from the central wetlands.

3.1.6 Significant Habitats

The concept of a significant habitat is primarily based on the number of individuals it has the capacity to support and the activities which were carried out. The number of species which occur is not seen to be particularly significant since many are present in small numbers only, or represent transient records brought about by occasional, exceptionally high tides. However, when a species is of some conservation significance and uses a localised area regularly, this has been taken into account.

Proposed Development Area: the nine MCRC seasonal surveys show that the waterbirds of the proposed development area, although present in much lower numbers than the adjacent estuary, were concentrated within isolated pools, inundated tracts of samphire and along the foreshore. Of these three sub-units, isolated pools and inundated samphire are considered to be the most significant because the major activity within them was feeding. Ninety-six percent of all feeding observations occurred in these areas. Thirty-two young waterbirds were recorded in the proposed development area and all were observed in these two habitats.

Adjacent Estuary: tidal flats, shallows and sandspits are the most significant habitat sub-units immediately offshore from the proposed development area. These extremely rich intertidal zones are crucial to maintaining waterbird species richness and abundance at Leschenault Estuary and are used by many species of trans-equatorial migratory shorebirds. Feeding is the most important activity which takes place in these locations.

3.1.7 Significant Species

Significant species are taken to be waterbirds which are uncommon at the estuary and breed within, or are dependent upon, a particular area for feeding. Species covered by international treaties are also considered to be significant.

Proposed Development Area: 18 species covered by the Japan/Australia and China/Australia Agreements (JAMBA, CAMBA Treaties) for the protection of migratory birds and their environment have been recorded at Leschenault Estuary. Seven of these were recorded in the proposed development area. These are listed with the numbers recorded followed by the total number observed at the estuary during

1987 and 1988. The percentage of this total which the proposed development area records represent is also given:

Caspian Tern	-	(3/105	=	2.9%)
Grey Plover	-	(19/614	=	3.1%)
Common Sandpiper	-	(5/63	=	8.0%)
Greenshank	-	(10/248	=	4%.0)
Red-necked Stint	-	(7/3534	=	0.2%)
Sharp-tailed Sandpiper	-	(79/367	=	21.5%)
Great Egret	-	(24/305	=	7.9%).

Of the above, three species, the Common Sandpiper, Sharp-tailed Sandpiper and Great Egret appear to be of some significance because of the numbers recorded in the proposed development area. The Sharp-tailed Sandpiper can be discounted since on the two occasions this species was recorded (February and October 1988) very high tides had forced many birds away from their preferred intertidal zones indicating that this was an event-related occurrence rather than day to day behaviour. Numbers of Common Sandpipers are particularly high for Leschenault Estuary but all records were concentrated on the foreshore rather than the inland portion of the proposed development area. The Great Egret numbers, however, are of note because most were feeding in isolated pools or inundated samphire during the breeding season. This species breeds relatively close to the proposed development area in a swamp adjacent to the LaPorte titanium dioxide plant. The proposed development area is obviously significant as a feeding area for this egret. Similarly, Yellow-billed Spoonbills breed at Little Marriott Swamp some 11 kilometres north of the proposed development area and apart from this location where a flock of 40 birds were recorded, the next two highest flock sizes (10 and 8 birds) were observed within the proposed development area. Once again these birds were feeding in isolated pools and inundated samphire.

It is therefore evident that the area is important to these two species, specifically the seasonally inundated circular depression with a drainage channel which is situated within the proposed location of Golf Estate 1 (Figure 1, Site 10). This site was classified as being of high significance by Ninox Wildlife Consulting (1989a) in their report to the Mosquito Control Review Committee. However, the landward habitats of the proposed development area include five locations classified as high priority mosquito control areas and two classified as moderate control (Wright 1986). The pre-existing drain from this depression is specifically categorised as a high priority control site and, as such, is already subject to potential modification because of its proximity to housing. Wright (1986) refers to this mosquito breeding

area as Site 106 and states that:

> "[the] option of filling breeding site 106 would involve considerable capital outlay. This capital outlay would be offset somewhat if an immediate economic use could be made of the substantially modified land, which currently appears to be little used. An example of such an immediate economic use would be to extend the nine hole golf course proposed for the Pelican Point resort onto site 106."

Adajacent Estuary: this location is significant for shorebirds, many of which are protected under international agreements. Fourteen wading species were recorded, 11 of which are protected. Two other birds, the Caspian Tern and Great Egret are also protected. A total of 3155 individuals from the above group were recorded.

3.2 Other Fauna

In general, the vegetation communities of the proposed development area are in poor condition and are described fully in Vegetation and Flora. The portion south of the Old Coast Road has been pasture for several decades and is devoid of taller vegetation except for a low rise at the southern limit with scattered mature trees consisting of Tuart *Eucalyptus gomphocephela* and Marri *E. calophylla*. Compaction of the ground and stock tracks are evident throughout. On Pelican Point itself, taller vegetation is restricted to low rises or along the banks of the Collie River (Flooded Gum *Eucalyptus rudis*, Paperbark *Melaleuca priessiana*) or surrounding some of the central wetlands (Paperbark *M. priessiana*). Lower vegetation is composed of mixed samphire with *Jacksonia* sp. and *Acacia* spp. on slightly higher ground. The area has been burnt repeatedly, shows high weed invasion, has been cleared along the western edge and is used for horse riding. A caravan park is situated across the northern portion of Pelican Point itself.

Because of this level of disturbance it is judged that the remaining fauna populations, particularly terrestrial species, are highly modified, and relictual. In its currently degraded condition the project area cannot be considered as a conservation area for fauna other than waterbirds although in selected locations moderate usage of the area is made by the more common species of bushbird.

3.2.1 Bushbirds

Twenty-three species of bushbird were recorded within the proposed development area during the 1985 survey. With the addition of

nomadic, migratory or uncommon birds the area is expected to support a total of 54 species (Annex 2). Birds are fairly uncommon in the central portions of Pelican Point but are concentrated in the Flooded Gums and Paperbark trees fringing the Collie River.

3.2.2 Mammals

Only three terrestrial species of native mammal are expected from the area: the Common Dunnart, a small marsupial carnivore which is expected to occur in low numbers throughout the higher ground of the proposed development area, the Southern Brown Bandicoot which could be present in the denser vegetation along the banks of the Collie River and the Water-rat which is expected to be fairly common and lead its semi-aquatic existence along the river bank. The remainder of the native mammals are bats (7 species) which are likely to use hollows in taller trees throughout the area and whose populations will be limited because of the lack of the same.

Six introduced or exotic species of mammals including the Rabbit *Oryctolagus cuniculus*, which was recorded in 1985, are expected to be present in the proposed development area (Annex 2). Stock animals have not been included in this total.

3.2.3 Amphibians and Reptiles

One frog and one reptile were recorded in 1985 (Annex 2). Because of the number of rainwater pools which form in winter and the deep sands of the area, six frog species are expected to be present, although numbers will be low because of the amount of human and stock animal disturbance which has taken place. The terrestrial reptile fauna is expected to be relictual for the same reasons and limited to the more common or burrowing species. Because of the presence of stock animals, attendant ground compaction and widespread disturbance such as clearing, tracks and repeated fires, populations are liable to be very low.

3.2.4. Significant Habitats

In consideration of the amount of current and historical clearing and development which has taken place in the vicinity of Bunbury and its hinterland, any reasonably large tract of undeveloped land takes on an ever-increasing significance to relict terrestrial vertebrate populations and nomadic birds. However, when a site reaches the condition such as is apparent within the proposed development area the prognosis for terrestrial vertebrate populations (i.e. mammals,

frogs and reptiles) is poor, particularly if they are isolated by roads, pasture, extensive wetlands and housing estates. Nomadic and resident birds by comparison can be encouraged back into development areas if judicious landscaping and plantings are an integral part of the conceptual design. This aspect is addressed in following sections of this report.

It was evident during the 1985 survey that bushbirds were mainly concentrated within the denser vegetation along the banks of the Collie River. The area of high ground at the southern limits of the project area supports relict stands of mature trees. These are significant to nesting birds and many other species of vertebrates such as bats, geckos and monitors. Within the context of the disturbed nature of the country, these communities can be regarded as significant, albeit highly modified. No other locations were of particular conservation significance for vertebrate fauna other than waterbirds, although some limited, opportunistic usage of the less disturbed portions of the proposed development area was apparent.

3.2.5 Significant Species

Some waterbirds are covered by international agreements, but in the sense that there are no species listed as "rare or otherwise in need of special protection" under Schedules 1 and 2 of the Wildlife Conservation Act (1950) present or expected to occur in the proposed development area, no significant species occur. The Southern Brown Bandicoot, however, is disappearing from more developed parts of the south-west because of disturbance to wetlands. There is a possibility that it is still present within Pelican Point (rather than the adjacent pasture land) and this marsupial needs to be considered in the planning of the project where it impinges on the Collie River. It may be possible to integrate suitable areas of habitat within the golf course. For example, there are regular reports to the W.A. Museum of bandicoots using the grounds of various outlying tertiary institutions in Perth (J. Henry, pers. comm.).

4.0 IMPACT OF THE PROJECT

4.1 Waterbirds

4.1.1 Habitat Loss

This involves the loss of areas of wetlands, fringing formations and woodland to make way for the proposed development. All of these can have an adverse effect on waterbirds particularly when cumulative

upon the extensive loss of wetland habitat on the Coastal Plain.

4.1.2 Human Disturbance

Until waterbirds become habituated to human presence, for example as occurs at Shenton Park and Monger Lake, they tend to be wary and move away. Prior to habituation, this can seriously disrupt activities such as feeding, breeding and roosting if disturbance occurs on a regular basis. An international literature search by the authors showed that the primary impact on waterbirds, apart from continuing, physical attrition of wetlands, resulted from disturbance through water sports, hunting and angling. None of these activities will take place in the series of permanent wetlands planned for the proposed development area

4.1.3 Domestic and Introduced Predators

Waterbirds on the southern side of the Old Coast Road have habituated to stock animals which freely move among birds without causing disruption. Some waterbird species, the Straw-necked Ibis for example, actively use cattle by preying on grasshoppers flushed by the passage of stock. The introduction of pet dogs and cats into the estate will have a deleterious effect on waterbirds through harassment and predation. This will be cumulative upon that of foxes and feral cats which, while not recorded during the surveys, must be present.

4.1.4 Noise and Light

These factors commonly appear in public submissions objecting to a project. In 1988 the authors commissioned an international literature search on these an other aspects in an attempt clarify this perceived issue. The following keywords were used: birds, waterbirds, waterfowl, disturbance, disruption, interference, interruption, human, traffic, domestic animal, animal, light, illumination, noise, sound. Over 100 publication abstracts were obtained and none contained references to light. Noise was covered indirectly and was primarily associated with human activity such as power boat racing, other water sports, angling and hunting. No references to traffic noise or other suburban sound sources were found. Noise and light are therefore not seen to be significant impacts since there is evidence clearly indicating that waterbirds and migratory shorebirds habituate to these disturbances. Perth metropolitan wetlands adjacent to freeways or surrounded by housing estates and street lights are typical examples.

4.1.5 Road Casualties

The combination of traffic and waterbirds inevitably means that casualties will occur. Some of these will be low-flying birds and others will be broods of young ducks crossing roads on the way to wetlands from their breeding areas. This latter activity will mainly occur in a northward direction from the tall nesting trees in the extreme southern limits of the proposed development area.

4.2 Other Fauna

The area is already badly degraded through fire, stock, ground compaction and clearing. Populations of terrestrial vertebrates are judged to be extremely low and impact on this group will be cumulative upon this pre-existing situation. Bushbirds are reasonably common in selected areas such as the banks of the Collie River and fringing, taller vegetation around wetlands. The impact on this group will be similar to that predicted for waterbirds: habitat loss, human and domestic animal disturbance and road casualties.

5.0 IMPACT REDUCTION STRATEGIES

5.1 Waterbirds

5.1.1 Habitat Loss

This section explores various methods of creating new waterbird habitat to make up for that lost through development of traditional sites. The creation of a variety of wetland types to encourage waterbirds is assessed, as is planned re-vegetation and rehabilitation with the objective of raising the quality of the area for nomadic and resident birds.

Waterbirds have three major requirements - water, shelter and food. Each species has its own particular needs so that the greater the variety of water depths and food sources available, the greater the diversity of species which will be attracted to the wetland.

Water: in the construction of an artificial wetland, a variety of water depths is most important with extensive areas of shallows being the greatest single factor in attracting a range of waterbirds. Where water is less than 1 metre deep, adequate light reaches the bottom and encourages the growth of plant life. These and the invertebrates on or near them are eaten by waterbirds. Deeper areas are used by diving species which feed on fish, crustaceans or bottom-growing plants.

In a natural wetland, seasonal variations in water levels allow access to new food sources and release soil-bound nutrients which increase productivity. Such variations should be allowed to occur naturally in man-made wetlands or should be accomplished by artificial raising and lowering of water levels; this aspect will eventuate in some of the proposed freshwater lakes through normal drawdown/pumping regimes associated with irrigation.

The edges of the wetland should be as irregular as possible since this increases the area of available shallows and is more pleasing aesthetically.

Shelter: many waterbirds utilise reeds and sedges for shelter, protection from predators and in some cases nesting. Plantings of various species of sedges and reeds (Annex 3) should be made in and around the shallow areas. Other birds require shrubs and trees set back from the water to provide roosting, refuge and, eventually, nesting sites when the trees are large enough. Shrubs and trees should not be planted too close together, since this may obstruct flight-paths to and from the water surface. Ideally, the plants should be species which are adapted to local conditions. A list of suitable species is provided in Annex 3.

Islands are an extremely important factor in encouraging waterbirds to artificial wetlands. They increase the amount of shallow water available, provide shelter from the weather when vegetated and if constructed at a sufficient distance from the shore in deeper water, become predator-free refuges. This latter aspect is most important in a development where domestic pets and foxes are likely to harass waterbirds. Three types of island should be considered:

- higher relief vegetated islands with gently sloping access ramps;
- low relief, bare, sandy islets subject to partial seasonal inundation or temporarily exposed by irrigation drawdown;
- anchored log piles for use as roosts.

These islands can be constructed from rubble, bulldozer spoil and dead trees and set well back from the shorelines so that drawdown for irrigation purposes does not allow access to them by domestic pets, feral cats and foxes.

Food: if the conditions outlined in the previous section are fulfilled, an adequate food supply for waterbirds will naturally follow. There is usually no need to introduce aquatic vertebrates and invertebrates to the water as they will tend to colonise from other areas. Gently sloping grassed banks such as those found at

Herdsman Lake can assist in attracting bird species not otherwise found in the area (Curry 1981). These locations are also suitable for recreation, e.g. Lake Monger.

Anticipated Problems: local conditions such as the presence of superphosphate fertilizers, water turbidity, excess acidity or alkalinity and algal blooms can seriously effect the capacity of a wetland to support waterfowl and can seriously lower food supplies. Treatment to rectify these problems after the event can be time-consuming and expensive. However, valuable information for attempting to control, or forestall these effects is given in "Ducks, Ponds and People (Swift 1976). Design strategies are also provided in "Farm Dams for Wildlife and Stock" (NSW National Parks and Wildlife Service 1983). A profile of an 'ideal' wetland is described in "Wetlands of the south-West of Western Australia, with special reference to the Busselton area" (Dept. of Fisheries and Wildlife 1978).

5.1.2 Recommendations for Specific Wetlands

Saltwater Lake - Golf Driving Range: in design, this wetland should follow the outline given in Section 5.1. As this wetland will be used as a driving range serviced by a boat, it will need to be fairly deep and have its inlet channel at the same level as the adjacent estuary. This aspect will tend to discourage mosquitoes by allowing regular flushing and the free passage of predatory fish. It will also allow replenishment of waterbird prey species.

To encourage waterbirds, as much as of the original samphire community as possible should be retained along the lake perimeter, especially expanses which are regularly flooded by tides; the value of this habitat is stressed in earlier sections of the report. The north western section section adjacent to the Old Coast Road (approx. 1.2 hectares) should be retained as a shallow samphire marsh with a maximum depth of about 30 cm and should be situated above the lake level of the main driving range. Mosquito breeding in this tidal marsh could be circumvented by installing a narrow diameter reinforced channel with the capacity to slowly drain the area over a period of about five days i.e. faster than the mosquito summer breeding cycle of about 7-10 days. A location such as this would be a rich feeding area for wading birds, herons, and ducks. Yellow-billed Spoonbills and great Egrets displaced from the original, partially drained wetland some 200 metres south of this point would tend to congregate here.

Freshwater Lakes - Golf Units and Estate 1: this series of five small freshwater lakes provide an ideal opportunity for waterbird

rehabilitation and for the encouragement of a greater year-round range of species than occurs at present (Figure 2a). Provided that a range of water depths are provided and that the banks are gently sloped rather than vertical, many birds will use these lakes which will act as valuable freshwater drought refuges in summer, a rapidly diminishing resource on the Coastal Plain. The edges of the lake should be gentle inclines rather than vertical embankments since the latter actively discourages waterbirds. This and all other wetlands should also have portions of the shoreline vegetated. In discussing wetlands on the Swan Coastal Plain, Storr and Johnstone (1988) consider that:

> "The degradation or removal of waterside herbage by livestock, farmers and local government "beautification" schemes (requiring the reduction of the interface between water and land to a wall) has been accompanied by a decline in the Brown Bittern, Marsh Harrier and Painted Snipe."

Storr also mentions the loss of many wetlands on the Coastal Plain through drainage, landfill and pollution. Creation of well-designed, secure wetlands within a project such as this can go some way to addressing this problem. While some pre-existing wetland areas within the proposed development area will be lost, their usage is not high because of their ephemeral nature (Figure 2b). It is expected that the number of species and abundance of individuals will rise within the area as a direct result of the creation of a series of permanent wetlands.

These areas will more than replace the loss of Yellow-billed Spoonbill and Great Egret feeding areas to the south and should prove valuable during the breeding season of these birds. Leaving conservation aspects aside, the visual aspect of encouraging these two large, attractive waterbirds should be one of the primary goals of the landscaping conceptual plan. Increasing the area of the islands and vegetating portions of them will provide waterbirds with secure refuges from dogs, cats and foxes.

Floodway and Botanic Parkland: this section of the proposed development area has the greatest potential as a conservation area for waterbirds because of the variety of habitat niches it will provide. Because the proposed development area and the adjacent portion of the estuary support at least 14 of the 18 trans-equatorial migratory shorebirds covered by international treaties, one of the main objectives of this wetland should be to provide areas of suitable habitat for this group. This will entail leaving in place or planting expanses of samphire, allowing bare tidal flats to form and managing most of the area as a shallow, tidal wetland. Migratory shorebirds tend to congregate on tidal flats (Figure 3b)

and require a wide field of view. Deeper areas can be set aside for other species. A list of plant species suitable for re-vegetation of wetland fringes is given in Annex 3.

Freshwater Lake - Lake Villas: this large lake of approximately two hectares will primarily be designed as an ornamental area and as such will be of limited value to many species of waterbirds because of human disturbance and lack of natural habitat areas. However, being freshwater it will attract a large number of ducks, coots and perhaps swans in summer. Adjacent grassed areas should prove attractive to the less shy species of waterbird.

Canal Estate: because of their depth and relatively high embankments, canals are not particularly attractive to most species of waterbirds. However, populations of fish-eating species such as cormorants, darters and pelicans should build up in the vicinity of these canals. Because of their primary function as an access route, very little can be done to improve their potential as conservation areas.

Foreshore: the foreshore of the proposed development area is not used by large numbers of birds but is rich in species (Figures 3a, 3b). However it is adjacent to and inseparable from tidal flats where most feeding birds congregate. Forty-two percent of all recorded birds were observed in this habitat alone and of the 2087 individuals seen, 1874 were feeding. When nearby shallows and sandspits are taken into account, the significance of the foreshore and its intimately linked estuarine habitats is immediately apparent (Figure 3b). While large numbers of feeding birds can co-exist with humans, as is evident at Koombana Bay south-west of the proposed development area, it is essential that certain criteria are met to limit disturbance. All walkways, cycling and jogging paths should be set well back from the water's edge to limit disturbance and a public education programme put in place to stress the significance of the waterbirds using the area. These guidelines should be applied to all other wetlands in the proposed development area.

If the Preston River diversion is re-aligned to run along the western edge of the proposed development area, the impact reduction guidelines given for the foreshore will become critical. The Preston River mouth was assessed as being the richest waterbird location on Leschenault Estuary during the MCRC surveys and its possible re-alignment adjacent to the proposed development area will result in the creation of a productive delta and large expanses of tidal flats immediately adjacent to Pelican Point. Numbers of birds in the vicinity of the project area will rise dramatically and there will inevitably be a spill-over into the project area, thus potentially raising the level of impact if conservation and wetland management

strategies are not in place.

5.1.3 Other Aspects

Breeding: some waterbird breeding, mainly ducks, takes place within the proposed development area and while the following has not been established as yet, it appears highly likely that the bulk of nesting takes place in hollow Tuarts *Eucalyptus gomphocephela* and Marri trees *E. calophylla* on higher ground at the south-eastern corner of the project area. **It is essential that as many of these trees as possible are maintained during construction of the golf course.** It takes upwards of 50 years for suitable nesting hollows to form and the loss of these trees near wetlands could affect breeding for many years. This aspect may require detailed consultation on the re-alignment of fairways to minimise tree loss.

Human Disturbance: because of their design which includes patches of trees, natural shrubland and wetlands, golf courses support a range of waterbirds. They are particularly attractive to species such as the Straw-necked and Sacred Ibis, two species which commonly use metropolitan golf courses (pers. obs.). Minimal disturbance is predicted for this area. Human disturbance is predicted for the series of freshwater lakes scattered throughout the proposed development area and can be minimised by the creation of islands, planting of shelter belts, setting paths back from the water's edge and developing a public education programme.

Domestic and Introduced predators: a 50 metre wide strip of land adjacent to the estuary has been set aside for protection of the foreshore. This will only function as waterbird protection area if dogs are kept under strict control as these are one of the major disturbances to waterbirds. All other wetlands within the proposed development area will require the same guidelines. A fox and feral cat reduction programme should formulated in association with the Agriculture Protection Board.

Light and Noise: as discussed earlier, these two aspects, particularly noise are not seen to be major problems. However, it may be expedient to ensure that all lighting surrounding wetlands or along the foreshore is directed away from the water. The provision of vegetated refuge areas and islands will reduce any potential effects of reflected light.

Road Casualties: these will occur as waterbird populations take advantage of permanent wetlands. Impact can be reduced by strictly limiting vehicle speed within the housing estates. Broods of young birds which cannot fly and consequently travel cross-country with

their parents from nesting sites to feeding areas are at particular risk. This behaviour will primarily take place in a northerly direction from the high ground in the southern limits of the project area, and casualties can be reduced by recognising traditional routes and placing warning signs on road verges as is the practice on many roads within the metropolitan area.

5.2 Other Fauna

5.2.1 Bushbirds

The provision of landscaped areas including a high proportion of flowering shrubs, retention of trees and areas of bushland within the golf course and the creation of a botanical parkland will inevitably result in a large number of bushbirds (probably more than occur at present) being attracted to the area. It is essential that as much of the original vegetation, particularly the mature Tuart *Eucalyptus gomphocephela* and Marri *E. calophylla* on the high ground at the southern limits of the proposed development area and the Flooded Gum *E. rudis* and Paperbarks *Melaleuca priessiana* along the Collie River are retained. The hollows in these trees and their large size provide breeding sites for a large number of species and as stated in Section 5.1.2 these hollows take many decades to form.

Grassed areas adjacent to wetlands should attract species of bird previously unrecorded within the proposed development area. Curry (1981) documented this effect after construction of a waterside estate at Herdsman Lake in Perth.

5.2.2 Mammals

Annex 2 shows that the mammal fauna of the area, apart from introduced species, is liable to be depauperate because of past usage of the land. Relict populations particularly bats could be retained by maintaining as much natural bushland as possible. Kangaroos and perhaps possums could be introduced into the golf course and should eventually establish themselves.

5.2.3 Amphibians and Reptiles

The creation of artificial, freshwater wetlands will allow an increase in frog numbers and may allow colonisation by summer breeders such as the Golden Bell Frog *Litoria moorei*. Frogs and their tadpoles are an important dietary component of herons, egrets and spoonbills and these species may therefore be advantaged by an

increase in amphibians.

The prognosis for relict reptile populations is not good, but some will persist in areas of natural bushland and may colonise planted areas in the golf course. As with mammals, little can be done in the short or long-term with this group which has already been severely impacted by clearing, fire and ground compaction by stock animals.

6.0 CONCLUSIONS

The results of the surveys of the proposed development area and the adjacent estuary therefore indicate that:

- for the most part the landward habitats of the proposed development area show a high level of degradation, support relictual populations of terrestrial species such as mammals, amphibians and reptiles and include five locations classified as high priority mosquito control sites and two classified as moderate control (Wright 1986):

- apart from certain species of conservation significance such as the Great Egret And Yellow-billed Spoonbill, the proposed development area landward habitats are relatively poorly used by waterbirds, and on the few occasions when trans-equatorial migratory shorebirds congregate on the site, this is a result of event-related circumstances such as unusually high tides and winds;

- isolated pools, inundated samphire and the foreshore are the most significant habitats in the proposed development area, particularly for birds such as herons, egrets and spoonbills, while tidal flats in the adjacent estuary, where a similar area of habitat was sampled, showed much larger concentrations of waterbirds including a high proportion of trans-equatorial migratory shorebirds covered by international treaties;

- roosting is the main activity which takes place in the proposed development area, while feeding is the primary activity in the adjacent estuary:

- the proposed development area and the adjacent estuary cannot be considered in isolation in that any impact in one will inevitably flow on to the other. The main impacts of the project are judged to be habitat loss, human disturbance, harassment by domestic pets, predation by introduced species

such as foxes and feral cats and some deaths as a result of road casualties;

- the establishment of a series of permanent, freshwater and saline wetlands, removal of stock animals and the presence of a golf course in the proposed development area will more than offset any waterbird habitat loss by providing a greater range of wetland and bushland niches than now occur. The permanent, freshwater wetlands with various types of island will also operate as valuable drought refuges in summer and the number of waterbird and bushland species currently using the area is expected to rise;

- the creation of buffer zones along the foreshore, strict controls over domestic pets, minimum clearing of vegetation, a replanting and rehabilitation programme, informed management of wetland and bushland areas, introduced predator control and a public education programme will all substantially contribute to reducing the impact of the project.

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ANNEX 1 Waterbird species recorded within and adjacent to the proposed development area. Data extracted from Ninox Wildlife Consulting (1989a).

STUDY AREA		DEVELOPMENT AREA	ADJACENT ESTUARY
PELECANIDAE			
Pelecanus conspicillatus,	Australian Pelican	35	16
ANHINGIDAE			
Anhinga melanogaster,	Darter	30	11
PHALACROCORACIDAE			
Phalacrocorax carbo,	Great Cormorant	4	1
P. varius,	Pied Cormorant	11	-
P. sulcirostris,	Little Black Cormorant	31	87
P. melanoleucos,	Little Pied Cormorant	128	302
ARDEIDAE			
Ardea novaehollandiae,	White-faced Heron	32	7
Egretta alba,	Great Egret	24	5
E. garzetta,	Little Egret	4	5
PLATALEIDAE			
Threskiornis aethiopica,	Sacred Ibis	10	1
Platalea flavipes,	Yellow-billed Spoonbill	27	-
ANATIDAE			
Cygnus atratus,	Black Swan	30	108
Tadorna tadornoides,	Australian Shelduck	25	9
Anas superciliosa,	Pacific Black Duck	76	36
A. gibberfrons,	Grey Teal	70	10
A. rhynchotis,	Australasian Shoveler	2	-
PANDIONIDAE			
Pandion haliaetus,	Osprey	1	-
RALLIDAE			
Gallinula tenebrosa,	Dusky Moorhen	2	-
Porphyrio porphyrio,	Purple Swamphen	1	-
HAEMATOPODIDAE			
Haematopus longirostris,	Pied Oystercatcher	2	-
CHARADRIIDAE			
Pluvialis squatarola,	Grey Plover	19	207
P. dominica,	Lesser Golden Plover	-	1
Charadrius leschenaultii,	Large Sand Plover	-	24
C. ruficapillus,	Red-capped Plover	-	226
C. melanops,	Black-fronted Plover	1	-
RECURVIROSTRIDAE			
Himantopus himantopus,	Black-winged Stilt	73	37
Cladorhynchus leucocephalus,	Banded Stilt	2	-
Recurvirostra novaehollandiae,	Red-necked Avocet	-	36
SCOLOPACIDAE			
Tringa brevipes,	Grey-tailed Tattler	-	2
T. hypoleucos,	Common Sandpiper	5	-
T. nebularia,	Greenshank	10	23
Limosa lapponica,	Bar-tailed Godwit	-	108
Calidris canutus,	Red Knot	-	19
C. tenuirostris,	Great Knot	-	209
C. acuminata,	Sharp-tailed Sandpiper	79	103
C. ruficollis,	Red-necked Stint	7	1893
C. ferruginea,	Curlew Sandpiper	-	267
LARIDAE			
Larus novaehollandiae,	Silver Gull	167	280
Hydroprogne caspia,	Caspian Tern	3	3
Sterna bergii,	Crested Tern	2	-
EPHTHIANURIDAE			
Ephthianura albifrons,	White-fronted Chat	15	-
TOTAL		**928**	**4036**

ANNEX 2 **Fauna other than waterbirds recorded or expected to occur in the vegetation communities of the proposed development area.**

KEY

R = Recorded in 1985 I = Introduced species

BUSHBIRD SPECIES

ACCIPITRIDAE		
Elanus notatus,	Black-shouldered Kite	
Accipiter fasciatus,	Brown Goshawk	
C. aeruginosus,	Marsh Harrier	R
FALCONIDAE		
Falco berigora,	Brown Falcon	
F. cenchroides,	Australian Kestrel	R
COLUMBIDAE		
Columba livia,	Feral Pigeon	I
Streptopelia senegalensis,	Laughing Turtle-Dove	I
Phaps chalcoptera,	Common Bronzewing	R
CACATUIDAE		
Cacatua roseicapilla,	Galah	
PLATYCERCIDAE		
Purpureicephalus spurius,	Red-capped Parrot	R
Barnardius zonarius,	Port Lincoln Ringneck	R
Neophema elegans,	Elegant Parrot	
CUCULIDAE		
Cuculus pallidus,	Pallid Cuckoo	
C. pyrrhophanus,	Fan-tailed Cuckoo	
Chrysococcyx basalis,	Horsfield's Bronze-Cuckoo	
C. lucidus,	Shining Bronze-Cuckoo	
STRIGIDAE		
Ninox novaeseelandiae,	Southern Boobook	
TYTONIDAE		
Tyto alba,	Barn Owl	
PODARGIDAE		
Podargus strigoides,	Tawny Frogmouth	
ALCEDINIDAE		
Dacelo novaeguineae,	Laughing Kookaburra	I
Halcyon sancta,	Sacred Kingfisher	R
MEROPIDAE		
Merops ornatus,	Rainbow Bee-eater	R
HIRUNDINIDAE		
Hirundo neoxena,	Welcome Swallow	R
Cecropis nigricans,	Tree Martin	R
MOTACILLIDAE		
Anthus novaeseelandiae,	Richard's Pipit	R
CAMPEPHAGIDAE		
Coracina novaehollandiae,	Black-faced Cuckoo-shrike	R
Lalage sueurii,	White-winged Triller	R
MUSCICAPIDAE		
Petroica multicolor,	Scarlet Robin	
Pachycephala pectoralis,	Golden Whistler	
P. rufiventris,	Rufous Whistler	
Colluricincla harmonica,	Grey Shrike-thrush	
Rhipidura fuliginosa,	Grey Fantail	
R. leucophrys,	Willie Wagtail	R

Annex 2 - Continued

SYLVIIDAE		
Megalurus gramineus,	Little Grassbird	R
ACANTHIZIDAE		
Smicrornis brevirostris,	Weebill	
Gerygone fusca,	Western Gerygone	R
Acanthiza apicalis,	Inland Thornbill	
A. inornata,	Western Thornbill	
A. chrysorrhoa,	Yellow-rumped Thornbill	R
MELIPHAGIDAE		
Anthochaera carunculata,	Red Wattlebird	R
A. chrysoptera,	Little Wattlebird	
Lichenostomus virescens,	Singing Honeyeater	
Melithreptus lunatus,	White-naped Honeyeater	
Lichmera indistincta,	Brown Honeyeater	
DICAEIDAE		
Dicaeum hirundinaceum,	Mistletoebird	
PARDALOTIDAE		
Pardalotus punctatus,	Spotted Pardalote	
P. striatus,	Striated Pardalote	R
ZOSTEROPIDAE		
Zosterops lateralis,	Silvereye	R
GRALLINIDAE		
Grallina cyanoleuca,	Australian Magpie-lark	R
ARTAMIDAE		
Artamus cinereus,	Black-faced Woodswallow	R
A. cyanopterus,	Dusky Woodswallow	
CRACTICIDAE		
Cracticus torquatus,	Grey Butcherbird	R
Gymnorhina tibicen,	Australian Magpie	R
CORVIDAE		
Corvus coronoides,	Australian Raven	

<u>MAMMAL SPECIES</u>

DASYURIDAE		
Sminthopsis griseoventer,	Common Dunnart	
PERAMELIDAE		
Isoodon obesulus,	Southern Brown Bandicoot	
MACROPODIDAE		
MOLOSSIDAE		
Tadarida australis,	White-striped Mastiff-bat	
Mormopterus planiceps,	Little Mastiff-bat	
VESPERTILIONIDAE		
Nyctophilus major,	Greater Long-eared Bat	
N. geoffroyi,	Lesser Long-eared Bat	
Chalinolobus gouldii,	Gould's Wattled Bat	
C. morio,	Chocolate Wattled Bat	
Eptesicus regulus,	King River Eptesicus	
MURIDAE		
Hydromys chrysogaster,	Water-rat	
Rattus rattus,	Black Rat	I
Mus musculus,	House Mouse	I
LEPORIDAE		
Oryctolagus cuniculus,	Rabbit	I R
CANIDAE		
Canis familiaris,	Domestic Dog	I
Vulpes vulpes,	Fox	I

Annex 2 - Continued

FELIDAE		
Felis catus,	Feral Cat	I

AMPHIBIAN AND REPTILE SPECIES

LEPTODACTYLIDAE	**Frogs**	
Crinia georgiana		
Heleioporus eyrei		R
Limnodynastes dorsalis		
Pseudophryne guentheri		
Ranidella insignifera		
HYLIDAE	**Frogs**	
Litoria adelaidensis		
GEKKONIDAE	**Geckos**	
Phyllodactylus m. marmoratus		
PYGOPODIDAE	**Legless Lizards**	
Lialis burtonis		
Pygopus lepidopodus		
SCINCIDAE	**Skinks**	
Cryptoblepharus plagiocephalus		R
Ctenotus impar		
C. labillardieri		
E. napoleonis		
Hemiergis p. peronii		
Leiolopisma trilineatum		
Menetia greyii		
Tiliqua r. rugosa		
VARANIDAE	**Monitors**	
Varanus gouldii		
V. rosenbergi		
TYPHLOPIDAE	**Blind Snakes**	
Ramphotyphlops australis		
R. pinguis		
ELAPIDAE	**Elapid Snakes**	
N. scutatus occidentalis		
Pseudonaja a. affinis		
Rhinoplocephalus gouldii		
R. nigriceps		
Vermicella bertholdi		

Annex 3 **List of plant species suitable for revegetation and encouraging the return of fauna to the proposed development area. (After D.C.E. 1980.)**

KEY

H = Herb, grass or sedge
S = Shrub less than 1 metre
TS = Shrub greater than 1 metre
ST = Small trees
T = Tree

(i) EMERGENT PLANTS - WETLAND MARGINS

Baumea articulata	*H*
Baumea juncea	*H (brackish)*
Scirpus validus	*H*
Scirpus subfascicularis	*H*
Typha orientalis	*H*
Polygonum minus	*H*
Juncus pallidus	*H*
Juncus polyanthemos	*H*
Juncus krausii	*H*
Melaleuca teretifolia	*TS*
Lepidosperma longitudinale	*H*
Triglochin procera	*H*

(ii) WETLAND EDGE - SEASONALLY INUNDATED

Melaleuca raphiophylla	*TS*
Melaleuca teretifolia	*TS*
Melaleuca uncinata	*TS*
Cenetella orbifolia	*H*
Eucalyptus rudis	*T*
Polygonum minus	*H*
Epilobum junceum	*H*
Scirpus inundatus	*H*
Patersonia umbrosa	*H*
Euchilopsis linearis	*H*
Eutaxia virgata	*S*
Oxylobium linearifolium	*S*
Myoprum gracilis	*S*
Agonis linearifloia	*TS*

Suitable for nutrient poor soils:

Melaleuca preissaina	*TS*
Melaleuca laterita	*S*
Viminaria juncea	*TS*
Aotus ericoides	*S*
Pultenea reticulata	*S*
Astartea fascicularis	*S*
Sphaerolobium vimineum	*S*
Cyatochoetae avenacea	*H*
Banksia littoralis	*T*
Deyeuxia quadriseta	*H*
Acacia saligna	*TS*
Leptospermum ellipticum	*S*
Kunzea vestita	*TS*
Hypocalymma angustifolia	*S*
Carex appressa	*H*

Pelican Point Pty Ltd

Pelican Point, Bunbury

Public Environmental Review

APPENDIX 5

PELICAN POINT, PREDICTED IMPACT OF RESORT DEVELOPMENT ON GROUNDWATER RESOURCES AND OPTIONS FOR ENVIRONMENTAL MANAGEMENT

LEC Ref: J186/R320

GRC - DAMES & MOORE

PELICAN POINT
PREDICTED IMPACT OF RESORT DEVELOPMENT ON GROUNDWATER RESOURCES AND OPTIONS FOR ENVIRONMENTAL MANAGEMENT

for

Pelican Point Pty Ltd

Project Code	:	20142-001
Report	:	425
Date	:	August 1990
Copy	:	2

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PELICAN POINT
PREDICTED IMPACT OF RESORT DEVELOPMENT ON GROUNDWATER RESOURCES AND OPTIONS FOR ENVIRONMENTAL MANAGEMENT

1.0 SUMMARY AND CONCLUSIONS

Construction of the Sanctuary Pelican Point Resort is proposed adjacent to foreshore areas of Vittoria Bay and the Collie River, approximately 5 km east-northeast of Bunbury. The site is generally of low elevation and flat-lying except in the south-eastern portion of the property where a 12-14 metre dunal ridge is present.

The site is underlain by the superficial formations, comprising largely quartzose and calcareous sands which form an inhomogeneous unconfined aquifer with a saturated thickness of about 20-25 metres. Except in areas beneath the dunal ridge, the depth to the water table is less than 2m and large portions of the property are inundated during the wet winter months. Except in the small area beneath the dunal ridge, the groundwater is saline and consequently the potential for development of the groundwater resources in this aquifer is limited. The superficial formations unconformably overlie the Leederville Formation.

The Leederville Formation forms a semi-confined, multi-layered aquifer which extends from 24.5 to 184.4 metres depth in a bore (PB1) drilled in the south-eastern corner of the resort site. Local variations in the thickness of Leederville Formation are known to occur and interpretation of the data available suggests that PB1 is sited in the western portion of a faulted structural feature known as the Dardanup Syncline. Fresh groundwater resources (TDS ~ 400 mg/L) have been identified in this aquifer by geophysical log interpretation and water sampling during pumping tests. The groundwater contains a soluble iron concentration of 0.6 mg/L, which can be treated by aeration or chlorination. The Leederville Formation is separated from the underlying Yarragadee Formation by the Bunbury Basalt.

The groundwater requirements for irrigation of the resort facilities are estimated to be 3.7 x 10^5 m^3/annum with peak abstraction rates of about 3000 m^3/day during the summer months.

These estimates will require review and revision as detailed design of the resort proceeds.

Activities associated with the development of the proposed resort which may affect local groundwater systems include:

- o groundwater abstraction for irrigation;
- o excavation of shallow lakes in the vicinity of the saline interface in the superficial formations; and
- o application of fertilisers to the golf course and landscaped areas.

In addition, increased recharge may cause small (<1m) increases in the water table elevation as a result of land clearing, higher runoff coefficients from buildings and paved areas, and the infiltration of excess irrigation water to the aquifer.

The predicted impacts of these activities on the groundwater systems are summarised below.

(i) Groundwater Abstraction

Use of hydraulic parameters derived from pumping tests, in conjunction with reference material, indicates that throughflow in the Leederville Formation within the Dardanup Syncline is adequate to provide the sustainable yields currently estimated to be required for irrigation of resort facilities. Modelling based upon the Theis non-equilibrium equation also indicates that abstraction of the proposed quantities of groundwater will cause minimal interference to other users. The proposed abstraction from the Leederville Formation is anticipated to cause little if any change in the position of the seawater interface.

(ii) Excavation of Shallow Lakes

Construction of shallow lined lakes on the proposed golf course in areas straddling the current position of the seawater interface may cause short-term, localised landward migration of the interface in the uppermost portion of the superficial formations. Any effects should be reversed during the first winter after completion of the lakes, or shortly after commencement of irrigation of the golf course.

(iii) Application of Fertilisers

The depth to water table over much of the proposed resort area is shallow and leaching of nutrients from fertilisers may cause some nitrogen and phosphorus enrichment of groundwaters within the superficial formations. However, the leaching of nutrients from fertilisers into the shallow groundwater system will be minimised and controlled by:

- Fertiliser management
- Irrigation management
- Vegetation up-take
- Soil amendment and regular sampling
- Filling of some golf course areas to increase thickness of the unsaturated zone.

Management strategies to conserve and protect the local hydrogeological environment are outlined in detail in the report and are related largely to:

- o limiting effects of abstraction from the Leederville Formation on other users and on the seawater interface; and
- o minimising nutrient flux into the Collie River and Leschenault Inlet.

Successful implementation of these strategies will involve:

- o installation of additional production bores to minimise local drawndown effects;
- o installation of additional observation bores to delineate and monitor any migration of the seawater interface in the Leederville Formation;
- o completion of soil analyses to determine the Phosphorus Retention Index of in-situ and fill materials from selected sites within the areas proposed for the golf course and landscaped gardens;
- o sampling of the existing monitoring bores in the superficial aquifer to determine background nutrient levels in groundwater; and
- o implementation of a monitoring programme to measure nutrient levels, water table fluctuations and groundwater salinity variations in new and existing monitoring bores completed in the superficial formations.

2.0 INTRODUCTION

The Sanctuary Pelican Point is a resort development proposed for a site approximately 5 km east-northeast of Bunbury, adjacent to Vittoria Bay (Leschenault Inlet) and Collie River foreshore areas. The site has an area of about 130 ha and comprises Leschenault Loc. 26 and Part Lot 60 Old Coast Road, Bunbury.

Development is proposed by Pelican Point Pty Ltd and the resort comprises a marina and canal connected to the Collie River, hotel and tavern complexes, golf links and associated residential accommodation. A development plan of the resort is presented in Figure 1.

GRC-Dames & Moore have been retained by Pelican Point Pty Ltd to investigate and report upon groundwater resources underlying the development site in support of application for a production licence, and to define appropriate management strategies for the protection of local groundwater resources.

This report has been prepared as an appendix to the Public Environmental Review Report and contains descriptions of the local hydrogeology, the water supply options and the water supply requirements. The report also addresses the potential impact of resort development on the local groundwater systems and outlines appropriate strategies for responsible management and protection of the groundwater resources.

3.0 RESORT SETTING

The land proposed for development is situated immediately adjacent to the eastern foreshore of Vittoria Bay (southern portion of Leschenault Inlet) on the western margin of the Swan Coastal Plain. Pelican Point, at the mouth of the Collie River, is the northern-most extent of the resort area.

Low elevation, flat, alluvial plains and river terraces associated with interdunal wet-lands of the Leschenault Inlet and Collie River respectively form three quarters of the development area. Samphire scrub exists over much of this area. Within the southern portion of the development area, eolian deposits (derived from reworked Tamala Limestone) form a prominent dunal ridge which reaches an elevation of about 14 metres AHD.

Surface drainage features, with the exception of the Collie River, are poorly developed locally. Low relief surface topography and predominantly sandy soil profiles enhance direct infiltration and hence drainage occurs to a large extent by subsurface flow. Groundwater flow is northwesterly and groundwater discharges into the Collie River and Vittoria Bay.

The regional climate is Mediterranean and characterised by distinctive seasons with hot, dry summers and mild, wet winters. Accurate rainfall and evaporation records are available from Wokalup (approximately 30 km to the north) and indicate rainfall averages about 980 mm/annum, whilst mean evaporation is about 1800 mm/annum. Evaporation exceeds rainfall except during the months May to August.

4.0 HYDROGEOLOGY

4.1 HYDROGEOLOGICAL SETTING

The proposed resort occurs within the Bunbury Groundwater Area; an area proclaimed under Section 18 of the Rights in Water and Irrigation Act, 1914-1976, to facilitate the protection of aquifers from overdevelopment and pollution, by licencing of groundwater abstractions.

An exploratory drilling programme, completed in the Bunbury area by the Geological Survey of Western Australia intermittently between 1967 and 1980, indicates that four aquifers underlie the development site; namely:

- superficial formations;
- Leederville Formation;
- Yarragadee Formation; and
- Cockleshell Gully Formation.

Hydrogeological investigations for the development of fresh groundwater supplies to the proposed resort involved drilling into the superficial formations and Leederville Formation. No drilling of the deeper lying Yarragadee or Cockleshell Gully Formations was undertaken.

The superficial formations extend from the ground surface to depths of approximately 20-25 metres and form an inhomogeneous, unconfined aquifer which unconformably overlies the Leederville Formation. The Leederville Formation forms a multilayered semi-confined aquifer.

The base of the Leederville Formation is marked locally by weathered Bunbury Basalt lava flows, which occur discontinuously in the region. Locally, the thickness of the Leederville Formation is believed to vary significantly due to structural features (probably block faulting), related to the formation of the Dardanup Syncline. The proposed resort site occurs on the western limb of this synclinal trough and the thickness of the Leederville Formation probably decreases towards the west.

Due to the proximity of the proposed resort site to the coast line and Leschenault Inlet, the quality of groundwaters within the superficial formations and the Leederville Formation in this vicinity is very largely dependent upon the extent of landward migration of the seawater interface.

4.2 LOCAL DATA BASE

Two drilling programmes were completed to define the local hydrogeology and to evaluate groundwater resources of the superficial formations and Leederville Formation.

Initially a soils and shallow groundwater investigation was completed by Ranson Site Investigation Pty Ltd, which comprised drilling and construction of ten investigation/monitoring bores (P1 to P9A) during 28th February to 2nd March 1990. Bores are located about 300-600 metres apart throughout the proposed resort area.

Drilling was undertaken with a Gemco trailer mounted rig, utilising rotary hollow-auger techniques. All holes were drilled at 150 mm diameter and equipped with 50mm nominal diameter, slotted PVC casing. Drill cuttings were lithologically logged.

Most holes (P1 to P7) were drilled upon the interdunal low-lands/river terraces which form the northern three-quarters of the property. These holes were drilled to depths of between 4.5 and 6.0 metres and, were completed with monitoring intervals immediately below the water table. Generally, the lithological profile comprised approximately one metre of light grey to black sandy topsoil overlying brown to black, variably silty and clayey, loosely consolidated sands and calcareous sands.

Sites P8 and P9 are located in areas of higher topographic relief, upon a dunal ridge in the southern portion of the property. Consequently these holes were drilled to depths of 14.5 metres and 20.0 metres respectively to intersect the water table.

The bores were developed by bailing immediately after completion of construction and then sampled for measurement of electrical conductivities to estimate the salinity of the recovered groundwaters.

Survey co-ordinates , reduced levels, bore construction details and electrical conductivity measurements are summarised in Appendix 1.

Following completion of the shallow drilling programme, Bunbury Boring Co mobilised to site and commenced work on a pilot-hole to investigate deeper aquifer zones. The site selected for this work is located in the south-eastern portion of the resort property.

Based upon the interpretation of geophysical and chip logging data, the drilling was terminated at the base of Leederville Formation (delineated by weathered Bunbury Basalt) and a test production (PB1) bore constructed with screens installed in aquifer zones within the basal portion of the Leederville Formation.

Following the installation of well screens, the bore (PB1) was demudded and developed by high pressure air-lifting and jetting techniques. The bore was then equipped for a series of pumping tests to determine local hydraulic characteristics of the aquifer. The bore produced artesian flows during and after demudding exercises. The pumping test programme comprised a five (5) stage step-drawdown test followed by a 24 hour constant-rate discharge test. Aquifer responses to pumping were monitored within the test production bore. A water sample was collected, for chemical analysis, upon completion of the 24 hour constant rate pumping period. Recovery of water levels was monitored after the constant rate test.

Bore construction, development and testing was completed during 7th-28th March 1990.

A summary of bore completion details, groundwater quality, and pumping test results is given in Appendix 2.

4.3 SUPERFICIAL FORMATIONS

The superficial formations unconformably overlie the Leederville Formation and extend from ground surface to depths of approximately 20-25 metres. These sediments consist primarily of alluvial and littoral deposits which form an inhomogeneous, unconfined aquifer. Generally, the sedimentary profile comprises sands and silty sands with minor clayey-sand intercalations. In near-shore areas, up to about 400 metres from Vittoria Bay, sediments are also characterised by a relatively small (5%) shell fragment component. Near the base of the superficial formations black anaerobic lacustrine/backswamp clay deposits occur. The base of superficial formations was identified in PB1 from drill-cuttings and interpretation of gamma-ray and resistivity logs, at approximately 24.5 metres depth.

The water table in the superficial formations is within two (2) metres of ground surface; except in the south-eastern part of the proposed resort, where the water table occurs at a depth of 10-12 metres below ground level. Contoured water table elevations shown in Figure 2 are based upon monitoring data collected during late summer to early autumn and as such reflect the lower limit of seasonal water-table fluctuations. Following rainfall recharge during winter, groundwater levels in the superficial formations rise by approximately 0.4-0.6 metres (Commander, 1982) causing inundation of lower lying areas.

Regional groundwater flow is in a north-westerly direction and groundwater discharges into Leschenault Inlet and the Collie River.

Groundwaters in the superficial formations are saline over most of the resort area, with electrical conductivities of 20 000 - 25 000 microSiemens/cm at 25°C. The extent of the seawater intrusion is approximately delineated in Figure 2, and generally appears to be located 600 - 800 metres east of the Vittoria Bay foreshore. Fresh groundwaters, with electrical conductivities of 600 - 850 microSiemens/cm at 25°C occur within the superficial formations only in the south-eastern portion of the proposed resort area.

Significant variation in water quality probably occurs both laterally and vertically in the superficial aquifer due to its anisotropic, inhomogeneous nature, especially in the vicinity of the seawater interface.

4.4 LEEDERVILLE FORMATION

The Leederville Formation, unconformably overlies weathered Bunbury Basalt and forms a semi-confined, multi-layered aquifer extending (at PB1) from approximately 24.5-184.4 metres depth. The sedimentary sequence at this site comprises interbedded quartzose sandstones, grey siltstones and claystones, and dark grey to black carbonaceous shale beds with minor coal horizons.

Information obtained from PB1 indicates that the screened aquifer interval has a potentiometric level of approximately 4 metres AHD, which provides artesian conditions with a positive head of approximately 1.5 metres above ground level at the site drilled. The potentiometric head in the Leederville Formation is higher than the water table elevation within the overlying superficial formations and there is potential for upward leakage from the deeper aquifer zones into the superficial aquifer.

Groundwater flow in the Leederville Formation is in a north-westerly direction (Commander, 1982).

Based on a chemical analysis and on the resistivity log, groundwater within the Leederville Formation, in the immediate vicinity of PB1, is potable throughout the aquifer zones intersected. The groundwater quality does appear to deteriorate marginally near the base of the aquifer. In general, groundwaters are of the sodium-chloride type, slightly acidic (pH 6.6), and fresh with a salinity of 350-800 mg/L Total Dissolved Solids (T.D.S). The salinity of the water discharged during the pumping test was <400 mg/L T.D.S. The measured soluble iron concentration of 0.6 mg/L in PB1 is high enough to cause staining and encrustation of fixtures unless the water is treated. To avoid staining, soluble iron concentrations should be <0.3 mg/L.

The seawater interface within the Leederville Formation was not intersected during the drilling of PB1. However the interface is probably present in the aquifer a few hundred metres west of the seawater interface within the superficial formations, nearer the Vittoria Bay foreshore.

The hydraulic characteristics of the aquifer, the potential bore yields, and the aquifer response to abstraction were determined from pumping tests on PB1.

Analysis of the test data indicates that the aquifer is semi-confined. The time-drawdown data show a downward deviation from the theoretical type curve for a confined aquifer and this is probably due to leakage. Leakage effects are pronounced after an elapsed time of only one (1) minute and continue throughout the duration of pumping. Downward leakage, from permeable zones above the screened interval, probably predominates.

Aquifer transmissivities have been calculated using the Jacob and Theis Recovery methods (plots in Appendix 2C) and the Walton specific capacity method on the early drawdown data, adjusted to account for well losses.

Calculated transmissivity values are 703, 680 and 667 m^2/day based upon Jacob, Theis Recovery and Walton methods respectively. Over the screened aquifer interval of 45.2 metres, these equate to average hydraulic conductivities of 14.7 - 15.6 m/day. The storativity of the aquifer is estimated to be 8×10^{-4} (dimensionless).

These results confirm that the permeability of the Leederville Formation in this area is relatively high and indicate a high yield capability for PB1, enhanced by efficient bore design.

Based on the pumping test data and reference material, regional groundwater throughflow within the Dardanup Syncline has been estimated by application of Darcy's Law:

$Q = KiA$,

where:

K ≈ Hydraulic conductivity (15m/day from pumping test).

i ≈ Hydraulic gradient. Estimated to be 1.3×10^{-3} or 1.3m per 1000m (Commander, 1982).

A = Cross-sectional area (average thickness of the aquifer unit multiplied by lateral extent or width). Based upon work by Commander (1982), these parameters are estimated as 100 metres and 15 000 metres respectively within the Dardanup Syncline.

Therefore throughflow appears to be in the order of 2.9×10^4 m^3/day or 10.7×10^6 m^3/annum.

The values of hydraulic gradient and cross-sectional area used in the above equation are estimates and even relatively small variations will significantly alter throughflow calculations. In addition, it is common in multi-layered aquifer systems like the Leederville Formation for differential potentiometric pore pressures to develop with depth within the layered profile and this characteristic further complicates throughflow determinations.

4.5 LOCAL GROUNDWATER USAGE

It is understood that small groundwater supplies are obtained locally from the superficial formations for stock, or pasture. Existing bores on the property may be operated following construction of the resort.

There are no large scale abstractions of groundwater from the Leederville or Yarragadee Formations in close proximity to PB1 (i.e. within 1.0 kilometre).

The nearest Leederville Formation production bore is sited at the Meadow Lea Factory (formerly Vegetable Oils (W.A.)) at Location 26 Lot 10, Old Coast Road, Bunbury. This site is approximately 1.9 kilometres southwest from PB1.

Eaton water supply bores (No. 1 and No. 2) located approximately 1.9 kilometres northeast of PB1 are the closest pumping bores producing from the Yarragadee Formation.

5.0 DEVELOPMENT OF GROUNDWATER SUPPLIES FOR THE RESORT

Evaluation of the groundwater resources in the superficial formations and the Leederville Formation beneath the proposed resort site has been undertaken under Groundwater Well Licence No. 33396.

The superficial formations adjacent to Vittoria Bay and extending over most of the resort site contain saline groundwater. Consequently, the superficial aquifer beneath the site contains only limited resources of low salinity groundwater.

The Leederville Formation contains large volumes of fresh groundwater and yield capacity is high. The resources available for development appear adequate to meet the requirements of the proposed resort.

Development of the fresh groundwater resources in the Leederville Formation is planned to meet a major portion the demand for irrigation of the golf course and recreational facilities at the proposed resort. Groundwater from the superficial formations and mains water may be utilised to supplement the supply from the Leederville Formation.

5.1 PROJECTED GROUNDWATER REQUIREMENTS

Groundwater is required for irrigation of golf links (greens, fairways and driving range), botanic parklands and landscaped gardens.

In accordance with the development plan (Figure 1), the irrigation water supply requirements have been determined for the resort facilities based upon:

- local climatic data, derived from mean monthly rainfall and pan evaporation measured at Wokalup Research Station;
- estimated areas of greens, fairways, lawns, hotel gardens etc.
- water application rates determined from regional field trials and experimental work carried out by The Department of Agriculture;
- previous experience of the consulting group on golf courses recently constructed near Perth.

Preliminary estimates of the water requirements for irrigation are outlined in Tables 1 and 2. These estimates are subject to change pending revisions to the design of the resort.

Peak abstractions of up to 3000 m^3/day are estimated to be required during the hot and dry summer months and no irrigation is forecast duing the wet winter months. An average annual abstraction of 3.7×10^5 m^3 (1000 m^3/day) is anticipated, including allowances for evaporation losses from storage lakes.

Additional demand is anticipated during the grow-in period of the golf links and for re-establishment of vegetation in areas disturbed during construction.

5.2 PROJECTED GROUNDWATER SUPPLY

Based upon the monitored response to pumping of PB1 and calculations of local throughflow within the Leederville Formation, this aquifer could adequately supply the peak 3000 m^3/day and average 1000 m^3/day groundwater abstraction required for irrigation of Pelican Point Resort. Long-term reliability of this source is very much based on regional hydrogeological factors, particularly the potential for landward migration of the seawater interface. Monitoring bores should therefore be installed within the resort site to define the current extent of seawater intrusion within the Leederville Formation and to provide local data on hydraulic gradients and changes to the salinity profiles, with time. This will ensure that fresh water supplies are not jeopardised by over-pumping and landward migration of the seawater interface.

Analysis of the pumping test data indicates that a pump setting of 20 metres below ground level should adequately provide for long term (10 year) pumping requirements assuming that no discharge barrier boundaries are intersected within the radius of influence of the drawdown cone, and that interference from other pumping bores is negligible.

Although the water required could be supplied solely by pumping from PB1, commissioning of another bore within Leederville Formation or production bores in the superficial formations is recommended since:

- irrigation supplies could be maintained in the event of failure of one bore; and,
- operation of all bores simultaneously would result in reduced local drawdown effects which would be of benefit in terms of operational water resource management.

5.3 WATER TREATMENT AND RETICULATION

Groundwater abstracted from the Leederville Formation during the testing of PB1 was fresh (TDS <400 mg/L). However, soluble iron concentrations were relatively high at 0.6 mg/L. This concentration will cause unsightly staining of fixtures, and consequently treatment is recommended. Treatment to remove iron would probably also be required for any supplies obtained from the superficial formations.

The abstracted groundwater will be discharged into lined storage lakes which will form a temporary water storage facility from which the reticulated supplies will be drawn. These lakes provide an ideal setting for installation of aeration treatments to reduce iron concentrations to levels below 0.3 mg/L which will minimise staining. Oxidising agents such as chlorine gas can also be employed to reduce iron concentrations by precipitation and chemical reagents, such as sodium silicate, may be added to irrigation supplies to ensure that the iron remains in solution.

6.0 PREDICTED IMPACTS OF DEVELOPMENT ON THE GROUNDWATER SYSTEM

Activities associated with resort development which are likely to have an impact on the local groundwater systems are listed below.

- land clearing;
- abstraction from the Leederville Formation and possibly from the superficial formations for irrigation supply;
- temporary, local dewatering of the superficial formations during excavation of the canal and the lakes;
- application of fertilisers to the golf course and landscaped areas; and
- potentially increased recharge from built-up areas (road pavements, roofs, etc) and irrigated areas.

The extent and significance of these impacts is discussed below.

6.1 EFFECTS OF ABSTRACTION FROM THE LEEDERVILLE FORMATION

PB1 is approximately 1.9 kilometres from the nearest, existing user (Meadow Lea Factory) of Leederville Formation groundwater resources.

To assess the potential effects of groundwater abstraction from PB1 on the Leederville Formation and existing users, a simple model based upon the Theis non-equilibrium equation has been utilised to simulate regional drawdown effects. The results are summarised below.

PREDICTED DRAWDOWN IN LEEDERVILLE FORMATION DUE TO PROGRESSIVE PRODUCTION FROM PB1

Period (years)	*Production Rate (m^3/day)*	*Radial Distance (m)*	*Predicted Drawdown (m)*
0.3*	3,000*	500	2.3
0.3	3,000	1,000	1.8
0.3	3,000	2,000	1.4
10	1,000ˣ	500	1.2
10	1,000	1,000	1.0
10	1,000	2,000	0.9
10	1,000	5,000	0.6
10	1,000	10,000	0.5

ˣ Annual abstraction averaged over 365 days.
* Peak summer discharge.

The results indicate that the long-term effects of abstraction will be minimal. The predicted drawdowns are approximately one metre at radial distances of up to two kilometres from the bore-site and 0.5 - 1.0 metre at distances of up to ten kilometres.

In addition, the predicted drawdowns outlined above are probably maximum levels since calculations are based upon a fully confined aquifer regime whereas the pumping test programme clearly indicates that the aquifer is semi-confined with significant leakage occurring during pumping.

The effects of abstraction on existing users are therefore likely to be minimal. The proposed abstraction rates are also predicted to cause minimal landward migration of the seawater interfaces in Leederville Formation and the superficial formations.

6.2 INCREASED RECHARGE

Recharge to the superficial formations is likely to be enhanced by development of the resort due to several factors, namely:

- o clearing of existing vegetation, resulting in reduced losses by evapo-transpiration, this impact is likely to be significant only in the short-term, during initial stages of the resort development whilst the golf course and landscaped areas are being established;
- o increased runoff coefficients from roofed and paved areas and, on-site disposal of drainage waters via lake systems;
- o infiltration of excess water from irrigation and domestic garden reticulation systems.

In addition to these effects, raising of ground levels in areas currently subject to inundation will result in reductions in evaporation losses and a marginal increase in water table elevations.

Actual changes to the water balance locally cannot be accurately assessed at this stage since they are dependent on a number of factors which can only be quantified as design and construction proceeds. These include outflow elevations from lake systems, surface area of lakes, local fill levels, and permeability of fill materials. Generally, fill levels and lake outflow elevations will determine maximum water table elevations and storm events (their frequency, duration and intensity) together with evaporation rates will determine seasonal water table fluctuations. Future water table fluctuations are unlikely to be significantly different from the range of 0.4-0.6 metres currently estimated for the resort area.

No detrimental effects are anticipated due to enhanced recharge of the superficial aquifer. which will offset the effects of any abstraction from this aquifer. Discharge of drainage waters derived from surface runoff is likely to be required during winter via the lake systems to Vittoria Bay and Collie River.

6.3 EFFECTS ON GROUNDWATER QUALITY

Groundwater quality may be affected by nutrients derived from fertilisers applied to the golf links, gardens and recreation areas within the resort site.

Runoff drainage systems, incorporating the unlined lakes may also allow introduction of oils and other potentially hazardous chemicals into the superficial formations.

Domestic sewage is not a potential source of nutrients since it will be discharged from the resort site to the Eaton Sewerage Treatment Plant or alternatively to the Bunbury No 2 Treatment Works.

6.3.1 Nutrient Loading

The application of fertilisers to the proposed golf course and resort gardens may result in phosphorus and nitrogen enrichment of shallow groundwaters within the superficial formations. A primary objective of the resort developer will therefore be the implementation of measures to minimise and limit the infiltration of nutrients.

Most of the golf course and resort gardens will be situated on low lying terrain where the depth to the water table is shallow. Infiltration of nutrients leached from fertilisers to the uppermost saturated levels within the superficial formations could occur relatively quickly because of the shallow depth to water table and the sandy soil profile. This is also true in those parts of the golf course located upon the dunal ridge in the southeastern portion of the proposed resort site. However, the significantly greater depth to the water table in this area will allow greater time for adsorption of nutrients before they reach the water table. The use of loamy fill would enhance attentuation of nutrients by adsorption within the soil profile.

Adsorption of nutrients by in-situ clayey and silty sediments occurs both above and below the water table. Fertiliser management programmes will be designed to closely balance application rates with local soil adsorption rates and seasonal vegetation growth, harvesting and dethatching periods. Analyses of moisture retention characteristics and Phosphorus Retention Index (PRI) of local soils and fill materials will be an integral part of fertiliser management plans together with the use of slow release fertilisers and foliar feeding. A balance of all these aspects will therefore be sought to minimise nutrient enrichment of shallow groundwaters which utlimately discharge into the Collie River and Leschenault Inlet.

6.4 IMPACT OF CANAL AND LAKES CONSTRUCTION

A number of lakes and a single canal (off the Collie River) are proposed within the resort site. Two types of lake are planned, saline and unlined and, fresh and lined. The location of each of the proposed lakes is shown on Figure 1.

Localised dewatering of the uppermost 3 to 4 metres of the superficial formations may be required to construct the canal and to allow excavation of some of the lakes. These developments are largely within the saline portion of the shallow aquifer and can be undertaken without any detrimental effects. Some of the proposed lakes (adjacent to the foot-slope of the dunal ridge) straddle the seawater interface delineated by shallow exploratory drilling, and dewatering activities prior to and during construction of these lined lakes may result in short-term, marginal, landward migration of the seawater interface in the upper part of the superficial formations. Development of a proposed freshwater habitat for birds on the foot slope of the dunal ridge is not expected to have a significant impact on the shallow groundwater system.

Natural throughflow within the shallow aquifer together with rainfall infiltration and enhanced recharge associated with development will limit the period and extent of any landward migration of the saline interface and offset additional evapo-transpiration losses associated with the development of the freshwater habitat.

7.0 MANAGEMENT STRATEGIES

Fresh groundwater resources have been identified within the Leederville Formation and to a limited extent within the superficial formations. To protect these resources, it is important to minimise potential adverse effects associated with the proposed development by:

- limiting effects of abstraction from the Leederville Formation on other users and on landward migration of the seawater interface; and
- minimising nutrient flux to the Collie River and Leschenault Inlet.

These effects can be minimised by adopting appropriate management strategies based on suitable monitoring programmes designed to meet the requirements of the EPA and the Water Authority.

7.1 GROUNDWATER MONITORING PROGRAMMES

Efficient maintenance of resort facilities requires a significant commitment by the developer to the management of the water supply/irrigation scheme. Routine monitoring of groundwater abstraction rates, water quality, pumping water levels in production bores, and water levels in observation bores is an integral part of groundwater resource management.

The following monitoring programmes are proposed:

7.1.1 Water Level Monitoring

Water levels in production bores and monitoring bores would be measured monthly. In the case of pumping bores, levels would be recorded immediately prior to pump start-up or alternatively immediately prior to cessation of production.

7.1.2 Pumpage Monitoring

Pumpage from individual production bores would be recorded on a monthly basis using cumulative flow meters. Both instantaneous and aggregate discharge volumes would be monitored.

7.1.3 Lakes Storage/Irrigation Monitoring

Water levels in lakes utilised for irrigation would be recorded monthly using staff gauges. Irrigation rates, together with areal distribution of reticulated water volumes throughout the resort, would also be recorded.

7.1.4 Groundwater Quality

The electrical conductivity of groundwater discharged from each production bore would be measured quarterly. Groundwater samples would also be taken once a year from each production bore and submitted to an approved laboratory for chemical anlaysis.

Additional bores would be constructed to monitor the saline interface within the Leederville Formation and the nutrient concentrations in the superficial formations in the vicinity of the golf course and other recreational facilities. Background data on the groundwater quality would be established by sampling of the existing shallow monitoring bores. Conductivity profiles would be run in the interface monitoring bores on a quarterly basis and nutrient monitoring bores would be sampled quarterly for chemical analysis.

7.2 NUTRIENT MANAGEMENT

Sources of nutrient loading to the shallow groundwaters at the proposed resort are:

- o fertiliser application to the golf course during establishment and for maintenance of turf and greens;
- o fertiliser application to resort gardens and lawns and, within private residences; and
- o nutrients in surface drainage waters discharged to on-site disposal systems.

The following management strategies are proposed to minimise nutrient migration from the resort site.

(i) Use of loamy fill materials with significant PRI in areas to be filled. Quality control of fill sediments will be employed to prevent drainage problems.

(ii) Establishment of vegetation in the lakes and drainage systems to remove nutrients.

(iii) Control of storage and useage of oils and other potentially hazardous chemicals.

(iv) Design and implementation of detailed fertiliser program based on:
- application of slow release fertilisers and foliar feeding; and
- encouragement of private lot owners to selectively cultivate native gardens and to use slow release fertilisers;

(v) Design and implementation of a comprehensive nutrient management plan based on:
- regular soil sampling and testing to determine residual soil nutrient levels and soil moisture levels, and adjustment of fertiliser and irrigation application rates according to results;
- minimising water application by establishment of deep-rooted turf and by planning of irrigation schedules to avoid excessive losses due to evaporation, wind interference and, oversaturation during storm events; and

- minimising water application by regular maintenance/ mowing/de-thatching of the golf links and gardens which will enhance infiltration to the root zones and reduce evaporation losses.

By implementation of these management measures, application rates for fertiliser and water can be fine-tuned to allow the resort to be maintained to the desired standard using the minimum quantities of groundwater and fertilisers.

August 1990
GRC131

I. G. BRUNNER
Project Hydrogeologist

AD:tma/20142-001-074/dk:121-2574

ADDENDUM TO REPORT No. 425
PREDICTED IMPACT OF RESORT DEVELOPMENT ON GROUNDWATER RESOURCES AND OPTIONS FOR ENVIRONMENTAL MANAGEMENT

Since Report No. 425 was completed, a number of discussions have been held with the Water Authority of WA concerning Pelican Point Pty Ltd's licence application to abstract groundwater for irrigation at the Resort. A copy of the Water Authority's written response to the application and subsequent discussions is attached.

The Water Authority have indicated that they would be willing to issue a licence for the abstraction of 200,000m^3/annum of groundwater from the Leederville Formation. Based on the preliminary estimate of water requirements given in Report No. 425, the above quantity of water would probably be sufficient for irrigation of the golf course but not for the proposed landscaped areas which were estimated to require a further 165,000m^3/annum of groundwater. A number of additional test production bores will therefore be constructed to further investigate the superficial aquifer.

The balance of the required supply will therefore be obtained from the superficial aquifer and supplemented as required by mains water. The Water Authority have indicated verbally that no restrictions will be placed on abstractions from the superficial aquifer.

A.C. Deeney
Principal Hydrogeologist

July 1991

AD:tma/20142-001-074/DK:121-2580

WATER AUTHORITY
of Western Australia

61 VICTORIA STREET
BUNBURY W.A.
Postal Address: P.O. Box 305 Bunbury
Western Australia 6230
Telephone: (097) 91 0400 Fax: (097) 91 0432

Your Ref
Our Ref 6-BY-250.026
Enquiries N Welsh
Tele Direct (097) 910490

Mr AC Deeney
C/- GRC Dames & Moore
273 Stirling Street
PERTH WA 6000

Dear Sir

THE SANCTUARY PELICAN POINT RESORT
APPLICATION FOR GROUNDWATER WELL LICENCE

Following this Authority's letter dated September 26, 1990 and the more recent discussions between both parties, this letter follows up the meeting between yourself and members of the Water Authority's Bunbury office which was held on February 28, 1991.

Firstly it should be clarified that the Water Authority has found that 366,000 cubic metres per annum is not available from the Leederville Formation from within this area. All indications are that 200,000 cubic metres per annum could be obtained from the Leederville Formation.

Finally the project is still dependent upon EPA approvals and before these approvals are obtained the Water Authority would like the Developer to rationalise the amount of groundwater required for the Resort Complex, Housing Villas, Hotel, Boat Ramp and miscellaneous Areas. The Authority also requires the developer to complete a more detailed investigation of the Superficial formation should more than 200,000 cubic metres per annum be required.

Should you wish to discuss this matter further then contact either Neville Welsh of the Regional office in Bunbury on telephone (097) 910490 or Mr Rob Hammond of the Authority's Groundwater Branch on (09) 420 2420.

Yours faithfully

Tony Ford
REGIONAL SERVICES ENGINEER
SOUTH WEST REGION

18 March 1991

Ausean1.Let:NEV1\DW4: NJW

TABLES

TABLE 1

The Sanctuary Pelican Point

CLIMATIC CONDITIONS AND ESTIMATED PROJECT WATER USAGE

MONTH	Epan* (mm/month)	Epan x 0.7 (mm/month)	Rainfall + (mm/month)	Projected Application Rate (mm/month)	
				GREENS	OTHERS
JAN	282	197	16	220	181
FEB	235	165	19	179	146
MAR	211	148	23	155	125
APR	123	86	55	48	31
MAY	84	59	148	0	0
JUN	63	44	207	0	0
JUL	62	43	168	0	0
AUG	74	52	137	0	0
SEP	99	69	86	0	0
OCT	143	100	67	53	33
NOV	180	126	36	115	90
DEC	239	167	16	184	151

* Based on mean daily pan evaporation rates for Wokalup Station

\+ Mean monthly rainfall for Wokalup

TABLE 2

The Sanctuary Pelican Point

IRRIGATION WATER REQUIREMENTS (KL)

MONTH	GREENS (2.2 ha)	FAIRW DRIVI S, TEES RANGE (25.0 ha)	GOLF RESORT (0.63 ha)	HOUSING, VILLAS, UNITS, HOTEL + KIOSK (12.38 ha)	LAWNS (2.42 ha)	BOAT RAMP + CAR PARK (1.17 ha)	OTHERS + MISC (2.41 ha)	NET EVAPORATION LOSS FROM FRESHWATER LAKES (4.22 ha)	TOTAL	AVERAGE DAILY ABSTRACTION RATE (KL/day)
JAN	4840	45341	1140	22408	4380	2118	4362	7638	92227	2975
FEB	3938	36573	920	18075	3533	1708	3519	6161	74427	2658
MAR	3410	31313	788	15475	3025	1463	3013	5275	63762	2057
APR	1056	7766	195	3838	750	363	747	1308	16023	534
MAY	0	0	0	0	0	0	0	-3756	-3756	0
JUN	0	0	0	0	0	0	0	-6879	-6879	0
JUL	0	0	0	0	0	0	0	-6035	-6035	0
AUG	0	0	0	0	0	0	0	-3587	-3587	0
SEP	0	0	0	0	0	0	0	- 717	- 717	0
OCT	1166	8267	208	4085	799	386	795	1393	17099	552
NOV	2530	22545	567	11142	2178	1053	2169	3798	45982	1533
DEC	4048	37826	951	18694	3654	1767	3639	6372	76951	2482
ANNUAL	20988	18963	4769	93717	18319	8858	18244	10971	365497	1001

FIGURES

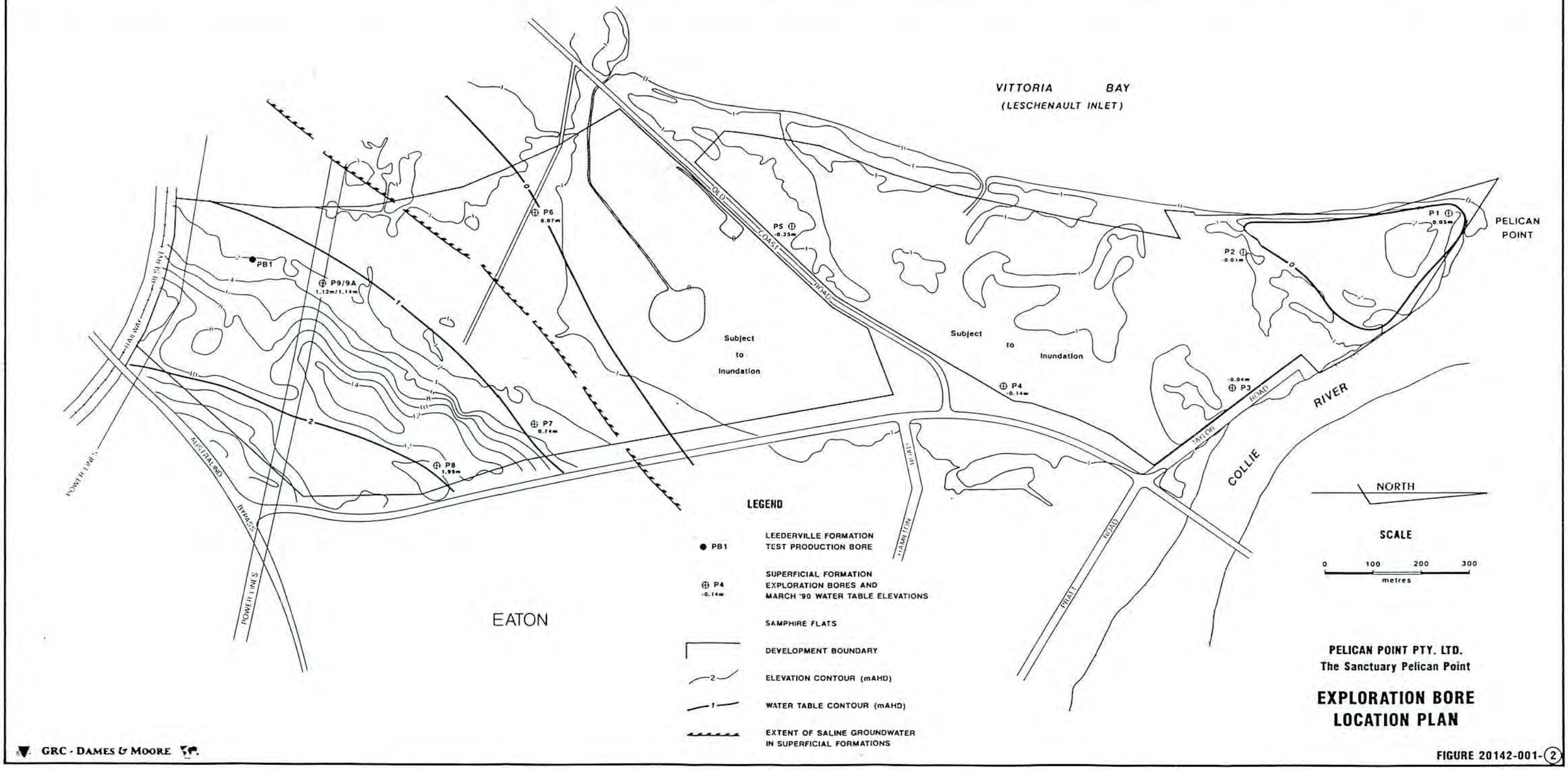
Pelican Point Bunbury Development Plan

PLAN NO.89/31/2

DATE July 1991

FIGURE 20142-001-①

GRC - DAMES & MOORE



PELICAN POINT PTY. LTD.
The Sanctuary Pelican Point

EXPLORATION BORE LOCATION PLAN

GRC - DAMES & MOORE

FIGURE 20142-001-(2)

APPENDIX 1

SUPERFICIAL FORMATIONS

APPENDIX 1A

BORE COMPLETION DETAILS

APPENDIX 1A

The Sanctuary Pelican Point

SUPERFICIAL FORMATION GROUNDWATER INVESTIGATION
BORE COMPLETION DETAILS

Bore	AMG Co-ordinates Eastings	Northings	Levels (mAHD) G.L.	Collar	Date Drilled	Bore Depth (m)	Bore Diameters(mm) Drilled	Cased	Open Interval	Water Levels (m AHD) (March 1990)	Conductivity µS/cm @ 25°C
P1	378007.30	6313988.55	1.06	1.365	28.2.90	4.5	150	50	0.3 - 4.5	0.05	22 000
P2	378082.27	6313600.21	1.08	1.283	28.2.90	5.0	150	50	0.3 - 5.0	-0.01	20 000
P3	378335.45	6313579.02	0.64	0.791	28.2.90	5.0	150	50	0.3 - 5.0	-0.04	24 000
P4	378332.39	6313113.41	0.77	0.924	28.2.90	5.0	150	50	0.3 - 5.0	-0.14	19 000
P5	378035.91	6312672.30	1.03	1.181	1.3.90	5.0	150	50	0.3 - 5.0	-0.35	25 000
P6	378002.69	6312104.03	1.85	2.205	1.3.90	5.0	150	50	0.3 - 5.0	0.07	20 000
P7	378409.08	6312129.98	2.41	2.650	1.3.90	6.0	150	50	0.3 - 6.0	0.74	1 490
P8	378493.07	6311915.87	9.26	9.607	1.3.90	14.5	150	50	2.5 - 14.5	1.99	840
P9	378105.11	6311679.42	2.00	2.349	1.3.90	6.0	150	50	0.3 - 6.0	1.12	600
P9A	378106.90	6311679.60	2.15	2.498	2.3.90	20.0	150	50	11.5 - 19.5	1.12	750

APPENDIX 1B

BORE COMPLETION DIAGRAMS

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P1

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 28/2/90

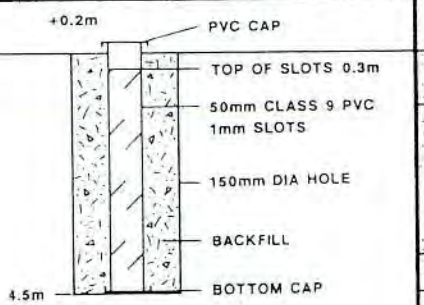
TOTAL DEPTH: 4.5m

REDUCED LEVEL DATUM: 1.36m AHD - casing collar

CO-ORDINATES: E378007.3m, N3613988.55m

DEPTH TO WATER: 1.31m btc ; March 1990

BORE DIAMETER: Cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µS/cm °C
0		0-1m SOIL, Grey-black, medium-coarse grained, rounded, moderate-well sorted, quartz sand, some shell fragments, some very coarse grains. 1-4m SAND, Slightly silty, as above 4-4.5m SAND, Silty, black, medium-fine grained, well sorted, rounded-subrounded, quartz, 15% shell fragments	22 000 @ 25°C
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			
22			
24			
26			
28			

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001-3

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P2

DRILLER: RANSON SITE INVESTIGATION PTY LTD

DATE DRILLED: 28/2/90

TOTAL DEPTH: 5.0m

REDUCED LEVEL DATUM: 1.28m AHD - casing collar

CO-ORDINATES: E378082.27m, N6313600.21m

DEPTH TO WATER: 1.29m btc ; March 1990

BORE DIAMETER: cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µs/cm	°C
0	GROUND LEVEL; +0.2m PVC CAP; TOP OF SLOTS 0.3m; 50mm CLASS 9 PVC 1mm SLOTS; 150mm DIA HOLE; BACKFILL; 5.0m BOTTOM CAP	0-1m TOPSOIL, Grey-black, medium-coarse grained, rounded, medium-well sorted, quartz sand, some shell fragments, some very coarse grains 1-2m SAND, Slightly silty, brown-grey, as above 2-5m SAND, Silty, grey-black, as above	20 000 @ 25°C	
2				
4				
6				
8				
10				
12				
14				
16				
18				
20				
22				
24				
26				
28				

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001-4

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P3

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 28/2/90

TOTAL DEPTH: 5.0m

REDUCED LEVEL DATUM: 0.79m AHD-casing collar

CO-ORDINATES: E378335.45m; N6313579.02m

DEPTH TO WATER: 0.83m btc ; March 1990

BORE DIAMETER: Cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µs/cm °C
0	GROUND LEVEL +0.2m; PVC CAP; TOP OF SLOTS 0.3m; 50mm CLASS 9 PVC 1mm SLOTS; 150mm DIA HOLE; BACKFILL; 5.0m BOTTOM CAP	0-1m TOPSOIL, Orange-light brown, medium-coarse grained, moderately sorted, rounded, quartz sand, some very course grains 1-2m SAND, Slightly silty, brown-grey, as above, 5% shell fragments 2-5m SAND, Silty, black-grey, as above	24 000 @ 25°C
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			
22			
24			
26			
28			

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001-5

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P4

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 28/2/90

TOTAL DEPTH: 5.0m

REDUCED LEVEL DATUM: 0.92m AHD - casing collar

CO-ORDINATES: E378332.39m, N6313113.41m

DEPTH TO WATER: 1.06m btc ; March 1990

BORE DIAMETER: Cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µs/cm	°C
0	GROUND LEVEL; +0.2m PVC CAP; TOP OF SLOTS 0.3m; 50mm CLASS 9 PVC 1mm SLOTS; 150mm DIA HOLE; BACKFILL; 5.0m BOTTOM CAP	0-1m TOPSOIL, Light brown, grey and orange, medium-coarse grained, rounded, moderate-well sorted, quartz sand 1-2m SAND, Slightly silty, orange-brown, medium-coarse grained, rounded, well sorted, mainly quartz 2-4.5m SAND, Silty, grey-black, as above 4.5-5m SILT, Clayey, green-brown, soft	19 000 @ 25°C	

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001-6

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P5

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 1/3/90

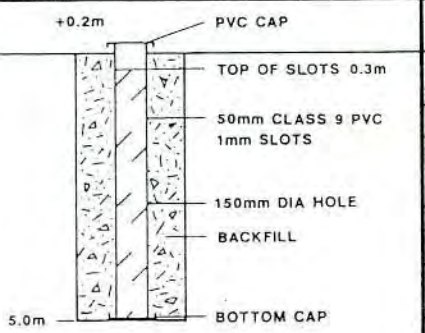
TOTAL DEPTH: 5.0m

REDUCED LEVEL DATUM: 1.18m AHD - casing collar

CO-ORDINATES: E378035.91m, N6312672.30m

DEPTH TO WATER: 1.53m btc ; March 1990

BORE DIAMETER: Cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µs/cm°C
0		0-1m TOPSOIL, White-grey, fine-medium grained, moderate-well sorted, subrounded-subangular, quartz sand 1-4m SAND, Slightly silty, grey, medium-coarse, moderate-well sorted, round-sub rounded, quartz, 5% shell fragments 4-5m SAND, Silty, some clay, green-brown, fine-coarse grained, moderately sorted, quartz, some shell fragments	25 000 @ 23°C
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			
22			
24			
26			
28			

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001-7

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P6

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 1/3/90

TOTAL DEPTH: 5.0m

REDUCED LEVEL DATUM: 2.2m AHD - casing collar

CO-ORDINATES: E378002.69m, N6312104.03m

DEPTH TO WATER: 2.13m btc ; March 1990

BORE DIAMETER: Cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µs/cm °C
0	GROUND LEVEL; +0.2m PVC CAP; TOP OF SLOTS 0.3m; 50mm CLASS 9 PVC 1mm SLOTS; 150mm DIA HOLE; BACKFILL; 5.0m BOTTOM CAP	0-1m TOPSOIL, Grey-brown, fine-medium grained, subangular-subround, moderately well sorted, quartz sand, some coarse grains 1-2m SAND, Brown-light brown, medium-coarse grained, well sorted, rounded-subrounded, quartz 2-4m SAND, Slightly silty, brown-grey, as above 4-5m SAND, Silty, grey-green, medium grained, as above	20 000 @ 23°C
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			
22			
24			
26			
28			

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P7

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 1/3/90

TOTAL DEPTH: 6.0m

REDUCED LEVEL DATUM: 2.65m AHD - casing collar

CO-ORDINATES: E378409.08m, N6312129.98m

DEPTH TO WATER: 1.87m btc; March 1990

BORE DIAMETER: Cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µs/cm °C
0	GROUND LEVEL; +0.2m PVC CAP; TOP OF SLOTS 0.3m; 50mm CLASS 9 PVC 1mm SLOTS; 150mm DIA HOLE; BACKFILL; 6.0m BOTTOM CAP	0-1m TOPSOIL, Black, medium grained, well sorted, subround, quartz sand 1-2m SAND, Grey-light brown, medium-coarse grained, moderate-well sorted, subround-rounded, quartz 2-4.5m SAND, Grey, as above, coarse-medium grained 4.5-6m SAND, Very silty, clayey, soft, yellow, fine-medium grained, subangular-subround, moderately sorted, quartz	1500 @ 26°C
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			
22			
24			
26			
28			

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001-9

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P8

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 1/3/90

TOTAL DEPTH: 14.5m

REDUCED LEVEL DATUM: 9.61m AHD - casing collar

CO-ORDINATES: E378493.07m, N6311915.87m

DEPTH TO WATER: 8.02m btc ; March 1990

BORE DIAMETER: Cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µS/cm
0	GROUND LEVEL; +0.2m PVC CAP; BLANK TO SURFACE	0-1m TOPSOIL, Brown-grey, medium grained, well sorted, subrounded, quartz sand 1-10m SAND, Yellow, medium grained, well sorted, subround-rounded, quartz	
2	2.5m TOP OF SLOTS 2.5m		
4	50mm CLASS 9 PVC 1mm SLOTS		
6			
8	BACKFILL		
10	150mm DIA HOLE	10-14m SAND, Silty-slightly silty, as above	
12			
14	14.5m BOTTOM CAP	14-14.5m SAND, Very silty, clayey, yellow-green, fine-medium grained, subangular-subround, moderately sorted, quartz	850 @ 26°C
16			
18			
20			
22			
24			
26			
28			

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001-10

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P9

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 1/3/90

TOTAL DEPTH: 6.0m

REDUCED LEVEL DATUM: 2.35m AHD - casing collar

CO-ORDINATES: E378105.11m, N6311679.42m

DEPTH TO WATER: 1.23m btc ; March 1990

BORE DIAMETER: Cased 50mm

DEPTH (m)	BORE CONSTRUCTION	LITHIOLOGICAL DESCRIPTION	COND. µs/cm °C
0	GROUND LEVEL; +0.2m; PVC CAP; TOP OF SLOTS 0.3m; 50mm CLASS 9 PVC 1mm SLOTS; 150mm DIA HOLE; BACKFILL; 6.0m; BOTTOM CAP	0-1m TOPSOIL, Grey-black, medium-coarse grained, rounded-subrounded, moderate-well sorted, quartz sand 1-3m SAND, Slightly silty, brown, medium-coarse grained, rounded, well sorted, quartz 3-5m SAND, Grey, as above, no silt, becoming grey-green 5-6m SAND, Silty, yellow-green, fine-medium grained, subrounded-rounded, moderately sorted, quartz, some coarse grained quartz	600 @ 25°C
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			
22			
24			
26			
28			

COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-001-11

GROUNDWATER EXPLORATION BORE COMPLETION REPORT

BORE No.: P9A

DRILLER: RANSON SITE INVESTIGATIONS PTY LTD

DATE DRILLED: 2/3/90

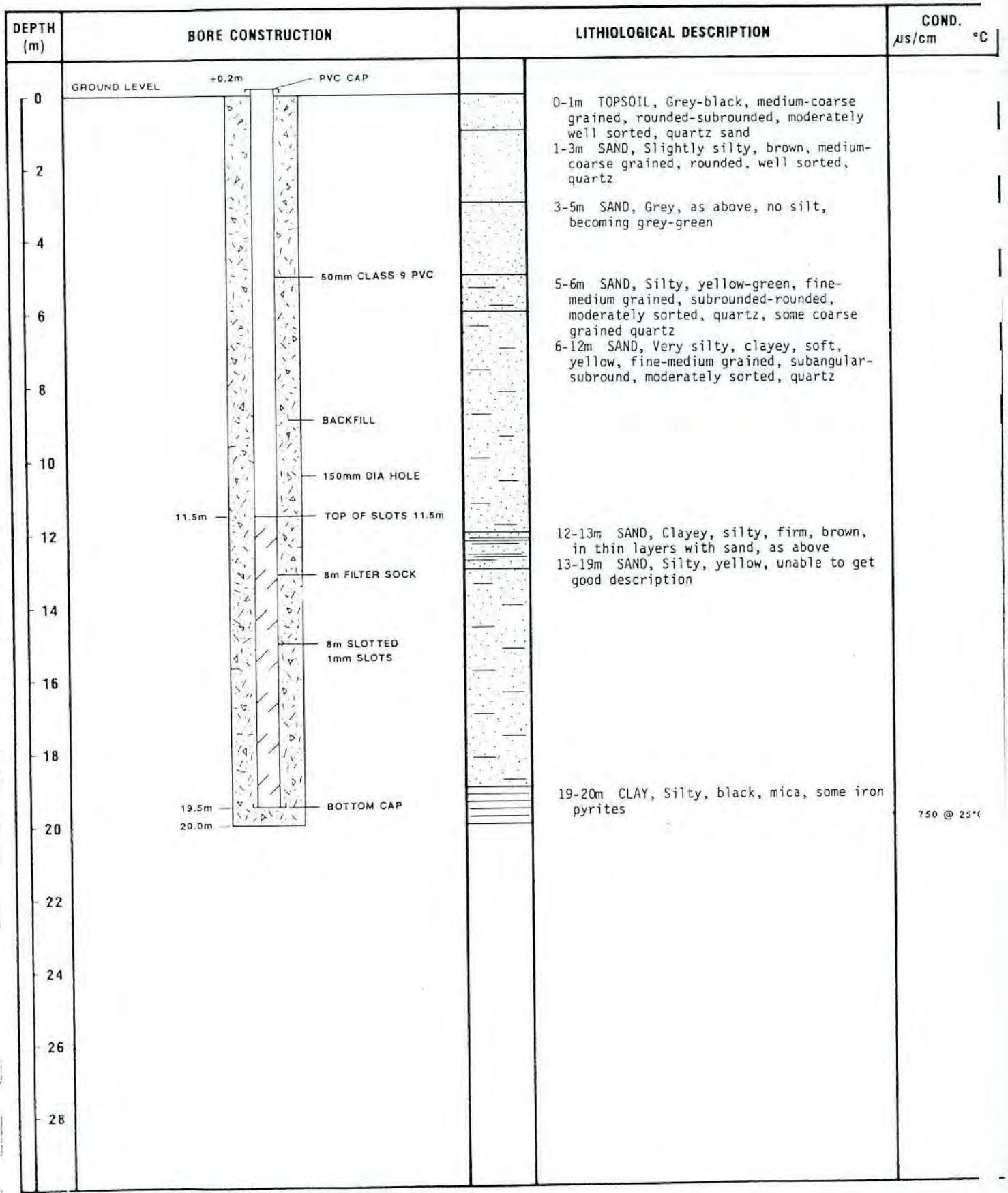
TOTAL DEPTH: 20.0m

REDUCED LEVEL DATUM: 2.5m AHD - casing collar

CO-ORDINATES: E378106.90m, N6311679.60m

DEPTH TO WATER: 1.36m btc; March 1990

BORE DIAMETER: Cased 50mm



COMMENTS: Development - Bailing
Development time - 15 minutes
Bailed sample taken immediately after development

GRC - DAMES & MOORE

Figure 20142-00

APPENDIX 2

LEEDERVILLE FORMATION

APPENDIX 2A

SUMMARY PB1 CONSTRUCTION

SUMMARY PB1 CONSTRUCTION

Status: Artesian Leederville Formation Production Bore for irrigation supply at The Sanctuary Pelican Point. The bore is currently capped; to be equipped.

Contractor: Bunbury Boring Co.

Date Completed: 21st March 1990

Drilling Method: Mud-rotary

Location (AMG Co-ordinates):

E 378132.59m
N 6311514.96m

Elevation:

2.801 m AHD (Casing Collar)
2.201 m AHD (Ground Level)

Drilling Diameters:

0.0 - 24.3 metres; 445 mm diameter
24.3 - 124.3 metres; 340 mm diameter
124.3 - 172.2 metres; 251 mm diameter
172.2 - 185.2 metres; 216 mm diameter

Construction Details:

1. Surface Casing:

   0.0 - 24.2 metres; 355.6 mm o.d. x 9.5 mm W.T. ERW API mild steel. Base of the casing was cement grouted.

2. Production Casing:

   0.0 - 124.3 metres; 273.1 mm o.d. x 9.3 mm W.T. ERW API mild steel. Assembly was pressure cemented from casing toe to surface with sulphate resistant grout.

3. Screen Assembly:

   121.0 - 122.0 metres; slip-on lead packer unit and stainless steel centraliser/extension assembly; 152 mm nominal i.d.
   122.0-125.1 metres; 152 mm nominal i.d. zero slot stainless steel wire wound screens.
   125.1-128.1 metres; 152 mm nominal i.d. x 0.64 mm aperture stainless steel well-screens.
   128.1-164.1 metres; 152 mm nominal i.d. x 0.76 mm aperture stainless steel well-screens.
   164.1-170.3 metres; 152 mm nominal i.d. x 0.89 mm aperture stainless steel well-screens
   170.3 - 170.7 metres; 152 mm nominal i.d. stainless steel J-latch lowering assembly and sump.

The screen assembly was lowered onto a grout plug comprising cement filled calico bags extending from 170.7 - 172.2 metres. Below this level a 216 mm diameter pilot-hole was backfilled with cuttings.

Bore Development: Completed by means of de-mudding, air-lifting, back-washing and high pressure jetting.

APPENDIX 2B

PB1 - BORE COMPLETION DIAGRAM

PELICAN POINT PTY LTD
THE SANCTUARY - PELICAN POINT

ARTESIAN BORE COMPLETION REPORT

BORE No. PB1

STATUS: PRODUCTION

STARTED: 7/3/1990

FINISHED: 21/3/1990

TOTAL DEPTH: 185.2m

CASED DEPTH: 170.7m

OPEN INTERVAL: 125.1-170.4m

ELEVATION: 2.801 m AHD (Top of casing)
2.201 m AHD (Ground Level)

STATIC WATER LEVEL: 4.0 m AHD (March 1990)

PUMPING TEST: 24 Hours @
4 500m³/day for
12.3m drawdown

GROUNDWATER SALINITY: 350mg/L TDS

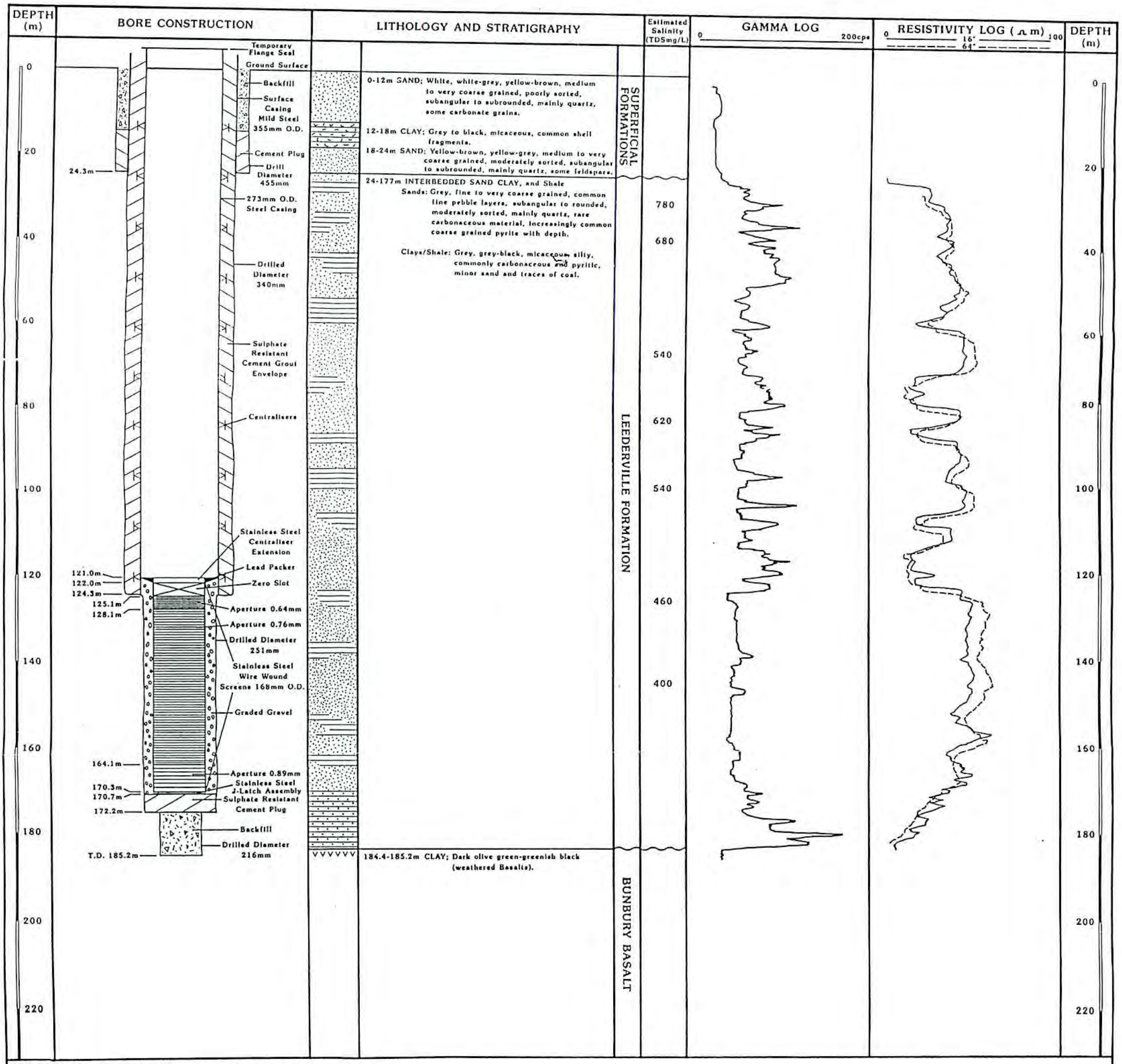
LOCATION: BUNBURY

AMG CO-ORDS. (ZONE 50): 378 065mE
6 311 536mN

DRILLED BY: BUNBURY BORING Co.

DRILLING METHOD: MUD ROTARY

GEOPHYSICAL LOGGING: 14/3/1990
MINES DEPT. DRILLING BRANCH



COMMENTS: Bore drilling undertaken under Groundwater Well Licence 0033396.
Bore development by High Pressure Jetting, Air-Lifting And Backwashing.

APPENDIX 2C

PUMPING TEST PROGRAMME - PB1

APPENDIX 2C

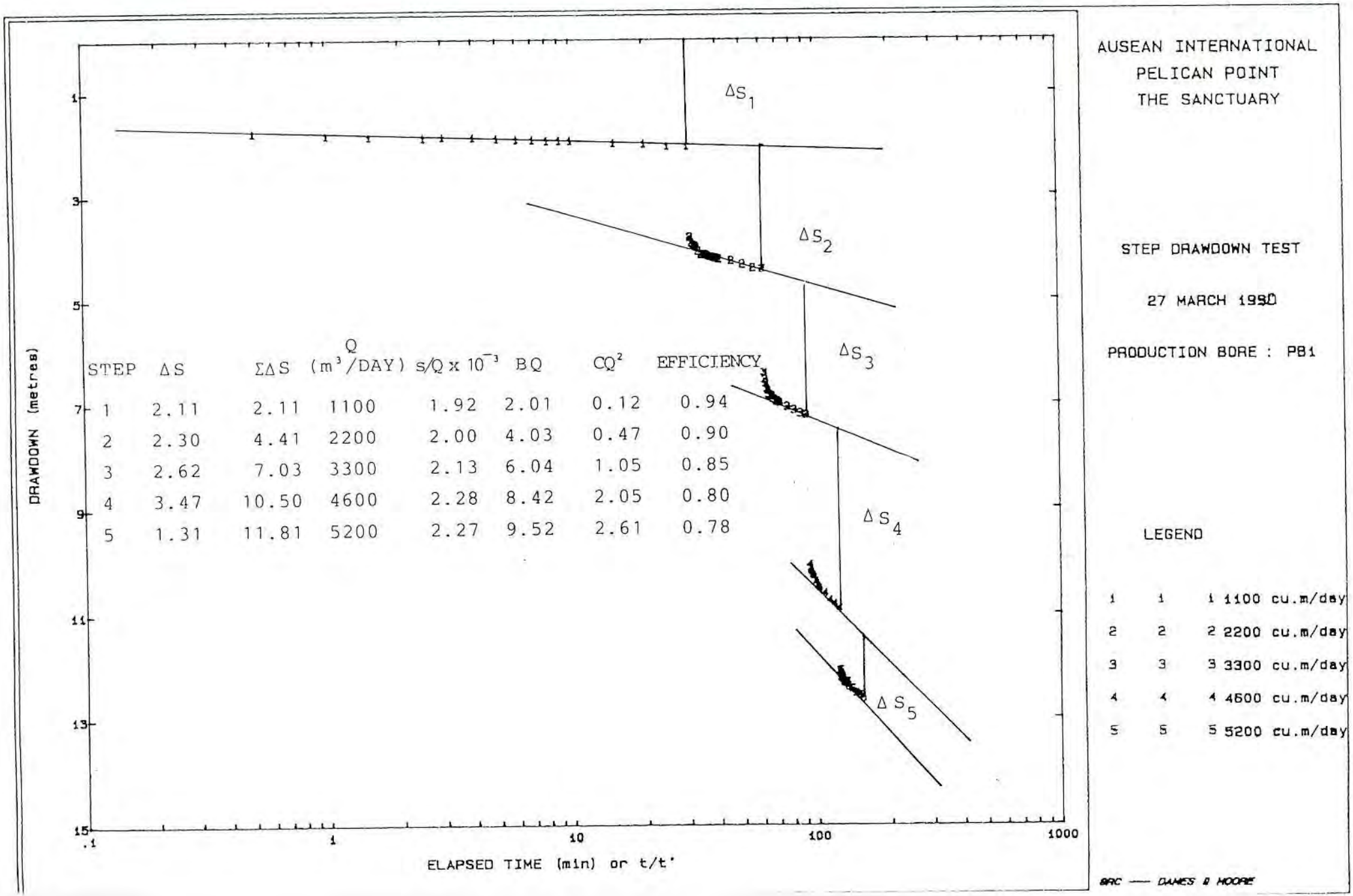
The Sanctuary Pelican Point
PUMPING TEST PROGRAMME - PB1

Testing Stage	Test Duration (mins)	Pumping Rate (m^3/day)	Drawdown at Completion of Stage (metres)
Step Test 1	30	1111	2.11
Step Test 2	30	2206	4.45
Step Test 3	30	3278	7.26
Step Test 4	30	4636	10.94
Step Test 5	30	5230	12.65
Constant Rate Test	1440	4496	12.34
Recovery Test	210	(4496)	1.20

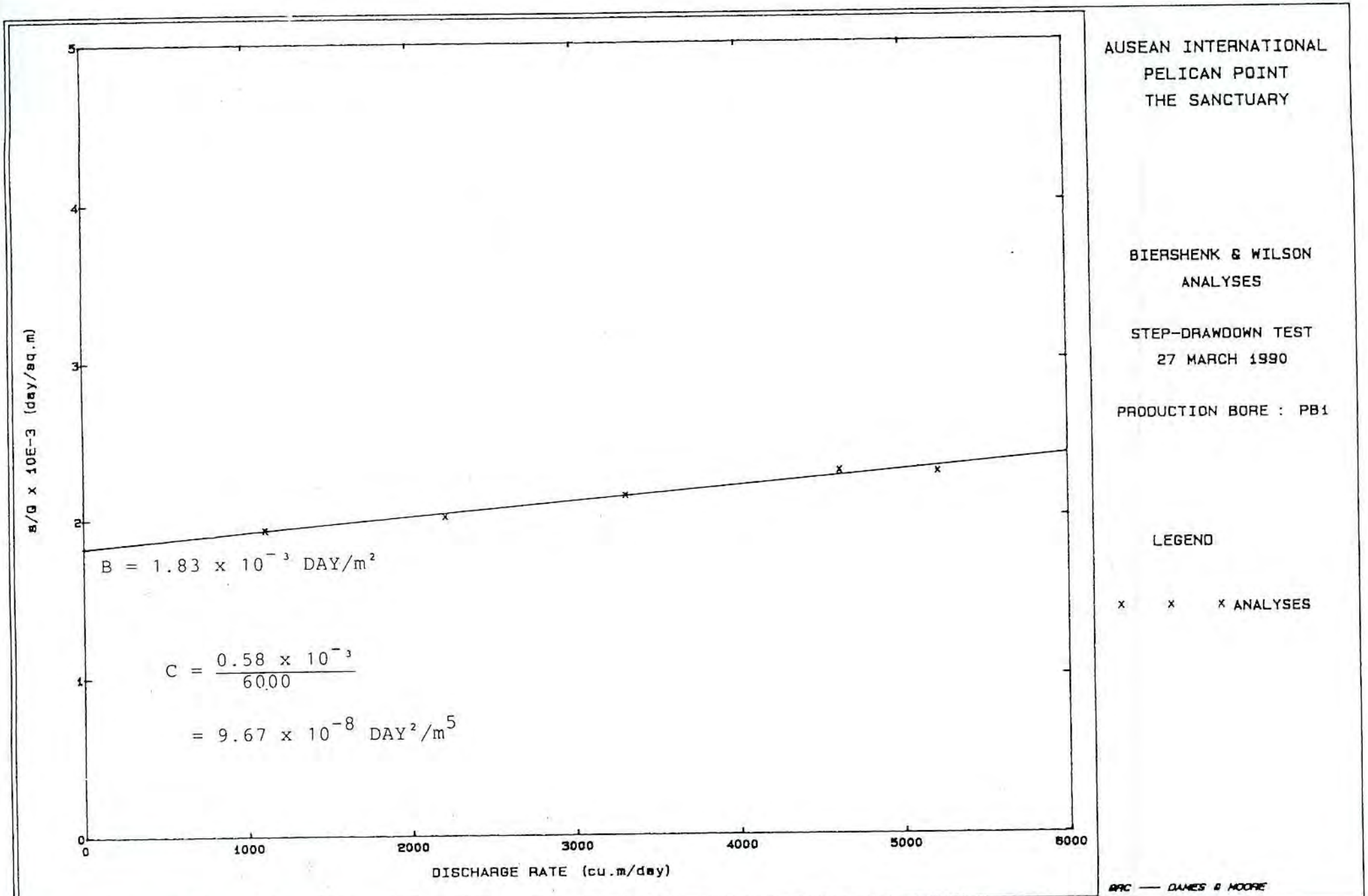
The bore had a pre-pumping closed hydraulic head 1.5 metres above ground level and was artesian at commencement of pumping. During pumping flow rates were controlled by use of a gate valve on the discharge pipes and pumping water levels, in the discharging bore only, were monitored by electric contact gauge. Pump setting was approximately 21.0 metres.

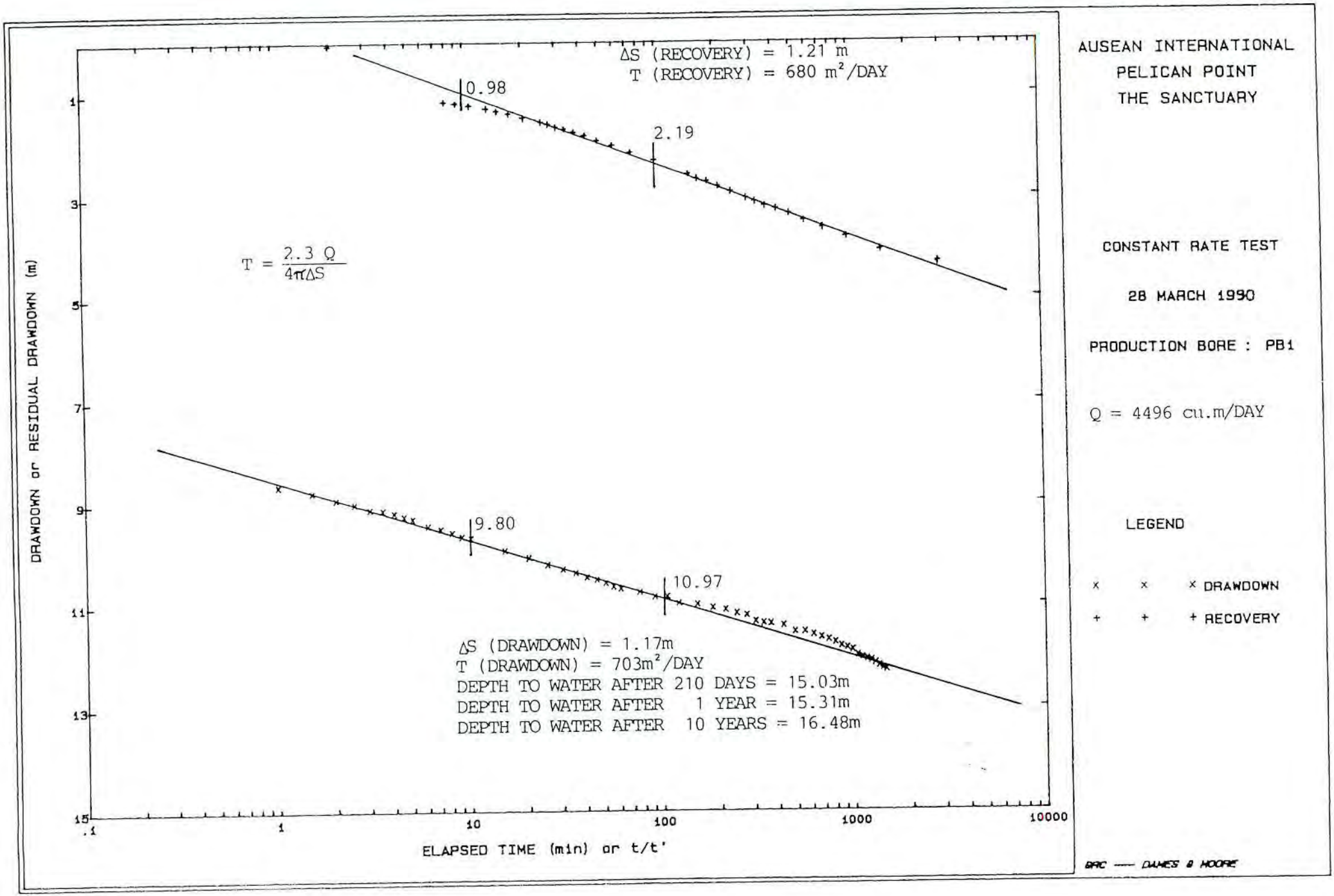
APPENDIX 2D

PLOTS OF PUMPING TEST ANALYSES



STEP	ΔS	ΣΔS	Q (m³/DAY)	s/Q x 10⁻³	BQ	CQ²	EFFICIENCY
1	2.11	2.11	1100	1.92	2.01	0.12	0.94
2	2.30	4.41	2200	2.00	4.03	0.47	0.90
3	2.62	7.03	3300	2.13	6.04	1.05	0.85
4	3.47	10.50	4600	2.28	8.42	2.05	0.80
5	1.31	11.81	5200	2.27	9.52	2.61	0.78


AUSEAN INTERNATIONAL
PELICAN POINT
THE SANCTUARY
BIERSHENK & WILSON
ANALYSES
STEP-DRAWDOWN TEST
27 MARCH 1990
PRODUCTION BORE : PB1
LEGEND
x x x ANALYSES
s/Q x 10E-3 (day/sq.m)
DISCHARGE RATE (cu.m/day)
0
1000
2000
3000
4000
5000
6000
1
2
3
4
5
B = 1.83 x 10⁻³ DAY/m²
C = 0.58 x 10⁻³ / 6000
= 9.67 x 10⁻⁸ DAY²/m⁵
BRC — DAMES & MOORE


ΔS (RECOVERY) = 1.21 m
T (RECOVERY) = 680 m²/DAY
0.98
2.19
T = 2.3 Q / 4πΔS
9.80
10.97
ΔS (DRAWDOWN) = 1.17m
T (DRAWDOWN) = 703m²/DAY
DEPTH TO WATER AFTER 210 DAYS = 15.03m
DEPTH TO WATER AFTER 1 YEAR = 15.31m
DEPTH TO WATER AFTER 10 YEARS = 16.48m
DRAWDOWN or RESIDUAL DRAWDOWN (m)
1
3
5
7
9
11
13
15
.1
1
10
100
1000
10000
ELAPSED TIME (min) or t/t'
AUSEAN INTERNATIONAL
PELICAN POINT
THE SANCTUARY
CONSTANT RATE TEST
28 MARCH 1990
PRODUCTION BORE : PB1
Q = 4496 cu.m/DAY
LEGEND
× × × DRAWDOWN
+ + + RECOVERY
BRC — DAMES & MOORE

APPENDIX 2E

RESULTS OF PUMPING TEST ANALYSES

STEP-DRAWDOWN TEST

CONSTANT RATE TEST

APPENDIX 2E

RESULTS OF PUMPING TEST ANALYSES

THE SANCTUARY PELICAN POINT

SUMMARY OF STEP-DRAWDOWN TEST ANALYSES
TEST PRODUCTION BORE PB1

Step	Pumping Rate (m^3/day)	Drawdown at End of Step (m)	Bore Efficiency (%)
1	111	2.11	94
2	2206	4.45	90
3	3278	7.26	85
4	4636	10.94	80
5	5230	12.65	78

The bore discharge equation derived from the Bierschenk and Wilson analysis is:

$$S_w = (1.83 \times 10^{-3})\, Q + (9.67 \times 10^{-8})Q^2$$

APPENDIX 2E

THE SANCTUARY PELICAN POINT

RESULTS OF CONSTANT-RATE TEST
TEST PRODUCTION BORE PB1

Pumping Rate (m^3/day)	4496
Drawdown after 1 minute of pumping (m)	6.94*
Drawdown at completion of pumping (m)	10.38*
Available drawdown (m)	171.8
Specific Capacity (t = 1 minute)(m^3/day/m)	667*
Specific Capacity (t = 1440 minutes)(m^3/day/m)	443*
Transmissivity	
Jacob Method (m^2/day)	703
Walton Method (m^2/day)	667
Theis Recovery Method (m^2/day)	680
Saturated Aquifer Thickness (Screen Interval)(m)	45.2
Hydraulic Conductivity (m/day)	14.7-15.6
Estimated Storage Coefficient (dimensionless)	8×10^{-4}

* Corrected for well losses

Pelican Point Pty Ltd

Pelican Point, Bunbury

Public Environmental Review

APPENDIX 6

REPORT ON A SURVEY OF ABORIGINAL SITES AT THE PROPOSED PELICAN POINT DEVELOPMENT, BUNBURY

LEC Ref: J186/R320

REPORT ON A SURVEY FOR ABORIGINAL SITES AT THE PROPOSED PELICAN POINT DEVELOPMENT, BUNBURY

Prepared for LeProvost Semeniuk and Chalmers

By R. O'Connor, G. Quartermaine and C. Bodney

June 1990

PART ONE

ETHNOGRAPHY

PART ONE : ETHNOGRAPHIC COMPONENT.

TABLE OF CONTENTS.

1.0 INTRODUCTION

1.1 Background

This report, which is based on a period of field research carried out in June, 1990, was commissioned by LeProvost, Semeniuk and Chalmer, Environmental Consultants. The aim of the research was to consult with Aboriginal people who retain traditional and current links with the Bunbury region, to ensure that the proposed development at Pelican Point between the Collie and Preston Rivers does not impact any areas of Aboriginal significance (See Figures One and Two for location of survey area). At the same time, and in recognition of the possible archaeological significance of the areas to be the impacted by the proposed development, an archaeological survey was conducted by Gary Quartermaine. Part Two of this report details the results of that survey.

1.2 Acknowledgements

The research was conducted by R. O'Connor and C. Bodney, who gratefully acknowledge the assistance and advice given by I. Bennell, G. Webb (Senior), N. Webb, W. Webb, B. Kahn, M. Harris, P. Blurton, T. Harris and G. Hill. The assistance of the Bunbury Progress Association is also acknowledged.

1.3 Research Brief

The research brief required the researchers to ascertain whether any areas of Aboriginal significance, within the meaning of Section 5 of the W.A. *Aboriginal Heritage Act*, 1972-1980, are located within the area of the proposed development. If such exist, they are to be reported in sufficient detail and in a format suitable for submission to the Western Australian Museum's Department of Aboriginal Sites, together with recommendations for their protection and management.

2.0 ABORIGINAL SITES IN SOUTH - WESTERN AUSTRALIA

2.1 Anthropological Considerations

The Aboriginal political geography of South-Western Australia has been described in O'Connor (1984 and 1985) and O'Connor and Quartermaine (1986 and 1987). The following summarised points are relevant to the present exercise.

2.1.1 South-Western Aborigines were a distinct sociocultural group in pre-contact times.

2.1.2 Dialectal variation occured within a single South-Western language family.

2.1.3 A regional system of land tenure, based on either kinship or dialectal units existed.

2.1.4 As contemporary accounts of these systems are internally inconsistent and sometimes contradictory, it is now impossible to reconstruct the pre-contact political geography of the region.

2.1.5 Territorial separateness disappeared soon after European settlement, due to population movements, deaths and the development of the fringe camps (and later settlements and "missions").

2.1.6 The development of a widely- scattered population of mixed -ethnic background, who live in the South-West of this State, see themselves as sharing a common identity and refer to themselves as "Nyungars" occurred during the nineteenth century.

2.1.7 Continuity with the traditional past, knowledge of regional mythology and knowledge of areas of religious significance were passed to the present senior adult generation of Nyungars by a pivotal generation of culture transmitters. Among these, in the Metropolitan Region were Maitland Sandy, Chitty Hedland, Daglish Granny, Sam Broomhall, Herbert Dyson, Bulyil, Wandi, Nyinda Bropho, Lottie Harris and Ollie Worrell; and in the Murray River region were George Windjan, who settled in Mandurah, and Kitty, who settled in Pinjarra. The two last-named were survivors of the Battle of Pinjarra.

2.1.8 There is now a determination among the present senior adult generation to protect remaining areas of significance from development.

2.2 "Significance"

"Significance", in the survey area is attributed by Aboriginal people on the basis of former or current domestic usage, or on the basis of relevance to traditional ritual or mythology. Broadly speaking, this distinction can be viewed as a series of dichotomies between historical and mythological, human and supernatural, or mundane and sacred areas. Thus, one area may be viewed as significant from a historical/human/mundane viewpoint, and another from a mythological/supernatural/sacred viewpoint.

As noted by O'Connor and Quartermaine (1989) in a recent report to the Water Authority of Western Australia (Aboriginal Site Survey of Proposed Jandakot Mound Borefield), a substantial number of Aboriginal sites are mentioned in Hammond (1933), Moore (1885), Bates (numerous dates) and other historical sources. Any sites not known to contemporary Aborigines cannot reasonably be classified as "sites of significance to living Aborigines." However, rediscovery or realization of the existence of such sites, could lead to an attribution of significance. The history of Western Australian Museum (archaeological) site number S0999 is a clear example of this : in that case, a 40,000 year old archaeological site, which was discovered by chance, has become an area of importance and significance to Aboriginal people from the Swan Valley (see Pearce and Barbetti [1981] for a description of this site). Therefore, the neat compartmentalization resulting from European academic disciplines may not fit absolutely the Aboriginal models; any archaeological or historical site in the survey region could also be potentially significant to Aboriginal people.

2.3 Regional Framework

Waugal (also Wagal, Wagyl or Uocol) is the Dreaming Ancestor who, according to local tradition, created the Swan, Canning, Murray and Serpentine River systems, and retains a presence in some of the deep pools in the area. Waugal beliefs, widespread throughout the south-west, refer to a water-creative spiritual force with a serpentine physical manifestation. In some cases, the Waugal is seen as ubiquitous (described by one person as "a bit like God", i.e. the Christian Deity) or, at least, multi locational; in others, as purely local and associated with a particular creek or spring. This religious philosophy is not unique to the south-west; Maddock (1982:114-115) describes a similar system in Arnhem Land.

Apart from Waugal beliefs, however, a number of other myths, fragments of which have continued to the present day, are associated with the coastal plain and its hinterland (see, for example, O'Connor, *et al*, 1985). Under the mythological/ supernatural/ sacred rubric could also be grouped rainmaking sites, which generally occurred in relationship with Waugal sites, and ritual grounds (colloquially known as "corroboree grounds"), generally located in proximity to large camping areas.

3.0 THE SURVEY

3.1 Methodology

Four separate phases were involved in the survey;

(i) examination of the existing ethnographic data base;

(ii) consultation and discussions with relevant Aboriginal persons and organizationions (see Section 1.2);

(iii) site visit in company of Aboriginal spokespersons;

(iv) report preparation.

3.2 Previously Recorded Sites

No sites of significance to living Aboriginal people have been recorded previously within the area to be impacted by the proposed development.

3.3 Newly Recorded Sites

The conclusion reached as a result of the survey is that no sites of significance to Aboriginal people will be affected by the proposed development.

4.0 RECOMMENDATIONS

Human intereference with Aboriginal sites in Western Australia is an offence under the Aboriginal Heritage Act, unless authorised as outlined in Section 17 of that Act.

As no Aboriginal sites were recorded in the course of the survey, no recommendations are incorporated into this report.

5.0 REFERENCES

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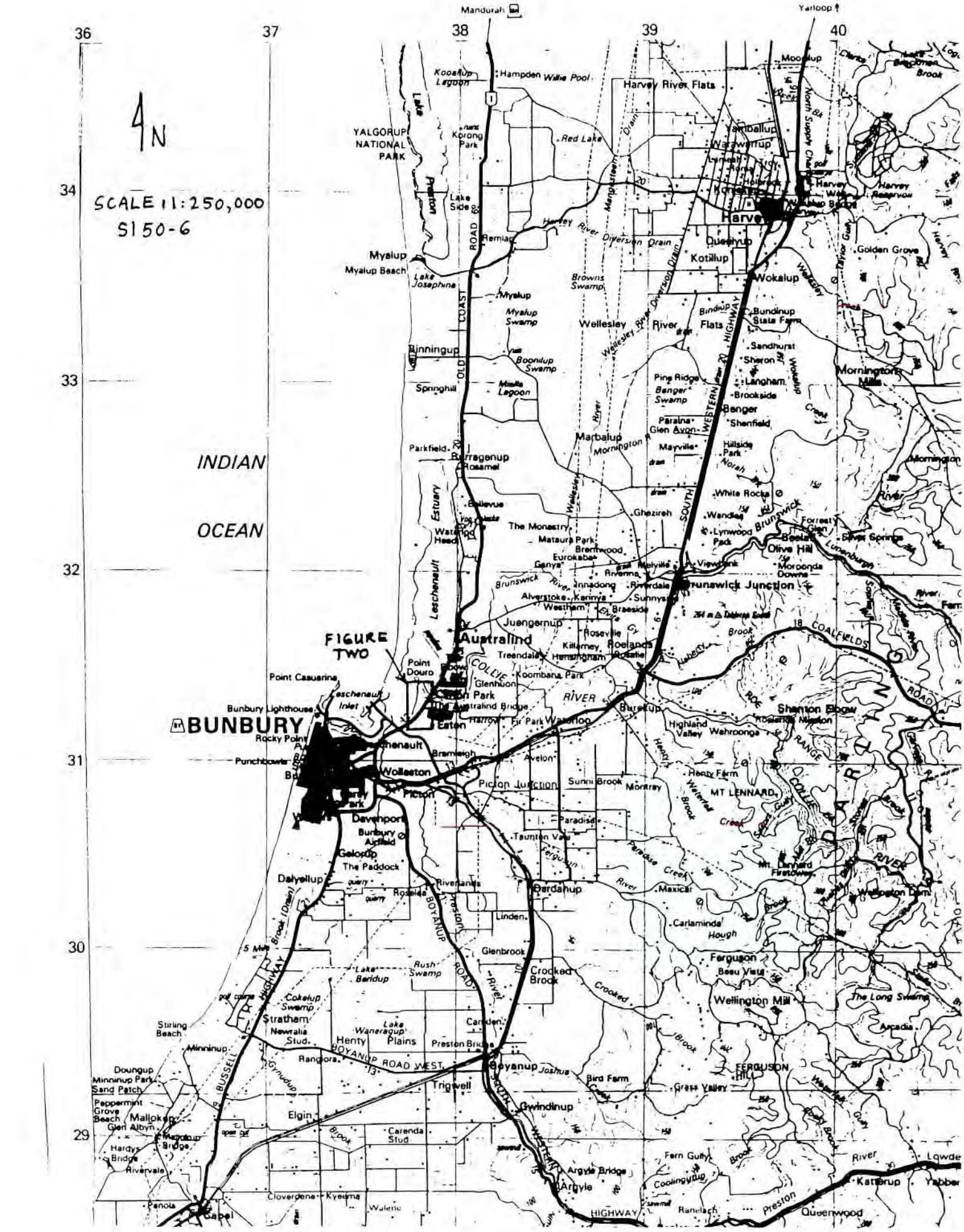
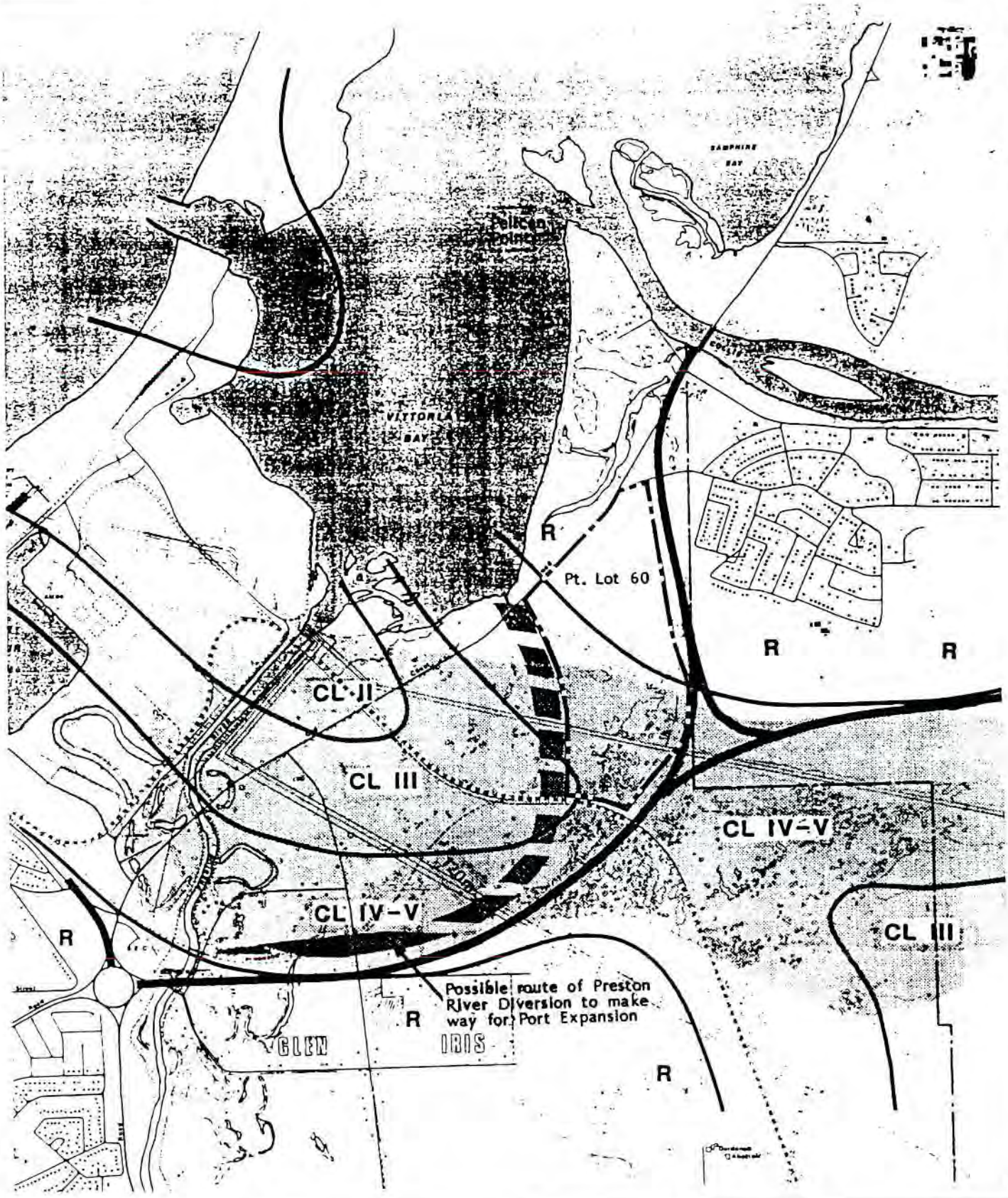


FIGURE 1 : Location of Proposed Development



BUNBURY REGION PLAN
RIGDEN LINES
Extract re Pelican Point and Pt. Lot 60 (ILDA)

N

SCALE 1:25 000

RUSSELL TAYLOR and WILLIAM BURRELL

LEGEND

R	EXISTING AND FUTURE RESIDENTIAL
CL IV-V	LIGHT INDUSTRY BUFFER ZONE CLASSES IV&V
CL III	MEDIUM INDUSTRY CLASS III
CL II	HEAVY INDUSTRY CLASS II
CL I	HEAVY INDUSTRY CLASS I
	AREA FROM WHICH DUSTY INDUSTRY SHOULD BE EXCLUDED
— — —	SUBJECT LAND
-------	RAILWAY LINE

FIGURE 2

PART TWO

ARCHAEOLOGY

PART TWO

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background to Survey

An Aboriginal site survey of a proposed development at Bunbury was commissioned by LeProvost Semeniuk and Chalmer and executed in May 1990. Gary Quartermaine conducted the archaeological survey with Caroline Heine as field and research assistant. Rory O'Connor conducted an ethnographic survey at the same time.

The objectives of the archaeological survey were as follows:

1. The assembly of data from previous work in the region, including information from W.A. Museum Aboriginal site files, previous survey reports, maps and environmental data.

2. A sample survey of the proposed development area.

3. The location and recording of archaeological sites within the designated survey area.

1.2 Location

The proposed development of a housind estate and golf resort involves around 1.25 square kilometres of land at Pelican Point, Bunbury. It has maximum dimensions of 2.78 kilometres NS by 0.74 kilometres EW. It is situated between the Collie and Preston Rivers on low lying land overlooking Vittoria Bay. It is bounded on the east side by the Old Coast Road and the Australind Bypass, on the south by the railway line, on the west by the proposed Preston River diversion channel, and in the north and west by the bay (see Figures 1 and 2 for location).

1.3 Environment

The climate of the project area is dry Mediterranean characterised by winter rainfall and a dry summer. The average annual rainfall in Bunbury is 855 mm (Beard, 1981). Mean monthly temperatures range from a minimum of 8 degrees Celsius in June to maximum of 28 degrees Celsius in February (Beard, 1979:26).

The project area is part of the Perth Basin geological unit. This is a deep trough filled with Phanerozoic sedimentary rocks with a surface mantle of Quaternary deposits (Playford, et al, 1975).

The survey area is situated on the Bassendean Dunes landform. this is an undulating sandy plain with low, vegetated hills of quartz sand with numerous interdunal swamps and lakes. Chief soils are leached sands.

The vegetation on the Bassendean Dunes is dominated by Banksia low woodland consisting of *Banksia attenuata, B. ilicifolia, B. menziesii, Casuarina fraserana* and *Nuytsia floribunda*. It has a rich understory of sclerophyll shrubs and scattered trees of *Eucalyptus marginata* (jarrah) are generally present. Numerous teatree and paperbark (*Melaleuca rhaphiophylla*) occur on freshwater swamps between the dunes.

The survey area has been greatly disturbed in many parts as a result of clearance for agriculture, housing, roads, drains and quarries, with only limited areas of undisturbed land.

1.4 Previous Archaeological Research

The earliest evidence for prehistoric occupation of the South-West of Australia is dated at 38,000 years ago, for a stratified site at Upper Swan, located 25 km northeast of Perth (Pearce and Barbetti, 1981). Two other sites in the south-west have also yielded Pleistocene dates, Devil's Lair and Helena River. A number of Holocene sequences have yielded data on possible cultural/environmental changes during, and after, the recent transgression of the sea, for the metropolitan region (see Clarke and Dortch, 1977; Hallam, 1974; and Pearce, 1978). This work postulates increased populations on the Coastal Plain, rising to a peak just before European contact.

Devil's Lair, a cave site in aeolian limestone 20km north of Cape Leeuwin in the Leeuwin-Naturalist Block, has yielded Pleistocene dates in the order of 30,000 years ago. A date of 31,400+/-15,000 years ago has been obtained for a sample taken from above two occupation features and artefact assemblages. The upper-most level that is believed to contain *in situ* archaeological material has a date of 6,490+/-145 years ago. Archaeological assemblages from this site contain a variety of mammal, bird and reptile species, mussel and emu shell, a number of different stone artefacts and a range of diverse bone tools. Some of the stone tools have a dark staining that may indicate hafting with gum (Dortch and Merrilees, 1973; and Dortch, 1977).

As part of a regional survey of the Metropolitan area, Hallam (1986:5) concludes that the majority of sites lie around the lakes and swamps of the Swan Coastal Plain, and that site numbers double in the last few hundred years. Four phases of occupation are suggested for the Coastal Plain. These are:

a. Early - low number of sites centred towards coast. Artefacts include steep scrapers on flakes and scrapers made from an Eocene fossiliferous chert. This phase was up to 5000 years ago.

b. Middle - from 5000 - 500 years ago. Showed a contraction of occupation to sites near permanent water. Artefacts were made on quartz and green chert and included backed blades, adzes, scrapers and flakes.

c. Late - from 500 years ago. Concentration of sites on the Coastal Plain. Fabricators (bipolar cores) were introduced and a large percentage of assemblages were made up of quartz flakes, chips and debitage (Hallam, 1973,1974 and 1986).

d. Final - post European contact and settlement. Use of introduced materials, such as glass, pottery and clay pipes, for the manufacture of artefacts.

Prehistoric stone tool industries in the South-West have been classified into earlier and later phases (Dortch, 1977). The early phase industries have only been documented from a few well-dated sites. They include small thick flake scrapers, bipolar cores, notched-denticulated pieces, flakes from discoidal cores, and single and multi-platform cores. These artefacts have been manufactured from a range of lithic materials, including a distinctive Eocene fossiliferous chert. It appears that access to this chert was lost after the last marine transgression (Dortch, 1977; and Glover, 1975).

Later phase stone industries, generally found in archaeological contexts dating from 4,000 years ago, include the addition of geometric microliths, backed blades, and a variety of adze flakes, which are part of the Australian "small tool tradition" (Dortch, 1977; and Mulvaney, 1975).

Anderson (1984) has proposed a land-use model for prehistoric exploitation of the Swan Coastal Plain, and its hinterland, based on regional research into the relative proportions of variously sized surface artefact scatters and their associated artefact densities. This model suggests that, due to the variation in resources available in the three different environmental zones investigated, there was more intensive use of the coastal plain than either the adjacent forest or open woodland plateau.

The seasonal movement of Aboriginal groups relates to the exploitation of the various resources available in the different environmental situations.

Hallam (1986) concludes that Aborigines congregated around the estuaries and lagoons of the coastal plain in the summer and dispersed, in small groups, in winter through a wider hinterland which included the area of the Darling Scarp and Plateau.

Bunbury (Bunbury and Morrell, 1930:79), while in the vicinity of the Leschenault Estuary, met a large party of Aborigines in the northern part and another party of 100-200 men and boys further south.

As a result of previous surveys and independent research, eleven archaeological sites have been recorded and registered with the W.A. Museum within 5 kms of the proposed development. These sites are all artefact scatters, with one including a burial (S0832) (see Table 1).

Of these sites, S1740, S1742, S1743 and S1744 are within the proposed development area. As well, two sites are just outside the survey area. These are S1741 and S1952. These sites were recorded as a result of a W.A. Museum survey in 1978 and a M.R.D. survey (Brown, 1984).

S1740 is described as an artefact scatter covering 500 x 300 metres in a sand-pit. One chert flake and quartz flakes, cores (some bipolar), scrapers and chips were recorded. An estimate of artefact numbers is between 10 and 100.

S1742 is a scatter of 12 quartz flakes immediately north of the railway line. It is situated in yellow sand on the north bank of the railway cutting.

S1743 is an artefact scatter of six quartz flakes in a yellow sand area near a dam.

S1744 is an artefact scatter of 10 quartz flakes and one core in a grey sand patch in an open paddock.

S1741 and S1952 are both quartz artefact scatters of 10 or less pieces on the east side of the Old Coast Road. Information is from W.A. Museum Aboriginal site files.

TABLE ONE : PREVIOUSLY RECORDED ARCHAEOLOGICAL SITES

WA Museum Site No.	1:250,000 Grid Ref.	Site Type	Site Name
	S1 50-6		
S1745	366.879	Artefacts	Bunbury 6
S0832	367.879	Artefacts/burial	Moorland, Bunbury
S1953	367.881	Artefacts	Australind Bypass Road 2
S1754	368.879	Artefacts	Bunbury 21
S1755	368.879	Artefacts	Bunbury 22
S1742	368.881	Artefacts	Bunbury 3
S1743	368.881	Artefacts	Bunbury 4
S1740	368.882	Artefacts	Bunbury 1
S1741	368.882	Artefacts	Bunbury 2
S1744	368.882	Artefacts	Bunbury 5
S1952	369.883	Artefacts	Australind Bypass Road 1

2.0 METHODS

2.1 Obligations under the Act

The Western Australian *Aboriginal Heritage Act*, 1972-1980, makes provision for the recording and preservation of places and objects customarily used by, or traditional to, the original settlers of Australia. The Act defines the obligations of the community relating to sites (Sections 15-18).

The archaeological survey should identify the effects of the proposed disturbance of the physical environment on any Aboriginal archaeological sites. In recognition of the significance of this area to living Aboriginal people, an investigation of Aboriginal interests was conducted by Rory O'Connor.

The consultant is obliged to submit site documentation for any newly recorded sites on appropriate forms for registration with the W.A. Museum.

2.2 Survey Design

The survey design involved the following stages of operation.

i) Background research - this involved familiarisation with W.A. Museum site files, survey reports, plus maps and environmental information for the area to be surveyed. Previously recorded Aboriginal sites, registered with the W.A. Museum, are listed in Table 1.

ii) Survey strategy - this consisted of a systematic survey of the proposed development.

The field survey was completed using 1:20,000, 1:100,000 and 1:250,000 topographic maps of the area plus plans of the development.

A 4WD vehicle was used to drive around the perimeter of the survey area and along the various tracks within the survey area. Inspections were then made on foot at regular intervals of 100 metres. Any clear areas or potential site locations were also inspected. This enabled a field inspection of at least 50% of the survey area.

The field survey was completed on foot in a series of EW and NS transects from the various tracks in the area. These transects were spaced at 100 metre intervals using maps and a compass which provided an adequate degree of accuracy for the purpose of this survey. Likely site locations in the remaining survey area were inspected.

Access was possible to all parts of the survey area by 4WD vehicle and on foot. Surface visibility varied depending on the grass cover but was reasonable. Disturbance was from farming and leisure activities, such as tree clearance, dams, tracks and firebreaks.

2.3 Site Definitions

Aboriginal material culture is based, to a large extent, on non-durable materials, such as wood, bark, fibre and skins, that have a limited life in the archaeological record. Stone tools, conversely, remain as often the only evidence of prehistoric activity. Bone, either as a tool, as refuse, or as a burial, falls somewhere between these extremes. Lofgren (1975:7) describes spears, spear-throwers and clubs for men, and digging sticks, wooden carrying dishes and grindstones for women, as the basic implements of Aboriginal life.

Therefore, stone artefact sites reflect only one aspect of Aboriginal material culture which utilised a wide range of materials from the natural environment.

For the purpose of this survey, a site was defined as any material evidence of prehistoric Aboriginal activity. This is manifested in a number of different site components which may occur singularly or with one or more of the others to form an archaeological site. The most common of these are surface artefact scatters, quarries, art sites, stone arrangements, rockshelters with evidence of occupation, grinding patches, burials, and marked trees. An artefact scatter will be recorded as a site if it contains two or more artefacts in association. Solitary artefacts will be recorded as Isolated Finds but will not be registered as sites.

As samples will not be collected in the field, it is important to standardise a recording format that will be of use for analysis and have relevance for other researchers. Categories under which site data will be recorded are as follows:

i) Site dimensions - extent and type:

ii) Artefact assemblage - number, type, lithic material, and dimensions of artefact;

iii) Environmental setting - vegetation, soil, drainage and proximity to water, surface visibility and disturbance.

iv) Stratigraphy - assessment of potential.

Site significance, in this report, is based on recognising that a body of archaeological data can answer regional research questions, as well as those concerning a particular sites attributes. Sites have been placed in the following catagories on the basis of uniqueness/representativeness, capacity to provide further scientific information, particularly potential stratified deposits, and need for protection because of danger of disturbance.

(a) High - important sites that could be preserved;
(b) High-Moderate - sites from which more information may be obtained by collection or excavation but which do not rate preservation if application for site disturbance is made for them;
(c) Low-Moderate - similar to above but less follow-up required;
(d) Low - sites with limited potential to yield further archaeological information.

3.0 RESULTS

Two newly recorded sites and four previously recorded archaeological sites are in the proposed development area. They are all quartz artefact scatters. Details are as follows. See also Table 2 and Appendix 3.

Field Site 1

1:250,000 Map Ref. S150-6 368.883

Description: This site is a small, low density quartz surface artefacts scatter. It is situated between Vittoria Bay and Estuary Road, 100 metres from the road, in a sandy depression. A sparse vegetation of grass and paperbarks is present.

The site dimensions are 15 by 15 metres. Details of the quartz artefacts are as follows:

2 flakes - 17 x 19, 15 x 13 mm;
3 chips.

This was the total visible surface assemblage although there is some potential for sub-surface archaeological material to be present.

Discussion : This site is considered to be of low importance because because it is small and contains few artefacts. It is similar to several other sites in this area.

Field Site 2

1:250,000 Map Ref. S150-6 368.883

Description : This site is a small, low density quartz artefact scatter situated near a well 200 metres SSW of the first site. The environment is similar. It is 30 metres from Estuary Drive.

The total visible artefact assemblage encompassed an area of 10 by 10 metres. There is some potential for the presence of sub-surface archaeological material. The seven artefacts recorded were all quartz chips.

Discussion : This site is also of low importance for similar reasons to Field Site 1.

Previously Recorded Sites

The locations of S1740, S1742, S1743 and S1743 were inspected during the course of the field survey. Seven quartz flakes were noted at S1740 but no archaeological material was found at the other three sites. Since there were only a few artefacts originally recorded at these sites, it is probable that they have been covered by moving sand or trodden into the sand by human and animal activity. There is no indication that collections were made during the original recording.

These sites are all considered to be of low importance for similar reasons to Field Site 1.

4.0 CONCLUSIONS

4.1 Discussion

The proposed development of a housing estate and golf resort involves around 1.25 square kilometres of land at Pelican Point, Bunbury. It has maximum dimensions of 2.78 kilometres NS by 0.74 kilometres EW. It is situated between the Collie and Preston Rivers on low lying land overlooking Vittoria Bay. It is bounded on the east side by the Old Coast Road and the Australind Bypass, on the south by the railway line, on the west by the proposed Preston River diversion channel, and in the north and west by the bay.

The archaeological survey involved an investigation of previous research in the area, a systematic field survey of the project area, and the recording of any archaeological material located.

Four previously recorded archaeological sites are within the survey area. As a result of the field survey, two more archaeological sites were located. These six sites are all low density quartz artefact scatters of low importance. All have some stratigraphic potential. All the recorded sites are at risk of disturbance from the proposed development. However, no further archaeological investigation is warranted.

Access was possible to all parts of the survey area. Visibility was not very good in some parts because of surface vegetation cover. However, this survey provided a sufficient sample.

The most likely site locations, water courses and swamp margins, were present in the survey area. Each of these locations was checked during the survey.

4.2 Recommendations

The recommendations which follow are based on field observations and investigations of previously recorded sites in area.

1. S740, S1742, S1743, S1744, Field Site 1 and Field Site 2 are all small surface artefact scatters in disturbed locations. They are of low archaeological significance and no further archaeological work is recommended at any of these sites.

2. Should any of these sites need to be disturbed, permission is required under Section 18 of the W.A. *Aboriginal Heritage Act*, 1972 - 1980. This is obtained by written application by the owner of the land to the Trustees of the W.A. Museum for permission to use the land under Section 18 of the Act.

3. It is pointed out that human interference to Aboriginal sites is an offence, unless authorised under the Act, as outlined in Section 17 of the W.A. *Aboriginal Heritage Act*, 1972 - 1980. Therefore, it is recommended that the Developers take adequate measures to inform any project personnel of this requirement.

Acknowledgements

The information and assistance provided by Caroline Heine, Silvia Waldmeier, R. Hunziker and Liz Bloor is gratefully acknowledged.

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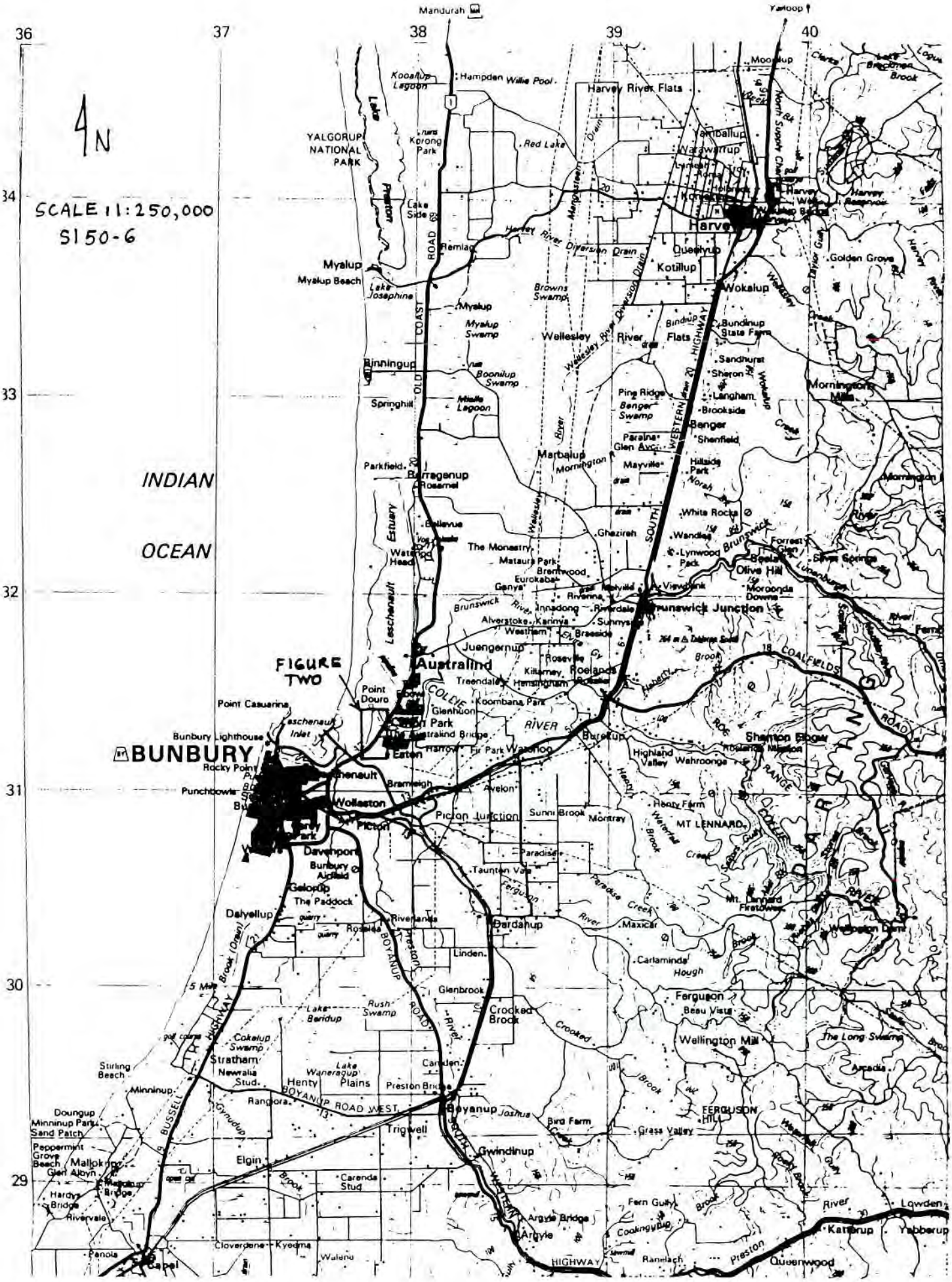
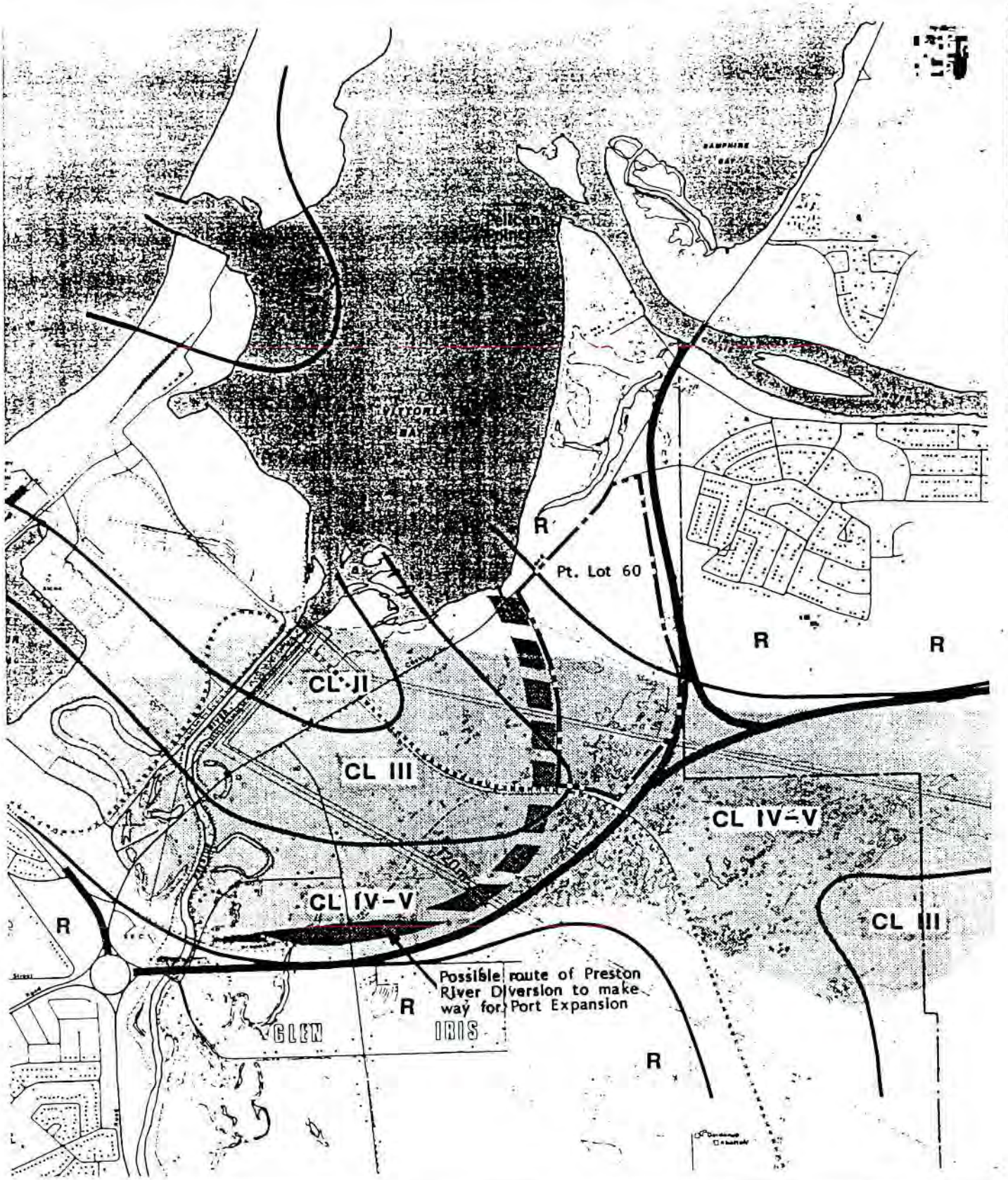


FIGURE 1 : Location of Proposed Development



BUNBURY REGION PLAN
RIGDEN LINES
Extract re Pelican Point and Pt. Lot 60 (ILDA)

N

SCALE 1:25 000

LEGEND

R	EXISTING AND FUTURE RESIDENTIAL
CL IV-V	LIGHT INDUSTRY BUFFER ZONE CLASSES IV&V
CL III	MEDIUM INDUSTRY CLASS III
CL II	HEAVY INDUSTRY CLASS II
CL I	HEAVY INDUSTRY CLASS I
	AREA FROM WHICH DUSTY INDUSTRY SHOULD BE EXCLUDED
— - —	SUBJECT LAND
------	RAILWAY LINE

FIGURE 2

FIGURE 3 : Location of Previously Recorded Archaeological Sites

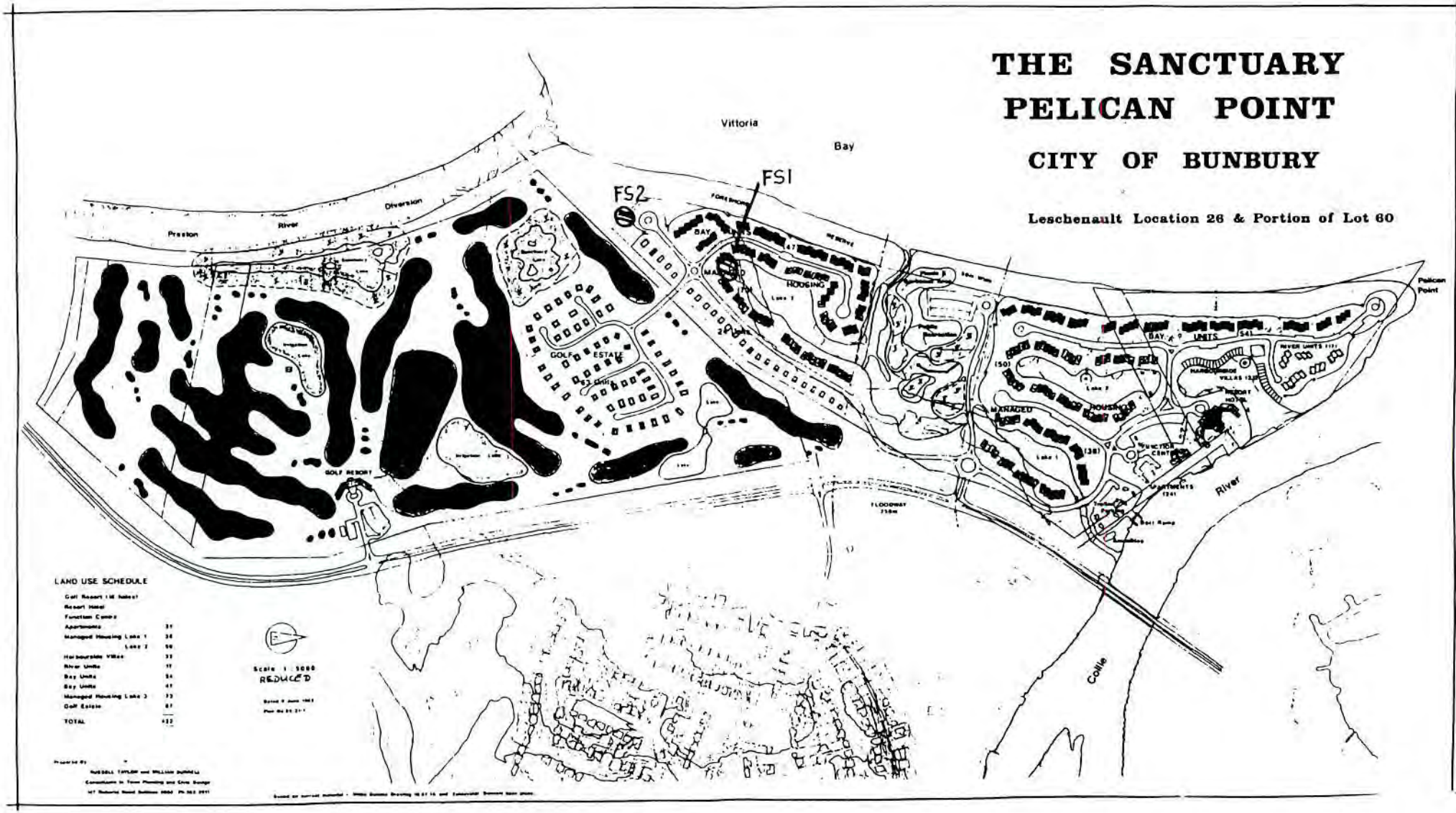


FIGURE 4 : Location of Newly Recorded Archaeological Sites

TABLE TWO : Details of Archaeological Sites in Survey Area

SITE NO.	1:250,000 MAP REF. SI50-6	SITE TYPE	DIMENSIONS (metres)	NO. OF ARTEFACTS	LANDFORM
S1740	368.882	Artefacts	500x300	10-100	Sand-pit
S1742	368.881	Artefacts	-	12	Railway cutting
S1743	368.881	Artefacts	-	6	Dam
S1744	368.882	Artefacts	-	11	Sand patch
FS 1	368.883	Artefacts	10 x 20	5	Sand patch
FS 2	368.883	Artefacts	5 x 5	7	Sand patch

APPENDICES

APPENDIX 1

OBLIGATIONS RELATING TO SITES UNDER THE ABORIGINAL HERITAGE ACT, 1972-1980

Report of Findings

"15. Any person who has knowledge of the existance of anything in the nature of Aboriginal burial grounds, symbols or objects of sacred, ritual of ceremonial significance, cave or rock paintings or engravings, stone structures or arranged stones, carved trees, or of any other place or thing to which this Act applies or to which this Act might reasonably be suspected to apply shall report its existance to the Trustees, or to a police officer, unless he has reasonable cause to believe the existance of the thing or place in question to be already known to the Trustees."

Excavation of Aboriginal Sites

"16. (1) Subject to Section 18, the right to excavate or to remove any thing from an Aboriginal site is reserved to the Trustees.

(2) The Trustees may authorise the entry upon and excavating of an Aboriginal site and the and the examination or removal of any thing on or under the site in such manner and subject to such conditions as they may direct."

Offences Relating to Aboriginal Sites

"17. A person who-

(a) Excavates, destroys, damages, conceals or in any way alters any Aboriginal site; or

(b) In any way alters, damages, removes, destroys, conceals, or who deals with in a manner not sanctioned by relevant custom, or assumes the possession, custody or control of, any object on or under an Aboriginal site, commits an offence unless he is acting with the authorisation of the Trustees under Section 16 or the consent of the Minister under Section 18."

Consent to Certain Uses

"18. (1) For the purposes of this section, the expression "the owner of any land" includes a lessee from the Crown, and the holder of any mining tenement or mining privilege, or of any right or privilege under the Petroleum Act, 1967, in relation to the land.

(2) Where the owner of any land gives to the Trustees notice in writing that he requires to use the land for a purpose which, unless the Minister gives his consent in this Section, would be likely to result in a breach of Section 17 in respect of any Aboriginal site that might be on the land, the Trustees shall, as soon as they are reasonably able, form an opinion as to whether there is any Aboriginal site on the land, evaluate the importance and significance of any such site, and submit the notice to the Minister together with their recommendations in writing as to whether or not the Minister should consent to the use of the land for that purpose, and, where applicable, the extent to which and the conditions upon which his consent should be given.

(3) When the Trustees submit a notice to the Minister under subsection (2) of this section he shall consider their recommendation and having regard to the general interest of the community shall either -

(a) Consent to the use of the land the subject of the notice, or a specified part of the land, for the purpose required, subject to such conditions, if any, as he may specify;

or

(b) Wholly decline to consent to the use of the land the subject of the notice for the purpose required,

and shall forthwith inform the owner in writing of his decision.

(4) Where the owner of any land has given to the Trustees notice pursuant to the subsection (2) of this section and the Trustees have not submitted it with their recommendation to the Minister in accordance with that subsection the Minister may require the Trustees to do so within a specified time, or may require the Trustees to take such other action as the Minister considers necessary in order to expedite the matter, and the Trustees shall comply with any such requirement.

(5) Where the owner of any land is aggrieved by a decision of the Minister made under subsection (3) of this section he may, within the time and in the manner prescribed by the rules of court, appeal from the decision of the Minister to the Supreme Court which may hear and determine an appeal.

(6) In determining an appeal under subsection (5) of this section the Judge hearing the appeal may confirm or vary the decision of the Minister against which the appeal has been made or quash the decision of the Minister, and may make such order as to the costs of the appeal as he sees fit.

(7) Where the owner of the any land gives notice to the Trustees under subsection (2) of this section, the Trustees may if they are satisfied that it is practicable to do so, direct the removal of any object to which this Act applies from the land to a place of safe custody.

(8) Where consent has been given under this section to a person to use any land for a particular purpose nothing done by or on behalf of that person pursuant to, and in accordance with any conditions attached to, the consent constitute an offence against the Act."

APPENDIX 2

Notes on the Recognition of Aboriginal Sites

There are various types of Aboriginal Sites, and these notes have been prepared as a guide to the recognition of those types likely to be located in the survey area.

An Aboriginal Site is defined in the Aboriginal Heritage Act, 1972-1980, in Section 5 as:

"(a) Any place of importance and significance where persons of Aboriginal descent have, or appear to have, left any object, natural or artificial, used for, or made for or adapted for use for, any purpose connected with the traditional cultural life of the Aboriginal people, past or present;

(b) Any sacred, ritual or ceremonial site, which is of importance and special significance to persons of Aboriginal descent;

(c) Any place which, in the opinion of the Trustees is or was associated with the Aboriginal people and which is of historical, anthropological, archaeological or ethnographical interest and should be preserved because of its importance and significance to the cultural heritage of the state;

(d) Any place where objects to this Act applies are traditionally stored, or to which, under the provisions of this Act, such objects have been taken or removed."

Habitation Sites

These are commonly found throughout Western Australia and usually contain evidence of tool-making, seed grinding and other food processing, cooking, painting, engraving or numerous other activities. The archaeological evidence for some of these activities is discussed in details under the appropriate heading below.

Habitation sites are usually found near an existing or former water source such as a gnamma hole, rock pool, spring or soak. They are generally in the open, but they sometimes occur in shallow rock shelters or caves. It is particularly important that none of these sites be disturbed as the stratified deposits which may be found at such sites can yield valuable information about the inhabitants when excavated by archaeologists.

Seed Grinding

Polished or smoothed areas are sometimes noticed on/near horizontal rock surfaces. The smooth areas are usually 25cm wide and 40 or 50cm long. They are the result of seed grinding by the Aboriginal women and indicate aspects of past economy.

Habitation Structures

Aboriginal people sheltered in simple ephemeral structures, generally made of branches and sometimes of grass. These sites are rarely preserved for more than one occupation period. Occasionally rocks were pushed aside or used to stabilise other building materials. When these rocks patterns are located they provide evidence for former habitation sites.

Middens

When a localised source of shellfish and other foods has been exploited from a favoured camping place, the accumulated ashes, hearth stones, shells, bones and other refuse can form mounds at times several metres high and many metres in diameter. Occasionally these refuse mounds or middens contain stone, shell or bone tools. These are most common near the coast, but examples on inland lake and river banks are not unknown.

Stone Artefact Factory Sites

Pieces of rock from which artefacts could be made were often carried to camp sites or other places for final production. Such sites are usually easily recognisable because the manufacturing process produces quantities of flakes and waste material which are clearly out of context when compared with the surrounding rocks. All rocks found on the sandy coastal plain , for example, must have been transported by human agencies. These sites are widely distributed throughout the State.

Quarries

When outcrops of rock suitable for the manufacture of stone tools were quarried by the Aborigines, evidence of the flaking and chipping of the source material can usually be seen in situ and nearby. Ochre and other mineral pigments used in painting rock surfaces, artefacts and in body decoration are mined from naturally occurring seams, bands and other deposits. This activity can sometimes be recognised by the presence of wooden digging sticks or the marks made by these implements.

Marked Trees

Occasionally trees are located that have designs in the bark which have been incised by Aborigines. Toeholds, to assist the climber, were sometimes cut into the bark and sapwood of trees in the hollow limbs of which possums and other arboreal animals sheltered. Some tree trunks bear scars where section of bark or wood have been removed and which would have been used to make dishes, shield, spearthrowers and other wooden artefacts. In some parts of the state wooden platforms were built in trees to accommodate a corpse during complex rituals following death.

Burials

In the north of the state it was formerly the custom to place the bones of the dead on a ledge in a cave after certain rituals were completed. The bones were wrapped in sheets of bark and the skull placed beside this. In other parts of Western Australia the dead were buried, the burial position varying according to the customs of the particular area and time. Natural erosion, or mechanical earthmoving equipment occasionally exposes these burial sites.

Stone Structures

If one or more stone are found partly buried or wedged into a position which is not likely to be the result of natural forces, then it is probable that the place is an Aboriginal site and that possibly there are other important sites nearby. There are several different types of stone arrangements ranging simple cairns or piles of stones to more elaborate designs. Low weirs which detain fish when tides fall are found in coastal ares. Some rivers contain similar structures that trap fish against the current. It seems likely that low stone slab structures in the south west jarrah forests were built to provide suitable environments in which to trap some small animals. Low walls or pits were sometimes made to provide a hide or shelter for a hunter.

Elongated rock fragments are occasionally erected as a sign or warning that a special area is being approached. Heaps or alignments of stones may be naturalistic or symbolic representations of animals, people or mythological figures.

Paintings

These usually occur in rock shelters, caves or other sheltered situations which offer a certain degree of protection from the weather. The best known examples in Western Australia occur in the Kimberley region but paintings are also found through most of the states. One of several coloured ochres as well as other coloured pigments may have been used at a site. Stencilling was a common painting technique used throughout the state. The negative image of an object was created by spraying pigment over the object which was held against the wall.

Engravings

This term described designs which have been carved, pecked or pounded into a rock surface. They form the predominant art form of the Pilbara region but are known to occur in the Kimberleys in the north to about Toodyay in the south. Most engravings occur in the open, but some are situated in rock shelters.

Caches

It was the custom to hide ceremonial objects in niches and other secluded places. The removal of objects from these places, or photography of the places or objects or any other interference with these places is not permitted.

Ceremonial Grounds

At some sites the ground has been modified in some way by the removal of surface pebbles, or the modeling of the soil, or the digging of pits and trenches. In other places there is not noticeable alteration of the ground surface and Aborigines familiar with the site must be consulted concerning its location.

Mythological Sites

Most sites already described have a place in Aboriginal mythology. In addition there are many Aboriginal sites with no man-made features which enable them to be recognised. They are often natural features in the landscape linked to the Aboriginal Account of the formation of the world during the creative "Dreaming" period in the distant past. Many such sites are located at focal points in the creative journeys of mythological spirit beings of the Dreaming. Such sites can only be identified by the Aboriginal people who are familiar with the associated traditions.

APPENDIX 3 : ARCHAEOLOGICAL SITE DETAILS

ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY PELICAN POINT BUNBURY DATE 16 May 1990

FIELD SITE NO. FS 1 / FS 2 GRID REF.

PHOTOS FS 1 FROM SOUTH 1:250,000 S150-6, 368.882
FS 2 FROM NORTH 1:100,000 2031; FS 1 778.127
Other FS 2 778.125

ENVIRONMENT

landform:
geology : SAND
vegetation: type..Pappbark, grass cover..sparse.....
species.....
water : type..permanent.....distance..100m.....
disturbance:type.....amount.....

SITE DESCRIPTION

site type : ARTEFACT SCATTERS
dimensions: NS..10./.15.m....EW...10./.15.m.....
FS 1 FS 2 FS 1 FS 2
boundaries: ~~natural~~/artificial . discrete/~~diffuse~~
components: stone artefacts

stratification:
no. of artefacts: approx. total..FS.1.:.5../.FS.2.:.7.....
density.....sparse.....
sample.....total . visible.....

Recorded by : CH.
Date : 16.5.90
Client : Bunbury

FIELD ID _____

FS 1

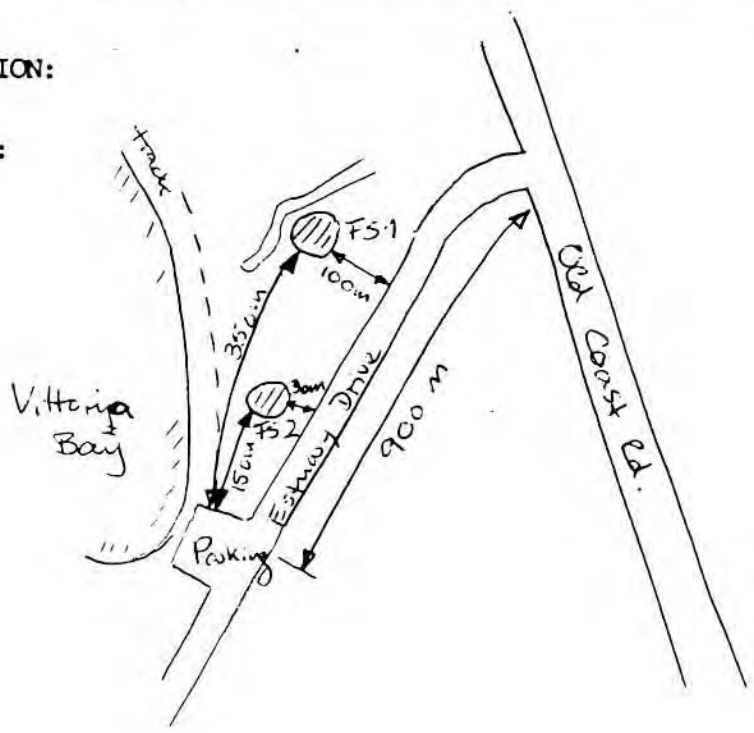
ARTEFACT TYPE	LITHIC	LENGTH	WIDTH	RETOUCH TYPE	EDGE SHAPE
Flake	Quartz	17	19		
"	"	15	13		
Chips 3	Quartz				

FS 2

ARTEFACT TYPE	LITHIC	LENGTH	WIDTH	RETOUCH TYPE	EDGE SHAPE
7 chips	quartz				

SITE LOCATION:

SKETCH MAP:
Scale
North



Pelican Point Pty Ltd

Pelican Point, Bunbury

Public Environmental Review

APPENDIX 7

CANAL GEOMETRIC ASPECTS, WATER QUALITY AND EXCHANGE

LEC Ref: J186/R320

REPORT:	CANAL GEOMETRY, WATER QUALITY & EXCHANGE
PROJECT:	THE SANCTUARY - PELICAN POINT
LOCATION:	BUNBURY, W.A
CLIENT:	PELICAN POINT PTY LTD
DATE:	OCTOBER 1990

Authorised for Release

_____

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Job No: J834
Report No: R390

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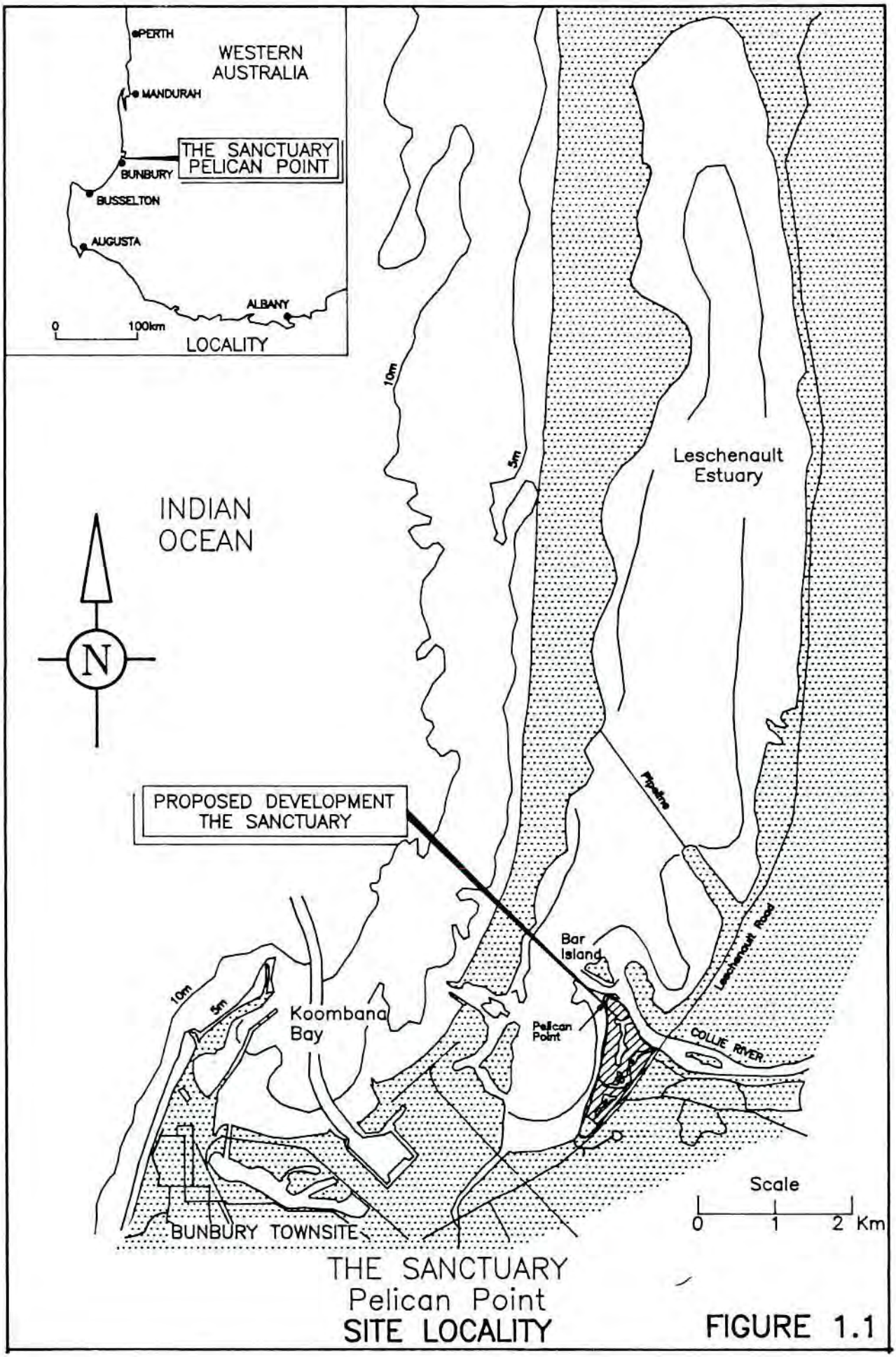
1. INTRODUCTION

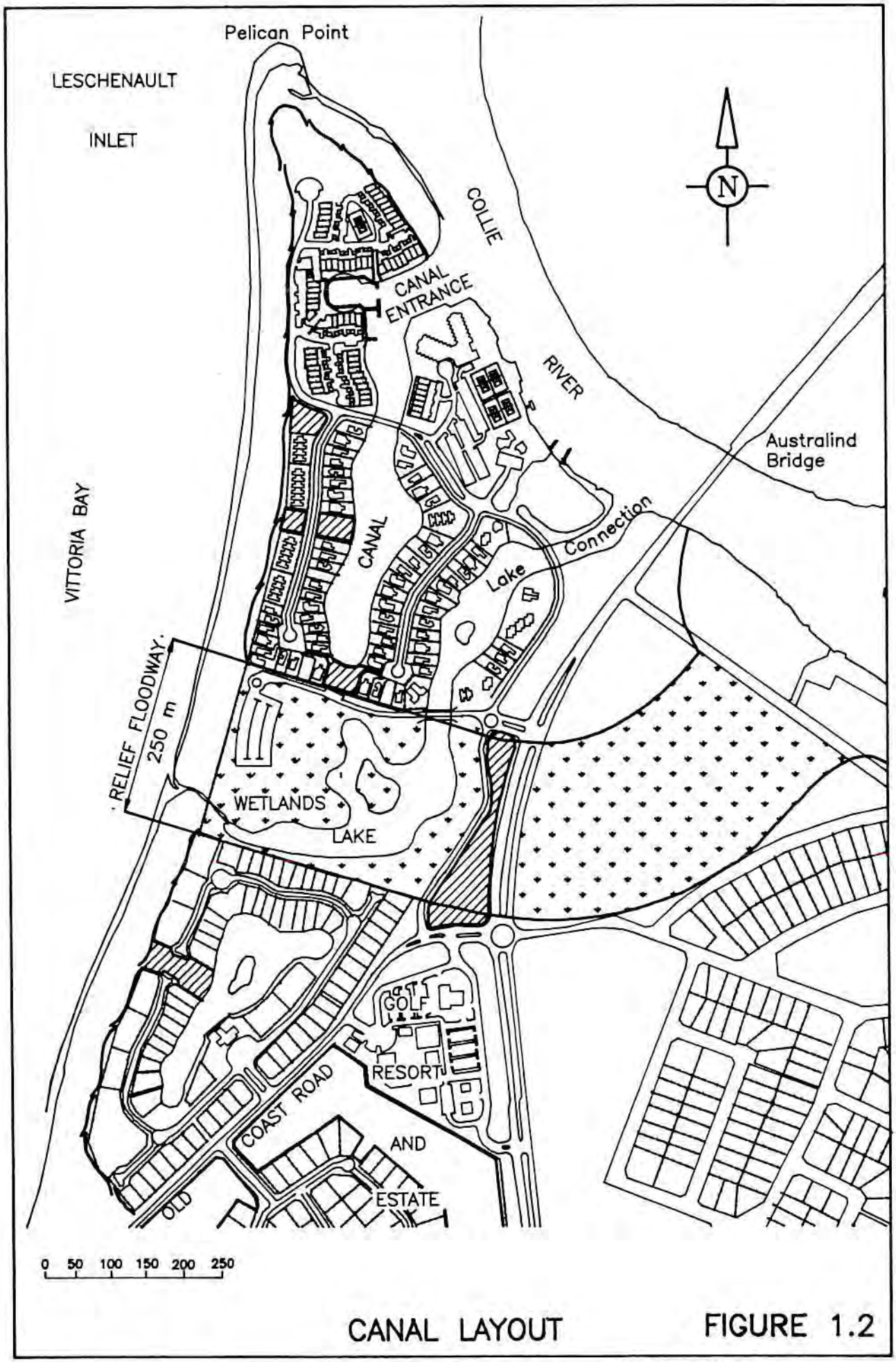
The proposed development `The Sanctuary Pelican Point' is located at Pelican Point near the mouth of the Collie River which flows into the Leschenault Estuary near Bunbury, see Figure 1.1.

The development has two water bodies connected to the Collie River, a residential canal and a lake which is integrated with wetlands on the site. Figure 1.2 gives the subdivision layout for the development with the two systems highlighted.

This report is prepared by Riedel and Byrne Consulting Engineers P/L for LeProvost Environmental Consultants (LEC), for inclusion in the Consultative Environmental Review. It assesses the canal and lake components of the development addressing a number of topics including:

- Water Quality - with particular reference to contaminant loadings from sources such as boats.
- Canal Geometry - assessing canal depth and orientation requirements.
- Flushing Characteristics - addressing the importance of tide, wind and salinity in maintaining exchange with source waters.
- Entrance Characteristics - assessing its stability and hydraulic behaviour.


PERTH
WESTERN AUSTRALIA
MANDURAH
THE SANCTUARY PELICAN POINT
BUNBURY
BUSSELTON
AUGUSTA
ALBANY
0
100km
LOCALITY
10m
5m
Leschenault Estuary
INDIAN OCEAN
N
PROPOSED DEVELOPMENT THE SANCTUARY
Pipeline
Bar Island
Leschenault Road
Koombana Bay
Pelican Point
COLLIE RIVER
Scale
0 1 2 Km
BUNBURY TOWNSITE
THE SANCTUARY
Pelican Point
SITE LOCALITY
FIGURE 1.1



CANAL LAYOUT FIGURE 1.2

2. WATER QUALITY

Care must be taken in developments such as The Sanctuary Pelican Point to ensure that water quality in the canals does not deteriorate.

The Steering Committee on Canal Development, in `Recommendations for the Development of Canal Estates', (1984), recommended that water quality within canals should not adversely affect the following beneficial uses:

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

In addition it should not measurably reduce water quality in any nearby natural water body.

Levels of water quality have been set for estuarine waters by the Environmental Protection Authority (EPA) (1981), such that aquatic ecosystems are maintained and any changes can readily be assimilated.

For the reasons above and on the basis of general aesthetic criteria the water should be:

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

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

A large number of developments of the type at The Sanctuary Pelican Point have been built successfully both overseas and interstate. Many developments have virtually no mixing due to tidal action yet maintain adequate water quality throughout the year. In New South Wales and Queensland many canal estates have been built more than 15 years and have successfully maintained water quality. Van de Kreeke et al (1977) and Hinwood (1989) have identified the importance of density and wind driven flows in closed end canals in Florida (USA) and Victoria respectively. In developments that have suffered deterioration of water quality, causes have been isolated and the situation satisfactorily rectified.

The main sources of contaminants which cause a deterioration in water quality in similar developments have been identified as:

- Nutrient inflow from inadequate sewerage (whether residential or accommodated boats), farm runoff, storm water, and indiscriminate rubbish dumping.
- Storm water carried silt and pollutants.
- Anti - fouling coatings.
- Oil, fuel and grease spillages or bilge discharges.

For the most part these can be controlled by a strict management policy.

The nutrient enriched waters of the river and the estuary are of particular concern and canals must exchange quickly to prevent localised algal blooms. Low levels of dissolved oxygen at the bottom in the Collie River are also of concern. Adequate exchange is important in preventing this situation occurring within the canals because it can result in anaerobic activity.

2.1 Source Water

The source water for exchange in the canal and the lake is the Collie River and the Leschenault Inlet. Unpublished Waterways Commission monitoring data over a number of years shows that the water is suitable for the four 'beneficial uses' identified in the recommendations for canal developments. The area is currently used by locals and visitors for those recreational activites with great frequency.

The lower Collie River is typical of a tidally influenced river with an agricultural catchment, discharging into a large shallow estuarine lagoon. Salinity alters seasonally according to runoff flows, and the waters show periodic nutrient enrichment. Unpublished Waterways Commission and LSC data from the Australind Bridge sampling site (refer to Tables A1 and A2 of this report, Volume 1 Section 3 of the PER text and LSC, 1986) shows the stratification in salinity occurs periodically throughout the year, while temperature variation through the water column are minimal. Salinity stratification during summer is also influenced by irrigation flows. Nutrient levels are also generally higher in the surface waters as would be expected in freshwater runoff where a saline wedge is present.

Algal blooms have occurred upstream of Alexander Island and washed downstream to the mouth of the Collie River on occasion.

The opening up of the Estuary at The Cut has increased the marine influence in the Collie River, especially with respect to the lower reaches of the river.

Waterways Commission guidelines on water quality elements of any body are set out in Section T.6. of the Leschenault Inlet Management Programme (1979). Unpublished data from the Leschenault Inlet Monitoring Survey shows guidelines are met at most times. Colour, although stratified and giving higher surface values, is within drinking water limits. Turbidity is generally less than 10 NTU except during winter runoff and Secchi disk depths are generally greater than 1.2 m. Dissolved gases are at most times shown to be above the accepted minimum level of 4 mg/l and in the range of 60% to 100% saturation with the lower saturations in bottom waters. Values as low as 50% saturation are known to support fish. Nutrient concentrations peak during winter flows and occasionally during non flow periods. Levels of ammonium nitrogen and total phosphorous at depth are twice that of the surface and indicate recycling of the nutrients. Levels are below accepted maximums at most times. Tables A.1 and A.2 in the appendix show typical values from the monitoring data.

Exchange of waters within the development is expected to be dominated by the more marine influence near the river delta area. Movement of the tidal saline wedge is expected to make a significant contribution to flushing of the development. Water within the development is expected to be of similar, if not better quality than indicated in river data. It is also likely that the mixing and circulation expected within the development waterways will result in less stratification than is shown in the river.

2.2 Contaminant Sources

2.2.1 Nutrient Loadings

Sources of nutrients are primarily the source water, septic tank sewerage systems, fertilisers in stormwater runoff, rubbish dumping and boat discharges.

As the proposed development is deep sewered, nutrient input from septic tanks would not be a problem.

The encouragement of the reduced use of artificial fertilisers and native planting will limit nutrient input from groundwater and storm water runoff. Also as the area is not agricultural there should be minimal input from this source.

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

Effluent loadings from boats should be minimal as long term accommodation on board vessels within the development will not be permitted and the discharge from holding tanks will be strictly prohibited. A low occupancy of permanently moored vessels is expected.

No commercial activity is permitted that would add other pollutants to the system and so canal nutrient levels should not be significantly different from those of the source water.

The incorporation of shallows in the lake provides inter–tidal areas supporting vegetation which removes nutrients from the water. In a canal design evaluation report for Florida regulatory bodies and developers, Morris (1981), states that not only does inter-tidal vegetation reduce nutrient levels but serves as a basis of the food chain making the waterway productive and `self purifying'. Under certain conditions the waterways could be expected to improve the water quality of the receiving waters by reducing nutrient content and by raising dissolved oxygen levels.

2.2.2 Anti - Fouling Coatings

Copper and Tributyl Tin Oxide (TBTO) are the principal chemicals currently used for anti–fouling coatings in Australia.

Copper

This element has been used in antifouling paints and coatings for more than a century and its toxicity to marine organisms at low concentrations is well known. Hart, (1982), recommended 5 ug/litre for protection of marine organisms.

Tributyl/Tin Oxide

In recent times, studies carried out by the French Oyster Industry and the NSW Fishing Industry have brought into question the use of TBTO as an anti foulant and it is probable that its future use in Australia will be curtailed by law. In the meantime, its use by vessels within the canals will be actively discouraged. A notice would be circulated to new residents warning of the danger of using TBTO and of moves by the Western Australian Government to ban its future use.

Unpublished data from monitoring of heavy metals in sediments by the Department of Marine and Harbours (DMH) at Hillarys Boat Harbour as a condition of its ERMP, has not shown harmful build-ups of copper attributable to accommodated vessels.

As boat occupancy for the proposed development is expected to be low, it is anticipated that levels of metals would not be above those of the source water, given adequate exchange.

2.2.3 Oils Fuels and Greases

The effect of oils in sea water 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 1200 times the rate of solution whereas for alkanes the rate is up to 100 times. McAuliffe, (1987), reports that lower hydrocarbons were completely lost from spilled oils with 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 have low toxicity but may have an aesthetic impact.

There is no data available for the release of hydrocarbons from owners servicing craft in residential canals. However during normal marina fuelling operation spillage would be negligible, at most a few tens of millilitres per refuelling. Monitoring at Hillarys by DMH has shown only slight build up of petrogenic hydrocarbons in sediments for its high level of traffic and on site fuelling facilities. It is therefore expected that there would be negligible impact on the development from this source.

2.2.4 Bilge Water Discharge

The NSW Public Works Department analysed discharge from bilges as part of the Environmental Impact Statement for the Rozelle Bay Marina, (1987). It found that steel hulled vessels contributed the majority of water of lower quality with elevated levels of suspended solids, greases, oils, phosphate, zinc, lead, copper and phosphorous. Elevated levels of all these parameters are indicated because of the use of corrosion - preventative coatings used typically on steel hulled vessels.

The accommodated vessels in the development are expected to be small in size and in the main of fibreglass or aluminium in construction. Minimal impact from this source is expected, due to the low level use of active corrosion preventive coatings.

3. CANAL GEOMETRY

The geometry of a canal development in terms of depth, width and orientation has an impact on water quality and the various mechanisms of water exchange. Morris (1981) shows these geometric characteristics affect circulation and mixing by allowing vertical mixing over the full depth profile by aligning the canal so that wind has access to the canal water surface, and providing a planform which promotes secondary currents to aid circulation. Navigable depths must also be able to be maintained.

The proposed canal is oriented north - south with an angled entrance cut into the bank of the Collie River at the northern end. It has an overall length of 600 m and an average width of 50 m. Canal front blocks are mainly of the residential villa type set back from the canal bank. Public open space allows access to the southern tip of the canal and to a point on its western side. A service road bridges the canal as shown in Figure 1.2.

The lake lies on an approximately southwest - northeast axis with its entrance adjacent to the Australind bridge and is non - navigable due to development road crossings at two locations. The lake has a constant bed slope from the shallows at its southern end to the residential lake villas at the depth of the entrance connection.

3.1 Canal Depth

Canal depths are established by the navigable depth required, siltation requirements, and maintenance of water quality through mixing over the whole depth profile. Depths are limited by the depth of the connecting waterways as a maximum and 1.0 m as the minimum set down by the Steering Committee on Canal Developments (1984).

Examination of dredging records and soundings to 1979 and in 1985 show the maintenance of the channel at about -1.6 m AHD. The channel depth past the bar island was unchanged over the 6 years, requiring no dredging. This would limit use of the river to boats of maximum draft 1.2 m - 1.3 m.

The depth of the Collie River at the site of the entrance to the proposed canal has remained constant over the period 1965 - 1985. The average depth of the river bed upstream and downstream shows an average maximum depth of -2.25 m AHD.

With the water level above -0.34 m AHD for almost all of the year, (Riedel and Byrne, 1986) and allowing a construction and siltation tolerance of 30 cm, a navigable depth of 1.4 m is provided by dredging the canals to -2.0 m AHD.

The depth of the residential canal is therefore set at -2.0 m AHD along its centreline.

River depths in the vicinity of the lake connection are in the order of -1.6 m to -2.3 m AHD. A connection depth of -1.6 m AHD would be appropriate to reduce the length of the dredged entrance channel into the river bank required at this location. This will provide greater than the 1.0 m minimum depth under the canal guidelines and allow the safe use of occasional paddle craft.

The residential portion and the connecting channel to the lake has its depth set at -1.6 m AHD. From this point invert levels will increase to mean water level at the southern portion of the wetlands lake.

Maximum depth limits are also imposed to prevent stagnation of the bottom layers of deep narrow canals. At the depths proposed, mixing over the full profile is effected by wind generated waves ensuring stratification of lower layers will not remain for long periods. Schwartz (1988), shows that stratification flow in a coastal marina at Hillarys, Western Australia was capable of being disrupted through the action of wind induced vertical circulation. Canal depths set at less than the depth of the source waterways also prevent the creation of a `sink' for nutrients and other contaminants and the deposition of the waterways bed load within the canal. Entrance depths must be no less than the canal system so that a sill cannot be created damming lower water in the deeper canals. Careful supervision of construction will ensure this.

3.2 Canal Orientation

3.2.1 Alignment

It is generally accepted that canals be aligned as near as possible to predominant winds to ensure mixing and exchange through stress over the water body surface. Researchers such as Van de Kreeke et al (1977), Hinwood (1989), and Schwartz (1988), have illustrated the contribution of wind induced circulation and mixing in canals and boat harbours due to wind stress over the water surface. Orientation of the canal and lake at Pelican Point should enable the maximum access of the prevailing winds to the water surface enabling the generation of circulation currents within them.

Analysis of EPA Australind half hourly wind data and Bunbury Station No. 9514 records for morning and afternoon show a predominantly southerly component and a typical summer southeast to southwest pattern. A low percentage of calms indicate that this mechanism is available for most of the time.

The canal and lake orientation on a north - south axis with access to open space at its southern end maximises the effect of southerly winds which occur over 50% of the time. Winds from the northeast sector, which occur about 25% of the time, are given access to both waterways through the orientation of their entrances along that axis.

3.2.2 Planform

Provision for safe width of navigable section must also be ensured. Mixing and circulation within a canal system are very important to its flushing efficiency. The planform of the proposed development provides sufficient width to allow wind to access the waterway surfaces without significant shielding. Morris, (1981), shows the inclusion of meandering banks and bends promotes the propagation of helical secondary flows along the canal improving vertical circulation. In addition, gradual transitions of canal geometry are important in reducing energy losses.

The residential canal has a bend of about 60° from its entrance with a meandering layout from this point to its southern end. Circulation is thus enhanced by the setting up of secondary flows at the head of the canal and maintained by the meanders along its length. Flushing efficiency is therefore improved due to increased circulation and mixing. A similar layout of meandering banks increases the flushing efficiency of the lake. All geometry transitions are gradual.

The residential canal has a boat basin adjacent to its entrance. Small boat basins achieve maximum flushing efficiency when their planform promotes circulation in a single gyre. Falconer et al (1976), recommend a single asymmetric entrance and a length/width ratio of close to unity for maximum efficiency. Rounding of corners improves local exchange preventing `dead spots' in corners.

The boat basin proposed has a curved (rip-rap) wall under a rectangular boardwalk servicing moorings. This will enable circulation of the contained waters in each tide with an efficiency approaching 100%. Access to wind at the southwest and northwest corners has been provided to aid flushing and reduce the build up of floating debris.

The recommendations by the Steering Committee on Canal Developments (1984), give a minimum safe navigable width between moorings as 15 m or twice the length of the design vessel. The minimum canal width is 40 m. Small power craft of less than about 7 m will be satisfactorily accommodated allowing a mooring envelope of approximately 12 m. A minimum navigable depth for small craft will be maintained at all stages of the tide. Vessels to 10 m can be accommodated within the boat basin but are limited by the navigable depth of 1.4 m. An approximate entrance width of 60 m provides an adequate navigable standard for this size vessel. With about a 0.3 m allowance, a maximum draft for vessels is 1.1 m to 1.2 m within the canal.

4. Water Exchange

4.1 Water Exchange Mechanisms

There are three likely mechanisms for the flushing of the residential canal and the lake at Pelican Point resulting in the exchange of water between them and the Collie River, and then the ocean via the Leschenault Inlet:

- Tidal Exchange which occurs at least once a day and longer term barometric water level increases with periods 5 - 20 days.
- Wind induced current and mixing within the canals.
- Density currents due to salinity and temperature gradients.

Van de Kreeke et al (1977), showed that the exchange rate of canals was largely based on density and wind induced flows and thermal convection. Tidal induced velocities were shown to play a lesser role and circulation and exchange consisted of a combination of all of the parameters above. One dimensional tidal dispersion equations, used in models to date, were shown not to be a true representation of the transport process in canals. 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 (1988), showed the importance of these effects in a coastal marina. Flushing times measured were significantly lower than those calculated and the combination of mechanisms to achieve flushing was evident.

Unpublished data was obtained from the Western Australian Waterways Commission and EPA of monitored salinity and temperature in the Collie River and the Leschenault Inlet. Analysis of the data in combination with tidal influences and wind circulation and exchange have been used in this study to estimate total exchange for the canal system.

The tide level variations are most effective in enhancing the density driven exchange which is shown to be predominant for the canal system, aided by wind circulation and mixing.

The lake is shown to be flushed by wind stress over its shallow areas and along its length and also by density currents. Tidal exchange with the residential portion of the lake is also shown to contribute.

4.2 Tidal Exchange

4.2.1 Astronomical Tide

For a simple straight canal similar flow patterns exist for the flood and ebb tide. Flow under tidal influence introduces new water to the canal. These will be exchanged as the tide ebbs provided there are asymmetries of flow caused by bends etc and if there is stratification due to density variations.

The typical daily tidal range is about 0.3 m to 0.4 m giving a typical tidal prism ratio of about 0.2 for the canal and 0.3 for the lake.

Under stratification conditions tidal exchange will influence the whole of the canal development, under fully mixed conditions tides can be expected to influence the lower reach of the canal encompassing that part to the restriction of the bridge, the boat basin and the entrance. The efficiency of exchange in this region can be gauged using work by Nece et al (1976), and Falconer (1980), indicating a coefficient of around 0.15. A contribution of about 20% to the total exchange of the canal volume with the source water under stratification conditions and about 7% under fully mixed conditions is expected.

Tidal influence up to the lakeside villa region of the lake can be expected, with reasonable efficiency due to the planform of the meandering channel and lake basin. An estimated exchange coefficient of 0.5 would give a contribution to total exchange of about 6% of the lake volume.

4.2.2 Barometric Effects

Longer period water levels are experienced along the Western Australian coast and can be as large as the daily astronomical range. However the change occurs over several days or weeks in response to:

- atmospheric pressure systems;
- shelf waves;
- storm wave set up;
- coastal currents and eddies.

These can provide a significant rise in water level within the development and provide an additional source of exchange, in the order of 1 to 2% each time they occur.

4.3 Wind Induced Exchange

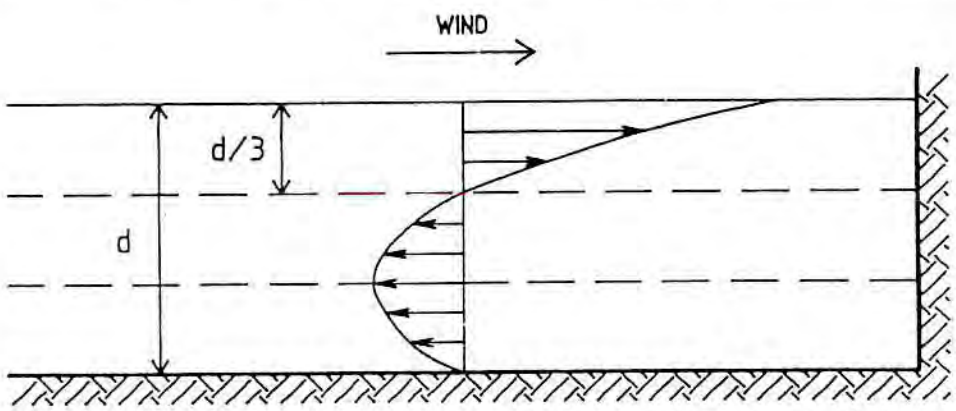
Surface currents that are mobilised by shear stress induced by wind passing across the water surface are important in the mixing and exchange of waters within canals and boat harbours.

A number of researchers have examined the relation between wind and surface currents (Wu, 1973; Bishop 1979; Shemdin 1972), and the general agreement is that the surface current is between 2-5% 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 water body a reverse current of equal mass flow forms to re-established 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
z = distance below the surface
h = total depth of water flow

The velocity profile corresponding to the above equation is shown in Figure 4.1 below.



Wind Induced Velocity Profile Figure 4.1

In a real canal the flow will not be truly two-dimensional. Some sheltering near the banks will occur and resistance to flow will be higher here also. Surface flow in the direction of the wind will be strongest at the centre of the canal. Return flows will 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 water bodies exhibiting flows entirely in the direction of the wind. Superimposed tidal velocities will also alter the model profile. 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.

As well as producing surface drift currents and return flows winds can induce significant vertical mixing through waves. The orientation of the development waterways open to the south and north-east sectors takes full benefit of the predominant winds. Figure 4.2 shows the wind rose summarised from the EPA wind data at Australind between 1/7/81 and 30/6/84. Records indicate that the wind is quite strong at 15 km/h about 50 % of the time. Table 4.1 shows the seasonal analysis indicating high percentage of winds >10 km/h.

TABLE 4.1

	Mean Speed (Km/hr)	% Exceedence >(10 Km/h)
Summer	19	82.75
Autumn	15	55.2
Spring	20	71.4
Winter	20	58.02

Winds from the southern sector with speeds greater than 10 km/h blow about 30 % of the time and winds greater than 10 km/h from the north-east quadrant blow about 15% of the time.

An estimated 50% daily exchange of water volume in the two waterways is driven by this mechanism alone.

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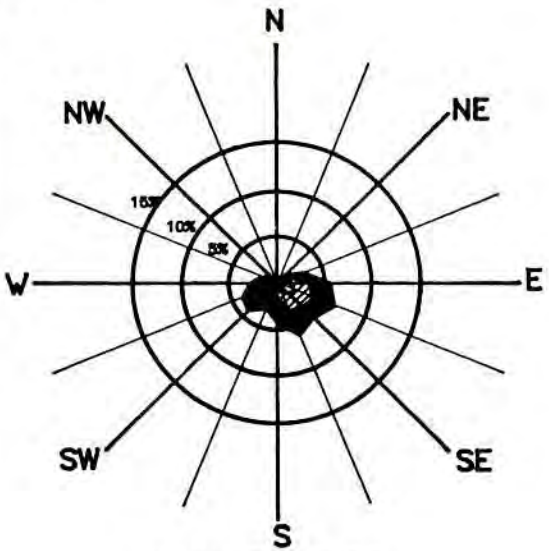
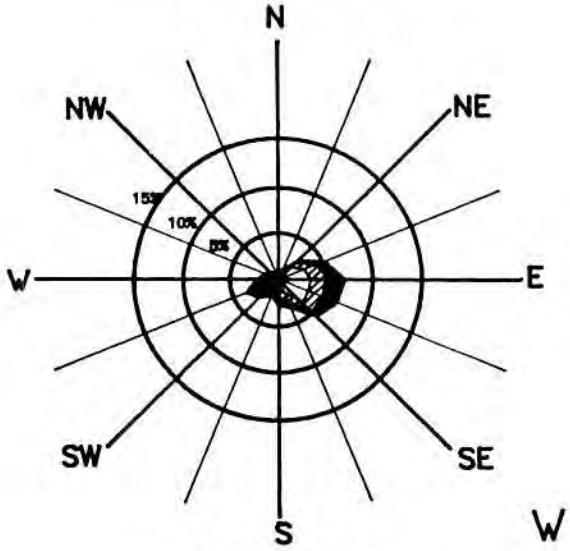
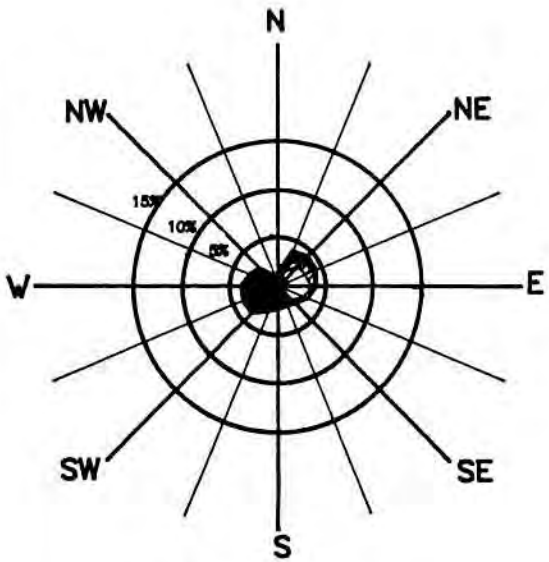


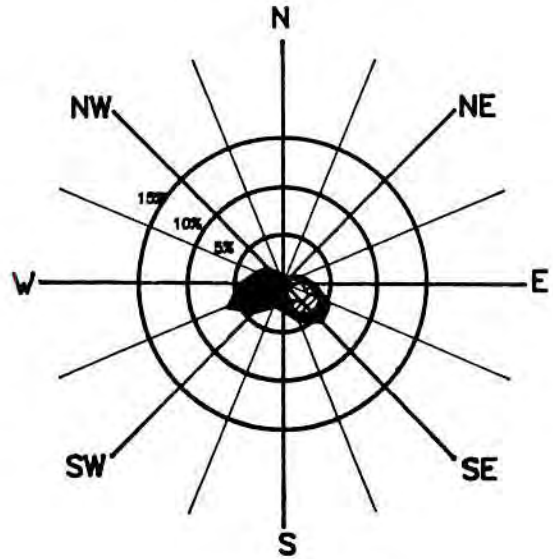
SUMMER WINDS



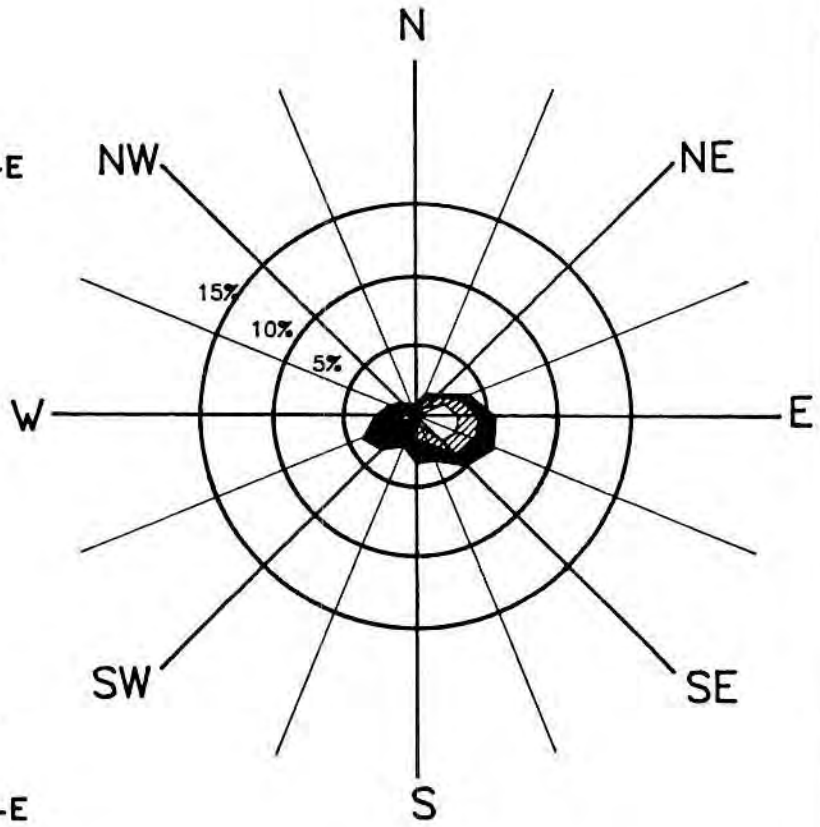
AUTUMN WINDS



WINTER WINDS



SPRING WINDS



WINDS FOR THE WHOLE YEAR

0 – 3 Km/h
3 – 4.5 Km/h
> 4.5 Km/h

AUSTRALIND WIND DATA

FIGURE 4.2

Surface wind drift water movements created by these winds are presented in Figure 4.3. Access to the south over the open space of the floodway allows the funnelling of wind along both waterways between canal front buildings, resulting in exchange of waters with the Collie River. North-easterly winds drive waters up into the canals with gravitational circulation providing return flows at dead ends. Significant opportunity for water movement by wind shear is provided by the shallows in the lake and would also significantly contribute to mixing in this waterway.

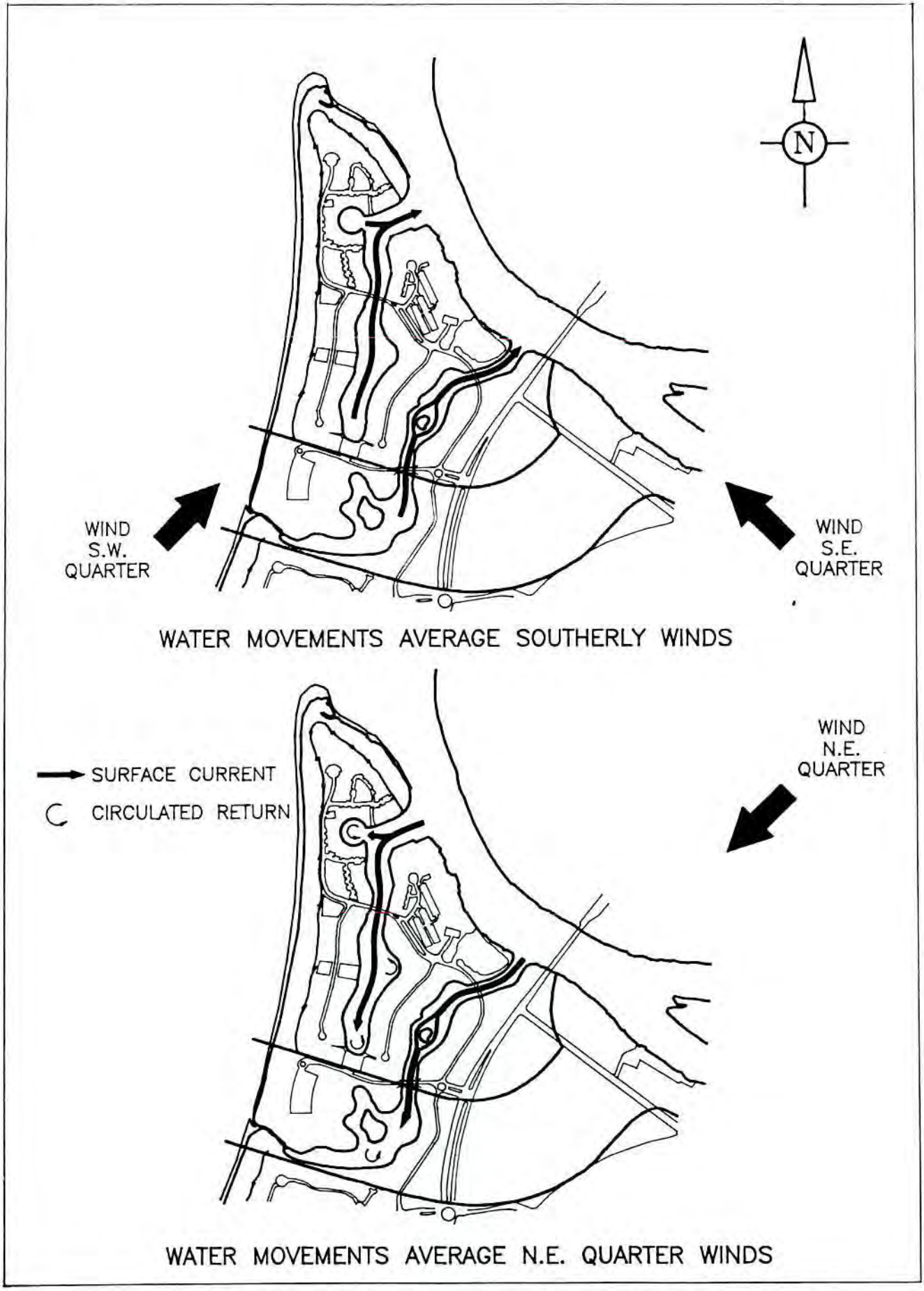
The models used are relatively simple and a conservative assumption of 50% efficiency has been made to allow for shielding and flow patterns. However it is clear that the predominant winds over the worst period of water quality in summer can have a significant contribution to flushing.

4.4 Density Currents

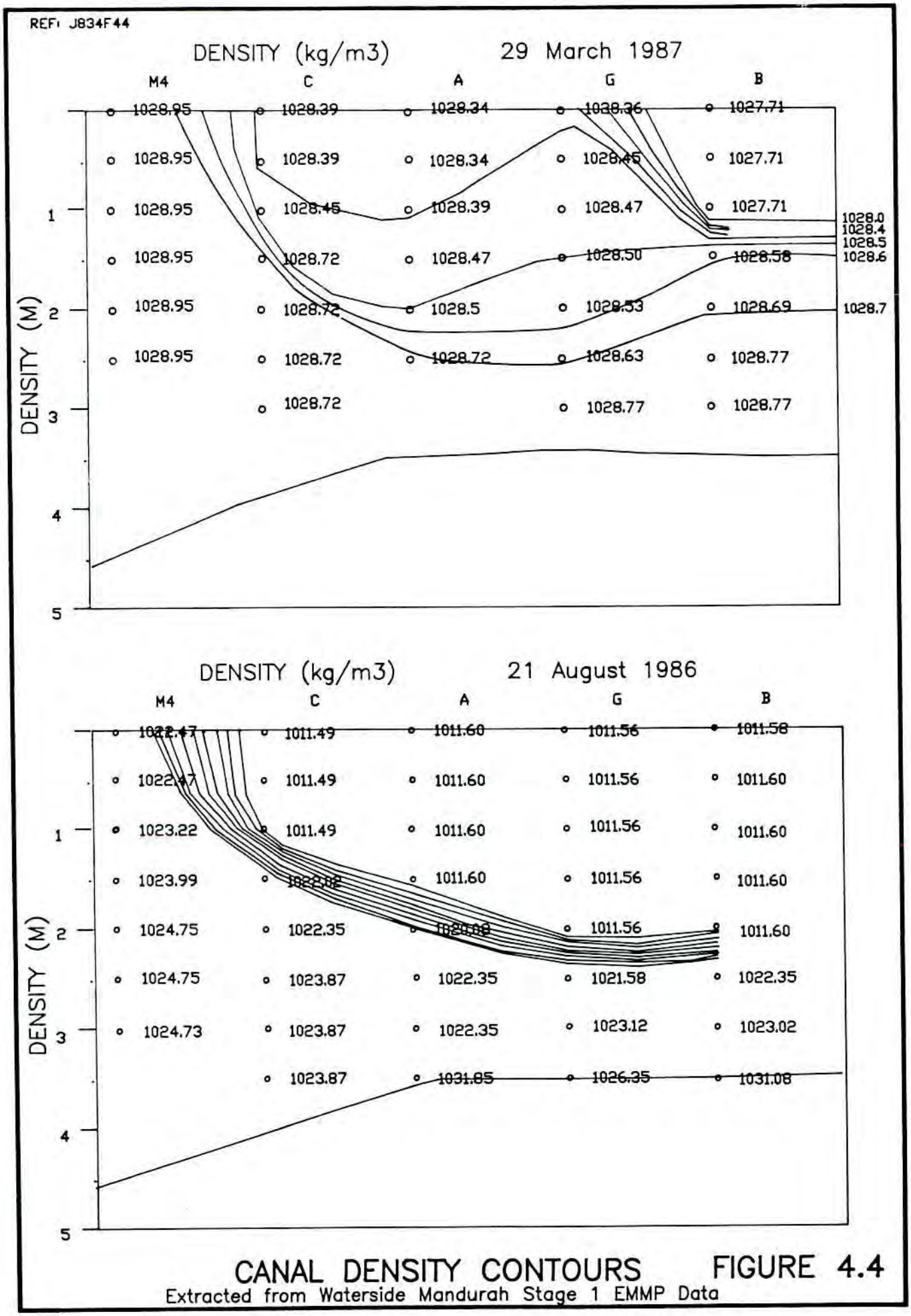
Stratification of the lower reaches of the Collie River in salinity and temperature is evident in the monitoring data. EPA data from the vicinity of Snake Island shows a significant intrusion of a saline wedge upstream, with daily movements reflected in the monitored halocline, salinities and temperatures. Large intrusions between winter runoff flows are evident with a mobile halocline evident through the summer but with less variation. Data monitored by the Waterways Commission in the vicinity of the Australind bridge indicate this also.

Monitoring as part of the ERMP for Waterside Mandurah Stage 1 has shown that where there is a variation in density within the source water this is reflected in the canal system. The density contours shown in Figure 4.4 illustrate the water body structure caused by this mechanism at Waterside Mandurah. The different densities set up gravitational flow resulting in significant water exchange between the Mandurah Channel and the canals. A similar situation is expected at Pelican Point. Near homogeneous saline conditions should be present over the summer due to lack of movement of the saline wedge in the Collie River, and exchange is primarily driven by temperature induced density differences such as those illustrated for March in Figure 4.4. Movement of the saline wedge is more active over the winter with large salinity variations, under those circumstances conditions similar to that shown for August might be expected.

In monitoring a simple canal in Florida, Van de Kreeke et al (1977), monitored layer velocities of the order 0.06 m/s. Hinwood and Pollock (1989), observed layer velocities of the order 0.1 m/s with little salinity variation measured. This compares favourably with density intrusion flow velocities obtained from the interfacial density differences evident in Figure 4.4. Allowing for bed friction, flows in the order of 0.1 m/s are possible for winter conditions, and around 0.05 m/s over the summer.



WIND DRIVEN WATER MOVEMENTS FIGURE 4.3



CANAL DENSITY CONTOURS FIGURE 4.4

Extracted from Waterside Mandurah Stage 1 EMMP Data

It is estimated that when density driven flows are active, total exchange of the Sanctuary Pelican Point waterways can occur within a matter of hours. Total exchange for the canal is estimated to occur over 4 to 7 hours and for the lake between 5 and 10 hours.

4.5 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 canals will closely reflect that of the source water in the lower reaches of the Collie River.

The principal exchange mechanisms are wind circulation and density currents. Wind induced currents are capable of total exchange of both the canal and lake over a period of 1 to 2 days. Density driven currents are dominant, capable of total exchange of both waterways in a matter of hours.

5. ENTRANCE STABILITY AND ALIGNMENT

5.1 Entrance Channel Stability

Exchange velocities in the entrance of the proposed canal and lake are estimated to be less than 0.1 m/s. Such velocities would be insufficient to significantly transport material in the entrance bed or side slopes. The flows out of the development are small and would have no measurable effect on the flow patterns of the Collie River or its adjacent banks.

Flows in the rivers are at most times tidal and of low velocities. However flood flow conditions over the winter can be expected to result in bed load movement into the channel from time to time. Inspection of accretion records at the mouth of the river has shown the deposition rate to be small. Analysis of bed samples and flood flows indicates that significant transport will occur infrequently. Deposition of bed material into the entrance channel will be minimised if flat transitions into the cut are provided.

Protection of the entrance channel against wave action from boat wash will be required. There is a variety of rip rap or bulkhead walling options available to achieve this. Bank protection to the meandering lake connection which has a smaller cross-section will be provided.

5.2 Entrance Alignment

Experience elsewhere has generally shown that no particular alignment to a bay or river was necessary for a canal development of this type. Velocities in the river are low and it is expected that exchange velocities in the entrance will be driven by factors independent of river flow. Exchange is driven mainly by density currents caused by differences in salinity and temperature between the development and outside in the river. These differences will be mainly governed by tidal interaction in the lower reaches of the river with the more marine Leschenault Estuary. The tidal range is also low and is not expected to influence entrance behaviour significantly.

The entrance alignments which are proposed take advantage of the site wind conditions as discussed in section 3.2. The entrance perpendicular to river alignment will allow efficient exchange to occur independent of river velocities and flow direction.

5.3 Comparison with other Canal Systems

5.3.1 Canals in Western Australia

Two developments in Western Australia which have entrances on to rivers or similar features are 'Murray Waters' on the Murray River and 'Waterside Mandurah' Stage 1 Canals on Mandurah Channel. The 'Murray Waters' development which has similar entrance alignment and cross-section to the proposed development has experienced no sedimentation problems associated with its entrance behaviour. The 'Waterside Mandurah' Stage 1 canals have also shown no problems in post - construction monitoring.

5.3.2 Other Canal Developments

The majority of canal developments in Australia have occurred in Queensland. These generally fall into two categories: canals having their entrance into bays (about 50%) and those having their entrance on to rivers. The operation of systems on to bays or similar large features such as wide estuaries and inlets, have no correlation to that of rivers. Shoreline processes in these cases are determined by the prevailing wind and wave climate and not channel flows.

Canal system entrances into navigable waterways on the Gold Coast, Queensland were inspected to assess siltation problems. In addition, discussions were held with Harbours and Marine and Albert Shire Engineering sections (Riedel and Byrne, 1984). From these discussions it was determined that:

- Canal entrance siltation occurred at no greater rate than siltation in the canals themselves.

- Canal entrance alignment has been determined by subdivisional requirements and most entrances are perpendicular to the river or creek alignment. Their sedimentation characteristics are indistinguishable from those of entrances with other alignments.

- Only canal entrances entering the bay have known sedimentation problems due to wave action.

- The Albert Shire has a continuous maintenance dredging operation, primarily moving sand from the bottom to canal and bankments. This is caused mainly by boat wash and local wind waves.

- Many of the canals have been in operation for over 15 years and no new sedimentation problems are likely to occur.

Canal entrances inspected on the Gold Coast were Rio Vista and Florida Gardens, Tallebudgera Creek Canals, and Marlin Waters.

Scour protection was used in the Rio Vista and Florida Gardens development where constrictions to the canal cross section at the entrance occurred on two entrances. Sedimentation was a problem at the entrance of the Tallebudgera development due to unequal bank lengths allowing slowing of velocities. In the Rio Vista estate sand built up opposite the first finger canal of the same geometry, illustrating the effect of expansion of the flow lines. Problems with scour were seen to be associated with constriction of canal cross-sections and sedimentation occurred where expansion of flow of the parent waterway was caused. Cross-sections of the canal were in general much smaller than those of the parent waterway and did not allow expansion of flow into them at the entrance.

The generalisation of experiences elsewhere shows no particular alignment to a bay or river was necessary where the canal cross sectional area is much smaller than parent waterways. However situations where special canal entrance design is appropriate are:

i) where both canal and parent waterways are of similar cross section and flow characteristics.
ii) where the parent waterway has large tidal flows and the canal cross section causes velocities of the same magnitude, causing spits to form. Physical modelling is the only method of correct entrance design in this situation.

The Queensland Department of Harbours and Marine recommends alignment of internal canals so as to smooth streamlines and to provide less tendency for siltation (Riedel & Byrne, 1984).

5.3.3 The Sanctuary

The waterways proposed at Pelican Point with the low velocities and flow anticipated do not reflect any of the problems identified above. With the provision of smooth transition to entrance channel cuts, stable behaviour of the entrance is expected.

6. CONCLUSIONS

This report examines the various aspects of the proposed development dealing with canal geometry, water quality and exchange. The results of the study may be summarised as follows:

- Water quality in a canal estate or harbour can deteriorate as a result of contaminants introduced into the water body or poor flushing resulting eventually in depletion of dissolved oxygen or algal blooms within the canals.

- The Steering Committee on Canal Development WA (1984) recommended that water quality within canals should not adversely affect the following beneficial uses.

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

In addition it should not measurably reduce water quality in a natural water body.

- Source water for exchange is dominated by the more marine influence near the delta area of the Collie River and is considered suitable for the `beneficial uses' proposed.

- Contaminant and nutrient loadings from accommodated vessels are not considered to be significant given adequate circulation and exchange.

- The two main exchange mechanisms are wind induced currents and density currents caused by temperature and salinity differentials between the development water bodies and the source water.

- It is estimated that likely flushing times in the order of 1 to 2 days may be expected depending on the activity of wind and density currents. This should ensure maintenance of water quality within the development.

- Waterway orientations are laid out to take maximum advantage of predominant winds from the south.

- The proposed canal planform provides additional circulation of the water body and provides adequate navigable and mooring widths for small power craft up to about 7 m in length. Navigation of vessels up to 10 m is provided

near the entrance of the canal but is limited by maximum draft at the river bar of 1.0 to 1.2 m.

- The canal depth is limited by river bed depth near its entrance and is set at -2.0 m AHD. Lake depth is similarly set at -1.6 m AHD.

- The entrance configurations proposed give adequate provision for efficient exchange by wind driven and density driven currents. No significant impact on river flow is expected and the provision of gradual transition to the river bank will ensure that the entrances will require only minimum maintenance.

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A.1 Unpublished Waterways Commission Collie River monitoring data.

A.2 Collie River - Australind Bridge water quality monitoring extracted from `Bunbury C Power Station Marine Environmental Studies. Vol 3 (LSC)

Appendix A

AUSTRALIND ROAD BRIDGE SITE COLLIE RIVER MONITORING DATA

DATE	DO (Surface) %	DO (Bottom) %	NH_4 (B)	PO_4 (B) mgL 1	BOD (B) mgL 1
Dec 1985	94	76	.03	.01	2
Sep 1985	87	75	.02	<.01	< 2
May 1985	77	70	.12	.02	2
Feb 1985	94	77	.02	<.01	2.6
Sep 1984	96	82	.03	<.01	< 2
Jun 1984	81	76	.06	.01	< 2
Mar 1984	81	86	.02	.02	< 2
Dec 1983	82	68	.02	.02	4
Aug 1983	80	80	.07	.01	< 2
May 1983	104	84	.14	.01 (TP) (.12)	< 2
Jan 1983	80	70	.08	.02	2
Oct 1983	85	78	.05	.01	< 2
Jun 1982	62	60	.14	.04	< 2
Mar 1982	94	66	.04	.01	< 2
Nov 1981	96	80	.02	.01	< 2
Aug 1981	70	62	.18	.03	< 2
Apr 1981	81	72	.02	.01	2
Dec 1980	98	64	.05		3.4
Jun 1980	66	100	.08		2
Mar 1980	86	68	.06		< 2
Oct 1979	99	76	< .02		< 2
Jul 1979	80	81	0.8		< 2
May 1979	88	86	.03		< 2
Jan 1979	96	64	.13		2.8
Sep 1978	80	74	.08		< 2
Jun 1978	63	49	.19		< 2
Mar 1978	84	78	.02		2.2
Dec 1977	94	61	.09		7.2
May 1977	79	85			< 2
Dec 1976					

TABLE A.1

SOURCE: Unpublished Waterways Commission (WA) - data from the Leschenault Inlet Monitoring Survey.

COLLIE RIVER - AUSTRALIND BRIDGE
TYPICAL PROFILE DATA

DATE/TIME	DEPTH m	SALINITY $^{0}/_{00}$	TEMPERATURE °C	SUSPENDED SOLIDS mg l^{-1}	SECCHI DEPTH m
MAY 1982/0900					
	0.1	10.0	16.0		
	0.5	11.6	16.0		
	1.0	27.0	16.0		
	1.5	33.6	16.0		
JUN 1982/1400					
	0.1	1.7	15.0		
	0.5	2.1	14.9		
	1.0	2.5	14.8		
	1.5	18.9	14.8		
JUN 1982/1445					
	0.1	4.8	13.0	10.0	1.5
	1.0	17.5	13.5		
	1.5	26.8	13.5	5.4	
JUL 1982/1246					
	0.1	1.5	13.2		
	1.0	7.6	13.2		
	1.5	11.1	13.2		
JUL 1982/1225					
	0.1	1.4	13.3		
	0.5	1.4	13.3		
	1.0	1.5	13.2		
	1.5	1.5	13.2		
AUG 1982/1745					
	0.1	2.5	12.0	18.3	1.0
	0.5	2.2	12.0		
	1.0	2.4	12.0		
	1.5	2.4	12.0	24.2	
AUG 1982/1245					
	1.0	2.9	15.0		
	0.5	2.9	14.9		
	1.0	30.4	15.9		
	1.5	33.0	15.9		
	2.0	33.3	15.9		
	2.5	33.7	15.9		
APR 1982/1700					
	0.1	2.5	16.0		
	0.5	2.5	15.8		
	1.0	24.2	15.5		
	1.5	27.5	16.0		
	2.0	28.4	16.4		

Continued

COLLIE RIVER - AUSTRALIND BRIDGE
TYPICAL PROFILE DATA

DATE/TIME	DEPTH m	SALINITY $^{0}/_{00}$	TEMPERATURE °C	SUSPENDED SOLIDS mg l^{-1}	SECCHI DEPTH m
SEP 1982/1650					
	0.1	3.5	18.9	5.4 1.5	
	0.5	13.2	17.7		
	1.0	29.9	16.8		
	1.5	31.0	16.7	5.4	
OCT 1982/1540					
	0.1	3.6	22.4	5.8	
	0.5	15.0	21.25		
	1.0	29.9	19.75		
	1.5	31.4	19.1	7.3	
DEC 1982/1100					
	0.1	22.5	24.0	4.0 1.5	
	0.5	22.8	24.0		
	1.0	32.1	23.4		
	1.5	33.71	23.2	7.2	
JAN 1983/1425					
	0.1	31.6	28.8	5.3 1.25	
	0.5	31.2	28.0		
	1.0	34.28	27.5		
	1.5	34.3	27.3	6.7	
MAR 1983/1335					
	0.1	30.0	25.6	5.3 1.0(+)	
	0.5	35.93	23.7		
	1.0	36.37	23.3	6.9	
MAY 1982/115					
	0.1	8.5	17.3	6.4	1.5
	0.5	9.3	17.4		
	1.0	10.9	17.6		
	1.5	11.5	17.6		

TABLE A.2
SOURCE: Envirochem
Bunbury C Power Station
Marine Environmental Studies Vol 3. (LSC)