LESLIE SALT

LESLIE SALT PROJECT

EXTENSION OF SALT PONDS, PORT HEDLAND

CONSULTATIVE ENVIRONMENTAL REVIEW

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THE PROPONENT

Leslie Salt is a wholly owned subsidiary of Cargill Incorporated of Minneapolis, Minnesota, USA. The proponent currently operates a solar salt production facility located on coastal flats near Port Hedland on the northwest coast of Western Australia. This facility is operated in accordance with terms and provisions of the *Leslie Solar Salt Industry Agreement Act, 1966.*

Salt is produced by the concentration and evaporation of seawater pumped from a tidal creek (Ridley Creek). A series of eight primary concentration ponds occupying approximately 6,000 ha are located 30 km east of Port Hedland. The salinity of the seawater is elevated at each concentration pond in series, after which the resulting brine travels through aqueducts to the saturated brine or 'pickle' pond located 10 km east of Port Hedland. Once the brine solution becomes fully saturated in the 'pickle' pond it is pumped into crystallization ponds located on the outskirts of Port Hedland. When the crop has grown, the salt is harvested , washed and stacked. After drying, the salt is transported (8 km) by truck to the port for stockpiling and shipment.

THE PROPOSAL

OBJECTIVES OF PROPOSAL

The proponent's objective is to maintain its viability and market share in the future by means of improving efficiency and increasing salt production. The proposal aims to increase salt production from 2.25 to 2.75 million tonnes per annum. The increased production would be worth approximately (Australian) $10 million in export earnings. To achieve these objectives it is necessary to expand the area of primary concentration ponds, and thereby increase the volume of brines that feed the crystallization ponds.

THE PROPOSED PROJECT

The proposal is to expand salt production levels by constructing a new concentration pond (referred to as Pond 0) covering approximately 1,600 ha. The proposed siting of Pond 0 is immediately west of existing ponds 7 and 8. As this

area lies outside existing mining leases the proponent is seeking access to this land by the granting of an additional mining lease covering 2404 ha in area. In return, the proponent is currently reviewing the possibility of surrendering portions of existing leases back to the Crown. Alternative locations to position a 1,600 ha pond were considered at sites both inside and outside the existing leases. These locations were not considered viable alternatives to the proposed location on the basis of engineering, operational and environmental factors.

In order to contain and direct water movement within the proposed extension area a series of internal, perimeter and diversion levees will be constructed from clay and rock. Clay will be obtained from borrow pits at the southern end of the proposed new lease and from within existing leases. Rock will be obtained from existing leases.

Seawater will be fed into Pond 0 by two intake pump stations sited on adjacent tidal creeks. The existing pump station on Ridley Creek will continue to be used and a second intake pump station on Rock Cod Hole Creek is proposed for construction.

Construction of Pond 0 will result in the need to increase the area of saturated brine, bittern and crystallization ponds in order to handle the larger volumes of brine moving through the system. The proponent proposes therefore to construct additional saturated brine, bittern and crystallization ponds within existing leases. These ponds would extend south and east of the existing crystallization ponds and encompass approximately 280 ha. Bitterns from the crystallizers will continue to be discharged into Paradise and Six Mile Creeks.

Currently, four triple road trains are used to haul 18 hours per day on normal shifts and 24 hours during shiploading times. Additional truck haulage will be required to transport the increased volumes of salt from the crystallizer area to the port. Five triple road trains would be used and haulage hours would increase from 4,700 to 5,100 hours per annum.

EXISTING ENVIRONMENT

PHYSICAL CHARACTERISTICS

The Port Hedland/De Grey delta coastal tract comprises the northern portion of the Pilbara coastal system - a unit that extends from the Ashburton delta in the south to the De Grey delta in the north, a longshore distance of some 550 km.

Coastal geomorphology is dominated by limestone barrier islands which are linked to a sand plain hinterland by expansive tidal flats. The tidal flats have formed behind, and in the protection of barrier islands by the accumulation of muds, silts

and fine grained sands. Tidal creek systems drain the flats and empty through breaches or gaps between barrier islands.

The nearshore oceanography of the Port Hedland region is tidally dominated with additional influences made by locally generated wind waves. There are large semi-diurnal tides, with a mean spring range of 5.8 m and a mean neap range of 1.2 m. Spring flood tides of at least 6.9 m above chart datum will raise water above tidal creek levels and onto the expansive tidal flats.

The climate of this region is typically semi-arid with an annual rainfall of 307 mm and annual evaporation of 3,497 mm. The coastal tract is periodically subject to tropical cyclones which can produce heavy rainfall, strong winds, storm surges and destructive waves.

BIOLOGICAL CHARACTERISTICS

The three main biological assemblages found within the vicinity of the proposed pond area are listed below.

(i) Tidal creek/mangrove assemblage

The coastline extending eastwards from Port Hedland is indented by a series of tidal creeks that have eroded into tidal flats. Mangrove habitats have developed as a narrow belt fringing the margin of tidal creeks. The dominant mangrove species is *Avicennia marina* with local occurrence of *Ceriops tagal* and *Rhizophora stylosa.*

(ii) Salt/mud tidal flat assemblage

The salt flats generally are of low productivity with biological activity being concentrated at the periphery or lower, wetter areas where a low density of samphires (*Halosarcia sp.*) occur. Blue-green encrusting algae form mats around the fringes of the samphire and on more frequently inundated sections of the tidal flats.

(iii) Low shrubland/grassland assemblage

This assemblage consists of a low shrubland of *Acacia translucens* with an interstitial grassland of *Triodia pungens*, and a ground cover of mixed herbaceous dicots and other grasses. The sandy islands and undulating sand plain are mostly covered with this vegetation type.

The above assemblages are widely distributed throughout the region and they are in relatively pristine ecological condition.

SOCIAL CHARACTERISTICS

The present population of Port Hedland is approximately 15,000. Of these about 4,000 live in the Port/Cooke Point area, 8,000 in South Hedland and the remainder are spread throughout the region on pastoral stations.

The economic base of Port Hedland is centred upon the mining operations of Mt Newman, Goldsworthy and Leslie Salt companies. The operations of harbour and shiploading facilities at Finucane Island (Goldsworthy) and the port area (Mt Newman) account for the main sources of employment in the area. Leslie Salt currently employs 90 personnel with a further 24 contract employees being engaged for haulage operations.

The remoteness of the proposed pond area from Port Hedland and the relative difficulty of gaining access to the area means that it is used only infrequently by tidal creek fishermen. The Port Hedland Town Council has identified the existence of an illegal net fishing problem in tidal creeks in the Port Hedland area. This problem is considered less severe in the vicinity of the existing salt ponds because of restricted access. No commercial fisheries operate in nearshore oceanic waters immediately offshore from the ponds although a small commercial prawn fishery operates near the mouth of the De Grey River.

An ethnographic and archaeological survey has determined that the area to be flooded within Pond 0 contains no sites of Aboriginal significance. While some sites have been identified on sandy islands in the proposed pond area, these will not be directly affected by the proposal.

ENVIRONMENTAL EFFECTS

The main environmental effects of the proposed project are summarised below.

PHYSICAL EFFECTS

Construction of pond 0 will modify the topography by:

(i) the emplacement of perimeter, internal and diversion levees,
(ii) the excavation of a stormwater drain parallel to the diversion levee,
(iii) the recovery of clay and rock from borrow pits.

The diversion levee and stormwater drain will divert periodic floodwaters flowing down a side arm of the Tabba Tabba Creek onto mud flats at a point approximately 1 km further to the west. This diversion will increase the volume of floodwaters discharging down from the mud flats into Rock Cod Hole Creek.

The perimeter levee across Catfish Creek will prevent tidal waters from following the creek's normal path into headwater areas due to the blocking influence of the levee. As a result siltation next to, and immediately downstream from the levee will develop new tidal mud flats suitable for mangrove recruitment.

Earthworks involved in the construction of Pond 0 have the potential to increase airborne dust levels in the vicinity of susceptible habitats (e.g. mangroves).

BIOLOGICAL EFFECTS

The construction and operation of Pond 0 will alienate or modify the following habitat/assemblage groups;

- salt/mud tidal flats;
- tidal creek and fringing mangroves;
- sand plain and associated grassland/shrublands.

The largest area of habitat modification would be the permanent flooding of salt/mud flats within the proposed pond area. Water depth (70 cm) and salinity (44 g/L) within Pond 0 would be strictly controlled. The biological productivity of this area would be altered from one of relatively low productivity to one supporting abundant fish, benthic fauna and avifauna populations.

The loss of 18 ha of mangroves resulting from impoundment within Pond 0 will occur mainly along the upper reaches of Catfish Creek. For approximately half of this distance the creek has become a shallow gutter and mangrove (*Avicennia marina)* growth is low and sparse. This area of mangrove habitat is both small and of limited diversity when compared to the regional characteristics of this habitat. The loss of mangrove/tidal creek habitat is expected to be replaced to a large extent as mangroves recruit into new headwater areas of Rock Cod Hole Creek and parts of Pond 0.

Vegetation in both the rock and clay quarry sites will be lost until rehabilitation measures are initiated following the construction of levees. Vegetation associations within these sites are widespread throughout the region.

SOCIAL EFFECTS

Regional economy

The project will provide substantial benefits to the local and regional economy at no cost to local ratepayers or the state and with minimal adverse impacts.

Under the proposed expansion the workforce employed by Leslie Salt would increase to 105 permanent staff and 29 contract employees. The monetary benefits to the local economy will increase in terms of both the direct contribution and indirectly through multiplier effects.

Export earnings and royalties paid to the Western Australian government will increase proportional to the projected increase in salt production. The proposed expansion would increase export earnings by approximately AUS$10 million per annum.

Trucking movements

A potential adverse impact of the proposal is the increased trucking movements between Leslie Salt operations and the port. Haulage trucks would be mobilised 24 hours per day rather than the present 18 hours under normal operations. During periods of busy ship loading in the past, trucks have been mobilised 24 hours a day over a 2-3 month period. As these busy periods have not been of great inconvenience to the local community, it is envisaged that the increased movements resulting from the proposed expansion would not create any major problems.

Access to tidal creeks

The construction of Pond 0 will reduce land access to adjacent tidal creeks for amateur and illegal net fishing parties, thereby increasing the protection of local creek fish resources. Given the present illegal net fishing problem, this effect is likely to benefit local fish stocks.

Conservation values

The existing concentration ponds are considered to be of world wide conservation importance as a major autumn refuge area for trans-equatorial migratory wading birds. The proposed pond is expected to support large numbers of migratory waders thereby increasing the already high conservation value of the salt ponds.

ENVIRONMENTAL MANAGEMENT

The adverse impacts of the proposal will be minimised by the implementation of the management programme summarised below.

(i) Protection of Aboriginal Sites - identified sites of Aboriginal significance will be left undisturbed during the construction and subsequent operation of Pond 0.

(ii) Rehabilitation of borrow pits.

(iii) Dust suppression - dust levels near mangrove habitats will be minimised by watering construction roads.

(iv) Workforce management - employees and contractors involved in construction works will keep within designated construction lines, thereby minimising unnecessary habitat modification.

(v) Trucking movements - should it be required, the proponent will reduce trucking movements during peak hours.

The proponent proposes to initiate a monitoring programme to assess the effectiveness of the management programme and to confirm the adequacy of predictions made in the Consultative Environmental Review. An annual report outlining the results of the monitoring programme will be prepared and forwarded to relevant authorities. The monitoring programme will involve:

- monitoring the effects of bitterns discharge on nearby mangrove assemblages;
- aerial photograph analysis to map changes in creek drainage and vegetation patterns;
- assessing the progress of rehabilitation in borrow pits;
- monitoring the biological productivity within the proposed new pond.

CONCLUSION

It is concluded that the proposed project will be of benefit to the community and that potential adverse impacts can be successfully managed by the implementation of the management and monitoring programme outlined in the report.

TABLE 1

POTENTIAL ADVERSE IMPACTS PREDICTED AND MANAGEMENT PROGRAMME PROPOSED FOR LESLIE SALT PROJECT: EXTENSION OF SALT PONDS

POTENTIAL ADVERSE IMPACTS	MANAGEMENT PROGRAMME AND COMMITMENTS
PHYSICAL ENVIRONMENT	
Construction of Pond O will modify the existing topography of the project area by: · the emplacement of perimeter, internal and diversion levees; · the excavation of a stormwater drain parallel to the diversion levee; and · the excavation of clay and rock from borrow pits.	Employees and contractors involved in construction works will keep within designated construction lines, thereby minimising unnecessary habitat modification. The borrow pits will be contoured and rehabilitated to blend in, as much as possible, with the existing topography.
The diversion levee and stormwater drain will divert periodic floodwaters down a side arm of the Tabba Tabba Creek onto mud flats approximately 1 km to the west. This diversion will increase the volume of floodwaters discharging down Rock Cod Hole Creek, thus creating new headwater areas.	The proponent will monitor the development of new headwater areas and the expected subsequent mangrove recruitment in those areas.
The perimeter levee across Catfish Creek will prevent tidal waters from following its normal path into headwaters areas upstream from the proposed levee. As a result siltation next to, and immediately downstream from the levee will develop new tidal mud flats suitable for mangrove recruitment.	The proponent will monitor changes in creek drainage, siltation areas and mangrove distribution in this area.

TABLE 1 (cont'd)

POTENTIAL ADVERSE IMPACTS PREDICTED AND MANAGEMENT PROGRAMME PROPOSED FOR LESLIE SALT PROJECT: EXTENSION OF SALT PONDS

POTENTIAL ADVERSE IMPACTS	MANAGEMENT PROGRAMME AND COMMITMENTS
BIOLOGICAL ENVIRONMENT	
Construction of Pond 0 will result in the permanent flooding of approximately 1600 ha of salt/mud flats.	Water depth (70 cm) and salinity (44 g/L) will be strictly controlled. The biological productivity of this area will be increased considerably.
Approximately 18 ha of mangroves, mainly along the upper reaches of Catfish Creek, will be lost from impoundment within Pond 0.	The loss of mangrove habitat is expected to be replaced to a large extent as mangroves recruit into new headwater areas of Rock Cod Hole Creek and into parts of Pond 0.
Construction works have the potential to increase airborne dust levels in the vicinity of susceptable habitats.	Dust levels near mangrove habitat will be minimised by watering construction roads.
Vegetation in both the rock and clay quarry sites will be lost.	The quarry sites will be rehabilitated following construction of the levees.

TABLE 1 (cont'd)

POTENTIAL ADVERSE IMPACTS PREDICTED AND MANAGEMENT PROGRAMME PROPOSED FOR LESLIE SALT PROJECT: EXTENSION OF SALT PONDS

POTENTIAL ADVERSE IMPACTS	MANAGEMENT PROGRAMME AND COMMITMENTS
SOCIAL ENVIRONMENT	
There will be increased trucking movements between Leslie Salt operations and the port. Haulage trucks would be mobilised 24 hours per day rather than the present 18 hours under normal operations.	During periods of busy ship loading, in the past, trucks have been mobilised 24 hours a day over a 2-3 month period which has not been of great inconvenience to the local community. Should it be required, the proponent will reduce trucking movements during peak hours.
Construction works have the potential to cause disturbance to aboriginal sites.	Identifed aboriginal sites will be protected and left undisturbed during the construction and subsequent operation of Pond 0.

TABLE 2

BENEFICAL IMPACTS PREDICTED TO RESULT FROM THE LESLIE SALT PROJECT: EXTENSION OF SALT PONDS

BENEFICAL IMPACTS	COMMENTS
The proposed pond is expected to be of high conservation value to large numbers of migratory waders.	The existing concentration ponds are considered to be of world wide conservation importance as a major autumn refuge area for transequatorial wading birds.
The proposed pond is likely to be of benefit to local fish stocks.	The construction of Pond 0 will reduce land access to adjacent tidal creeks for amateur and illegal net fishing parties, thereby increasing the protection of local creek fish sources.
The project will provide substantial benefits to the local and regional economy at no cost to local ratepayers or the state.	Under the proposed expansion, the workforce employed by Leslie Salt would increase by 15 permanent staff and 5 contract employees and export earnings would increase by approximately AUS $10 million per annum.

EXTENSION OF SALT PONDS, PORT HEDLAND

CONSULTATIVE ENVIRONMENTAL REVIEW

1 INTRODUCTION

1.1 THIS DOCUMENT

This document is a Consultative Environmental Review (CER) of a proposal to expand solar salt facilities at Port Hedland, Western Australia. This level of assessment was determined by the Environmental Protection Authority (EPA) on the basis of a Preliminary Appraisal and a Proposal Application submitted by the proponent to the EPA in February 1990.

The purpose of the document is to describe the salient features of the proposed salt pond extension and the existing environment, assess the environmental effects of the proposal and present appropriate management procedures designed to ameliorate any potentially adverse effects of the proposal. This document is the result of both a desk study review, field surveys and consultation with relevant local and state authorities.

1.2 THE PROPONENT

Leslie Salt, a department of Cargill Australia Ltd, is a wholly owned subsidiary of Cargill Incorporated of Minneapolis, Minnesota, USA. The Port Hedland operation has inherited experience and technical expertise from its parent and predecessor companies dating back to 1869. The company's operations in the San Francisco Bay area are the largest solar salt facilities in the United States of America.

The Port Hedland solar salt facility was constructed in 1966. The first shipment of salt from Port Hedland was made in 1969 and since that time it has become one of the world's leading producers of solar salt. Leslie Salt currently produces two million tonnes of high purity sodium chloride per year, generating approximately (Australian) $40 million in export earnings. As a result of recent upgrading work, salt production will increase to 2.25 million tonnes per annum as extra crystallizer area comes into use. Most of the salt is used in industry for the production of chlorine, caustic soda and soda ash.

1.3 LOCATION AND EXISTING FACILITIES

The Leslie Salt project is located on coastal flats near Port Hedland on the northwest coast of Western Australia (Fig. 1). The region is ideally situated for a solar evaporation plant because of its low rainfall and high evaporation rates. It also has large expanses of low-lying impervious, flat land suitable for the concentration of brines. The deepwater port at Port Hedland handles large bulk carriers and is relatively close to the major Asian markets.

Leslie Salt's Port Hedland plant has complete facilities that have proven reliable since operations began in 1969. Since 1980 the plant has been involved in a continuing process of efficiency improvement and introduction of innovative techniques aimed at increasing productivity.

Salt is produced by the concentration and evaporation of seawater pumped from a tidal creek (Ridley Creek). A series of eight primary concentration ponds occupying approximately 6,000 ha are located 30 km to the east of Port Hedland (Fig. 2). The ponds were formed by the construction of levees that join with natural barriers (i.e. sandy islands) to produce a perimeter bund surrounding coastal flats. The flats were then flooded with seawater pumped from Ridley Creek.

The salinity of the seawater is elevated in each concentration pond in series, after which the resulting brine travels through aqueducts to the saturated brine or 'pickle' pond located 10 km east of Port Hedland. Once the brine solution becomes fully saturated in the 'pickle' pond it is pumped into crystallizing ponds located on the outskirts of Port Hedland (Fig. 2). When the crop has grown in the crystallization ponds the salt is harvested, washed and stacked. After drying, the salt is transported (8 km) by truck to the port for stockpiling and shipment.

1.4 EXISTING AGREEMENT AND LEASES

Leslie Salt operates its solar salt project in accordance with the terms and provisions of the Leslie Solar Salt Industry Agreement Act, 1966. Incorporated in this act was the granting of mining lease (ML No. 242SA). This lease comprises Areas A, B and C shown in Figure 2. An additional lease (ML 250SA) was granted in 1973 incorporating Areas D and E shown in Figure 2. Leslie Salt also utilises two smaller leases (ML 45/79 and ML 45/450) which are quarried for levee wall armour rock.

1.5 THE PROPOSAL

The present proposal is to further expand salt production levels by constructing a new primary concentration pond (referred to as Pond 0) covering an area of approximately 1,600 ha. The preferred siting of Pond 0 is immediately to the west

of existing Ponds 7 and 8 (Fig. 2).

Seawater will be fed into the proposed Pond 0 by two intake pump stations sited on adjacent tidal creeks. The existing pump station on Ridley Creek will be supplemented by a second intake pump station on Rock Cod Hole Creek which is proposed for construction (Fig. 3). To contain and direct water movement within the proposed extension area, a series of internal, perimeter and diversion levees will be constructed from clay and rock (Fig. 3). Clay will be obtained from borrow pits at the southern end of the proposed new lease and from within the existing lease. Rock will be obtained from exisitng leases (Section 3.4.2).

Construction of the proposed Pond 0 will result in the need to increase the area of saturated brine, bittern and crystallization ponds to handle the larger volumes of brine moving through the system. The proponent therefore proposes to construct additional brine, bittern and crystallization ponds within existing leases. These ponds would extend south and east of the existing crystallization ponds and encompass approximately 280 ha (Fig. 2). The total expansion is planned to increase production by an additional 500,000 tonnes/yr.

1.6 NEED FOR THE PROPOSED EXTENSION

Over the last 10 years there has been a steady growth in the demand for salt in South East Asian countries. With this demand expected to continue, Leslie Salt wishes to maintain its market share and viability in the future. Due to high inflation in Australia, production costs continue to rise at a rate far higher than for the selling price of salt. Therefore, to remain viable the Port Hedland operation wishes to further improve its efficiency and production. To achieve this it is necessary to expand the area of primary concentration ponds that currently feed the crystallization ponds.

1.7 NEED FOR NEW MINE LEASE

The location of the proposed Pond 0, selected on the basis of environmental, engineering and economic considerations, lies outside of the existing lease areas and consequently the proponent is seeking a new mining lease (Section 2.3.2). The proposed lease area covers 2,404 ha (Fig. 4). Leslie Salt is currently investigating the possibility of surrendering to the Crown land within existing leases that it considers to be unsuitable for salt production.

1.8 RELEVANT LEGISLATIVE REQUIREMENTS

Leslie Solar Salt Agreement Act

The *Leslie Solar Salt Industry Agreement Act* was declared by the Western Australian Government in July 1966. This approves the Leslie Solar Salt Industry Agreement which specifies terms and conditions relating to the mining lease (ML 242SA), production levels, royalties, transportation of salt, water usage, etc. The term of the present lease expires after 31 years (i.e. 1997), after which the lease can be renewed for a further 21 years and following this for a further 11 years (*Leslie Solar Salt Industry Agreement, 1966*).

Mines Act

Under the *Leslie Solar Salt Industry Agreement Act*, the company shall observe, perform and carry out the provisions of the *Mines Regulation Act, 1946* and as modified by the Agreement, the *Mining Act, 1904*.

Environmental Protection Act

The granting of the proposed lease by the Mines Department is conditional to the requirements of the *Environmental Protection Act, 1986*. The *Environmental Protection Act, 1986* makes the EPA responsible for assessing the environmental impact of such proposals.

Leslie Salt therefore initiated assessment procedures by submitting a Proposal Application and Preliminary Appraisal to the EPA in February 1990. On the basis of this information the EPA then notified the company that formal assessment was required under Part IV of the *Environmental Protection Act*. The level of assessment deemed necessary was that of a CER.

Aboriginal Heritage Act

The Western Australian *Aboriginal Heritage Act, 1972-1980*, makes provision for the recording and preservation of places and objects customarily used by, or traditional to, the original settlers of Australia. The Act defines the obligations of the community relating to Aboriginal sites of both an ethnographic and archaeological nature.

1.9 ACKNOWLEDGEMENTS

The assistance of the following individuals in providing information for this report is gratefully acknowledged.

- Messrs R. Chapple & T. O'Connor, Port Hedland Town Council,
- Mr M. Wallwork, Main Roads Department,
- Captain I. Baird, Port Hedland Port Authority,
- O'Connor & Quartermaine, Aboriginal Heritage Consultants,
- Dr P. Briggs, CSIRO - satellite imagery.

2 ALTERNATIVES TO PROPOSAL

2.1 INTRODUCTION

The following section discusses potential alternatives to the proposal for increasing salt production and justifies the proposed location of the new pond in the light of environmental, engineering and financial considerations. Basically, there is no alternative to creating a new primary concentration pond because the current system is operating at maximum capacity for the current level of feed stock. To further increase salt production it is necessary to expand the concentration pond area and therefore increase the volume of feed stock available for crystallization.

2.2 ALTERNATIVE MEANS OF ACHIEVING OBJECTIVES

2.2.1 INCREASING CRYSTALLIZING PONDS

In some solar salt projects it is possible to increase production volume by merely increasing the efficiency of salt extraction from within the existing facilities. However, Leslie Salt has already undertaken such an improvement.

Leslie Salt initiated an upgrade project in 1988 to achieve maximum efficiency of salt extraction from the volume of brine presently available. This involved increasing the pumping capacity and the construction of four new crystallizers. When these new crystallizers come into full operation by 1991 the average annual capacity is expected to be 2.25 million tonnes.

The capacity of a solar salt operation is a function of the area of ponds producing brine and the net evaporation rate. Without an increase in the volume of brine available, the construction of any further crystallizers to increase salt production is not a viable alternative because the crystallizers would be starved of their feed stock. Consequently, to increase production levels by a further 500,000 tonnes, the proponent requires an increased concentration pond area to produce the required volumes of brine.

2.2.2 ALTERNATIVE LOCATIONS

Alternative locations to position a 1,600 ha pond were considered at sites both inside and outside the existing leases. These locations were not considered viable alternatives to the proposed location on the basis of engineering, financial and environmental grounds.

The area within the existing lease (ML 242SA, Part A) to the north of the present intake channel is not suitable because the mud flat areas are at the outlet of the Ridley Creek. In times of flood, Ridley Creek receives floodwaters from the larger Strelley and De Grey river systems. Hence the large volumes of water that periodically flow down Ridley Creek would present great difficulties in maintaining levees and redirecting water movement. The remaining area is mostly high ground (sand plain) leading to higher seepage losses, and higher construction and operating costs due to additional pumping requirements.

Other locations between Port Hedland and the existing concentration ponds do not contain the large expanses of mud flat suitable for the size of pond required. These areas contain large expanses of sand plain as well as extensive tidal creek and mangrove systems (e.g. 16 Mile and 26 Mile Creeks).

Within Parts B and D of the existing lease (Fig. 2), a much greater area of mangrove and tidal creek habitat would be destroyed in order to contain a pond of this size. By comparison with the proposed location, these areas are more heavily used for recreation purposes as they are more accessible from Port Hedland.

2.3 JUSTIFICATION OF SELECTED OPTION

2.3.1 SIZE OF EXTENSION

The function of the salt concentration ponds is to produce brine by increasing the density of saline water at a constant rate as it flows from Ponds 1 to 8. The density changes within and between ponds needs to be kept close to constant to ensure the regulated concentration and precipitation of the various salts.

The density of seawater is increased by volume reduction due to evaporation. Large volumes of water are required to be evaporated initially to produce very small density changes. For the proposed pond (Pond 0) to be of sufficient size to produce the required density rise (i.e. from Pond 0 to Pond 1), it needs to cover a minimum area of 1,600 ha.

The lease area that the proponent is seeking covers 2,404 ha. The additional area (outside Pond 0) of 804 ha allows for clay borrow pits and the construction of levees, storm drains and an intake pump station (Section 3.4), as well as undisturbed areas such as sandy islands.

2.3.2 LOCATION OF POND 0

The proposed location for Pond 0 is the most suitable alternative for the following reasons:

(i) the area encompasses large expanses of salt and tidal flats. A small number of sandy islands lie within the proposed lease, however there is sufficient area of coastal flats to provide the area of 1,600 ha required for the pond;

(ii) the proposed pond would be constructed alongside the existing ponds, thereby reducing the costly requirement of lengthy connecting channels which are a barrier to wildlife movement;

(iii) the positioning of levees makes use of natural barriers (sand islands) to help contain water within the pond system (Fig. 3), thereby further reducing the volume of earthworks;

(iv) it is possible to minimise the impact on environmentally-sensitive habitats such as mangrove-lined creeks. The location of the lease boundary has been selected to minimise disturbance to mangrove systems. For example, the proposed lease boundary is diverted to the north of Rock Cod Hole Creek (except at the intake pump site) in recognition of mangrove habitats along this creek (Fig. 3);

(v) the proposed pond does not straddle major drainage routes from the hinterland, thereby minimising impact on drainage or creek hydrology.

2.3.3 INTAKE PUMP SITE

To provide Pond 0 with the required volume of water, it will be necessary to operate a second intake pump station in conjunction with the existing pumps. The most suitable site for this facility is on Rock Cod Hole Creek located in the southwest corner of the lease area (Fig. 3). Details of this facility are presented in Section 3.3.2.

2.4 NO DEVELOPMENT OPTION

Leslie Salt view the extension proposal as being vital to the future economic viability of its Port Hedland operation. As the trend of high inflation in the Australian economy and small increases in the overseas selling price is expected to continue for several years, it is essential to increase production if the Port Hedland solar salt operation is to remain financially viable in what is essentially an export market.

Should the expansion not take place the operation may become uneconomic in the future, thus leading to the shutdown of the operation with consequent loss of local employment opportunities and income to the Port Hedland Shire and local service industries, as well as loss of export revenue.

3 DESCRIPTION OF PROJECT

3.1 INTRODUCTION AND LAND TENURE

Incorporated in the Leslie Solar Salt Industry Agreement Act, was the granting of mining lease ML 242SA. This lease encompasses Areas A, B and C shown in Figure 2. An additional lease (ML 250SA) was granted in 1973 incorporating Areas D and E shown in Figure 2.

The proponent is seeking a new lease covering 2,404 ha of land to the south and west of the concentration ponds. Specifications of the proposed lease boundary are shown in Figure 4. The tenure of this land is currently Vacant Crown Land except for a small area of sand plain in the southern section of the proposed lease. This section is part of a larger pastoral lease operated by the De Grey Station (Fig. 5). This lease extends from further inland down to the eastern edge of the coastal flats (i.e. high water mark). The Pippingarra and Strelley Stations also operate pastoral leases in the region and a small government water reserve (No. 13636) is situated around the Tabba Tabba Well. These are all outside the proposed lease boundary (Fig. 5).

3.2 EXISTING FACILITIES AND MODE OF OPERATION

The location of the existing facilities are shown in Figure 2. The salt production process is reliant upon the steady flow and concentration of brine through the system so that the crystallization ponds receive the necessary feed stock.

Currently, seawater is pumped from Ridley Creek into a channel which directs the water into concentration Pond 1. Eight diesel-driven pumps are employed with a combined pumping capacity of 16 m^3/s. The pumps are located on the south arm of Ridley Creek with four pumps being set within a holding dam. The dam was constructed in 1978 to hold seawater brought in by the incoming tide and enable pumping to continue after the tide had receded. Flap gates were installed to allow only water movement into the dam. Siltation of the entrapped tidal creek has since occurred and the effective increase in pumping has reduced from 50% to 25% over normal tidal creek pumping. At present pumping can occur only on tides above 4.7 m (Port Hedland chart datum).

The water is directed through a series of eight concentration ponds by a series of stopper gates. During this process the salinity of the water increases from 44 g/l NaCl (5.6° Be) to 199 g/l NaCl (21.2° Be) (Table 1). The brine then flows along an aqueduct and into Pond 9, known as the saturated brine or 'pickle' pond. Brine held in Pickle Pond 9 becomes the feed stock for the crystallizer ponds.

The crystallizing ponds are periodically topped up with brine to maintain the optimum density range required for sodium chloride (NaCl) precipitation. After as many as three 'top ups' and final evaporation, the spent concentrated brine (bitterns) is drained from the pond. Bitterns are collected in desalting or bittern ponds before being discharged during high tides into 6 Mile Creek and Paradise Creek (Fig 6). The discharge of bitterns is presently carried out once a fortnight over a 2-3 day period. This period is coincident with high tidal ranges (high tides exceeding 5.6 m) to ensure maximum flushing and dispersal of bitterns from tidal creeks into the nearshore ocean environment.

When the crop has grown sufficiently (approx. 20-30 cm), the feed brine is drained off in preparation for harvesting. The harvesting of salt is a mechanical process that commences with ripping the new crop after which mechanical harvesters pick up the salt and transfer it into large trucks which transport the crop to the washing plant. When harvesting of the crop is completed the floor is levelled and sloped in preparation for making a new crop. Fresh brine is introduced into the crystallizer, thus commencing the growth of a new crop of salt.

The harvested salt is put through a washing process to reduce impurities such as calcium, sulphate, magnesium and insoluble matter. After drying, the salt is transported by triple, bottom-dump trailers to the port for stockpiling and shipment.

3.3 PROPOSED DEVELOPMENT CONCEPT

3.3.1 INCREASED SALT PRODUCTION

The current average field capacity is two million tonnes/yr. This will increase to 2.25 million tonnes/yr in 1991 as a result of an upgrade project initiated in 1988. The proposed expansion will increase production by an additional 500,000 tonnes/yr, thus generating an average field capacity of 2.75 million tonnes/yr.

To facilitate an increase of this magnitude, there are various aspects of the solar salt operation that need to be expanded or altered to cater for greater production levels. These details are given below.

3.3.2 INCREASED SEAWATER INTAKE

The existing intake facility located on Ridley Creek pumps approximately 144 million m^3/yr of seawater. The volume required with the proposed expansion is 184 million m^3/yr. It is proposed to obtain the required volume by drawing equal amounts (92 million m^3/yr) from the existing pump station and a proposed pump station on Rock Cod Hole Creek.

3.3.3 INCREASED AREA OF PONDS

The area of primary concentration ponds would increase by 26.4% (1,600 ha) with the construction of Pond 0. A larger area of bitterns and crystallization ponds would be required to handle the increased volumes of brine moving through the system. The proponent therefore proposes to construct additional bittern, saturated brine (pickle), and crystallization ponds within existing leases. These ponds would extend south and east of the existing crystallization ponds and encompass an area of approximately 280 ha (Fig. 6).

3.3.4 INCREASED SALINITY IN PONDS

Table 1 shows the present and predicted salinity values in the concentration and pickle ponds. Pond 0 is expected to average salinities similar to the present Pond 1 (44 g/L or 5.6° Be), while Pond 1 will have its salinity increased to 55 g/L or 6.9° Be.

With the construction of Pond 0 and an additional pickle pond (pp10), the salinity increases required between each pond are smaller than the present arrangement. This will enable a more accurate regulation of salinities between ponds.

3.3.5 INCREASED VOLUME OF BITTERNS

Currently the volume of bitterns discharged per annum is 5,215,800 m^3. The major components of the bitterns are magnesium chloride ($MgCl_2$), magnesium sulphate ($MgSO_4$), sodium chloride (NaCl), potassium chloride (KCl) and water. The upgrade project initiated in 1988 resulted in an increased pumping capacity and the construction of four new crystallizers. These crystallizers are now coming into operation and when fully operational (1991), the efficiency of salt (NaCl) extraction will be increased and the volume of bitterns discharged will decrease to 3,477,200 m^3/yr.

Under the proposed expansion there would be an increase in the quantity of bitterns discharged proportional to the increase in salt production. The increase in bitterns discharge is expected to be 772,700 m^3/yr, producing a total bitterns discharge volume of 4,248,800 m^3/yr under normal operations. It is anticipated that this volume will be reached approximately two years after filling Pond 0 is complete. The proportion of the various components constituting the bitterns is summarised with the above information in Table 2.

4,249,900?

3.3.6 INCREASED TRUCK AND SHIPPING MOVEMENTS

Currently, Leslie Salt produces and ships an average of two million tonnes of salt per year. After harvesting, washing and drying, the salt is transported by trucks to the storage and shiploading area at the port. Four triple road trains are used, hauling 18 hours per day (0600-2400 hrs) on normal shifts and 24 hours per day whilst ship loading. Present trucking requirements average 4,700 hours of port haul operations. For an annual production of 2.75 million tonnes, five triple road trains would be used and haulage hours would increase to approximately 5,100. A considerable amount of this extra haulage time would occur during the period of 0000-0600 hrs.

At around two million tonnes per year, some 60-65 vessels are used to ship the salt to customers. At 2.75 million tonnes/yr, shipping movements will increase to 75-80 vessels. This number may decrease with the trend towards using larger ships.

3.3.7 INCREASED EMPLOYMENT

The current Port Hedland workforce is 90 with a further 24 contract employees being engaged on haulage operations. With the proposed expansion these numbers will increase to 105 and 29 respectively.

Currently salaries and wages paid to Port Hedland employees are in excess of $4,000,000 and goods and services purchased in the town exceed $1,500,000.

3.4 POND CONSTRUCTION DETAILS

3.4.1 LOCATION OF PROPOSED LEVEES

The position of proposed levees, storm drains and lease boundary are shown in Figure 3.

The internal levees are designed to partially divide Pond 0 so that water circulation is encouraged throughout the pond. After circulation the water will be directed into the existing ditch feeding into Pond 1 (Fig. 3).

Approximately 5.2 km of perimeter levees are required to contain water within Pond 0. The length and volume of internal and perimeter levees has been minimised by utilising sandy islands as natural barriers. At Catfish Creek, the perimeter levee alignment intentionally heads away (i.e. east) from the lease boundary to minimise impoundment of mangroves (Fig. 3).

A diversion levee and storm drain are aligned across the southern end of the pond so that floodwaters from Tabba Tabba Creek are diverted away from the new pond area. This levee will be a continuation of an existing diversion levee that extends along the eastern perimeter of the concentration ponds.

3.4.2 SOURCE AND VOLUME OF LEVEE MATERIAL

Figure 7 summarises the design specification and volumes of material required for the construction of internal, perimeter and diversion levees. The levees will be constructed mostly of clay, excavated to a depth of 2 m from borrow pits located as shown in Figure 8. The diversion levee will be rock armoured one side, and the perimeter and internal levees rock armoured on both sides. Armour rock will be obtained from existing lease areas (Fig. 8). The total volume of clay and rock material required is 805,000 m^3 and 174,300 m^3 respectively. Rehabilitation of borrow pits and rock quarries will be carried out in accordance with Mines Department guidelines (Section 6.2.2).

3.4.3 RELATIVE HEIGHT OF LEVEES AND DRAINS

Perimeter levees will be built to a height of 9.8 m above chart datum or 5.64 m above AHD (Fig. 7). This represents a level of 4 m above the tidal flats and 2 m above the highest astronomical tide (HAT). The 2 m freeboard above HAT is required to protect the ponds from the additional influence of storm surges generated by intense low pressure systems.

In the light of the available data (Section 4.3.6) it is considered that the perimeter levee should be adequately protected against storm surge events because the perimeter levee is:

- higher than storm surge levels (9.16 m above chart datum) recorded for protected coasts in the Port Hedland area;
- located in a tidal embayment 1.5-2.0 km inland from the present coastline and protected in most seaward aspects by a limestone barrier or foredune buffer zone.

The diversion levee height (Fig. 7) will be 11.0 m above chart datum, which is 4.0 m above the surrounding sand plain. It is expected that this will be sufficiently high to divert the periodic floodwaters brought down by the sidearm of the Tabba Tabba Creek. A levee of this height has proved adequate in diverting much larger volumes of floodwater from Ridley Creek located to the north of the existing ponds. A stormwater drain parallel to the levee (Fig. 3) will be excavated to a depth of 2 m and width of 50 m.

3.4.4 PROPOSED SEAWATER INTAKE

The other major construction within the proposed lease area is an intake pump station located on Rock Cod Hole Creek (Fig. 9). At this location the creek is 170 m wide and is fringed by mangrove flats. The width of mangroves at the proposed site (approx. 40 m) is narrow by comparison with alternative locations both upstream and downstream (Fig. 9).

The preferred option is to cut a channel of about 15 m length from the creek bank to a pump station onshore. The channel and pump station would be retained by sheet piling. This construction arrangement is shown in Figure 10. An alternative arrangement is for the pumps to be mounted on a platform above the creek channel. A jetty supporting the platform would extend approximately 15 m out from the creek bank. Discharge pipes would connect the pumps to an intake channel feeding Pond 0.

3.5 PROPOSED OPERATION DETAILS

Under the proposed expansion, Pond 0 will be fed seawater by two pump stations. The existing intake pump station will be modified to feed into Pond 0. Pumping at this site will occur on tides exceeding 4.7 m at a rate of 16 m^3/s. Pumping from the proposed intake pump site on Rock Cod Hole Creek will occur at tides above 3.7 m at a rate of 12 m^3/s. Each location is expected to pump roughly the same volume (92 million m^3/yr) of seawater. Water from Pond 0 would enter Pond 1 through the existing drain feeding Pond 1 (Fig. 3).

From this point on the system will be operated in a similar manner to the present operation with the only difference being the addition of another pickle pond (pp10) and the slightly higher salinities predicted for the existing ponds (Table 1).

Bitterns discharge will also follow the present system, whereby bitterns are discharged over high tidal ranges (high tides exceeding 5.6 m) and thus are flushed out and rapidly dispersed by receding tidal waters into the nearshore ocean environment. It is proposed to discharge mostly into Paradise Creek, however 6 Mile Creek will also be used.

3.6 PROPOSED TIMING OF DEVELOPMENT

The proponent wishes to commence construction as soon as possible to enable much of the work to be completed by the next wet season (i.e. December 1990). The pump station and concentration pond would be completed first and seawater pumping commence as soon as possible thereafter. Construction would continue through into 1991 with the additional salt becoming available toward the end of 1992.

4 EXISTING ENVIRONMENT

4.1 INTRODUCTION

The physical, biological, ecological and social aspects of the study area are described in this section to the level necessary to provide both regional and long-term perspective of the proposed development area.

4.2 AVAILABLE INFORMATION

Description of the physical, biological and social environments of the study area has been obtained from a desk review of available information, aerial photographic analysis and, where necessary, field work to confirm or supplement existing information. While little specific information exists on the study area, studies conducted in and around Port Hedland (e.g. LSC, 1984; 1985; 1987) and of a regional nature (Semeniuk, 1986; Johnstone, 1990) are of direct relevance to this proposal.

4.3 PHYSICAL ENVIRONMENT

To provide a perspective of the proposed extension area as it occurs within the larger Port Hedland/De Grey delta region, it is appropriate to describe some of the physical characteristics on both a regional and local scale.

4.3.1 REGIONAL SETTING

Regionally Port Hedland and its adjoining submarine shelf comprise the northern portion of the Pilbara coastal system - a unit that extends from the Ashburton delta in the south to the De Grey delta in the north, a longshore distance of some 550 km.

4.3.2 CLIMATE

The climate of this region is typical of the Pilbara with an annual rainfall of 307 mm, annual evaporation of 3,497 mm and 31 rain days/year. About 40 percent of the rainfall is associated with cyclones, and the remainder with thunderstorms. Thus most falls are heavy and of short duration. The mean maximum temperature in summer (January) is 36.5°C and the mean minimum temperature in winter (July) is 11.8°C (LSC, 1986).

4.3.3 GEOLOGY

The Port Hedland coastal system contains Quaternary deposits that have accumulated during Pleistocene and Holocene times (i.e. 1.5 million years to present). The coastal system extends inland to a series of ranges that form part of the main Pilbara block.

The coastal stratigraphic arrangement resulting from the deposition of Quaternary sediments consists of:

- a Pleistocene red alluvial plain sediment unit that forms the hinterland and underlies all other sediment and limestone units;
- a Pleistocene oolitic limestone that forms a series of shore-parallel ridges (= barrier islands). This unit rests on the red alluvium unit as discrete bars or ridges;
- a Holocene (dune and beach) sand unit that forms shore-parallel bars and ridges; this unit is stacked on the oolitic limestone or occurs as discrete ridges. Locally it is cemented in the tidal zone to form beachrock;
- a Holocene muddy unit deposited under mangrove and tidal zone conditions. This unit commonly forms extensive sheets of tidal/salt flats which overlies the oolitic limestone, and either underlies or interfingers with the Holocene sand unit (LSC, 1987).

4.3.4 GEOMORPHOLOGY

Morphologically the Port Hedland/De Grey delta coastal tract is a small part of a regionally extensive Pilbara coastal system. The regional scale geomorphic units of the system are (LSC, 1984):

- a submarine shelf that gently slopes from tidal at the shoreline to depths greater than 15 m some 20 km from shore;
- barrier islands that are linked to the mainland by tidal flats. They are composed of cemented limestone and are exposed as rocky cliffs and platforms on shorelines subject to dominant erosion. In some areas beach and dune deposits blanket the limestone forming beaches and shoreward migrating dune systems;

- shallow embayments and tidal flats have formed behind, and in the protection of, barrier islands. These tidally exposed units have accumulated sediment in the Holocene. The tidal flats are incised by tidal creek systems that drain the flats and empty through breaches or gaps between barrier islands;

- the De Grey delta is a large cuspate lowland located at the mouth of the De Grey River;

- a hinterland of undulating sand plain which extends inland towards a series of ranges.

In the regional setting context, it should be noted that the Port Hedland coastal type of barrier islands and associated protected tidal embayments/flats recurs along the Pilbara coast at numerous localities. For instance, it occurs along the coastal tract between Onslow and Weld Island, along the coastal zone of the Fortescue River and to the southwest of Port Hedland. As such, the coastal setting of Port Hedland/De Grey delta area is not regionally unique (LSC, 1987).

Each of these units may be further subdivided into diagnostic medium-scale and small-scale geomorphic units. For the purpose of this report, only those medium-scale geomorphic units (habitats) within the proposed extension area or immediate surrounds have been documented (Section 4.3.9).

4.3.5 OCEANOGRAPHY

The nearshore oceanography of the Port Hedland region is tidally dominated with additional influences made by locally generated wind-waves. There are large semi-diurnal tides, with a mean spring range of 5.8 m and a mean neap range of 1.2 m (Australian National Tide Tables, 1990). The Australian National Tide Tables (1990) define tidal levels at Port Hedland as:

HAT	+7.7 m	above chart datum
MHWS	+6.8 m	
MHWN	+4.7 m	
MSL	+4.1 m	(= approx. 0.0 AHD)
MLWN	+3.5 m	
MLWS	+1.3 m	
LAT	+0.2 m	

Chart datum is 4.155 m below AHD. In this document all references to level refer to Chart datum unless qualified.

Tidal current data is sparse but experience shows currents greater than 50 cm/s locally during spring tides. Periods of neap tides are coincident with generally low current velocities and clear marine water.

Spring flood tides of at least 6.9 m height are required to raise water above creek level and onto the expansive tidal flats. Given tides of this magnitude, the area of tidal flats that would be flooded is dependent upon the prevailing wind direction.

The coastal and nearshore zone has a variable wave climate with effects from combined swell and locally generated wind waves. Swell waves generally arrive from northwesterly directions; wind waves are generated locally by onshore and offshore winds, and wave heights seldom exceed 1.5 m. Prevailing winds in winter tend to be easterly in the morning varying to northeasterly/southeasterly in the afternoon, whilst summer winds mainly originate from western, northern and southeastern sectors in the morning and from the western and northwestern sectors in the afternoon. Tropical cyclones occur periodically during the summer period (December to April). Since the coast is open, all waves from west to northeast sectors impinge upon the shore (LSC, 1984).

4.3.6 STORM SURGE

Meteorological factors such as strong winds and abrupt atmospheric pressure reduction can cause significant water level changes independent from astronomical tides. A storm surge is an abrupt rise in water level induced by strong onshore winds (generating large surface waves) and low atmospheric pressures accompanying a cyclone. Storm surge may raise the water levels by several metres above the highest tides, thus inundating areas generally not subject to wave attack.

The Pilbara coast is periodically subject to tropical cyclones, hence it is important for the planning of coastal developments to incorporate data on maximum levels or heights of storm surge activity. This data can be derived from the examination of storm surge sediment deposits and its stratigraphic relationship to present sea level.

While a stratigraphic survey of storm surge levels was not carried out in the proposed pond area, data obtained from nearby studies can be related to this site. The main conclusions drawn from a study conducted in the Port Hedland and Pretty Pool area (LSC, 1985) are:

(i) storm records/events preserved in the stratigraphic column indicate that the maximum storms in the past 1,000-2,000 years involved elevated water levels and waves to heights of 7 m above AHD (11.6 m above chart datum) on exposed coasts as typified by the Cooke Point-Spinifex Hill shoreline;

(ii) protected coasts and those coasts not facing north retain a storm record that indicates that surge levels reached only 5 m above AHD (9.16 m above chart datum).

4.3.7 COASTAL EVOLUTION AND PROCESSES

The development and maintenance of coastal landforms found within the area can be explained in terms of its evolution (development) and the processes operating in the coastal environment.

The coastal stratigraphy (Section 4.3.3) indicates that the coastal system developed in at least three stages. The first involved alluvial sedimentation to develop broad, outwash fans from the eroding hinterland (i.e. Pilbara ranges). This resulted in the development of a red alluvial plain gently inclined to the north (LSC, 1987). The second stage of coastal evolution involved the accumulation and emplacement of oolitic sand (later to become oolitic limestone) in shore-parallel ridges. These ridges represent former shorelines and their spacing, splaying and recurved extremities indicate variable shoreline dynamics during the Pleistocene.

This arrangement of a red alluvial sheet with overlying oolitic limestone ridges comprises the ancestral geomorphic framework which sealevel flooded after the last glacial period. With rising sealevels, the alluvial plain terrain was inundated and the oolitic limestone ridges became elongate (barrier) islands. Consequently three processes then began to operate:

(i) the limestone ridges eroded on their seaward flank;

(ii) Holocene sands were stacked up by shore processes and accumulated on the limestone ridge;

(iii) in the sheltered areas to landward behind the limestone ridge, tidal mud deposits accumulated as the alluvial plain was fluvially flooded and eroded, and mud was winnowed from the sediment.

These deposits have formed the extensive mud/salt flats that cover much of the study area. The flats are interrupted only by sandy islands (i.e. remnants of the alluvial plain) and tidal creeks. Their distribution is defined by the inland extent of tidal influence (i.e. where the continuous hinterland sand plain starts) and by the modern shoreline.

The contemporary coastal processes are dominated by tide, wind and wave regimes. The tidal processes involve along-shore currents and sediment transport, creek erosion, creek mouth deposition, and creek headwater mud accumulation. Current erosion and sand deposition are most pronounced during spring tides. Wind-generated processes in the coastal region include littoral transport, onshore

sand movement and accumulation typically forms strandline deposits either overlying limestone barrier islands or as beaches on the seaward side.

Erosional features of shorelines subject to destructive wave activity are low limestone cliffs, exposed rocky platforms, cliffed sand dunes and exhumed mangrove muds.

Creek systems are a tidal erosional feature incised into tidal flats and barrier dunes. The creeks, while eroding at their headwaters and mid trunk regions, are accumulating temporary shoals in mid channel regions and in temporary dynamic mouth fans. They also function to trap and redistribute littoral sand transported along the coast.

A study into the coastal natural history in the Port Hedland area indicates that the coast is undergoing long-term and net erosion (LSC, 1987). This is evidenced by the stratigraphy, the present geomorphology, the age structure and the aerial photographic record.

4.3.8 HINTERLAND DRAINAGE

A series of river and creek channels drain the hinterland to the south and east of Port Hedland. The headwaters are situated in the ranges which form the northern edge of the Pilbara block. For most of the year, these creeks are dry with flow occurring only after periods of heavy rainfall associated with cyclonic disturbances. Water is directed by the Beebingarra, Petermarer, Tabba Tabba and Ridley Creeks across the alluvial sand plain and out onto the expansive tidal flats. During times of flood these creek systems transport significant amounts of sand and silt from the hinterland into the coastal system.

4.3.9 LOCAL SETTING AND HABITATS

The proposed pond area is situated on coastal flats 30 km east of Port Hedland. The flats are formed in the protection of limestone barrier islands and are incised by tidal creeks. The following habitats have been identified to occur within or adjacent to the proposed pond area. Figure 11 shows the distribution of these habitats.

4.3.9.1 Nearshore waters

The extensive shallow (less than 5 m) nearshore waters are exposed to oceanic wave and wind forces as well as tidal currents. Periodic fluviatile input from adjacent rivers after periods of heavy rainfall also affects this habitat. Physical

processes are highly variable, ranging from quiescent to highly energetic as a result of periodic calms and storms. Processes are also highly seasonal as a result of changes in prevailing wind directions. Water clarity therefore varies from relatively clear to highly turbid. The substrate is typically fine to medium sand of varying thickness over limestone (LSC, 1984).

4.3.9.2 Salt/mud tidal flats

This habitat covers the largest area of any single habitat within the study area. It has little or no relief and may be regularly or only periodically inundated by high tides. Spring tides over 6.9 m are required to flood the large expanses of this habitat. For the remainder of the time, the flats are superficially dry with a surface crust of crystalline salt or algae. Hypersaline groundwater is usually present at shallow depths (less than 1.0 m).

The substrate of the flats reflect sediment input of tidal origin (muds, silts and shell debris), from wind-generated sources (medium fine sand blown from sandy islands) and fluviatile input.

4.3.9.3 Sand plain

This unit is represented by numerous sandy islands up to 2-3 m above the level of surrounding tidal/salt flats. On some islands, tidal and wind erosion have formed low cliffs (1-2 m high) exposing a friable sandstone overlain by fine grained brown sand with some shell *in situ*. Further inland and outside the area affected by tidal influences, this unit becomes an undulating plain interrupted only by creek channels draining the hinterland (Fig. 11).

4.3.9.4 Tidal creeks

Three tidal creeks are located within the study area - Catfish Creek, Ridley Creek and Rock Cod Hole Creek (local names). Near their entrance to the ocean these tidal creeks become a delta of wide channels seperated by depositional shoals and bars. In their upper reaches the creeks become narrow gutters (1 m wide) which gradually shallow to mud/salt flat level.

The tidal creek channels accumulate cross layered coarse sand, pebbly sands, muddy sand and shell grit. Sediments become finer with a higher mud content as the creek progresses from ocean entrance to upper reaches.

4.3.9.5 Mangrove flats

A mangrove flat of varying size fringes the tidal creeks. The distribution of this habitat within the study area is limited by the extent of tidal flooding in a given location. Thus, mangrove flats adjacent to tidal creeks decreases progressively upstream or upslope away from creek channels (Fig. 11). The sediment includes bioturbated shelly mud and grey sandy muds.

4.3.9.6 Limestone barrier islands

The barrier islands are shore parallel ridges of Pleistocene limestone that are blanketed by modern beach and dune sediments. In erosional sectors of the coastline, the limestone is exposed as low cliffs and rocky platforms. Limestone barrier islands occur on the present shoreline to the west of the study area. A much larger limestone barrier system extends north from Ridley Creek towards Spit Point.

4.3.9.7 Hinterland drainage channels

A small side arm of Tabba Tabba Creek disects the undulating sand plain in the southern sector of the study area. This narrow channel (15 m wide by 1 m deep) is connected to the main Tabba Tabba channel which drains the hinterland after periodic heavy rainfall (usually following cyclonic activity). Ridley Creek, immediately north of the study area performs a similar function by directing floodwaters via river channels onto the expansive coastal flats. The Ridley Creek receives floodwaters from Strelley River, De Grey River and Ord Ranges to the east of the study area.

4.3.9.8 Habitats in existing ponds and intake channels

Conditions in the existing concentration ponds are strictly controlled to produce regular concentrations of brine. Salinity variations between ponds are given in Table 1. The bottom of the ponds are relatively flat, reflecting the salt flat that previously covered most of the area. Irregularities occur in the form of sand bars in a delta area adjacent to the intake channel and on the south eastern edge of the ponds. Water depth within the ponds averages 70 cm depending on prevailing winds. Mangroves have colonised some shallow areas around the intake channel and delta areas (see Appendix 2).

4.4 BIOLOGICAL ENVIRONMENT

4.4.1 REGIONAL SETTING

The biological assemblages found within the Port Hedland/De Grey region are determined by the distribution of large scale habitats. These habitats are:

- tidal embayments,
- limestone barrier islands,
- offshore submarine shelf.

Within these habitats are smaller scale habitats that determine the nature and distribution of specific biotic assemblages. Those found within the study area correspond closely to the habitats given in section 4.3.9 and are listed below.

4.4.2 BIOTIC ASSEMBLAGES

4.4.2.1 Tidal creeks/mangrove systems

Within the study area this unit is restricted to tidal creek areas such as Catfish Creek. Mangrove habitats are dominated by *Avicennia marina* with scattered shrubs of *Ceriops tagal* occurring on the landward fringe of mangroves. Mangroves vary in height from 1.5-3 m at the western boundary of the proposed pond area (Plate 1) to 0.5-1.5 m open *Avicennia* shrubland at the upper reaches of Catfish Creek (Plate 2). The tidal creek and associated mangroves support a varied biota that includes infauna of crabs, worms and molluscs, snakes and birds.

Seine netting in Ridley Creek gives an indication of the diversity of estuarine and oceanic fish that inhabit tidal creeks in the area (Appendix 1). Resident mangrove birds recorded from the area include the Mangrove Heron, Mangrove Robin, White-breasted Whistler, Mangrove Grey Fantail, Dusky Flyeater, Yellow White-eye and White-breasted Woodswallow (Johnstone, 1990).

4.4.2.2 Salt/mud tidal flat assemblage

The salt flats generally are of low productivity with biological activity being concentrated at the periphery or lower, wetter areas where a low density of samphires (*Halosarcia* spp.) occur (Plate 3). The only benthic fauna recorded from the flats were polychaetes with an average density of 36/m^2 (Appendix 1). Blue-green encrusting algae form mats around the fringes of the samphire and on more frequently inundated sections of the tidal flats. These areas can support a transient biomass of consumers on high tide. This would include detritus feeders

(crabs, molluscs etc) and some wading birds.

4.4.2.3 Low shrubland/grassland assemblage

This assemblage consists of a mixture of low (1-1.5 m) shrubland of *Acacia translucens* with an interstitial grassland of *Triodia pungens*, and a ground cover of mixed herbaceous dicots and other grasses. The sandy island and undulating sand plain are mostly covered with this vegetation type (Plate 4).

Shrub and grass dwelling birds recorded in this assemblage include Zebra Finch, Painted Finch, Singing Honeyeater, Australian Pipit and Rufous Songlark.

4.4.3 BIOTA OF SALT PONDS

4.4.3.1 Benthos

A benthic fauna survey conducted in Ponds 1 and 2 recorded a total of 26 species and 12 species in each pond respectively. The most abundant infauna in both ponds are Polychaetes, Bivalves and Nematodes. In Pond 1, the density of benthic animals ranged from 200 to 1,598/m^2 with a mean of 760/m^2. Densities in Pond 2 ranged from 469 to 1,008/m^2 with a mean of 631/m^2 (Appendix 1).

4.4.3.2 Fish

A total of 41 fish species were caught in Ponds 1 and 2 during a beach seine netting survey (see Appendix 1). Thirty three species were caught in Pond 1 and 24 in Pond 2. The high proportion of juvenile fish caught reflects the entrainment of fish eggs and larvae through the pump and their subsequent development in the benign pond environment. The decrease in abundance and diversity of fish in Pond 2 is a response to the higher salinities found in Pond 2.

4.4.3.3 Avifauna

The abundant fish, crustacea and benthic fauna found in the pond, provide the food source for a rich diversity of avifauna including raptors (osprey, sea eagles), waterbirds (pelican, cormorants), seabirds (terns) and wading birds. Table 3 lists the bird species recorded on the salt ponds.

Expeditions to the Port Hedland-Broome area over the last 10 years by the Royal Australasian Ornithological Union (RAOU) have confirmed that the Leslie Salt ponds are a major autumn refuge for trans-continental migratory waders. Up to

40,000-50,000 migratory waders and terns regularly gather in the salt ponds in February to April to feed on the abundant food source (small fish, benthic infauna and brine shrimp). This includes large numbers of common waders such as Red Necked Stints, Curlew Sandpipers and Bar Tailed Godwits, but also a number of waders that rarely visit Australia (e.g. Redshank and Asian Dowitcher).

Leslie Salt ponds, Eighty Mile Beach and Roebuck Bay (Broome) are recognised as being amongst the top five wader refuge areas in the world and possibly the most suitable for intensive wader studies (RAOU, 1988). Studies conducted at the salt ponds have involved the catching, banding and weighing of waders as well as taking additional biometric and moult data. The results from this research has considerably advanced the knowledge of wader migration in the Asian/Australian region.

4.4.4 ECOSYSTEM CONSIDERATIONS

4.4.4.1 Proposed pond area

The ecological relationships both within and between the major habitats described in the preceding section have not been researched and hence little is known about the ecosystem characteristics of the study area. However, based on general ecological principles, it is possible to construct a preliminary conceptual model.

For any ecosystem analysis it is necessary to identify:

(1) the location of areas of high biological productivity;
(2) the physical processes which maintain these productive areas.

Biological productivity can be classified as either primary production (synthesis of organic material) or secondary production (production from organic material). Primary producers derive energy from sunlight and, in the study area, consist largely of photosynthetic plants. The main location of primary producers in the study area are mangroves and samphires. Algal mats also fringe the wetter areas of these habitats.

Secondary producers (or consumers) derive energy from existing organic material. They occur either at sites of primary productivity or at sites to which nutrients are exported and collected (nutrient sinks). Thus the areas listed above for primary productivity are also likely to be important for secondary productivity.

The physical processes that maintain the above areas of biological productivity (e.g. mangrove systems and tidal creeks) are essentially tide related with the characteristic processes being tidal currents, turbid waters and low wave energy.

4.4.4.2 Existing ponds

Biological processes governing productivity in the ponds are determined by the conditions required to produce certain salinity concentrations. Leslie Salt strictly regulate conditions within the ponds resulting in a homogeneous, warm and sheltered environment capable of supporting abundant populations of primary and secondary producers (Appendix 1).

The physical processes maintaining such a high biological productivity are the flow of water through the ponds, evaporation and precipitation.

4.4.4.3 Present condition of ecosystems

The proposed pond area is in a largely pristine and unmodified condition. Illegal net fishing may have reduced creek fish populations, but no data are available to confirm this.

4.5 SOCIAL ENVIRONMENT

4.5.1 ABORIGINAL HERITAGE

Traditional Aboriginal habitation in the Pilbara region was centred upon the large drainage systems that dissects the area. Following rain, groups spread out across the plains and then gradually retreated to reliable water sources as the land dried. The Port Hedland region falls within the traditional lands of the Ngarla dialect group, who were adjoined by the Kariera and Nyamal people. The coastal Nyamal and Ngarla people now resident in Port Hedland and South Hedland have recently incorporated to form the Ngarla and Coastal Nyamal Group.

To ensure that the proposed pond expansion does not impact any areas of Aboriginal significance, the proponent commissioned an Aboriginal site survey that was conducted by Rory O'Connor and Associates. This survey involved the following:

- consultation with Aboriginal people such as the Ngarla and Coastal Nyamal Group, who retain traditional and current cultural links with the Tabba Tabba Creek/DeGrey River area;

- an archaeological survey.

The results of this study are presented in Appendix 3 and the main findings summarised below.

The saline mudflats which are to be flooded within Pond 0 are known to Ngarla people as Kwiyuruwarra which translates into English as 'the place of the mirage'. These mudflats do not contain sites of significance to present Aboriginal inhabitants of the area.

The distribution of both ethnographic and archaeological sites found within the area, reflects the land use pattern of coastal and riverine usage by Aboriginal people where access to water and economic resources was maximised. Local elders identified an acacia thicket which they claim has been a source of fresh soakage water for the Aboriginal campers. Four newly recorded archaeological sites were shell middens (artefacts scatters) that were situated on ridges on sandy islands. Human skeletal material was found at two burial sites with one site containing a skull that indicates robust, archaic features not found in modern Aboriginal people. Further study potential and possibilities of material dating therefore makes this an important site. The location of these sites are shown in Appendix 3.

4.5.2 REGIONAL DEVELOPMENT -A HISTORICIAL PERSPECTIVE

The Pilbara region was settled by pastoralists during the late 1860's and the initial settlement occurred in the region of the De Grey River. A convenient port suitable for the importation of stock, stores and producer requirements together with the export of pastoral produce, was of high priority. Shellborough at Condon Creek first filled this requirement, however over time siltation rendered this port less viable and the move to the less convenient but more suitable location of Port Hedland took place.

The townsite of Port Hedland was officially gazetted on 23rd October 1896. Construction of the first Port Hedland jetty commenced in the same year and was completed in 1899. With the subsequent growth of trade in the town and the development of Marble Bar following the discovery of gold in that area, pressure was brought to bear for a new jetty, which was completed in 1908. The port was also used by pearling luggers, especially after the 1880's when the pearling trade at nearby Cossack declined.

The transportation of stores to the Marble Bar goldfields and the removal of gold from there, was a hazardous and difficult exercise. To overcome this a railroad was completed in 1911, joining the two centres. In the same year the two Port Hedland jetties were joined to provide a more efficient facility.

It appears that during the period from World War I to the 1930s the port was mainly used for exports of pearl shell, wool, livestock, gold, tin and small amounts of other minerals such as copper, with an import trade of stores and producer items for the various pastoral and extractive industries (LSC, 1984).

The town's role changed dramatically with the development of iron ore deposits in the 1960's. The Goldsworthy, Shay Gap and Mt Newman mines were linked by rail to Port Hedland and the Port was extended to cater for larger scale iron ore export (Shire of Port Hedland, 1984).

The Port area grew to its present population of 4,000, however from the 1970's most population expansion was provided for in the new town of South Hedland (current population 8,000). The two towns are 23 km apart, separated by a coastal flat which connects to mangrove-fringed tidal inlets. The area's other key industry, the Leslie Salt works is located on these coastal flats.

4.5.3 ECONOMIC PROFILE

4.5.3.1 Mining

The economic base of Port Hedland is centred upon the mining operations of the Mt Newman, Goldsworthy and Leslie Salt companies. The operations of harbours and shiploading facilities at Finucane Island (Goldsworthy) and the port area (Mt Newman) account for the main sources of employment in the area.

The Port is now one of the largest in Australia in terms of tonnage of shipping handled annually and large, ocean-going vessels of up to 225,000 dwt and 315 m LOA are continuously using the Port's facilities.

Leslie Salt also contributes significantly to Port Hedland's economic base, and currently employs 90 personnel and 24 contract employees engaged on haulage operations.

4.5.3.2 Commercial fishing

The professional fisheries operating in the Port Hedland area and offshore waters are (Jones, 1986):

- inshore prawn trawling around the De Grey delta some 80 km northeast of Port Hedland;
- offshore deepwater trawling of shelf waters for scampi and other fish;
- offshore line fishing for Spanish mackerel;
- occasional net fishing of tidal creeks for mullet, threadfin salmon and barramundi.

While very few commercial fishing vessels are based in Port Hedland, the Port is visited for re-fuelling and re-stocking purposes. It is estimated by the Port Hedland Port Authority that since 1986, fishing vessel visits have averaged 144 per year. During this time 60 different vessels have used the port. Approximately 16 of these vessels were deep water trawlers and the rest mainly nearshore prawn trawlers (Captain I. Baird, pers. comm.).

4.5.3.3 Tourism

Port Hedland's primary role in the tourist industry is seen as a service area for people travelling through the wider regional area. The town also plays an important information role in that it is the southern arrival point for the Kimberley region and the northern arrival point for the Pilbara. The Tourism Development Plan - Pilbara Region, proposes a tourism development strategy for Port Hedland that increases the length of visitors stays from the large volume of passing traffic (Western Australian Tourism Commission, 1986).

4.5.3.4 Pastoral industry

A pastoral industry operating in the wider Pilbara area also contributes to the local and regional economy by using the town as a service centre and through exports of produce.

4.5.4 DEMOGRAPHIC PROFILE

The present population of the Port Hedland area is approximately 15,000. Of these about 4,000 live in the Port/Cooke Point area, 8,000 in South Hedland and the remainder are spread throughout the region on pastoral stations.

There is a high population turnover in the region although moves to reduce this are beginning to take effect as the already high standard of social and recreational facilities available continues to increase.

4.5.5 COMMUNITY FACILITIES AND SERVICES

A wide range of facilities and services are now available to the communities in the Port Hedland area. Port Hedland contains the town centre, council offices and a residential area based on ocean frontage, while South Hedland has a large shopping centre, community centre and government offices. A separate industrial area is located at Wedgefield.

4.5.6 COMMUNITY ATTITUDES

Community attitudes in Port Hedland are not entirely typical of traditional country towns where strong family ties and local allegiance have evolved through generations (State Planning Commission, 1988). Sectors of its population are more like that of a company town being transient, with mobility and city lifestyle expectations. Other sectors and tourists prefer the isolated outback port image, with its northern waters and tropical climate.

Discussions with the Port Hedland Town Council concerning the proposed solar salt expansion indicate that the Council is in support of the proposal provided that adverse environmental impacts are minimised. Both the Council and Port Authority expressed their willingness to work with Leslie Salt towards these objectives.

4.5.7 BENEFICAL USES OF MARINE AND ESTUARINE WATERS

Water quality guidelines for Western Australia's coastal waters are contained in "Marine and Estuarine Water Quality Criteria" (Environmental Protection Authority, 1981). This document identifies 16 Beneficial Uses of the marine environment and lists a range of physical, chemical and biological criteria applicable to each use. Only five of these Benefical Uses apply to the Port Hedland-De Grey Delta area. These are:

(i) Direct contact recreation - a minor use confined largely to diving on offshore reefs and swimming around Port Hedland;

(ii) Harvesting of aquatic life for food - the closest professional fishing ground to the study area is a prawn trawling area near the De Grey River Delta;

(iii) Preservation of aquatic ecosystems;

(iv) Flushing and water replenishment - the use of Paradise and 6 Mile Creeks for the flushing and dispersal of bitterns (Section 5.3.4);

(v) Recovery of minerals - the pumping of seawater from tidal creeks into concentration ponds for salt production.

Fishing is a popular recreational pursuit for the people of Port Hedland. Fishing is conducted from boats in offshore reef areas and by shore based anglers from public jetties, rocky outcrops and tidal creeks (LSC, 1984). Fish caught in tidal creeks include mangrove jack, threadfin salmon, barramundi and yellowfin bream (Jones, 1986).

The Port Hedland Town Council has identified an illegal netting problem in creeks in the area. This includes creeks from Port Hedland to Ridley Creek. Presently, Fisheries Department regulations ban net fishing in these creeks and within 400 m of their entrance to the ocean.

To develop an understanding of the nature of the illegal netting problem, two LSC personnel and a Port Hedland Town Councillor (Mr Robin Chapple) carried out an inspection of the tidal creeks mentioned above. It was evident from the inspection that an illegal net fishing problem does exist in the area, however the extent of this problem is difficult to assess. Evidence of illegal netting included:

- star pickets driven into mud banks to provide support for set nets;
- small sections of mangroves cleared to provide access;
- people seen illegally netting a small side creek. This involved two parallel nets across a creek entrance that totally drains at low tide;
- conversation with other fishermen in the area who complained about illegal netters operating in the Port Hedland area.

The extent of this problem is considered to be serious in creeks within easy access from Port Hedland (e.g. 6, 12 and 26 Mile Creeks), but less severe in creeks where access is restricted due to Leslie Salt's operations. Such creek systems are the Ridley Creek, Catfish Creek and several smaller tidal creeks between the two.

4.5.8 CONSERVATION VALUES

Areas having potential conservation value in the region are identified in the report, Conservation Through Reserves Committee Report for System 9 (EPA, 1975). According to this document there are no sites or areas of particular conservation value within the location of the proposed pond extension.

Regionally however, the area does contain resources of conservation value. These are the mangrove assemblages which line the coast and tidal creeks adjacent to Leslie Salt ponds. Mangrove habitats are widely recognised for their high biological productivity, contribution to offshore fisheries and land stabilisation functions and as such are generally protected wherever possible.

The existing salt concentration ponds are considered to be of world wide conservation significance as a major autumn refuge for trans-equatorial migratory wading birds (RAOU, 1988).

5 ENVIRONMENTAL EFFECTS

5.1 INTRODUCTION

The objective of this section of the report is to determine the significance of environmental effects resulting from the proposed project. No specific literature exists on the potential impacts of salt ponds and therefore the assessment has been made on the basis of:

- observed effects of the existing ponds and operation methods,
- field surveys,
- aerial photographic record analysis,
- satellite imagery/thematic mapping,
- Aboriginal heritage survey,
- discussions with the Main Roads Department (MRD) and Port Hedland Town Council regarding trucking movements.

5.2 EFFECTS ON PHYSICAL ENVIRONMENT

5.2.1 TOPOGRAPHY

The topography of the perimeter of the proposed pond area will be altered by the construction of levee banks and stormwater drains. The location of levees is shown in Figure 3. Internal and perimeter levees will be built to a height of 2 m and 4 m respectively above the level of the tidal flats. These levees will join onto sandy islands to make use of the islands as a natural barrier to water movement.

A river drainage diversion levee will be built to a height of 4 m above the level of the surrounding sand plain. A stormwater drain (2 m deep by 50 m wide) will be excavated parallel to the diversion levee (Fig. 3).

Open quarry pits will alter the topography at the locations shown in Figure 8. Mining lease 45/50 would be used to recover armour rock and gravel to a depth of 3 m. Clay borrow pits would also be excavated to a maximum depth of 3 m.

5.2.2 HINTERLAND DRAINAGE

Under the proposed extension, a small side arm of the Tabba Tabba Creek will be diverted by means of a diversion levee and stormwater drain (Fig. 3). Floodwaters redirected by this construction will spill out onto tidal flats at a point approximately 1 km west of where it would presently do so. Currently, floodwaters travelling down this side arm of the Tabba Tabba Creek would head north and spill out onto tidal flats in the southern section

of the proposed pond area. Upon reaching the tidal flats, the floodwaters predominantly drain out to sea through Rock Cod Hole Creek. A small proportion also drains through Catfish Creek, however with construction of the diiversion and perimeter levees, these waters will be redirected through Rock Cod Hole Creek. Drainage of floodwaters from the hinterland will therefore not be impeded by the proposed new pond.

5.2.3 CREEK HYDROLOGY

Creek hydrology is likely to be altered as a result of construction of the perimeter and diversion levees. Diversion of the floodwaters that presently flow to the ocean through Catfish Creek would be diverted into Rock Cod Hole Creek. This may increase erosion of its headwaters and result in landward expansion of tributaries of Rock Cod Hole Creek. The perimeter levee across Catfish Creek would prevent tidal waters from entering the existing headwater areas due to the blocking influence of the levee. As a result, siltation next to and immediately downstream from the levee will create new tidal mud flats suitable for mangrove colonisation (see Appendix 2).

Operation of the proposed intake pumps on Rock Cod Hole Creek has the potential to reduce the volume of water that will flow upstream of the intake pumps. No data are available on the present flow discharges or velocities in the creek, therefore it is not possible to make a quantitative prediction of the impact of the proposed seawater extraction. However, an analogy can be made with Ridley Creek at the existing intake pump site.

Leslie Salt installed a seawater intake pump on Ridley Creek in 1967 to extract water for their crystallization ponds. During the first 11 years of operation (1967-1978), the intake pipe extracted 12 m^3/s of water from the channel which had a cross-sectional area of approximately 900 m^2 at the spring high water mark. During this period, aerial photograph analysis (see Appendix 2) indicates that there were no physical changes to areas of tidal creeks or mangroves in the region upstream from the pump site. This suggests that the pumping operation did not cause any significant changes in the tidal hydrodynamic regime of the upper reaches of Ridley Creek.

The proposed intake pump for Rock Cod Hole Creek will extract 12 m^3/s of water on tidal levels exceeding 3.7 m above chart datum. The cross-sectional area at this tide level will be 290 m^2, while the cross-sectional area at spring high water will be approximately 820 m^2.

Due to the similarity of the pumping rates and the cross-sectional areas of the channels at spring high water between Ridley Creek and Rock Cod Hole Creek, it is not expected that extraction of water from Rock Cod Hole Creek will have any adverse physical impacts on the channel morphology or the mangrove habitats. On spring flood tides, seawater will continue to reach the mangrove colonies in the upper reaches of Rock Cod Hole Creek.

5.2.4 WATER QUALITY

While no specific studies have been conducted on the effects of levees on creek water quality, it is expected that some turbidity will be temporarily created in the Catfish Creek channel area immediately adjacent to the perimeter levee during the construction phase. Turbidity in these tidal creeks is naturally high due to high tidal currents, and the mobilisation of fine-grained silts and muds in the water column.

Apart from during the construction phase, the water quality of Rock Cod Hole Creek in the vicinity of the proposed intake pump station is not expected to be affected.

5.2.5 DUST LEVELS

While construction and earthworks have the potential to increase airborne dust levels in the vicinity of susceptible habitats (e.g. mangroves), this impact can be avoided by sound management practices.

5.3 EFFECT ON BIOLOGICAL ENVIRONMENT

5.3.1 HABITAT LOSS AND MODIFICATION

The major impact of the proposal is the alienation and modification of large and small areas of natural habitat. The major area affected will be the proposed new primary concentration pond. Smaller scale impact will occur in the vicinity of the proposed quarry sites, levee and drain construction areas and the site for the additional bitterns, crystallization and pickle ponds.

5.3.1.1 Proposed primary concentration pond

The largest area of habitat modification resulting from the proposed pond construction is the permanent flooding of salt/mud flats. Presently this habitat consists of a mud/clay base either exposed at the surface or covered by a filamentous algal mat.

Following impoundment, drainage within the new pond area will become unidirectional with flow being directed towards Pond 1. Tidal oscillations will no longer occur and water depths will be maintained at approximatley 70 cm. It is expected that water depth, salinity and temperature regimes, and the substrate presently found in Pond 1 will be replicated in the new Pond 0. Given these similar conditions, it is reasonable to assume that over time the biological productivity of Pond 0 will increase to approach that presently found in Pond 1 (see Appendix 1). Such an increase in productivity will provide additional forage areas for the trans-equatorial migratory waders which currently take refuge on the concentration ponds during Autumn. It will also provide additional forage area for local

avifauna. Therefore the loss of this large area of salt/mud flat habitat is balanced by its modificaton into a more biologically productive habitat which is likely to develop similar avifauna conservation values to that currently existing on the concentration ponds.

Construction of the pond will also alienate 18 ha of mangrove assemblage. The main location of mangrove habitat loss is on a section (2-3 km long) of the upper reaches of Catfish Creek (Plate 5). For approximately half of this distance the creek has become a shallow gutter, and mangrove (Avicennia marina) growth is generally small and sparse (Plate 2). Samphires fringing the mangroves and in the wetter parts of the mud flat area would also be destroyed as a result of permanent flooding. This area of mangrove habitat is both small and of limited diversity when compared to the regional characteristics of this habitat (see Section 5.4.5). A small area of mangroves (0.2 ha) would also be lost at the proposed intake pump site (Fig. 9).

The loss of mangrove/tidal creek habitat is expected to be balanced to some extent as mangroves and samphires recruit into new headwater areas of Rock Cod Hole Creek (Section 5.2.3) and into parts of Pond 0. Within Pond 0, those areas suitable for mangrove recruitment will be inundated banks of the islands, sand bars and those areas subject to periodic inundation caused by minor water level variation (e.g. under prevailing wind regimes). It is also expected that mangroves will recruit into tidal mud flats developed by siltation immediately downstream from the perimeter levee (Section 5.3.3).

The loss of mangrove and samphire habitat is considered to be of low ecological significance given both the extensive amount of this habitat type available in the region and the balancing effects of natural recruitment and increased productivity of the pond area.

5.3.1.2 Clay and rock quarry sites

Vegetation in both the rock and clay quarry sites will be lost, however rehabilitation measures (see Section 6.2.2) will be initiated following the completion of the proposed levee. Although a detailed survey of the flora and fauna in the proposed quarry sites has not been undertaken, site inspection indicates that the sand plain vegetation if these sites is widespread throughout the region.

5.3.1.3 Additional bitterns and crystallization ponds

Proposed alterations to the present bitterns and crystallization pond area are shown in Figure 6. The construction of pickle Pond 10, four new bitterns or desalting ponds, and a crystallization pond will result in approximately 280 ha of mud flat and sand plain habitat loss within existing leases (ML 242SA, Part C and ML 250SA, Part D).

5.3.2 BITTERNS DISCHARGE

Bitterns are presently discharged into 6-Mile Creek and Paradise Creek (Fig. 6) with the latter being the main discharge area. Prior to mid-1984, bitterns discharge into Paradise Creek was across tidal mud flats and damage to mangroves in this area followed. In response to this, Leslie Salt dug a channel that directed discharging bitterns to a point below the mangrove root systems and rehabilitation of the mangroves has since occurred naturally (Leslie Salt, pers. comm).

Currently, the volume of bitterns discharged per annum is 5,215,800 m^3. Table 2 shows the components constituting the bitterns and their discharge quantities per annum. While the upgrade project will result in decreased quantities of bitterns (3,477,200 m^3 per annum) due to more efficient extraction of NaCl and water, it will however increase the concentration of some components (e.g. $MgCl_2$, $MgSO_4$, KCl and KBr) within the bitterns. The proposed expansion project will subsequently increase the volume of bitterns discharged by some 772,700 m^3/yr under normal operations. This will produce a total annual discharge volume of 4,248,800 m^3 by two years after the construction and flooding of Pond 0.

Observation of renewed mangrove growth adjacent to the present discharge site indicated that the method of disposal since 1984 appears to have been successful in reducing the impact of discharged bitterns. No specific biological monitoring has however been undertaken to determine the actual effects of discharge. Conclusions based on monitoring work conducted by Dampier Salt (1980), indicate that bitterns discharge did not adversely affect the health of mature mangroves and the colonisation of seedlings. Given this and the success of current discharge methods it is expected that no major adverse impact will result.

5.4 EFFECT ON SOCIAL ENVIRONMENT

5.4.1 ABORIGINAL HERITAGE

The expansive mudflats that would be flooded by Pond 0 are clear of sites of Aboriginal significance. Sites located on sandy islands vary in significance from low (limited potential to yield further archaeological information) to high (important sites that should be preserved).

The recommendations of the Aboriginal Site Survey (Appendix 3) are incorporated into the management plan (Section 6.2.1) to ensure that the proposal does not adversely impact on Aboriginal heritage values.

5.4.2 REGIONAL ECONOMY

Currently, Leslie Salt employs a work force of 90 people with a further 24 contract employees being engaged on haulage operations. With the proposed expansion, these numbers will increase to 105 and 29 respectively. The monetary benefits to the local economy will increase in terms of both the direct contribution and indirectly through multiplier effects.

Export earnings and royalties paid to the Western Australian Government will increase in proportion to the projected increase in salt production. The operation currently produces two million tonnes of salt per year, generating approximately AUS$40 million in export earnings. The proposed extension would increase salt output to 2.75 million tonnes per year, generating AUS$55 million in export earnings at current prices.

5.4.3 COMMUNITY

The increased trucking requirements identified in Section 3.3.6 highlights the need for haulage trucks to be increasingly mobilised to 24 hours per day rather than the present 18 hours per day. In the past, during periods of heavy ship loading, trucks have been mobilised to haul for 24 hours per day over two to three months at a time. Discussions with the MRD and the Port Hedland Town Council, indicate that hauling 24 hours per day has not created any major problems within the community because the haulage route is not close to any major residential areas.

The proponent and the MRD have identified the main inconvenience as being the presence of large (triple tandem) trucks on a road heavily used by the motoring public. For this reason, the MRD, with financial assistance from Leslie Salt, have constructed an overtaking lane on Wilson Street at the point where hauling trucks first pull out into the traffic on their way to the Port. This enables the hauling trucks to gradually build up speed without inconveniencing the motoring public.

It is therefore considered that the motoring public is unlikely to be inconvenienced as a result of the proposal.

5.4.4 BENEFICIAL USES OF MARINE AND ESTUARINE WATERS

Of the five Beneficial Uses identified (section 4.5.8) to apply to the regional area, only the following are expected to be affected (in a minor way) by the proposed expansion:

(i) preservation of aquatic ecosystem (see below);

(ii) flushing and water replenishment (Section 5.3.2);

(iii) recovery of minerals (e.g. salt) will become the main benefical use for Pond 0.

The area of Catfish Creek that would be enclosed within Pond 0 is narrow and mostly dry at low tide. As such, it is not a major amateur fishing resource and is considered to be of minor value as a regional fish nursery area although it would undoubtedly contribute in a small way. The loss of potential nursery habitat is to some extent balanced by the restriction of access to creeks by illegal net fishermen.

Under the pond expansion proposal, the opportunities available for fishermen to illegally net in the tidal creeks adjacent to the proposed lease area will be reduced due to:

- increased surveillance by Leslie Salt personnel over a wider area (Rock Cod Hole Creek to Ridley Creek);

- restricted access to fishing areas resulting from the construction of levees, locked gates and the flooded pond area itself. Previously fishermen would drive across the salt flats encompassed in the new lease area to reach Catfish and Ridley Creeks.

5.4.5 CONSERVATION VALUES

5.4.5.1 Mangrove habitat loss

On a regional basis, mangroves are recognised as performing several important functions in coastal environments. These functions include production of primary material, providing habitats for fauna, and coastal stability (Semeniuk *et al.*, 1978). As such, mangrove habitats are considered to be of significant conservation value and therefore represent a potential issue concerning this proposal.

To place the impact of the proposed development into a regional perspective, an asessment was made of the distribution of mangrove habitats in the Port Hedland-De Grey Delta region. Mangrove distribution was identified by using thematic mapping data obtained from satellite imagery. Image processing techniques were used to distinguish mangrove areas from surrounding habitats. The results of this assessment are given below.

Mangrove assemblages along the Port Hedland-De Grey Delta coastline are found in the following settings:

(i) delta environments - the mangroves of the De Grey Delta comprise approximately 31% of the mangrove population in the region;

(ii) sheltered embayment deposits protected by barrier islands - these deposits are incised by tidal creeks which are fringed by mangrove assemblages. The most significant area inhabited by mangroves is the embayment protected by the Finucane Island-Cooke Point limestone barrier system (Plate 6). This accounts for 38% of the mangroves found regionally. This embayment contains the West, South, South-East and Sting Ray Creeks. The coastline extending eastwards from Port

Hedland is periodically indented by a series of tidal creeks that incise tidal embayments formed behind limestone barrier systems. These tidal creeks are fringed by significant stands of mangroves. Mangroves found along tidal creeks between Port Hedland (Cooke Point) and Ridley Creek some 30 km to the east, contain 31% of mangroves found within the region (Plate 7).

Analysis of thematic mapping data indicates that the area of mangroves contained within the proposed pond extension constitutes only 0.68% of mangroves found in the Port Hedland-De Grey Delta region. Therefore, the area of mangroves impounded as a result of the proposed development is considered to be of minor significance in terms of the regional distribution of this habitat. Additional information on the occurrence and diversity of mangroves in this region is available in Semeniuk *et al.*, (1978) and Johnstone (1990).

5.4.5.2 Existing ponds

The existing concentration ponds are considered to be of worldwide conservation importance as a major autumn refuge for migrating wading birds (RAOU, 1988). The abundant food source and protected habitat make the ponds an ideal area for large numbers of waders to gather (see Table 3). The value of these ponds to migratory waders and avifauna will be maintained or enhanced by the expansion proposal. The sandy delta at the intake entrance to Pond 1 is an important feeding and resting area for waders. Under the proposed extension, the water level in Pond 1 and the delta area will be unaffected and therefore the conservation value of this area will be maintained.

Following the flooding of Pond 0 it would be expected that a similar ecosystem to that existing in Pond 1 would develop (Appendix 1). In addition, sandy islands contained within Pond 0 would provide shallow margins suitable for wader feeding areas. Pond 0 would then assume a similar conservation significance to Pond 1 in terms of an additional refuge area for migratory waders.

6 ENVIRONMENTAL MANAGEMENT

6.1 INTRODUCTION

The objective of environmental management is to minimise the effect of the development on the existing environment.

Leslie Salt proposes to achieve this objective by:

- implementation of a management programme aimed at ameliorating or controlling adverse impacts resulting from the proposal;
- design and implementation of monitoring programmes to confirm the efficiency of the above management strategies, and the accuracy of predictions made regarding the environmental effects of the proposal.

6.2 MANAGEMENT COMMITMENTS

6.2.1 PROTECTION OF ABORIGINAL SITES

The proponent endorses the recommendations of Appendix 3 and will ensure that the significant Aboriginal sites identified within the proposed pond area are left undisturbed. The proponent will incorporate the location of identified sites onto their working maps and company personnel and contractors involved in construction works will be made aware of the position and sensitivity of these sites.

6.2.2 REHABILITATION OF BORROW PITS

During excavation of borrow pits, the top soil will be stripped and stockpiled. Pits would be left with a 3:1 batter (slope) and top soil will be replaced. Where possible, the pits are to be sloped and end in drains that would connect to natural drainage lines. Evidence from other borrow pits in the area demonstrate that this method is successful in initiating natural revegetation.

6.2.3 DUST SUPPRESSION

The proponent will comply with guidelines of the Department of Occupational Health, Safety and Welfare concerning dust levels for employees involved in construction works.

During construction, dust levels adjacent to sensitive areas (e.g. mangroves) will be minimised by the watering of construction roads and levee tops.

6.2.4 WORKFORCE MANAGEMENT

Workforce education and induction at both contractor and operator level will establish a philosophy of environmental care, preservation and restoration as being an essential and integral part of the project. Construction management personnel will ensure that employees and contractors involved in earthworks will not stray from designated construction lines and hence ensure minimum additional loss of habitat. Access will be strictly controlled and after construction is complete, access into the pond system will be restricted to Leslie Salt personnel.

6.2.5 TRUCKING MOVEMENTS

Should it become necessary, the proponent proposes to reduce trucking movements during peak traffic hours (0645-0700 and 1530-1545). These are the times when staff involved in the Mt Newman Mining port operations are travelling to and from work. Regular liasion with the MRD and Port Hedland Town Council will identify any public concerns arising from the increased trucking movements.

6.3 MONITORING PROGRAMME

6.3.1 OBJECTIVES

The objectives of the monitoring programme will be to:

(i) confirm the accuracy of predictions made in this CER;

(ii) provide feedback on the effectiveness of management and rehabilitation programmes so that they can be amended if necessary;

(iii) provide warning of the occurrence of potentially undesirable and unexpected changes to adjacent ecosystems.

6.3.2 MAIN PREDICTIONS OF THE CER

The main predictions made in the CER concerning the environmental impacts and management of the proposal are:

(i) the existing habitat within the proposed pond area will be altered to become similar to that existing in Pond 1. This will be of benefit to the regional ecosystem via increased fish and bird populations;

(ii) bitterns discharge will not adversely affect nearby biological communities;

(iii) rock and clay borrow pits will be revegetated.

6.3.3 MONITORING COMMITMENTS

6.3.3.1 Aerial photography

Low level aerial photography (1:5,000) of Catfish Creek, Rock Cod Hole Creek, clay borrow pits and bitterns discharge areas will be conducted over the following schedule:

- one baseline series prior to construction;
- one series per year for the first three years following construction;
- one series per three years after this point.

This facilitates the mapping of medium to large-scale changes in creek drainage and vegetation patterns in areas that may be subject to impacts from the proposal.

6.3.3.2 Bitterns discharge monitoring programme

A biological monitoring programme will be established at the bitterns discharge site to provide confirmation that adjacent mangrove assemblages are not being adversely affected by the discharge.

The proposed scope of the programme involves a one to two day survey of mangroves and selected fauna on an annual basis prior to, and for up to five years after, bitterns discharge reaches maximum volume and concentration.

6.3.3.3 Inspection of borrow pits

A site inspection will be made on an annual basis to monitor the revegetation of borrow pits. Following the replacement of topsoil, transects will be established to document and photograph rehabilitation progress.

6.3.3.4 Biological productivity of Ponds 0 and 1

A fish and benthic fauna survey (as outlined in Appendix 1) will be conducted three years after construction of Pond 0.

6.4 REPORTING

An annual report outlining the effectiveness of the management plan and the results of the monitoring programme will be prepared and forwarded to the EPA, DRD and the Mines Department.

7 CONCLUSION

The potentially adverse impacts associated with this proposal are:

- the loss and modification of large and small areas of habitat in the vicinity of the proposed new ponds;
- the increased concentration but reduced volume of bitterns discharge to Paradise Creek;
- the increased trucking movements between the Leslie Salt operations and the Port.

The above impacts are considered to be of minor ecological and sociological significance because they can either be mitigated by management (as in the case of trucking movements and bitterns discharge), or balanced to a large extent by a community benefit arising from the impact (as in the case of pond construction).

The proposed new primary concentration pond will alienate large expanses of relatively barren salt/mud flat and a small area of mangrove assemblage. Neither of these assemblages are in short supply in the region and, whilst mangroves in general have conservation value, those which occur in the area that will be impounded represent only an extremely small proportion of similar assemblages available elsewhere in the region.

The alienation of these habitats will be compensated to a large extent by:

- natural replacement of assemblages as mangroves recruit into new headwaters of Rock Cod Hole Creek and areas of Pond 0;
- increased biological productivity occurring within the shallow water of the new pond. The new pond will provide additional habitat for trans-equatorial migratory waders which take refuge in the salt ponds during autumn each year. This increases the already high conservation value of the concentration ponds;
- reducing land access to adjacent tidal creeks for illegal net fishing parties, thereby increasing protection of local creek fish resources.

In addition, the proponent proposes to establish an environmental management programme aimed at confirming major predictions and ameliorating impacts of the development. This programme will involve:

- rehabilitation of quarry sites;
- dust suppression during construction activities, particularly in mangrove environments;

- workforce control to minimise unnecessary habitat modification;
- protection of archaeological sites and adherence to the requirements of the *Aboriginal Heritage Act*;
- monitoring the effects of bitterns discharge;
- monitoring the biological productivity within the proposed new pond.

Furthermore, the following benefits will result from the project:

- Leslie Salt will remain economically viable and competitive in world salt markets;
- increased local employment opportunities will be generated;
- increased revenue will accrue to the State from royalty payments;
- increased foreign exchange earnings to the nation through increased production.

The additional new mining lease and proposed pond boundaries which are the subject of this proposal have been selected to minimise both the amount of earthworks required and the amount of biologically productive mangrove habitat impounded. The proponent has existing mining leases which, under the terms and provisions of the *Leslie Solar Salt Industry Agreement Act, 1966*, it can develop for the production of salt. However, development of these leases would require both substantially more earthworks and the alienation of more mangrove assemblage than is required for development within the proposed lease area. The proponent is considering the surrender of some land within existing leases back to the Crown.

It is therefore concluded that:

- the proponent has been environmentally responsible in its approach to this project;
- the associated environmental impacts are of minor significance to both the regional ecosystem and the local community;
- most of the adverse impacts of the proposal can be ameliorated by management;
- substantial benefits will accrue to the local community and the State.

8 REFERENCES

DEPARTMENT OF DEFENCE, 1990: Australian National Tide Tables 1990. Australian Hydrographic Publ. No. 11.

ENVIRONMENTAL PROTECTION AUTHORITY, 1975: Conservation Reserves for Western Australia. Systems 4,8,9,10,11,12.

ENVIRONMENTAL PROTECTION AUTHORITY, 1981: Water Quality Criteria for Marine and Estuarine Waters of Western Australia. EPA, West. Aust., Bull. No. 103.

ENVIRONMENTAL PROTECTION AUTHORITY, 1987: Disturbance to mangroves in tropical-arid Western Australia: Hypersalinity and restricted tidal exchange as factors leading to mortality. EPA, West. Aust., Tech. Ser., No. 12.

ENVIRONMENTAL PROTECTION AUTHORITY, 1989: Review of Environmental Impact Assessment Procedures. EPA, West. Aust., Bull. No. 402.

DAMPIER SALT, 1980: Trial bitterns discharge. Progress Report No. 1.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 1975: Geology of Western Australia. West. Aust. Geol. Surv., Mem. 2, 541p.

GULF HOLDINGS PTY LTD, 1990: Environmental review and management programme - Onslow salt project.

JOHNSTONE, R.E., 1990: Mangroves and mangrove birds of Western Australia. Records of Western Australian Museum, Supp. No. 32.

JONES, H.E., 1986: Marine Resources Map of Western Australia. Fisheries Dept, West. Aust., Rept No. 74.

LePROVOST, SEMENIUK & CHALMER, 1984: Port Hedland Port Development, Notice of Intent. Rept prepared on behalf of Mt Newman Mining Co. Pty Ltd, Brief No. 112/1011/5196.

LePROVOST, SEMENIUK & CHALMER, 1985: Pretty Pool Development Project, Environmental Evaluation. Unpubl. rept to Richard Wittenoom & Associates, No. R088: 64p.

LePROVOST, SEMENIUK & CHALMER, 1987: Coastal Natural History in the Port Hedland Area. Unpubl. rept to Mt Newman Mining Co. Pty Ltd, No R175: 26p.

LESLIE SOLAR SALT INDUSTRY AGREEMENT ACT, 1966.

R.K. STEEDMAN & ASSOCIATES, 1977: Physical oceanographic aspects of the dispersion of residual bitterns, Nickol Bay, Western Australia, Prepared for Dampier Salt (Operations) Pty Ltd.

ROYAL AUSTRALIAN ORNITHOLOGICAL UNION, 1989: 1988 N.W. Australia Wader Expedition Report.

SEMENIUK, V., 1986: Terminology for geomorphic units and habitats along the tropical coast of Western Australia. J. Roy. Soc. West. Aust, Vol. 68: 53-79.

SEMENIUK, V., KENNEALLY, K.F., & WILSON, P.G., 1978: Mangroves of Western Australia. West. Aust. Naturalists Club, Handbook No. 12.

STATE PLANNING COMMISSION, 1988: Port Hedland Townscape Improvement - concept designs (draft). Rept prepared for the Shire of Port Hedland.

SHIRE OF PORT HEDLAND, 1984: Town Planning Scheme No. 4 Scheme Rept. Prepared by Russell Taylor & William Barr, Consultants in Town Planning and Civic Designs.

WESTERN AUSTRALIAN TOURISM COMMISSION, 1986: Tourism Development Plan - Pilbara Region. Prepared by Barrington Partners.

TABLE 1

SALINITY LEVELS IN CONCENTRATION PONDS

	APPROXIMATE PRESENT SALINITIES AT 15.5°C		APPROXIMATE FUTURE SALINITIES AT 15.5°C	
	g/L *	°Be **	g/L	°Be
Pond 0	-	-	44	5.6
Pond 1	44	5.6	55	6.9
Pond 2	58	7.2	66	8.2
Pond 3	70	8.7	76	9.4
Pond 4	85	10.2	94	10.7
Pond 5	102	12.2	99	11.9
Pond 6	123	14.4	108	13.9
Pond 7	158	17.7	152	17.2
Pond 8	199	21.2	196	21.0
Pickle Pond 9	243	24.6	234	23.9
Pickle Pond 10	-	-	243	24.6

TABLE 2

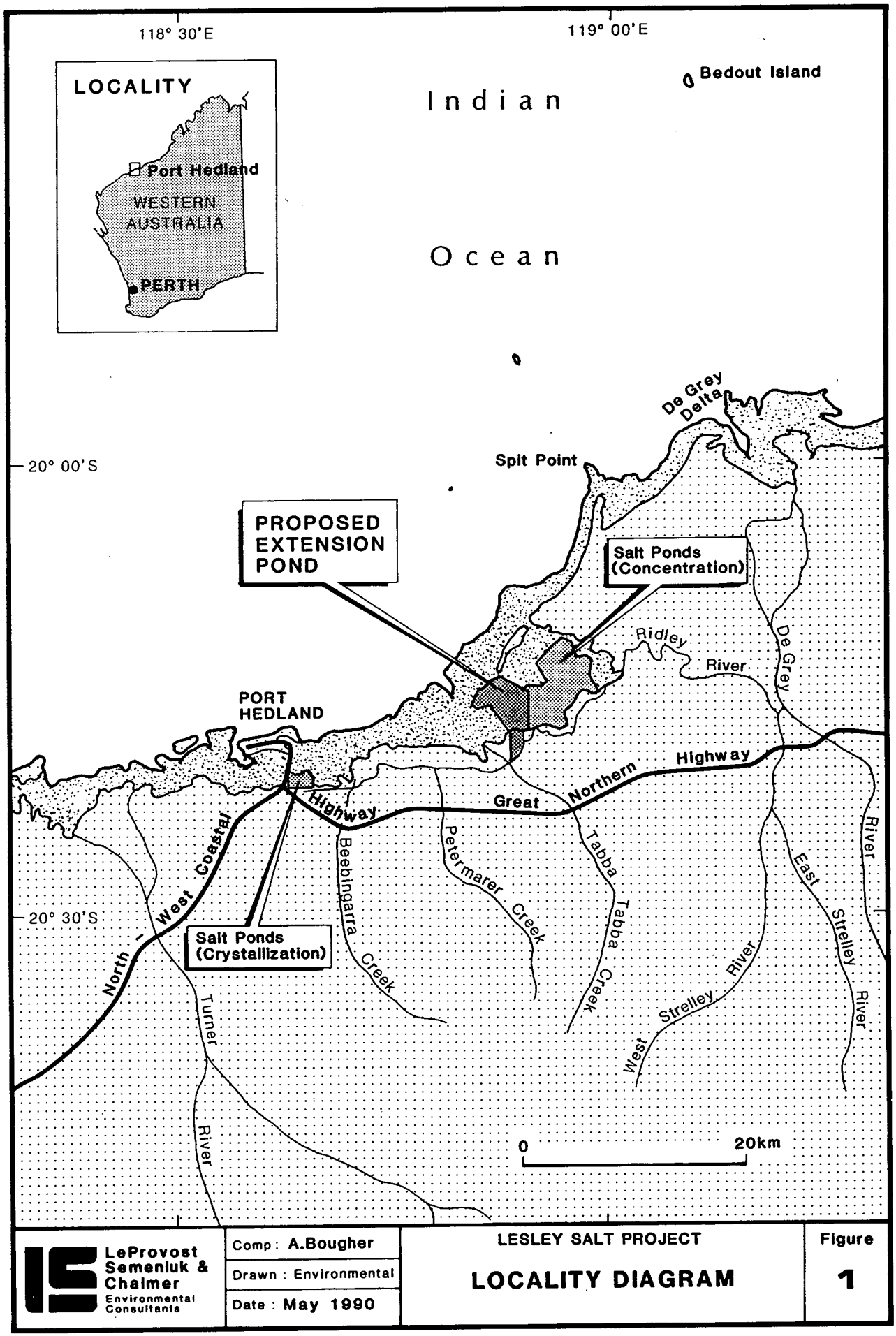
BITTERNS DISCHARGE QUANTITIES PER ANNUM

ITEM	DESCRIPTION	PRIOR TO UPGRADE PROJECT	TONNES ON COMPLETION OF UPGRADE PROJECT 1991	AFTER EXPANSION PROJECT
1	Calcium sulphate	4,000	900	1,100
2	Magnesium chloride	468,800	468,800	573,000
3	Magnesium sulphate	286,200	286,200	349,800
4	Sodium chloride			
5	Potassium chloride	124,300	124,300	151,900
6	Magnesium bromide	13,700	13,700	16,700
7	Water	4,679,300	3,207,100	3,919,900
8	TOTAL TONNES	6,519,700	4,461,200	5,452,600
	CUBIC METRES			
9	TOTAL CUBIC METRES	5,215,800	3,477,200	4,249,900

TABLE 3

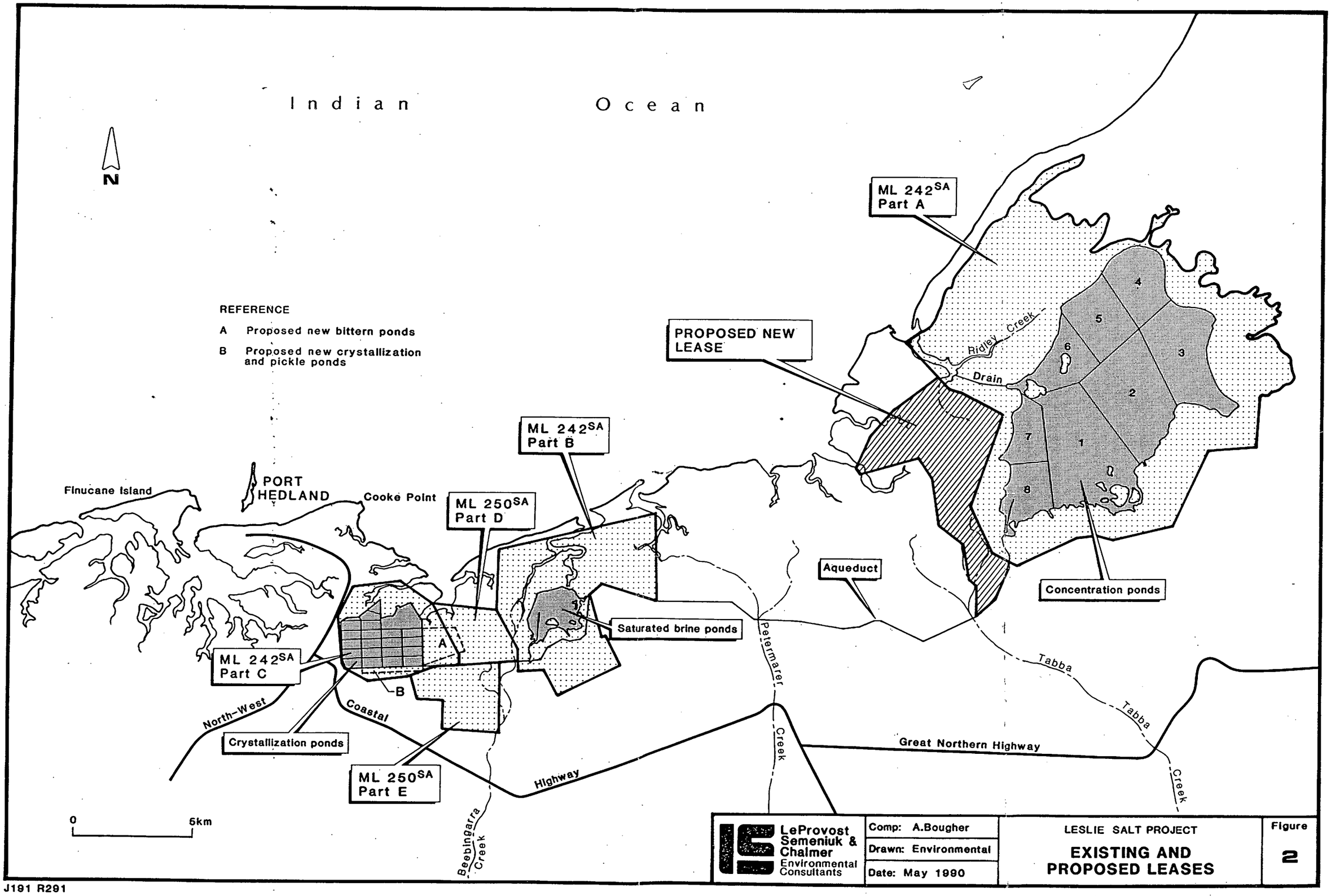
BIRD SPECIES RECORDED FROM LESLIE SALT CONCENTRATION PONDS

Australian Pelican	Grey-tailed Tattler
Darter	Common Sandpiper
Pied Cormorant	Greenshank
Little Pied Cormorant	Redshank
Little Black Cormorant	Marsh Sandpiper
White Faced Heron	Terek Sandpiper
Great Egret	Black-tailed Godwit
Black-necked Stork	Bar-tailed Godwit
Yellow-billed Spoonbill	Asian Dowitcher
Osprey	Red Knot
Brahminy Kite	Great Knot
White-breasted Sea Eagle	Sharp-tailed Sandpiper
Grey Plover	Red-necked Stint
Lesser Golden Plover	Curlew Sandpiper
Mongolian Plover	Sanderling
Large Sand Plover	Broad-billed Sandpiper
Oriental Plover	Oriental Pratincole
Red-capped Plover	Silver Gull
Black-winged Stilt	Whiskered Tern
Banded Stile	White-winged Tern
Red-necked Avocet	Gull-billed Tern
Ruddy Turnstone	Caspian Tern
Eastern Curlew	Common Tern
Whimbrel	Crested Tern
Little Curlew	Little Tern

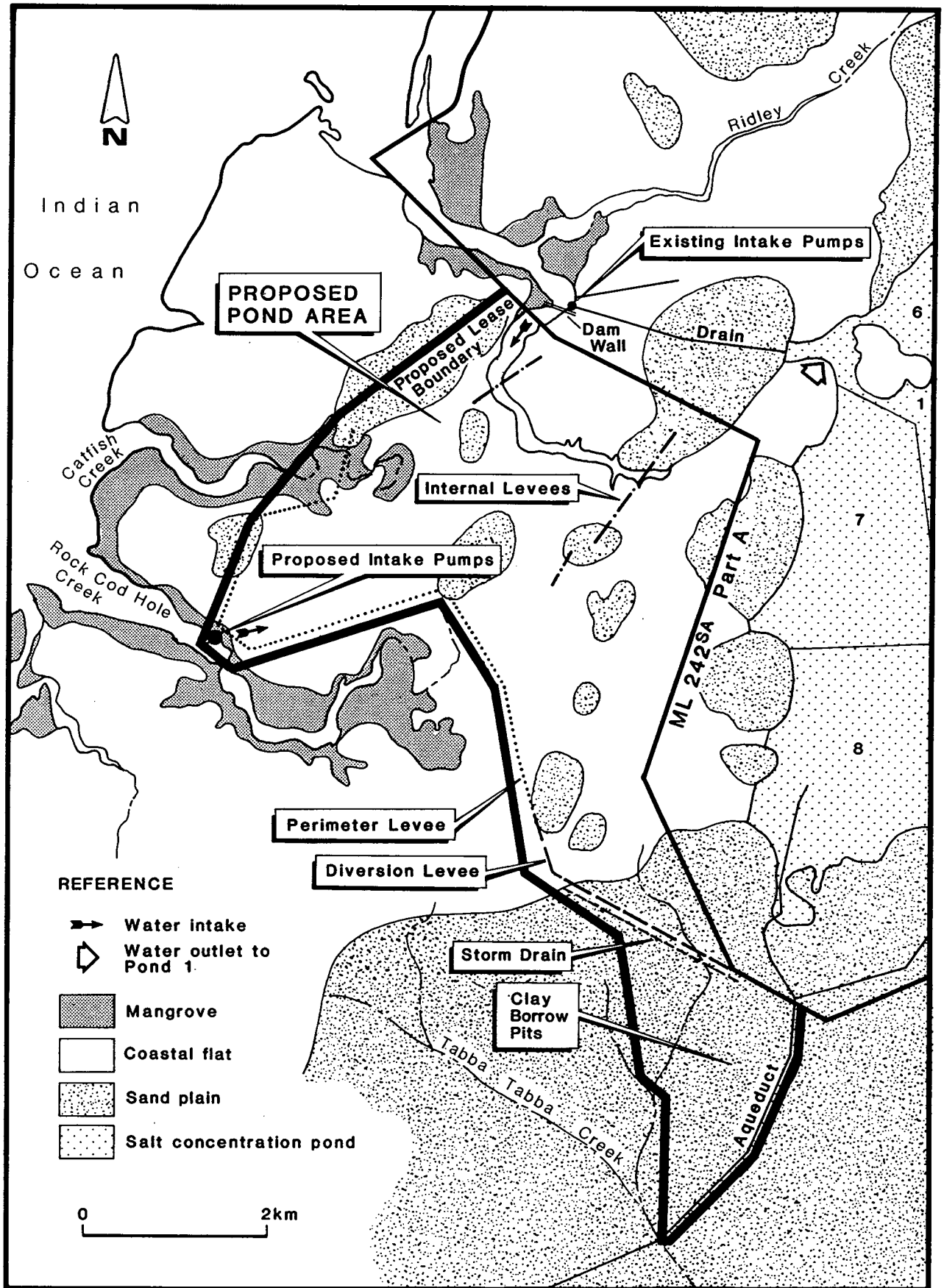


LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : A.Bougher Drawn : Environmental Date : May 1990	LESLEY SALT PROJECT **LOCALITY DIAGRAM**	Figure **1**

J191 R291

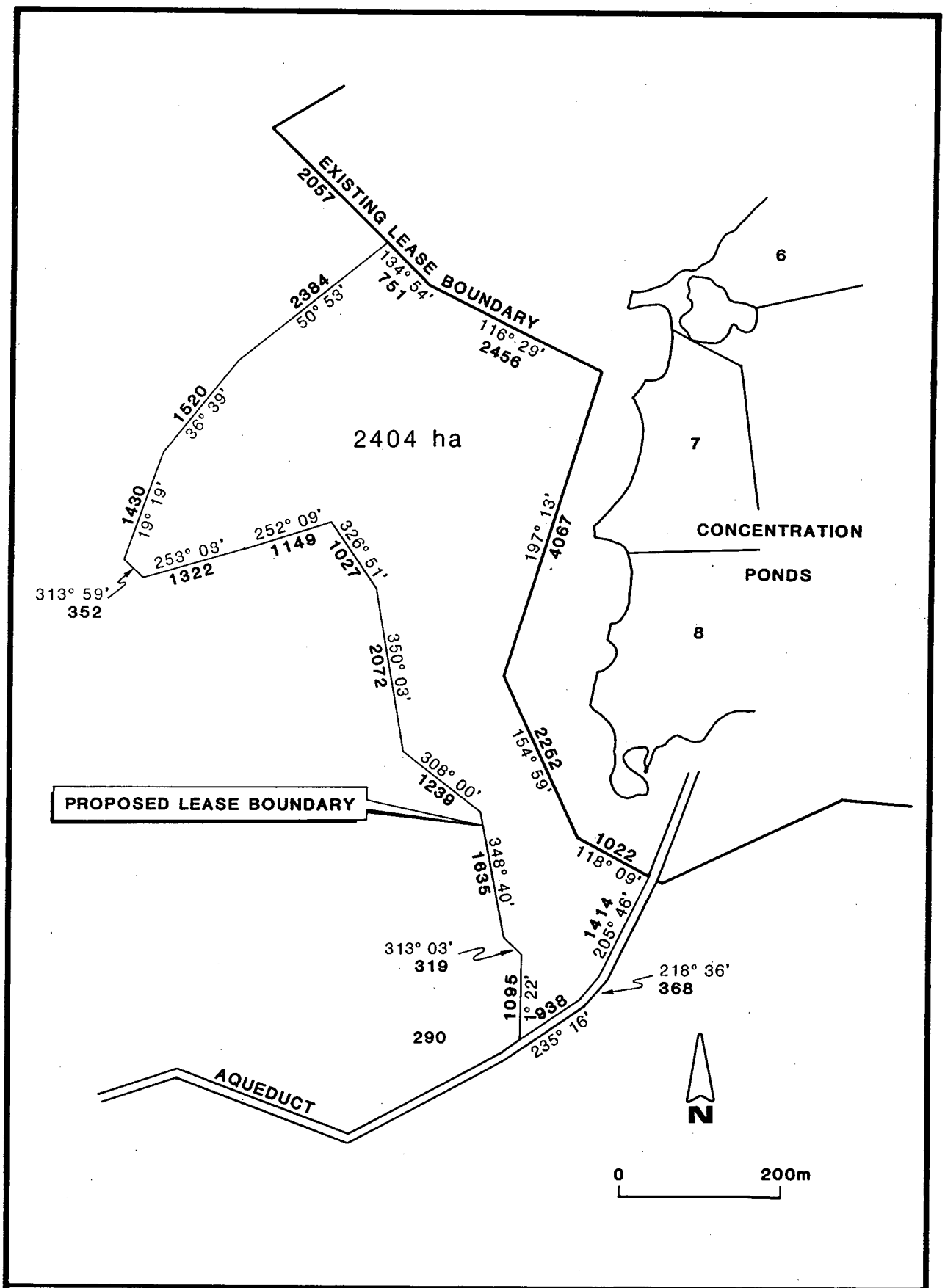

Indian Ocean
N
REFERENCE
A Proposed new bittern ponds
B Proposed new crystallization and pickle ponds
ML 242SA Part A
PROPOSED NEW LEASE
ML 242SA Part B
Ridley Creek
Drain
4
5
6
3
2
7
1
8
Finucane Island
PORT HEDLAND
Cooke Point
ML 250SA Part D
Aqueduct
Concentration ponds
Saturated brine ponds
A
B
ML 242SA Part C
Petermarer Creek
Tabba Tabba Creek
North-West Coastal Highway
Great Northern Highway
Crystallization ponds
ML 250SA Part E
Beebingarra Creek
0
5km
LeProvost Semeniuk & Chalmer Environmental Consultants
Comp: A.Bougher
Drawn: Environmental
Date: May 1990
LESLIE SALT PROJECT
EXISTING AND PROPOSED LEASES
Figure 2

J191 R291



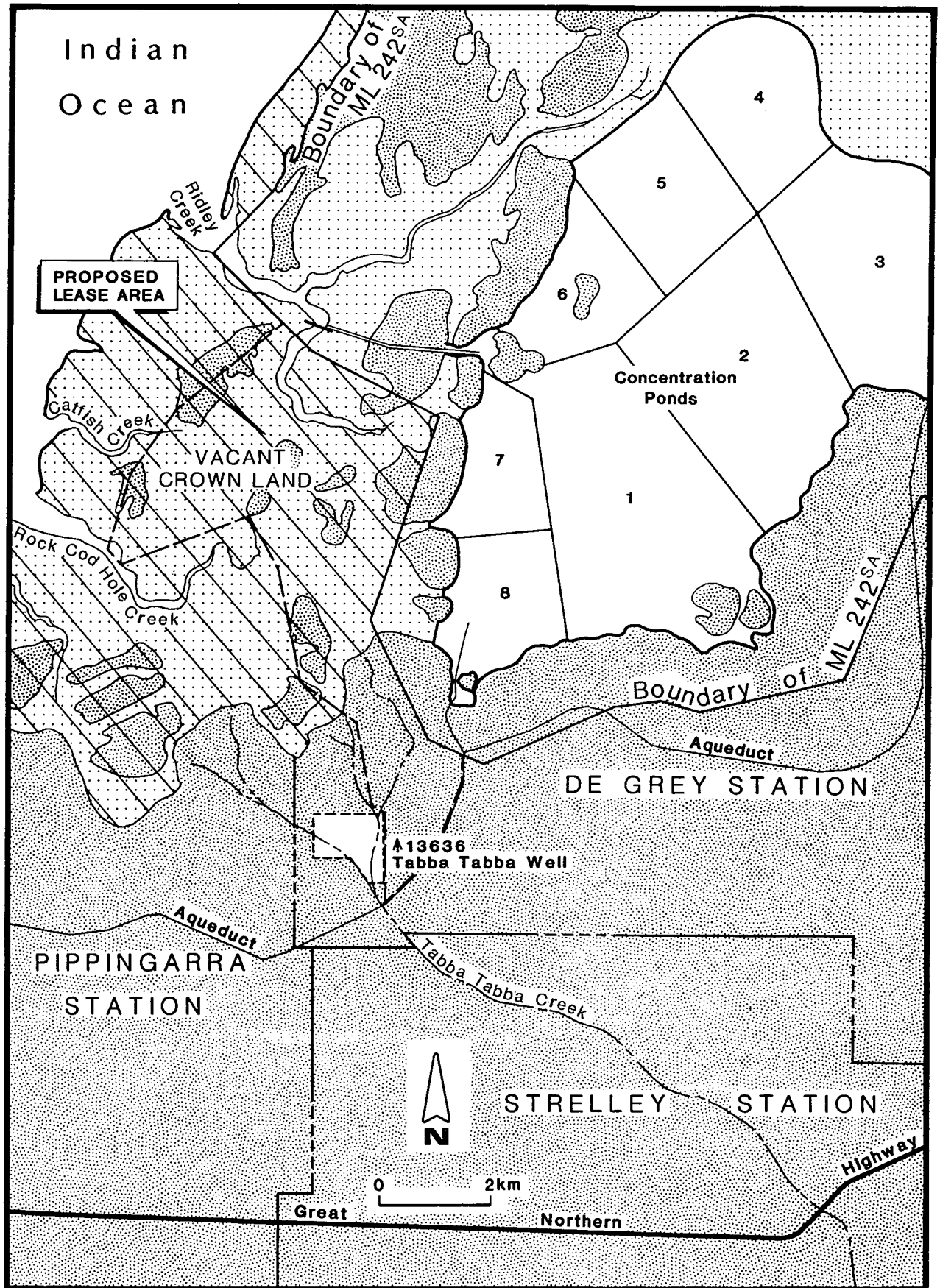
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **PROPOSED POND AREA**	Figure **3**

J191 R291



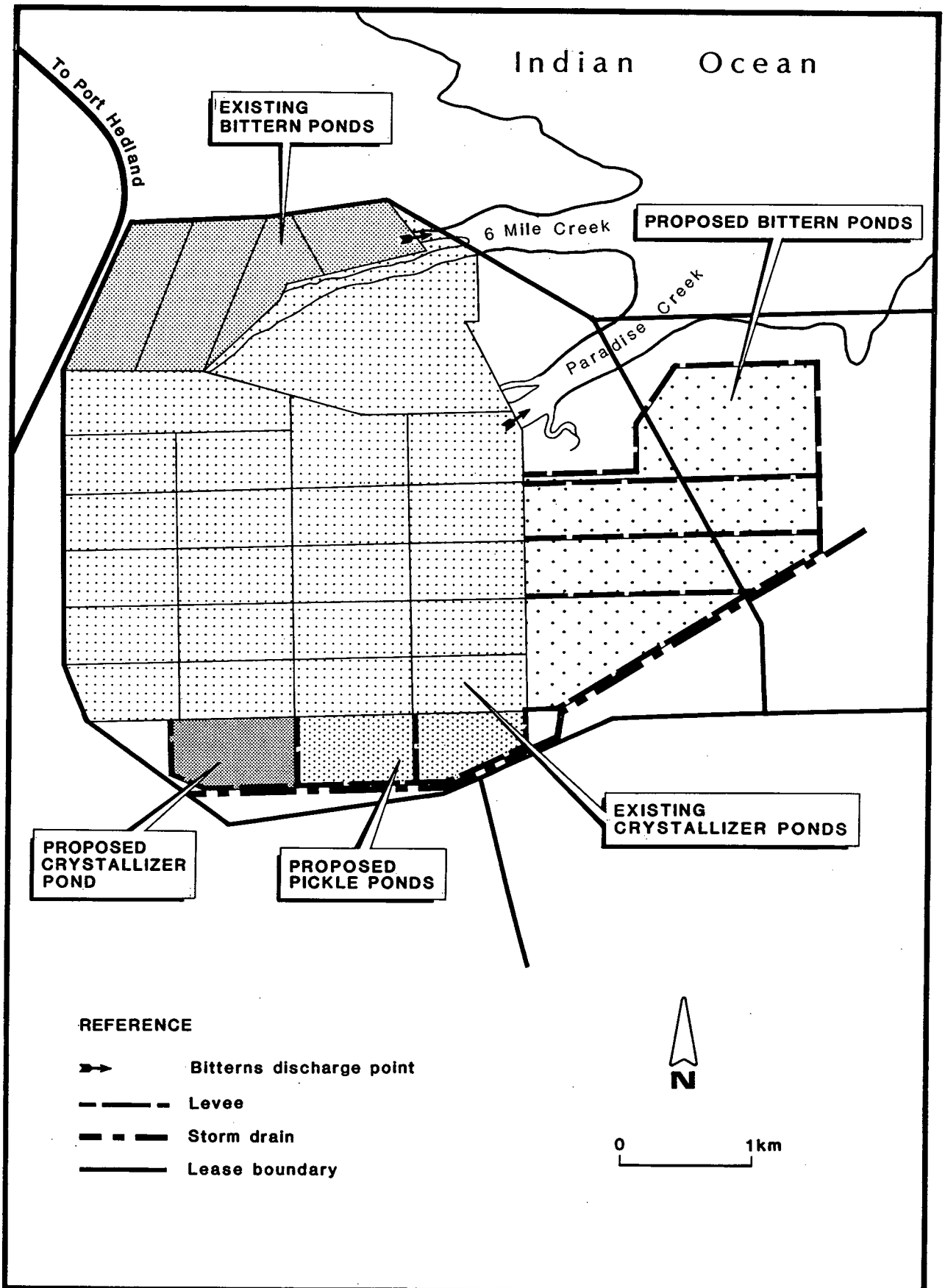
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **PROPOSED LEASE BOUNDARY**	Figure **4**

J191 R291



LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **LAND TENURE**	Figure **5**

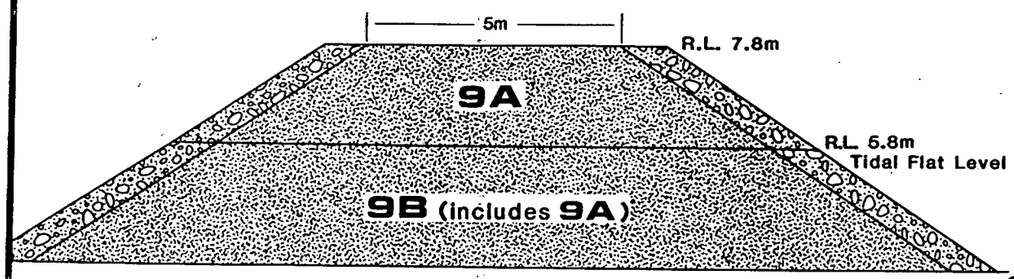
J191 R291



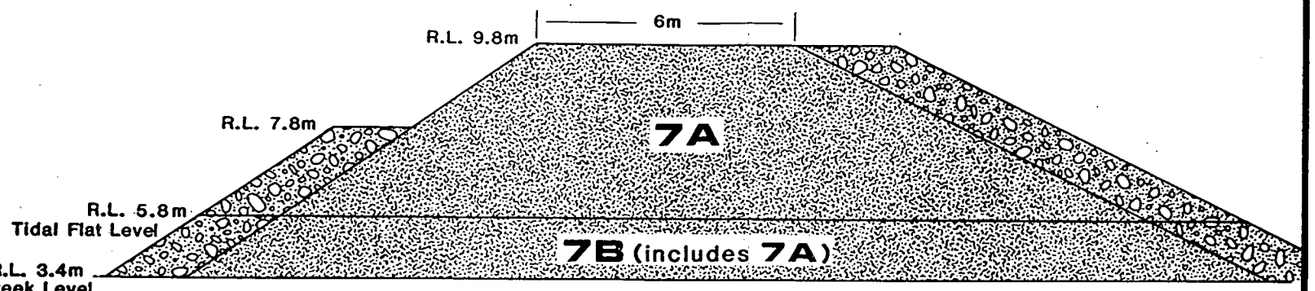
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **BITTERNS AND CRYSTALLIZATION PONDS**	Figure **6**

J191 R291

INTERNAL LEVEE PROFILE



PERIMETER LEVEE PROFILE

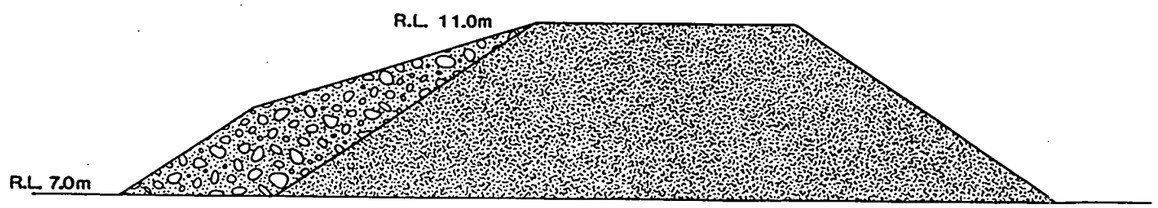


REFERENCE

Clay

Rock

DIVERSION LEVEE PROFILE



LEVEE	LEVEE LENGTH	VOLUME REQUIRED Clay	Rock
Perimeter Levee			
7A	780 + 4 455m	314 000m^3	75 400m^3
7B	1 700 + 100m	235 000m^3	43 500m^3
Internal Levee			
9A	2 480m	40 000m^3	9 000m^3
9B	560m	29 000m	4 400m
Diversion Levee	3 890m	187 000m^3	42 000m^3

N.B. : R.L.'s are relevant to Port Hedland tide datum.
Subtract 4.155m to give Australian Height Datum.

Highest Astronomical Tide (H.A.T.) = 7.7m

LeProvost Semeniuk & Chalmer Environmental Consultants

Comp: A.Bougher

Drawn: Environmental

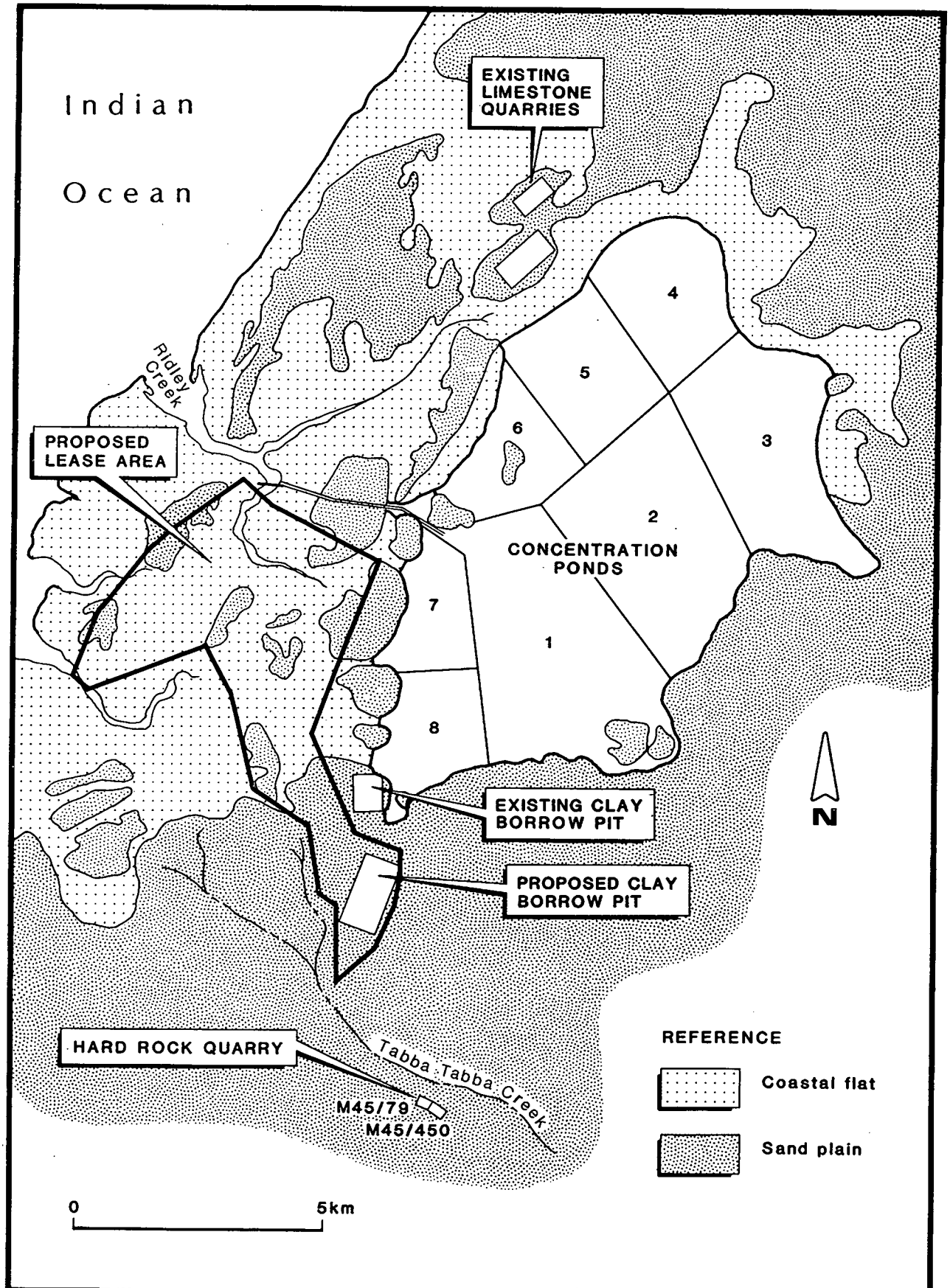
Date: May 1990

LESLIE SALT PROJECT

LEVEE CONSTRUCTION PROFILES

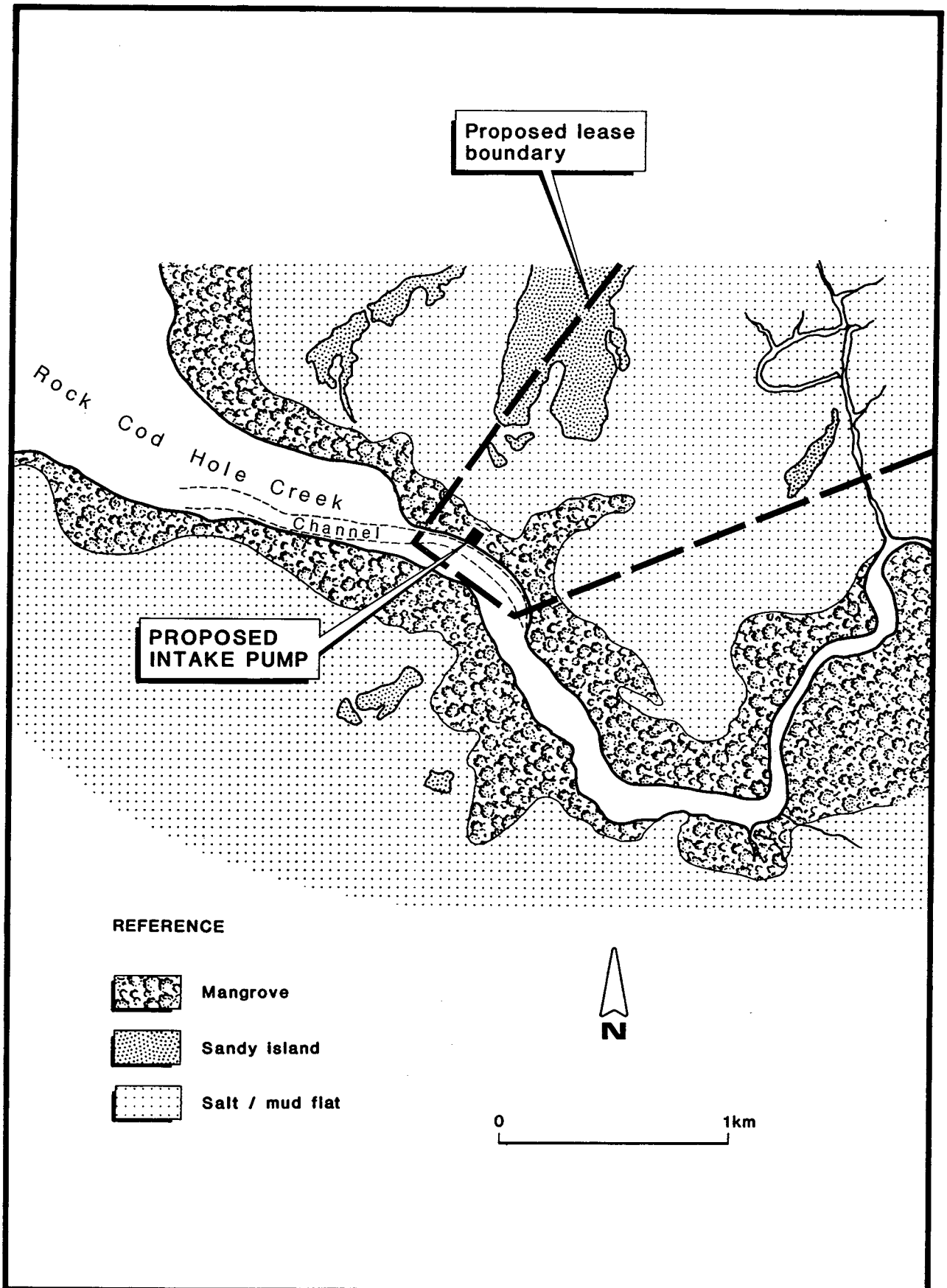
Figure 7

J191 R291



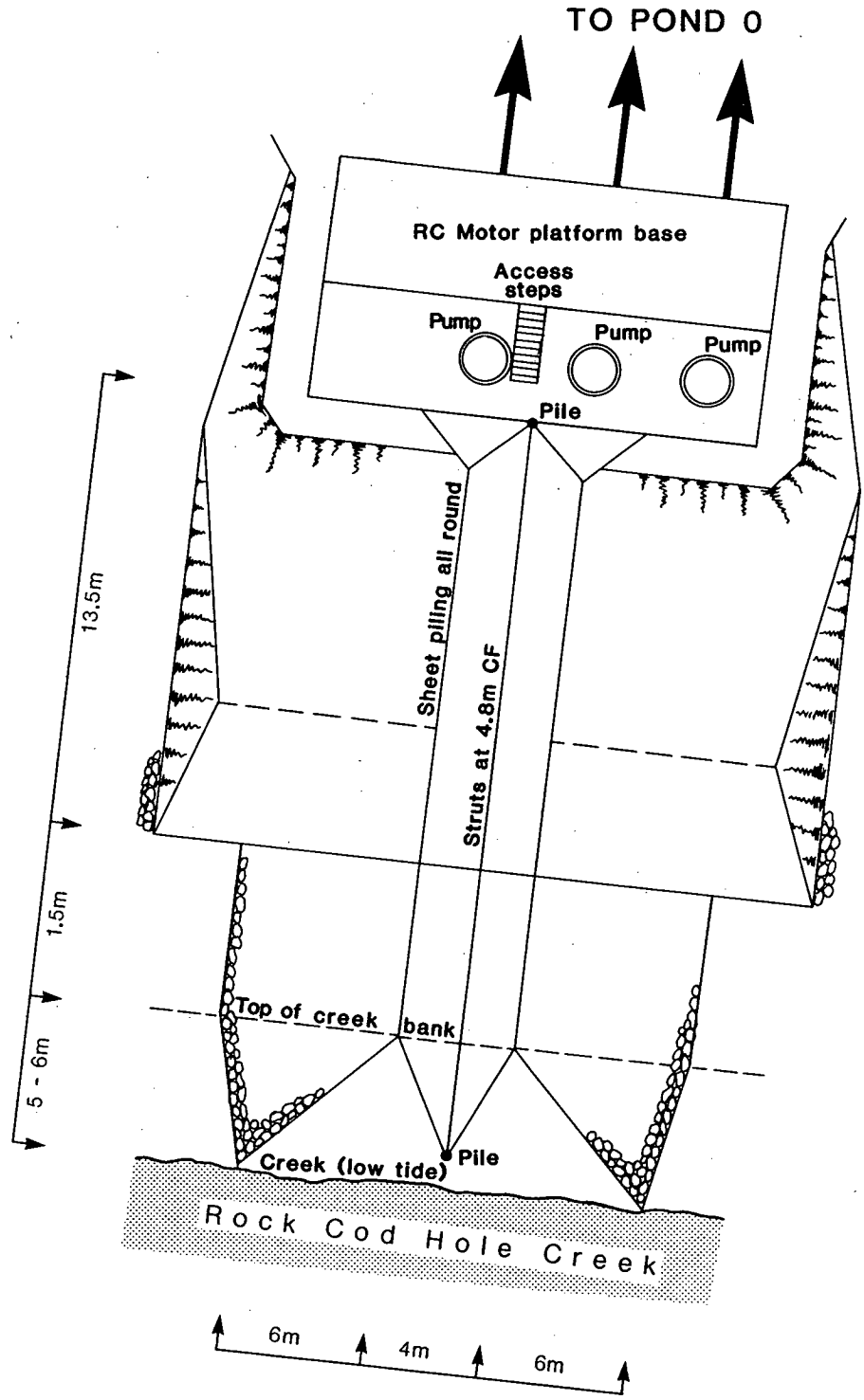
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **CLAY AND ROCK QUARRY SITES**	Figure **8**

J191 R291



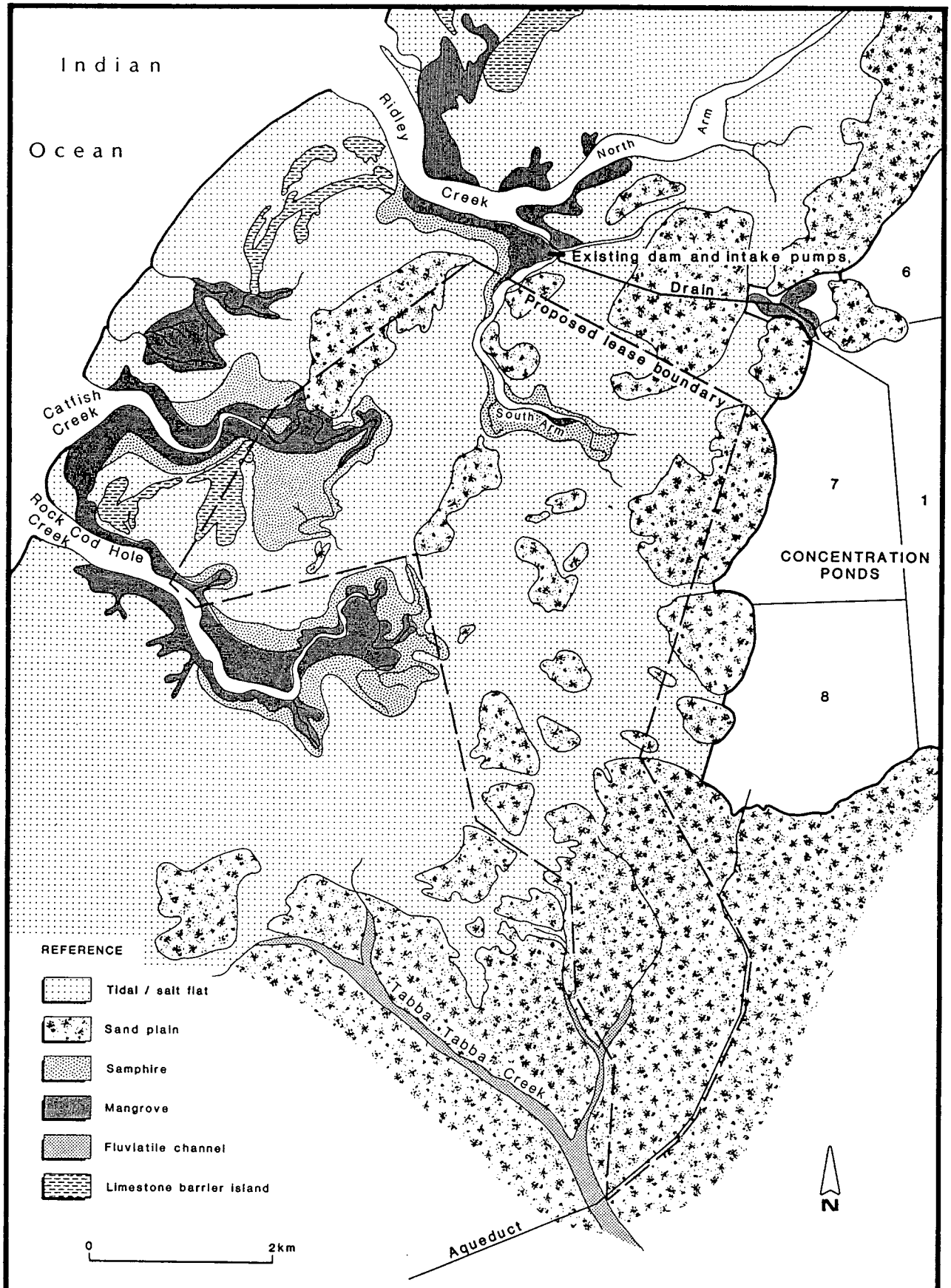
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **LOCATION OF PROPOSED INTAKE PUMP STATION**	Figure **9**

J191 R291



LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **INTAKE PUMP STATION CONSTRUCTION**	Figure **10**

J191 R291



LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **HABITAT DISTRIBUTION**	Figure **11**

J191 R291

Plate 1: Catfish Creek and fringing mangroves at the site of the proposed perimeter levee.

Plates 2: Upper reaches of Catfish Creek with low mangroves (Avicennia marina) and samphire.

Plate 3: Salt/mud flats with scattered samphire in wetter areas.

Plate 4: Low shrubland/grassland assemblage covering sand plain.

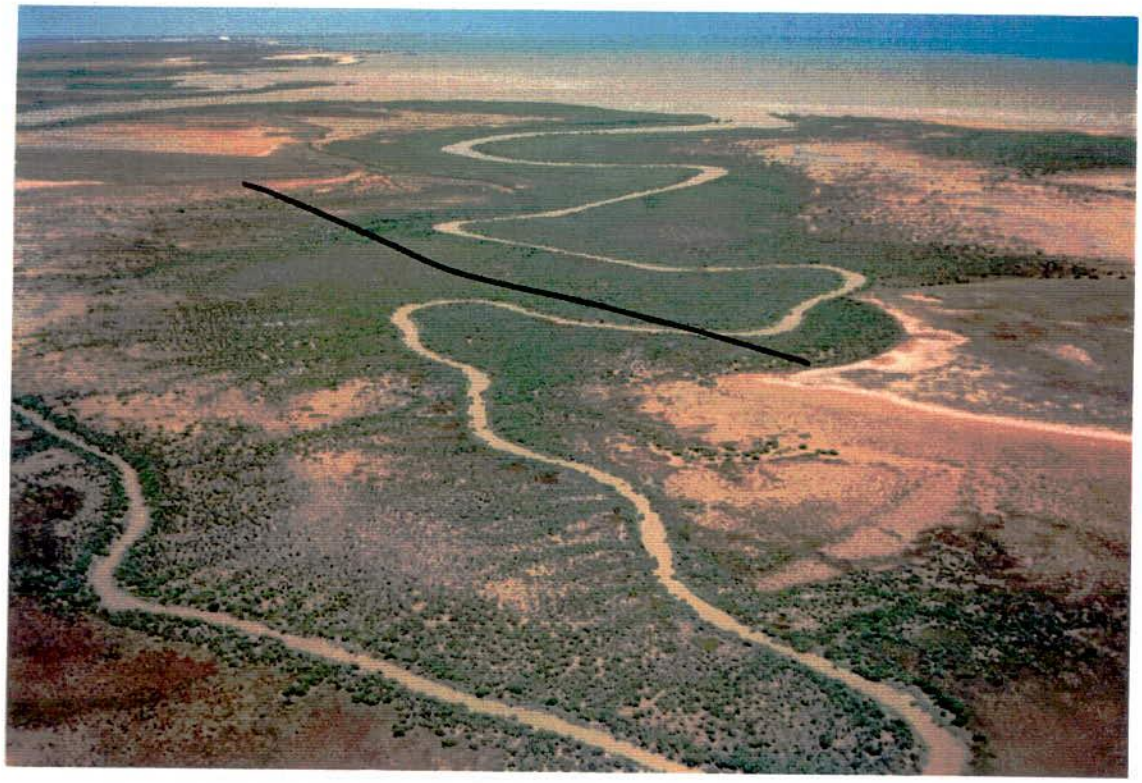


Plate 5: The area of Catfish Creek to be impounded within the proposed pond is in the foreground below the line (perimeter levee position).

Plate 6: Extensive mangrove systems inhabiting the embayment protected by the Finucane Island - Cooke Point limestone barrier system.

Plate 7: Mangrove systems (green areas) fringing tidal creeks in the Port Hedland to Ridley Creek area.

Leslie Salt

Extension of Salt Ponds, Port Hedland

Consultative Environmental Review

APPENDIX 1

RESULTS OF FISH AND BENTHIC FAUNA SURVEYS

LSC Ref: J191/R306
Appendix to R302

RESULTS OF FISH AND BENTHIC FAUNA SURVEYS

Report to : Leslie Salt,
1st Floor, 225 St George's Terrace,
PERTH WA 6000.

by : LeProvost, Semeniuk & Chalmer,
Suite 2, Preston Centre,
175 Labouchere Road,
COMO WA 6152.

30 July 1990

LSC Ref: J191

Report No. R306

RESULTS OF FISH AND BENTHIC FAUNA SURVEYS

Table of Contents

TABLES

FIGURE

RESULTS OF FISH AND BENTHIC FAUNA SURVEY

1 INTRODUCTION

1.1 BACKGROUND

The Leslie Salt project is located on coastal flats near Port Hedland on the northwest coast of Western Australia. Salt is produced by the concentration and evaporation of seawater pumped from a tidal creek connected to the Indian Ocean. A series of eight primary concentration ponds occupying approximately 6,000 ha are located 30 km east of Port Hedland.

In order to increase production, Leslie Salt proposes to create a new concentration pond (Pond 0). The location proposed for the new pond is outside the company's present mining lease. Leslie Salt therefore seeks the granting of an additional lease of some 2,404 ha from the Mines Department in order to incorporate the proposed pond alongside the existing ponds (Fig. 1). Conditional to the granting of this lease is approval by the Environmental Protection Authority (EPA) regarding the environmental concerns of the proposal following their assessment of this proposal. Leslie Salt commissioned LeProvost, Semeniuk & Chalmer (LSC) to undertake the required assessment and preparation of the CER. As part of this assessment it was necessary to identify:

(i) the biological resources to be consumed within the new pond area;

(ii) the biological resources within existing primary concentration ponds that would replace the resources identified in (i) above following the flooding of Pond 0;

(iii) methods by which tidal creeks in the area could be monitored in the future to produce meaningful data on fish stocks. This arises from concern expressed by the Port Hedland Town Council regarding the impact of illegal netting activities on tidal creeks. Presently little data exist on the nature of fish stocks utilising tidal creeks in the Port Hedland-De Grey region.

1.2 OBJECTIVES AND SCOPE

The primary objective of this survey was to assess the present biological value of the proposed new pond area (Pond 0) and compare this with the biological resources of the existing concentration ponds. A secondary objective was to determine the feasibility of conducting reliable and cost-efficient sampling surveys in order to monitor fish stocks in creeks in the future.

To achieve these objectives, the following four tasks were undertaken during a field survey on 6-10 November 1989. Two of these tasks were:

(i) a fish seine survey of existing Ponds 1 and 2,
(ii) a benthic fauna survey in existing Ponds 1 and 2.

Ponds 1 and 2 were targeted during the survey because the water depth, salinity and substrate that would exist in Pond 0 is expected to replicate that presently found in Pond 1 and to a lesser extent, Pond 2. With similar pond operations and substrate characteristics, it is reasonable to assume that over time a similar range of organisms will develop in the new Pond 0.

The remaining two tasks consisted of:

(iii) benthic fauna survey in the proposed pond area;
(iv) experimental fish seine survey of Ridley Creek.

The methods and results of these four surveys are presented separately in the following sections (Sections 3-5).

2 DESCRIPTION OF POND ENVIRONMENT

The primary concentration ponds were constructed in 1966. The surface area of Ponds 1 and 2 are 1,225 ha and 1,141 ha respectively. The bottom of the ponds is relatively flat, reflecting the salt flats that were previously exposed over most of the area. The substrate is composed of silt and find-grained sands mixed with shell grit and organic detritus. Low sand bars (<0.5 m high) occur in a delta area in Pond 1 (adjacent to the intake channel) and on the southeastern edge of both ponds.

Seawater is pumped from a tidal creek into a channel and then into Pond 1 (Fig. 1). Pumped water is filtered by a 50 mm gauge mesh which allows small crustaceans, plankton and the eggs, larvae and juveniles of fish into Pond 1. Rainfall is the only other water source entering the pond system. Water moves from Pond 1 to Pond 2 via one-way flap gates. Therefore, once inside Pond 2, fish cannot return to Pond 1.

Typical salinities found in Ponds 1 and 2 are 44 g/L (5.6° Be) and 57.5 g/L (7.2° Be) respectively. Water temperatures in the shallow (70 cm deep) ponds are typically 2.0-3.0°C warmer than in surrounding tidal creeks. Water contained within Ponds 1 and 2 is turbid due to the presence of organic detritus and planktonic algae (Euglenas, Chroomonas, Gymnodiums and Cryptomonas).

3 FISH SEINE SURVEY IN PONDS 1 AND 2

3.1 METHODS

Fish were sampled by beach seining which was conducted as a series of 'blind' daylight shots in depths up to 0.7 m. The beach seine had a 1.56 cm mesh size pocket (with a 5 m mouth) attached to 100 m wings of 2.5 cm mesh. This seine samples a surface area of approximately 6,000 m^2 within a semi-circle extending from the shore. Five beach seines were conducted in representative areas scattered throughout each of Pond 1 and 2 (Fig. 1). After sorting each catch, abundance, biomass and length data were recorded for each species. In the case of large catches, abundance was determined by subsampling.

3.2 RESULTS

A total of 41 species comprising two decapod crustaceans and 39 teleost fish were caught in Ponds 1 and 2 (Table 1). Thirty-three species were present in Pond 1 and 24 in Pond 2. Seventeen of the 37 species caught were commercial and/or recreationally fished species. Adults of only nine species were caught (Table 1). Schools of adult milkfish (approximately 0.7 m in length) were observed in Pond 1 around the water intake site, however none were caught in the beach seine net.

The average catch per beach seine in Pond 1 consisted of 1,378 fish weighing 12.77 kg. The same sampling effort yielded only 377 fish weighing 6.28 kg per seine in Pond 2. The mean weight of fish caught in Ponds 1 and 2 was 9 g and 16 g respectively.

3.3 DISCUSSION

The abundance of juvenile fish in Pond 1 reflects the entrainment of eggs and larvae through the pump, and their subsequent development in the benign and productive pond environment. The marked drop in abundance and diversity of fish in Pond 2 probably reflects the higher salinity in this pond. Although smaller numbers of fish were caught in Pond 2, these were larger in size.

4 FISH SEINE SURVEY IN RIDLEY CREEK

4.1 RATIONALE AND OBJECTIVES

The Port Hedland Town Council is concerned about illegal netting in tidal creeks. To date, only an approximate assessment of this problem has been made on the basis of illegal netting and evidence of such activities being discovered. It is considered that creeks in the vicinity of the primary concentration ponds are less affected by illegal net fishing than creeks closer to Port Hedland owing to more restricted access and the presence of Leslie Salt personnel.

To assess the effects of illegal fishing, it is necessary to obtain comparative data on fish stocks within tidal creeks. To produce meaningful data for the comparison of fish stocks between tidal creeks a sampling regime must not only be reliable but also logistically feasible and cost effective. Experimental beach seines were therefore conducted in Ridley Creek during the period of the salt pond survey to assess the feasibility of this technique.

4.2 METHODS

Two beach seines were conducted near the mouth of Ridley Creek in the afternoon of 10 November 1989 (Fig. 1). This time marked the ebb of a neap tide (2.8 m above chart datum) and the creek had become two channels (about 2 m deep) separated by a central sand bank. This location was chosen because of easy access, helped by the fact that the surrounding tidal flats had not been inundated since the previous spring tides some two weeks before the survey date.

The same netting procedures were used as for Ponds 1 and 2 with the net extending out from the central sand bank. The substrate of Ridley Creek consisted of coarse sand with shell fragments. Seine netting efficiency was reduced owing to the leadline of the net becoming buried within the large sand ripples on the bottom of the creek.

4.3 RESULTS

A total of 13 species was caught by the two seines (Table 1). Six of these represent recreational or commercial species. The total number of fish caught was 62 weighing 3.02 kg (Table 2).

While the diversity and abundance of species caught in Ridley Creek were lower than those from Ponds 1 and 2, comparisons between the two areas must be qualified by the following points:

(i) the variability of the substrate and difficulty in operating the beach seine;
(ii) low tide and the consequent potential reduction in the number of fish at the time of seining;
(iii) the warm and relatively more productive habitat of the ponds;
(iv) the lack of predatory species such as sharks in the salt ponds.

4.4 DISCUSSION

In the eventuality of a future sampling exercise aimed at determining fish stock levels in tidal creeks, LSC has identified additional access points and netting sites in other tidal creeks. Future cost-effective sampling programmes should avoid spring tides as these make the mud flats surrounding tidal creeks impassable to vehicles for up to 10 days. The same consideration applies to the summer 'wet' season, a period in which heavy rain can also constrain access.

With these points in mind, a useful investigation of fish stocks in the area could be conducted by the following sampling techniques:

(i) beach seining (with smaller wings) in creek mouths during the ebb of neap tides;

(ii) set netting in narrow channels of upper reaches of creeks over the flood period of neap tides.

Such a sampling programme would be designed in conjunction with advice from Fisheries Department research officers.

5 BENTHIC FAUNA SURVEY

5.1 METHODS

A benthic fauna survey was conducted in both the proposed pond area and Ponds 1 and 2. Benthic fauna in Ponds 1 and 2 was sampled at the same sites used for the fish survey (Fig. 1). At each sampling site, sediment samples were collected from three replicate areas of 0.1 m^2 to a depth of 10 cm. The mud tidal flats that occupy most of the proposed pond area were sampled at six sites (Fig. 1). At each sampling site, sediment samples were collected from three replicate areas of 0.1 m^2 to a depth of 10 cm.

The sediment samples were wet sieved through a 1 mm mesh. Coarse material and animals retained by the sieve were fixed in 80% alcohol and stored for subsequent sorting in the laboratory. After sorting, animals were identified to family level or higher taxonomic level and counted.

The substrate within the ponds was fairly homogeneous. The top surface consisted of silts and organic detritus mixed with fine to medium grain sand, bivalve shells and shell grit. This surface layer varied in thickness from 0.1 to 0.5 m. Below this surface layer, the substrate was relatively hard and impermeable. By contrast, sediments within the proposed pond area were typically a fine sandy mud that was overlain by an algal or salt crust.

5.2 RESULTS

The distribution and abundance of benthic fauna in Ponds 1 and 2 are shown in Tables 3 and 4 respectively. A total of 26 species were recorded from Pond 1 and 12 species from Pond 2 (Table 3). In Pond 1, the density of benthic animals ranged from 200 to 1,598 per m^2, with a mean of 763 per m^2. The lowest densities in Pond 1 were at sites 1 and 2 where the substrate was more sandy. Densities in Pond 2 ranged from 469 to 1,008 per m^2 with a mean of 634 per m^2.

The most abundant infauna in both ponds were polychaetes, bivalves and nematodes in descending order. The mean size of bivalves in Pond 1 was larger than that in Pond 2 (i.e. 70% of bivalves were longer than 5 mm in Pond 1, compared with only 54% of shells in Pond 2).

The only benthic fauna found in the proposed pond area were polychaetes which ranged in density from 0 to 133 per m^2. Mean density of polychaetes was 36 per m^2.

5.3 DISCUSSION

Compared to the proposed pond area, both existing ponds contained a far more diverse and abundant benthic fauna. There are only minor variations in benthic fauna densities between the two ponds, with the most notable exception occurring in the case of bivalves which were smaller and less abundant in Pond 2. This variation may be due to the increased salinity in Pond 2.

The low level of organisms found within the proposed pond area is a reflection of the generally low biological productivity of the flats compared to the existing ponds and their exposure for considerable periods (up to 10 days) between spring tide cycles.

6 CONCLUSION

The results of the fish and benthic fauna survey indicate that the ecosystem supported by Ponds 1 and 2 is more productive and contains abundant populations of fish and benthic fauna. Both these stocks provide an important food source for a wide diversity of avifauna including raptors (osprey, sea eagles), waterbirds (pelicans, egrets), seabirds (terns) and wading birds (godwits, sandpipers, etc.).

Following the creation of Pond 0, it is expected that its present salt falt ecosystem would be substituted by that ecosystem presently found in Pond 1 and therefore create an additional resource for local and migratory avifauna.

TABLE 1

FISH SPECIES LIST

	SPECIES NAME	COMMON NAME	1*	2*	R*	$*	A*
CRUSTACEA							
NATANIA		Juvenile prawns	•	•	•	$	
REPTANIA	Portunus pelagicus	Blue manna crab	•			$	
TELEOSTEI							
APOGONIDAE	Sp 2	Cardinal fish		•			
CLUPIDAE	Anodotostoma chacunda	Gizzard shad (Perth herring)	•	•	•		A
	Sp 2		•				
	Sp 3		•	•	•		
ELOPIDAE	Elops hawaiiensis	Giant herring		•	•		
CHANIDAE	Chanos chanos	Milkfish	•				A
CLUPEIDAE	Sp 1	Anchovy	•			$	A
	Sp 2			•	•		
SILLAGINIDAE	Sillago analis	Coarse scale whiting	•	•		$	
	S. maculata burras	Trumpeter whiting	•	•		$	
	S. schomburgkii	Western sand whiting	•	•		$	
	S. vittata	School whiting	•	•	•	$	
ATHERINIDAE	Sp 1	Hardyhead	•	•	•		
	Sp 2			•			
SERRAINIDAE	Epinephelus suillus	Estuarine cod	•			$	A
HEMIRAMPHIDAE	Arramphus sclerolepis	Snub nosed garfish	•	•			A
	Sp 2	Garfish	•	•			
LEIOGNOTHIDAE	Leiognathus equulus	Common pony fish	•	•	•		
SPARIDAE	Acathopagrus liatus	Yellowfin bream	•	•		$	A
BOTHIDAE	Pseudorhombus sp	Flounder	•	•		$	
PLATYCEPHALIDAE	Platycephalus sp	Flathead	•	•		$	A
MUGILIDAE	Mugil cephalus	Sea mullet	•	•	•	$	A
POLINEMIDAE	Eleutheronema tetradactylum	Giant threadfin			•		
GERREIDAE	Gerres subfasciatus	Roach	•	•	•		
BELONIDAE	Strongylura sp.	Longtom	•	•	•		
TERAPONIDAE	Pelates sexlineatus	Six lined trumpeter	•				
	Amniataba caudovittatus	Yellow tail trumpeter	•	•			
CALLIONYMIDAE	Sp 1	Dragonet	•				

TABLE 1

FISH SPECIES LIST

	SPECIES NAME	COMMON NAME	1*	2*	R*	$*	A*
SOLEIDAE	Sp 1	Sole	•				
	Phyllichtys punctatus	Spotted sole		•		$	
GOBIIDAE	Sp 1	Goby	•	•			
	Sp 2		•				
HAEMULIDAE	Pomadasys maculatum	Blotched javelin fish	•			$	
TRIACANTHIDAE		Tripod fish	•				
MONACANTHIDAE	Pseudomonacanthus peroni	Pot bellied leather jacket	•				
CARANGIDAE	Scomberoides commersonnianus	Talang queenfish	•			$	A
SCOMBRIDAE	Sp 1	Mackerel	•			$	
POMATOMIDAE	Pomatomus sp	Tailor			•	$	
		TOTAL	33	24	13	16	9

* 1 = Pond 1
2 = Pond 2
3 = Ridley Creek
$ = potential commercial species
A = adult fish

TABLE 2

BIOMASS AND ABUNDANCE OF FISH AND CRUSTACEANS
FROM BEACH SEINE SAMPLING

SPECIES	POND 1		POND 2		RIDLEY CREEK	
	N	g	N	g	N	g
Prawns	11	2	16	2	2	1
Blue manna crab	4	700	0	0	0	0
Cardinal fish	107	590	6	25	0	0
Sp 2	0	0	428	2,255	0	0
Gizzard shad (Perth herring)	398	17,085	6	450	3	80
Sp 2	315	245	0	0	0	0
Sp 3	4,417	8,376	304	172	4	26
Giant herring	0	0	3	1,400	1	675
Anchovy	6	10	0	0	0	0
Sp 2	0	0	19	50	5	6
Coarse scale whiting	7	275	33	3,600	0	0
Trumpeter whiting	37	335	24	160	0	0
Western sand whiting	204	1,875	24	240	0	0
School whiting	43	2	18	90	4	10
Hardyhead	234	55	230	490	1	1
Sp 2	0	0	148	30	0	0
Estuarine cod	2	3,750	0	0	0	0
Snub nose garfish	355	12,885	410	10,715	0	0
Sp 2	7	1	100	80	0	0
Pony fish	261	1,975	5	75	12	76
Yellowfin bream	73	1,125	31	975	0	0
Flounder	11	80	2	15	0	0
Flathead	17	1,420	1	200	0	0
Mullet	104	1,225	6	8,430	7	80
Giant threadfin	0	0	0	0	2	850
Roach	133	1,325	16	35	5	6
Striped butterfish	3	1,025	0	0	0	0
Longtom	7	550	8	835	11	810
Six lined trumpeter	3	15	0	0	0	0

TABLE 2

BIOMASS AND ABUNDANCE OF FISH AND CRUSTACEANS
FROM BEACH SEINE SAMPLING

SPECIES	POND 1		POND 2		RIDLEY CREEK	
	N	g	N	g	N	g
Yellow tail trumpeter	36	1,215	38	910	0	0
Dragonet	3	2	0	0	0	0
Sole	39	81	0	0	0	0
Spotted sole	0	0	4	145	0	0
Goby	10	22	5	1	0	0
Sp 2	1	2	0	0	0	0
Blotched javelin fish	4	1,261	0	0	0	0
Tripod fish	14	5	0	0	0	0
Pot bellied leather jacket	1	1	0	0	0	0
Talang queenfish	4	6,325	0	0	0	0
Mackerel	1	1	0	0	0	0
Tailor	0	0	0	0	5	400
TOTAL ABUNDANCE TOTAL BIOMASS	6,892	63,841	1,887	31,380	62	3,021

Standardised totals are grams and N per beach seine x 5.

TABLE 3

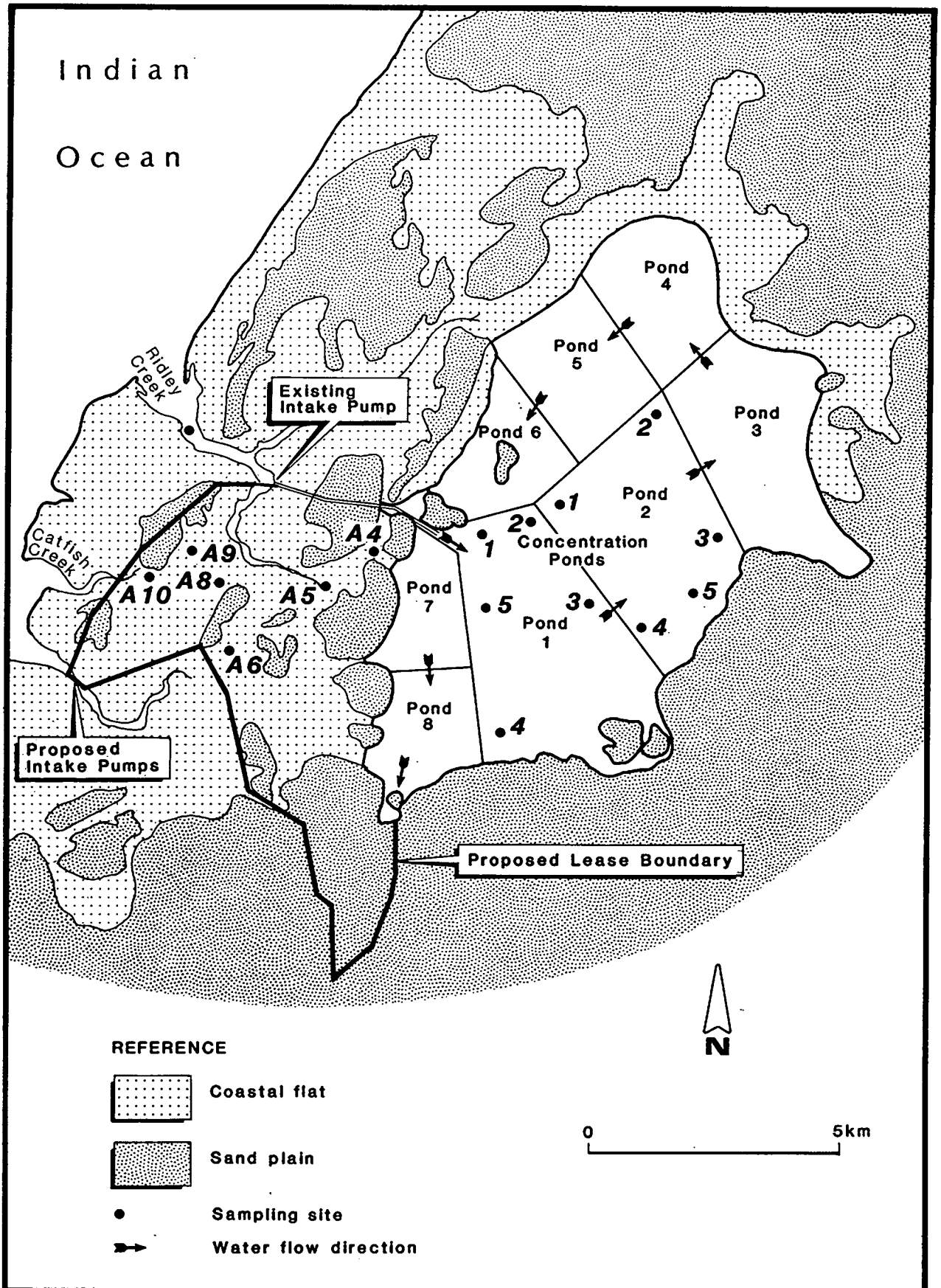
BENTHIC FAUNA SPECIES LIST

SPECIES NAME		POND 1	POND 2
PLATYHELMINTHES	Sp 1	•	
NEMATODES	Sp 1	•	•
	Sp 2	•	•
	Sp 3	•	•
POLYCHAETES	Sp 1	•	•
	Sp 2	•	•
	Sp 3	•	•
	Sp 4	•	•
	Sabellid	•	
	Sp 6	•	•
	Sp 7	•	
OLIGOCHAETES	Sp 1	•	
HIRUDINIDS	Sp 1	•	
SIPUNCULIDS	Sp 1	•	•
BRACHIOPODS	Lingula	•	
ASCIDIANS	Sp 1	•	
GASTROTRICHS	Sp 1	•	
BIVALVES	Tellinidae	•	•
	Laternulidae	•	•
	Placamen gravescens	•	
	Veneridae Sp 2	•	•
	Veneridae Sp 3	•	
	Cerithiidae	•	
	Unidentified	•	
GASTROPODS	Morula	•	
CEPHALOPODS	Loligo	•	
TOTAL		26	12

TABLE 4

BENTHIC FAUNA ABUNDANCE

		ABUNDANCE (N/m2)											MEAN TOTALS PER GROUP		
		Pond 1 Site						Pond 2 Site							
	SPECIES	1	2	3	4	5	Mean Pond 1	1	2	3	4	5	Mean Pond 2	Pond 1	Pond 2	Proposed Pond Area
Platyhelminthes	*Species 1*	3					1							1		
Nematodes	*Species 1*	57		20	20	90	37		3	10	13		5			
	Species 2		17			60	15									
	Species 3		10	140	13		33							85	5	
Polychaetes	*Species 1*	57	63	87	450	200	172	333	270	260	497	80	287			
	Species 2	3	40	53	287	153	107	87	30	97	290	23	105			
	Species 3	13	3		23	63	20	3		17	40		16			
	Species 4		57	13	53	13	27	93	70	50	67	33	63			
	Sabellariidae					20	4									
	Species 6				7	3	2		10				2			
	Species 7					3	1							333	473	36
Oligochaetes	*Species 1*	17				13	6							6		
Hirudinids	*Species 1*					3	1							1		
Sipunclids	*Species 1*	3	7			53	11				7		1	11		
Brachiopods	*Lingula*					63	12							12		
Ascidians	*Tunicate*					3	1							1		
Gastrotrichs	*Rotifera*	7					1							1		
Bivalves	*Tellinidae*	7	57	333	26	63	97	76	123		14	210	85			
	Laternulidae				3	6	2	3		130	30	123	57			
	Placamen gravescens					20	4									
	Veneridae Species 2	3	157		10	763	187				3		1			
	Veneridae Species 3				13	13	5									
	Carithiidae	3				3	1									
	Juvenille	10				10	4							300	143	
Gastropods	*Morula*		3		10		3							3		
Cephalopods	*Loligo*			3			1							1		
Crustaceans	*Natantia*	17	3	3			5		3				1			
	Squilla				17		3		10		47		11	8	12	
	TOTAL	200	417	652	932	1598	763	595	519	564	1008	469	634			



LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **SAMPLING LOCATIONS**	Figure **1**

J191 R291 A1

Leslie Salt

Extension of Salt Ponds, Port Hedland

Consultative Environmental Review

APPENDIX 2

HISTORY OF CREEK MODIFICATION AND MANGROVE DISTRIBUTION

LSC Ref: J191/R290
Appendix to R302

HISTORY OF CREEK MODIFICATION AND MANGROVE DISTRIBUTION

Report to : Leslie Salt,
1st Floor, 225 St George's Terrace,
PERTH WA 6000.

by : LeProvost, Semeniuk & Chalmer,
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COMO WA 6152.

30 July 1990

LSC Ref: J191

Report No. R290

HISTORY OF CREEK MODIFICATION AND MANGROVE DISTRIBUTION

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HISTORY OF CREEK MODIFICATION AND MANGROVE DISTRIBUTION

1 INTRODUCTION

Leslie Salt proposes to construct and operate a new concentration pond (Pond 0) immediately to the west of existing Ponds 7 and 8 (Fig. 1). This project involves the flooding of coastal flats, construction of a perimeter levee across one tidal creek and the pumping of seawater from another. Potential environmental impacts from this proposal include modification to creek hydrology, sedimentation patterns and mangrove distribution. In the light of similar impacts having resulted from the existing pumping operations in Ridley Creek, it seems appropriate to document these changes to assist with design, construction and management plans for the current proposal.

2 METHODS

The following study involved the examination of aerial photographs from pre-construction days (1966) to present. The extent of tidal creek channels, mangrove habitats and sand plain was mapped and the results are presented in Figures 2, 3 and 4. These figures correspond to habitat distribution as of February 1966, May 1968 and July 1987, respectively. These dates were chosen to illustrate baseline conditions and modifications resulting from the development of existing facilities. Sections 3.1-3.4 discuss these modifications to the distribution of tidal creek channels and mangrove habitats.

3 SUMMARY OF PHOTOGRAPHIC ANALYSIS

3.1 PRE-CONSTRUCTION PHASE (1966)

The location of habitats presented in Figure 2 corresponds to baseline conditions existing prior to the construction of concentration ponds, intake channel and pump stations. At that time (February 1966), the main channel and hence water movement in Ridley Creek was concentrated into the southern arm which extended into salt flats that are now enclosed in Pond 7. A smaller northern arm branched from the main channel and extended for approximately 2 km across salt flats in a northeasterly direction. Mangrove habitats (Fig. 2) fringed the above channel areas with the landward extent being governed by the degree of tidal inundation at a given location.

3.2 POST-CONSTRUCTION PHASE (1967-1978)

The construction of concentration ponds, a pump station and connecting intake channels took place over the latter half of 1966 and during 1967. By comparing habitat distribution between pre- and post-construction phases (Figs 2 and 3), the changes resulting from the construction can be seen. These changes include the flooding of salt flats contained within concentration ponds and the loss of mangrove habitat (0.5 ha) at the intake pump site.

Two pump stations were built onshore and a small channel (approx. 20 m) was excavated to connect the pump station to Ridley Creek. Water was then pumped at a rate of 12 m^3/s from Ridley Creek into an intake channel which flowed into Pond 1. The operation of the pump station in this manner had no noticeable impact on the hydrological and sedimentological patterns of Ridley Creek. This was reflected by the distribution of creek channels and mangrove habitats (Fig. 3) having remained the same as pre-construction days (Fig. 2). This situation is expected to be similar to that created at the proposed intake site on Rock Cod Hole Creek. The pump station construction type is the same (i.e. pump onshore with a small connecting channel to the water source) and pumping rates are not expected to alter tidal regimes prevailing in Rock Cod Hole Creek.

3.3 POST TIDAL DAM CONSTRUCTION (1978-1987)

In 1978, Leslie Salt constructed a tidal dam across Ridley Creek at the existing pump station site (Fig. 4). The dam was built in an attempt to enable longer pumping times by trapping water inside the dam that would normally recede with falling tides. One pump station was located inside the holding dam while the other remained outside (or downstream from the dam) in its original position.

The impact of the dam was to significantly restrict water volumes flowing into the southern arm of Ridley Creek in areas upstream from the dam wall. The changed tidal regime reduced this section of the creek to half its previous length and loss of mangrove habitat in this area followed. Siltation next to and downstream from the dam wall took place in subsequent years. As a result, tidal mud flats have replaced previous channel areas and approximately 6 ha of mangrove habitat has become established.

The construction of the dam reduced the existing capacity of the Ridley Creek channel system, but did not affect the oceanic tidal forces that drive tidal flows into the creek on flood tides. Consequently, water that previously flowed into both the northeastern and southern arms of the Creek was forced into the northeastern arm. This resulted in erosion and extension of the upper reaches of the northeastern arm to expand its channel length from 2 km to 6 km during the years 1978 to 1987. This extension is approximately the same as the effective channel length that was lost in the southern arm of the creek when it was dammed. Mangroves have subsequently become established in the extended reaches of the northeastern arm.

Scouring of the northeastern arm of Ridley Creek may also have been due to enhanced catchment runoff during cyclonic storm events. However, it seems more likely that the establishment and maintenance of the extended channel of the northeastern arm is due to the daily influence of tidal flows rather than the episodic occurrence of storm-induced flood flows.

3.4 MANGROVE RECRUITMENT WITHIN THE EXISTING POND SYSTEM

Over the life of the project (1966-1990) mangrove recruitment has taken place within the pond system at sites along the intake channel and on levee edges that enclose Pond 1. Substantial mangrove recruitment (2 ha) has occurred in a shallow delta area at the eastern end of the intake channel (Plate 1). At this point, water brought down by the intake channel is spread out over a 25 ha delta area (formerly salt/mud flats) before being concentrated back into a channel and directed into Pond 1. Silt and clays brought down by intake waters have been deposited over this area, thus creating suitable substrate for mangrove recruitment.

Another delta area has formed at the point where intake waters first enter Pond 1. Deposition of sediments transported by intake waters have formed numerous sand bars in this area which are extensively used by large numbers of migratory wading birds. Scattered mangrove recruitment is also evident as this location.

4 CONCLUSION

The construction and operation of the existing pond system has caused modification to tidal regimes, hydrology, sedimentation patterns and mangrove distribution within Ridley Creek and intake channel areas. These modifications are presented in Sections 3.2, 3.3 and 3.4, and Figures 2, 3 and 4. On the basis of this knowledge, conclusions can be made regarding the modifications expected by the construction and operation of Pond 0.

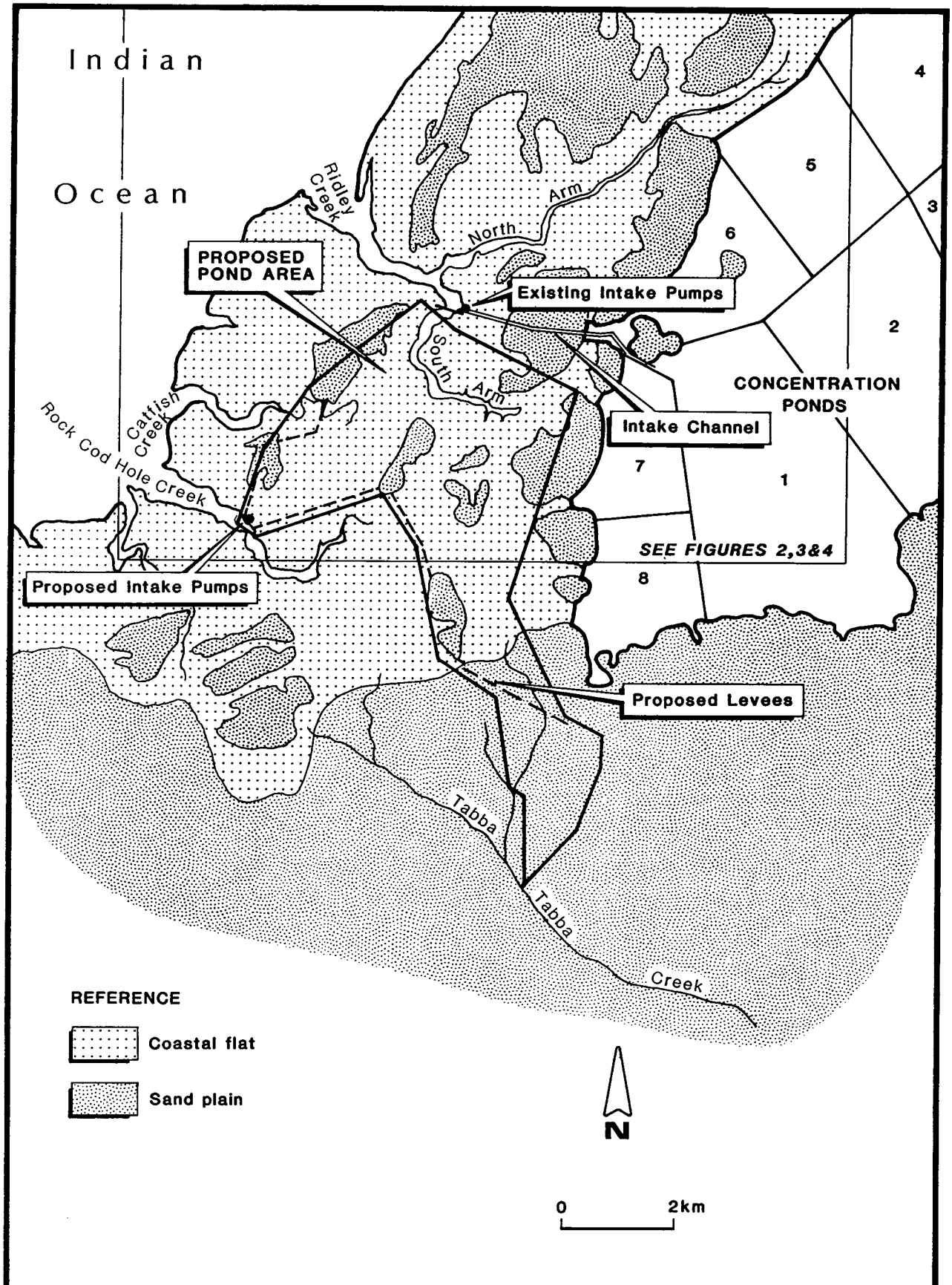
4.1 PROPOSED INTAKE SITE

The construction type and operation proposed for the pump intake site on Rock Cod Hole Creek will be similar to that which existed between 1966 and 1978 at the existing pump site. In this case, water was drawn from Ridley Creek by onshore pumps without affecting the hydrological patterns and tidal regimes upstream from the intake pumps. This was reflected by no alteration to mangrove and creek channel distributions over this time.

Significant changes to the tidal regime of Ridley Creek occurred only after the construction of a tidal dam. The proposed intake site on Rock Cod Hole Creek avoids any construction of this type and therefore should not adversely affect creek and mangrove areas upstream from the pumps.

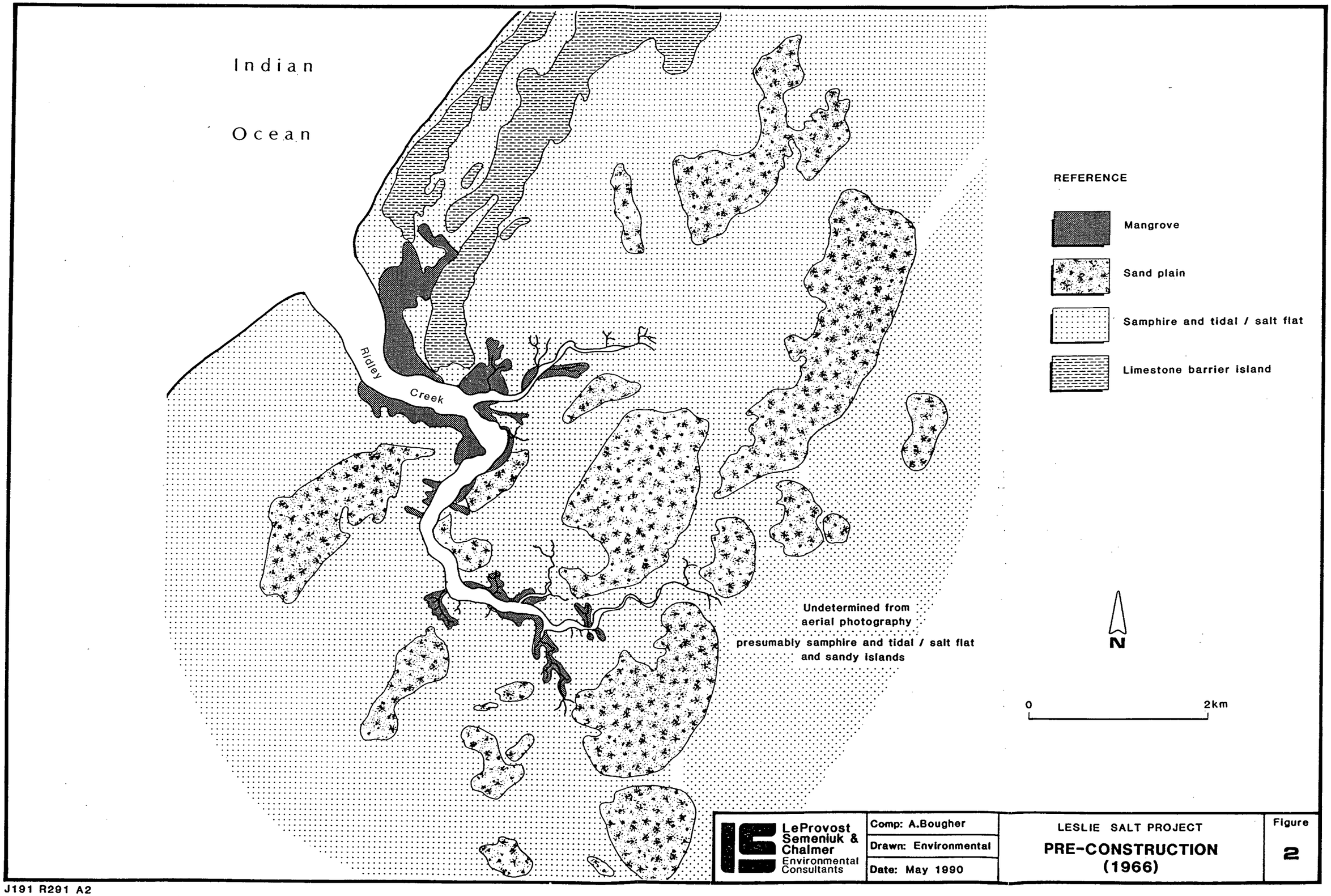
4.2 PERIMETER LEVEE ACROSS CATFISH CREEK

The construction of a dam across Ridley Creek resulted in mangrove habitat loss upstream in the southern channel, however replacement of mangrove habitat took place (and continues to take place) as tidal waters concentrated their flow into the northeastern channel. The perimeter levee across Catfish Creek may create a similar situation, with redirected tidal waters eroding new headwaters and channel areas. The proximity of these new headwater areas to existing mangrove stocks on Catfish Creek (downstream from the levee) would ensure that mangrove recruitment is successful.



LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn : Environmental Date : May 1990	LESLIE SALT PROJECT **LOCATION DIAGRAM**	Figure **1**

J191 R291 A2



LeProvost Semeniuk & Chalmer Environmental Consultants

Comp: A.Bougher
Drawn: Environmental
Date: May 1990

LESLIE SALT PROJECT

PRE-CONSTRUCTION (1966)

Figure 2

J191 R291 A2

Indian

Ocean

Ridley Creek

North Arm

Catfish Creek

South Arm

4

5

6

7

1

N

0 2km

CONCENTRATION PONDS

REFERENCE

Mangrove

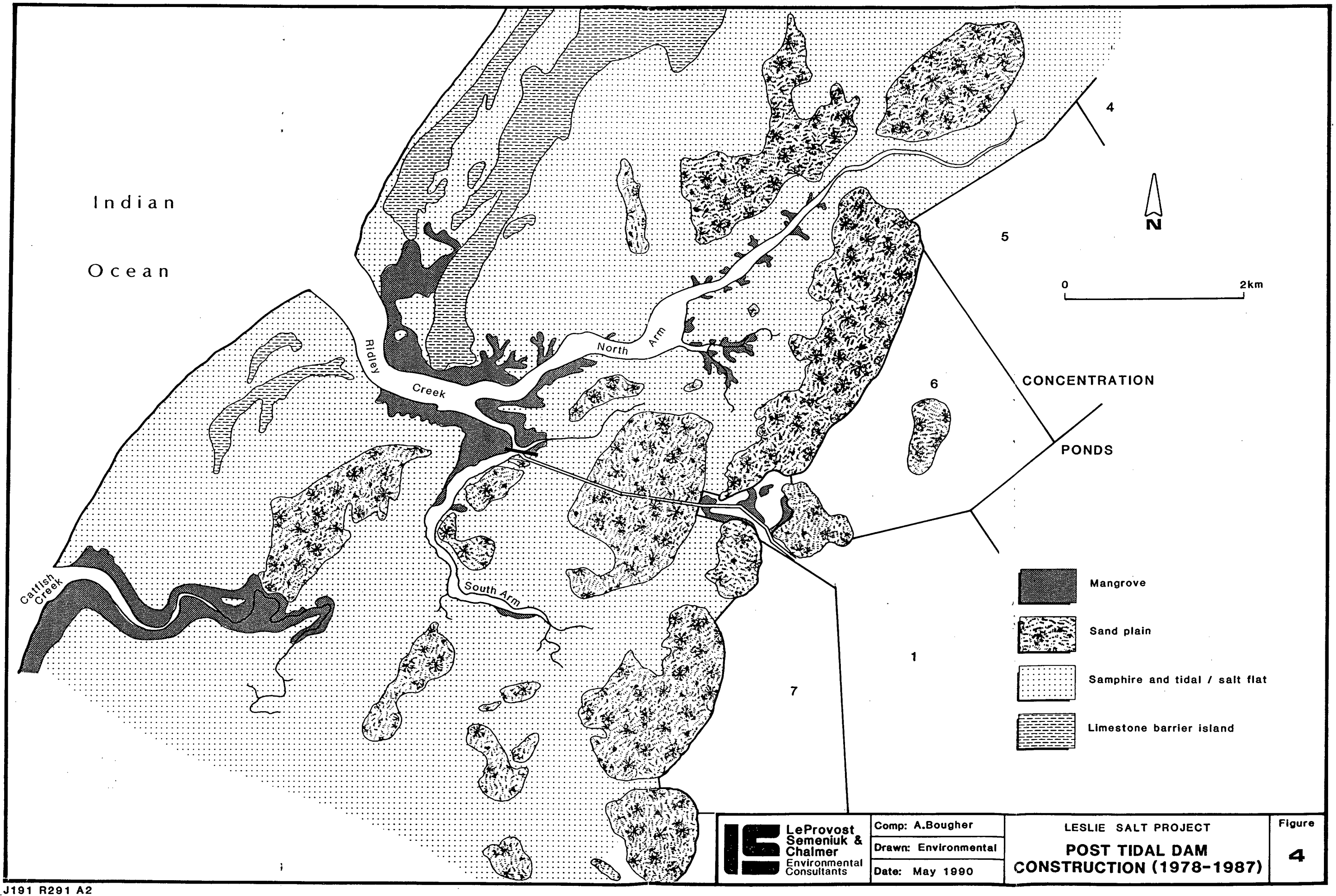
Sand plain

Samphire and tidal / salt flat

Limestone barrier island

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: A.Bougher Drawn: Environmental Date: May 1990	LESLIE SALT PROJECT **POST-CONSTRUCTION (1967-1978)**	Figure **3**

J191 R291 A2



LeProvost Semeniuk & Chalmer Environmental Consultants

Comp: A.Bougher
Drawn: Environmental
Date: May 1990

LESLIE SALT PROJECT

POST TIDAL DAM CONSTRUCTION (1978-1987)

Figure 4

J191 R291 A2

Plate A2.1: Mangrove recruitment in a delta area at the eastern end of the intake channel.

Leslie Salt

Extension of Salt Ponds, Port Hedland

Consultative Environmental Review

APPENDIX 3

REPORT ON A SURVEY FOR ABORIGINAL SITES AT THE PROPOSED SALTWORKS EXPANSION AREA AND QUARRY SITE NEAR PORT HEDLAND

LSC Ref: J191/R302

REPORT ON A SURVEY
FOR ABORIGINAL SITES AT
THE PROPOSED SALTWORKS EXPANSION
AREA AND QUARRY SITE
NEAR PORT HEDLAND

Prepared for Leslie Salt

By Rory O'Connor and Gary Quartermaine

May 1990

PART ONE

ETHNOGRAPHY

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background

This repot, which is based on a period of field research carried out in May 1990, was commissioned by Leslie Salt. The aim of the research was to consult with Aboriginal people who retain traditional and current cultural links with the Tabba Tabba Creek/De Grey River area, near Port Hedland, to ensure that a proposed saltworks expansion and quarrying operations do not impact any areas of Aboriginal significance. At the same time, and in recognition of the possible archaeological significance of the areas to be impacted by the proposed developments, an archaeological survey was conducted by Gary Quartermaine. Part Two of this report details the results of that survey.

1.2 Brief Description of Project

The quarry lease is situated on the northern side of the Goldsworthy–Hedland railway line, close to Tabba Tabba Creek. Material from this quarry has been previously used in the course of construction of the railway.

The proposed saltworks expansion would involve construction of levee banks and permanent flooding of saline mudflats between Ridley's Creek and Tabba Tabba Creek.

The locations of these proposed developments are shown in Figure One.

1.3 Acknowledgements

The author gratefully acknowledges the assistance and advice of members of the Ngarla and Coastal Nyamal Group, especially T. Allen and Left-hand J. Attwood, and of members of the Nomads Group, especially C. Yakarla, L. Yanki, N. Williams and P. Yapurla.

1.4 Research Brief

The research brief required the researcher to ascertain whether any areas of Aboriginal significance within the meaning of Section 5 of the Aboriginal Heritage Act (1972-80) are located within the areas of proposed development. If such exist, they are to be reported in sufficient detail and in a format suitable for submission to the W.A. Museum's Department of Aboriginal Sites, together with recommendations for their protection and management.

2.0 ABORIGINAL HISTORY IN SURVEY AREA

2.1 The Pre-Contact Era:

The proposed developments are located within the traditional lands of the Ngarla dialect group, who were adjoined by the Kariera and Nyamal people. Although there is disagreement about the distribution of these groups (see Radcliffe-Brown 1912, von Brandenstein 1967, Elkin 1938, and Tindale 1974), it is generally agreed that the Kariera inhabited the country stretching South and Southwest from the present Port Hedland, that the Njamal (an inland group) had an avenue to the sea in the vicinity of Petermarer Creek, and that the Ngarla were on the De Grey and through the present Pardoo Station to Cape Keraudren. The lands of the Ngarla stretched inland past the present town of Goldsworthy.

The Pilbara Aborigines were described by early authors (see Curr 1886 and Withnell 1901) as "river people", whose lives were centred upon the large drainage systems that dissect the area. Traditionally, it appears, habitation and land utilisation were indeed centred upon permanent and semi-permanent pools on these rivers and their tributaries, spreading out across the plains following rain and gradually retreating to the reliable water sources as the land dried. The potential for locating Aboriginal sites is therefore greatest near these water sources. In addition, most important pools are themselves named Aboriginal sites and have mythological association.

2.2 Social Change Following Contact

This materials can be summarised briefly as follows:

(i) A pastoral industry developed rapidly in Kariera, Njamal and Ngarla lands between 1863 and 1880.

(ii) Unfavourable Aboriginal reaction to the settlers led to reprisals, depleting the numbers of coastal Aborigines.

(iii) Introduced smallpox and measles, also served to reduce the indigenous population.

(iv) Survivors tended to settle on stations in "blacks' camps".

(v) The pearlshell trade relied on Aboriginal labour and, following the depopulation of the coastal tribes, began recruiting inland people.

(vi) Ultimately, these newcomers intermarried with the remnants of the coastal tribes, thereby forming the basis for today's mixed Aboriginal population.

2.3 Recent Aboriginal Population Movements

(i) Aboriginal involvement in mining in the Pilbara dates back to the industry's earliest years there.

(ii) In 1946, Aboriginal station workers in the Pilbara went on strike, demanding increased wages and improved conditions.

(iii) Many of these strikers supported themselves by dry shelling and mining operations.

(iv) Two groups of strikers obtained control of Yandeyarra and Strelley stations, where they are living today.

(v) After the adoption of the Pastoral Award in 1968, the "blacks' camps" were either evicted from or abandoned most of the Pilbara stations and resettled in Reserves around the townships.

(vi) Many Reserve Aborigines have relocated to houses within the townships in the course of the last decade.

2.4 The Proposed Developments – Aboriginal Consultation

The coastal Njamal and Ngarla people now resident in Port Hedland and South Hedland have recently incorporated to form the Ngarla and Coastal Njamal Group. The members of this group were consulted in the course of the survey.

The Aboriginal strikers who obtained control of Strelley station are still resident there and at Warralong Station. They also were consulted.

3.0 THE SURVEY

3.1 Methodology

Four separate phases were involved in the survey:

(i) examination of the existing ethnographic data base;

(ii) consultation and discussion with the Nomads Groups, whose pastoral leases adjoin the survey area, and with the Ngarla and Coastal Nyamal Group, whose members retain cultural links with the survey area;

(iii) site visit in company of Aboriginal elders;

(iv) report preparation.

3.2 Previously Recorded Sites

No sites of significance to living Aboriginal people have been recorded previously within the areas of the proposed developments.

3.3 Newly Recorded Sites

The proposed quarry site does not contain any areas of Aboriginal significance.

The saline mudflats which are to be flooded in the course of the saltworks expansion are known to Ngarla people as Kwiyuruwarra,

which translates into English as "the place of the mirage". As a result of the survey, these mudflats have been passed as clear of Aboriginal sites of significance.

The sand dunes to the North and South of Ridley's Creek were used as camping areas by the Aboriginal people who settled on De Grey Station between 1910 and 1968. Oral tradition records that these dunes and associated limestone ridges were also used as camping grounds before the arrival of European settlers, a tradition corroborated by the extensive middens of Anadara granosa shells which have accumulated there (see Part Two for description of middens). The dunes to the North of Ridley's Creek are under no threat from the proposed development; however the limestone ridges to the northwest of the proposed development which were used as a camping area and which have been recorded by the archaeological survey as Field Site 1, are close to the proposed area of inundation. These latter ridges also contain a burial described in Part Two of this report.

During the 1940s, a group of Aboriginal strikers set up camp near Tabba Tabba Well. Two deaths occurred here, and the deceased were buried a short distance from the camp. These burials are shown as EFS1 on Figure Two.

3.4 Aboriginal Consultation

The burial incorporated into (archaeological) Field Site 1 was inspected by the elders, as was the shell midden. The description of this site incorporated into the archaeological report was approved by the elders, but they requested that its

north eastern boundary be extended a further three hundred metres to incorporate the acacia thicket which they claim to have been a source of fresh soakage water for the Aboriginal campers. This extended site boundary is shown in Figures 2 and 3.

The burial incorporated into (archaeological) Field Site 3 was not visited, as the elders involved were too frail to undertake the long walk across the saline mudflats. However, the burial was described to them, and their wishes in this regard are incorporated into the recommendations below.

4.0 RECOMMENDATIONS

4.1 Human interference with Aboriginal sites in this State is an offence under the Aboriginal Heritage Act, unless authorised as outlined in Section 17 of that Act.

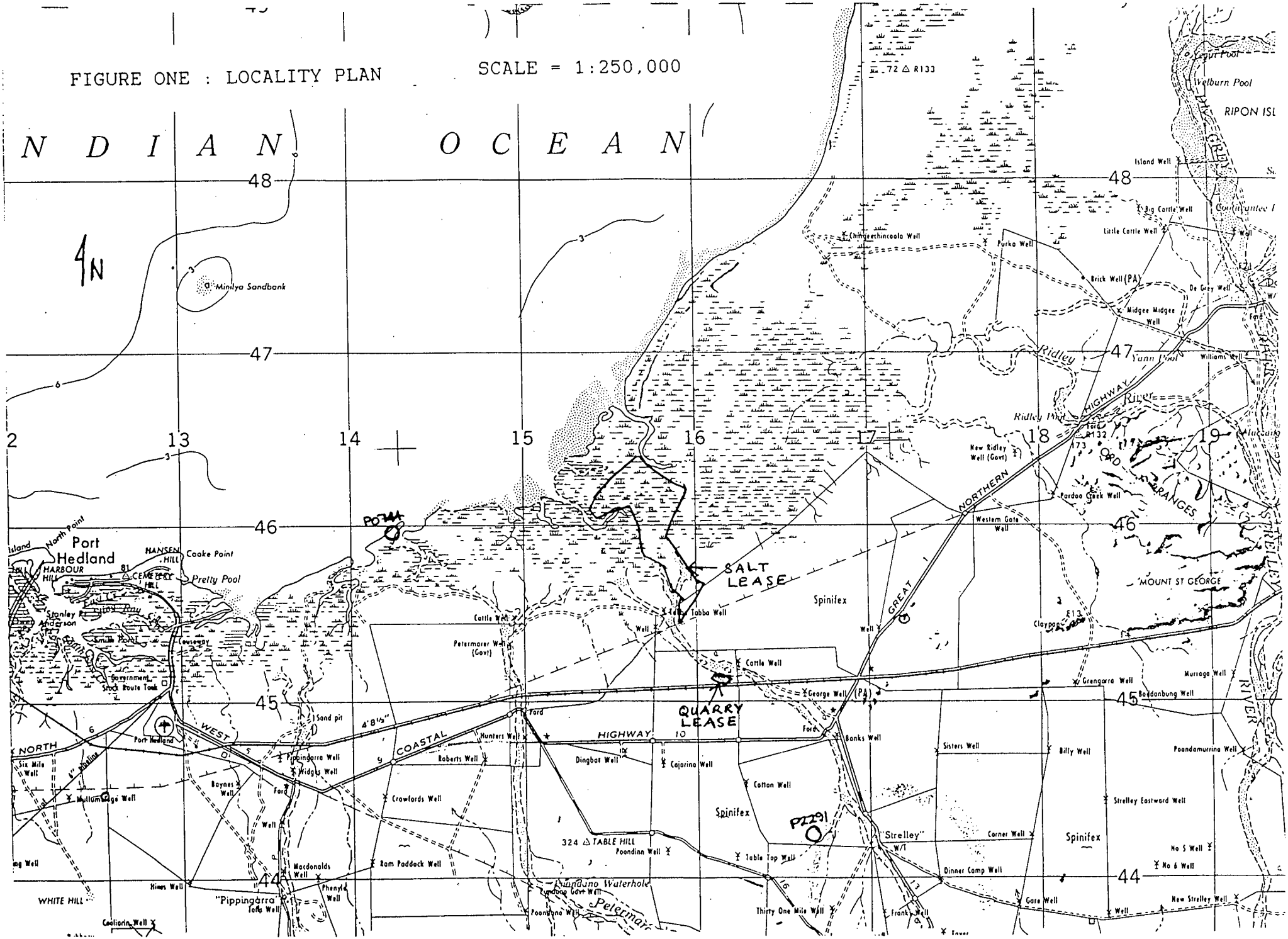
4.2 It is recommended that the expanded (archaeological) Field Site 1 should be left undisturbed.

4.3 It is recommended that the existing track should be rerouted to the south to skirt the green thicket which incorporates the soak area noted in 3.4 above.

4.4 It is recommended that (archaeological) Field Site 3 should be left undisturbed, and that material for levee bank construction should not be removed from this site.

4.5 It is recommended that the location of E.F.S.I should be marked on Leslie Salt maps and plans and that the vicinity of this burial should not be in any way disturbed.

FIGURE ONE : LOCALITY PLAN SCALE = 1:250,000



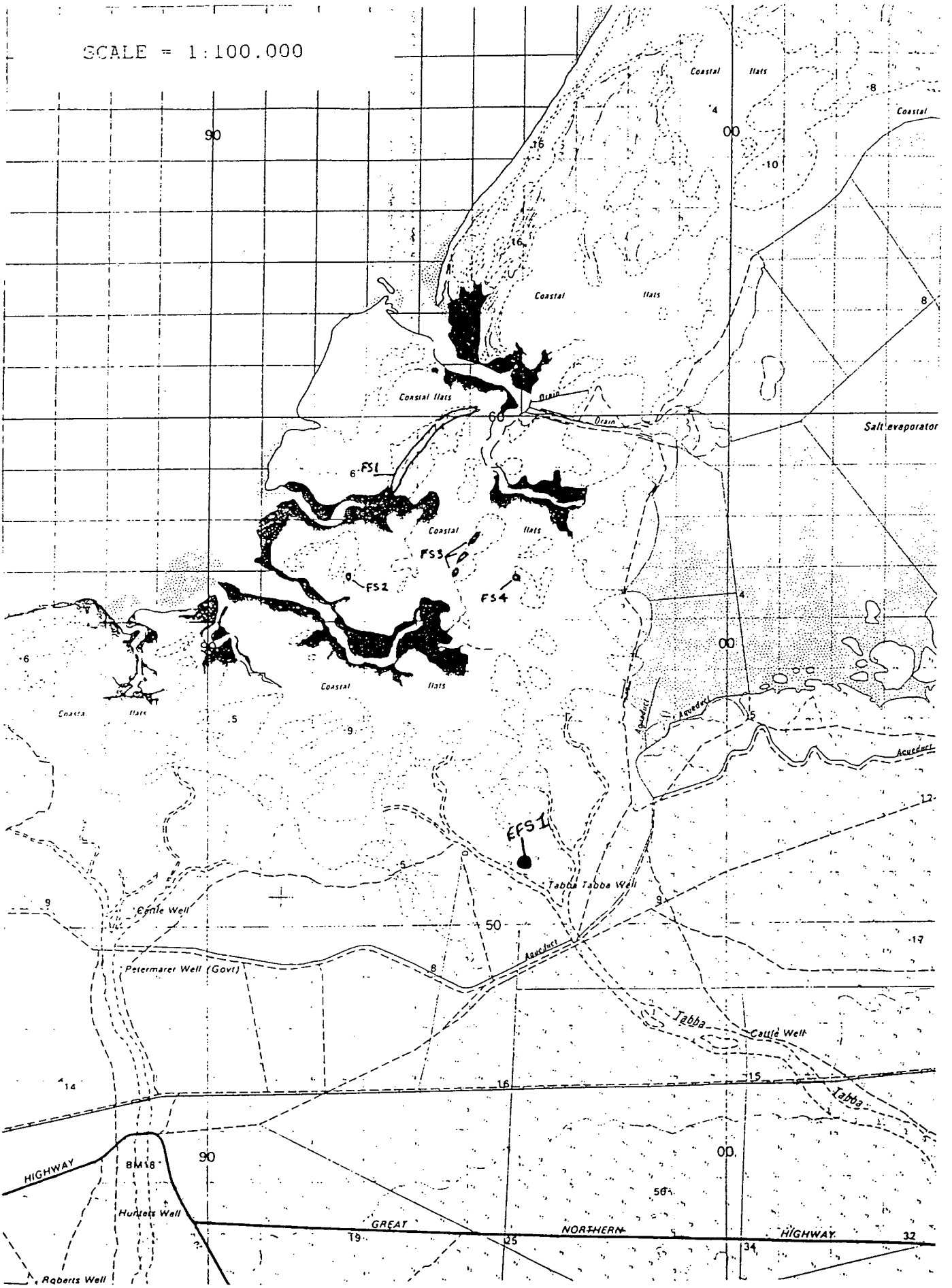


FIGURE TWO : LOCATION OF ABORIGINAL SITES

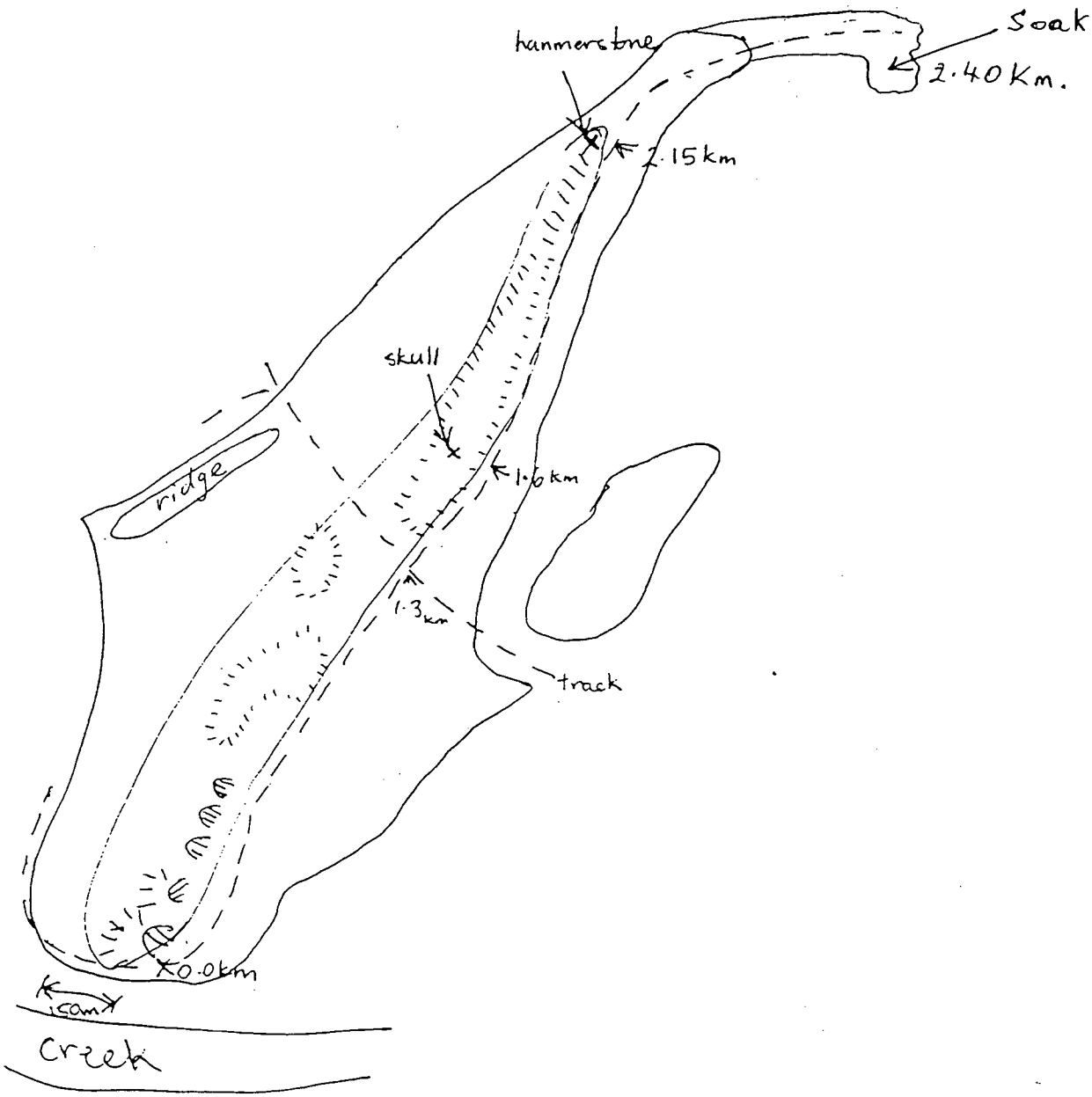


FIGURE 3

Extended Archaelogical Field Site 1

REFERENCES

Carr, E. 1986, The Australian Race, Melbourne: Ferris.

Elkin, A. 1938, The Australian Aborigines, Sydney: Angus and Robertson.

O'Connor, R and P Veth 1983, Report of the Survey for Aboriginal Sites in the Vicinity of the Proposed 220kV Overhead Powerline Route from Cape Lambert to Port Hedland. Prepared for State Energy Commission of Western Australia.

Radcliffe-Brown, A. 1912 The Distribution of Native Tribes in Part of Western Australia, Man. 75.

Tindale, N. 1974, Aboriginal Tribes of Australia, University of California Press.

von Brandenstein, C. 1967, The Language Situation in the Pilbara - Past and Present, Papers in Australian Linguistics 2.

Withnell, J. 1901, The Customs and Traditions of the Aboriginal Natives of North Western Australia, Roebourne, Geyer.

PART TWO

ARCHAEOLOGY

PART TWO

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background

An Aboriginal site survey of a proposed saltworks expansion area and quarry site at Port Hedland was commissioned by Leslie Salt. The fieldwork component of this survey was executed in March, 1990, by Gary Quartermaine, Caroline Heine was research assistant while Rory O'Connor conducted the Aboriginal consultation.

There were three objectives of the archaeological survey. These were:

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

2. A systematic sample archaeological survey of the proposed development area.

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

1.2 Location

The proposed development involves a proposed quarry site and the construction of facilities to harvest salt in the saline mudflats near Port Hedland. Facilities to be developed include sea walls, tracks and a haul road. The survey areas are located approximately 30 kilometres east of Port Hedland, the quarry lease between Tabba Tabba Creek and the Port Hedland - Goldsworthy Railway line, and the additional salt production leases north of it in the mudflats of the Tabba Tabba delta. The proposed quarry area encompasses about 10 hectares, while the salt production leases encompasses 2,500 hectares (see Figure 2).

1.3 Environment

The survey areas are located approximately 30 kilometres east of Port Hedland. the quarry lease between Tabba Tabba Creek and the Port Hedland - Goldsworthy Railway line. and the additional salt production leases north of it in the mudflats of the Tabba Tabba delta.

The climate of the project area is semi-desert tropical with summer rain and winter drought. The annual average rainfall is approximately 300 mm, with most of the rain falling during cyclones and thunderstorms. There are very high summer temperatures.

The survey area lies in the Quaternary alluvium of the Abydos Plain in the Pilbara Block.

Chief soils are red earthy sands with extensive areas of red earths and hard red soils along creek lines. On the coastal mudflats chief soils are saline loams with shelley sands. Small areas of calcareous earths and shallow loams are associated with marls.

The vegetation of the alluvial sandplains is a dwarf-shrub steppe with a general cover of *Triodia pungens* interspersed by numerous very low spreading shrubs of *Acacia translucens*. There may sometimes be scattered tall shrubs of *Acacia pyrifolia, A.pachycarpa. A. holoseticea. A. tumida* or patches of *Hakea subera.* There are some *Eucalyptus papuana foruna* and *E.sp.aff.aspera* on drainage channels.

The coastal mudflats are hypersaline and so totally devoid of vegetation. Along the seaward margin low, shrubby mangrove of *Avicennia marina* and *Rhizophora muccronata* lines the creeks and inlets as well as the outer edge of the land if it is muddy, growing between the levels of high and low tide. There may occasionally be samphire communities immediately inland of the mangrove (Beard, 1975).

Most of the quarry area has been previously disturbed by earlier quarrying activity. The salt production leases are mostly tidal mudflats with some islands of higher ground. These are sand or sand covered limestone areas that have spinifex and some low scrub vegetation.

2.0 ARCHAEOLOGY

2.1 Previous Archaeological Research

A number of archaeological surveys have been commissioned by various government departments and mining companies planning to develop particular areas in the Pilbara and these have provided a range of recorded evidence of Aboriginal use and occupation of the region. The large body of archaeological data that has been generated by this work provides documentation of several types of sites. These include a variety of stone artefact scatters, rockshelters, scarred trees, grinding patches, paintings, rock engravings and stone arrangements. A particular location that has been identified as an archaeological site may contain one or more of these site types in various combinations.

A range of ethnographic and mythological sites have also been identified and located by contemporary Aboriginal people with traditional knowledge of the region. Such sites often also contain an archaeological component.

Two Aboriginal sites have been recorded in the vicinity of the project locations. These are P0744 and P2291 (see Table 1). P0744 is an engraving site on flat limestone with an associated shell midden. P2291 is a quarry and artefact scatter situated near a granite outcrop. Both sites are well clear of the present survey areas.

Occupation by Aboriginal people of the Pilbara region is dated to 20,740+/-345 years ago from a charcoal sample in association with artefacts from a rockshelter near Newman (Maynard, 1980). The earliest dates for coastal shell midden sites comes from the Burrup Peninsula, with a date of 7,000 years BP (Lorblanchet, 1983). However, a date of 25,200+/-250 years BP has been obtained recently from North West Cape (Morse, 1988). So, although the sites on the modern dune system are unlikely to be older than 6,500 years BP, sites on the older systems are likely to be considerably older.

Analysis of the results of previously recorded sites and information from a survey at Onslow in a similar environment (Quartermaine & O'Connor, 1989), indicates the following distribution:

(i) Modern Coastal Dunes

Extensive shell middens with stone artefacts only making-up a small percentage of the total material, except at the largest sites where diversity and numbers of shell and stone is great. Burials may be present.

(ii) Ancient Dunes

Single species shell middens located in blowouts, but generally with a small stone artefact component.

(iii) Saline Mudflats

A very low site discovery potential with only occasional isolated artefacts previously recorded in this zone.

Previously recorded sites in the Coastal Pilbara region indicate that water-worn pebbles were the main lithic resource. These occur throughout the plain and adjacent claypan area. The various lithic materials include quartz, quartzite, silicified sediments, chert, chalcedony, basalt and silcrete. As previously mentioned, glass and porcelain have been used for the manufacture of artefacts, in post-contact times.

Stone artefact types include grindstones, mullers, adzes, a variety of scrapers, and various pebble tools, flakes and pieces. Shell species recorded at sites include baler (*Melo* spp.), *Anadara* spp., *Terebralia* spp., oyster (*Hyatissi hyotis*) and *Syrinx* spp. with some pieces of coral.

The shell species appears to fall into two distinct catagories, namely food and tools. *Anadara* spp. and *Hyatissi* spp. would have been exploited for food, and the former two are usually found in discrete concentrations which they dominate numerically. *Melo* spp. would most likely have been used as containers, for water or seeds, or fragments for tools because of the extra thickness of the shell.

Likewise, the stone artefacts appear to fall into two catagories, these being seed grinding and shellfish exploitation. Mullers, muller fragments and grinding slab fragments make up the former category. Pebble tools make up the majority of the latter category. These are usually split water-worn pebbles with one working edge that appears to have been used for a prising or chopping task.

The sites reflect a coastal economy dependent on the exploitation of the various shellfish species available. Whether these sites are seasonal camps or all year habitation sites is difficult to determine on the present information. However, extensive artefact scatters along the rivers further inland, points to the possibility of seasonal marine exploitation.

There is not much historical information on methods for the disposal of the dead in this area. Berndt (1977:459-460) gives a general description of Australia wide ways of ways of disposing of the corpse. These include exposure on a platform or a tree; desiccation or mummification; cremation; placement in a hollow tree; use of coffins; and burial cannibalism. Often, a sequence of events is involved with the placement of the bones at a particular location being the final step.

An early description from the Roebourne area may be of relevance here. Withnell (1901:35-37) give an account of burial practices that he witnessed. The usual method was the placement of the body in a grave about four feet deep, generally in a seated posture facing the direction of its birthplace. The body is then covered with paperbark and the grave filled in with earth. If the deceased had been a good hunter, the body was placed among rocks and when sufficient time had elapsed, the small bones were collected and kept by the family circle for good luck in hunting.

Two methods for the disposal of the dead are described (Kee & Quartermaine, 1986). One involved wrapping the remains in cadjeput bark and covering the bundle with earth in a shallow grave. The other involved wrapping the bones in cadjeput bark and placing the bundle in a niche or recess in a rockshelter or a rock-face of the mesas. It is presumed that the latter method was a secondary burial following exposure of the corpse.

Scientific information on burials and human skeletal material is very limited for this area. Robust skeletal remains, excavated from a sand dune near cossack, are estimated to be less than 6,500 years old (Freedman and Lofgren, 1979a and 1979b). The Cossack remains shows similarities with robust, heavy skeletons found at Kow Swamp, in northern Victoria, dated between 13,000 and 9,300 years ago. The Kow swamp skeletons contrast with the gracile skeletons, with fine features, found at nearby Lake Mungo, estimated to be about 30,000 years old (Thorne, 1976: 96,111).

TABLE ONE : PREVIOUSLY RECORDED ARCHAEOLOGICAL SITES

WA Museum Site No.	SF 50-4 1:250.000 Grid Ref.	Site Type	Site Name
P2291	166.442	Quarry,artefacts	Strelley Site
P0744	142.459	Engravings,artefacts	23 Mile Creek

2.2 Obligations Under the Act

The Western Australian *Aboriginal Heritage Act*, 1972-1980, makes provision for the recording and preservation of places and objects customarily used by, or traditional to, the original inhabitants of Australia. The Act defines the obligations of the community relating to sites (see Appendices 1 & 2).

The archaeological survey is aimed at identifying the effects of proposed disturbance of the physical environment on historic and pre-historic Aboriginal sites.

Aboriginal people were involved in the archaeological survey. An ethnographic survey for this project was undertaken at the same time.

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

2.3 Survey Design

The survey design involved three stages of operation. These were as follows:

(1) Background research - this involved familiarisation with previously recorded sites in the region, relevant previous archaeological investigations, plus relevant literature, maps and environmental data for the survey areas. Previously recorded Aboriginal sites registered with the W.A. Museum are listed in Table 1.

(2) Survey strategy and site recording - the survey strategy consisted of a systematic sample survey of the proposed development area.

The field survey was completed using a 1:50,000 and 1:250,000 topographic maps of the area plus plans of the proposed development.

A 4WD vehicle and a 4WD motorcycle was used to gain access to the survey area. Inspections were made on foot in areas of high site potential such as the margins of the watercourses and deflated sand ridges, as well as those areas of direct impact, such as the haul road, proposed sea walls. This enabled a field inspection of the total area of the sea walls area with a buffer zone of 50 metres and approximately 10 % of the saline mudflats islands' boundaries. The saline mudflats were inspected but were considered to be of very low archaeological site potential.

The ground visibility, afforded by the fairly sparse ground cover vegetation throughout the sandhills and plain provided a reasonably good site discovery potential. Any decreases in site discovery potential from reduced visibility in the denser vegetation alongside watercourses is considered to have been countered by the survey methods in these areas.

A site recording form compiled prior to the survey using information from previous research, was used to record sites located. This enabled a standardised set of data to be obtained from each site in an efficient manner. Such a recording format would be of use for analysis, and have relevance to other researchers. Catagories under which site data was recorded are as follows:

(1) site dimensions - extent and type;
(2) environmental setting - vegetation, soil, geology, landform, drainage and proximity to water, surface visibility and disturbance;
(3) artefact assemblage - estimated number, types and lithic materials;
(4) stratigraphy - assessment of potential;
(5) location - mapped.

(3) Report Preparation - this brings together all the data into a form suitable to the client and the Department of Aboriginal Sites of the W.A. Museum.

2.4 Site Definitions

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

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

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

(a) High - important sites that could be preserved;

(b) High-Moderate - sites from which more information may be obtained by collection or excavation but which do not rate preservation if application for site disturbance is made for them;

(c) Low-Moderate - similar to above but less follow-up required;

(d) Low - sites with limited potential to yield further archaeological information.

3.0 RESULTS

Four newly recorded sites are proximate to the proposed development. Details of these sites are as follows (see also Appendix 3).

Field Site 1

1:100,000 Map Ref 2657 935-951.585-602

Description: This site is an extensive midden/artefact scatter on the eroding top of an ancient dune situated on an island in the saline mudflats. It is adjacent to, and overlooking, tidal creeks at the north an south ends. Site dimensions are 2.15 km by 150 metres.

The shell species present include *Anadara*, *Terebralia* and baler. *Anadara* is the main species but there are small numbers of *terebralia* while fragments of baler shell are scattered throughout. There are concentrations of shells that are quite dense but generally there is a scatter of shells along the ridge.

The only stone artefact noted was a hammerstone made from basalt (69 x 56 mm) at the northern end of the site.

An exposed human burial is located on a high sand hill within the north end of the site. The bones are heavily weathered and appear to be the incomplete skeleton of a single individual. The front part of the cranium was reasonably well preserved and had pronounced brow ridges and a backward sloping forehead. This appears to be similar to the Cossack skull (Freedman and Lofgren, 1979 a & b) and other robust remains found in eastern Australia.

Other fragments of skull plus some long bones were also present. The skeleton has been exposed for a t least 8-9 years as it was reported to the police at that time. Apart from a sample being taken, which identified the bones as Aboriginal, nothing else was done then. There is potential for other burials along this ridge. Some excavations for fill material have been made at the southern end of the site. These show shells to a depth of one metre below surface level in the profiles exposed.

Discussion: This extensive site is in the vicinity of a proposed access road and although not directly affected, it may be affected by human disturbance.

This site is considered to be of high importance because of its large size, burial, shell and stone components and the potential for stratified archaeological material on the ancient dune system. The skeletal material is considered to be of great importance because of the scientific significance.

Field Site 2 1:00.000 Map Ref 2657 927.568

Description: This site is a small shell midden on a low sand dune situated above the saline mudflats, south of FS1. Site dimensions are 150 x 100 metres.

Anadara is the main shell species but some baler and *Terebralia* were also noted. No stone artefact material was noted. There is some stratigraphic potential at this site.

Discussion: This site is considered to be of low to moderate importance because of its small size, lack of stone artefacts and location in a modern dune system. It is clear of the proposed disturbance and is unlikely to be affected.

Field Site 3 1:100.000 Map Ref 2657 948.574

Description: This site is also an Anadara dominated shell midden. It is located on the west side of an island in the mudflats east of FS 1 & 2. The island is sandy, spinifex covered over limestone.

The shell midden was concentrated in three parts over a distance of one kilometre. It extends inland for 20 metres.

Some very weathered pieces of bone were recorded in the middle section. These appear to be skull fragments and are possibly another burial that has been exposed. Also in this area was a quartz flake (26 x 19 mm).

In the northern section, several stone artefacts were noted. These include a chalcedony flake (46 x 35 mm), a silicified sediment flake (24 x 20 mm) and a quartz flake (46 x 23 mm).

Discussion : This site is considered to be of moderate to high importance because of the extent of the midden, the presence of a possible burial, and the possible stratigraphic potential.

Field Site 4 1:100.000 Map Ref 2657 959.569

Description: This site is also a small Anadara dominated shell midden. It is located east of FS3 on an island in the central part of the survey area. The site dimensions are 100 by 50 metres.

No stone artefacts were noted at this site.

Discussion: This site is considered to be of low to moderate importance because of its small size, lack of stone artefacts and location in a modern dune system. It is clear of the present development and is unlikely to be affected.

4.0 CONCLUSIONS

4.1 Discussion

The proposed development involves a quarry site near Tabba Tabba Creek and the construction of facilities to harvest salt in the saline mudflats east of Port Hedland. The construction of sea walls, tracks and a haul road, will impact the physical environment.

The archaeological investigation involved background research and a systematic sample survey designed to locate and record sites in the designated survey area.

Four newly recorded archaeological sites were recorded as a result of this field survey. The newly recorded sites were shell midden/artefact scatters. These were all situated on sand ridges and have been exposed by deflating sand. None of these sites will be directly affected by the development.

Human Skeletal material was found at Field Sites 1 and 3. The bones at FS3 were small, weathered fragments. However, at Field Site 1, parts of a skull and long bones were exposed and appear to be of a single burial. The features of the skull, a low sloping forehead and heavy brow ridges, indicate a robust, archaic human type. Modern Aboriginal people do not share these features. Further study potential and possibilities of material dating make this an important site.

The terrain of the areas surveyed is made up of modern and older sand dunes, spinifex sand plain and saline mudflats. The vegetation is dominated by spinifex, which occurs at each location, with other grasses and low shrubs, predominantly *Acacia* spp. Larger trees are found along Tabba Tabba Creek. The low areas are subject to flooding following heavy rains and, on the coast, to tidal inundation. Visibility was reasonable throughout although most sites were located in areas that were vegetated to some extent.

Although surface visibility varied across the survey area, it is considered that any concentrations of archaeological material present were located. The areas most likely to contain archaeological sites, the margins of water courses and sand ridges plus the direct impact areas were subject to a more intense inspection.

Site distribution, both ethnographic and archaeological, reflects the land-use pattern of coastal and riverine usage by Aboriginal people where access to water and economic resources was maximised.

4.2 Recommendations

The recommendations which follows are based on discussion with relevant Aboriginal people, field observations and previous experience.

1. Field sites 1-4 will not be directly affected by the proposed development. It is recommended that the site areas be left undisturbed, particularly FS1 and FS3.

2. The saline mudflats are considered to be clear of Aboriginal sites. The proposed sea wall should be positioned so that it does not impact FS3.

3. Further study and dating of the skeletal material at FS1 is recommended. This is considered to be of major importance since the skull indicates robust, archaic features not found in modern Aboriginal people.

4. Permission to disturb an Aboriginal site is required under Section 18 of the W.A. *Aboriginal Heritage Act,* 1972-1980. This is obtained by written application by the owner of the land to the Trustees of the WA Museum for permission to use the land under Section 18 of the Act.

5. It is pointed out that human intereference to Aboriginal sites is an offence, unless authorised under the Act, as outlined in Section 17 of the WA *Aboriginal Heritage Act* (1972-80). Therefore, it is recommended that the Developers take adequate measures to inform any project personnel of this requirement.

Acknowledgements

The information and assistance provided by Bob Cunning. Ralph Ninham, Emma Quartermaine and Caroline Heine is gratefully acknowledged.

5.0 REFERENCES

Beard, J. S. 1975. *Vegetation Survey of Western Australia: Sheet 5 Pilbara*. 1:1,000,000 Vegetation Series Map and Explanatory Notes. University of W.A. Press, Perth.

Berndt, R. and Berndt, C. 1977. *The World of the First Australians*, Ure Smith (Sydney).

Freedman, C. & Lofgren, M. 1979. Human Skeletal Remains from Cossack, Western Australia. Journal of Human Evolution, v.8:283-299.

Freedman, C. & Lofgren, M. 1979. The Cossack Skull and a Dihybrid of Australian Aborigines. Nature v.282:298-300

Kee, S. and Quartermaine, G. 1986. Report on further Archaeological Investigations at the Eastern Deepdale Development, Pannawonica. Prepared for Robe River Iron Associates.

Lofgren, M. 1975. *Patterns of Life*. W.A. Museum Information Series No. 6.

Lorblanchet, M. 1977. Report on the Excavation of a Shell Midden at Skew Valley, Dampier, W.A. W.A. Museum Report.

Maynard, L. 1980. A Pleistocene Date from an Occupation Deposit in the Pilbara Region, Western Australia. *Australian Archaeology*, 10:3-8.

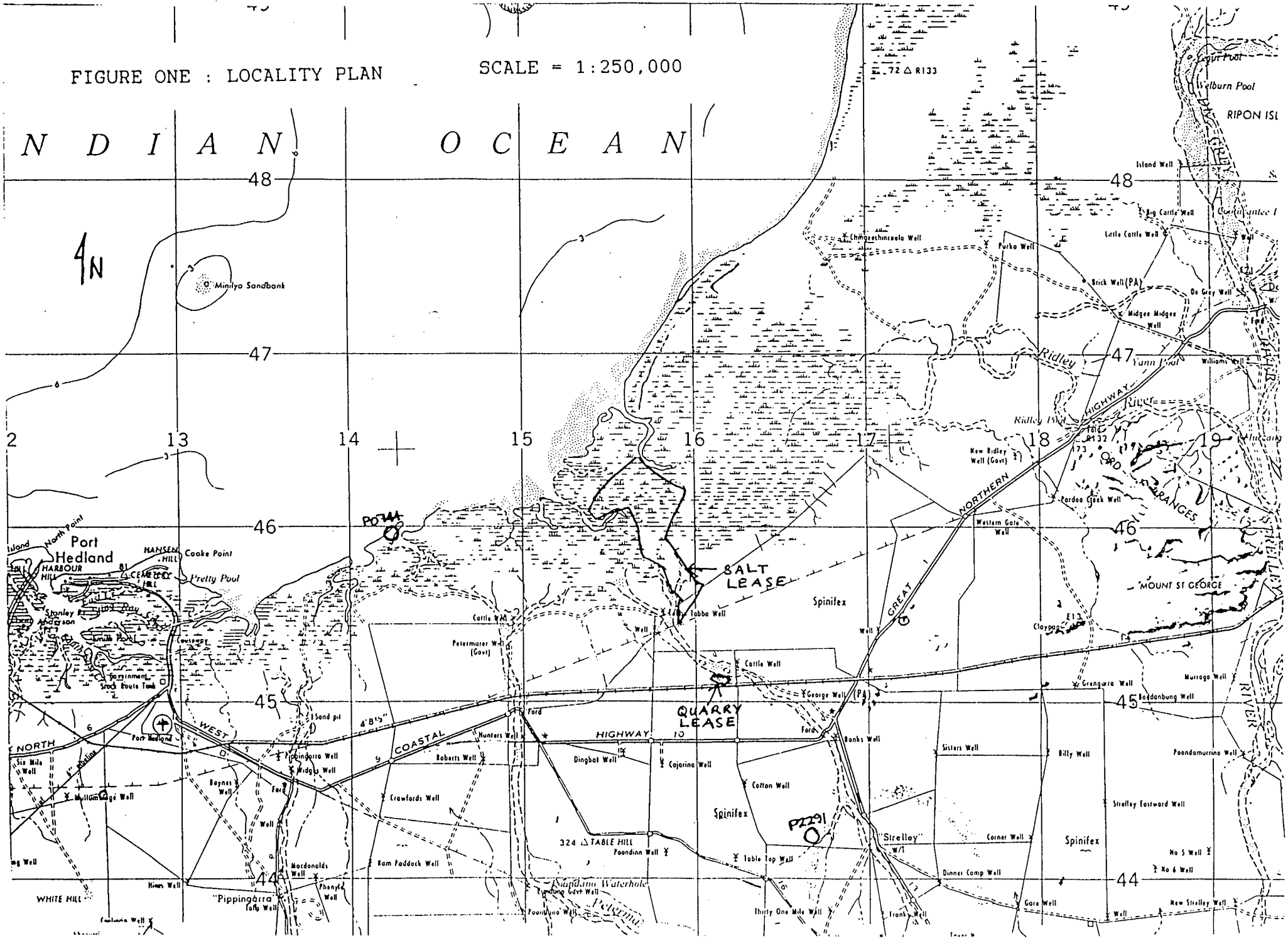
Morse, K. 1988. Mandu Mandu rockshelter : Pleistocene human coastal occupation of North West Cape, Western Australia. *Archaeology in Oceania*, 23 :81 -88.

Quartermaine, G. and O'Connor, R. 1989. Report on a Survey for Aboriginal Sites at the Proposed Exmouth Salt Pty Ltd Saltworks, Onslow. Prepared for Gulf Holdings Pty Ltd.

Thorne, A.G. 1976. Morphological Contrasts in Pleistocene Australians, in the Origin of the Australias (Kirk, R.L. & A.G. Thorne, ed) Pp 95-112 A.I.A.S., (Canberra).

Withnell, J. 1901. *The Customs and Traditions of the Aboriginal Natives of North Western Australia*, Geyer, Roebourne.

FIGURE ONE : LOCALITY PLAN SCALE = 1:250,000



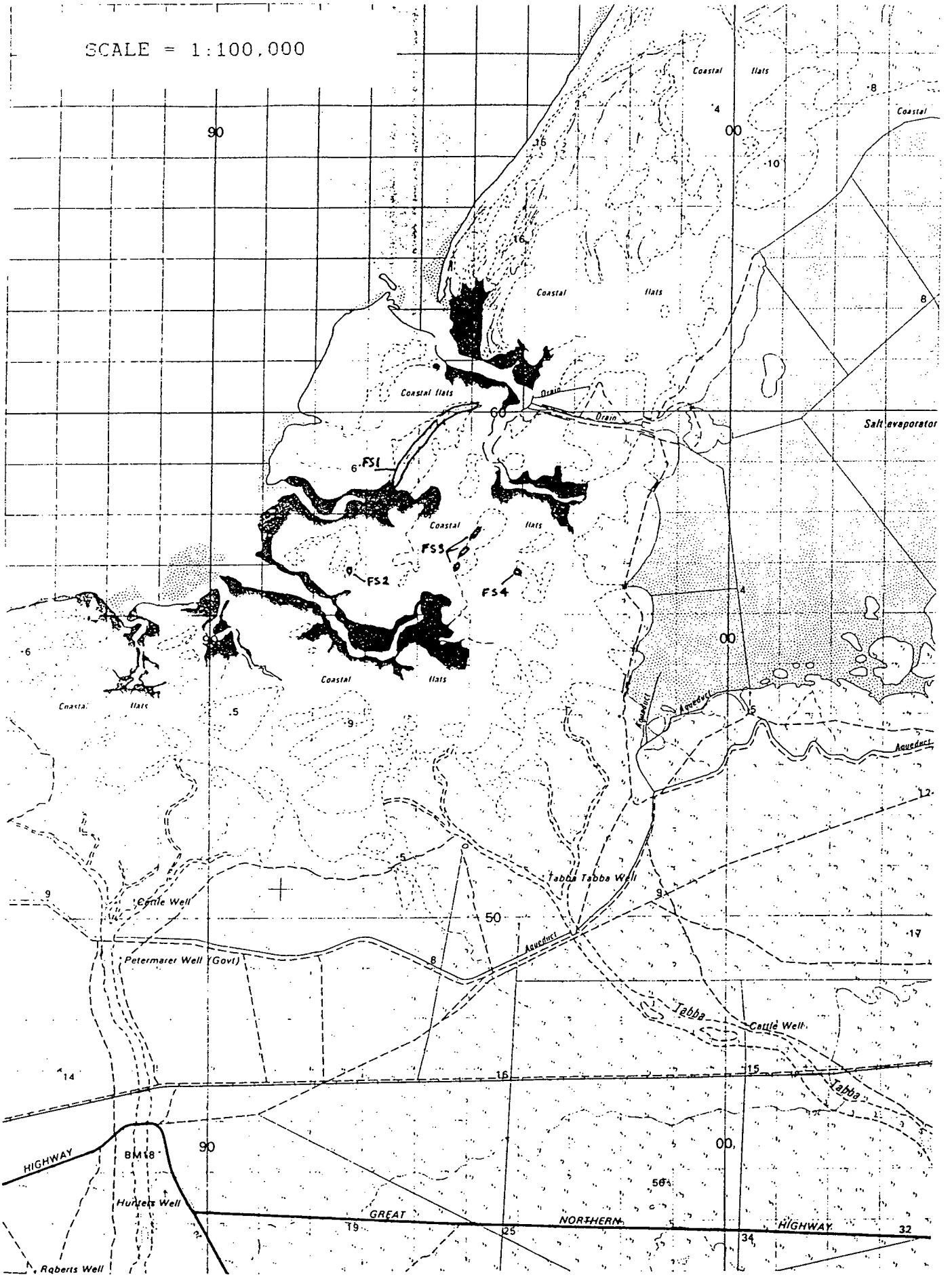


FIGURE TWO : LOCATION OF ABORIGINAL SITES

TABLE 2 : ARCHAEOLOGICAL SITES NEAR PROJECT AREA

Site No.	2657 1:100,000 Map ref.	Site Components	Dimensions	Location
FS1	935.585	Burial/midden/artefacts	2.15km x 150m	Limestone Ridge
FS2	927.568	Shell midden	150 x 100 m	Sand Island
FS3	948.574	Burial/midden/artefacts	1.0 km x 50 m	Limestone Ridge
FS4	959.569	Shell midden	100 x 50m	Sand Island

PLATE 1 : Field Site 1 from south

PLATE 2 : Field Site 1, profile in quarry area

PLATE 3 : Field Site 2 from north

PLATE 4 : Field Site 2, shells

APPENDIX 1

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

Report of Findings

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

Excavation of Aboriginal Sites

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

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

Offences Relating to Aboriginal Sites

"17. A person who-

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

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

Consent to Certain Uses

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

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

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

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

or

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

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

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

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

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

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

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

APPENDIX 2

Notes on the Recognition of Aboriginal Sites

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

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

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

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

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

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

Habitation Sites

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

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

Seed Grinding

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

Habitation Structures

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

Middens

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

Stone Artefact Factory Sites

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

Quarries

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

Marked Trees

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

Burials

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

Stone Structures

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

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

Paintings

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

Engravings

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

Caches

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

Ceremonial Grounds

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

Mythological Sites

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

APPENDICE THREE

ARCHAEOLOGICAL SITE DATA SHEETS

ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY LESLIE SALT DATE 23-3-90
25-3-90

FIELD SITE NO. FS1 GRID REF.

PHOTOS Site
Burial
1:250,000
1:100,000 2657 935-951.585-602
Other

ENVIRONMENT

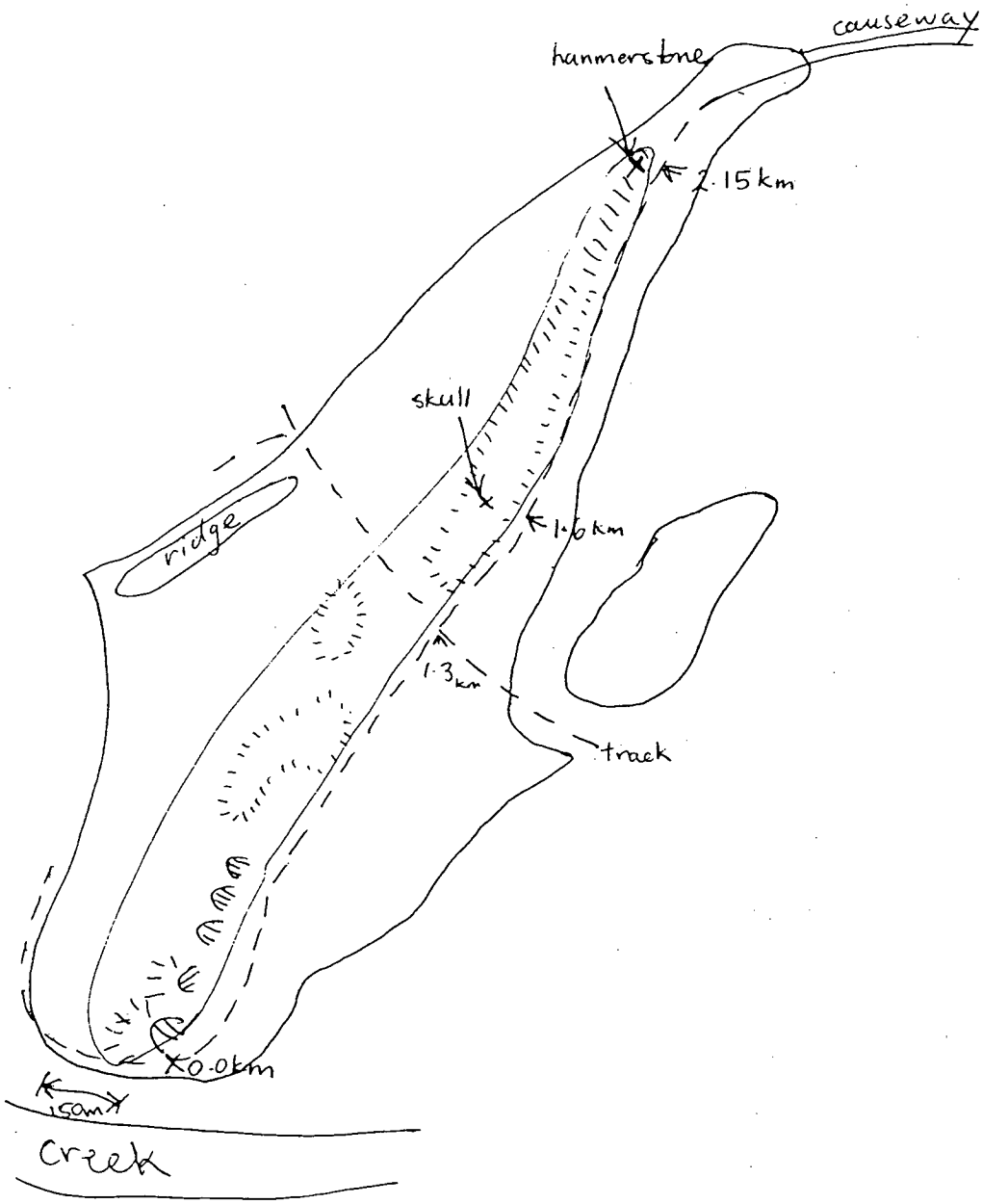
landform: Sand covered limestone ridge
geology : Limestone
vegetation: type. spinifex, scrub cover... medium.....
species.....
water : type.....distance.....
disturbance: type. tracks, quarrying amount. low.-moderate..

SITE DESCRIPTION

site type : Burial, midden
dimensions: NS.....2-15 km...EW.....150 m.....
boundaries: ~~natural~~/artificial . discrete/~~diffuse~~
components: skeletal material, shells, occ. artefact

stratification: good potential
no. of artefacts: approx. total....one noted.....
density...shells - moderate.....
sample.....—.....

Recorded by : GSQ
Date : 23-3-90
Client : LESLIE SALT


causeway
hammerstone
2.15km
skull
ridge
1.6km
1.3km
track
0.0km
150m
Creek

Field Site 1

ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY LESLIE SALT DATE 24-3-90

FIELD SITE NO. FS 2 GRID REF.

PHOTOS Site 1:250,000
1:100,000 2657 927.568
Other

ENVIRONMENT

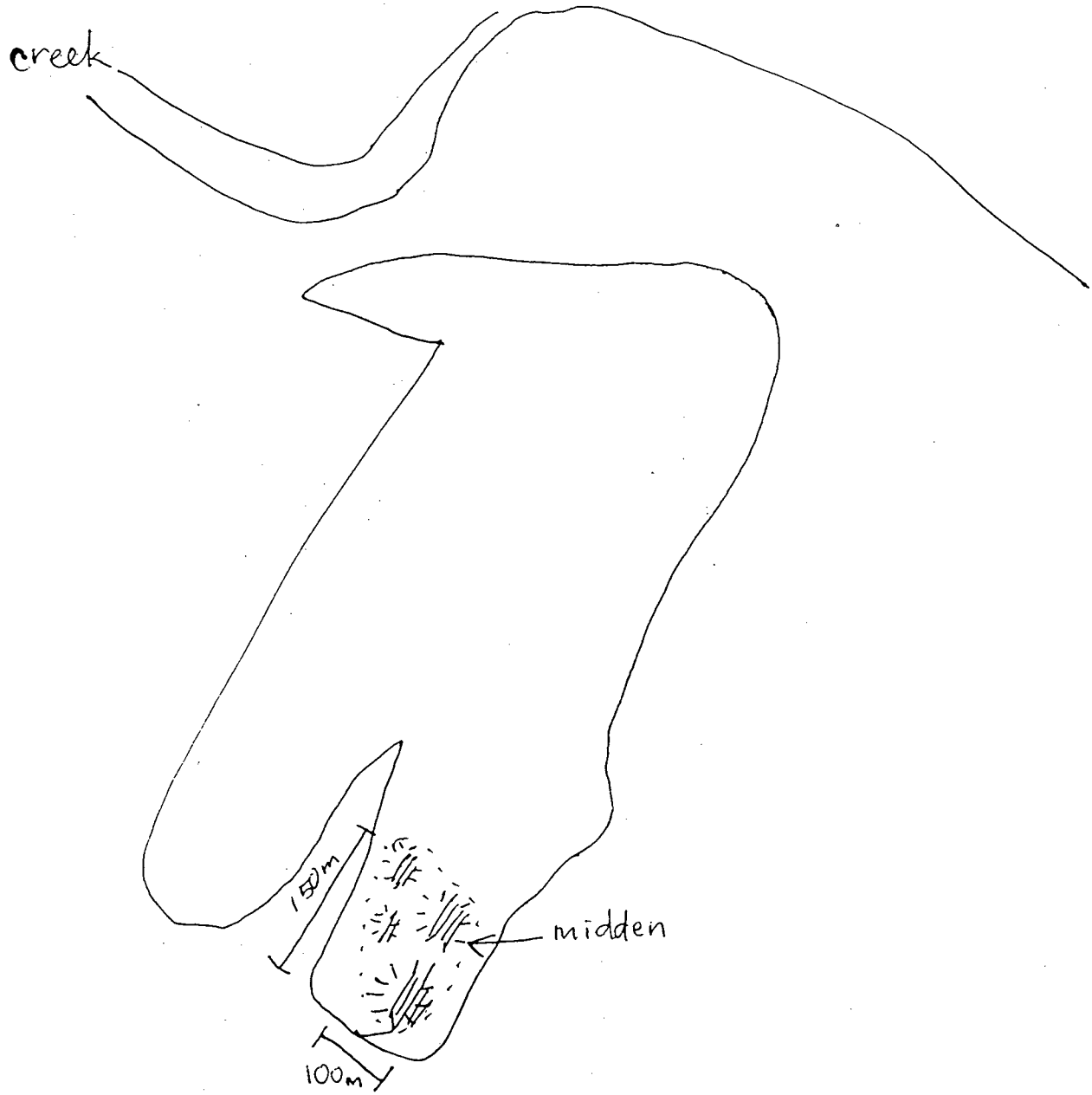
landform: Sandy island in mudflats
geology : Recent
vegetation: type. spinifex., scrub cover... moderate.....
species.....—.....
water : type.....distance.....
disturbance: type..natural.....amount..minimal.....

SITE DESCRIPTION

site type : shell midden
dimensions: NS.....150.....EW.....100 m.....
boundaries: ~~natural~~/artificial . discrete/~~diffuse~~
components: shells, mainly Anadara

stratification: some potential
no. of artefacts: approx. total.....—.....
density.....shells - moderate.....
sample.....—.....

Recorded by : GSQ
Date : 24-3-90
Client : LESLIE SALT



Field Site 2

ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY LESLIE SALT DATE 24-3-90

FIELD SITE NO. FS3 GRID REF.

PHOTOS Site
Burial

1:250,000
1:100,000 2657 948·574
Other

ENVIRONMENT

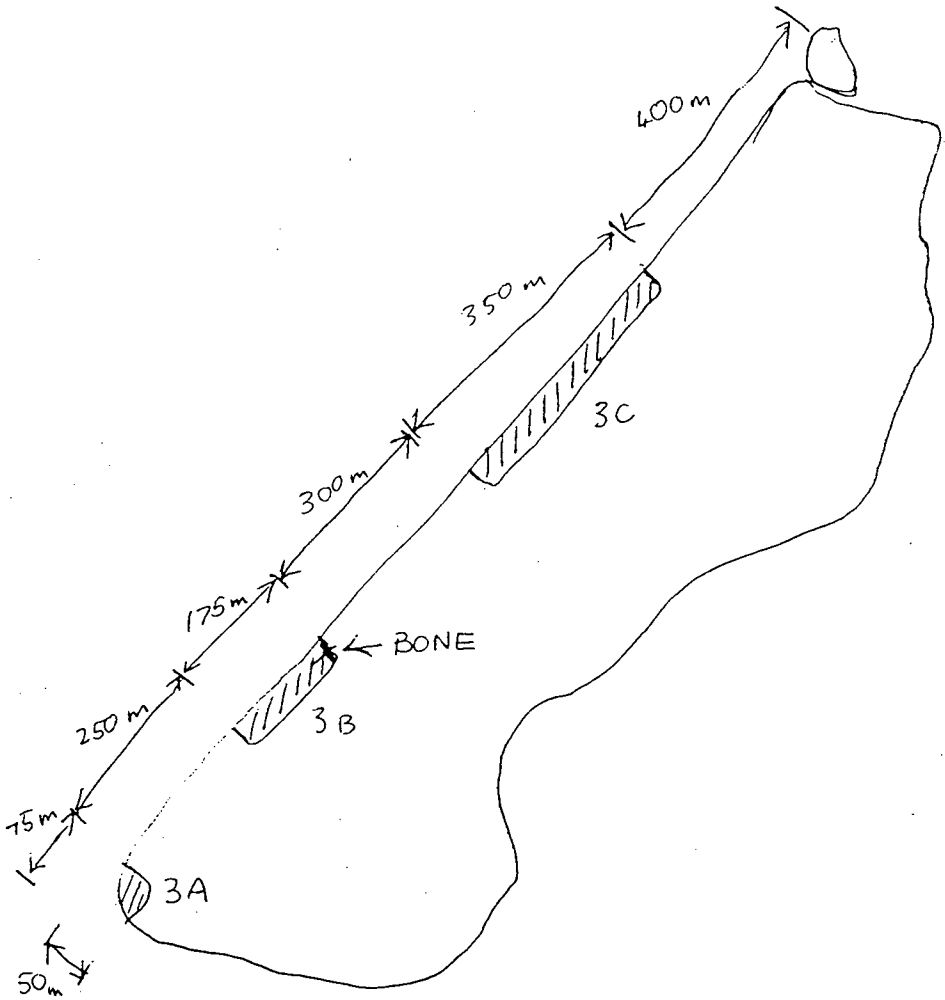
landform: sand covered limestone ridge/island in mudflats
geology : Limestone
vegetation: type spinifex, scrub cover ... moderate ...
species ... — ...
water : type ... — ... distance ... — ...
disturbance: type .. natural ... amount .. low moderate ..

SITE DESCRIPTION

site type : burial, midden, artefacts
dimensions: NS ... 1:0 km ... EW ... 50 m ...
boundaries: ~~natural~~/artificial . discrete/~~diffuse~~
components: skeletal material, shells, stone artefacts

stratification: good potential
no. of artefacts: approx. total ... several noted ...
density .. shells - moderate, artefacts - v. sparse
sample ... — ...

Recorded by : GSQ
Date : 24-3-90
Client : LESLIE SALT



Field Site 3

ARCHAEOLOGICAL SITE SURVEY DATA SHEET

SURVEY LESLIE SALT DATE 24-3-90

FIELD SITE NO. PS 4 GRID REF.

PHOTOS Site 1:250,000
1:100,000 2657 959.569
Other

ENVIRONMENT

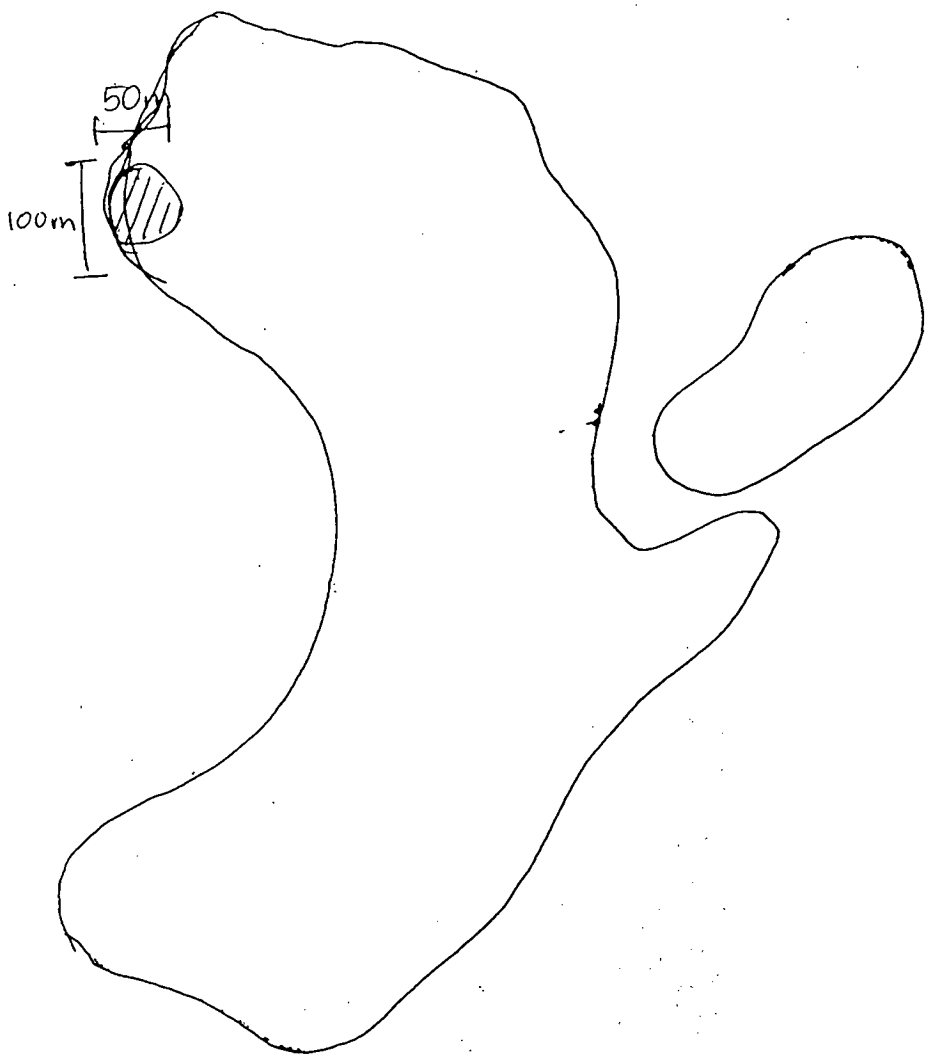
landform: Sandy island in mudflats
geology : Recent
vegetation: type ~~spinifex~~, ~~scrub~~ cover ~~...~~ moderate
species —
water : type — distance —
disturbance: type natural amount ~~minimal~~

SITE DESCRIPTION

site type : midden
dimensions: NS 100 EW 50 m
boundaries: ~~natural~~/artificial . discrete/~~diffuse~~
components: shells - mainly Anadara

stratification: some potential
no. of artefacts: approx. total —
density shells - moderate
sample —

Recorded by : GSQ
Date : 24-3-90
Client : LESLIE SALT



Field Site 4