SWAN RIVER TRUST

Swan River foreshore fact finding study

Rocky Bay to Point Roe

Swan River Trust
Report No 17
1994

SWAN RIVER TRUST

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SWAN RIVER FORESHORE FACT FINDING STUDY

ROCKY BAY TO POINT ROE

Prepared for the Swan River Trust
by Ben Davy

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Report No 17,
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ABBREVIATIONS

AHD	Australian Height Datum
BP	Before Present
CALM	Conservation and Land Management
CER	Consultative Environmental Review
CSBP	Cuming Smith British Phosphate
CSR	Colonial Sugar Refinery Ltd
DAS	Dept. of Aboriginal Sites
DCE	Dept. of Conservation and Environment (now EPA)
DOLA	Dept. of Land Administration
DPUD	Dept. of Planning and Urban Development
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority (ex DCE)
FCC	Fremantle City Council
GSWA	Geological Survey of Western Australia
IFAP	Industrial Foundation for Accident Prevention
JAMBA	Japan-Australia Migratory Birds Agreement
LANDCORP	Western Australian Land Authority
LGA	Local Government Authority
MPTC	Mosman Park Town Council
MRS	Metropolitan Region Scheme
M57	System 6 Locality M57 Minim Cove Foreshore
PER	Public Environmental Review
POS	Public Open Space
RAOU	Royal Australian Ornithologists Union
SEW	State Engineering Works (now Rocky Bay Estate)
SRT	Swan River Trust
VCL	Vacant Crown Land
W.A.	Western Australia
WAM	Western Australian Museum
WANC	Western Australian Naturalists' Club
WAWA	Water Authority of Western Australia

1.0 INTRODUCTION

The Swan River foreshore between Rocky Bay and Point Roe has been highly modified since the arrival of European settlers in 1829. Figure 1 best captivates the pristine character of the foreshore before European development. Plate 1 presents the area in its current state, taken from a similar perspective, outlining the remnants of the 'Seven Sisters'. Although highly modified, the area still contains many valuable physical, biological and social attributes worthy of preservation.

In 1990 the Western Australian Government gave in-principle support for a Regional Park system to be developed in the Leighton Peninsula area. The proposal was put forward by the Leighton Peninsula Planning Study Group which was established by the Department of Planning and Urban Development in 1989. The Study Group was comprised of representatives from the City of Fremantle (FCC), Town of Mosman Park (MPTC) and community representatives from Fremantle and Mosman Park. In 1992 the Leighton Peninsula Park Study was released.

The Swan River foreshore, between Rocky Bay and Point Roe, constitutes a significant component of the proposed regional park. The area has been the subject of many studies and reports. Recent reports include: North Fremantle Foreshore Management Plan (1993), Proposed Clean-Up McCabe Street Site Mosman Park CER (1992) and, Parks and Reserves in Mosman Park (1990). Previous reports have covered a wide variety of topics; including the area's environmental attributes, management policies and concept proposals for specific urban developments.

The aim of this study was to compile a comprehensive environmental resource inventory in order to effectively assess the environmental impacts of proposed collective urban development upon the Swan River foreshore between Rocky Bay and Point Roe. The report will provide information to the Swan River Trust to enable better decision making for future development in the area.

The objectives of this study were to:

- Prepare an environmental resource inventory of the study area's natural and cultural attributes.
- Determine the value of environmental resources identified within the study area.
- Identify management issues associated with future development of the area for residential purposes.

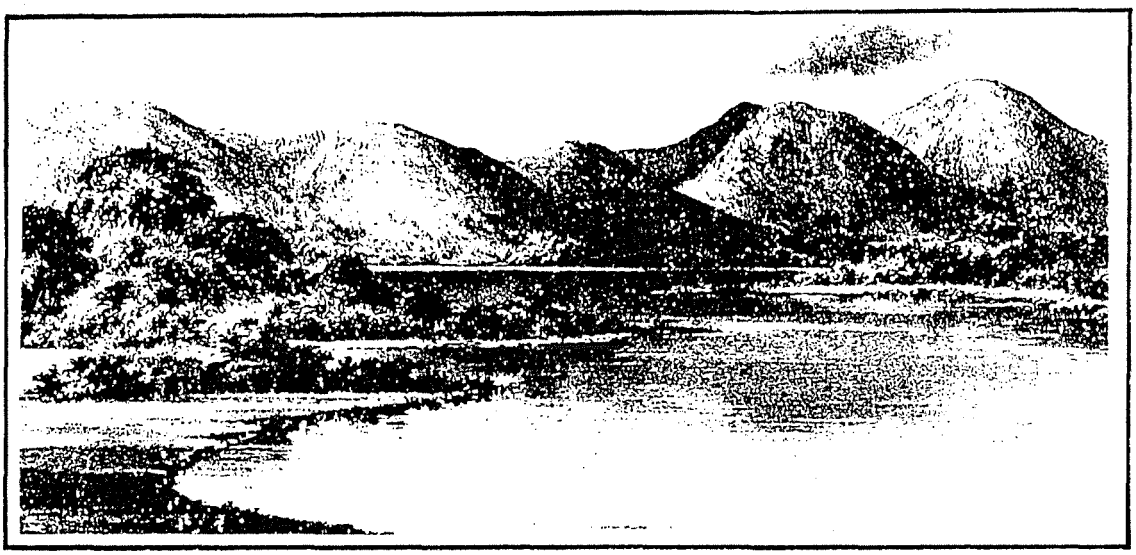

Figure 1: Rocky Bay and the 'Seven Sisters' Range, c.1880
E. Finnerty, Glimpses of Western Australia

Plate 1: Current view of 'Seven Sisters' remnants

2.0 STUDY AREA

2.1 Location and boundaries

The study area is located on the Swan River foreshore between Rocky Bay in North Fremantle and Point Roe in Mosman Park, Western Australia (Figure 2). The boundaries of the study area are formed to the north by McCabe Street and Downey Drive, to the east and south by the centre of the Swan River from Blackwall Reach (adjacent to Downey Drive) to Rocky Bay (adjacent to Craig Street), and to the west by the western boundary of State Engineering Works (SEW), now Rocky Bay Estate. The former Cuming Smith British Phosphate (CSBP) site, Colonial Sugar Refinery (CSR) site and System 6 locality recommendation M57 are contained within the area.

Appendix 1 presents a series of maps which cover the entire study area in detail. These maps are compiled from digital cadastral and orthophoto data. Information contained on the maps includes the cadastral boundaries, contours, reserve information, roads, buildings and the Swan River shoreline.

2.2 Zoning and land tenure

The study area comprises land of varying zoning and tenure including: Metropolitan Region Scheme (MRS) Reservations for Parks and Recreation, and Waterways; Local Scheme (LGA) Zones of Development, Residential and Industrial, and Reserves for Public Purposes; Vacant Crown Land (VCL) and Crown Reserves vested in LANDCORP, FCC, MPTC or the Minister for Lands (ie. DOLA); and privately owned land. Figure 3 presents the MRS Reserves and Local Planning Scheme Zones, and Figure 4 presents the land tenure. Land tenure is discussed below.

SEW site

(Lot 329, Maps 1+2) is zoned Development (residential) by FCC, and is vested in LANDCORP. Rocky Bay Estate Stage 1 is currently being developed for residential purposes. Land sales for Stage 2 will take place in late 1993. The SEW site foreshore (Reserve 7077) is reserved for MRS Parks and Recreation, and is vested in FCC.

CSBP site

(Reserves 36169 and 36170/and VCL, Maps 2-4) is zoned Development (residential) by MPTC, and is vested/owned in/by LANDCORP. The CSBP site foreshore (VCL) is reserved for MRS Parks and Recreation, and is vested in the Minister for Lands.

CSR site

(Swan Locations 79 and 80, Maps 5+6) is zoned Industrial by MPTC and is still owned and operated by CSR. MPTC is currently rezoning this site as Development (residential) (C. Terelinck, pers. comm.). The CSR foreshore is reserved for MRS Parks and Recreation.

M57 Minim Cove foreshore, Mosman Park

(Reserves 1630, 31156, 31157, 1631, 39570 and 24242, Maps 4+5) this System 6 locality recommendation is reserved for MRS Parks and Recreation. M57 contains valuable fossiliferous shell beds and is a major focus of this study. The DCE's System 6 'Red Book' M57 locality recommendations and the EPA's 1993 'Red Book' M57 Status Report are presented in Appendix 2.

Buckland Hill Primary School, Rocky Bay Village, T.J. Perrott Reserve (Map 4), Mosman Park Tennis Courts (Map 5) and a number of other reserves are also contained within the study area. Appendix 3 provides a detailed tenure list for the study area.

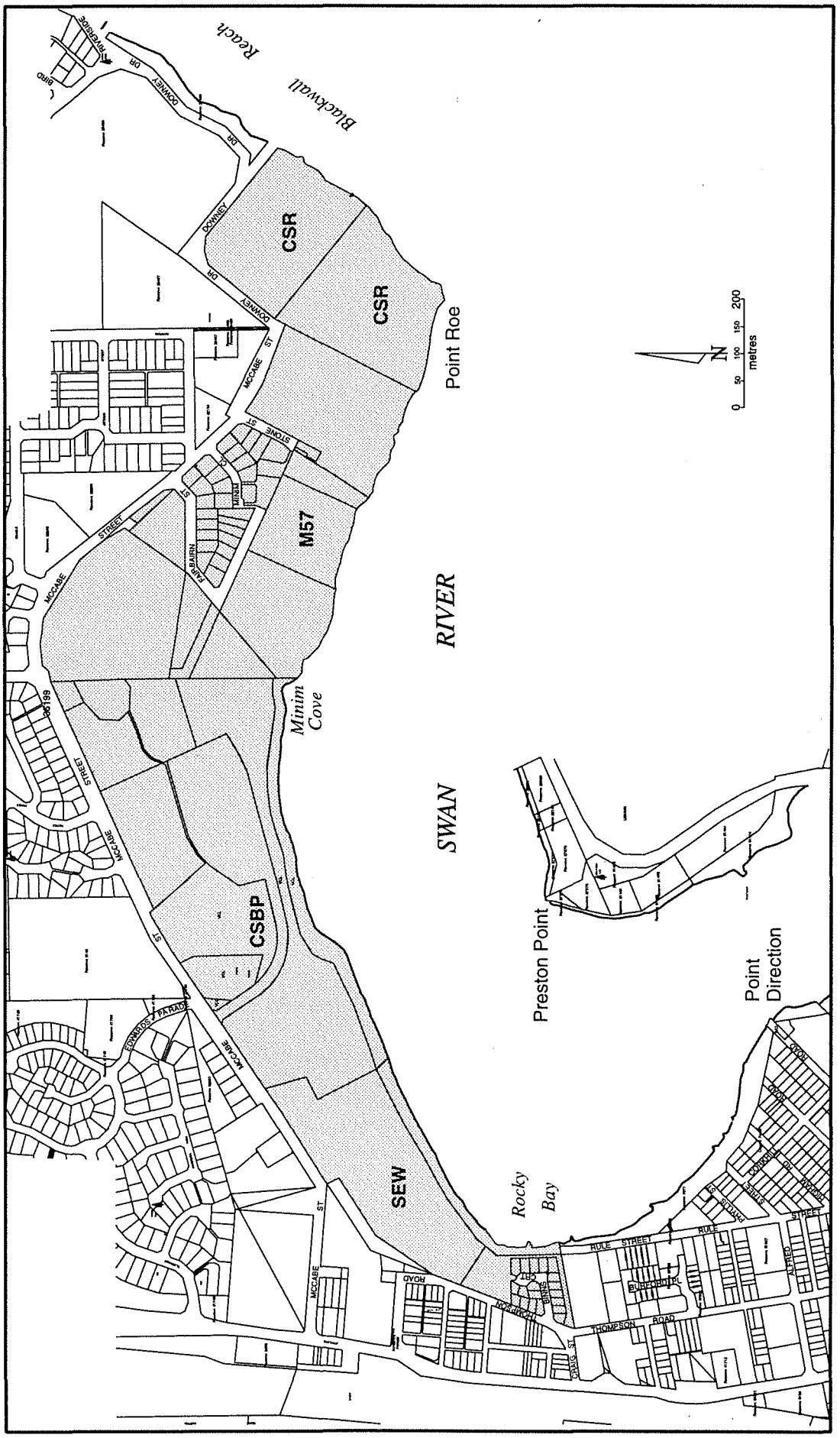

Figure 2 : STUDY AREA

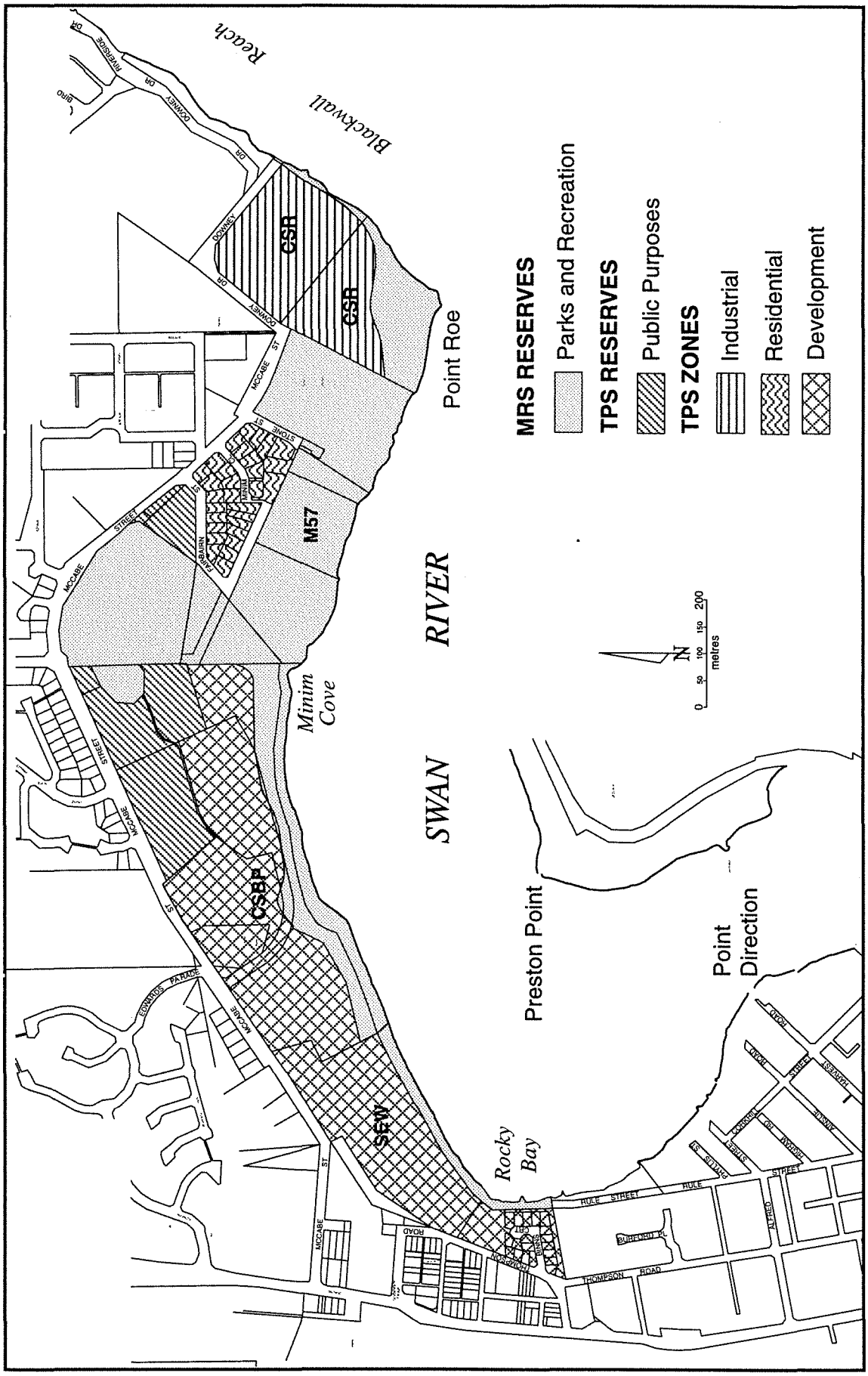

Figure 3 : MRS RESERVES AND TOWN PLANNING SCHEME ZONES

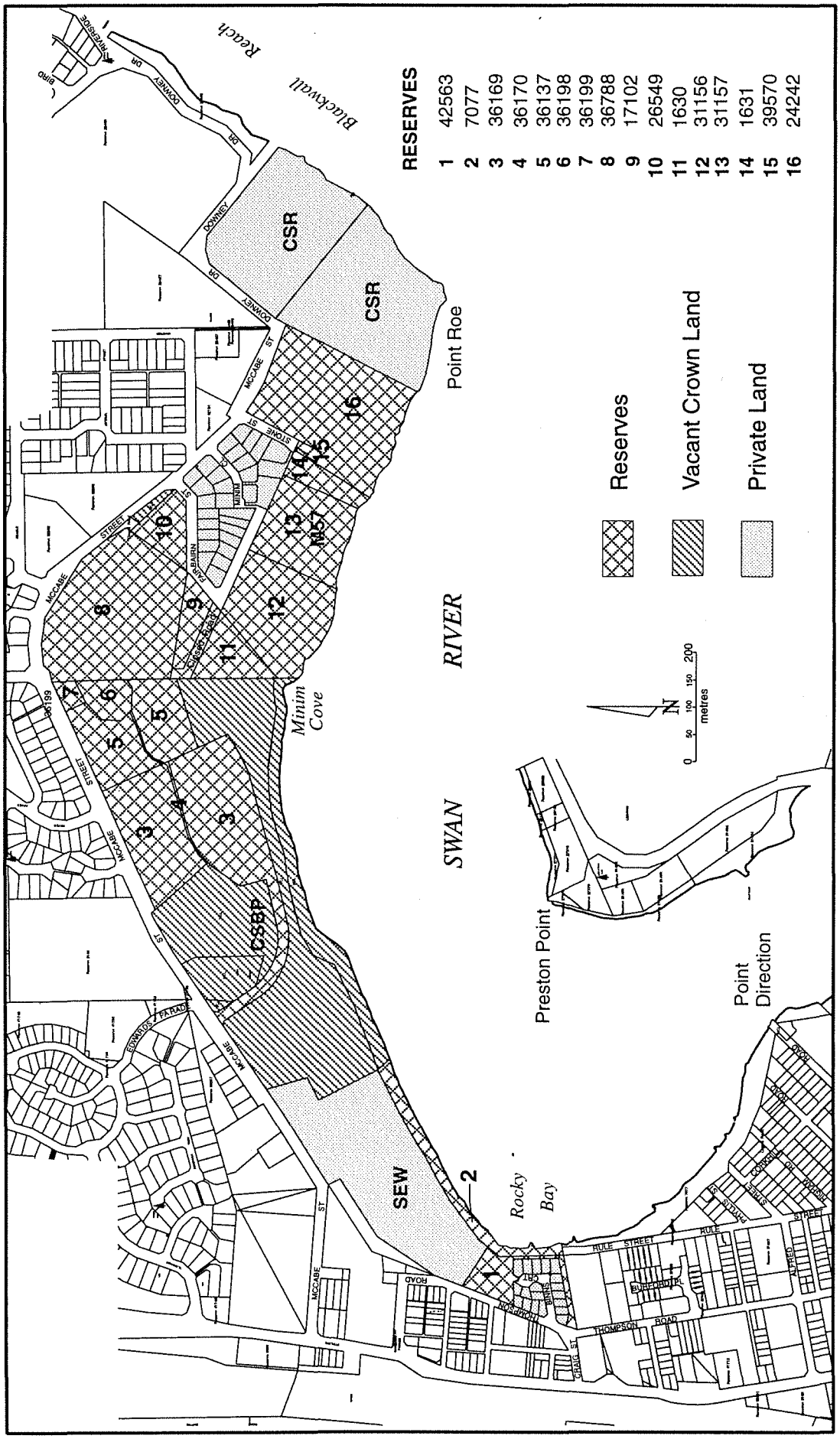

Figure 4 : LAND TENURE

3.0 PHYSICAL ENVIRONMENT

3.1 Climate

The study area experiences a typically Mediterranean climate, seasonally marked by hot dry summers and mild wet winters. The annual rainfall is 698mm with 91% falling between April and September. Mean maximum temperatures range from 29.9°C in February to 17.4°C in July while the mean minimum temperatures range from 18.0°C in February to 9.0°C in July. Summer winds are predominantly east to south easterly between 3.00am and midday, when a sudden change to a strong south westerly sea-breeze occurs. This prevails until approximately 6.00pm and, by midnight, conditions are usually still. Winter wind directions are more variable, with strong gusty storms from the north-west and south-west (Robinson, 1987).

3.2 Geology and geomorphology

The geological history of the area dates back to the late Pleistocene age at around 140,000 years before present (BP). The area is made up of Tamala Limestone (formerly known as Coastal Limestone) which is a unit of eolian (wind formed) calcarenite, and is characterised by large-scale eolian cross-bedding, marking successive dune slopes. Tamala Limestone is recognised along the coastal strip from Shark Bay to the south coast (Playford, 1988). It accumulated largely as belts of coastal sand dunes during the Pleistocene and early Holocene, with a number of marine incursions (R. Halligan, pers. comm.).

Tamala Limestone is made up of calcareous sandstones and limestones in a series of hills and ridges stretching from around Kings Park to the coast, where the narrow fringe of present day calcareous sand dunes and beaches occur (Seddon, 1970). Tamala Limestone is composed of calcareous shell fragments of marine origin and quartz grains eroded from the crystalline rocks of the Darling Plateau and transported to the sea by rivers and along the coast by longshore movements. Calcium carbonate leached from overlying dune sands has cemented the grains of quartz and shell fragments together to form a solid mass (Seddon, 1972).

The Tamala Limestone is variable in outcrop; the variation comes either from differences in sedimentary structures or in later erosional history. The common sedimentary structure is cross-bedding, which is typical of sand dunes. Eolian cross-bedding is found in the study area and generally dips towards the east and north-east, being built by prevailing westerly and south-westerly winds (like those of today). This may extend through several metres across the bedding. Marine laid sands are often cross-bedded on a much finer scale and occur in layers no more than a metre thick (Seddon, 1972). Marine layers containing fossiliferous shell beds are found at Minim Cove and have been described as part of the Peppermint Grove Limestone (Kendrick, 1960). These marine deposits are covered in Section 3.3.

Rhizoliths are often associated with Tamala Limestone, they are initiated by lime precipitation around roots of trees and shrubs that grew in the original dunes, the cavities left after root decay being filled by clastic limestone and cement, or secondary calcium carbonate (Playford, 1988). Plate 2 presents an outcrop of Tamala Limestone at Minim Cove, with rhizoliths occurring above a layer of marine cross-bedding and sparse shell deposits which overlie steeply dipping eolian cross-bedding near the base.

In many places a hard layer of capstone (Kankar) covers the softer underlying limestone outcrops. This is possibly formed as a subsurface hardpan below a layer of loose quartz sand from which the original calcium carbonate cement was dissolved by rainwater seeping downwards; the Kankar capping might then be exposed when the loose sand blew away. Further rainfall would form pools in depressions between dunes, eventually dissolving through the Kankar, and

flowing down to sea-level to form the extensive solution pipes found in the area. Large scale subterranean drainage, by percolation through the Tamala Limestone, has also led to the formation of caves (Seddon, 1972). Solution pipes may also start down cracks and joints in the original bedding or via large rhizolith cavities and subsequent joint erosion (R. Halligan, pers. comm.). Geological features once common throughout the study area, such as Kankar capstone, solution pipes, caves (sinkholes), pinnacles and columns are still extensively developed at the Rocky Bay cliffs.

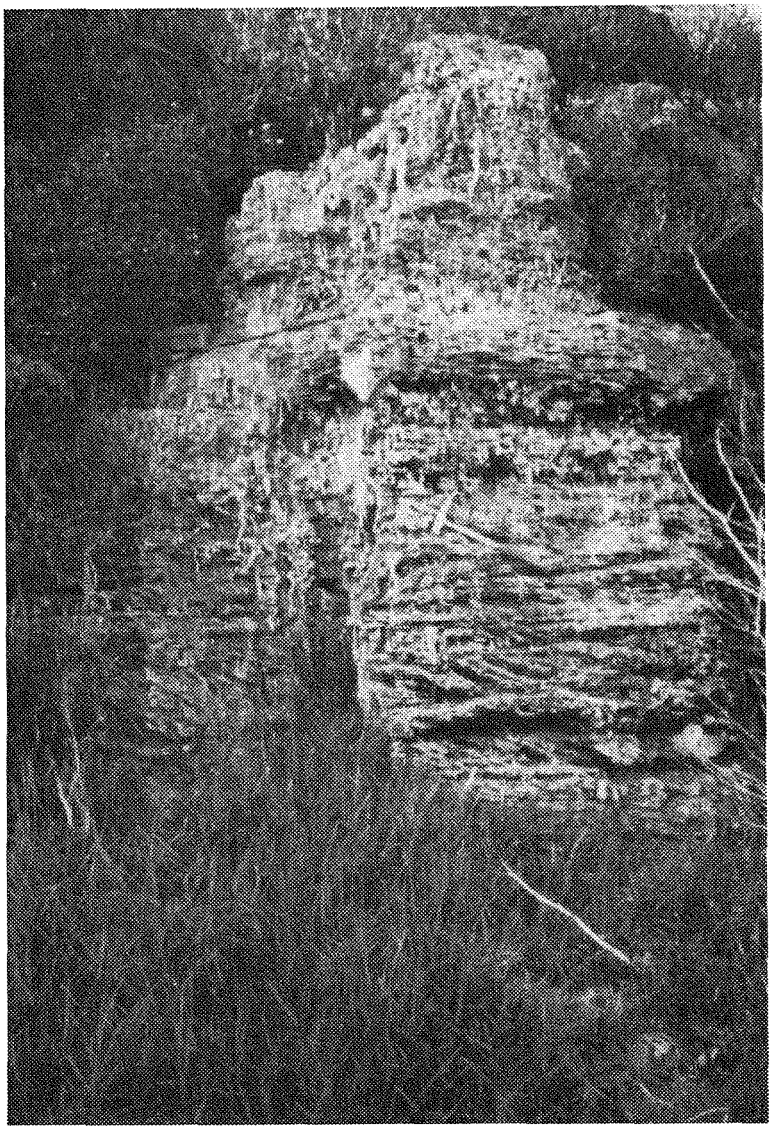

Plate 2: Minim Cove Tamala Limestone Outcrop

3.3 Fossiliferous shell beds

To assess the significance of the Minim Cove fossiliferous shell beds effectively, they need to be discussed in context with the other significant deposits occurring around the Swan River Estuary. Sites around the Swan River Estuary are in the process of being nominated as a geological monument for the National Estate Register (see Perrigo and Halligan, 1992).

The following description is based largely on recent work by G.W. Kendrick, who has published extensively on the Quaternary of W.A. The most recent publication being Kendrick, Wyrwoll and Szabo (1991).

Early interests in the Quaternary of the Perth Basin was greatly influenced by the belief that the fossiliferous deposits were laid down at a stable continental margin, and that tectonic movement had no effect, therefore differences in elevation were due only to glacio-eustatic sea-level changes. More recent work has shown that W.A. is not the stable continental margin envisaged by the early workers, however, tectonic movement has not been great in the central Perth Basin, which includes the area under discussion. The Middle Pleistocene of the Perth area comprises marine and terrestrial (eolian) members, which together make up the major part of the Tamala Limestone (Perrigo and Halligan, 1992).

Kendrick compiled the following summary of the Swan River sites and their importance in a letter dated 24 Feb 1992.

> "There are two questions of scientific importance here. The first is that within a few km of each other on the lower reaches of the Estuary, we have deposits representing four separate glacio-eustatic transgressions of the sea, in natural outcrop. These are:
>
> (i) Point Waylen radio transmitter reserve - age Middle Holocene. This is the last remaining undisturbed example of its kind on the Swan Estuary;
>
> (ii) The Minim Cove beds - age Late Pleistocene;
>
> (iii) The Peppermint Grove beds and correlates - age late Middle Pleistocene;
>
> (iv) The lower bed at the Coombe, Mosman Park (below massive calcrete) - age Middle Pleistocene.
>
> I know of no other location anywhere in Australia where such a diversity of emergent transgressive units from the Middle to Late Quaternary has been preserved. Taken together, these sites represent much more scientific 'value' than the mere sum of the parts and each should be regarded as one of a suite of related deposits covering something like the last 3-400,000 years. That is the first point. The second is that the Swan Estuary-to-Rottnest transect comprises a sequence of deposits, all richly fossiliferous, which begins at the emergent coral reef at Fairbridge Bluff, Rottnest, thence to a similar reef located in the entrance channel to Fremantle Harbour, thence to a fossil bed combining marine and estuarine elements at Fremantle (between the two road bridges), thence to Minim Cove at Mosman Park, thence to the Redcliffe site (referred to above)* and thence to Caversham (Brisbane and Wunderlich's clay pit). These deposits, representing open marine, inshore marine, lower estuary and upper estuary facies are all of the same age (Substage 5e of the Last Interglacial) and provide a unique entry into the linkage and correlation of marine and continental climatic factors at that time of deposition. Again, this situation has no comparable equivalent anywhere else in Australia to the best of my knowledge and again, viewed as a system, their value exceeds the mere sum of the parts. So we have one unique cross-facies transect and another stratigraphic sequence, both without equal in this country." (extract from Perrigo and Halligan, 1992)
>
> * The Redcliffe site, and Brisbane and Wunderlich's clay pit, represent marine shell beds well upstream from the Minim Cove beds.

Note the unique importance of the Minim Cove locality, ie. being in both points raised in Kendrick's letter. In this extract, Kendrick has clearly demonstrated the geological importance, on both local and national scales, of the fossiliferous beds in the Swan River Estuary.

The Minim Cove shell beds are one of several marine units within the predominantly eolian Tamala Limestone. They were originally correlated with the Peppermint Grove Limestone (Kendrick, 1960) but recent studies by Kendrick indicate that the Minim Cove Beds are younger. It is now thought they were deposited about 100,000 years BP (R. Halligan, pers. comm.).

A field survey was undertaken in April 1993, with R. Halligan and M. Freeman from the Geological Survey of W.A. (GSWA), to determine the location, extent, geology and value of these shell beds. The Minim Cove shell beds are located in the cliff face on the Swan River foreshore between Minim Cove and the western boundary of the CSR site (Maps 4+5). Fossil shell deposits are sparse between Minim Cove and the eastern side of the old quarry (Map 4), while from here to the CSR site boundary fossil-rich beds are abundant. Figure 5 displays the location and extent of the marine shell beds, which are intermittently exposed between the 1-6 metre AHD contours along the Tamala Limestone cliff face over a distance of about 600 metres.

There appears to be a sequence of marine shell beds at least five metres in thickness overlain by eolian dunal limestones exposed along the foreshore. Bivalve molluscs are by far the dominant forms present (Perrigo and Halligan, 1992). The richly fossiliferous calcarenite represents sand bank or sill deposition up to 6 metres above AHD within the 'Lower Estuary' under conditions of good oceanic exchange (Kendrick et al., 1991). As a result of wave action, the singular shell valves within the rich shell beds are orientated convex side upwards with their umbonal (hinged) end facing shorewards, while shells which lack uniform orientation were deposited in a subtidal environment below effective wave base (Playford, 1988).

Plate 3 shows a typical section of the fossil shell beds located near the eastern end of the exposed cliff face deposits. At the base is a friable calcarenite, richly to sparsely shelly, overlain by a richly fossiliferous shell bed. Shell orientations indicate quiet water (subtidal) deposition for the lower unit and current deposition for the richly fossiliferous unit. Overlying the latter is another richly to sparsely shelly calcarenite, which is in turn overlain by limestone eolianite.

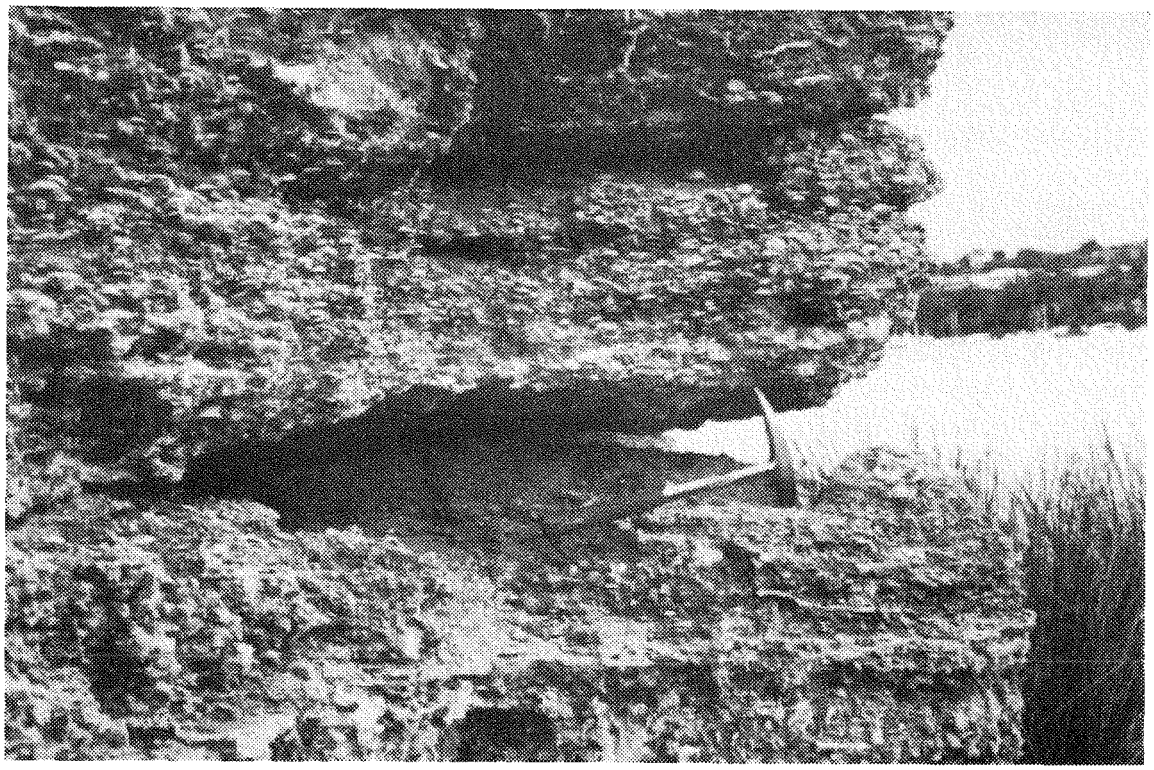

Plate 3: Fossiliferous shell beds

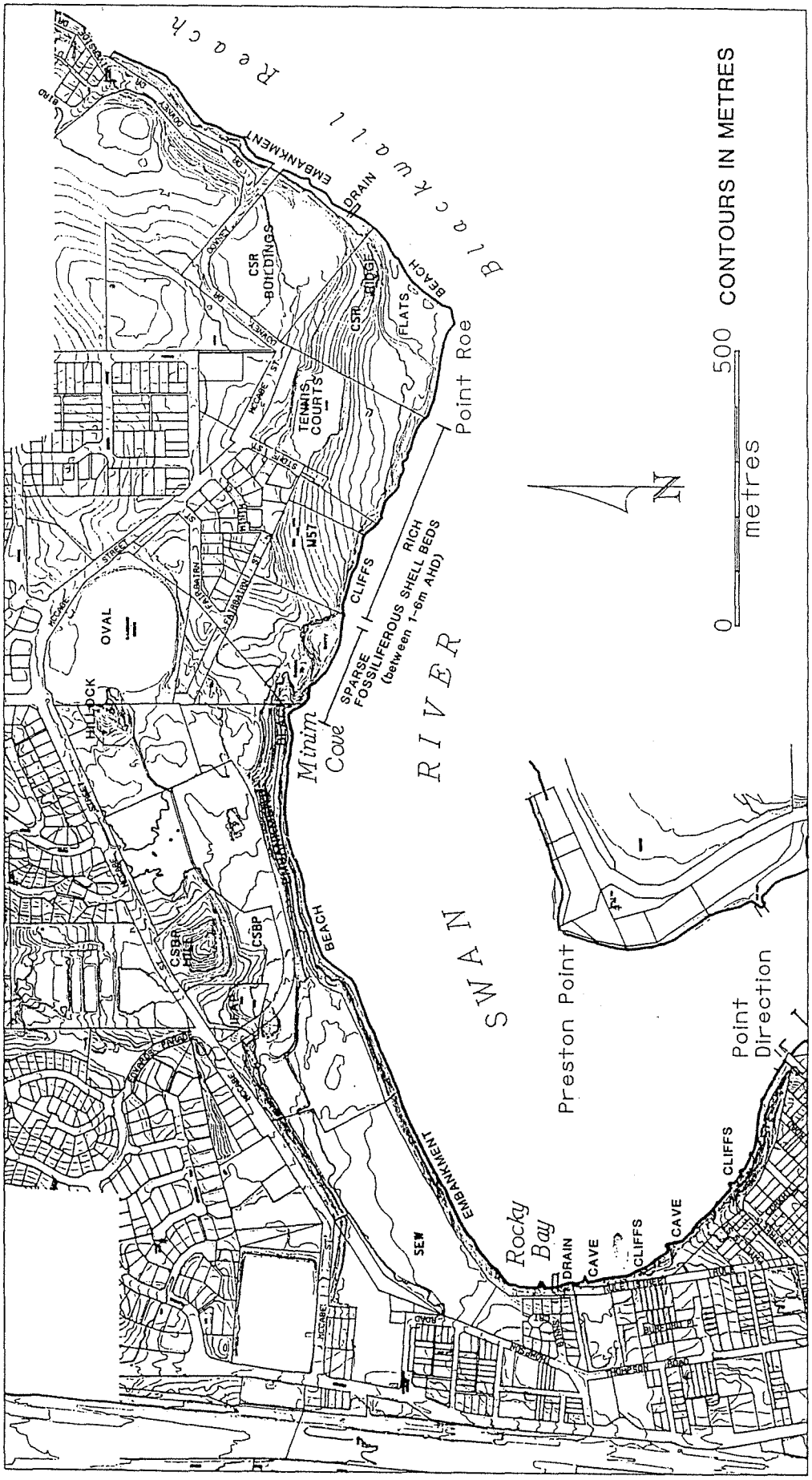

Figure 5: Fossil beds, contours and landscape features

Kendrick (1960) found that the Minim Cove fossil mollusca indicated the presence of a shallow marine gulf with a sandy to muddy floor during deposition. 70% of all individual species sampled, live at present along the south-west coast of W.A. near Fremantle. A further 20% of specimens live east, but not north, of Cape Leeuwin. There is a small element of 4-6%, not known to live south of Geraldton. Four species from the Minim Cove sample are still living in the Swan River Estuary, they also occur in Cockburn Sound. Kendrick (1960) and WAM (1971) provide comprehensive species inventories for the area.

Present-day distributions of the component species do not support the estimate of warmer sea temperatures at the time of deposition (Kendrick, 1960). However, the role of the Leeuwin Current (a southward flow of warm tropical water) in maintaining populations of subtropical fauna in the south-west of W.A. is now recognised. The presence of a significant element within the Middle Pleistocene mollusc fauna of the Perth Basin, with distinct tropical and subtropical affinities, suggests an active Leeuwin Current at that time (Kendrick et al., 1991).

The Minim Cove outcrop is without doubt the best exposed, best preserved and most informative deposit of its age in W.A. It is also one of few fossiliferous outcrops that occur conveniently close to Perth. Its value to the study and teaching of the history of the Swan River district in the recent geological past is outstanding (WAM, 1971).

In summary, the Minim Cove fossiliferous shell beds, as one of the Swan River Estuary Pleistocene and Holocene sites, have significant value for the following reasons:

(a) The site represents one of four separate marine transgressions in the Swan Estuary area during Middle to Late Quaternary times (3-400,000 to 4,000 years BP). The four sites are of national and international significance, and lie within a few kilometres of each other in the metropolitan area.

(b) The sites include rich and highly diverse fossil remains, and are of important palaeontological and stratigraphic significance.

(c) The sites are important research areas and have been extensively studied. Results of research are of world-wide significance, and studies are still in progress.

(d) The sites are important geological teaching areas for schools and universities in Perth.

3.4 Soils

Soil of the study area are mainly eolian in origin and is part of the Cottesloe Soil Association. Weathering of the Tamala Limestone gave rise to the Cottesloe Soil Association, which is described as a shallow yellow and brown sand overlying eolianite. The Spearwood Dune System is a part of the Cottesloe Soil Association (Seddon, 1972). These soils are naturally infertile, supporting closed heath communities where shallow (eg. M57 Reserve at Fairbairn St) and tall open woodland where deeper soils occur (eg. upper CSR site). Some alluvial soil occurs at Point Roe's foreshore flats, however, it is infertile sand and mainly supports only salt tolerant vegetation.

3.5 Groundwater

A study carried out by the Water Authority of W.A. and other government agencies into Perth's urban water balance found that the area's groundwater supply consists of a thin lens of freshwater overlying salt water. This thin lens is recharged only from local rainfall. The watertable is less than 0.5 metres above sea-level throughout the area and, as a result, salt water occurs at a shallow depth below the watertable. There is a risk that salt water could be drawn into artesian bores (WAWA, 1987).

The CSBP site was used between 1910 and 1969 for the production of superphosphate. As a result of CSBP's industrial processes, various parts of the site contain soil contaminated with heavy metals and chemical by-products (EPA, 1988). Studies into the quality of groundwater below the CSBP site were undertaken as part of the 'Proposed Development at McCabe Street Mosman Park' PER. All groundwater heavy metal concentrations were well below the World Health Organisations (WHO's) maximum allowable levels for potable water, except for the occasional raised levels of iron. However, part of Lot 416 (southern portion of Reserve 36169) had groundwater contaminated with mercury, nitrate and phosphate exceeding WHO's levels (Maunsell & Partners Pty Ltd).

Rockwater Pty Ltd (1980) found that CSBP's groundwater constituted an unconfined aquifer with a saturated thickness of about 30 metres. The groundwater was generally fresh in the upper part and saline in the lower part. Depths to the watertable ranged from 18.6 to 24.2 metres below ground level, corresponding to reduced watertable levels of 0.408 and 0.429 metres AHD. The hydraulic gradients were uniform with a downwards slope of about 1:10,000 towards the south-south-west. This indicated that any contaminates reaching the watertable would migrate towards the Swan River. Permeability ranged from 200-430 metres/day for members of the Tamala Limestone. That is, the formation is very permeable and transmits groundwater at a high volume of flow. However, due to layering, vertical percolation can be much less than horizontal (Maunsell & Partners Pty Ltd, 1987).

The SEW operated on the SEW site between 1908 and 1986, being involved with repairs of harvesters, ploughs, naval hardware and metal fabrication. A Notice of Intent, for the proposed remedial treatment of the SEW site North Fremantle, was submitted to the EPA by LANDCORP in 1989. Surveys found that contaminated wastes occurred in a shallow layer over the whole site at depths ranging from a few centimetres to about a metre. It comprised burnt coal wastes, clinker slag and pyritic cinders, and contained elevated levels of lead, arsenic, zinc, copper, iron, mercury and cadmium. The underlying sand had levels of metal ions higher than normally found in soils. The groundwater was tested and found to be minimally contaminated with arsenic and cyanide, at levels either equal to or slightly above recommended levels for drinking water quality in Australia. Complete removal of the waste material (initiated in 1990, see Plate 7) should have effectively prevented any further groundwater contamination (EPA, 1989).

3.6 Drainage

CSR has a cooling water outlet which enters the Swan River at Blackwall Reach adjacent to the CSR buildings (Figure 5). Pollution from this source is not seen as a concern. There was a proposal to pipe CSR's waste warm water across the river to heat the East Fremantle swimming pool. The CSBP and SEW sites no longer have any wastewater drainage entering the Swan River, however, some of CSBP's wastewater outlets are still present.

MPTC has no stormwater drains entering the Swan River in the study area. MPTC stormwater is contained and disposed of via soak wells, gully drains and compensation basins (R. Gorbunow, pers. comm.). FFC disposes of stormwater in northern North Fremantle directly into Rocky Bay/Swan River via the North Fremantle drainage system, with an outlet pipe located adjacent to Binns Court in Stage 1 of Rocky Bay Estate SEW (Figure 5) (S. Morrison, pers comm).

3.7 Swan River water quality

The Swan River Estuary downstream from the causeway is a healthy productive estuarine system with good water quality. Water quality is poorer in the upper riverine reaches of the estuary, where marine flushing is weaker and there is a greater input of stormwater (SRT, 1992a).

Therefore, in general the study area also experiences good water quality. However, localised deterioration in water quality (due to heavy metal contamination) may still exist adjacent to the CSBP and SEW sites. In 1984 sediments and molluscs were sampled (for the Technical Assessment Group) and analysed for arsenic, cadmium, copper, lead, mercury, nickel and zinc. Adjacent to the CSBP outfall pipe levels of arsenic, copper, lead and zinc were considerably higher than at other locations on the Swan River. Levels of cadmium and lead in molluscs exceeded the Food and Drug Regulations maximum permitted concentrations by 3 and 7 times respectively. At the other sampling sites heavy metal concentrations were within acceptable levels (Maunsell & Partners Pty Ltd, 1987).

3.8 Landscape features

As discussed previously, the area is part of the Spearwood Dune System which is characterised by an undulating landscape of limestone hills. The most noticeable feature of the pristine landscape is its gently undulating nature dominated by seven large hills known as the 'Seven Sisters' (see Figure 1).

The 'Seven Sisters' were a significant landscape feature before extensive quarrying began in 1890 and altered the area to it's current relief (see Plate 1). Buckland Hill was the highest of the 'Seven Sisters' at about 61 metres AHD (now 45 metres). The second largest of the 'Seven Sisters', at about 55 metres, was situated at the intersection of McCabe and Palmerston Streets near T.J. Perrott Reserve (Map 4). A small unnamed hillock is still present at 42 metres (Reserve 36198). A ridge of smaller hills extended from here, across the CSBP and SEW sites, to Rocky Bay. These sites are partly located on ground reclaimed by the dumping of quarry spoils into the river; which also considerably filled in, ruined and reformed the northern shoreline of Rocky Bay (Downey, 1971). The SEW and CSBP embankments are now between 10-20 metres AHD. Another unnamed remnant of the 'Seven Sisters' is located within the CSBP site and is now the highest point within the study area at 43 metres (Map 2+3). Figure 5 shows the area's contours, landscape features and the location of this remnant; termed the CSBP Hill for reference purposes. CSBP Hill offers impressive panoramic views of the region (these views are presented in Plates 4-7).

The original natural beauty of the area was noted by early explorers and settlers. According to early settlers Rocky Bay, then known as Rocky Cove, was the most beautiful bay in the Swan River with its high cliffs overhung with peppermint trees, cypress pine and many shrubs. James Turner observed in March 1830: "The foliage of the trees was exquisite, and together with the many turnings in the river, one might fancy themselves in fairy land." (Downey, 1971).

The elevated nature of the landscape and erosional processes have given rise to the many steep cliffs in the area. The cliffs at Rocky Bay were probably the most impressive at 45 metres (now only 10-15 metres AHD). As previously mentioned they were quarried to a platform; the rock was used to build the north and south harbour moles, many public buildings such as the University of W.A., and limestone residences throughout the area (Downey, 1971). The original landscape has also been highly modified since colonisation by other land uses such as farming, logging and urban development (Ecoscape, 1990).

Todays landscape features include both natural and cultural elements of significance. The main natural features include; the Swan River, hills, cliffs, embankments, foreshore beaches and vegetation. Foreshore beaches are located at Point Roe, Minim Cove, the old quarry, and the CSBP foreshore (Figure 5). Many smaller localised beaches are exposed at low tide. These natural features are visual focal points and provide texture, colour and diversity in composition.

Plate 4: CSBP Hill north to Buckland Hill, obelisk, vacant industrial site and vegetation.

Plate 5: CSBP Hill east across CSBP site to Minim Cove, M57, Point Roe, Swan River and Bicton.

Plate 6: CSBP Hill south across CSBP site and Swan River to Swan Yacht Club at Preston Point, East Fremantle, Point Direction and Cypress Hill.

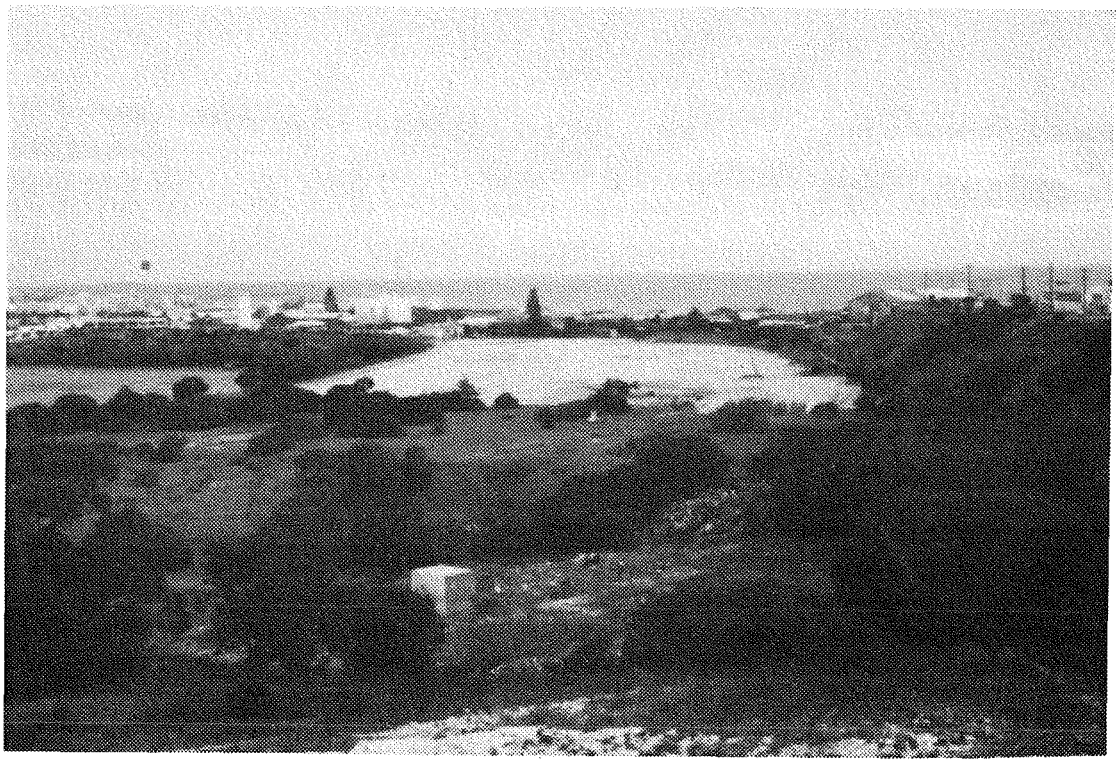

Plate 7: CSBP Hill west across IFAP ruins and CSBP site to Rocky Bay, cleared SEW site, North Fremantle industry and Indian Ocean.

Impressive views are offered from the cliffs, embankments and CSBP Hill. Certain points along the cliff and at CSBP Hill offer river and ocean views simultaneously. These features provide both viewing positions and are themselves visual focal points. They contribute to the diversity of the Swan River foreshore, particularly for river users. Vegetation communities and associations provide visual interest in terms of variety in height, colours and texture. They also serve to integrate disparate parts of the landscape (Ecoscape, 1992). Plates 8-11 provide further evidence of the landscape values of the area.

The cultural landscape is made up of historic and modern buildings (industrial, commercial, residential and institutional), roads, tracks, dual use paths, an oval, tennis courts, parks, gardens, lawns, and disused quarries. Cultural modifications have had both positive and negative effects on the area's natural attributes. Some of the area's historic buildings, contribute to the character of the landscape namely; the CSR building (Plates 14+15 and glimpses in 5,8+9), Burford's Soap Factory (Plate 10) and the Dingo Flour Mill (glimpses in Plates 7+10).

The CSR buildings' character, in particular, was noted by Seddon (1970): "The Colonial Sugar Refinery is one of the best sites on the river, a Pennsylvanian Dutch Castle on the Rhine, well sited and with unimpaired foreshores."; "The Colonial Sugar Refinery near Point Roe shows that the needs of industry and the landscape amenity need not conflict. The sheer bulk of the buildings is impressive; they sit well on the site, and the roof lines compose and recompose in Gothic variety as one moves around the river." and "where but in an industrial complex such as this can one find a functionally related group of tall buildings, varied in outline, uniform in style and finish? There is a cluster of small low buildings huddled around the base, like the cottages of a mediaeval town.". The CSR buildings currently appear as impressive and extensive as they did to Seddon.

More recent structures such as the local marinas (Plate 6), and the Homeswest flats and surrounding residences (Plate 11) also contribute to the area's character. The dual use paths, oval, tennis courts, parks and gardens integrate with the natural and cultural environments. They provide viewing points and are attractive settings for recreational activities. Disused quarries such as the remnant hillock and an old quarry east of Minim Cove (Plate 9) offer visual interest. However, quarrying in general has had enormous negative impacts on the area's landscape values. Other features which have negative impacts include power transmission lines (Plates 5,8+9), vacant industrial sites (Plates 4-7), and some industrial and commercial buildings (Plates 7+10).

McCabe Street offers views of the landscape, and in some places both river and ocean views. Dual use paths provide pedestrians and cyclists with extensive views of the river, foreshore, opposite river bank, vegetation, general landscape and some ocean glimpses. Walk trails, including the Rocky Bay and proposed Mosman Park Heritage Trails, offer perhaps the best views of the landscape. Excellent views of the landscape are found along the river, particularly from boats, and include the cliffs, vegetation and elements of the cultural environment (Ecoscape, 1992).

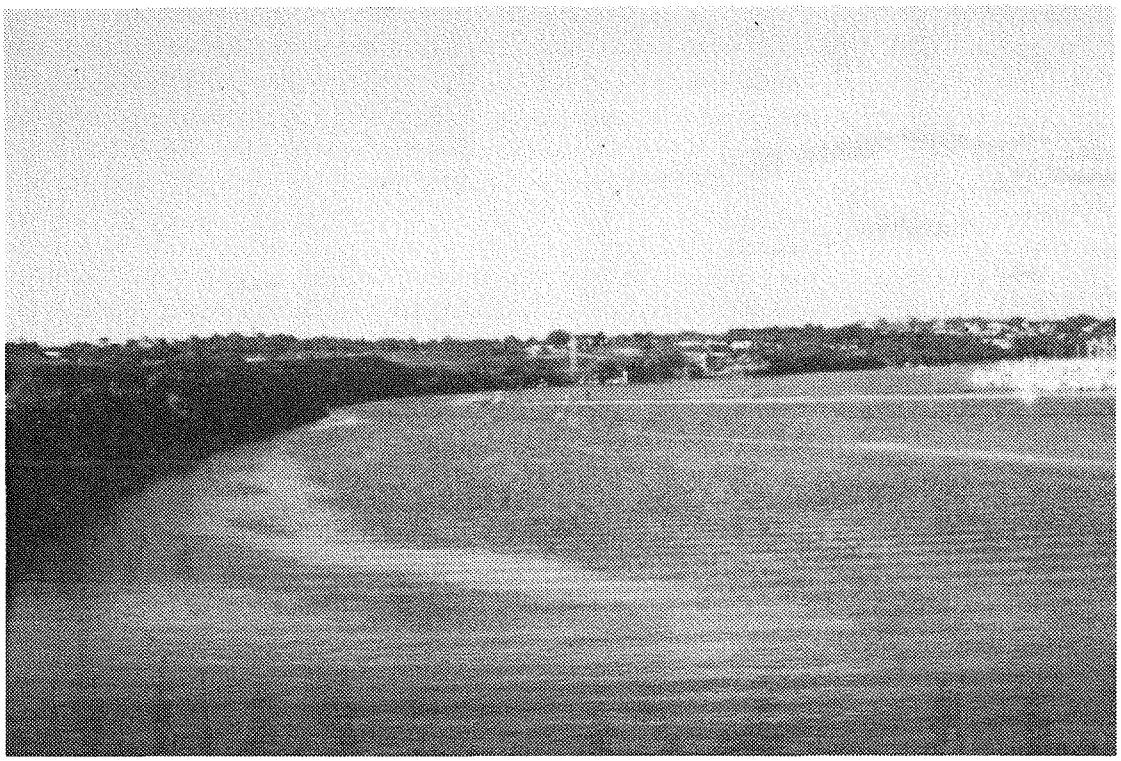

Plate 8: Rocky Bay east along CSBP embankment to Minim Cove, old quarry, M57, CSR and Point Roe.

Plate 9: Preston Point north to Minim Cove, old quarry, M57 and CSR.

Plate 10: Preston Point west across Rocky Bay to cliffs, Burford's Soap Factory and SEW embankment.

Plate 11: SEW embankment south across Rocky Bay to Point Direction, Cypress Hill, Homeswest flats, North Fremantle and Rocky Bay cliffs.

4.0 BIOLOGICAL ENVIRONMENT

4.1 Terrestrial flora

A number of different vegetation communities would have been present before European settlement in 1829. Prior to settlement these communities would have varied according to various environmental factors like soil depth and moisture, wind, salinity, proximity to the watertable, fire and aboriginal management practises. Subtle variations in these conditions would have provided similar responses in composition and structure of the vegetation communities. Four vegetation communities can be identified within the study area, largely being described as they would have existed prior to European settlement. **Nb.** Community species listed may not occur in the study area at present. This section should be read in conjunction with Appendix 4, which presents a flora species list including common names.

4.1.1 Vegetation communities:

(a) Rottnest Cypress low closed-forest

This community occupies a very small area now, but was once wide spread. The only remaining mainland stand occurs near Woodman Point, south of Fremantle. The community consists almost solely of *Callitris preissii* (Rottnest cypress) with occasional *Melaleuca lanceolata* (Rottnest tea-tree) present. This is a single-storeyed forest, with under-storey shrubs present only where there is a break in the canopy: *Phyllanthus calycinus* (false Boronia) is a common species, with isolated bushes of *Spyridium globulosum* (basket bush), *Eremophila glabra* (tar bush) and *Leucopogon parviflorus* (Seddon, 1972).

Interspersed *Agonis flexuosa* (peppermint), *Acacia xanthina*, *Eucalyptus decipiens* (limestone marlock) and E. *foecunda* (Fremantle mallee) may have been found in the community at Rocky Bay, particularly since specimens are still surviving on the opposite bank in East Fremantle. Repeated fires and clearing resulted in the degradation of the community, particularly as *Callitris preissii* is not a fire tolerant species. This community type was once common along the banks of the lower Swan River and has virtually disappeared today (Ecoscape, 1993).

(b) Limestone closed-heath

Limestone closed-heath communities are found near the coast on limestone hills and ridges; in shallow soils, exposed to windy, low nutrient environments. They are generally less than two metres high with a projected foliage cover of 30-100%, and have a diverse flora in the undisturbed state (Ecoscape, 1990).

Dominant species include: *Acacia cuneata*, A. *xanthina* and A. *lasiocarpa*, with *Melaleuca huegelii* and M. *acerosa* sometimes dominant. Other species occurring are: *Dryandra sessilis* (parrot bush), *Grevillea crithmifolia*, G. *thelemanniana*, *Hemiandra pungens*, *Templetonia retusa* (cocky's tongue) and *Spyridium globulosum*; with some *Lepidosperma angustatum* (sword sedge) and *Xanthorrhoea preissii* (black boy). Many naturalized exotic species also occur on limestone heath: *Foeniculum vulgare* (fennel), *Lobularia maritima*, *Nicotiana glauca* (tree tobacco), *Pennisetum* sp. (grasses), *Scabiosa atropurpurea* (purple pincushion) and *Ricinus communis* (castor oil bush) (Seddon, 1972).

(c) Tuart-Jarrah-Marri tall open-forest

On deeper soils, under more sheltered conditions, open-forest woodland communities are supported. The canopy has generally between 30-70% foliage cover, and where less the community develops a woodland character. Some of the taller trees would approach 30 metres high. Dominant tree species include: *Eucalyptus gomphocephala* (tuart), E. *marginata* (jarrah), E. *calophylla* (marri) and in shallower soils the occasional E. *decipiens*. Beneath the tree canopy there is a well marked small-tree layer, made up of: *Banksia attenuata*, B. *menziesii*, *Allocasuarina fraseriana* (Fraser's sheoak) and *Agonis flexuosa*. *Macrozamia riedlei* (zamia palm) and *Xanthorrhoea preissii* are both frequently present.

There are two shrub layers in undisturbed areas. The tall shrubs are: *Acacia cyclops*, A. *cyanophylla*, *Dryandra sessilis*, *Hakea glabella* and *Jacksonia sternbergiana*. The low shrub layer is even richer and more variable containing: *Acacia pulchella* (prickly moses), *Allocasuarina humilis* (dwarf sheoak), *Calothamnus quadrifidus*, *Dryandra nivea* (couch honey pot), *Grevillea thelemanniana*, *Hemiandra pungens*, *Hibbertia racemosa*, *Leucopogon parviflorus*, *Melaleuca acerosa*, *Oxylobium capitatum*, *Petrophile serruriae* and *Synaphea spinulosa*. Common creeper species are: *Cassytha* sp. (dodder laurels), *Clematis microphylla*, *Hardenbergia comptoniana* (native wisteria) and *Kennedia prostrata* (running postman) (Seddon, 1972).

(d) Juncus-Casuarina foreshore

Rush communities would have been found growing along the rivers edge. Species such as *Juncus kraussii* (shore rush) and *Isolepis nodosa* (knotted club rush) would have been abundant along the foreshore. *Casuarina obesa* (swamp sheoak) would have been found right to the rivers edge (Ecoscape, 1992). Other salt tolerant species found cohabiting with this community in the lower estuary are: *Carpobrotus aquilaterus* (native pig-face), *Halosarcia* sp. (glasswort shrub), *Lepidosperma angustatum*, *Mesomelaena pseudostygia* (telegraph sedge), *Myoporum insulare*, *Sarcocornia quinqueflora* (samphire) and *Suaeda australis* (seablite).

4.1.2 Area descriptions:

As a result of European settlement vegetation communities within the study area have been highly degraded and modified. Very little of the original floral composition remains, however, what does remain has value on local and regional levels.

The following area descriptions are based on species observed during field surveys undertaken in April 1993.

(a) Rocky Bay cliffs

The cliffs at Rocky Bay would have consisted of Rottnest Cypress Low Closed-Forest, merging into Limestone Closed-Heath further back from the cliff face, before being cleared and quarried. The level of vegetative cover can be seen in Plates 7+10. The cliffs are now dominated by *Acacia saligna* and *Templetonia retusa*; interspersed less dominantly with *Acacia rostellifera*, A. *cyclops*, *Acanthocarpus preissii* (prickle lily), *Alyxia buxifolia* (hop bush), *Dryandra sessilis*, *Eucalyptus* sp., *Melaleuca acerosa*, M. *huegelii*, *Pittosporum phillyraeoides* (cheese-wood) and *Rhagodia baccata* (salt bush). Native grasses such as *Stipa elegantissima* are also present. At the base of the cliffs some *Juncus kraussii* and *Isolepis nodosa* can be found with occasional *Casuarina obesa*.

Introduced exotic species; such as *Avena fatua* (wild oat), *Cynodon dactylon* (couch), *Foeniculum vulgare*, *Nicotiana glauca*, *Leptospermum laevigatum* (Victorian tea-tree), *Oenothera drummondii* (evening primrose), *Pelargonium capitatum* (wild geranium), *Pennisetum* sp. (grasses), *Ricinus communis* and *Scabiosa atropurpurea*; are abundant on the cliff face.

Pittosporum phillyraeoides is a species of some regional significance as it is rarely seen on the banks of the Swan River today. The Rocky Bay Heritage Trail Revegetation Programme was undertaken in 1988, and as a result many more tree species are now regenerating along the Rocky Bay cliffs (Ecoscape, 1993). Appendix 4 indicates species revegetated along the cliffs.

(b) SEW embankment

Prior to quarrying, this location would have contained the same original communities as the Rocky Bay cliffs. The present SEW embankment was artificially created during SEW contaminated waste clean-up operations in 1990. The embankment was cleared of vegetation and wastes; clean fill was applied and a revegetation programme was then instigated by LANDCORP and FCC in 1991 (see Ecoscape, 1993). Plate 10 shows the degree of regeneration.

The only remnant species consists of five well established specimens of *Melaleuca lanceolata* (Plate 7). Regenerated species are dominated by *Acacia xanthina*; less dominant are: *Agonis flexuosa, Callitris preissii, Dryandra sessilis, Eremophila glabra, Eucalyptus* sp., *Grevillea thelemanniana, Hakea prostrata, Hardenbergia comptoniana, Kennedia prostrata, Melaleuca huegelii, Pittosporum phillyraeoides, Rhagodia baccata, Spyridium globulosum, Scaevola crassifolia* and *Templetonia retusa*. Introduced species are dominated by *Foeniculum vulgare* and *Ricinus communis*; *Nicotiana glauca, Oenothera drummondii* and *Pennisetum* sp. are also present.

(c) CSBP site

The CSBP sites original community structure would have consisted of a *Juncus-Casuarina* Foreshore backed by a Rottnest Cypress Low Closed-Forest merging into Limestone Closed-Heath prior to intense clearing and quarrying. Many indigenous species have since recolonised this area (see Plate 8). The CSBP foreshore is now dominated by *Acacia cyclops*, A. *xanthina, Agonis flexuosa, Melaleuca lanceolata* and M. *huegelii*. Other natives found along the foreshore are: *Acanthocarpus preissii, Alyxia buxifolia, Eucalyptus* sp., *Hardenbergia comptoniana, Lepidosperma angustatum, Pittosporum phillyraeoides, Rhagodia baccata, Scaevola* sp. (fan flowers), *Spyridium globulosum, Templetonia retusa* and *Trymalium ledifolium. Isolepis nodosa* and *Leucopogon parviflorus* are recolonising the river foreshore. *Boronia alata* and *Logania vaginalis* (white spray) are two locally rare species found on the CSBP foreshore.

CSBP Hill has some regenerated vegetation, mainly on the north-eastern corner, consisting of *Acacia rostellifera, Melaleuca lanceolata*, M. *huegelii, Templetonia retusa* and *Xanthorrhoea preissii* (Plate 4). The IFAP ruins have several *Eucalyptus gomphocephala, Acacia* sp. and *Melaleuca* sp. surrounding them (Plate 7 and Map 2).

The CSBP site has been invaded by many exotic weeds (Plates 4-7). Introduced species are dominated by: *Cynodon dactylon, Foeniculum vulgare, Leptospermum laevigatum, Lupinus angustifolius* (New Zealand blue lupin), *Pennisetum* sp. and *Ricinus communis*. Additional exotics include *Ficus carica* (edible fig), *Pelargonium capitatum, Phoenix* sp. (date palms), *Scabiosa atropurpurea, Shinus terebinthifolius* (Japanese pepper) and *Stenotaphrum secundatum* (buffalo grass).

(d) M57 Minim Cove foreshore and reserve 36198

The original community structure of this area would have consisted of a *Juncus-Casuarina* foreshore backed by a Rottnest Cypress Low Closed-Forest merging into Limestone Closed-Heath (on western portion) and Tuart-Jarrah-Marri Tall Open-Forest (on eastern portion). The area now consists of Limestone Closed-Heath and extensive mowed lawns (*Cynodon dactylon*) planted with scattered trees and shrubs including *Agonis flexuosa, Casuarina obesa, Eucaluptus* Sp., *Melaleuca* sp. and *Xanthorrhoea preissii*; especially south of the Tennis Courts in Reserve 24242.

Plate 12: CSR ridge south, across Point Roe's foreshore vegetation and Swan River, to east Fremantle.

Plate 13: Point Roe west across *Juncus kraussii* community and Swan River to marinas and SEW embankment.

Between Fairbairn Street and the cliffs surrounding the old quarry (north and east sides) a well preserved ridge of Limestone Closed-Heath exists. This ridge is probably the richest and most diverse community of its type in the area (C. Nicholson, pers. comm.). Species present include: *Acacia cyclops, Acanthocarpus preissii, Agonis flexuosa, Allocasuarina humilis, Alyxia buxifolia, Boronia alata, Carpobrotus aquilaterus, Conostylis candicans, Dianella revoluta* (flax lily), *Dryandra nivea*, D. *sessilis, Eremophila glabra, Grevillea thelemanniana, Hakea prostrata* (harsh hakea), *Hardenbergia comptoniana, Lepidosperma angustatum, Leschenaultia linarioides, Leucopogon parviflorus, Lomandra maritima, Loxocarya flexuosa, Macrozamia riedlei, Melaleuca acerosa*, M. *huegelii, Mesomelaena pseudostygia, Myoporum insulare* (boobialla), *Olearia axillaris, Opercularia vaginata, Petrophile serruriae, Poa poiformis, Rhagodia baccata, Scaevola holosericea*, S. *nitida, Solanum symonii, Sollya heterophylla* (bluebell), *Spyridium globulosum, Templetonia retusa, Tricoryne elatior* (yellow lily) and *Xanthorrhoea preissii* (list adapted from WANC, 1985).

The old rubbish tip, located east of Minim Cove, is revegetated with *Acacia xanthina*, A. *cyclops* and the exotic *Olea europaea* (European olive). Plates 5+9 shows a view of the locality's foreshore vegetation. *Juncus kraussii, Sarcocornia quinqueflora* and *Halosarcia* sp. are found in patches along the M57 foreshore. A uniform *Juncus* community exists adjacent to Reserve 24242, transforming into a *Juncus-Casuarina* community near the CSR site MRS Reserve (Plate 13 and Map 5).

Introduced species are abundant in M57 including: *Avena barbata* (bearded oat), A. *fatua, Arundo donax* (giant reed/false bamboo) (see Plate 9), *Cynodon dactylon, Erharta calycina* (veldt grass), *Euphorbia terracina* (Geraldton carnation weed), *Ficus carica, Lagurus ovatus* (pussy tails), *Pelargonium capitatum, Pennisetum villosum* (feather top grass), *Ricinus communis, Scabiosa atropurpurea, Sonchus oleraceus* (sow thistle) and *Stenotaphrum secundatum.*

The small unnamed hillock (Reserve 36198), north of Minim Cove, has a reasonable cover of native vegetation and would have been part of the Limestone Closed-Heath community. *Acacia xanthina*, A. *cyclops, Eucalyptus gomphocephala, Melaleuca lanceolata* and *Templetonia retusa* exist on the hillock; along with a suite of exotic weeds, particularly *Pennisetum villosum* (Ecoscape, 1990).

(e) CSR foreshore reserve

The CSR site would have consisted originally of a *Juncus-Casuarina* foreshore community, backed by a Tuart-Jarrah-Marri Tall Open-Forest. Although the area has been modified since European settlement it still retains many pristine characteristics. This could be a result of the sites isolation and the owners using management practices compatible with retaining endemic vegetation. The Tuart-Jarrah-Marri Tall Open-Forest community now contains: *Acacia pulchella*, A. *saligna, Agonis flexuosa, Banksia attenuata*, B. *menziesii, Eucalyptus calophylla*, E. *gomphocephala*, E. *marginata, Hakea prostrata, Nuytsia floribunda* (Christmas tree), *Macrozamia riedlei* and *Xanthorrhoea preissii.* Introduced flora is made up of *Arundo donax, Avena fatua, Cynodon dactylon, Euphorbia terracina, Ficus elastica* (rubber plant), F. *carica*, F. *macrophylla* (Moreton Bay fig), *Lagurus ovatus, Lupinus angustifolius, Oxalis pes-caprae* (soursop), *Pennisetum* sp., *Ricinus communis* and *Stenotaphrum secundatum.*

The CSR ridge is vegetated with *Agonis flexuosa, Banksia attenuata, Chamaelaucium unicinatum* (Geraldton wax), *Eucaluptus citriodora* (lemon scented gum), *Eucalyptus* sp., *Nuytsia floribunda* and the exotic *Olea europaea* (Plates 12+15). The northern end of the ridge extends north along Blackwall Reach to a valuable natural stand of endemic vegetation. The regionally rare species *Santalum acuminatum* (sweet quandong) can be found amongst *Agonis flexuosa, Allocasuarina humilis, Dianella revoluta, Dryandra sessilis, Hakea prostrata, Hardenbergia comptoniana* and *Rhagodia baccata.*

The MRS Parks and Recreation Reserve starts below the CSR ridge (Plates 12+15 and Map 6) at about the 5 metre AHD contour. The majority of this area is grassland covered by the exotic species *Avena barbata*, A. *fatua, Cynodon dactylon* and *Erharta calycina*, being interspersed with

Acacia cyclops, A. *saligna*, *Casuarina obesa*, *Hakea prostrata* and *Macrozamia riedlei* (Plates 12,14+15). A patch of *Shinus terebinthifolius* and a *Phoenix* sp. also occur here.

The foreshore consists mainly of a *Juncus-Sarcocornia* sub-community, characterised with *Juncus kraussii*, *Sarcocornia quinqueflora* and *Suaeda australis* (Pen, 1983). Other foreshore species are *Casuarina obesa*, *Halosarcia* sp., *Isolepis nodosa*, *Lepidosperma gladiatum* (coastal sword sedge), *Mesomelaena pseudostygia*, *Myoporum insulare*, *Schoenoplectus validus* (club rush), *Sporobolus virginicus* (sand couch) and *Stipa elegantissima* (Plates 13+14). The dune plant *Spinifex longifolius* (long leaved spinifex) also occurs here, as a result of the high salinities in the lower estuary (Plate 14).

4.2 Terrestrial fauna

The distribution and abundance of terrestrial fauna is closely related to wildlife habitat areas. Within the study area the majority of these habitats have been lost, being replaced by industry and urban development. This has resulted in a severe reduction in native species. Appendix 5 presents a list of the study area's terrestrial fauna found in the area; including mammal, reptile and bird species.

The area had an abundant native wildlife prior to European settlement. In 1917 Thomas Briggs reported that "Between Subiaco and North Fremantle was teeming with game-kangaroos, wild turkeys, large bronze wing pigeons, blue pigeons, parrots, magpies and wild ducks-" (cited in Downey, 1971). The rabbit-eared bandicoot or bilby (*Macrotis lagotis*) was once frequently seen; the last one was killed on the CSR site in 1928. The last wild brush wallaby (*Macropus irma*) was shot in 1905, adjacent to the CSR site. Robins, blue wrens and many other small birds were once plentiful but have now gone. The introduced kookaburras (*Dacelos gigas*) supposedly have killed them off (Downey, 1971).

Many other mammal, reptile, bird and insect species would have been common in the area's different habitats. Only one native mammal, the brushtailed possum (*Trichosurus vulpeca*) has been found on the area in recent years. The brushtailed possum is perhaps the only native species able to adapt to urban areas. The presence of the water rat (*Hydromys chrysogaster*) and an unidentified species of native bat have been reported, but neither have been positively identified.

Many introduced species are present including: the laughing turtle-dove, foxes, mice, rats, rabbits, and non-endemic kookaburras. Vegetation remnants and landscape features still provide valuable habitats for many native reptiles such as: the western bearded dragon, bobtail lizard, Burton's legless lizard, Bynoe's gecko, dugite, king skink and stripped skink. Introduced predators such as cats, and non-endemic kookaburras, have reduced reptile numbers considerably (Ecoscape, 1993).

A survey by WANC (1985) observed a number of aquatic birds at Point Roe including the: Australian pelican, black duck, caspian tern, cormorants, greenshank, herons, pied oyster catcher and silver gull. Large flocks of cormorants and silver gulls can often be seen flying up the river. Common terrestrial birds include the Australian magpie and raven, kookaburras, laughing turtle-dove, singing honeyeater and welcome swallow. Some uncommon species are the pied butcher bird, sacred kingfisher and striated pardalote. The rainbow bee-eater uses the SEW embankment for summer nesting. The study area is important as a wildlife corridor and habitat area for both aquatic and terrestrial birds. The diversity of species recorded in the study area is large considering the range of habitats available (Ecoscape, 1993).

A public submission for M57, submitted by the W.A. Group of the Royal Australian Ornithologists Union (RAOU), states that the M57 marshes are probably the last strongholds of the sharp-tailed sandpiper in the Swan River Valley (DCE, 1983). The sharp-tailed sandpiper and the greenshank are both protected under the JAMBA treaty (Jaensch, in John, 1987).

Plate 14: Point Roe north across foreshore community to CSR ridge, CSR buildings and Blackwall Reach.

Plate 15: Point Roe flats north-east to CSR ridge vegetation and CSR buildings.

4.3 Aquatic flora

The aquatic flora of the lower Swan River Estuary (Fremantle Harbour to Blackwall Reach), and study area, includes seagrasses, macroalgae and microscopic algae. Aquatic flora plays a vital role in estuarine ecosystems, being highly productive despite the severe conditions placed on them by the estuarine environment. The aquatic flora not only provides a food source for a diverse and productive aquatic fauna but also a habitat in which to live; as shown by the importance of seagrass meadows as nursery areas for fish (Thurlow, Chambers and Klemm, 1986).

4.3.1 Seagrasses

Halophila ovalis (paddle weed) is the dominant benthic plant of the Swan River Estuary. The only other estuarine seagrass is *Zostera mucronata*, which chiefly occurs in small amounts near the estuarine mouth. H. *ovalis* occupies 550-600 ha in the lower reaches of the estuary, which represents about 20% of the area of the main estuarine basin. Growth and distribution of H. *ovalis* is strongly influenced by seasonal changes in salinity, temperature and turbidity. The main growing period is summer, when light supply and temperatures are highest, and the more favourable marine salinities prevail. Over 90% of the seagrass is found in waters less than two metres deep (relative to Fremantle datum). A dense stand (mainly 85-100% cover) of H. *ovalis* occurs at Rocky Bay's centre on a shallow sand bank, while adjacent to Point Roe a less dense stand (5-85% cover) occurs (Hillman, in John, 1987).

4.3.2 Macroalgae

A total of 66 species of macroalgae have been identified in the Swan River Estuary; this compares to about 600 species occurring in nearby coastal marine waters. This is a large number of species for an estuarine system and indicates both a strong marine influence and a lack of pollution in the estuary. *Glacillaria verrucosa* (red algae) is very abundant and occurs above Perth water. Other common species include *Bangia fuscopurpurea*, *Calothrix parietina*, *Cladophora* sp., *Colpomenia peregrina*, *Cystoseria trinodis*, *Enteromorpha* sp., *Grateloupia filicira*, *Griffithsia corallina*, *Ulva lactuca* (sea lettuce) and *Ulvaria oxysperma*. Nine species of marine algae occur no further up the estuary than Preston Point. Lower estuary species mainly proliferate in late summer to early winter (ie. peak of the estuary's marine phase) and this grouping occurs in waters of an average annual salinity of 25 ppt or more (Thurlow et al., 1986). There has been no deterioration of macroalgae in the lower estuary since a mid 1980s survey (SRT, 1992a).

4.3.3 Microalgae

The microscopic flora can be divided into three main groups depending on their habitat.

(i) Planktonic (phytoplankton) fauna is dominated by diatoms (Bacillariophyta) of which 363 species belonging to 79 genera have been recorded, about half of these preferring the higher salinities of the lower estuary (John, in John, 1987). The remaining micro-flora is made up of Dinoflagellates and microscopic forms of other algal groups eg. Chlorophyta.

(ii) Epiphytic microalgae distribution generally follows that of the seagrasses and macroalgae to which they attach. *Melosira moniliformis* (an epiphytic diatom) is dominant, with the genera *Cocconeis*, *Licmophora*, *Grammatophora* and *Achnanthes* being less dominant.

(iii) The benthic flora is also dominated by diatoms. The predominant species in the lower estuary being *Paralia sulcata*, with a winter association of *Opephora martyi*, *Plagiogramma appendiculatum* and *Navicula* sp. (Thurlow et al., 1986).

4.4 Aquatic fauna

A wide variety of aquatic fauna is found in the study area; including fish, crustaceans and molluscs exploited by both professional and recreational fishers. Aquatic fauna are classified as belonging to either the invertebrate or vertebrate phyla.

4.4.1 Invertebrates

There is a large range of invertebrates in the Swan River Estuary including crustaceans, molluscs, annelids, coelenterates, echinoderms, foraminiferans, bryozoans and platyhelminths. Invertebrates are a very important part of the estuarine ecosystem and are the food of most estuarine fish and wading birds (Thurlow et al., 1986).

Crustaceans can be divided further into decapods (crabs and prawns), copepods (zooplankton), barnacles; and small benthic or pelagic amphipods, isopods, tanaids and ostracods. Large decapods important for fishing are *Penaeus latisulcatus* (western king prawn), *Metapenaeus dalli* (school/river prawn) and *Portunus pelagicus* (blue manna crab). Other non-fished species include the crabs *Haklcarcinus australis*, H. *bedfordii* and *Heteropanope serratifrons* which commonly occur amongst mussels. The palaemonid shrimp *Macrobranchium intermedium* occupies *Zostera mucronata* (seagrass) beds, while *Palaemonetes affinis* is present in the rocky channel of the lower estuary. The barnacle (*Balanus amphitrite*) is common on rocks and piles. Amphipods are found among mussel masses and plants or may be free swimming. One amphipod *Talorchestia sp.* is restricted to the lower estuary during summer. Copepods and ostracods are found in the lower estuary, the copepod *Gladioferens imparipes* being particularly abundant during late winter and early spring (Rippingale, in John, 1987).

Molluscs of the lower estuary are dominated by those with a marine affinity. Out of a total of 97 mollusc species, identified for the entire estuary, 89 species (92%) occur in the lower estuary. The well known edible mussel (*Mytilus edulis planulatus*) attaches on rocks and piles up to Blackwall Reach (Thurlow et al., 1986). However, the abundance of the edible mussel along the river from SEW to CSR is low (EPA, 1988). This is fortunate, as another mollusc (*Venus chemnitzii*) sampled adjacent to the CSBP site had mercury levels 3 times higher than allowed under Food & Drug Regulations (Maunsell & Partners Pty Ltd, 1987). See Section 3.7.

The annelids are predominantly represented by polychaete worms. Of the 12 estuarine species identified it is thought that only six are permanent residents. There are two species of coelenterates (jellyfish) in the estuary, the transparent *Aurelia aurita* and the brown spotted *Phyllorhiza punctata.* An anemone *Radianthus concinnata* was dredged from 4-8 metres depth in Rocky Bay in 1973, and a living colony of a small semi-colonial coral (*Culicia tenalla*) was dredged up in the river channel adjacent to Minim Cove in 1974. The echinoderms *Temnopleurus michaelseni* (sea-urchin), *Anthena australiae* and *Astropecten triseriatus* (starfishes), and *Amphiura* sp., *Ophiactis* sp. and *Amphipholis squamata* (brittle-stars) are common species in the lower estuary. A group of foraminiferans called the miliolids make up the majority of the fauna below Blackwall Reach. One unidentified platyhelminth (flatworms), one bryozoan *Membranipora* sp. (found encrusted on the edible mussel) and a prochordate (sea squirt) are also found in the lower estuary (Thurlow et al., 1986).

4.4.2 Vertebrates

A total of 122 fish species, representing 62 families, have been recorded for the entire Swan River Management Area, showing that a relatively diverse and abundant fish fauna is present in the estuary. These fish can be divided into three types; lampreys (upper estuary only), elasmobranchs (sharks and rays) and teleost fish. Teleost fish make up the majority of the fish fauna (116 species) with freshwater, estuarine, estuarine-marine and marine groups (Thurlow et al., 1986). The study area is comprised of fish from the last three groups only.

Estuarine fish are capable of living out their entire life cycles within the estuarine system; however, some of these species can live entirely in marine environments. Estuarine species include: *Acanthocarpus butcheri* (black bream), *Amniotaba caudavittatus* (yellow-tailed trumpeter), *Apogon rueppelii* (gobbleguts), *Cnidoglanis macrocephalus* (cobbler), *Engraulis australis* (southern anchovy), *Nematalosa vlaminghi* (Perth herring) and *Platycephalus endrachiensis* (flathead) (Lenanton, 1978).

Estuarine-marine fish usually reproduce in the ocean and then utilize the estuary's *Halophila ovalis* (seagrass) beds as a nursery habitat during the summer marine phase. A number of fish in this group also use the estuary for their adult stage feeding grounds. Fishes in this group make up the bulk of important commercial and recreational species. *Mugil cephalus* (sea mullet) and *Aldrichetta forsteri* (yelloweye mullet) are commonly found in the lower estuary throughout the year. Other species in this group are: *Argyrosomus hololepidotus* (mulloway), *Pomatomus saltator* (tailer), *Pseudorhombus jenynsii* (small-toothed flounder), *Sillago maculata* (trumpeter whiting) and *Torquigener pleurogramma* (common blowfish). Years of heavy freshwater flushing usually restrict these species to the lower estuary (Lenanton, 1978).

Marine fish make up the majority of species found in the estuary. They are often older fish, that enter the lower estuary typically during the summer-autumn marine phase. Some important fishing species are: *Arripis georgianus* (Australian herring), *Caranx georgianus* (skipjack trevally), *Engraulis australis fraseri* (southern anchovy), *Hyperlophus vittatus* (whitebait), *Hyporamphus melanochir* (sea garfish), *Pelates sexlineatus* (striped perch), *Sillago bassensis* (school whiting) and *Spratelloides robustus* (blue sardine) (Lenanton, 1978).

The abundance of fish was reported in anecdotes by early settlers; fish being an important resource for both local Aboriginals and Europeans. A further report by Thomas Briggs states: "The river was alive with fish, crabs and prawns, flounder, flathead, kingfish, schnapper, skipjack, mullet, tailer and many other varieties." (cited in Downey, 1971). One elasmobranch, *Carcharhinus leucas* (Swan River whaler), has been caught at intervals by professional and recreational fishers during spring-summer. Larger sharks have been sighted and some attacks have occurred (Thurlow et al., 1986). Marine mammals such as dolphins are often found playing and feeding in Rocky Bay, and a seal has been seen on a North Fremantle beach (Ecoscape, 1993).

5.0 SOCIAL ENVIRONMENT

5.1 Aboriginal

The study area contains significant Aboriginal camping and tool making sites, tracks or pads. The Department of Aboriginal Sites (DAS) part of the W.A. Museum has five sites listed for the area. The provisions of the Aboriginal Heritage Act 1972-1980 protect all Aboriginal sites, whether listed with the DAS or not. Reference to Aboriginal sites may be sensitve unless with the express permission of the traditional Aboriginal custodians and it is considered advisable to seek permission from these people prior to publication of the location of any Aboriginal site.

In 1987 Mr Ken Colbung (Chairperson of the Nyungar Community at Gnagara) met the North Fremantle Heritage Trail Committee. At the meeting Mr Colbung explained that he was not the custodian for Rocky Bay, and he would therefore consult Corrie Bodney (the areas custodian) and some other elders for further information. Mr Colbung did say that the cave in front of Burford's Soap Factory in Rocky Bay (northern cave in Figure 5 and see Plate 10) was known as Garungup, and that it was enshrined in Aboriginal methodology as the place where the Rainbow Snake (Waugal) slept after the great flood inundated the land between Wadjimup (Rottnest) and the coast. He explained how you can see where the Rainbow Snake curled around the central pillar of the cave on its journey upriver to its home in another cave near where Bennett Brook meets the Swan River. All the land around Rocky Bay and Buckland Hill is the dreaming place of the Rainbow Snake. Minim Cove was a corroboree ground. There were many watering holes and springs along the river, including one at Minim Cove, one east of Stirling Bridge and another opposite Point Brown in East Fremantle (Ecoscape, 1993).

Mr Corrie Bodney has since advised that he was appointed in 1952 as the custodian for the Ballaruk people. These people used the area known as Wadjuk which extends west to Rottnest, south to Mt Cook, north to the Moore River and east to Gingin and includes the Rocky Bay area. Mr Bodney confirmed the significance of the Rock Bay to Point Roe area, however pointed out that the terms Waugal and Rainbow Serpent are often incorrectly used. The Wagyle relating to the Ballaruk people inhabits the Swan River. In contrast the Balladong people of the south-west have a mythical creature called the Waugal (Note different spelling) which is commonly known as the carpet snake. The rainbow serpent relates to Aboriginal peoples of the northern part of the State (C. Bodney pers. comm.).

In 1933, J.E. Hammond wrote that the area was among the places where traditional Aboriginals would visit their place of birth and stay as long as food conditions would allow them to do so. Tracks and pads connected various localities and campsites. One such pad led from Perth along the north shore of the Swan River to North Fremantle, where a shallow ford allowed the river to be traversed. This pad led to Bibra Lake and eventually through to Mandurah, Pinjarra, and Busselton to Albany (Ecoscape,1992).

The length of occupation by the indigenous Aboriginals of South West Australia has been estimated at possibly more than 40,000 years. Archaeologists date Devil's Lair near Augusta as at least 29,000 years BP and a Swan Valley site yielded an age of 38,000 years BP. Aboriginal stays in various parts of the Swan River area were determined by the seasonal supply of food to be found there by hunting, gathering and fishing (Ecoscape, 1992). The study area's Aboriginal/archaeological site descriptions follow, with DAS site numbers in brackets.

(a) Minim Cove camp site (S0183)

In 1970-71 G.W. Kendrick recovered several chert flakes (artifacts from tool making) in sand, overlying limestone of the Spearwood age, collected at the rubbish tip site adjacent to Minim Cove (Map 4). An archaeological survey in 1975 discovered two chert flakes in situ at the rubbish tip. Systematic trench excavations found traces of charcoal, quartz chips and a large lens

of charcoal, which was radiocarbon dated at between 9,800 and 10,060 years BP, at 70 cm below trench datum. Deeper down, even older chert and quartz chips were found, along with stone artifacts and pebbles. The closest this type of stone is found to Minim Cove is at the Darling Scarp (25 km to the east). This is factual evidence for movement between the Scarp and the area for at least 10,000 years BP. At this time the Minim Cove site was probably situated on a high limestone ridge overlooking the deep gorge of the Swan River, and that the coastal plain extended westward 10-30 km from the present shoreline. Evidence of even older occupation, a single quartz crystal, was found in the Minim Cove marine shell beds (late Pleistocene) by J.L. Sommerville (Clarke and Dortch, 1977).

Minim Cove would have been a camping ground for Aboriginals taking advantage of the area's excellent fishing, or as a waiting point for low tide before crossing the river. One early settler wrote that families living near the Preston Point ferry would occasionally; "...see the natives on the opposite side of the water; they used at night to kindle huge fires and dance around in the most fantastic manner, more like demons than anything else." (Robinson, 1987). In 1829, Captain Fremantle reported seeing Aboriginals running along the hill tops to the river bank between Minim Cove and Point Roe (Ecoscape, 1992). A recent newspaper article reported, that the houses adjacent to Minim Cove could be subject to a future 'Mabo-style' land rights claim (Witham, 1993).

(b) CSR site (S2492)

An interesting find was made during excavations for building the CSR Company's refinery in 1928-30 (Map 6). About 2.5 metres below the surface (on virgin ground) and in clean pale yellow sand was about 3 metres of jarrah charcoal and a bun-shaped, water-worn, smooth granite stone, indicating an old Aboriginal campsite buried long ago by the encroaching sand dunes. The stone, which was about 15 cm in diameter and 6 cm thick, could only have come from the Darling Range, and must have been carried to the campsite for use as a grinding or hammering instrument (Downey, 1971). According to Corrie Bodney the charcoal was probably from fires the Aboriginal people lit to frighten off ships out to sea or along the river. The artifacts were granite, probably traded from the Redcliffe area (Ecoscape, 1992).

(c) Blackwall Reach sites (S2264 and S2265)

These two sites were associated with traditional freshwater sources in the vicinity of the limestone cliffs on both sides of Blackwall Reach (Figure 5). Their exact locations are unknown (Ecoscape, 1992).

(d) Rocky Bay (S2422)

According to information held by DAS the two to three caves at Rocky Bay, also known as Garungup, are the final resting place of the Rainbow Snake before he made the tunnel underneath out to the Indian Ocean (Map 1). The spirit of an Aboriginal person goes to rest at Garangup before going out under the sea. The snake slept at Garangup after he had created the local hills ('Seven Sisters'). Before that he made the Avon (Swan) River, got constipated and had to shake off his skin with its orange spots (Ecoscape, 1993). Rocky Bay's Aboriginal features are discussed further in this section's introduction.

(e) Swan River (S2548)

This site, also known as Derbal Yaragen, is of more general significance and is well documented in previous reports (Ecoscape, 1992).

5.2 European

The study area has a rich and interesting European history of considerable cultural value to all Western Australians. The first European explorations date back nearly 300 years and thus, in the Australian context, is one of the continents first locations explored.

The first European description of the area came from the Dutch navigator Willem de Vlamingh, who landed on the mainland (after first visiting and naming Rottnest) on 5 January 1697 south of Cottesloe Beach (the Vlamingh memorial marks the approximate landing position). The landing party headed inland towards Buckland Hill, from where they surveyed the Swan River (Seddon, 1970) and most probably viewed the study area for the first time. The landing party left the Swan River area on 13 January 1697. They had not been greatly impressed, having found sandy soils and thorny vegetation with no edible fruit. However, they did sight many varieties of geese, cockatoos, parakeets and plenty of fish (Ecoscape, 1992).

Captain James Stirling and Charles Fraser (the Colonial Botanist) surveyed the Swan River, arriving onboard the HMS 'Success' in 1827, this survey being prompted by earlier French exploration during 1800-04 under Baudin, Hamelin and Freycinet (as the British were afraid the French would colonise W.A. first). Both Stirling and Fraser were enthusiastic about prospects for a British settlement. Fraser was already familiar with the Australian landscape on the east-coast. He could therefore see the potential of this area. Two years later, on 18 June 1829, the first settlers arrived with the now Lieutenant-General James Stirling onboard HMS 'Parmelia' and the new colony was then proclaimed (Seddon, 1972). A number of early land grants were subsequently made. The land grants and several other places are considered to have significant historical and cultural value.

Swan Location 78. The title of this block, referred to as Billy Goat Farm, was granted to John Lewis and is dated 1839. The very old stone farm cottage remained there until about 1930, while some of the fig trees still stand. It is said to be the site of some of the first crops ever grown in the state, sharing the distinction with Preston Point, Hamilton Hill and Mulberry farms. Its last use was as Lawrence's dairy until 1930 (Downey, 1971). It was adjacent to Minim Cove and the track between Fremantle and Perth passed through it (Maps 4+5). The semi-isolation and the large area available for grazing permitted the farmer to keep a large herd of goats. The river foreshore of Billy Goat Farm was very popular with campers, who could get water from the farm well and hire rowing boats from the family for fishing and crabbing parties. T.J. Briggs bought the farm in 1904. Briggs also ran quarries and lime kilns in the area (Ecoscape, 1992).

Swan Location 79. This location (Maps 5+6), title dated 1840, was granted to Captain J.S. Roe, RN, the Surveyor-General of the colony from 1829 to 1870 (d. 1878). He gave his name to Point Roe. Roe undertook surveys of the northern and western coasts of Australia, the Swan River, and the first townsite allotments for Fremantle (in 1833) and Perth. He also surveyed Gage Roads, Cockburn Sound, the offshore islands, beacons and navigation aids, and the two lighthouses at Rottnest (Downey, 1971; Seddon, 1970 and Seddon, 1971).

Swan Location 80. This title is dated 1841 and was granted to E.H. Pollard (Map 6). Both Swan Location 79 and 80 are now owned and used by CSR (Downey, 1971).

Rocky Bay cave (Figure 5 and Plate 10) was used for burning lime by T.H. Briggs and Co. Quarrying and lime burning took place in the area from the 1890's until 1914. The squaring out of the cave's natural 'chimney' to the surface was probably to fit materials being hoisted up and down by head gear on top of the cliff face. Moving down from the cave to the water's edge the entrance to a tunnel can be seen. This tunnel has an unlocked steel-mesh gate and extends as far as Thompson Road. Its original purpose was to carry industrial effluent from Burford's Soap Factory to the river for disposal. Before the Swan River was dredged the river beach here was wider and you could see two freshwater springs oozing through the sand at low tide close to the tunnel entrance. Members of Stirling's 1827 expedition proposed that a cut be made from Rocky Bay to Leighton Beach, where Stage 1 of Rocky Bay Estate is now located (Map 1), in order to provide a safe deepwater anchorage for shipping in Rocky Bay. This was proposed because the

river was naturally inaccessible to larger shipping due to a limestone bar across the entrance. The problem was eventually solved by C.Y. O'Connor who designed and built the Fremantle Harbour. O'Connor's solution unfortunately removed one of the Aboriginals' original crossing points (Ecoscape, 1992).

The river ferry crossing, known as the Minim Cove ferry crossing, was the first land transport route between Fremantle and Perth. An 1898 Lands and Surveys map shows the original ferry route running between East Fremantle adjacent to Wauhop Street (near the Army's Perth Water Transport Unit) and Mosman Park where Stone Street met the river (Reserve 1631 Map 5). A lone fig tree, an old steam boiler and some of the ferry jetty piles still remain on the north side of the crossing point. The lower section of Stone Street has since been closed and incorporated into the M57 reserve. According to T.J. Briggs, the track ran from here along the ridge top to Peppermint Grove, through Claremont, Karrakatta Cemetery, Shenton Park, Kings Park, along Mount Street to St George's Terrace (Downey, 1971). The ferry crossing was replaced as the only land transport route when the Fremantle Traffic Bridge and Perth-Fremantle Road were officially opened in 1867 (Robinson, 1987).

The opening up of the study area to quarrying, for the harbour and other buildings, changed the landscape irreversibly and many industries followed, attracted by the proximity to the harbour's North Quay. As previously discussed the area has been intensively quarried for limestone, beginning in the 1890's. All the land from Wellington Street, Mosman Park to Leighton Beach has been surface-quarried for capstone for limekilns which were scattered widely over the area (Downey, 1971). By 1904 the community was becoming alarmed at the disappearance of Buckland Hill. W.J. Westlake, from the Mosman Park Roads Board, commented that this "was a landmark which should not be removed". After this quarrying operations were stopped on Buckland Hill. However, quarrying continued on a much smaller scale at various sites until the early 1960's. The small limestone hillock (Figure 5 and Map 4) was still being quarried as late as 1961.

Some of the state's first industry was carried out in the area including: Burford's Soap Factory (1905-46) which was later used by Unilever to produce the state's first margarine (1959), Great Southern (Dingo) Flour Mill (1922-94), various oil companies (1930's-93), Ford Motor Company and Purina Grain Foods Ltd (1930's), SEW, CSBP and CSR (Robinson, 1987). The old Ford Motor Company premises are now used in Matilda Bay Brewing Co Ltd's operations (Map 1).

The State Engineering Works commenced operations in 1912 (1908 in EPA, 1989) and was then known as the State Implement Works. In 1914 the SEW employed about 600 men (Robinson, 1987). It was built on the platform remaining after quarrying ceased at Rocky Bay. The SEW played an extremely significant role in the state's industrial development. It first provided farm machinery for the expanding wheat industry. Later it became a marine and general engineering works and foundry for the government and private industry. Amongst its achievements were the manufacture of the 'stump-jump' plough, portable cranes for the port, and more recently, for the casting of lead keels for the 12 metre yachts Australia II and III (Ecoscape, 1992). Operations ceased in 1986 and the SEW site closed in 1987. Pockets of contaminated soil remained, which have since been cleaned up in preparation for urban development (see Section 3). A SEW theme park has been proposed for Reserve 42563 (see Ecoscape, 1993).

The CSBP site was established at the eastern end of the Rocky Bay quarry platform, and was first leased by Mount Lyell Mining and Railway Company in 1909. The production of superphosphate fertiliser began in 1910. The company was restructure in 1929 as Cuming Smith Mount Lyell Farmers Fertilisers, and again in 1966 as CSBP. The site closed in 1969. Large areas of contaminated soil were left behind as a result of the chemical processes used at the site (Maunsell & Partners Pty Ltd, 1987).

Two environmental reviews have been released concerning the clean-up of the site: a PER in 1987 and a CER in 1992. The PER proposed on-site containment to protect the environment from the site's toxic wastes, while the CER proposed that a mix of on-site containment and off-site disposal,

at the Shire of Williams' landfill site, would control the pollution (Maunsell & Partners Pty Ltd, 1987; and Bowman Bishaw Gorham, 1992). The Shire of Williams has recently rejected this proposal. This is due to local public concerns (S. Sadlier, pers. comm.). The latest proposal is again on-site treatment and containment. MPTC favours a method known as limestone entombment, which allows the toxic material to bind directly with the limestone surrounding it (Post, 1993).

The Colonial Sugar Refinery purchased Swan Locations 79 and 80 in 1927 (about 10 hectares). Construction of the CSR buildings and plant commenced in 1928. Access to the CSR site was poor until the early 1960's, when McCabe Street was built to connect the factory with Stirling Highway. For more than 30 years the raw materials were brought in, and the refined sugar was exported out, via a railway line between the CSR site and Fremantle's port. The railway line ran from the CSR site along the top of Billy Goat Farm, north of the quarry at T.J. Perrott Reserve, down onto the old quarry platform, past the SEW site to connect with the main line opposite the Dingo flour mills at the North Fremantle marshalling yards. The last train used the line in 1966, the rails being removed in 1978. The factory was established in dense natural bush and remains today an attractive landmark (Ecoscape, 1992). CSR is still using the site for its operations. MPTC is in the process of rezoning the CSR site from industrial to development (Section 2.2).

5.3 Recreation

The Swan River and adjacent foreshore offer a wide range of recreational activities, many of which occur within the study area. Family groups, adults, children, individuals; sporting, social and activity clubs, and many other organisations are known to partake in the variety of recreational activities available in the area. The recreational importance of the study area is high. There are far too few locations remaining along the Swan River foreshore that can offer the types and diversity of recreational activities that this area provides.

Perth's climate encourages outdoor pursuits, particularly those associated with water-based activities. One of the main river-based activities is boating. The Swan River Estuary provides a naturally safe haven for boating. The nearest similar alternative for safe boating is the Peel-Harvey Inlet at Mandurah, located about 55 kilometres south of Fremantle. The Department of Marine and Harbours estimates that more than 21,000 pleasure vessels use the river at some time (Spencer, in John, 1987). A number of yacht clubs, marinas and swinging moorings are located along this section of the river (Plates 6,8+12). The narrowness of the river channel unfortunately restricts the majority of boating use to the basic passage of vessels up and down the river (Plates 6+8). Boating in the area, particularly at Rocky Bay, was a popular pastime at the turn of the century (Ecoscape, 1992).

Canoeing takes place along the entire foreshore, at Rocky Bay in particular. Some local residents canoe as a hobby. A Dragon Boat Club, located in East Fremantle, also use this section of the river for training (Ecoscape, 1992). Twenty five local residents recently used canoes to transport bundles of *Juncus kraussii* rushes to the SEW site's foreshore, as part of the embankment's revegetation programme (Fremantle Herald, 1993). Foreshore beaches are used for swimming and snorkelling, which is popular from the sand bank off Preston Point in Rocky Bay. Older children and teenagers use certain rock outcrops at Rocky Bay for diving and jumping off (Ecoscape, 1993).

Excellent recreational fishing opportunities exist along the entire river foreshore. Boats are used occasionally for fishing, crabbing and prawning expeditions. Numerous rocky outcrops and ledges provide good fishing platforms, and attract local and regional fishers to Rocky Bay and Blackwall Reach. This practice is causing serious erosion on some fragile embankment areas. During the 'run' of the western king prawn, numerous boats line the river. At night the Rocky Bay cliffs are set aglow by a myriad of boat lamps (Ecoscape, 1992). Commercial fishing also takes place in the area, when justified by increased catch rates of the more valuable species.

Land-based activities are also very popular in the area. They are accessible to a greater number of people and are less dependent on suitable climatic conditions (ie. you can't run for cover in a canoe). Several good condition dual use paths traverse the study area, connecting to local roads which integrate into the metropolitan cycleway grid. This makes them attractive to local and regional commuters. The Rocky Bay Heritage Trail links into the dual use path at the end of Rule Street (Map 1). MPTC has a proposed heritage trail which would run along the foreshore and then through Mosman Park. These paths are very popular for walkers, joggers, power-walkers, cyclists, roller-skaters, exercising the dog, and people just out to enjoy the landscape views. Some of the dual use paths cause a level of conflict between pedestrians and the faster cyclists (Ecoscape, 1992).

A football oval and cricket field are located at T.J. Perrott Reserve (Map 4) and there are public tennis courts in Reserve 24242 (Map 5). Public BBQ facilities are located in M57 near Minim Cove and picnic may take place throughout the foreshore, where access permits. People often just sit, relax and view the area. Other recreational pursuits found in the study area include: nature studying, photography, bird watching, kite flying, children's games, and sightseeing from the elevated points in the area's landscape (Ecoscape, 1992).

A 1984-85 summer survey ranked the Swan River's recreational activities in order of importance. Relaxing came out on top, with 48% of visitors observed engaging in simple relaxation. This was followed by socialising (30%), enjoying the view (26%), BBQs and picnics (25%), windsurfing (21%), swimming (17%), walking and water skiing equal (14%), yachting (13%), sunbathing (10%) and power boating (7%) (Thurlow, 1990).

5.4 Public Access

Dual use paths provide extensive access along the top of the foreshore reserves and VCL, from Rocky Bay to the fenced off CSR boundary (Map 5). Sections of this path follow the original alignment of the rail line, which serviced the area's quarries. Access all the way to the river's edge is generally restricted, due to the area's high cliffs, extensive steep embankments, and the dense and often prickly foreshore vegetation.

The majority of the Rocky Bay cliff face is inaccessible to all but the best climbers. This practise should be discouraged as it unnecessarily erodes the cliffs and further degrades the already precarious vegetation. There is one steep staired path leading down the cliff face, providing access to the caves, Burford's Soap Factory tunnel and a small beach.

A dual use path runs from the end of Rule Street, between the fenced off SEW site and the steep SEW embankment, to the CSBP site. The SEW embankment is protected by a continuous one metre high mesh fence. The fence prevents people from trampling the replanted vegetation and from eroding the embankment.

An old vehicle track gains access to a small beach, at the CSBP site's river foreshore (Figure 5 and Map 3). Public access onto the actual CSBP site from the foreshore reserve is generally unrestricted; being difficult only when the embankment becomes steeper towards to Minim Cove. The CSBP site is fenced off along the McCabe Street side. Minim Cove has a footworn path which leads down to the rivers edge and a small beach.

M57 has an extensive system of dual use paths meandering through a mixture of lawns, weeds, replanted non-endemic and remnant endemic vegetation, and some BBQ facilities. Access to the old quarry on the river foreshore (Map 4) is difficult and should not be encouraged, as valuable endemic vegetation rimming the quarry (and the regionally rare *Boronia alata*) could be degraded further. General access to the M57 foreshore is prevented by the presence of steep cliffs. This area of river foreshore should remain basically inaccessible, in order to protect the valuable fossiliferous shell beds located there. The old ferry landing point, Reserve 1631 foreshore (Map 5), is accessed via a path winding past a fig tree, and through giant reeds and

amongst broken limestone containing fossil shell deposits. If the ferry landing was to be developed, as an historic site with a fossil information display, access would need to be improved.

The CSR site is completely fenced off, however, a small hole now exists near the south-west corner. This makes access possible, but would be unappealing to most people as it is a reasonable walk from the nearest car-park or path. Access within the CSR site is via footworn paths and old vehicle tracks winding through endemic and introduced flora to the open foreshore beach (Figure 5). Access north along Blackwall Reach is difficult, and in order to protect some regionally rare species should remain so. The CSR foreshore reserve has good potential for passive recreation, but the level of usage will have to be balanced with conservation, especially considering the area's protected wading birds (see Section 4.2).

6.0 DEVELOPMENT ISSUES

A series of urban developments are proposed for the SEW, CSBP and CSR sites. The following sections identify and assess the potential impacts of urban development on the environmental resources identified in this report's preceding sections.

6.1 Physical environment

6.1.1 Fossiliferous shell beds

The fossiliferous shell beds, located along the M57 foreshore reserve, have significant value and should be protected from the impacts of adjacent urban development. The M57 shell beds are one of four valuable marine shell deposits exposed around the Swan River Estuary. They contain rich and diverse fossil remains and have international geological importance. The well exposed M57 fossil beds are an important geological teaching location for Perth's schools and universities. The fossil beds are in the process of being nominated as a geological monument for the National Estate Register.

Intense urban development would create additional demand for public access and recreation along the M57 foreshore. This has the potential for creating erosional pressure and degradation of the fossil bed outcrops. Direct public access to the fossiliferous shell beds is already naturally difficult. Relatively easy access can only be obtained adjacent to Reserve 1631 in Map 5 (see Section 5.4) and down the sides of the old quarry in Map 4.

Future access should remain as difficult as it currently is. Public access to the fossil beds should only be improved, directly to the foreshore, at Reserve 1631. At this location a fossiliferous outcrop could be displayed and an information board constructed. This could be in conjunction with a reconstruction of the old ferry landing in the same location (see Section 5.2 and 6.4).

6.1.2 Groundwater and Swan River water quality

New residential developments in the study area have the potential to adversely impact on water quality, unless designed and maintained to effectively prevent contaminant leaching to the groundwater and the Swan River.

The effective clean-up of contaminated soils at the CSBP and SEW sites should prevent any further decrease in the water quality of groundwater or the adjacent Swan River (see Sections 3.5 to 3.7). Levels of groundwater contaminates, and any possible leaching to the Swan River, should be regularly monitored.

All new developments should be connected to reticulated sewerage; and have on-site stormwater containment via soak wells, gully drains and compensation basins. This should sufficiently prevent any polluted or high nutrient water entering the Swan River Estuary via septic tanks or stormwater drains.

6.1.3 Landscape features

The original pristine landscape has been dramatically altered by quarrying, industry and urbanisation. Proposed urban development has the capacity to further degrade these features, unless they are appropriately planned and designed.

Many significant natural and cultural landscape features still exist (see Section 3.8). Significant natural landscape features still found in the study area include: remnants of the 'Seven Sisters',

Rocky Bay and Minim Cove, cliffs, embankments, beaches and the structure and form of the remnant vegetation. Valued cultural features include: historic and some more recent buildings (eg. CSR buildings), sporting facilities, parks and gardens, and some disused quarries.

The design of future urban developments should be compatible with, and either increase or improve, the area's landscape values; without adversely impacting on the area's other environmental resources. The style, composition and materials used for residences should compliment the landscape and be visually appealing.

6.2 Biological environment

6.2.1 Terrestrial flora and fauna

Very little native terrestrial flora and fauna remains in the study area. Remnant communities that do remain have been severely degraded by a diverse range of introduced exotic species, which have also invaded the area's few natural habitats. Increased pressure on foreshore reserves could endanger any remaining endemic species.

Some areas of valuable remnant endemic vegetation are still present (see Section 4.1.2). In particular, a ridge of Limestone Closed-Heath in the M57 Minim Cove Foreshore reserve, and the Tall Open-Forest and *Juncus-Casuarina* foreshore community in the CSR foreshore reserve. The remnant community at M57 should be isolated from public trampling by fencing with 'Koppers' logs or by planting dense prickly shrubs (eg. *Hakea prostrata*).

Four regionally rare endemic species are found in the study area. These are: *Boronia alata* (CSBP and M57), *Pittosporum phillyraeoides* (Rocky Bay cliffs, SEW and CSBP), *Logania vaginalis* (CSBP) and *Santalum acuminatum* (CSR). These species need to be precisely mapped. They should also have their significance accurately determined in a regional context. This information should be supplied to the developers, to prevent endangering these species any further. The retention of existing endemic vegetation and large trees, within the developments, should be of a high priority.

The terrestrial fauna is more difficult to assess (Section 4.2). Reports of brushtailed possums in the area account for only one native mammal. Several reptile species have been identified in the area. Many terrestrial and aquatic bird species frequent the area, particularly at Point Roe. Two aquatic wading birds, the sharp-tailed sandpiper and the greenshank, have been observed at the Point Roe/M57 foreshore marshes. These two species are both protected under the JAMBA treaty. The study area's remaining native fauna could become increasingly threatened with the introduction of a greater number of cats straying from the proposed residential developments.

6.2.2 Aquatic flora and fauna

Impacts are not expected to be significant, as the Swan River's lower estuary is well flushed and has good water quality (Section 3.7). However; increased fishing, boating, public access and recreational pressures (see Sections 4.3, 5.3 and 5.4) could have a negative impact on the area's aquatic flora and fauna. These impacts should be monitored in the local and regional context. The risk of the public collecting and consuming molluscs (ie. mussels) with high concentrations of heavy metals is low, as few molluscs habit the vicinity of the CSBP and SEW foreshore vicinity (see Section 4.4.1).

6.3 Social environment

6.3.1 Aboriginal and European attributes

Geological and anecdotal evidence suggests that the area contains significant Aboriginal camping, tool making and mythologically important sites (see Section 5.1). Significant archaeological and mythological sites identified by DAS, in the study area, include the: Minim Cove camp site (Map 4), CSR site (Map 6), Blackwall Reach sites (Figure 5), Rocky Bay and caves (Map 1 and Figure 5), and the Swan River in general.

The area has a rich and interesting European history (Section 5.2). It was first viewed by the dutch navigator Willem de Vlamingh in 1697. Early European settlers had their first land transport link in the area. A ferry ran between East Fremantle and the M57 reserve. The ferry landing would form an interesting regional historic focus if reconstructed. Some of W.A.'s first agriculture was carried out at Billy Goat Farm. Limestone used in the construction of the harbour moles, and many historic public and private buildings, was quarried from the study area. Some of the earliest W.A. land grants were made in the area. The area was also an important location for industry in the late 1800's and early 1900's.

6.3.2 Recreation

Increases in urban development have the potential to dramatically increase recreational demand on the area, in terms of foreshore usage and the need for recreational facilities.

The study area offers a diverse range of recreational activities for family groups, adults, children, clubs and individuals. Boating, fishing and swimming are carried out in the Swan River, adjacent to the study area. Land based recreational activities include: cycling, walking, jogging, dog exercising, children's games, BBQs and picnics, relaxing, nature studying, and simply taking in the area's landscape views (see Section 5.3).

To mitigate the impacts on the area's recreational attributes, developments should be planned to provide maximum on-site public open space (POS) and appropriate recreational facilities (eg. parks and playgrounds). Potential demand for additional recreational facilities should be assessed by the developers and LGAs. Additional recreational facilities should be planned on a regional basis, taking the requirements of regional users into consideration.

6.3.3 Public access and foreshore reserves

Proposed urban development will create additional demand for public access to foreshore reserves, and to the CSBP foreshore VCL. The CSBP foreshore VCL should be reserved and vested in MPTC. Proposed developments should not decrease the level or quality of public access.

Dual use paths currently provide extensive access along the foreshore cliffs and embankments, from Rocky Bay to the M57 Minim Cove Foreshore reserve. Direct access to the river's edge is generally restricted. Easy access, to the river's edge, can only be obtained at a few locations along the foreshore (see Section 5.4).

It is essential that developers retain sufficient (or alternative) public access during site development, and that after development public access is returned to its former state, or actually improved in some cases.

Public access to environmentally sensitive areas should be restricted by fencing, or by planting dense prickly vegetation. Environmentally sensitive areas identified are the: fossiliferous shell beds, foreshore marshes at Point Roe and M57, areas of remnant vegetation in M57, and the

Rocky Bay cliffs. Restricting access should prevent further erosion and degradation of these sensitive areas.

Dual use paths should be located on the development side of the foreshore reserves and not be positioned as to divide these reserves. They should be set back at least 10 metres from the river's edge at all points. Adequate foreshore reserves, of at least 50 metres width, should be ceded free of charge by the developers of the CSR, CSBP and SEW sites, in accordance with Swan River Trust policies (SRT, 1992b). If developers find the 50 metre recommended width unacceptable, they should then be prepared to provide an equivalent area of POS within the development.

6.4 Conclusion

The area is already highly modified and degraded. However, many valuable attributes are still present. These attributes must be conserved and enhanced, so that future generations can also explore and enjoy them.

Proposed urban developments should be planned and designed to be compatible with their surrounding environment. Developments should be designed to coexist with, and hopefully enhance, the area's natural and cultural attributes. If developments are well planned and designed, with their surrounding environment as a major focus, they should be environmentally acceptable.

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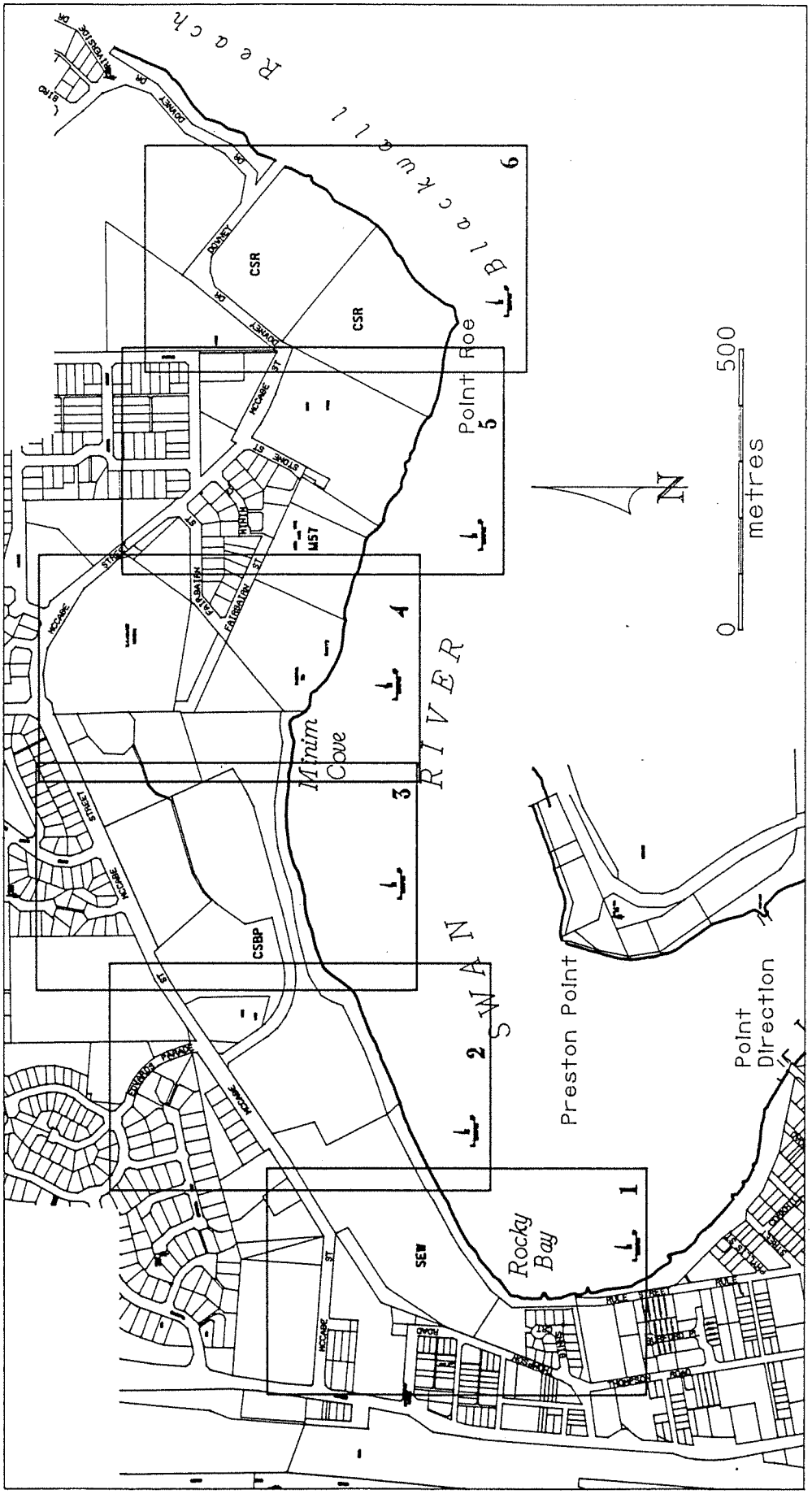
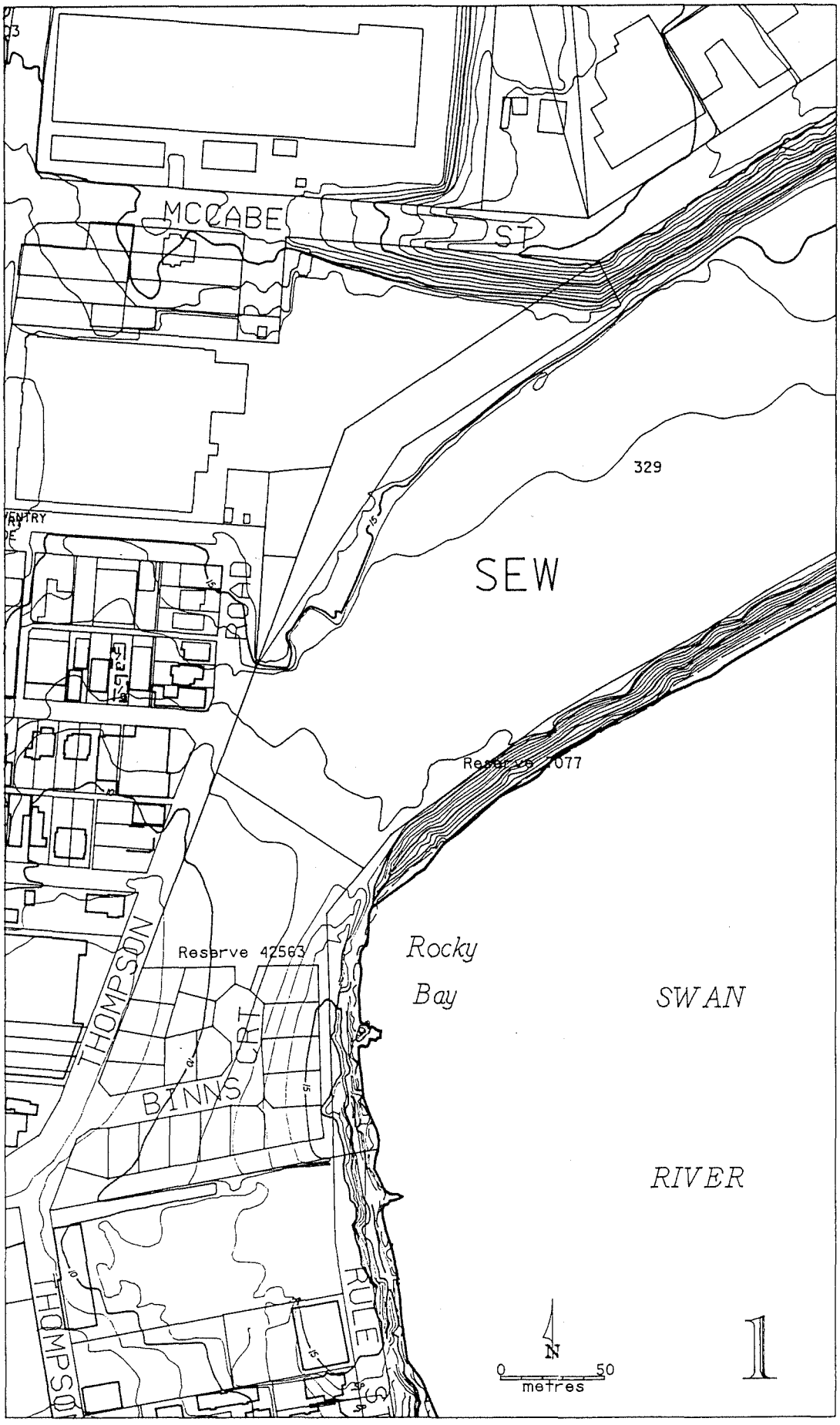
APPENDIX 1: STUDY AREA MAPS - KEY

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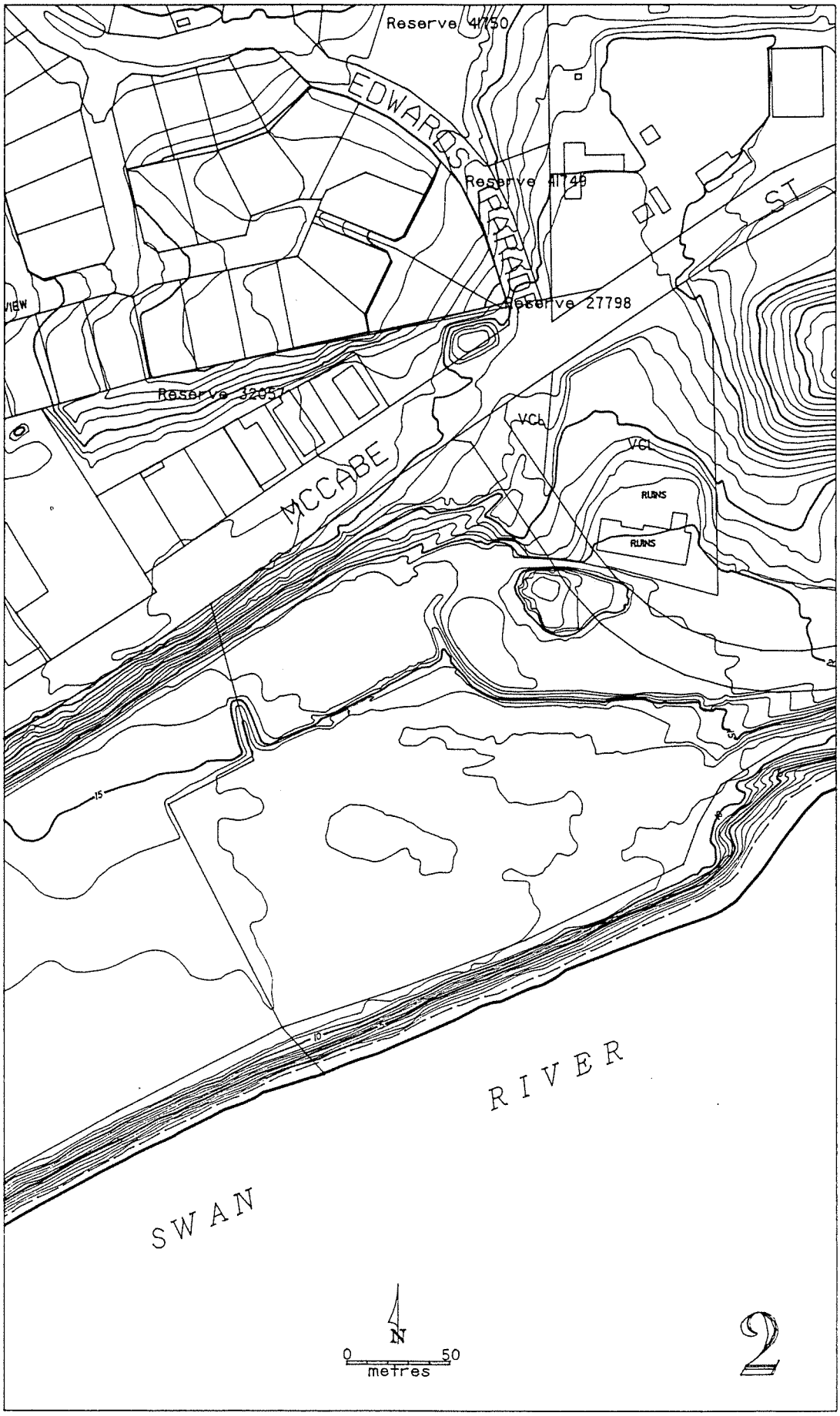
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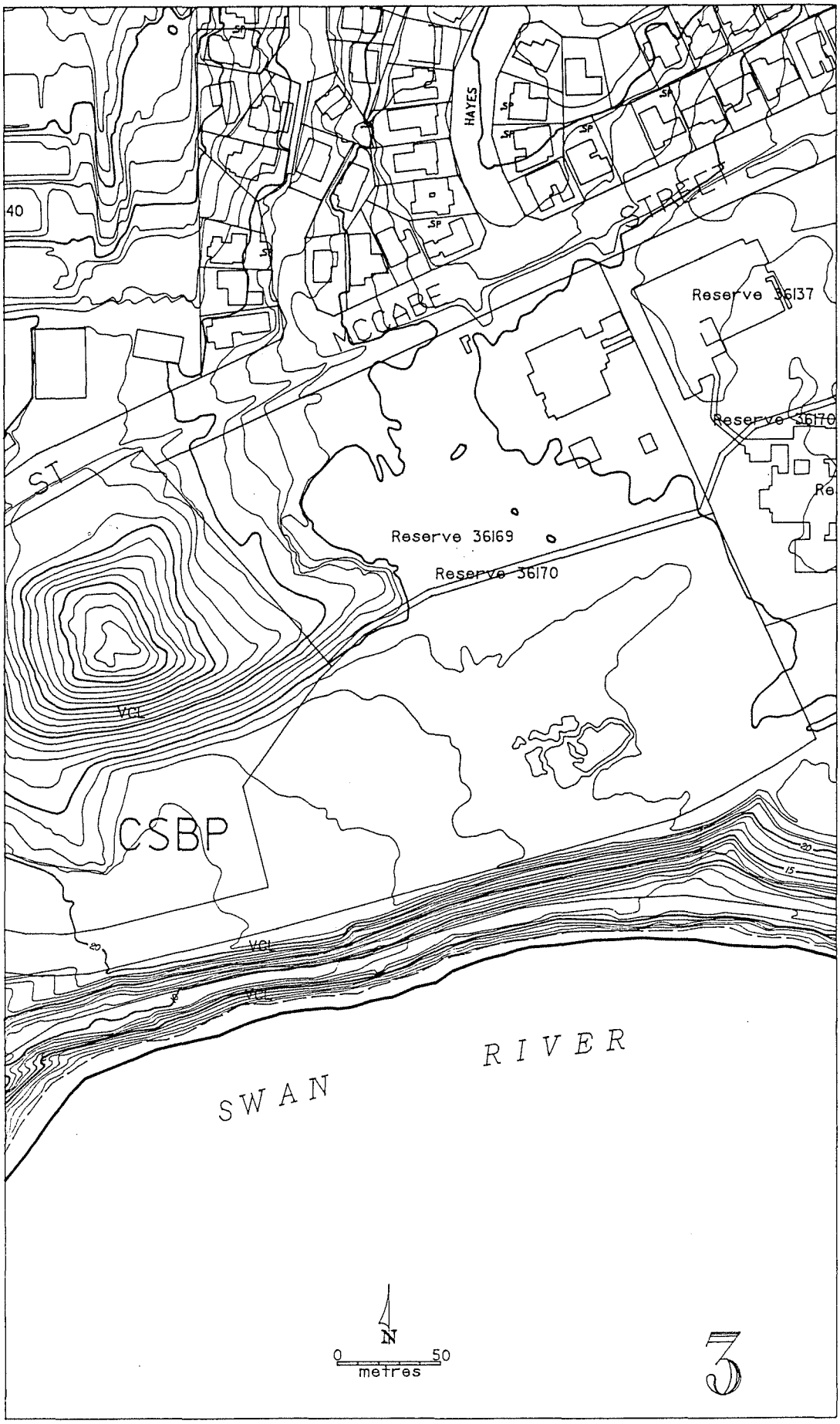
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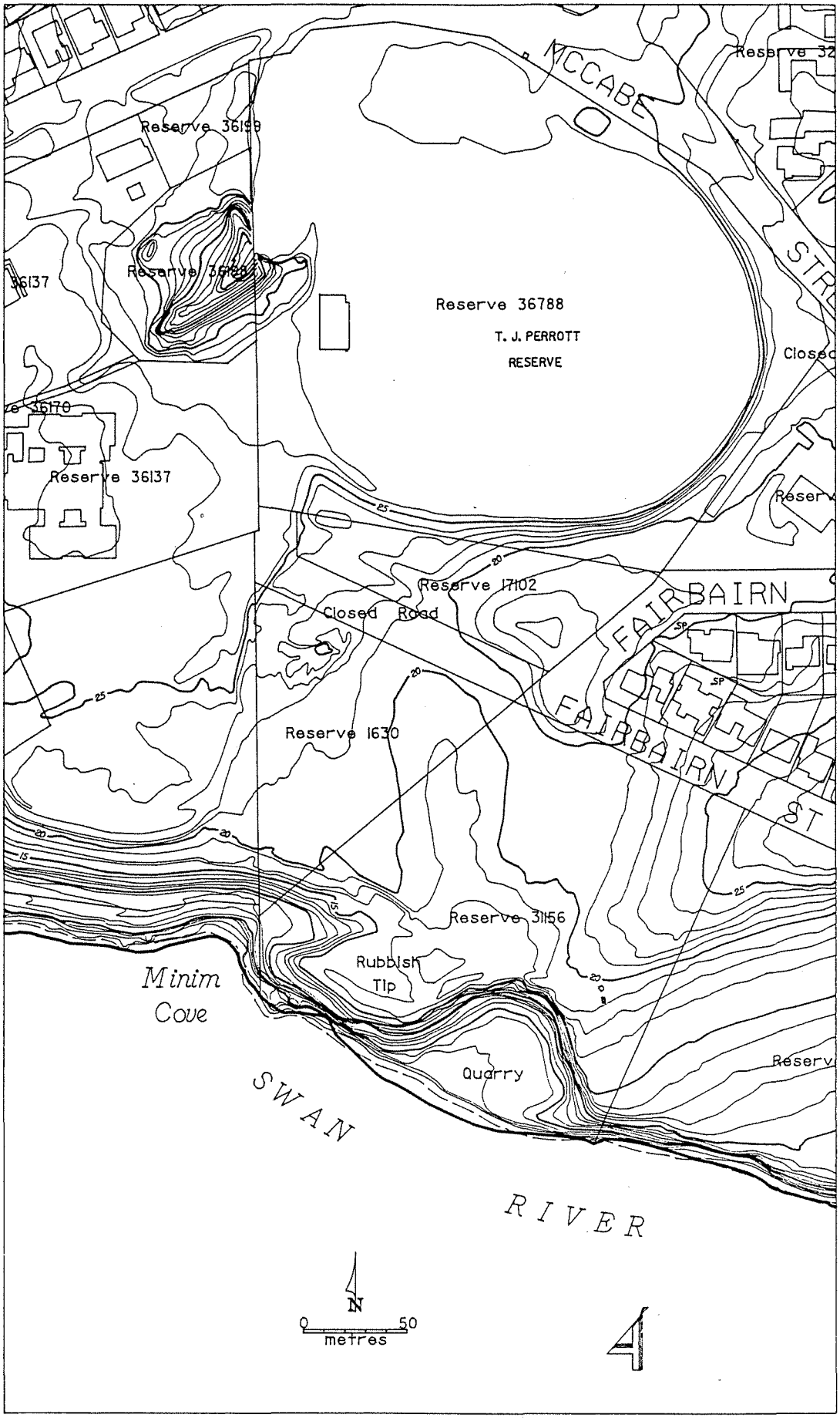
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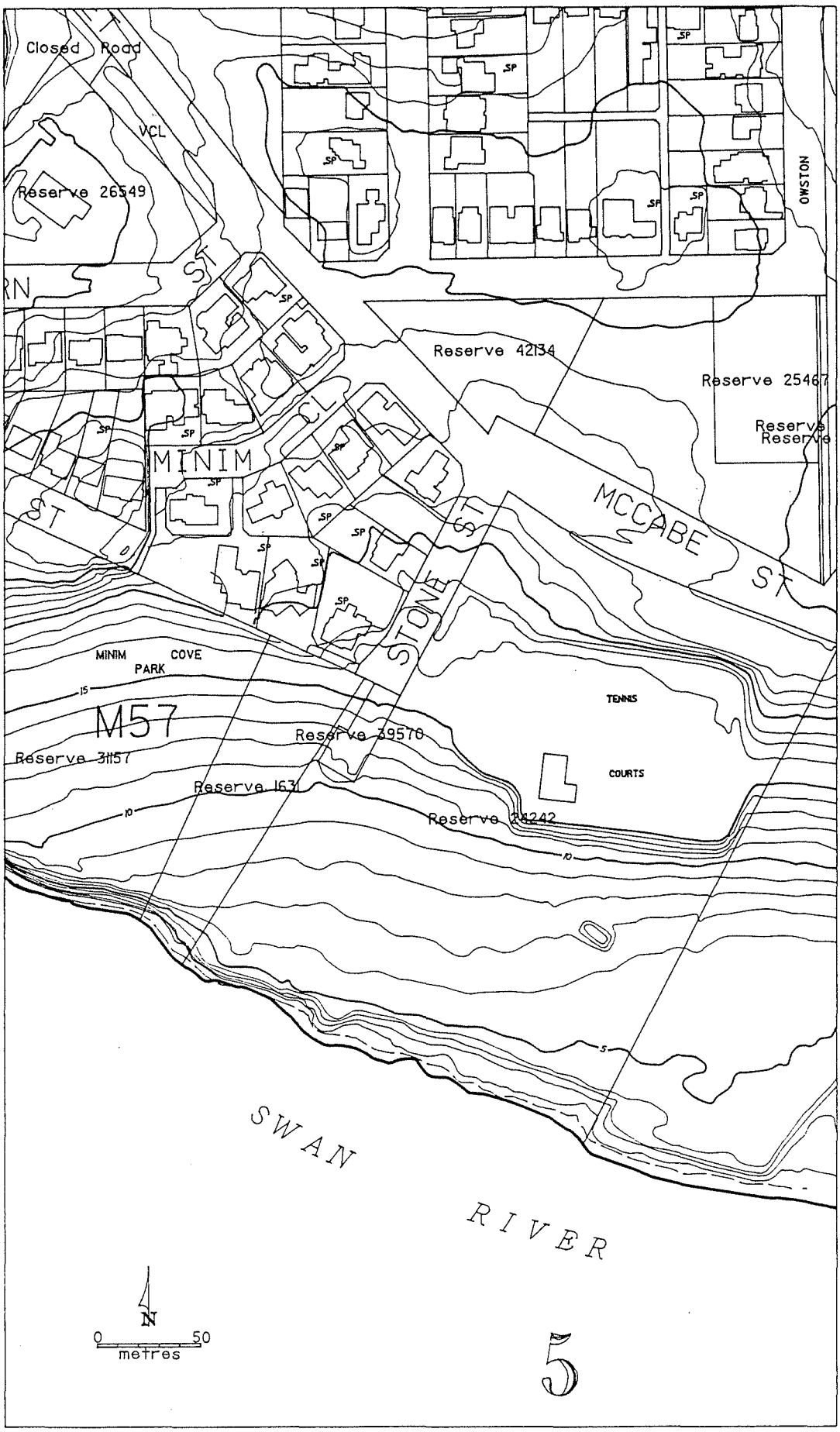
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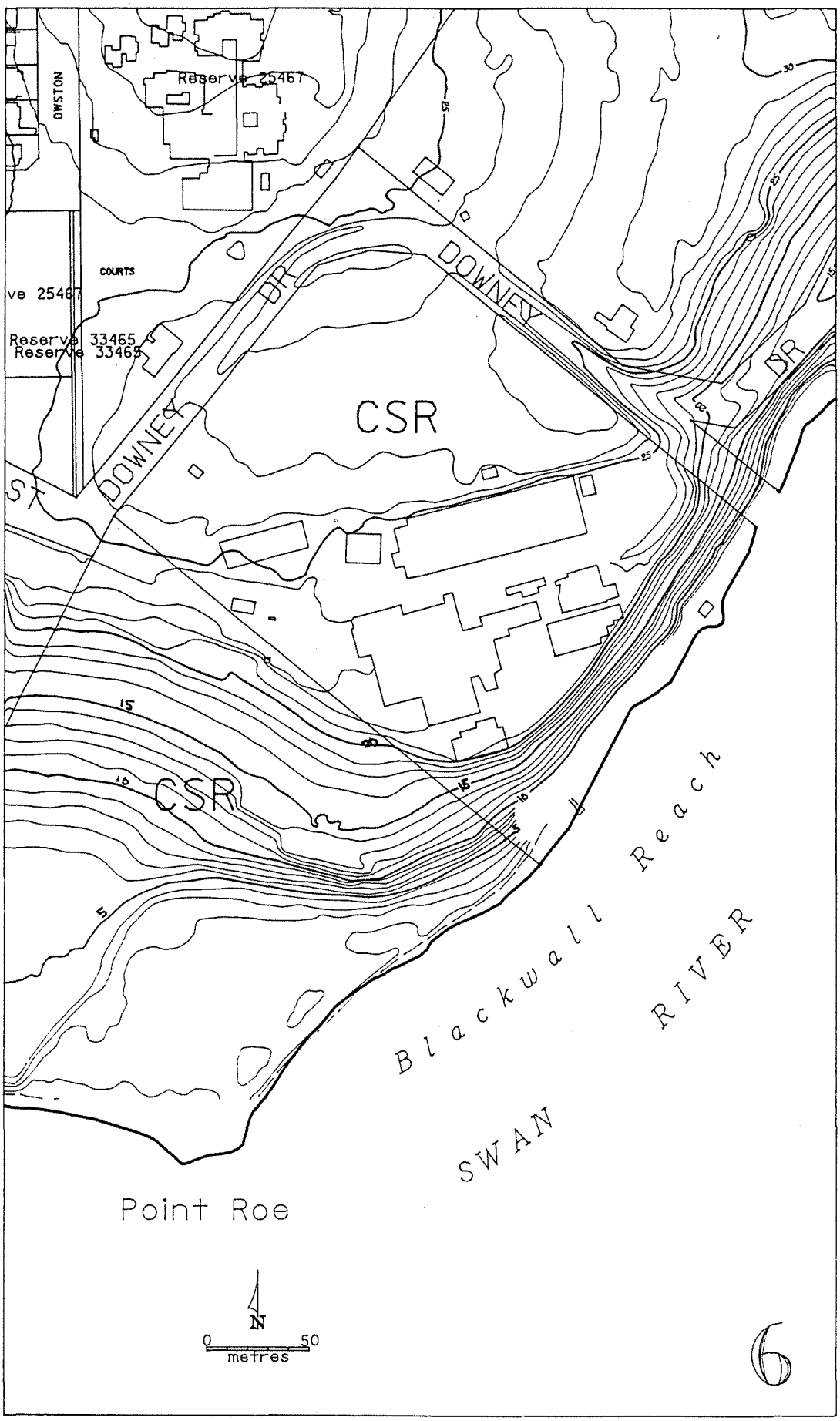
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M57 MINIM COVE FORESHORE, MOSMAN PARK

The recommended area comprises Reserve C31157, for Park, and Reserves C31156, A1630, A1631 and C24242, for Recreation, all vested in the Town of Mosman Park; and two closed roads which are vacant Crown land (Figure 125). The area is "reserved" for Parks and Recreation under the Metropolitan Region Scheme.

There is a proposal for the development of a restaurant on the disused quarry site within Reserve C31156.

The cliffs expose a rich fossiliferous shell bed that was probably deposited towards the latter part of the Pleistocene Era. The bed is one of the best preserved and most informative deposits of its age in Western Australia, and is located conveniently close to Perth. It has been studied by geologists and others for the past fifty years, and its value to the study and teaching of history and geology is outstanding.

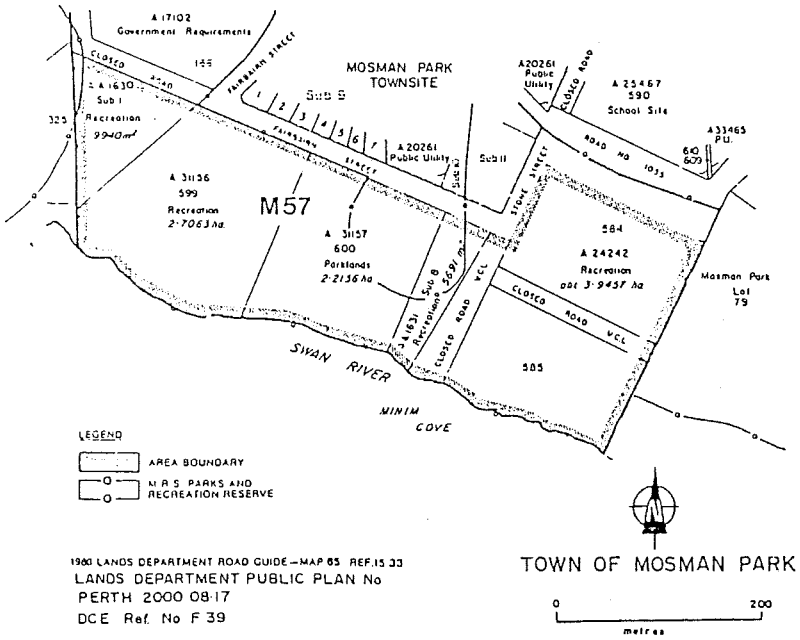
The area contributes to open space of regional significance extending along the Swan River (see Figure 1, Chapter 4) because of its high conservation, recreation and education value.

Recommendations:

M57.1 That our general recommendations on planning and management of Regional Parks be applied to this area (see Recommendations 15 and 16, Chapter 5).

M57.2 That the vacant Crown land be declared a Class C Reserve for Recreation and that the Reserve be vested in the Town of Mosman Park.

M57.3 That the Geological Sites Committee, in consultation with the Mosman Park Town Council and the Metropolitan Region Planning Authority, prepare a management plan for protection of the shell deposits.



RECOMMENDATION NUMBER	IMPLEMENTATION STATUS	COMMENTS
M57 Minim Cove Foreshore, Mosman Park		
M57.1 Regional park recommendations be applied to this area.	Unresolved Issues	The Regional Parks Task Force Report proposes that the Swan Estuary be considered analogous to a regional park managed under Swan River Trust legislation. The Swan River Management Strategy (1988) recommends that all the foreshore reserves and waterways of the Swan Canning Rivers be treated as a single entity for the purposes of planning and management. However, areas of high conservation value may be added to CALM's existing Swan Estuary Marine Park estate.
M57.2 Vacant Crown land be declared Class "C" Reserve, vested in Town of Mosman Park.	Implemented	Recreation reserve vested in the local authority.
M57.3 Geological Sites Committee in consultation with EPA prepare a management plan for protection of shell deposits.	Unresolved Issues	The Geological Sites Committee no longer exists. The Swan River Trust should be consulted. To date the local authority has not allocated resources for preparing a management plan.
M58 Blackwall Reach Foreshore, Bicton		
M58.1 Regional park recommendations be applied to this area.	Unresolved Issues	The Regional Parks Task Force Report proposes that the Swan Estuary be considered analogous to a regional park managed under Swan River Trust legislation. The Swan River Management Strategy (1988) recommends that all the foreshore reserves and waterways of the Swan Canning Rivers be treated as a single entity for the purposes of planning and management. However, areas of high conservation value may be added to CALM's existing Swan Estuary Marine Park estate.
M58.2 Part of Reserve A4813 west of Honor Ave be excised, purpose declared as Conservation of Flora and Fauna and Reserve be vested in City of Melville.	Implemented	Excision achieved by Reserves Act 1992. Swan Location 11240 will now be reserved for 'Conservation' vested in the City of Melville.
M58.3 City of Melville prepare management plan in consultation with CALM.	Implemented	The local authority has a management plan. Friends of Blackwall (Greening WA) has an interest in this area.

APPENDIX 3: LAND TENURE

Nb. Refer to Figures 3 - 4 and Maps 1 - 6

Location: Reserve/Lot	Vesting/Owner	Class	Area(ha)	Purpose
SEW Site:				
7077	FCC	A	2.5177	Recreation
42563	FCC	C	0.7978	Recreation
Lot 329	LANDCORP		7.9336	Development
CSBP Site:				
36169	DOLA	C	2.5629	School (1)
36170	MPTC	C	0.0978	Access (2)
VCL	LANDCORP		*	Development
VCL(foreshore)	DOLA		*	Recreation
T.J. Perrott and surrounding reserves:				
36137	(3)	C	2.7535	Institutional
36198	DOLA	C	0.5833	Recreation (4)
36199	DOLA	C	0.2053	Kindergarten
36788	MPTC	C	5.5144	Recreation (5)
17102	DOLA	C	0.6382	Govt. Req.
26549	MPTC	C	0.8192	MPTC Depot
M57 Minim Cove Foreshore, Mosman Park:				
1630	MPTC	A	0.9940	Recreation
31156	MPTC	C	2.7063	Recreation
31157	MPTC	C	2.2156	Recreation
1631	MPTC	A	0.5691	Recreation
39570	WAWA	C	0.0800	Sewage Pumping
24242	MPTC	C	5.0000	Recreation (6)
CSR Site:				
Swan Loc. 79+80	CSR		*	CSR Industry

KEY:

* Information Unavailable
(1)Special School (Buckland Hill Primary School)
(2)Pedestrian and Drainage
(3)W.A. Society for Crippled Children (Crown Grant)
(4)Adventure Playground
(5)Football Oval and Transmission Line Corridor
(6)Mosman Park Tennis Courts (21yr lease)
DOLA Minister for Lands (ie. unvested)

APPENDIX 4: TERRESTRIAL FLORA SPECIES LIST

Codes:
+ revegetated endemic species
# revegetated non-remnant endemic species
* exotic/introduced/weed species
R regionally rare species

Botanical name	Code	Common name/s or (form)
Acacia cochlearis	#	Rigid Wattle
Acacia cyclops	+	Red Eyed Wattle
Acacia littorea	#	(wattle)
Acacia pulchella		Western Prickly Moses
Acacia rostellifera	+	Summer Scented Wattle
Acacia saligna	+	Golden Wreath Wat./Coojong
Acacia truncata	#	(wattle)
Acacia xanthina	+	White Stemmed Wattle
Acanthocarpus preissii	+	Prickle Lily
Agonis flexuosa	+	Peppermint Tree/Wonnil
Allocasuarina humilis	+	Dwarf Sheoak
Allocasuarina fraseriana		Fraser's Sheoak
Alyxia buxifolia	+	Hop Bush
Anagallis arvensis	*	Pimpernel
Arthropodium capillipes		(lily)
Arundo donax	*	Giant Reed/False Bamboo
Atriplex isatidae	#	Salt Bush
Avena barbata	*	Bearded Oat
Avena fatua	*	Wild Oat
Banksia attenuata	+	Candle Banksia/Biara
Banksia menziesii		Firewood Banksia
Boronia alata	R	(shrub)
Briza maxima	*	Blowfly Grass
Bromus madritensis	*	Madrid Brome
Caladenia latifolia		Pink Fairy Orchid
Callitris preissii	#	Rottnest Cypress/Pine
Carpobrotus aquilaterus		Native Pig-Face
Cassytha glabella		Tangled Dodder Laurel
Cassytha racemosa		Dodder Laurel
Casuarina obesa	+	Salt/Swamp Sheoak/Cooli
Chamaelaucium unicinatum		Geraldton Wax
Chrysanthemum frutescens	*	Paris Daisy
Clematis microphylla	+	Old Man's Beard
Conostylis candicans	+	Grey Cottonheads
Conyza bonariensis	*	Fleabane
Cynodon dactylon	*	Couch Grass
Dianella revolutaSpreading		Flax Lily
Diplotaxis muralis		Wall Rocket
Dodonaea aptera	+	Hop Bush
Dryandra nivea	+	Couch Honey Pot
Dryandra sessilis	+	Parrot Bush/Boojak
Eremophila glabra	+	Tar Bush
Erharta calycina	*	Perennial Veldt Grass
Eucaluptus calophylla		Marri

Eucalyptus citriodora		Lemon Scented Gum
Eucalyptus decipiens	+	Limestone/Fremantle Marlock
Eucalyptus foecunda	#	Fremantle/Red Mallee
Eucalyptus gomphocephala	+	Tuart
Eucalyptus marginata		Jarrah
Euphorbia terracina	*	Geraldton Carnation Weed
Ficus carica	*	Edible Fig
Ficus elastica	*	Rubber Plant
Ficus macrophylla	*	Moreton Bay Fig
Foeniculum vulgare	*	Fennel/Aniseed
Freesia affin. leichtlinii	*	Freesia
Gladiolus caryophyllaceus	*	Gladiolus
Grevillea crithmifolia	+	(shrub)
Grevillea thelemanniana	+	Spider Net Grevillea
Guichenotia ledifolia	#	
Hakea prostrata	+	Harsh Hakea
Halosarcia sp.		Glasswort Shrub
Hardenbergia comptoniana	+	Native Wisteria
Hedypnois rhagadioloides	*	Cretan Weed
Hemiandra pungens		Snake Bush
Hibiscus huegelii		Lilac Hibiscus
Hypochaeris glabra	*	Smooth Cat's Ear
Isolepis nodosa	+	Knotted Club Rush
Jacksonia sternbergiana		(pea flower shrub)
Juncus kraussii	+	Shore Rush
Kennedia prostrata	#	Running Postman/Red Runner
Lagunaria patersonia	*	Norfolk Island Hibiscus
Lagurus ovatus	*	Pussy/Hare's Tail Grass
Lepidosperma angustatum		Sword Sedge
Lepidosperma gladiatum		Coastal Sword Sedge
Leptospermum laevigatum	*	Victorian/Coastal Tea-Tree
Leschenaultia linarioides		Fountain/Yellow Lesch.
Leucopogon parviflorus		Coast Beard-Heath
Lobularia maritima	*	Sweet Alyssum
Logania vaginalis	R	White Spray
Lolium rigidum	*	Rye-Grass
Lomandra maritima		Mat Rush
Loxocarya flexuosa		(rush)
Lupinus angustifolius	*	New Zealand Blue Lupin
Macrozamia riedlei	+	Zamia Palm
Malva parvifloria	*	Smallflower Mallow
Medicago polymorpha	*	Medick
Melaleuca acerosa	+	(shrub)
Melaleuca huegelii	+	Chenille Honey-Myrtle
Melaleuca lanceolata	+	Rottnest Tea-Tree/Moonah
Melilotus indica	*	King Island Melilot
Mesomelaena pseudostygia		Telegraph Sedge
Myoporum insulare		Boobialla
Nicotiana glauca	*	Tree Tabacco
Nuytsia floribunda		Christmas Tree/Mooja
Oenothera drummondii	*	Evening Primrose
Olea europaea	*	European Olive
Olearia axillaris	+	Coast Daisy Bush
Opercularia vaginata		
Orbanche minor	*	Lesser Broomrape

Oxalis pes-caprae	*	Soursop
Pelargonium capitatum	*	Rose Pelar./Wild Geranium
Pennisetum clandestinum	*	Kikuyu Grass
Pennisetum setaceum	*	Fountain Grass
Pennisetum villosum	*	Feather Top Grass
Petrohagia veluntina		
Petrophile serruriae		(protea)
Phoenix canariensis	*	Canary Island Date Palm
Phoenix dactylifera	*	Date Palm
Phoenix reclinata	*	Senegal Date Palm
Phyllanthus calycinus		False Boronia
Pimelea leucantha	+	Bunjong
Pittosporum phillyraeoides	R+	Cheese-Wood/Weeping Pittos.
Poa poiformis		(native grass)
Ptilotus polystachyus		(native grass)
Rhagodia baccata	+	Sea-Berry Saltbush
Ricinus communis	*	Castor Oil Bush
Romulae rosea	*	Guildford Grass
Santalum acuminatum	R+	Sweet Quandong
Sarcocornia quinqueflora		Samphire/Glasswort
Scabiosa atropurpurea	*	Purp.Pincushion/Sweet Alice
Scaevola crassifolia	+	Thick Leaved Fan Flower
Scaevola holosericea		(fan flower)
Scaevola nitida		(fan flower)
Scaevola parvifolia	+	Fan Flower
Scenecio lautus		Coastal Groundsel
Schoenoplectus validus		Club Rush
Schoenus curvifolius		
Shinus terebinthifolius	*	Japanese Pepper
Solanum nigrum	*	Blackberry Nightshade
Solanum symonii		(climber)
Sollya heterophylla	+	Australian Bluebell Creeper
Sonchus asper	*	Rough Sowthistle
Sonchus oleraceus	*	Common Sowthistle
Spinifex longifolius		Long Leaved Spinifex
Sporobolus virginicus		Sand Couch
Spyridium globulosum	+	Basket Bush
Stenotaphrum secundatum	*	Buffalo Grass
Stipa elegantissima		Feather Spear Grass
Suaeda australis		Seablite
Syringa vulgaris	*	Cape Lilac
Templetonia retusa	+	Cocky's Tongue
Tetragonia decumbens	*	Sea Spinach
Thomasia triphylla		
Tricoryne elatior		Yellow Autumn Lily
Trymalium ledifolium		(basket bush)
Ursinia anthemoides	*	Ursina
Watsonia bulbillifera	*	Watsonia
Xanthorrhoea preissii	+	Black Boy/Balga

Species list taken from WANC (1985) and Ecoscape (1993); adapted using field surveys, Seddon (1970), Blackall and Grieve (1974), Pen (1983), Powell (1990), Ecoscape (1990) and Ecoscape (1992).

APPENDIX 5: TERRESTRIAL FAUNA SPECIES LIST

Common Name	Botanical Name
Mammals	
Black Rat	*Rattus rattus*
Brushtailed Possum	*Trichosurus vulpeca*
Domestic Cat	*Felis catus*
House Mouse	*Mus musculus*
Red Fox	*Vulpes vulpes*
Reptiles	
Bobtail Lizard	*Tliqua rugosa*
Burrowing Skink	*Lerista praepedita*
Burton's Legless Lizard	*Lialis burtonis*
Bynoe's Gecko	*Heteronotia binoei*
Dugite	*Pseudonaja affinis*
Fence Skink	*Cryptoblepharus plagiocephalus*
King Skink	*Egernia kingii*
Spiny Tailed Gecko	*Diplodactylus spinigerus*
Striped Skink	*Ctenotus fallens*
Western Bearded Gecko	*Pogona minor*
Yellow Bellied Skink	*Hemiergis peronii quadrilineata*
(unnamed)	*Menetia greyii*
(unnamed)	*Morethia obscura*
Birds	
Australian Kestrel	
Australian Pelican	*Pelecanus conspicillatus*
Australia Magpie-lark	
Australia Magpie	
Australian Raven	
Black-faced Cuckoo-shrike	
Black-shouldered Kite	
Brown Honeyeater	
Caspian Tern	*Hydroprogne caspia*
Cormorant, Great/Black	*Phalacrocorax carbo*
Cormorant, Little Black	*Phalacrocorax sulcirastris*
Cormorant, Little Pied	*Phalacrocorax melanoleucas*
Cormorant, Pied	*Phalacrocorax varius*
Crested Tern	*Sterna bergii*
Eastern Reef Heron	*Egretta sacra*
Feral Pigeon	
Greenshank*	*Tringa nebularia*
Laughing Kookaburra	*Dacelos gigas*
Laughing Turtle-Dove	*Stretopelia senegalensis*
Mistletoebird	

New Holland Honeyeater	
Pacific Black Duck	*Anas superciliosa*
Pied Butcherbird	
Pied Oystercatcher	
Pink and Grey Galah	
Port Lincoln Ringneck	
Rainbow Bee-eater	
Sharp-tailed Sandpiper*	*Calidris melanotos*
Red Wattlebird	
Rufous Night Heron	*Nycticorax caledonicus*
Sacred Kingfisher	
Silver Gull	*Larus novaehollandiae*
Silvereye	
Singing Honeyeater	
Southern Boobook	
Spotted Turtle-Dove	
Striated Pardalote	
Tree Martin	
Welcome Swallow	*Hirundo neoxena*
White-faced Heron	*Ardea novaehollandiae*
White-tail Black Cockatoo	*Calyptorhynchus baudinii*

* protected under the Australia-Japan Migratory Birds Treaty.

Species list adapted from WANC (1985), Ecoscape (1993) and Thurlow et al. (1986).