LESCHENAULT INLET MANAGEMENT AUTHORITY CITY OF BUNBURY

Draft Management Plan Koombana Park Reserve Bunbury Western Australia

Waterways Commission Report 32 August 1992

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DRAFT MANAGEMENT PLAN KOOMBANA PARK RESERVE BUNBURY WESTERN AUSTRALIA

Prepared for the City of Bunbury and the Leschenault Inlet Management Authority by the Waterways Commission

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Waterways Commission
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Front cover: Seedling of the White Mangrove *Avicennia marina* - from Lear and Turner (1977) "Mangroves of Australia".

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CHAIRMANS FOREWORD

Koombana Park is a major feature in the development of Bunbury Harbour City. When completed, it will provide a focus for recreation whilst combining elements of education with an emphasis toward conservation.

In 1992 the Leschenault Waterways Management Programme was released. The programme establishes a framework for the appropriate management of the Leschenault Waterways to ensure that they continue to exist as a healthy living system. This management plan will implement the relevant recommendations of the programme by recognising the demand for recreation whilst ensuring that the conservation requirements of the mangroves and samphire are accommodated. The park also through its design will create an entry statement to the City of Bunbury and with appropriate management it will promote the area's considerable natural significance as an asset to be enjoyed and appreciated by the entire community.

The Leschenault Inlet Management Authority looks forward to assisting Council in continuing this excellent work in planning and managing the waterways and foreshores. I urge you to read the Management Plan and if you need more information, feel free to approach the Leschenault Inlet Management Authority or the Waterways Commission staff for assistance.

Sir Donald Eckersley OBE
Chairman
Leschenault Inlet Management Authority

MAYORS FOREWORD

Bunbury Harbour City is an exciting concept of urban renewal aimed at taking Bunbury into the 21st Century as a dynamic developing community.

The overall theme of the project recognises the ties between Bunbury and the sea and links the water and foreshore to the buildings and landscape. With the opening of the Koombana Bridge, Koombana Park now provides the entry statement to the City.

This management plan will help create and maintain an entry to the City of attractive parkland which has been regenerated from an industrial waste site. It also preserves Bunbury's unusual feature of a natural foreshore setting, with saltmarsh, mangroves and the associated water birds, in the middle of a vibrant city.

E C Manea - Mayor of Bunbury

ACKNOWLEDGEMENTS

This Draft Environmental Management Plan was prepared on behalf of the City of Bunbury, in whom the land is vested, with the support of the Leschenault Inlet Management Authority (LIMA) and the Department of Conservation and Land Management (CALM).

We wish to thank the following for their help -

The staff at the Waterways Commission, especially Colin Chalmers, Bev Thurlow, Verity Klemm, Vas Hosja, Caroline Seal, Dave Deeley and Greg Davis.
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Capt. Clyde Ambrose of the Department of Marine and Harbours, Bunbury.
Cable Sands Pty Ltd
Dr Philip Ladd, Assoc. Prof. Phil. Jennings, Dr Roger Lethbridge and Dr Jenny Davis at Murdoch University.

PUBLIC SUBMISSIONS

This draft management plan was prepared by Waterways Commission for the Leschenault Management Authority and the City of Bunbury.

Copies of the management plan will be available at the State Library and local government public libraries, also at:

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City of Bunbury
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Public submissions on the draft management plan are now invited. All public submissions received will be considered before the preparation of the final management plan.

Please send your comments to :

Co-ordinator
Draft Management Plan for Koombana Park
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Officers will be able to discuss any aspect of the draft and provide further background information.

In publishing this report both council and LIMA wish to make it clear that they do not, at this stage, specifically endorse any of the recommendations.

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SUMMARY

The study area includes part of the foreshore and waters of Leschenault Inlet, near the City of Bunbury in the south-west of Western Australia. It includes Koombana Park which is on the north shore of the Inlet, and Anglesea Island which lies within the Inlet between Koombana Park and the city. The area consists of low-lying saltmarsh of importance to waterbirds, the remnants of a coastal dune system, and a mangrove community of special significance. A wide variety of waterbird species can be seen at the site, including trans-equatorial migrant waders.

A great many artificial changes have been made to the landscape since European settlement. A new Inner Harbour, completed in the 1970s cut off the lower part of the Inlet from the main waterbody, changing it from an estuarine to a marine environment, and truncating Anglesea Island. Tailings have been dumped in the area from a nearby mineral sands separation plant, covering part of a tidal creek and much of the original mangrove community. These changes have had a severe impact on the natural environment.

In 1983 the Department of Conservation and Environment recommended that the area be reserved for conservation purposes (DCE 1983). This report is commonly known as the System 6 Report. Since then, a new major road, Koombana Drive, has been built as a "gateway" to the city centre of Bunbury. A new "Harbour City" concept has led to plans for major redevelopment in this "gateway" area. Part of that concept is to manage the Koombana Park/Anglesea Island area for conservation, education and recreation - the mangroves and saltmarshes would be protected while the public would be able to enjoy the area and learn about its ecosystem without causing damage.

The aim of this management plan is to:

> **To develop and manage Koombana Park and Anglesea Island as a reserve for conservation, education and low-impact recreation.**

It recognises the special significance of the mangrove community and the waterbird habitat. These ecosystems should be conserved,while the public is given access to parts of the reserve for enjoyment and to observe and learn about these ecosystems and their flora and fauna.

Part of the saltmarsh is a prime breeding ground for the saltwater mosquito, which is a nuisance to Bunbury residents and is a potential carrier of the Ross River virus. Historically, broadscale chemical insecticides were used for mosquito control but Bunbury City Council now use a combination of channelling and opportunistic larvicide application. There have been problems with the channelling, but good mosquito control appears to have been achieved and the new strategy is more environmentally benign than the former methods.

The mangrove community is significant in that it is an isolated occurrence, the closest being at the Abrolhos Islands in Western Australia and near Adelaide in South Australia. Mangroves are adapted to tidal saline conditions but require some fresh groundwater. The energy they expend in desalinating water can lead to water stress. In the species at Bunbury, *Avicennia marina*, the seeds germinate while attached to the plant. When they fall, the tide distributes these buoyant seedlings until they take root on gently sloping mud banks. They require protected shores for successful colonisation.

Much of the city drainage system flows into the Inlet contributing to the phosphate levels in the water. Nitrogen levels are normal, and algal blooms are not a problem in the Inlet. The tidal range at Bunbury is less than a metre. Tide gates in the artificial entrance channel are not used to substantially impede the normal tidal pattern - only to prevent storm surges.

The tailings dump contains a radioactive isotope of thorium. Preliminary readings of gamma radiation levels, when compared with guidelines given by the Radiological Council, suggest that the risk to visitors is minimal and acceptable.

Mangrove and saltmarsh are the two principle vegetation types, with a small area of remnant sheoak community and a very small area of coastal dune vegetation. The saltmarsh is of two types - samphire flat and sedgeland. There is also a small community of Peppermint trees. Introduced weeds cover the tailings dump and an adjacent area of disturbed ground. Natural revegetation of several species of native vegetation has occurred on the older tailings, but the newer tailings are largely bare and subject to wind erosion.

Mangroves form the base of detrital food chains, and the mangrove ecosystem is a highly productive one. Tidal movement is required to distribute nutrients within the system. They can act as a useful nutrient sink, helping to prevent eutrophication. The mangroves at Bunbury appear to be surviving well despite the change in the salinity regime caused by the building of the Inner Harbour.

Waterbirds are abundant at certain times of the year, feeding on a wide range of invertebrates in the saline pools, the tidally flooded samphire flats and the tidally exposed mudflats. The saltmarsh serves as a storm refuge for the birds and a possible breeding area for some species.

The people of Bunbury have a strong expectation that continuous public access to foreshores will be provided. Aquatic recreational facilities will be placed under increasing pressure as the population of the south west and the number of holiday-makers increases. The new Koombana Drive entrance to the city centre will inevitably attract more visitors to the Koombana Park area. A dual-use path is planned to pass through the area.

RECOMMENDATIONS

1 Reserve for Recreation:
- That part of Reserve C 28034 covered with tailings and north to the old road.
- That part of Reserve C 28034 between the tailings and the shoreline.
- That part of Reserve B 5275 that lies between the old and new alignments of Koombana Drive.
- That part of Reserve 28033 between the shore and the southern access road of the caravan park.
- and all parts to be incorporated into Reserve C 28034.

2 Reserve for Environmental Management:
- Reserve A 12636 - Anglesea Island.
- The parts of Reserve C 28034 that are not overlain with tailings excluding the above areas designated for recreation.
- and the above two parts to be incorporated into Reserve A 12636.

3 Vest the areas reserved for Recreation and for Environmental Management in the City of Bunbury to be managed in accordance with this management plan.

4 Direct public access mainly to the elevated area at the eastern end of the reserve, leaving the more ecologically sensitive areas relatively free of visitors.

5 Direct resources towards public education of conservation needs rather than towards the construction of physical barriers to human movement.

6 Restrict jet skis from the area.

7 Restrict vehicle access to the Koombana Drive perimeter of the Recreation Reserve. Details to be in accordance with the Landscape Master Plan.

8 Construct public toilet facilities to the north of the access road if user surveys indicate a need for them.

9 Revegetation to be undertaken in accordance with the Landscape Master Plan developed by WG Martinick and Associates Pty Ltd for the South - West Development Authority.

10 Control weeds in a selective way, taking into account the biology of each species, rather than by broadscale spraying or digging.

11 Dredge a 20 metre wide channel to restrict public access to The Blunders. Construct the channel to prevent 4WD and motorbike access and to ensure the channel will not dry out. The Blunders to become effectively an island similar to Anglesea Island.

12 Construct a lookout and birdhide in accordance with the Landscape Master Plan.

13 Construct a dual - use path through the eastern part of the tailings to allow views of the Inlet, connecting with Bunbury to the west via the disused road and Koombana Bridge, and to the east alongside Koombana Drive.

14 Establish an interpretation programme to provide information about the natural history, ecology and conservation significance of the area. Include signs, pamphlets and displays.

15 Undertake an independent radiological survey of the tailings site in consultation with the WA Radiological Council to determine the degree of safety for visitors.

16 Maintain present tidal regime by judicious use of the tide gates.

17 Avoid large-scale earthmoving works that would cause silting of the inlet.

18 Keep interference to the saltmarsh and mudflat areas to a minimum, so that good drainage and the correct gradients of banks are maintained.

19 Continue the present regime of mosquito control using opportunistic larvicide application and continual refining of the channel system, subject to the direction of the Leschenault Inlet Management Authority in accordance with the monitoring programme results.

20 Undertake biological and social monitoring as required by LIMA and the Bunbury City Council. Interpret and use as a guide to future management.

21 Ongoing management of the reserve should be undertaken by the City of Bunbury. A committee comprising LIMA, CALM and the City of Bunbury will be established to provide advice on proposed activities that are not outlined in the management plan.

22 Creation of additional facilities should be provided only after public needs and potential environmental impacts have been properly evaluated, and only if they are compatible with the objectives of the management plan.

23 Timing of the implementation of the Management Plan should be undertaken as follows:

- Public Consultation.
- Land vesting and reserve tenure.
- A list of priorities drawn up.
- Implementation in order of priority as funds become available.

(Plate 1 : Rushes)
Rushes and sedge prevent foreshore erosion and provide habitats for waterfowl.

(Plate 2 : Proposed Channel)
A channel will be created to effectively isolate the mangroves from direct human disturbance.

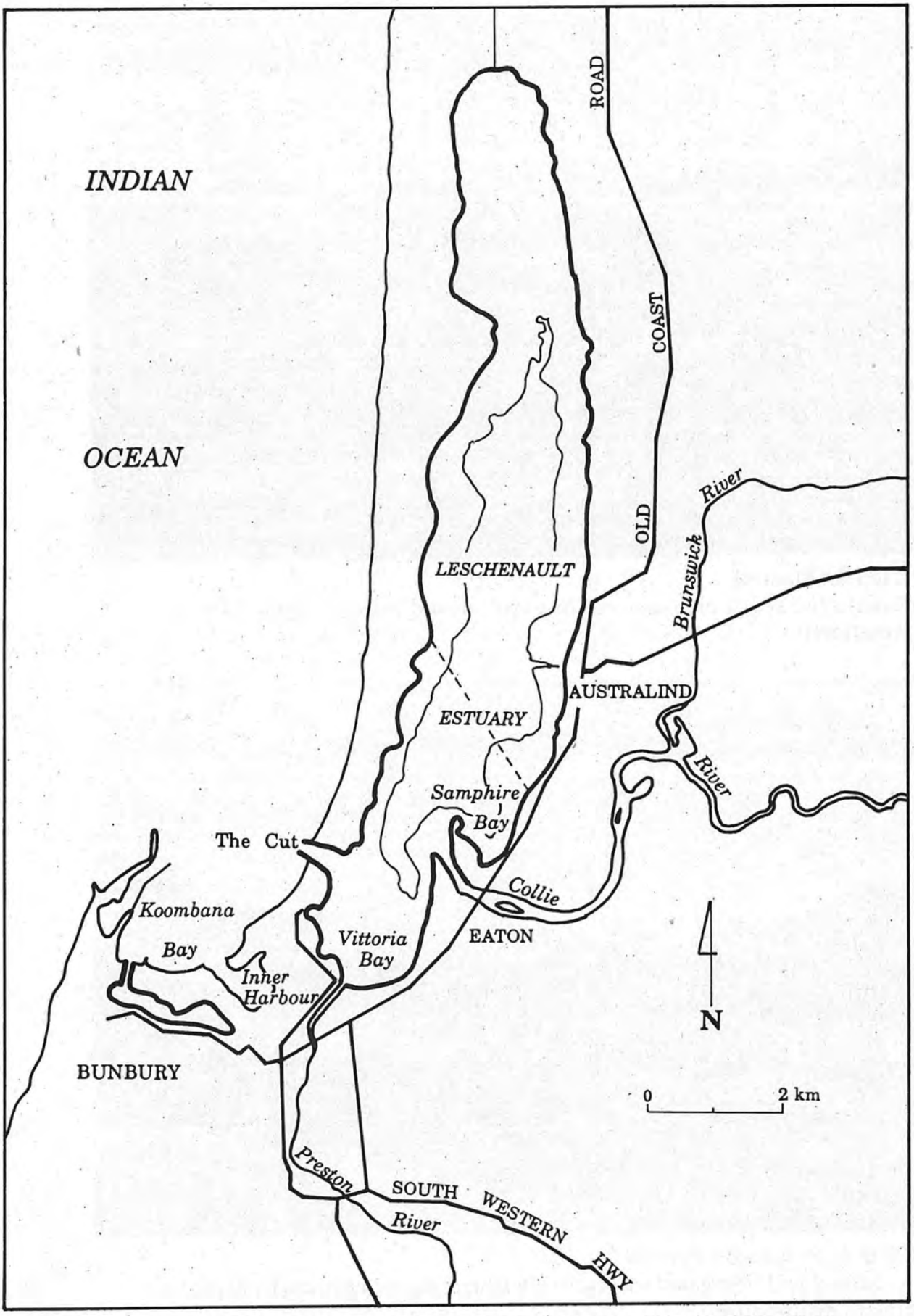


FIGURE 1 GREATER LESCHENAULT INLET, SHOWING THE ESTUARY TO THE NORTH AND THE LOWER INLET TO THE SOUTH.

1.0 Introduction

Koombana Park is on the north shore of the Leschenault Inlet, Bunbury, Western Australia. Anglesea Island lies within the Inlet, between Koombana Park and the City of Bunbury. The area consists of low-lying saltmarsh of importance to waterbirds, remnants of a dune system, and a mangrove community of special significance (Fig. 1).

A great many artificial changes have been made to the landscape since European settlement, including alterations to the structure of the inlet/estuary system and the dumping of tailings from mining operations onto part of the area. This has resulted in significant changes to the natural environment.

In 1983 it was recommended that the area be reserved for conservation purposes (DCE 1983). Since then, a new major road has been built as a "gateway" to the City of Bunbury.

A new "Harbour City" concept has led to plans for major redevelopment in this "gateway" area (Gianfranco Rasile 1990). Part of that concept is to manage the Koombana Park/Anglesea Island area for conservation, education and recreation - the mangroves and saltmarshes would be protected while the public would be able to enjoy the area and learn about its ecosystem without causing damage.

Several concept plans have been considered for the management of the area. This study, set up on the initiative of the Leschenault Inlet Management Authority, brings those ideas together to create a management plan that will ensure the protection of the natural attributes while allowing for public education and enjoyment.

1.1 Nomenclature

1 The name of the water body north of the Inner Harbour, which connects the Collie and Preston Rivers with the sea, is "Leschenault Estuary"

2 The name of the water body south west of the Inner Harbour between Bunbury and Koombana Bay is "Leschenault Inlet" (sometimes referred to as "the Inlet" in this document).

3 Koombana Park Reserve as proposed in this document includes:
   a) Reserve A12636 - Anglsea Island,
   b) Reserve C28034 - The Blunders west to Kombana Drive and,
   c) The area between the shore and the southern access road of the caravan park, Reserve 28033.

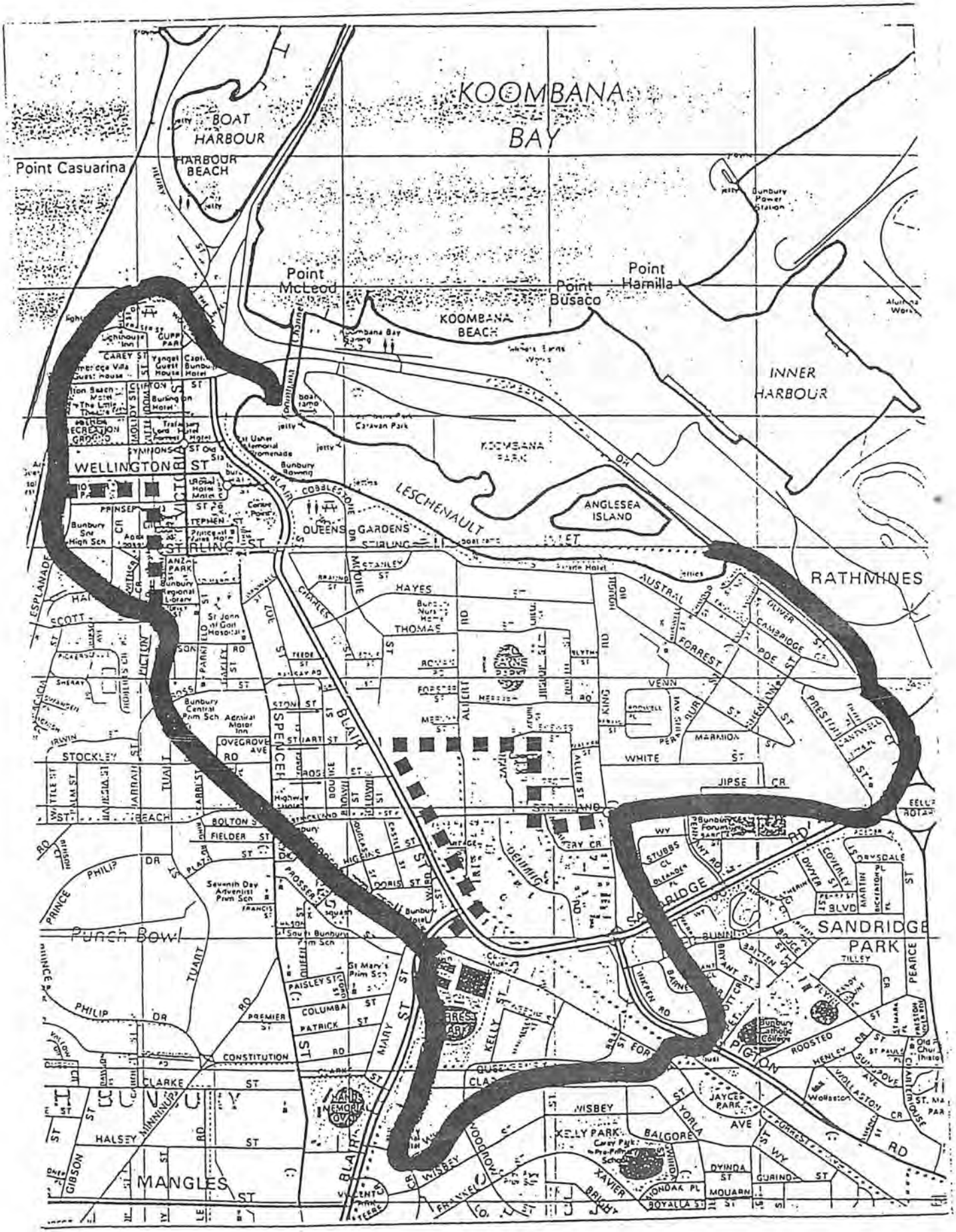


FIGURE 2 STORMWATER DRAINAGE. (FROM BUNBURY CITY COUNCIL)

THE BOUNDARY OF THE AREA THAT DRAINS INTO THE INLET IS SHOWN IN BOLD. THE AREAS WITHIN THAT CATCHMENT WHICH ARE UNSEWERED ARE OUTLINED WITH BROKEN LINES. (SEE SECTION 2.3)

2.0 The Physical Environment

2.1 Location and Climate

Koombana Park lies at the eastern end of Leschenault Inlet which is about 2 km long. The area overlooks the Inlet and the City of Bunbury to the south, and Koombana Beach and the Indian Ocean to the north (Fig.1).

Bunbury, with a population of 26 000, is a large, growing centre of population in the south west region of Western Australia. Lying on the west coast at 33^0 16' South, it has a mild Mediterranean climate with an annual rainfall of 870 mm. Westerly winds predominate in the summer.

The site covers about 42 ha, about 12 ha of which is water and 30 ha land. Maximum dimensions are about 1200 m from east to west and 500 m from north to south. It is bounded by Koombana Drive to the north and east and the Koombana Caravan Park to the west, and includes Anglesea Island and part of Leschenault Inlet to the south.

2.2 Geomorphology

Koombana Park is situated on part of the Quindalup Dune System (Glover 1980) which consists of recent calcareous sands that have formed along the beaches in the last 10 000 years (Seddon 1972). Remnants of these dunes are still evident here, even though the landscape has been highly modified. The Inlet separates this young beach-and-dune system from the Bassendean Dune System. The City of Bunbury is situated on these older, grey, leached sands. The low-lying "Blunders" area and Anglesea Island are mudflats composed of 10-30 cm of clay overlying sand, bordered along the Inlet by a narrow sandy beach. Behind the beach in some places is a small sand dune or levee (<1 m high).

Deposits of mineral sands occurred along old beach lines at Koombana Bay, and have been mined. Tailings from the separation plant, after the mining of these minerals, have been deposited over sand dunes and mudflats immediately to the north and east of Merredith Creek to a depth of about 2 m, and have truncated the creek. Where the creek enters the Inlet there are sandbanks which are exposed at high tide.

2.3 Hydrology

As a result of the artificial changes to the landscape (see Section 3.1), the Inlet is now a tidal arm of the sea which has been deprived of the annual winter injection of fresh water which it received in earlier times. The only fresh water intake now is from local runoff and groundwater seepage (these have not been quantified), and from municipal stormwater drains.

2.3.1 Drainage

There are eight catchment areas in the City of Bunbury which drain into the Leschenault Inlet, of which four are pump-assisted (Fig.2). This amounts to 480 ha of urban catchment draining into about 40 ha of Inlet.

The principal consequences of urban drainage are:

1 Dilution of Inlet water in winter.

2 The high phosphorus level of the Inlet water (see Section 2.4).

Most of the catchment area is sewered, but there are two areas within the catchment that area not :

1 An area north of Wilson St, east to Barnes Crescent, and north to include the entire industrial area of Denning Rd.

2 A very small area immediately north and east of Bunbury Senior High School.

It is possible that the nutrients from septic tanks in these areas may contribute to high phosphorous levels in the Inlet. (This assumes that shallow groundwater flow corresponds with stormwater drainage patterns, which may not always be so.) However, since the unsewered areas are relatively small, it is probable that runoff from lawns and gardens treated with fertiliser is the main cause.

2.3.2 Tides

Tide charts show a maximum range of exactly one metre at Bunbury, although this can be modified by storm surges. The tidal regime of the Inlet is similar to that of the ocean, and there is a good water exchange with the ocean. The flood gates at the artificial entrance do not significantly impede the normal tidal exchange (LIMA 1985). Some of the saltmarsh flats at the site are periodically inundated by the tide.

The flood gates were installed in about 1981 to prevent any flooding caused by storm surges. They are closed by an officer of the Marine and Harbours Department when the tide reaches 1.35 m above the low water mark, or in anticipation of a surge. Since winter storms bring rain as well as wind, and a closed gate prevents escape of stormwater that is fed into the Inlet, gate closure can exacerbate flooding instead of reducing it. A volume of 40 000 m^3 of stormwater discharge will raise the water in the Inlet by 10 cm (LIMA 1985).

2.3.3 Depth

Before dredging most of the Inlet ranged from 1 to 2 metres below mean tide level, with some deeper water down to 3 m in the central reaches near the south bank. A channel has now been dredged for a rowing course, which extends for almost the full length of the Inlet, passing south of Anglesea Island. About 4 ha of sandbank occurs along the north shore of the Inlet at the mouth of Merredith Creek, averaging about 40 cm above mean sea level. This is exposed at low tide.

2.4 Water Quality

Water quality sampling is carried out by LIMA on a regular basis. Three midstream sampling sites are used on the Inlet. Samples are taken at surface and depth.

The **salinity** of the Inlet ranges from slightly hypersaline in the summer months, averaging about 36.7 parts per thousand (ppt) (103% sea water), down to varying levels during winter due to dilution. The lowest average winter reading was 28.1 ppt (79% sea water) opposite the mouth of Merredith Creek. Stratification occurs in winter but not in summer.

Total **phosphorus** levels, sampled between 1984 and 1988, ranged from 0.02 to 0.08 mg/l. Vollenweider's classification of trophic levels puts this at mesotrophic to eutrophic, but not severely eutrophic. Concentrations of phosphorus were greater in summer than in winter, and higher levels occurred at depth than on the surface.

Total **nitrogen** levels in June 1988 were between 0.38 and 0.57 mg/l. This range is below Vollenweider's oligotrophic state of 0.66mg/l, suggesting that nitrogen levels are not a problem. However, it is based on a single sampling day only.

Chlorophyll 'a' was sampled in June 1988 also. Levels were between 3 and 4 µg/l, which is meso-oligotrophic, and shows that there was no excessive growth of phytoplankton on that day.

pH ranged from 7.9 to 8.3, compared with normal sea water pH of 8.2.

Water temperatures at the surface range from about 15 ^{0} C in winter to between 23 ^{0}C and 29 ^{0}C in summer in the Inlet. This can be compared with an annual marine temperature at Bunbury (Schwinghammer 1978) of 16 ^{0}C to 21 ^{0}C. The shallower eastern end of the Inlet has a mean temperature about 1.5 ^{0}C higher than the western end.

2.5 Radiation Levels

A significant proportion of the proposed Koombana Bay reserve is overlain by secondary tailings from the Cable Sands mineral processing plant. The tailings constitute the waste fraction of the silicious sand separation process. It contains traces of ilmenite, zircon and monzonite. The radioactive isotope thorium 232 is contained in the mineral monzonite.

Cable Sands completed a systematic gamma survey of the tailings dump in 1989, which was subsequently updated in 1991. The results described in Table 1, show a highest recoded reading of 0.50µGy/hr with an average of 0.34µGy/hr (Cable Sands, 1992).

Table.1 :

Tailings Dump Gamma Radiation Suvey Results 1991

Mean	0.34 ± 0.07 μGy/hr
Max. Level	0.05μGy/hr
Min. Level	0.15μGy/hr

These readings can be compared with the guidelines proposed by the Radiological Council as maximum acceptable levels of gamma radiation for various degrees of use. These guidelines, shown below, are expressed in micrograys per hour (μGy/h), which is a measure of the absorbed dose rate, and is numerically equivalent to a dose rate measured in microsieverts per hour (μSv/h) for gamma radiation. These are based on a maximum acceptable background level for W.A. of 0.35 μGy/h..

	Percentage occupancy	Levels (μGy/h)
Dwellings	100%	0.46
Schools	50%	0.57
Other areas	25%	0.79
Roads	10%	1.45

The mean figure of 0.34 ± 0.07μGy/hr suggests that the tailings area is within acceptable limits for the purpose of recreation.

A layer of sand 17cm thick is said to reduce gamma radiation by 50%. To cover the area with sand of that depth would bring the figure down to a maximum of 0.17 μGy/h. However, sand is subject to rapid erosion, and organic processes can mix soil layers over time, so that such shielding is not considered to be effective in the long term.

Apart from direct gamma-ray irradiation, there are two other possible exposure pathways to the body. One is through the lungs which can be from inhalation of either dust or radon/thoron gas and the other is by ingestion of food or water.

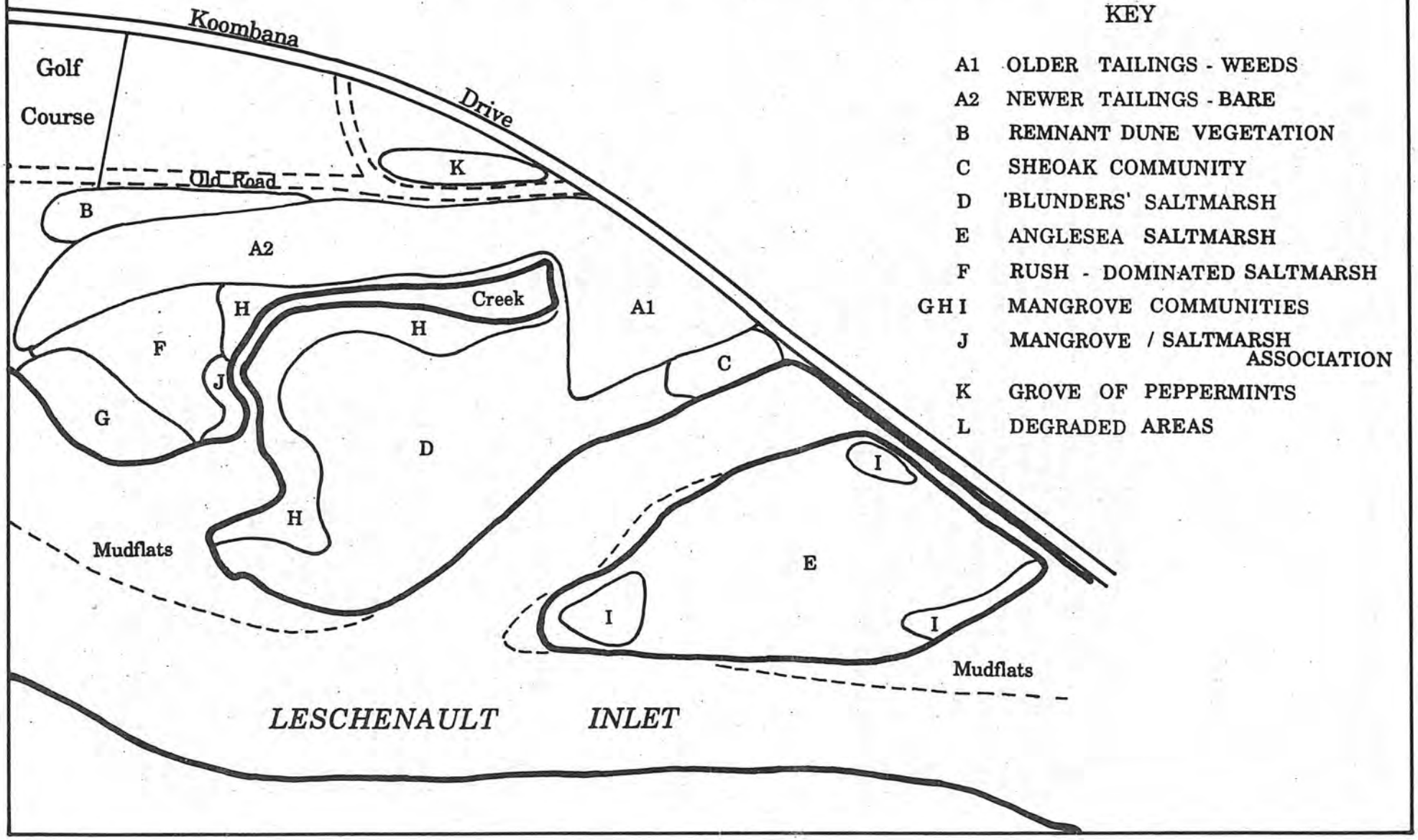
There is the question of whether radioactive isotopes could enter aquatic food chains via leachates or runoff from the tailings, or from dust blowing into the Inlet.

If radioactive substances entered the creek or Inlet, they could become concentrated in higher-order predators through the process of bio-amplification, and in the filter feeders such as bivalves which process large quantities of water. It is possible therefore, that fish, crabs, mussels and other seafood caught in the Inlet may have radioactivity levels that are higher than normal because of substances derived from the tailings. If this could occur, then it would be exacerbated by any disturbance to the tailings that caused large amounts of the material to enter the water.

The radioactive isotope in the tailings, thorium 232, has a daughter-product, radium 228, which is highly soluble and has a short half-life. However, the thorium 232 itself has low solubility and a very long half-life, and is locked within the monazite crystals, so that even its daughter-products are unlikely to escape. Therefore it is unlikely that the thorium 232 or its daughter-products would enter the food chain in any significant quantities (Kerrigan 1988).

Nevertheless, there remains the possibility that levels dangerous to human health could accumulate in seafood, and it would be prudent to monitor levels of radioactivity in the Inlet. Bivalves may be good indicator species to monitor since they filter large amounts of water, and crab shells may be suitable, since some crabs eat mussels, and it is likely that radium 228, if ingested by a crab, will accumulate with the calcium in the shell.

FIGURE 3 VEGETATION COMMUNITIES



KEY

A1	OLDER TAILINGS - WEEDS
A2	NEWER TAILINGS - BARE
B	REMNANT DUNE VEGETATION
C	SHEOAK COMMUNITY
D	'BLUNDERS' SALTMARSH
E	ANGLESEA SALTMARSH
F	RUSH - DOMINATED SALTMARSH
G H I	MANGROVE COMMUNITIES
J	MANGROVE / SALTMARSH ASSOCIATION
K	GROVE OF PEPPERMINTS
L	DEGRADED AREAS

3.0 The Biological Environment

3.1 Vegetation

3.1.1 Vegetation Classification

Fig. 3 shows the distribution of the vegetation types at the site. The twelve areas (A) to (L) shown on the map can be grouped into nine main vegetation types.

1 Tailings dump (A1 and A2)

The tailings are yellowish sands containing dark, glistening particles, from Cable Sands' separation plant. Parts of the deposit have been covered with woodchips.

The older section at the eastern end (A 1) has a covering of naturalised alien plants such as rhizomatous grasses, lupins, *Sonchus* and other flatweeds, soursob, clovers, fennel, *Trachyandra divaricata* and *Pelargonium capitatum*. Native herbs include *Senecio lautus* and *Suaeda australis*. A row of *Agonis sp.* has been planted along Koombana Drive. About 20 *Casuarina obesa* saplings are growing on the tailings, presumably self-seeded from the mature trees along the foreshore. A number of the shrubs *Olearia axillaris, Acacia saligna* and *Acacia cochlearis* occur near the western edge of this section. The last four are native shrubs and trees that have established themselves by seed on this older portion of the tailings dump. Several mature weeping willow trees (*Salix babylonica),* from early plantings, have survived partial burial by the tailings.

The newer section of the tailings (A 2), extending to the west, has little plant cover. Much of it is completely bare or covered sparsely with couch grass and subject to wind erosion. At the western end is a group of introduced trees that were planted several decades ago. These are the Japanese Pepper, the Poplar and *Erythrina.*

2 Remnant coastal dune vegetation (B)

The steep, northward-facing slope of the tailings area is a remnant of a sand dune that existed before the tailings were deposited. Vegetation on this slope is of the Quindalup Coastal Dune Complex and includes *Alyxia buxifolia, Spyridium globulosum, Acacia cochlearis, Hardenbergia comptoniana, Cakile maritima, Lepidospermum gladiatum, Acanthocarpus preissii, Trachyandra divaricata* and *Scaevola crassifolia.*

3 Sheoak community (C)

This occupies a strip of land about 40 m long between the tailings dump and the Inlet. This is a remnant of what aerial photographs from the 1940s show to be a larger area (>3 ha) of open woodland dominated by *Casuarina obesa.* About 30 of these swamp sheoaks survive at the eastern end of the strip, with dead trees near the western end. The understorey includes species of *Atriplex, Halosarcia, Sueda* and *Juncus kraussii.* Alien plants include several rhizomatous grasses, *Allium sp.* and a clump of Pampas grass close to the road. Several saplings of the mangrove *Avicennia marina* occur within 3 m of the Inlet.

4 Saltmarsh areas (D)

These are low-lying areas with samphires and reeds, parts of which are periodically inundated by tides.

The area south of the tidal creek, known as "The Blunders" (D), has been dissected by drains to reduce the mosquito-breeding habitat. It is dominated by the prostrate samphire *Sarcocornia quinqueflora,* with patches of *Suaeda australis,* mostly close to the drains, and *Halosarcia indica.* Some *Frankenia pauciflora* occurs also. *Avicennia marina* saplings occur along the Inlet foreshore, within 3 m of the drains, and across the northern part of this area of saltmarsh. Mature mangroves line the creek to the north and west of the area, and surround two small water bodies in the western portion. A strip of saltmarsh (about 50 m wide) along the eastern edge of the Blunders is dominated by *Juncus kraussii* , with some *Isolepis nodosus* near the bank of the tailings dump, and a clump of *Typha orientalis* in the north east corner.

5 Anglesea Island (E)

This area has similar saltmarsh covering about 90% of its area. This was not investigated in detail.

6 Saltmarsh (F)

The area of saltmarsh (F) west of the creek has a very different character, with *Isolepis nodosus* and *Juncus kraussii* predominating. At the north west corner is a body of water and near the southern end of the area is an "island" of sand up to 1.2 m high. This sand contains shells of a marine gastropod *Carpobrotus*. *Halosarcia indica* and *Senecio lautus* are some of the plants occurring in the sandy section, with a few shrubs of *Eremophila* and *Exocarpos*. This sandy section has a greater diversity of plant species than the surrounding saltmarsh areas.

7 Mangrove areas (G H I J)

These occur in the western section (G), along the tidal creek (H) and in several patches on Anglesea Island (I). There is a distinct area (J) which is dominated by *Suaeda* and interspersed and surrounded by *Avicennia marina*. Some of the mangroves on the western (landward) side of this area have dead branches. This is the only evidence of morbidity among the mangroves of the Inlet. *Avicennia* at Leschenault Inlet grows as a small gnarled tree or large shrub up to about 4 m high. There is no understorey below the mangroves - only seedlings or young saplings of *Avicennia* itself growing sparsely among the pneumatophores of the parent plants. They are monospecific mangrove stands.

8 Peppermint area. (K)

There is a small grove of W.A.Weeping Peppermint trees (*Agonis flexuosa*) just north of the old road in the north east corner.

9 A degraded area. (L)

This area surrounds the old carpark in the northern section of the reserve. The ground is very disturbed and covered with introduced weeds.

3.1.2 Significance

The greatest diversity of plant species can be found on the undisturbed remnant dune and the sandy "island" in Saltmarsh (F). The older section of the tailings is undergoing natural revegetation with alien and native species, including native trees. The younger tailings, being unconsolidated and subject to wind erosion, are in danger of encroaching on the mangroves along the creek.

Several sheoaks have died. These may be in danger because of the small size of the remnant community. Also, the more saline root environment since 1969 (see Section 5.1) may contribute to their apparent demise along the foreshore. *Casuarina obesa* is "salt tolerant, and grows with its feet in brackish water" (Seddon 1972) - not marine water. Sheoaks, however, are spreading onto the higher tailings area. This is surprising, since the area appears to be well-drained.

The saltmarsh areas are of two types - one dominated by samphire and the other by rushes - both of low species-diversity. Alien plants have not encroached significantly on the low-lying areas - only isolated areas of *Typha orientalis,* one clump of Pampas grass and some rhizomatous grasses near the banks of the tailings area. The significance of the mangroves is discussed in Section 4.1. They are growing in monospecific stands and appear, as a rule, to be healthy and increasing in number.

3.2 Fauna

3.2.1 Invertebrates

Over 100 species of aquatic invertebrates occur in the saltmarsh and mudflats surrounding the Inlet. A preliminary study by Halse *et al.* (1989) produced tentative results suggesting that the saline pools and the flooded samphire contain the greatest number of invertebrate species, while the mudflats and tidal channels contain an intermediate number and the mangal the lowest number.

Polychaetes, amphipods, gastropods and bivalves are common in the tidal mudflats, while ostracods, amphipods, gastropods and the larvae of insects including mosquitoes occur in the saline pools in the saltmarsh. Prawns occur in the Inlet, and crabs frequent various habitats including the mangal. The pneumatophores of the mangroves serve as points of attachment for the barnacle *Balanus variegatus* and the Littorinid gastropod *Bembicium melanostomum*.

3.2.2 Fish

The study by Halse *et al* (ibid) found three species of fish in the saltmarsh and mudflats. Fish are often washed into saline pools at high tide and are trapped there until the tide again reaches that level.

3.2.3 Birds

The saltmarsh in this area is an important feeding ground for many species of waterbird. Over fifty species have been observed on the Inlet (DCE 1983). Waterbirds that feed in the area include :

Greenshank
White-faced Heron
Great Egret
Common Sandpiper
Sharptailed Sandpiper
Darter
Little Pied Cormorant
Pied Cormorant
Pacific Black Duck
Grey Teal
Sacred Kingfisher
Nankeen Night Heron
Little Grassbird
Black-winged Stilt
Pied Oystercatcher

See Appendix 3 for scientific names.

A survey of Leschenault Estuary (Ninox 1989) lists 58 species of waterbird, showing their relative abundance at different times of the year and in different habitats. Samphire saltmarsh, pools and shorelines were the habitats where most birds fed. A small number of waterbirds and other birds such as the Brown Honeyeater use the mangroves. Darters and cormorants often use the dead sheoaks and disused power poles for roosting.

Halse *et al (op. cit)* found that Grey Teal and Pacific Black Duck breed in dense beds of sedges. They feed in the saline pools and flooded samphire where ostracods form their main diet. When submerged by the tide, the saltmarsh is a feeding area for ducks, swans, herons and egrets (Schwinghammer 1978).

Whereas the mudflats form the main feeding ground for most of the waterbirds, the saltmarsh serves as a refuge for birds during storms and for waders when their feeding grounds are covered by the tide.

Of significance is the fact that three bird species which feed here are trans-equatorial migrants. These are the Greenshank, the Common Sandpiper and the Sharp-tailed Sandpiper. These small waders breed in the tundra regions of northern Europe and Asia. During the summer thaw, dense populations of insects provide abundant food for the breeding birds and their young. They then fly thousands of kilometres to Southern Hemisphere locations where they feed on tidal mudflats or the retreating margins of lakes during the southern summer. An international agreement in 1974 between Australia and Japan gives these migrant waders legal protection.

Because of the variety of habitats in this area, including rich intertidal feeding grounds, many species of waterbird can be seen within a small area. This is significant, being so close to the City of Bunbury. One study (Ninox 1989) ranks this site as having "very high significance for waterbird conservation".

3.2.4 Mosquito control

3.2.4.1 Biology and Effect

The **saltwater mosquito** *Aedes vigilax* breeds in saline pools in the saltmarsh. This species has been found to occur in high numbers at The Blunders and Anglesea Island, and to be the only mosquito species in significant numbers there (Klemm 1989). It has nuisance value to the residents of Bunbury and is the major carrier of Ross River Virus, which is active throughout Australia, causing Epidemic Polyarthritis in humans.

3.2.4.2 Local Control Strategies

A **Mosquito Control Review Committee** (MCRC) was established by the Waterways Commission in 1984 to evaluate the conservation value and waterbird usage of the estuarine mosquito-breeding areas in the south west of Western Australia, and to assess the environmental impact of various control techniques. The MCRC recognised the conflict between conservation interests and the interests of local authorities wishing to reduce public nuisance and health problems. To facilitate the development of a long term strategy, the MCRC initiated studies into local breeding areas in relation to waterbird usage and researched interstate and overseas developments in mosquito control.

and the interests of local authorities wishing to reduce public nuisance and health problems. To facilitate the development of a long term strategy, the MCRC initiated studies into local breeding areas in relation to waterbird usage and researched interstate and overseas developments in mosquito control.

The MCRC recommended that certain wetlands in the south west - mostly degraded ones - undergo physical modifications such as filling and channelling. It pointed out however, that the use of heavy machinery had the potential to increase the mosquito problem because wheel ruts served as ideal breeding places. Hand filling would often suffice. For other areas it recommended the larvicide Temephos, to be applied by helicopter and timed to coincide with susceptible larval stages. This would be replaced with Bti when it became available. Results would be monitored, including any development of resistance (Klemm 1987).

A Draft Strategy for integrated mosquito control in the Leschenault Estuary region was produced by the MCRC in 1990. It recommended the formation of a Contiguous Local Authority Group (CLAG) to coordinate the task, and the establishment of a Mosquito Control Advisory Committee (MCAC) to administer and advise the CLAG. The strategy is to tackle the problem in six ways: research, land-use planning, education, monitoring, larvicide application and physical source reduction. An interesting finding of the MCRC was a general correlation between the level of disturbance of a wetland and the intensity of mosquito breeding (Waterways Commission 1990).

Channelling was carried out in the Blunders area in 1987 by the Bunbury City Council. A number of problems have arisen including wheel ruts left by machinery, breaching of the shallow clay layer leading to over-draining, and erosion of the banks of the channels. However, monitoring results by the City of Bunbury suggest that mosquito breeding intensity has been reduced at this site. Larvicide application with Temephos has been carried out by the Council also, as part of the State Government's Interim Strategy. Currently, periodic checks on larval occurrence are carried out by the Council, and treatment has not been found necessary for some months.

The best strategy for mosquito control at The Blunders now is to use a specific larvicide (Bti when available) applied opportunistically, in combination with the present channelling system. This would be the most cost-effective in environmental and economic terms in the long run and is being adopted by the Council. If any further modification is found necessary, it should be in the form of hand-dug runnelling.

It must be pointed out that even though an integrated strategy would have fewer environmental impacts than other methods, it would nevertheless reduce an important source of food for waterbirds - the mosquito larvae themselves (see Section 3.2.3). This may be a necessary ecological sacrifice for the health and comfort of Bunbury residents.

(Plate 3 : Mangrove)

Mangroves have a specialised type of root structure which rise above the soil surface to increase the plant's capacity to respire.

4.0 Conservation Significance

4.1 Mangrove Distribution

The presence of a mangrove community at Leschenault Inlet is highly significant. This is because its presence here (together with a small patch at Waterloo Head, 20 km to the north) is the only mangrove community in Western Australia south of the Abrolhos Islands, about 700 km to the north. Mangroves occur commonly around the northern and eastern coasts of Australia, extending in patches around the coast of Victoria and as far as Spencer Gulf in South Australia. In Western Australia they extend from the Kimberleys southwards to Shark Bay and Carnarvon, and on the Abrolhos Islands at 28° 40' South (Semeniuk et al. 1978). Thus the community at Leschenault Inlet, at 33° 16' South, is a very isolated one. Moreover, it is a very small one, with only about 3 ha of mature mangroves.

Pollen analysis suggests that this outlying community at Bunbury is likely to be a remnant of a former southerly distribution of *Avicennia*, rather than a new colonisation (pers. comm. V. Semeniuk).

4.2 Mangrove Productivity

The productivity of mangrove ecosystems is high compared with other coastal and most marine systems. They play an important part as the basis of food chains that support coastal and estuarine fisheries. This community also plays a part in supporting the large waterbird population that feeds on the adjacent mudflats and saltmarsh.

The Mangrove ecosystem is described in detail in Appendix 6.

4.3 Waterbird Habitat

In a study of the Inlet and the Estuary by Schwinghammer (1982), the Blunders and Anglesea Island areas were described as "...possibly the most productive flats for wading birds in the entire estuary." A more recent study (Ninox 1989) ranks the area as being of "very high significance for waterbird conservation" - a ranking in the top 25% of sites in the Inlet and Estuary. The site supports about sixty waterbird species, including three species of trans-equatorial wading birds which are protected by international law. Two or three species of duck may breed in the area.

Since European settlement, habitat for waterbirds on the Swan Coastal Plain has been reduced to a very small proportion of its former area because of drainage for farming and urban development. Nearly 60% of the saltmarsh of Leschenault Estuary have been disturbed (Waterways Commission 1990). The opportunity should be taken to retain the remaining areas in their natural state.

4.4 Genetic Diversity

With continued clearance of land that accompanies population growth it is important that representative samples of vegetation types and their associated fauna be preserved. Not only is worldwide maintenance of genetic diversity of scientific interest and aesthetic and recreational value, but also it may be of extreme value to reserve gene pools if rapid global climate change occurs as a result of the "enhanced greenhouse effect", bringing with it extinction of many species and communities and expansion of other communities.


FIGURE 4
KOOMBANA BEACH
KOOMBANA DRIVE
Golf Course
Old Carpark
A 28033
Caravan Park
Remnant Dune
Tailings Dump
Saltmarsh
Tidal Creek
Saltmarsh
Mangroves
Mangroves
Tailings Dump
Sheoaks
Cable Sands
Mineral Sands Separation Plant
RAILWAY
INNER HARBOUR
Woodchip Stockpile
Tidal Mudflats
Channels
Saltmarsh
THE BLUNDERS
Mangroves
A 12636
ANGLESEA ISLAND
Saltmarsh
Recreation
Mangroves
Mudflats
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SCALE 1:3500
0
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LESCHENAULT INLET
SYSTEM 6 RECOMMENDATION C 68

5.0 Development and Management

5.1 History of the Leschenault Inlet

Originally, Leschenault Inlet was an estuary which received the Collie and Preston Rivers and flowed into the sea at the western end of Koombana Bay. In 1951 this original estuary mouth at Point MacLeod was "plugged", and a new entrance was cut, opposite the mouth of the Collie River.

The development of the Bunbury Inner Harbour has divided the original estuary into two completely separate parts (see Fig.1). The two sections have been separated since 1969 when reclamation for the Inner Harbour began. What used to be known as Leschenault Inlet is now composed of :

1 **Leschenault Inlet** (or the Lower Inlet) was originally the lower reaches of the estuary. It is now merely an arm of the sea about 2 km long, connected to the sea near the original mouth via Koombana Channel. This artificial channel contains a flood gate or storm surge barrier to control flooding resulting from very high tides and storms.

2 **Leschenault Estuary**, which is the northern section. The Collie River flows into it, and the Preston River has been diverted into it. This section is connected to the sea by the artificial opening known as The Cut.

Anglesea Island, about 100 m offshore in the Inlet, has been truncated by the development of the Inner Harbour and the construction of Koombana Drive. A channel has been dug between the island and the road.

There is an L-shaped tidal creek (Merredith Creek) about 500 m long running into the inlet. The area of saltmarsh between this creek and the Inlet is known as The Blunders. This low-lying area has been dissected by a series of channels which have been dug to reduce the amount of standing water available for mosquito-breeding. The main drain has been lined with sandbars near its opening to the Inlet.

A large section of the site to the north and east of Merredith Creek (about 7 ha) has been overlain by a deposit of tailings from the processing of mineral sands by Cable Sands Pty Ltd. A slurry of this waste sand was piped to the site from a separation plant which lies to the north-east of Koombana Drive, adjacent to the Inner Harbour. This pipe was operating as late as 1985 (Koeyers 1985). The bed of tailings raises the level of the land by about 2 m. The tailings dump has truncated the tidal creek at its eastern end.

The coastline of Koombana Bay has changed considerably over the years, presumably from alluvial deposition due to the construction of the breakwater in 1898, which effectively extends Casuarina Point for more than a kilometre. During the interval between 1826 and 1920, the beach at Koombana Bay extended about 200 m further northwards almost doubling the width of Leschenault Peninsula at its southern end adjacent to Anglesea Island (LePage, 1986).

The body responsible for the management of these water bodies is the Leschenault Inlet Management Authority (LIMA), a twelve-member body that operates within the Waterways Commission. LIMA is charged with the task of balancing the competing demands of use and development with the need to maintain a healthy, functional estuarine environment for present and future generations.

5.2 Current Vesting and Land Use

The current vesting of the area is illustrated in Fig 4 and listed below.

1 Reserve C 28034 (recreation).

2 Reserve A 12636 "Anglesea Island" (recreation).

3 Part of Reserve 28033 (Recreation and Aquatic Sports).

4 That part of Reserve B 5275 (Harbour Extension and Industrial Purposes) that lies between the old and now alignments of Koombana Drive.

5 The area of water that includes all the mudflats and the channel between Anglesea Island and the mainland. All of this land is currently vested in the City of Bunbury as a Recreation Reserve.

6 Reserve C 28033 is currently leased as a caravan park.

7 A large portion of Reserve C 28034 has been used to dump tailings under an agreement between Cable Sands Pty Ltd and the Bunbury City Council.

8 In the northern part of the reserve (part of B 5275) is a portion of a public golf course and also a closed road and carpark that are rarely used.

The saltmarsh area has been subject to mosquito control measures including the excavation of channels to flush areas of standing water. Wheel marks are evidence of the occasional use of vehicles in the saltmarsh. The Inlet is used for fishing and the collection of bivalves for bait. Apart from the golf course and the portion of the caravan park, the area as a whole is rarely frequented by people.

5.3 System 6 Recommendations

In 1983 the Department of Conservation and Environment (Now the Environmental Protection Authority (EPA)) identified areas throughout the state worthy of conservation. Areas in the Darling System and Swan Coastal Plain are listed in the Conservation Reserves for Western Australia System Report 6.

Figure 4 shows the area delineated in the System 6 Report as C 68 Anglesea Island (DCE 1983). The report recognises the significance of the mangrove community and the importance of the saltmarsh areas for waterbirds. It recommends that Reserve A 12636 (Anglesea Island) be amended to Conservation of Flora and Fauna and be vested in the W.A.Wildlife Authority. It also recommends that-

1 The Vacant Crown Land area of water,
2 The southern portion of Reserve C 28033, and,
3 Reserve C 28034 (except the eastern section of the tailings)
- be added to A 12636 (Anglesea Island).
(Note: The eastern arm of the tailings did not exist at the time.)

These recommendations have not yet been implemented.

5.4 History of Planning Proposals

1 The City of Bunbury **Town Planning Scheme** No.6 declared that the north shore of the Inlet be predominantly reserved for recreation, access from the city centre be established and industrial activity not be permitted.

2 The "**System 6 Report**" in 1983 recommended that a section of the north shore be reserved for conservation.

3 In 1983 the Leschenault Inlet Management Authority (**LIMA**) developed a **management proposal** that included the north shore of the Lower Inlet or "Koombana Park" area. It recommended that ". . . the existing dumping of waste cease and the area of landfill. . . be landscaped using natural vegetation". The mangrove area was to be conserved and boardwalks established for recreational and educational purposes. The mangrove and saltmarsh area was to be reserved as a "natural sanctuary" and the area north of the old road was to be re-zoned "Recreational", with parking facilities among the peppermint trees in that area. The entire north shore area was conceived as a future "city park" including commercial areas with motels and restaurants, recreation areas and boating in the Inlet (LIMA 1983).

4 In 1984 a **traffic study** commissioned by the City of Bunbury recommended a new access road to the city centre and that a bridge be built across Koombana Channel for this purpose.

5 "An Investigation into the Lower Inlet" was published by LIMA in 1985. This included the "**Hoborough Plan**", which proposed that a new island be created by digging a channel to isolate the large area of saltmarsh ("The Blunders"). Also envisaged was a system of boardwalks, two carparks with toilets, the re-shaping of some shorelines and the landscaping of the tailings area for beautification and visual screening. An information centre and new LIMA headquarters were suggested. A motel/boatel and other recreational facilities would replace the adjacent caravan park.

caravan park.

6 A **study of the Bunbury Central Area** in 1985 proposed intensive tourism development on the north shore of the Inlet and greater use of the Inlet by small boats. It described the proposed Koombana Drive as an "exciting approach to the city centre".

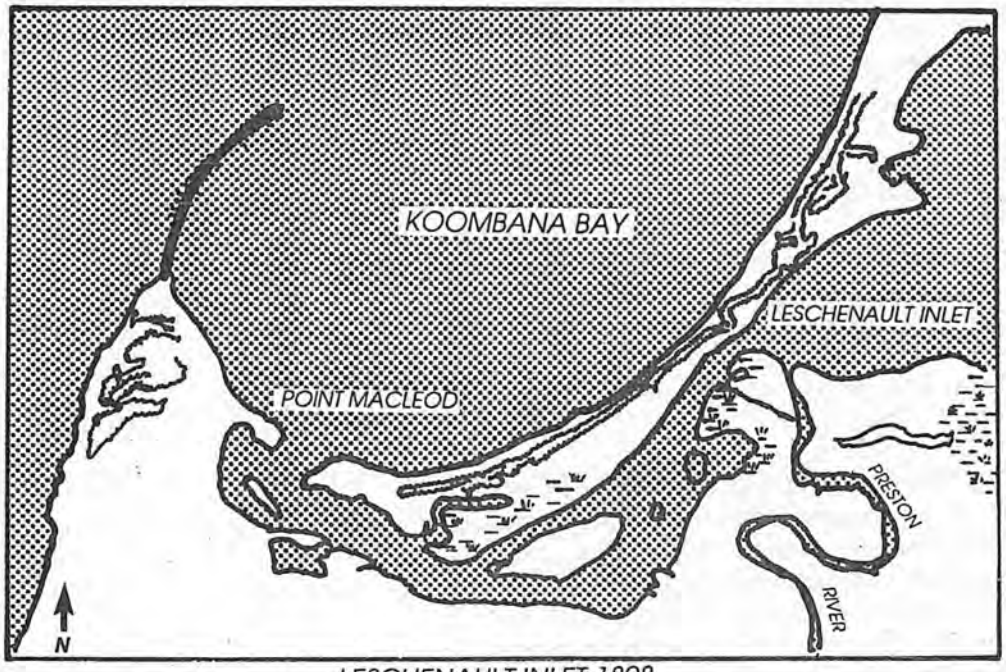
7 In 1986 the **Bunbury Region Plan** proposed a bridge across Koombana Channel and an upgrading of Koombana Drive. The result was the new Koombana Drive and Bridge which have now been built.

8 The **"Bunbury Harbour City"** concept plan is proposed by the South West Development Authority. The plan involves redevelopment of a large section of the Outer Harbour and the North Shore for a marina/resort complex. As part of the plan, a "holiday village" will be established at the caravan park site and the boating clubs upgraded. A network of small parks is part of the landscape design.

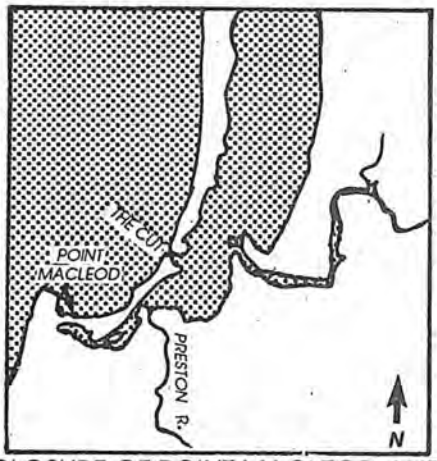
There is an emphasis on improving the "entrance statement" or "sense of arrival", with Norfolk Pines as a strong visual feature of the area as well as a windbreak. Koombana Beach will be retained as a major recreational beach The adjacent mangrove area, seen as complementing the Bunbury Harbour City project, is to be retained as a conservation park and to provide an environmental and educational asset for the community.

9 In 1990 the South-West Development Authority contracted **WG Martinick and Associates Pty Ltd** to develop a Landscape Master Plan for the Koombana Park area. The WG Martinick proposal forms the basis of this management plan's landscape objectives. A copy of the architect's impression of the Inlet's northern shore is included in Appendix7.

Figure 5



LESCHENAULT INLET 1898



CLOSURE OF POINT MACLEOD AND INSTALLATION OF THE CUT 1951

ALTERATIONS TO THE LESCHENAULT INLET

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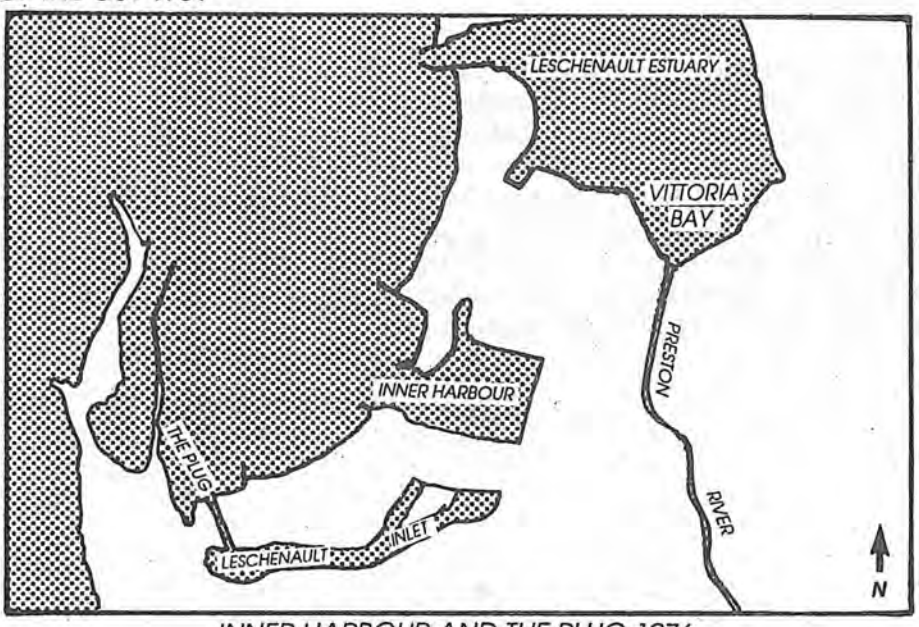


INNER HARBOUR AND THE PLUG 1976.

6.0 The Social Environment

6.1 Demography

Bunbury and its environs constitute the major residential and industrial centre for a large section of the lower south-west of WesternAustralia. Its population has grown from 23 000 in 1986 to 26 000 in 1990. The small "satellite" centres in the Bunbury district - Eaton, Australind, Gelorup and Clifton Park - add another 25% to the population. The average age of the population is increasing. The south west region as a whole is growing rapidly - its population was 119 000 in 1986 and is expected to reach about 250 000 by the end of the century (Gianfranco Rasile 1990).

Bunbury attracts tourists and holiday-makers during the summer months. The average length of stay for visitors is about four nights, and January is the most popular month.

6.2 Recreation

Bunbury people enjoy a diversity of aquatic activities. These include fishing, prawning, crabbing and collecting worms and shellfish for bait. Sailing and powerboat activities are popular, as well as swimming, surfing and skindiving.

Adjacent to Koombana Channel in Leschenault Inlet is a power boat club with a boat ramp, a jetty and wash-down facilities. To the east of this is the caravan park which abuts the study area. On the southern shore of the Inlet there is a rowing club with a dredged course that extends the length of the Inlet. East of that is a sailing club with three jetties and further east again is the Stirling Street boat ramp and several smaller jetties.

Koombana Beach is a safe swimming beach for families. This beach has become a special attraction because of the appearance of dolphins close to shore. Dolphins are being encouraged to the area by the Bunbury Dolphin Trust. The "Back Beach" to the west of the town attracts swimmers and surfers to rougher waters.

A dual-use path is planned to pass through the area as part of the Greater Bunbury Bikeplan.

Because of the expanding population of Bunbury and its increasing tourist flux, it is likely that foreshore facilities will be put under increasing pressure. This makes it more important than ever to manage the foreshores carefully. Management should allow the public to use and enjoy the water bodies while minimising the impacts of those recreational activities on the environment.

Part of LIMA's management plan has been to establish foreshore reserves around the waterways as buffers to help conserve the estuarine ecosystems. Conservation of the mangrove and saltmarsh areas at Koombana Park and the revegetation of the degraded areas there would help continue that buffer zone across to the Inlet.

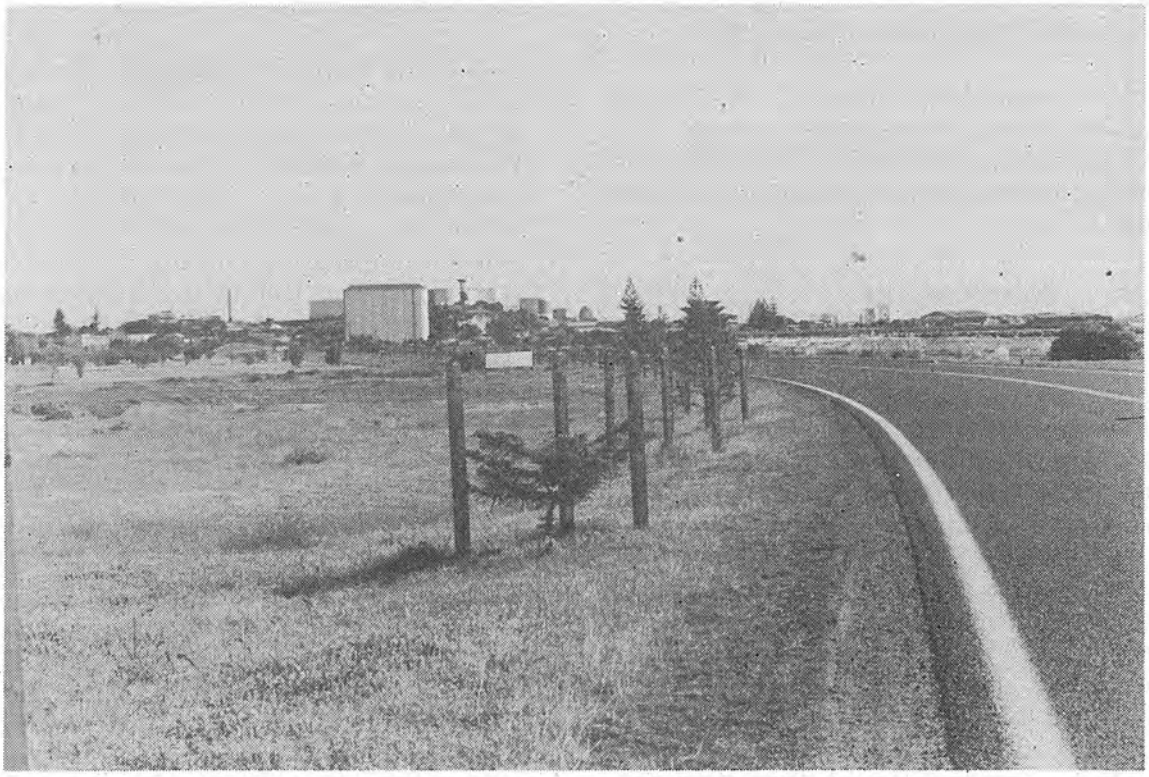
The development of the new Koombana Drive as the "front door" to Bunbury provides greater opportunities for the use of Koombana Beach by visitors to the town. If Koombana Park was developed for recreation it could also become a stopping point, where visitors entering the town could rest or picnic or look at the mangroves and the waterbirds and the views of Bunbury across the Inlet.

6.3 Cycling Facilities

At present there is a dual-use path for pedestrians and cyclists along the southern shore of the Inlet from Hale Street to King Road. The Greater Bunbury Bikeplan (Bikeplan Study Team 1986) proposes a high standard, segregated dual-use path along the foreshore on the north side of the Inlet, to carry both recreational and commuter bicycle traffic from the Koombana Channel to the western end of Oliver Street. The western end of this path would connect to the city centre by a path along the south side of the bridge over Koombana Channel, with access to Koombana Beach under the abutment of this bridge. The eastern end of the path, near Oliver Street, would be linked to the Old Coast Road as part of a plan to link Bunbury and Australind with safe cycling facilities. On-road cycling facilities would then be constructed to connect Oliver Street, via Oxford Street and Austral Parade, to the existing path at the northern end of King Street.

The result would be a recreational cycling- and - walking path around the Inlet. At the

same time it would give cyclists commuting between Australind and Bunbury two alternative routes from the city centre to Old Coast Road.



(Plate 4 : Entrance Statement)
Norfolk Pines have been planted beside Koombana Drive to create an entrance statement to the City of Bunbury.

7. AIM AND OBJECTIVES

Aim

'To develop and manage Koombana Park and Anglesea Island as a Reserve for conservation, education and low-impact recreation'.

Objectives

1 Recognise the special significance and isolation of the mangrove community and its importance in the food chain and nutrient sink.

2 Recognise the importance of the saltmarsh as feeding and breeding habitat of waterbirds including trans-equatorial migrant waders.

3 Enhance the conservation, aesthetic and recreation values of the area.

4 Protect the existing ecosystems from damage and degradation.

5 Provide opportunities for walking, picnicking, viewing and general enjoyment of the area.

6 Provide facilities to help the public understand the ecosystems and their significance and to gain knowledge of the flora and fauna of the area.

(Plate 5 : Samphire)
Samphire marsh functions as an effective nutrient trap and organic recycler.

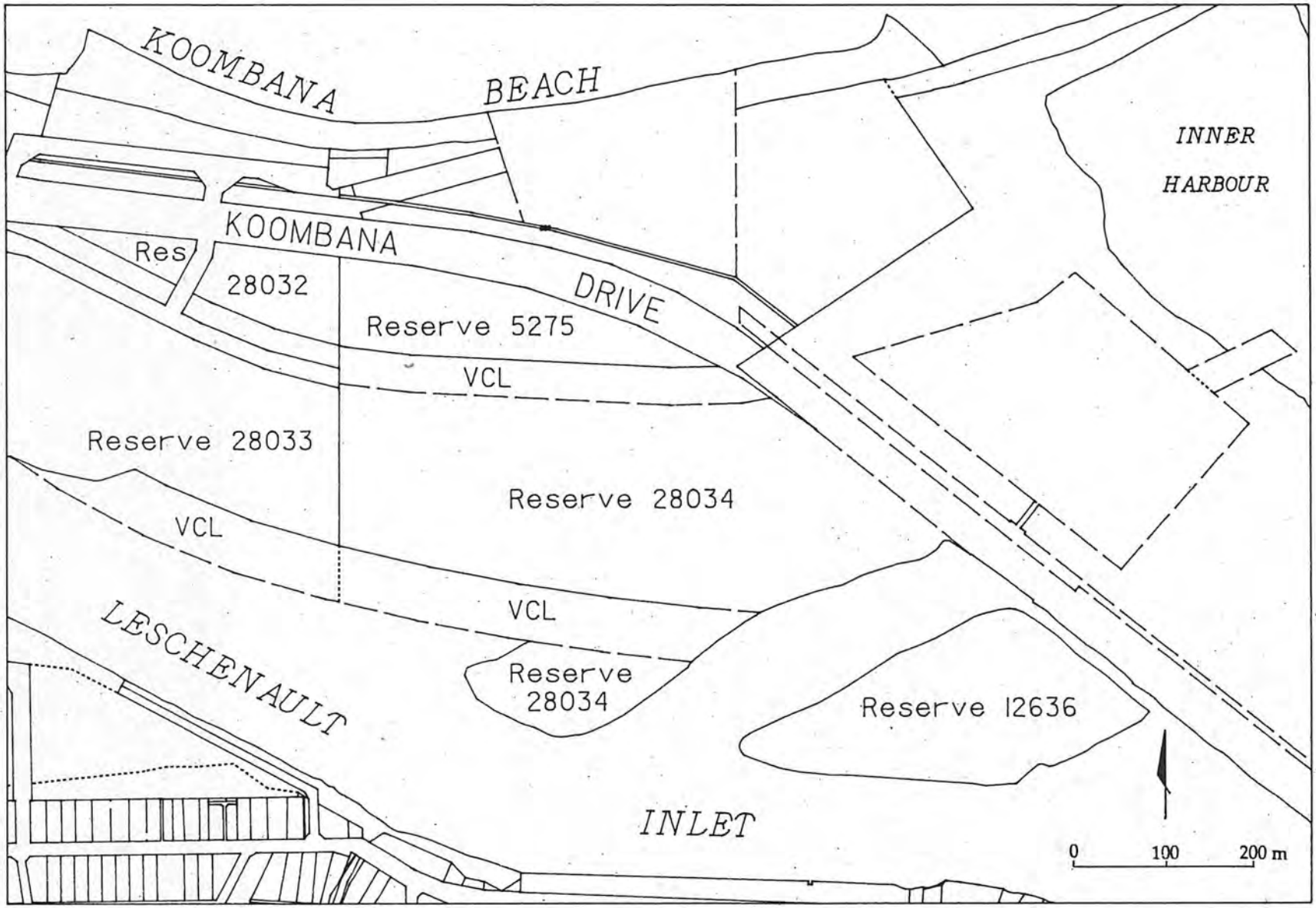


FIG. 6 RESERVE BOUNDARIES

8.0 Recommendations for Management

8.1 Reserve Tenure and Purpose

Since the System 6 Report was published (DCE 1983) a much larger portion of the area has been covered with tailings. The tailings area, together with the land between the old and the new alignments of Koombana Drive, is highly degraded and is no longer suitable to reserve for conservation purposes. It should be rehabilitated, reserved for appropriate recreation and managed for that purpose.

The low-lying areas including Anglesea Island, the sheoak area and all the mangrove and saltmarsh areas, together with Merredith Creek, the sandbanks and the Inlet water to mid-channel line are worthy of conservation and environmental management, and should be reserved for that purpose.

The Land Act (1933) does not presently allow land below low water mark to be reserved. However, the legislation is currently being reviewed. As soon as the legislation is amended to that effect, the area should be reserved for Environmental Management as soon as possible.

If the land reserved for Environmental Management is vested in the City of Bunbury, then it could be managed in accordance with a management plan approved by the Minister for Lands (Land Act 1933, s.34 A).

Recommedations

1 Reserve for Recreation:
- That part of Reserve C 28034 covered with tailings and north to the old road.
- That part of Reserve C 28034 between the tailings and the shoreline.
- That part of Reserve B 5275 that lies between the old and new alignments of Koombana Drive.
- That part of Reserve 28033 between the shore and the southern access road of the caravan park.
- and all parts to be incorporated into Reserve C 28034.

2 Reserve for Environmental Management:
- Reserve A 12636 - Anglesea Island.
- The parts of Reserve C 28034 that are not overlain with tailings excluding the above areas designated for recreation.
- and the two parts to be incorporated into Reserve A 12636.

3 Vest the areas reserved for Recreation and for Environmental Management in the City of Bunbury to be managed in accordance with this management plan.

8.2 Public Access

Since the reserve has two purposes, a careful balance has to be struck between conservation and recreation. A division between the two is made in Recommendations 1, 2 and 3. The public should be generally restricted to the "Recreation" reserve rather than the "Environmental Management" reserve.

The older tailings area at the eastern end of the reserve, being stable and having no conservation value, is the most appropriate section for regular public access. The western end, with its large stand of mangroves, a less-stable tailings dump, and the remnants of a dune system, would be best kept restricted to principally pedestrian traffic with access to the mangal being highly discouraged.

Rather than rely on physical barriers, which can be costly and are often ignored or subjected to vandalism, resources should be used to persuade and educate the public to value the natural features and respect their conservation requirements. This educative function can be implemented in conjunction with facilities for low-impact recreation such as paths, shelters and viewing platforms. Small, unobtrusive barriers can be used in conjunction with public education to dissuade people from encroaching on ecologically sensitive areas.

The use of boats in the Inlet is likely to become more common as the city grows. The use of powerboats close to mangroves could contribute to erosion of the banks and death of the mangroves. The 8 knot speed limit should therefore be strongly enforced. It is important also that people do not land in areas that are zoned for Environmental Management purposes. It is expected that tidal movement will govern access to most boats by restricting them to deep water, the exceptions may be enforced through regulations under the Waterways Conservation Act 1976. All jet skis should be prohibited from entering that area.

Recommendations

4 Direct public access mainly to the elevated area at the eastern end of the reserve, leaving the more ecologically sensitive areas relatively free of visitors.

5 Direct resources towards public education of conservation needs rather than towards the construction of physical barriers to human movement.

6 Restrict jet skis from the area.

8.3 Vehicle Access and Public Facilities

Facilities for the public should be concentrated to the north-east part of the reserve, so as to keep the focus of human activity at a distance from the conservation areas. No commercial activity should be allowed in the reserve - shops would detract from the quiet, semi-natural character of the area.

Kerbing on the access road and carpark should be constructed with gaps at regular intervals for water harvesting. That means that stormwater runoff is directed immediately into the ground where it will be used by nearby plants. A small pile of rubble and limestone should be buried to a depth of 30 cm adjacent to the gaps to prevent erosion and aid absorption into the soil.

After all other recommended works have been implemented, a survey of visitor numbers and activities should be carried out to determine whether there is a need for toilets to be built and picnic facilities developed.

The design of the toilet and the materials used should be such as to be in visual harmony with its surroundings. A limestone appearance is recommended.

Recommendations

7 Restrict vehicle access to the Koombana Drive perimeter of the Recreation Reserve. Details to be in accordance with the Landscape Master Plan.

8 Construct public toilet facilities to the north of the access road if user surveys indicate a need for them.

8.4 Rehabilitation

Attempts at rehabilitation must be regarded as experimental and subject to revision, as there is no certainty as to what plants will thrive on disturbed ground. Advice should be sought from the Department of Conservation and Land Management (CALM) before drawing up a detailed program of revegetation and weed control.

Revegetation to be undertaken inaccordance with the Landscape Master Plan developed by WG Martinick and Associates Pty Ltd for the South - West Development Authority.

As a rule, weeds should not be dug or pulled up, as this prepares the ground for more weed invasion. Where possible, lupins and other weeds should be cut for several years before they produce seed each year. The clump of Pampas grass should be dug out to prevent its spreading, and the introduced trees should be poisoned or excavated because they are out of character with the native vegetation. A systemic herbicide such as "Round-up" can be used to control fennel and other weeds that cannot be controlled by cutting. The rhizomatous grasses on the banks of the tailings should probably be left, as they stabilise the banks and are unlikely to spread into the high salinity of the saltmarsh (pers, comm. C. Nicholson). The spread of the bulrush *Typha* should be monitored and a decision made as to whether to remove these plants, which have probably started to colonise as a result of disturbance to the ecosystem. A range of methods for suppressing weeds is

A range of methods for suppressing weeds is outlined in "Bush Regeneration" (Buchannan 1989), including mulching with woodchips and commercially available suppressant mats.

Recommendations

9 Revegetation to be undertaken in accordance with the Landscape Master Plan developed by WG Martinick and Associates Pty Ltd for the South - West Development Authority.

10 Develop a weed control programme to the satisfaction of the Leschenault Inlet Management Authority and the Department of Conservation and Land Management.

8.5 Channels and landscaping

The construction of a 20 metre channel to link the tidal creek (northern end) with the inlet is considered necessary to restrict public access to the Blunders. Motorbike and 4WD activities have previously led toa partial degradation of the saltmarsh and the resultant wheel ruts form stagnant pools which encourage mosquito breeding.

The channel is described in the WG Martinick Master Landscape Plan. Access to the blunders by monitoring teams will be required occassionally and it is expected that this will be achieved by boat.

Depending on future developments at the caravan park site, a similar channel could be dug at the extreme western end of the newer tailings to protect the large patch of mangroves there from the effects of trampling. This should be done only if the first channel is found to have served its intended function well, without any adverse effects.

Previous plans have included landscaping proposals in which a hill would be created on and around the remnant dune. However, this would destroy the remnant vegetation, and the intended screening function could be provided, in the long term, by the dense plantings of Norfolk Pines.

Recommendations

11 Dredge a 20 metre wide channel to restrict public access to The Blunders. Construct the channel to prevent 4WD and motorbike access and to ensure the channel will not dry out. The Blunders to become effectively an island similar to that of Anglesea Island.

8.6 Lookout and birdhide

The Landscape master plan identifies an area overlooking the mangal to accomodate a lookout. This would provide an uninterrupted view of the mangrove without the disturbance associated with a walkway.

A birdhide has also been provisioned for along the northern edge of the tidal creek, overlooking The Blunders. The educational facilities to be incorporated into this system are outlined in Section 8.8.

Recommendations

12 Construct a lookout and birdhide in accordance with the Landscape Master Plan.

8.7 Dual-use path

Plans for a dual-use path through the reserve are included in the Bunbury Bikeplan. It is likely to be used for both recreational and commuting proposes. The bridge over Koombana Channel already has a path along its southern side.

The old alignment of Koombana Drive carries very light traffic as far east as the caravan park entrance and is closed to traffic from there on. This road could be used to link the dual-use path over the Channel with a path to be built over the tailings area of the reserve. As an alternative or possible future development, a path could be built around the southern boundary of the caravan park, joining the disused road at a point opposite the western end of the tailings. A path would then take cyclists and pedestrians along the southern edge of the proposed carpark and over the older tailings area, about 5 m from the western and southern edges of the older tailings, to meet Koombana Drive.

The connection from here to Oliver St. poses problems. There are two alternatives :

1) To build a path along the narrow foreshore opposite Anglesea Island. This would require either -
   - a widening of the foreshore using landfill,
   - a realignment of Koombana Dr. towards the railway line, or
   - a bridge-like structure along the bank.

2) To construct two crossovers - one at the eastern corner of the tailings and one opposite Oliver St. - and build a path along the strip of land between Koombana Drive and the railway.

Alternative 1 would be more expensive. The path may have to be 3 m wide and would require a safety fence. Any landfill would have to be kept to a minimum because the channel that isolates Anglesea Island is only 10 m wide. However, it would give cyclists and pedestrians good views of the island and Inlet. Moreover, a well-designed bridge-like structure may enhance the appearance of an otherwise unsightly bank.

Alternative 2 would require around-the-inlet cyclists to cross Koombana Drive twice, but those travelling to or from Australind would have only one crossing in either case. Crossovers would require safety rails and modification of the road to include an appropriate median strip.

The recommended route from Koombana Drive to Oliver St is fairly direct, while including good vantage points for views over the saltmarsh and estuary to the city.

Recommendations

13 Construct a dual - use path through the eastern part of the tailings to allow views of the Inlet, connecting with Bunbury to the west via the disused road and Koombana Bridge, and to the east alongside Koombana Drive.

8.8 Education and Information

An educational purpose has been recommended for the reserve since the 1983 proposal by LIMA (see Section 5.4). The reserve offers the public an opportunity to view a wide variety of waterbirds close to the city centre. Therefore it is important that suitable information and viewing facilities are provided. Also, the special significance of the mangroves creates a focus of interest that can be used to educate the public in matters of ecology and natural history.

These purposes can be met by providing viewing shelters overlooking the saltmarsh and mangroves. They would provide rest and shelter and a secluded facility for bird-watching. These wooden shelters would be open at the back and have a viewing window and bench at the front. Inside, seats would be provided and information would be displayed on the walls and on the bench, and in pamphlets available from dispensers.

Information specific to mangrove biology and ecology should be displayed along the walkway and on the viewing platform in the form of "interpretive totems". These consist of information printed onto an anodised aluminium plate covered with a protective polymer such as polycarbonate, and mounted on a post. The Recreation, Landscape and Community Education branch of CALM has experience with the establishment of interpretive facilities such as these.

Information should be of three kinds :

1 Aids to the identification of local plants and animals, particularly birds - mainly pictorial.

2 Information on the significance of the mangrove community and the waterbird habitat, and guides to understanding those ecosystems.

3 A guide to the public as to how they can help preserve the natural features of the reserve, and the reasons for restricting public access to certain areas.

It may be decided in the future that an education centre is required. This could be modelled on the Herdsman Lake Wildlife

Centre in Wembley, which provides live displays of local wildlife, a bookshop, a classroom and a bird-observation deck. School groups, tourists and the general public could be catered for. The building could include headquarters for LIMA and a base for a CALM ranger if required.

Such a centre could only be built after careful consideration of any health risk associated with radiation (see Section 6.9), and may have to be situated away from the tailings for safety reasons, depending on the results of a radiological survey. Also for consideration is the effect that large numbers of school children would have on the vegetation if "hands on" experience was to be encouraged.

Recommendations

14 Establish an interpretation programme to provide information about the natural history, ecology and conservation significance of the area. Include signs, pamphlets and displays.

8.9 Radiation

Section 2.5 outlines the possibility of health risk from the radioactivity of the tailings. The preliminary findings suggest that the tailings area is within acceptable limits for the purpose of recreation.

Recommendations

15 Undertake a radiological survey of the tailings site in consultation with the WA Radiological Council, after the completion of lanscaping, to assess any changes and to provide a comparison with the previous survey.

8.10 Mangrove Survival

Mangrove survival depends on regular tidal inundation and flushing. It is therefore important that the flood gates continue to be used with discretion, so that the present tidal regime of the Inlet is maintained.

It is important also that interference to the saltmarsh and mudflat areas is kept to a minimum, since white mangroves depend on the maintenance of gently-sloping banks and well-drained soil.

There should be no interference to the sandbanks in the Inlet, since these cut down wave-energy and reduce erosion of the banks. The spread of *Avicennia* depends on gradual accretion of sand. On the other hand, any activity that causes sudden and severe sedimentation to cover the pneumatophores will stress the mangroves.

Nutrients from stormwater drains may reach levels dangerous to mangrove survival. Therefore it may be necessary at some time to carry out a phosphate-management programme for domestic and civic lawns and gardens in the city (see Sections 2.3 and 2.4). On the other hand, the vigour of the mangroves may be enhanced by the seasonal injection of fresh water from these drains. (Although they will survive in sea water, they are subject to less stress in less saline water.) Therefore any proposal to alter the city's drainage system should take this into account.

These measures, together with protection from trampling by visitors, should ensure that the mangroves remain unstressed and therefore free of dieback disease.

It may be possible to use seedlings from this community to establish mangrove colonies at selected sites in Leschenault Estuary. This could be used to rehabilitate degraded shorelines, and could also be seen as an insurance policy against the possible demise of the community at Koombana Park. Transplanting seedlings to disturbed areas of the shoreline at Vittoria Bay in the Estuary may help to rehabilitate those shores. Schwinghammer (1982) describes how freshly fallen seedlings can be collected and grown in a glasshouse or transferred directly to shorelines.

Recommendations

16 Maintain present tidal regime by judicious use of the tide gates.

17 Avoid large-scale earthmoving works that would cause silting of the inlet.

18 Keep interference to the saltmarsh and mudflat areas to a minimum, so that good drainage and the correct gradients of banks are maintained.

8.11 Mosquito Control

Section 3.2 outlines the problems caused by mosquitoes and the methods that have been used to control them. The low-lying "Blunders" area appears to be the major breeding area, other saltmarsh such as Anglesea Island being higher and seldom flooded by the tide. The Bunbury City Council have indicated that the channelling there has significantly reduced mosquito numbers. Currently the Council checks larval numbers regularly, and applies larvicide only when significant emergence of adults is imminent. This is required only occasionally. This strategy should be continued, and a change from Temephos to Bti (see Section 2.7.4) should be effected as soon as the latter becomes available.

The existing channelling system needs to be maintained. Any further channelling should make use of a detailed survey of levels, such as that done by Eaton and Moir Pty Ltd in June 1989. The proposed barrier channel (see Section 6.7) could be incorporated into the existing system. Any remaining wheel ruts should be filled by hand. No heavy machinery should be used in future excavation on the saltmarsh - only a "tracscavator", which leaves no wheel ruts and does minimal damage to vegetation.

Recommendations

19 Continue the present regime of mosquito control using opportunistic larvicide application and continual refining of the channel system, subject to the direction of the Leschenault Inlet Management Authority in accordance with the monitoring programme results.

8.12 Monitoring

Monitoring is an essential part of the management of an ecosystem. An appropriate monitoring program may be able to detect any detrimental changes in their early stages so that remedial action can be taken in time. Some parameters that need to be monitored are as follows:

1 Evidence of advance or retreat of the mangal

This can be done by aerial photography, but inserted markers give a more accurate measure. Another method is to observe the distribution of seedlings - an abundance of seedlings on the seaward margin of the mangal grading up to mature plants is evidence of advance, while a sharp margin with exposed roots suggests that it is receding (Clough 1982). Periodic records of the numbers of Avicennia seedlings along the mosquito channels would give a measure of their success in colonising these shallow artificial tidal creeks.

2 Populations of selected indicator-species

One or two common invertebrate species that are easily sampled could be selected by CALM for regular monitoring. The density of certain higher-order predators may give a general indication of the health of the ecosystem.

3 Bird counts

The Royal Ornithologists' Union (RAOU) may be willing to conduct species counts and population estimates to help determine whether management of the waterbird habitat is succeeding.

4 Levels of pollutants

The Bunbury City Council is currently measuring pathogens in the drainage outlets (coliform and faecal streptococcus). This should be continued. LIMA should carry out the following monitoring program:

a Test sediments annually for nutrient levels, especially non-apatite phosphorus and organic matter, and for BOD at the sediment surface.

b Test mussels every two years for heavy metals, radiation, biocides and pathogens.

c Test Inlet water several times each summer for the presence of pathogens and algal blooms.

5 Social surveys

The public use of the reserve should be monitored to show trends in visitor numbers and how the reserve is used. Opinion surveys may help to suggest what additional facilities, if any, should be provided, bearing in mind the management objectives (see Section 5.0).

This data should be collated and interpreted by LIMA and published biannually by the City of Bunbury in a form that can be easily understood by the general public. This should be used by the management body as a guide to future management strategies. Monitoring can also be used as an early warning system so that remedial action may be taken before gross changes have time to set in.

Recommendations

20 Undertake biological and social monitoring as required by LIMA and the Bunbury City Council. Interpret and use as a guide to future management.

8.13 Implementation and Management

8.13.1 Responsibilities

The two sections of the reserve - Environmental Management and Recreation - need to be managed as a whole, since the management of one affects the other.

The City of Bunbury is willing to accept the role of Management Authority subject to formal agreement being reached with the South West Development Authority to fund maintainance work for the Recreational area from Harbour City Development funds until funds become available from the Koombana Caravan Park re-development. The City of Bunbury should manage the reserve according to the agreed Environmental Management Plan. The Leschenault Inlet Management Authority (LIMA) has responsibility for the management of the Inlet and the Department of Conservation and Land Management (CALM) has expertise in the management of ecosystems and interpretive facilities. Accordingly, a committee comprising the City of Bunbury, LIMA and CALM will be established to provide management advice on proposed activities not outlined in the management plan.

LIMA should arrange for the collation and interpretation of all monitoring results and advise the Bunbury City Council regarding any action to be taken.

Recommendations

21 Ongoing management of the reserve should be undertaken by the City of Bunbury. A committee comprising LIMA, CALM and the City of Bunbury will be established to provide advice on proposed activities that are not outlined in the management plan.

22 Creation of additional facilities should be provided only after public needs and potential environmental impacts have been properly evaluated, and only if they are compatible with the objectives of the management plan.

8.13.2 Timing and Costing

After the period of public consultation, matters of vesting and reserve tenure (see Section 8.1) should be arranged as soon as possible. A list of priorities for implementation of the Management Plan should then be drawn up. Timing of each stage will then depend on the degree of priority assigned to it and the availability of funds. Stabilisation of the newer tailings area should be given high priority because of the danger of its encroachment onto the mangroves and the tidal creek.

Recommendations

23 Timing of the implementation of the Management Plan should be undertaken as follows:

- Public Consultation.
- Land vesting and reserve tenure.
- A list of priorities drawn up.
- Implementation in order of priority as funds become available.

(Plate 6 : *Typha orientalis*)
Control of the *Typha orientalis* (Bulrush) is essential in maintaining the natural integrity of the wetland.

(Plate 7 : Dead Trees)
Dead trees provide ideal roosting sites for birds.

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APPENDIX 1 GLOSSARY OF TERMS AND ABBREVIATIONS

anaerobic -	(of soil, mud, etc.) - lacking in oxygen.
bio - amplification	(bio - accumulation) - the increasing concentration, in living things, of a substance such as a pesticide as it passes through the food chain (eg. DDT reaches high concentrations in bird of prey).
bioassay -	technique of determining the presence of a chemical in living organisms other than by chemical analysis - eg. by measuring comparative mortality.
biocide -	a chemical designed to kill certain living things - eg. insecticides, herbicdes, fungicides.
BOD -	Biological Oxygen Demand - the amount of dissolved oxygen consumed by micro-organisms as they decompose organic material in water. It is often used as a measure of polluted water.
community	a natural group of organisms that live together and interact as a relatively self-contained unit .
daughter - products	the products of radioactive decay of substances with unstable nuclei.
ecosystem	an ecological system that includes all the living things and the environment in which they occur naturally.
estuary	the tidal mouth of a river, or a partially enclosed body of water having variable salinity due to its connection with river (s) and sea.
eutrophic	having a very high nutrient content.
eutrophication	nutrient enrichment usually due to accumulation of nutrients from agricultural lands. May bring about rapid growth of algae, causing unpleasant odours and death of aquatic life.
flood gates	stormwater surge barrier.
half-life	the time taken for the radioactivity of an element to decay to half of its original value.
invertebrate	animal without backbone - e.g. worm, crab, fly.
leachates	materials carried out of a system by percolating water.
lenticel	a ventilation organ in a plant, having raised cells over an air cavity.
low-impact recreation	forms of recreation that have minimal impact on the environment e.g. walking, birdwatching.
mangal	a mangrove plant community.
mesotrophic	having intermediate levels of nutrient content (see eutrophic).
monospecific	one species occurring by itself.
nutrient	material taken in by living things for growth and maintenance.
oligotrophic	having very low levels of nutrient content (see eutrophic).
orthoptera	the group of insects that includes grasshoppers and crickets.
phytoplankton	plant plankton or single-celled algae in water.
pneumatophore	an aerial root of a mangrove with the function of absorbing oxygen.
polychaete	a type of segmented worm - mostly marine.
productivity	the amount of new material generated in a given time in an ecosystem (measured either in biomass or energy terms).
saltmarsh	a coastal marsh, inundated by only the highest tides.
stomata	openings in the surface of leaves that allow exchange of gases.
substrate	the object or material on which or within which an organism lives.
trophic pathway	food chain, or flow of nutrients and energy through an ecosystem.
xerophytic	adapted to growing in dry conditions.

ABBREVIATIONS

CALM - Department of Conservation and Land Management.
LIMA - Leschenault Inlet Management Authority.
RAOU - Royal Australasian Ornithologists Union.
SWDA - South-West Development Authority.
ha = hectare μSv = microsievert μGy = microgray

(Plate 8 : Anglesea Island)
The proposed channel Shall be similar to that which presently separates Anglesea Island from Koombana Drive.

APPENDIX 2 - Plant species referred to in the text - scientific and common names.

Acacia saligna	golden wreath wattle
Acacia cochlearis	a wattle
Acacia rostellifera	a wattle
Acanthocarpus preissii	prickle lily
Agonis flexuosa	W.A weeping peppermint tree
Allium sp.	an onion relative
Alyxia buxifolia	---
Atriplex isatidea	coast saltbush
Avicennia marina	white mangrove
Beaufortia squarrosa	sand bottlebrush
Cakile maritima	sea rocket
Carpobrotus sp.	pigface
Casuarina obesa	swamp sheoak
Diplolaena dampieri	southern diplolaena
Eremophila	---
Exocarpus sparteus	broom ballart
Frankenia pauciflora	---
Hakea varia	(= *H. attenuata*)
Halosarcia indica	a samphire
Hardenbergia comptoniana	native wistaria
Hypocallyma angustifolium	white myrtle
Isolepis nodosus	knotted club rush
Juncus kraussii	sea rush
Lepidospermum gladiatum	coast sword sedge
Leptospermum ellipticum	(= *Pericallyma ellipticum*)
Melaleuca lanceolata	Rottnest ti-tree
Olearia axillaris	beach rosemary
Pelargonium capitatum	wild geranium
Regelia ciliata	---
Rhagodia baccata	---
Sarcocornia quinqueflora	a samphire
Spyridium globulosum	basket bush
Scaevola crassifolia	hand flower
Senecio lautus	ragwort or groundsel
Suaeda australis	a succulent
Templetonia retusa	cocky's tongue
Trachyandra divaricata	onion weed
Typha orientalis	bulrush
Viminaria juncea	swishbush

APPENDIX 3 - Bird species referred to in the text - scientific and common names.

Black-winged stilt	*Himantopus himantopus*
Common Sandpiper	*Tringa hypoleucos*
Darter	*Anhinga melanogaster*
Great Egret	*Egretta alba*
Greenshank	*Tringa nebularia*
Grey Teal	*Anas gracilis*
Little Grassbird	*Megalurus gramineus*
Little Pied Cormorant	*Phalacrocorax melanoleucos*
Nankeen Night Heron	*Nycticorax caledonicus*
Pacific Black Duck	*Anas superciliosa*
Pied Cormorant	*Phalacrocorax varius*
Pied Oystercatcher	*Haematopus longirostris*
Sacred Kingfisher	*Halcyon sancta*
Sharptailed Sandpiper	*Calidris acuminata*
White-Faced Heron	*Ardea novaehollandiae*

APPENDIX 4 - The Biology of the White Mangrove

Mangroves require protected shores that are subject to regular tidal inundation. Most mangroves also require a warm climate, with the average temperature of the coldest month over 20 °C and a seasonal temperature range of less than 5 °C. Shallow, shelving slopes with a muddy substrate are a general requirement also (Semeniuk et al. 1978).
Of the many species of mangrove (17 spp. in Western Australia alone), only one occurs at Leschenault Inlet - the White Mangrove *Avicennia marina* . Although this species occurs with other mangrove species in tropical regions, it occurs as a monospecific stand in many parts of the temperate, winter-rainfall parts of Australia's coast (Lear and Turner 1977). It is a pioneer species, colonising areas where sedi-mentation is currently occurring.

Mangroves are better able to compete with terrestrial plants in highly saline conditions, and will only grow in the presence of some salt. They do require some fresh water in the soil however, and individuals growing in conditions of lower soil salinity often grow more vigorously. Soil salinity depends on the evaporation rate, the tidal frequency, the soil type, the rainfall and any influx of fresh water.

Avicennia is tolerant of a wide range of salinity and temperature, and has been known to tolerate salinities of up to 90 ppt (sea water is 35 ppt) (Hutchings and Saenger 1897). This species adapts to high salinity in several ways :

1) Filters in the roots exclude 80-90% of the salt in the absorbed water and so reduce salt intake.

2) Glands in the leaves excrete salt.

3) Salt is deposited in the bark and older leaves which are shed.

In this way, a physiologically acceptable water balance is maintained. Salt exclusion is particularly efficient in seedlings, which contain very little salt.

Mangroves expend considerable energy in desalinating water. Therefore fresh water is contained within the trees only at a high cost in terms of metabolic energy. This can lead to water stress. Because of this, they display xerophytic or water-conserving features: *Avicennia* has sunken stomata, glandular hairs on the lower leaf surfaces and a thick, waxy cuticle on the upper surface. It responds to water stress also, in highly saline conditions, by reducing its growth rate and adjusting its growth habit to a low, shrubby form (ibid).

The root system of *Avicennia* is well adapted to tidal conditions. There is no tap root but a shallow and extensive set of cable roots. This widely spreading heavy mass below ground helps survival in estuarine conditions where the substrate may be unstable. Two sets of roots grow from this cable system:

1 Fine feeder-roots which absorb nutrients near the surface of the mud.

2 Vertical, pencil-like roots which protrude through the mud and are exposed to the air at low tide. These aerial roots, or pneumatophores, are equipped with lenticels or ventilation organs so as to give continual aeration to the root system despite the accumulation of sediment and the anaerobic conditions of the mud.

Avicennia has abundant reserve buds in the stem for rapid recovery from leaf or twig damage.

The flowers are scented and are pollinated by the honey bee *Apis mellifera* as it feeds on them. Like many mangrove species, *Avicennia* has viviparous reproduction, the seeds germinating while still attached to the plant. The seedlings fall in November and December (Schwinghammer 1982).

The seeds are buoyant, but if carried by the tide will sink after four days and will become firmly rooted in the mud within five days. Seedlings will not grow in the shade but may wait until a gap occurs in the canopy before growth continues. Colonisation takes place in areas where sedimentation is taking place, and seedlings take root in places above mean tide level where the substrate is gently sloping or shelving. This usually takes place along the banks of tidal creeks where there is good drainage at low tide.

APPENDIX 5 - The Biology of the Saltwater Mosquito

Aedes breeds between November and April in the south west. The eggs are laid in saltmarsh. They are resistant to desiccation and lie dormant until inundated by the tide or by rain. One or two days later, all the eggs hatch synchronously. The larvae (wrigglers) moult four times and then become non-feeding pupae before emerging as adults. This process takes 7 to 10 days in summer or three weeks in winter. The adult males remain close to the site of emergence and feed on plant juices while the females disperse over many kilometres to extract blood from mammals, birds and sometimes reptiles and amphibians, as nourishment for the eggs. They mate and lay eggs.

From the 1940s, broadscale use of **chemical insecticides** was used to control mosquitoes. This included organochlorines such as DDT. However, the chemicals accumulated in the food chains and killed non-target organisms and the mosquitoes quickly developed resistance. Currently, integrated management strategies are being developed, which use a combination of minimal-impact techniques and natural population controls. These strategies require an understanding of the ecosystem, monitoring of results and constant updating of the programme. They do not aim to eradicate the mosquitoes - only to manage their populations so that fluctuations do not normally exceed an acceptable level in terms of human health (Chester 1990).

Integrated pest management uses specific agents that are environmentally benign, together with some physical modification of the breeding grounds and sometimes biological controls such as predators or pathogens. Using a combination of such strategies, control of pests can be effected while causing minimal environmental impact, avoiding counter-strategies by the insects (e.g. resistance), and at the same time reducing the overall cost of pest control.

An appropriate strategy to control *Aedes* at Leschenault Inlet is to use a combination of runnelling and larvicide application.

Runnelling is the construction of small channels that follow the natural drainage lines. They should be 30 to 60 cm wide and 10 to 20 cm deep and on a very low gradient (e.g. 1:1000). The runnels connect to one another and to the estuary. They should be hand-dug and spoil should be used to fill pools that are not connected. The idea is not to completely drain the area but to reduce the time that water remains in the pools, to increase the access of predatory estuarine fish and to flush mosquito larvae out into the estuary, exposing them to further predation. Preliminary trials in Queensland suggest that if implemented carefully and with proper surveying, this method may have fewer environmental impacts than other types of drainage systems (Chester 1990).

Larvicide application is preferable to killing adult mosquitoes because treatment can be confined to breeding sites. The synchronous hatching of *Aedes* eggs means that the application of larvicides can be timed to target the early larval stage, which usually follows the highest tide in the cycle.

Organophosphorous toxins have been used as larvicides. Of these, Temephos (Abate) has been widely used. It has a very low toxicity towards birds, mammals and fish and a short persistence, but is toxic to some invertebrates such as copepods and amphipods.

Bti is a bacterial toxin derived from *Bacillus thuringiensis* subspecies *israeliensis*. It is highly specific and toxic to the larvae of mosquito and blackfly and a few midge species. "Predators fed on larvae killed by Bti have shown no ill effects" (Chester 1990). Application has to be timed carefully because the early larval stages are the most susceptible. Since the *Aedes* larva feeds on the bottom of the pools, it is best to use a granular formulation which falls to the bottom. The toxin breaks down quickly and has no residual or cumulative effects. Resistance to Bti can develop but it is less likely to develop than in traditional toxins and is slower to do so. Trials have been carried out in Queensland into an automatic system that drips Bti into pools during the flooding tide.

Bacillus sphaericus is another bacterial larvicide that has good potential. It is applied as living cells. Another recent development is the use of insect **growth hormones** such as juvenile hormone analogues which act by preventing larvae emerging as adult insects. These two techniques are not currently available for broadscale use.

APPENDIX 6 - The Mangrove Ecosystem

The mangrove ecosystem is a highly productive one, and is the base of a detrital food web that begins with the mangrove's continual leaf fall. Mangroves may produce in the order of 1 kg (dry weight) of leaves per square metre per year. Fungi break down fallen leaves and the fragments may be eaten by fish and crustaceans. Further breakdown is effected as they pass through the gut of these animals.

Dissolved organic substances that are liberated during this process are absorbed by various micro-organisms, which are eaten by small crustaceans such as amphipods. These in turn may be eaten by fish. Algae, living on the dissolved organic substances, may be grazed by marine snails. Very small particles of food are eaten by filter-feeders such as mussels and polychaete worms. Products of excretion, death and decay enrich the mud and so become nutrients for absorption into the roots of the mangrove (Fig.5).

The food value of the leaves increases as fungi break down the cellulose of the leaves into more useful carbohydrates while nitrogen-fixing bacteria and blue-green algae raise the protein content of the detritus. Tidal movement is required by mangroves to transport nutrients around the system. Animals that burrow in the mud may trap air at high tide and water at low tide. The photosynthetic process which feeds solar energy into the system is carried out not only by the mangroves but by the phytoplankton or microscopic algae that live in the nutrient-rich waters around them.

By rapid recycling of nutrients and increase in biomass, a mangrove ecosystem can act as a nutrient sink, storing nutrients such as nitrogen, carbon, phosphorus and minerals within the system. " Nitrogen and phosphorus are quickly utilised by mangroves and are converted to food for fish and crustaceans" (Lear and Turner 1977). Because of this, the probability of eutrophication problems is reduced by the presence of the mangroves.

Certain pollutants can be locked up in the system also, alleviating potential problems that they may cause. The many filter feeders within the mangal, such as polychaete worms and mussels, can concentrate pollutants such as heavy metals because of the large volume of water they process.

Mangrove ecosystems can have very high productivity, some tropical mangals with high tidal ranges producing up to 3.6 kg (dry weight) per square metre per year. At Koombana Park this productivity flows into the food chains of the Inlet and its fringing saltmarsh and mudflat areas. The wealth of seafood in the Inlet and the large biomass of wading birds that feed there is partly derived from the productivity of the mangrove ecosystem.

Since the building of the Inner Harbour (see Section 3.1), the annual winter influx of fresh water from the Collie and Preston Rivers has not occurred leaving the mangroves in an essentially marine environment as distinct from an estuarine one. However, fresh water is provided by local run-off and shallow groundwater, and the Inlet water is diluted by the outflow from the stormwater drains in winter (see Section 2.3.1). Little if any fresh water is available in summer.

Leschenault Inlet provides the protected shores and the regular tidal inundation that mangroves require. It also provides the necessary shallow, shelving slopes and muddy substrates. Normally mangroves are found where there is a high tidal range, but tides at Bunbury do not exceed a metre, and the range in the Inlet is likely to be a little less - about 90 cm. The winter water temperatures as low as 15 ^{o}C in the Inlet, and an annual range of about 15 ^{o}C are both outside the general rule for the temperature tolerance of mangroves.

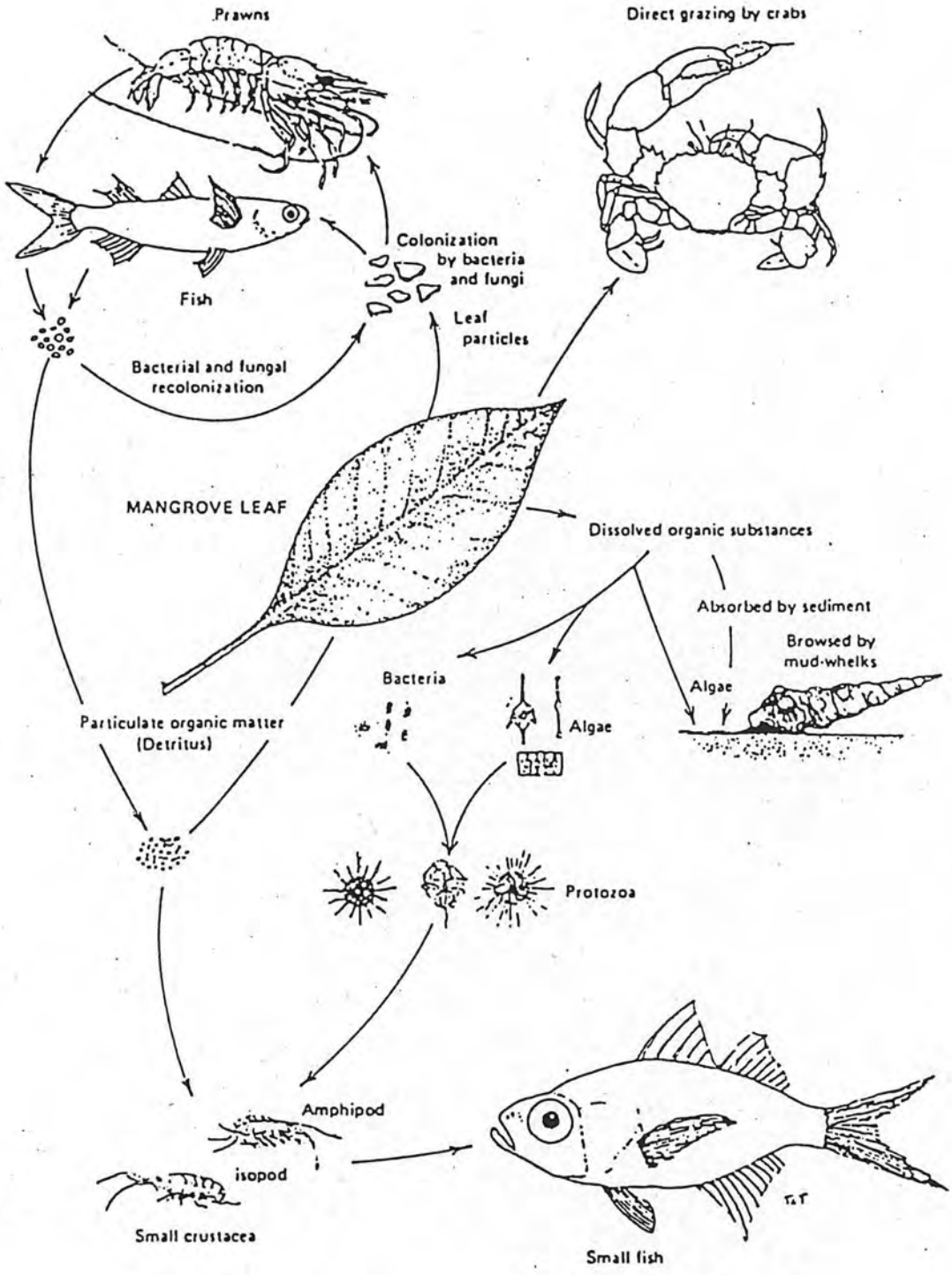
Mangroves link marine and terrestrial ecosystems - a link which is lacking in most parts of the south-west coastline. They do this through their tolerance to saline water while retaining some dependence on fresh groundwater. The salinity creates water-stress in the mangroves, as it does for the salt-adapted plants of the saltmarsh. This water-stress is exacerbated by the

winds that are usually salt-laden in winter and drying in summer.

The low, shrubby habit of mangroves is a typical response of *Avicennia* to dry or highly saline conditions. The effect may be to reduce transpirational water loss by reducing the area of leaf exposed to wind.

Avicennia marina has been known to succumb to dieback disease from a species of the fungus *Phytophthora*. This fungus is normally a leaf-litter decomposer, occurring commonly in mangrove communities. However, it has the capacity to attack the roots of *Avicennia* . It is thought to do this only when the mangroves are subjected to stress - e.g. water-stress. (Hutchings and Saenger 1987)

The ecosystem of the nearby dune system is fairly distinct from that of the fringing vegetation, but water-stress exists there also because of the nature of the sand which is low in water-holding clay and humus, and again because of drying winds and a summer drought. The dune plants are xerophytic, having special features for water retention.



Supply of Mangrove Material To Basic Estuarine Food Chain (Lear & Turner, 1977)

Figure 7

APPENDIX 7 - WG Martinick and Associates Pty Ltd : Landscape Master Plan

E 378000
E 378250
E 378500
N 6312000
N 6311750
A
B
C
D
E
F
KOOMBANA
DRIVE
THE SAILS 'MEMORIAL'
12-20 BAYS
NORTH AMERICAN HIDE
PICNIC
PICNIC SHELTER
INTERPRETIVE CENTRE PARKING
PICNIC SHELTER
ERSKINE McLEOD LOOKOUT
SHADE SHELTER
BIRD HIDE
END OF LAGOON (EXISTING)
PROPOSED CANAL
REGENERATING MANGROVES
'THE BLUNDERS'
INTERPRETATIVE CENTRE
SHORELINE
STAGE 2 21 BAYS
STAGE 1 33 BAYS
BOUNDARY OF CROWN LAND
AS
AS

LEGEND

NORFOLK ISLAND PINE ARAUCARIA HETEROPHYLLA
EXISTING AVENUE PLANTING

LOW EUCALYPTUS WOODLAND :
EUC PLATYPUS HETEROPHYLLA, EUC LEHMANII

SHE-OAK FOREST
CASUARINA OBESA, CASUARINA FRASERIANA

PAPERBARK WOODLAND
MELALEUCA CUTICULARIS, MELALEUCA RHAPHIOPHYLLA

MEDIUM-TALL SHRUBS : CASUARIA LEHMANNIANA,
GREVILLEA OLIVACEA, GREV. WINHARAGEM, CHAMELAUCIUM SP.

LOW-MEDIUM SHRUBS : ACACIA LASIOCARPA,
OLEARIA AXILLARIS, MELALEUCA HUEGELII, SCAEVOLA SP.

GROUND COVERING PLANTS
GREVILLEA CRITHMIFOLIA PROSTRATE
ACACIA LASIOCARPA, CALOCEPHALUS BROWNII

IRRIGATED GRASS
SALTENE

UN-IRRIGATED GRASS
(POTENTIAL TO IRRIGATE)
KIKUYU OR COUCH

SALT MARSH
SAMPHIRES AND SEDGES

MANGROVES :
AVICENNIA MARINA

10 FINISHED CONTOURS (A.H.D)

ALIGNMENT OF CLOSED SECTION OF KOOMBANA ROAD : ROAD TO BE REMOVED

SEC OVERHEAD POWER LINE - TO BE REMOVED IN THE FUTURE

DUAL-USE PATHWAY (BITUMEN) : 2.4M WIDE

INTERPRETATIVE TRAIL : 1.2 M WIDE LIMESTONE

POST AND RAIL FENCING

VIEW LINES
DELINEATES EDGE OF EXISTING BITUMEN AREA

N

No	Date	Revision	Approved
A	7-1-91	REVISED SALE & ADDITIONAL TECHNICAL DETAILS	RB

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Checked : Date :
Approved : Date :

LESCHENAULT INLET PARKLANDS NORTHSHORE BUNBURY
LANDSCAPE MASTER PLAN FOR THE SOUTH-WEST DEVELOPMENT AUTHORITY.

Scale 1:1000 (0 10 30 METRES)
Job No 33
Sheets
Dwg No 1 Rev A